

SPECIFICATION FOR LOW ALLOY STEEL ELECTRODES AND FLUXES FOR SUBMERGED ARC WELDING



SFA-5.23



(Identical with AWS Specification A5.23-90)

1. Scope

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

PART A — GENERAL REQUIREMENTS

2. Classification

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

(a) The mechanical properties of the weld metal obtained with the combination of a particular flux and a particular classification of electrode, as specified in Tables 6 and 7.

(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, and of the weld metal produced with that flux (for both solid and 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. Fluxes may be classified under any number of classifications, for weld metal in either or both the as-welded and postweld heat treated conditions, 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

Acceptance¹ of the electrodes and fluxes shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.²

4. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.³

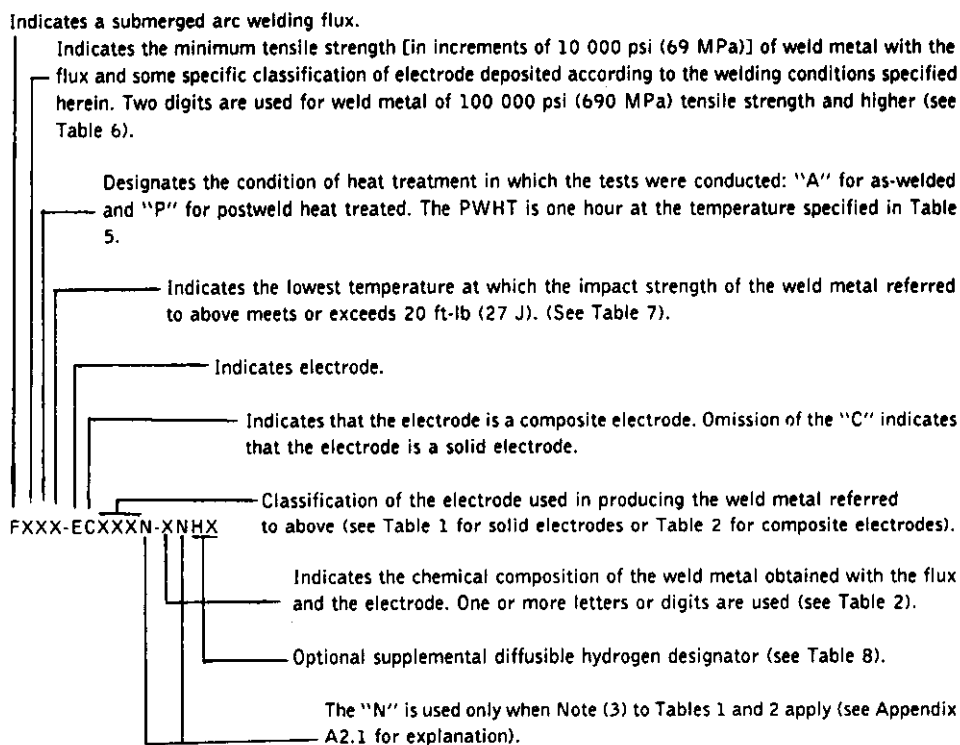
5. Units of Measure and Rounding-Off Procedure

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 system will not always coincide with a standard size or dimension in

¹ See section A3 (in the Appendix) for further information concerning acceptance, testing of the material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

² AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

³ See section A4 (in the Appendix) for further information concerning certification and the testing called for to meet this requirement.



EXAMPLES

F9P0-EB3-B3 is a complete designation for an electrode-flux combination. It refers to a flux that will produce weld metal which, in the postweld heat-treated condition, will have a tensile strength of 90 000-110 psi (620-760 MPa) and Charpy V-notch impact strength of at least 20 ft-lb (27 J) at 0°F (-18°C) when made with an EB3 electrode under the conditions called for in this specification. The composition of the weld metal will be B3 (see Table 2).

F9A2-ECM1-M1 is a complete designation for a flux when the trade name of the composite electrode used in the classification tests is indicated as well [see para. 16.4.1(d)]. The designation refers to a flux that will produce weld metal that, with the M1 electrode, in the as-welded condition, will have a tensile strength of 90 000-110 000 psi (620-760 MPa) and Charpy V-notch energy of at least 20 ft-lb (27 J) at -20°F (-29°C) under the conditions called for in this specification. The composition of the weld metal will be M1 (see Table 2).

FIG. 1 CLASSIFICATION SYSTEM

PART C — SPECIFICATIONS FOR WELDING RODS,
ELECTRODES, AND FILLER METALS

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TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES

AWS Classification	UNS Number ⁽⁴⁾	Wt. Percent ^{(1) (2) (3)}												
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu ⁽⁵⁾	V	Al	Ti	Zr
EL12K ⁽⁶⁾	K01012	0.04-0.14	0.25-0.60	0.10	0.030	0.030	...	...	...	0.35	...	...	...	...
EM12K ⁽⁶⁾	K01113	0.05-0.15	0.80-1.25	0.10-1.35	0.030	0.030	...	...	...	0.35	...	...	...	...
EA1	K11222	0.07-0.17	0.65-1.00	0.20	0.030	0.025	...	...	0.45-0.65	0.35	...	...	...	...
EA2	K11223	0.07-0.17	0.95-1.35	0.20	0.030	0.025	...	...	0.45-0.65	0.35	...	...	...	...
EA3	K11423	0.07-0.17	1.65-2.20	0.20	0.030	0.025	...	...	0.45-0.65	0.35	...	...	...	...
EA3K	K21451	0.07-0.12	1.60-2.10	0.50-0.80	0.025	0.025	...	...	0.40-0.60	0.35	...	...	...	...
EA4	K11424	0.07-0.17	1.20-1.70	0.20	0.030	0.025	...	...	0.45-0.65	0.35	...	...	...	...
EB1	K11043	0.10	0.40-0.80	0.05-0.30	0.025	0.025	0.40-0.75	...	0.45-0.65	0.35	...	...	...	...
EB2	K11172	0.07-0.15	0.45-1.00	0.05-0.30	0.030	0.025	1.00-1.75	...	0.45-0.65	0.35	...	...	...	...
EB2H	K23016	0.28-0.33	0.45-0.65	0.55-0.75	0.015	0.015	1.00-1.50	...	0.40-0.65	0.30	0.20-0.30	...	...	...
EB3	K31115	0.05-0.15	0.40-0.80	0.05-0.30	0.025	0.025	2.25-3.00	...	0.90-1.10	0.35	...	...	...	...
EB5	K12187	0.18-0.23	0.40-0.70	0.40-0.60	0.025	0.025	0.45-0.65	...	0.90-1.20	0.30	...	...	...	...
EB6 ⁽⁷⁾	S50280	0.10	0.35-0.70	0.05-0.50	0.025	0.025	4.50-6.50	...	0.45-0.70	0.35	...	...	...	...
EB6H	S50180	0.25-0.40	0.75-1.00	0.25-0.50	0.030	0.025	4.80-6.00	...	0.45-0.65	0.35	...	...	...	...
EB8 ⁽⁷⁾	S50480	0.10	0.30-0.65	0.05-0.50	0.030	0.040	8.00-10.50	...	0.80-1.20	0.35	...	...	...	...
ENi1	K11040	0.12	0.75-1.25	0.05-0.30	0.020	0.020	0.15	0.75-1.25	0.30	0.35	...	...	...	...
ENi2	K21010	0.12	0.75-1.25	0.05-0.30	0.020	0.020	...	2.10-2.90	...	0.35	...	...	...	...
ENi3	K31310	0.13	0.60-1.20	0.05-0.30	0.020	0.020	0.15	3.10-3.80	...	0.35	...	...	...	...
ENi4	K11485	0.12-0.19	0.60-1.00	0.10-0.30	0.020	0.015	...	1.60-2.10	0.10-0.30	0.35	...	...	...	...
ENi1K	K11058	0.12	0.80-1.40	0.40-0.80	0.020	0.020	...	0.75-1.25	...	0.35	...	...	...	...
EF1	K11160	0.07-0.15	0.90-1.70	0.15-0.35	0.025	0.025	...	0.95-1.60	0.25-0.55	0.35	...	...	...	...
EF2	K21450	0.10-0.18	1.70-2.40	0.20	0.025	0.025	...	0.40-0.80	0.40-0.65	0.35	...	...	...	...
EF3	K21485	0.10-0.18	1.70-2.40	0.30	0.025	0.025	...	0.70-1.10	0.40-0.65	0.35	...	...	...	...
EF4	K12048	0.16-0.23	0.60-0.90	0.15-0.35	0.035	0.025	0.40-0.60	0.40-0.80	0.15-0.30	0.35	...	...	...	...
EF5	K41370	0.10-0.17	1.70-2.20	0.20	0.010	0.010	0.25-0.50	2.30-2.80	0.45-0.65	0.50	...	...	...	...
EF6	K21135	0.07-0.15	1.45-1.90	0.10-0.30	0.015	0.015	0.20-0.55	1.75-2.25	0.40-0.65	0.35	...	...	...	...
EM2 ⁽⁸⁾	K10882	0.10	1.25-1.80	0.20-0.60	0.010	0.010	0.30	1.40-2.10	0.25-0.55	0.25	0.05	0.10	0.10	0.10
EM3 ⁽⁸⁾	K21015	0.10	1.40-1.80	0.20-0.60	0.010	0.010	0.55	1.90-2.60	0.25-0.65	0.25	0.04	0.10	0.10	0.10
EM4 ⁽⁸⁾	K21030	0.10	1.40-1.80	0.20-0.60	0.010	0.010	0.60	2.00-2.80	0.30-0.65	0.25	0.03	0.10	0.10	0.10
EW	K11245	0.12	0.35-0.65	0.20-0.35	0.040	0.030	0.50-0.80	0.40-0.80	...	0.30-0.80	...	...	...	...
EG	-----	Not Specified -----												

TABLE 1 (CONT'D)
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES

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) The letter "N" as a suffix to a classification indicates that the electrode is intended for welds in the core belt region of nuclear reactor vessels, as described in para. A2.1 of the Appendix to this specification. This suffix changes the limits on the phosphorus, vanadium, and copper, as follows

P = 0.012% max.

V = 0.05% max.

Cu = 0.08% max.

"N" electrodes shall not be coated with copper or any material containing copper. The "EF5" and "EW" electrodes shall not be designated as "N" electrodes.

- (4) SAE/ASTM Unified Numbering System for Metals and Alloys.
- (5) The copper limit includes any copper coating that may be applied to the electrode.
- (6) The EL12 and EM12K classifications are identical to those same classifications in ANSI/AWS A5.17-89, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*. They are included in this specification because they are sometimes used with an alloy flux to deposit some of the weld metals classified in Table 2.
- (7) The EB6 and EB8 classifications are similar, but not identical, to the ER502 and ER505 classifications, respectively, in ANSI/AWS A5.9-80, *Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Arc Welding Electrodes and Welding Rods*. These classifications will be dropped from the next revision of A5.9.
- (8) The composition ranges of classifications with the "EM" prefix are intended to conform to the ranges for similar electrodes in the military specifications.

the other. Suitable conversions, encompassing standard sizes of both, can be made, however, if appropriate tolerance are applied in each case.

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi (7 MPa) for tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry*.

PART 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. See Table 3.

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. See Table 3.

6.2 Fluxes. The tests required for classification of fluxes (each electrode-flux combination) are specified in Table 3. They determine the chemical composition, the mechanical properties, and the soundness of the weld metal obtained with that electrode-flux combination. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in sections 8 through 13.

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 (8), of Fig. 3.

7. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. 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 the test requirement.

PART C — SPECIFICATIONS FOR WELDING RODS,
ELECTRODES, AND FILLER METALS

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TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL (BOTH SOLID ELECTRODE-FLUX AND
COMPOSITE ELECTRODE-FLUX COMBINATIONS)

AWS Weld Metal Classifi- cation ⁽⁵⁾	UNS Number ⁽⁶⁾		Wt. Percent ^{(1) (2) (3) (4)}											
	Solid	Composite	C	Mn	Si	S	P	Cr	Ni	Mo	Cu	V	Ti	Zr
A1	K11222	W17041	0.12	1.00	0.80	0.040	0.030	...	...	0.40-0.65	0.35	...	...	...
A2	K11223	W17042	0.12	1.40	0.80	0.040	0.030	...	...	0.40-0.65	0.35	...	...	...
A3	K11423	W17043	0.15	2.10	0.80	0.040	0.030	...	...	0.40-0.65	0.35	...	...	...
A4	K11424	W17044	0.15	1.60	0.80	0.040	0.030	...	...	0.40-0.65	0.35	...	...	...
B1	K11043	W51040	0.12	1.60	0.80	0.040	0.030	0.40-0.65	...	0.40-0.65	0.35	...	...	...
B2	K11172	W52040	0.15	1.20	0.80	0.040	0.030	1.00-1.50	...	0.40-0.65	0.35	...	...	...
B2H	K23016	W52240	0.10-0.25	1.20	0.80	0.040	0.030	1.00-1.50	...	0.40-0.65	0.35	0.30	...	...
B3	K31115	W53040	0.15	1.20	0.80	0.040	0.030	2.00-2.50	...	0.90-1.20	0.35	...	...	...
B4	...	W53346	0.12	1.20	0.80	0.040	0.030	1.75-2.25	...	0.40-0.65	0.35	...	...	...
B5	K12187	W51348	0.18	1.20	0.80	0.040	0.030	0.40-0.65	...	0.90-1.20	0.35	...	...	...
B6	S50280	W50240	0.12	1.20	0.80	0.040	0.030	4.50-6.00	...	0.40-0.65	0.35	...	...	...
B6H	S50180	W50140	0.10-0.25	1.20	0.80	0.040	0.030	4.50-6.00	...	0.40-0.65	0.35	...	...	...
B8	S50180	W50440	0.12	1.20	0.80	0.040	0.030	8.00-10.00	...	0.80-1.20	0.35	...	...	...
Ni1 ⁽⁷⁾	K11040	W21048	0.12	1.60	0.80	0.030	0.030	0.15	0.75-1.10	0.35	0.35	...	0.05 ⁽⁸⁾	...
Ni2 ⁽⁷⁾	K21010	W22040	0.12	1.60	0.80	0.030	0.030	...	2.00-2.90	...	0.35	...	...	...
Ni3	K31310	W23040	0.12	1.60	0.80	0.030	0.030	0.15	2.80-3.80	...	0.35	...	...	...
Ni4	K11485	W21250	0.14	1.60	0.80	0.030	0.030	...	1.40-2.10	0.35	0.35	...	...	...
F1	K11160	W21150	0.12	0.70-1.50	0.80	0.040	0.030	0.15	0.90-1.70	0.55	0.35	...	...	...
F2	K21450	W20240	0.17	1.25-2.25	0.80	0.040	0.030	...	0.40-0.80	0.40-0.65	0.35	...	...	...
F3	K21485	W21140	0.17	1.25-2.25	0.80	0.040	0.030	...	0.70-1.10	0.40-0.65	0.35	...	...	...
F4	K12048	W20440	0.17	1.60	0.80	0.040	0.030	0.60	0.40-0.80	0.25	0.35	...	0.03 ⁽⁸⁾	...
F5	K41370	W22640	0.17	1.20-1.80	0.80	0.030	0.030	0.65	2.00-2.80	0.30-0.80	0.50	...	...	...
F6	K21135	W21040	0.14	0.80-1.85	0.80	0.030	0.030	0.65	1.50-2.25	0.60	0.40	...	...	...
M1	...	W21240	0.10	0.60-1.60	0.80	0.040	0.030	0.15	1.25-2.00	0.35	0.30	...	0.03 ⁽⁸⁾	...
M2	...	W21340	0.10	0.90-1.80	0.80	0.040	0.030	0.35	1.40-2.10	0.25-0.65	0.30	...	0.03 ⁽⁸⁾	...
M3	...	W22240	0.10	0.90-1.80	0.80	0.030	0.030	0.65	1.80-2.60	0.20-0.70	0.30	...	0.03 ⁽⁸⁾	...
M4	...	W22440	0.10	1.30-2.25	0.80	0.030	0.030	0.80	2.00-2.80	0.30-0.80	0.30	...	0.03 ⁽⁸⁾	...
W	...	W21040	0.12	0.50-1.60	0.80	0.040	0.030	0.45-0.70	0.40-0.80	...	0.30-0.75	...	...	...
G	----- Not Specified -----													

TABLE 2 (CONT'D)
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL (BOTH SOLID ELECTRODE-FLUX AND COMPOSITE ELECTRODE-FLUX COMBINATIONS)

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) The letter "N" as a suffix to a classification indicates that the weld metal is intended for welds in the core belt region of nuclear reactor vessels, as described in A2.1 of the Appendix to this specification. This suffix changes the limits on the phosphorus, vanadium, and copper as follows

P = 0.012% max.

V = 0.05% max.

Cu = 0.08% max.

"N" electrodes shall not be coated with copper or any material containing copper. The F5 and W classifications shall not be designated as "N" weld metals.

- (4) A low dilution area of the groove weld of Fig. 3, or the reduced section of 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.
- (5) The electrode designation for composite electrodes is obtained by placing an "EC" before the appropriate weld metal classification.
- (6) SAE/ASTM Unified Numbering System for Metal and Alloys.
- (7) Manganese in Ni1 and Ni2 classifications may be 1.80% maximum when carbon is restricted to 0.10% maximum.
- (8) A single value spanning the columns for V, Ti, and Zr is the total of these elements.

TABLE 3
REQUIRED TESTS

AWS Classification	Chemical Analysis		Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
	Electrode	Weld Metal				
All Solid Electrodes	Required	Not Req'd	Not Req'd	Not Req'd	Not Req'd	Not Req'd
All Composite Electrodes	Not Req'd	Required	Not Req'd	Not Req'd	Not Req'd	Not Req'd
All Electrode-Flux Combinations	Not Req'd	Required	Required	Required ⁽¹⁾	Required ^{(1) (2)}	(3)

NOTES:

- (1) Classification is based on the properties of the weld metal obtained with $\frac{5}{32}$ in. (4.0 mm) electrodes, or the largest size manufactured if only smaller sizes are manufactured. Testing is required only for one size. See also Note (8) to Fig. 3.
- (2) Impact testing is required for all impact designators except "Z". See Table 7.
- (3) Diffusible hydrogen test is required only when specified by the purchaser and when the manufacturer puts the diffusible hydrogen designator on the label. (See also A3 and A6.4 in the Appendix).

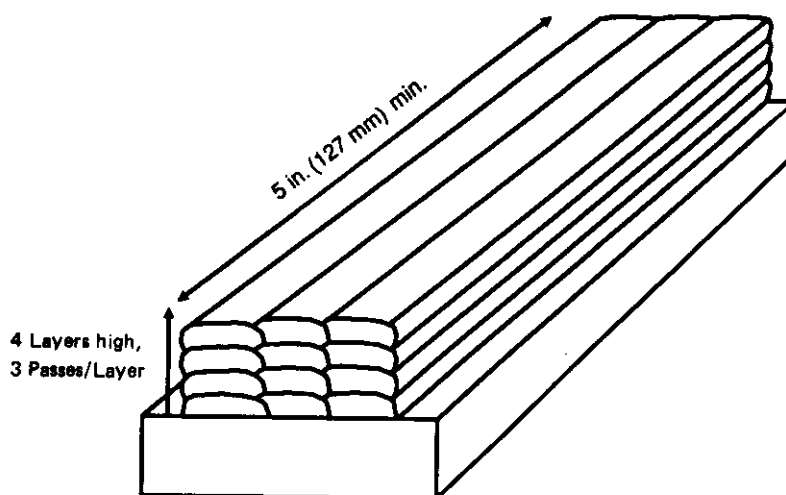
8. Weld Test Assemblies

8.1 Requirements for Classification

8.1.1 Classification of Solid Electrodes. Weld test assemblies are not required for classification of solid electrodes.

8.1.2 Classification of Composite 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 weld metal.

8.1.3 Classification of Electrode-Flux Combinations. In addition to the above, one weld test assembly is required for each classification of a composite electrode-flux combination. This is the groove weld in Fig. 3 for mechanical properties and soundness of the weld metal. Two weld test assemblies are required for each classification of a solid electrode-flux combination. These are the weld pad in Fig. 2 for chemical analysis of the weld metal, and the groove weld in Fig. 3 for mechanical properties and soundness of the weld metal.



NOTES:

- (1) The base metal may be of any width or thickness suitable for the size of electrode under test. [See Note (8) to Fig. 3 for electrode sizes].
- (2) The first and last 2 in. (51 mm) of the weld pad shall be discarded.
- (3) Weld beads shall be deposited without oscillation. The welding conditions shall be in accordance with the manufacturer's recommendations.

FIG. 2 ALL WELD METAL PAD FOR CHEMICAL ANALYSIS

Note (4) to Table 2 allows the sample for chemical analysis to be taken from a low dilution area in the groove weld in Fig. 3, or from the fractured tension test specimen, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be referee method. When a Certificate of Test is prepared, it shall indicate whether the groove weld or the pad was used for chemical analysis.

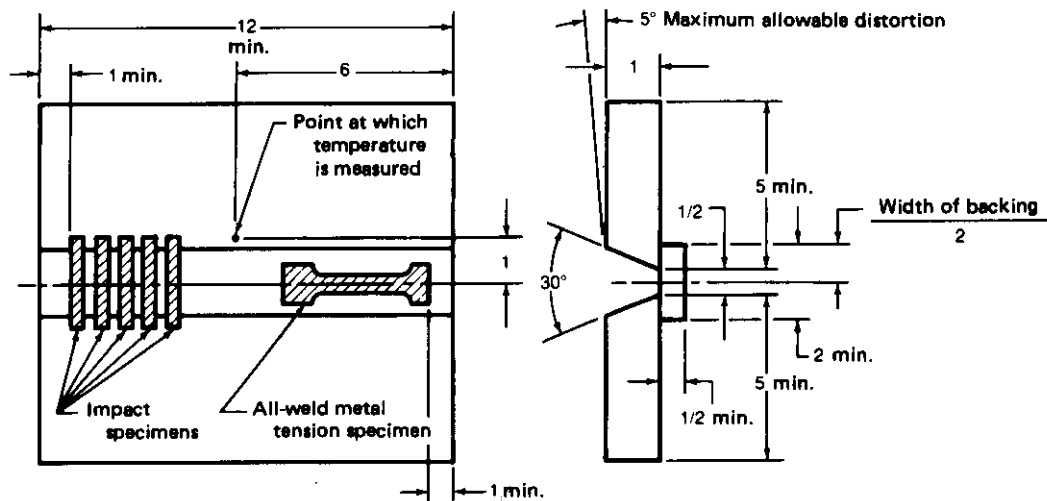
8.2 Preparation. Preparation of each weld test assembly shall be as prescribed in paras. 8.3 and 8.4. The base metal for each assembly shall be as required in Table 4 according to the tests to be conducted and shall meet the requirements of the appropriate ASTM specification shown there, or an equivalent specification. Testing of the assemblies shall be as prescribed in sections 9 through 13.

8.3 Weld Pad. For all electrode-flux combinations, a weld pad shall be prepared as specified in Fig. 2, except when the alternative in para. 8.1 (taking the sample from the weld metal in the groove or from the tension test specimen) is selected. Base metal of any convenient size, of the type specified in Table 4, shall be used as the base metal for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat

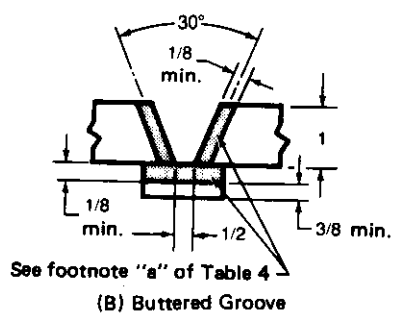
position, three passes per layer, four layers high, using the flux for which classification of the electrode is intended. The preheat temperature shall be not less than 60°F (16°C) and the interpass temperature shall not exceed 325°F (163°C). The slag shall be removed after each pass. The pad may be quenched in water between passes. The dimensions of the completed pad shall be as shown in Fig. 2. Testing of this assembly shall be as specified in section 9, Chemical Analysis.

8.4 Groove Weld for Mechanical Properties and Soundness. 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, and the preheat and interpass temperature specified in Table 5. Testing of this assembly shall be as specified in sections 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 postweld heat-treated), two such assemblies or one single assembly of sufficient length to provide the specimens required for both conditions shall be prepared.

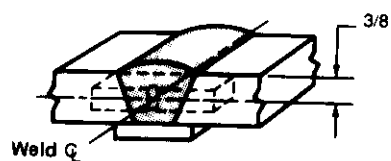
In this case, the single assembly shall be cut transverse to the weld into two pieces; one of the pieces shall



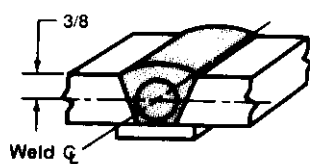
(A) Joint Configuration and Location of Test Specimens



(B) Buttered Groove



(C) Location of Impact Test Specimens



(D) Location of All-Weld-Metal Tension Test Specimen

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	125
12	305

GENERAL NOTE: All dimensions except angles are in inches.

FIG. 3 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS

WELDING CONDITIONS							
Electrode Size		Welding Current, Amps (± 25)	Welding Voltage, Volts (DCEP) (± 1)	Contact Tube-to-Workpiece Distance		Travel Speed	
in.	mm			in.	mm	ipm (± 1)	mm/sec (± 0.4)
1/16	1.6	300	29	1/2-3/4	13-19	10	4.2
3/64	2.0	325	29	1/2-3/4	13-19	11	4.7
1/32	2.4	350	29	3/4-1-1/4	19-32	11-1/2	4.9
7/64	2.8	400	30	3/4-1-1/4	19-32	13	5.5
1/8	3.2	450	30	1-1-1/2	25-38	14	5.9
5/32	4.0	500	30	1-1-1/2	25-38	16	6.8
3/16	4.8	550	30	1-1-1/2	25-38	17	7.2
7/32	5.6	-----as agreed between supplier and purchaser-----					
1/4	6.4						

NOTES:

- (1) Base metal shall be as specified in Table 4.
- (2) The surfaces to be welded shall be clean.
- (3) Prior to welding, the assembly may be preset so that the welded joint will be sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 degrees of plane. A test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assembly is prohibited.
- (4) These welding conditions are intended for machine or automatic welding. Welding shall be performed in the flat position. The first layer shall be produced in one or two passes and lower current than that specified above may be used. All other layers shall be produced at the specified current in two or three passes per layer, except the last layer shall be made in three or four passes. When an electrode manufacturer recommends a contact tube-to-workpiece distance outside the range shown, those recommendations shall be followed within ± 1/4 in. (6.4 mm). Welding conditions for composite electrodes shall be as agreed between purchaser and supplier.
- (5) The preheat temperature and interpass temperature shall be as specified in Table 5.
- (6) The weld shall be made with stringer beads. The completed weld shall be at least flush with the surface of the test plate.
- (7) The tests shall be conducted without a postweld heat treatment or after the PWHT specified in Table 5.
- (8) Classification is based on the properties of the weld metal with 1/32 in. (4.0 mm) electrodes or the largest size manufactured, if smaller than 1/32 in. (4.0 mm). The conditions given above for sizes other than 1/32 (4.0 mm) are to be used when classification is based on those sizes, or when they are required for lot acceptance testing under AWS A5.01, *Filler Metal Procurement Guidelines* (unless other conditions are specified by the purchaser). Amperage and travel speed other than those listed above may be used when required by the manufacturer and communicated to the purchaser.

FIG. 3 GROVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS (CONT'D)

be tested in the as-welded condition, and the other piece shall be heat-treated at the temperature specified in Table 5 for 1 hr (-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 specified holding temperature in Table 5 shall not exceed 400°F per hour (220°C per hour). When to one hour holding time has been completed, the assembly shall be allowed to cool in the furnace to a temperature below 600°F (320°C) at a rate not exceeding 350°F per hour (190°C per hour). The assembly may be removed from the furnace at any temperature below 600°F (320°C) and allowed to cool in still air to room temperature. Testing of the assembly shall be as specified in sections 10 through 12.

8.5 Diffusible Hydrogen. In those cases in which an optional diffusible hydrogen designator is to be added to the electrode-flux classification designation, four diffusible hydrogen test assemblies shall be prepared, welded, and tested as specified in section 13, Diffusible Hydrogen Test.

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 electrodes, 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

TABLE 4
BASE METAL FOR TEST ASSEMBLIES

Weld Metal AWS Classification	Base Metal ASTM Standard ⁽¹⁾	Base Metal UNS Number ⁽²⁾
A1, A2, A3, A4	A204 Grade A	K11820
B2 and B2H	A387 Grade 11	K11789
B3	A387 Grade 22	K21590
B4	A387 Grade 22	K21590
B5	A387 Grade 11	K11789
B6 and B6H	A387 Grade 5	S50200
B8	A387 Grade 9	...
Ni1	A516 Grade 60, 65, or 70	K02100, K02403, or K02700
Ni2	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, or K22103
Ni3	A203 Grade D or E	K31718 or K32018
Ni4	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, or K22103
F1 and F4	A537 Class 1 or 2, or A533 (any type or grade in these specifications)	K12437, K12521, K12539, K12654, or K12529
F2 and F3	A302 Grade C or D, or A533 Type B, C, or D	K12039, K12054, K12539, K12554, K12529
F5 and F6	A514 or A517 (any type or grade in these specifications)	K11856, K11630, K11511, K11662, K21604, K11576, K11872, K11646, K11625, K11523, K11682, K11683, K11847, K21650 or K42339
M1, M2, M3, M4	A514 to A517 (any type or grade in these specifications), or A543 Type A or B	...
W	A572 or A588 (any type or Grade in these specifications)	K12040

NOTES:

- (1) For any weld metal classification in this specification, ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70 may be used. In that case, the groove faces and the contacting face of the backing shall be buttered, as shown in Fig. 3, using an electrode-flux combination of the same weld metal composition as that specified for the combination being tested, or using an electrode of the specified composition classified in another AWS low alloy steel filler metal specification. Alternatively, for the indicated weld metal classification, the corresponding base metals may be used for weld test assemblies without buttering. In case of dispute, buttered A36 steel shall be the referee material.
- (2) ASTM/SAE Unified Numbering System for Metals and Alloys.

elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for other elements. Rod stock analyzed for elements not in the coating may be analyzed prior to applying the coating.

9.2 Composite electrodes and any electrode-flux combination shall be analyzed in the form of weld metal, not filler metal. The sample for analysis shall be taken from weld metal obtained with the electrode and the flux with which it is classified. The sample shall come from a weld pad, the reduced section of the fractured tension test specimen, or a low dilution area of the groove weld in Fig. 3. The top surface of the pad described in para. 8.3 and 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 sample from a low dilution area of the groove weld in Fig. 3 or the reduced section of the fractured

tension test specimen shall be prepared for analysis by any suitable 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*.⁴

9.4 The results of the analysis shall meet the requirements of Table 1 or 2 for the classification of electrode or electrode-flux combination 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

⁴ ASTM standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

TABLE 5
PREHEAT, INTERPASS, AND POSTWELD HEAT TREATMENT TEMPERATURES⁽¹⁾

AWS Weld Metal Classification	Preheat and Interpass Temperature ⁽²⁾		Postweld Heat Treatment Temperature ⁽³⁾	
	F ± 25	C ± 14	F ± 25	C ± 14
A1	300	149	1150	621
A2	300	149	1150	621
A3	300	149	1150	621
A4	300	149	1150	621
B1	300	149	1150	621
B2	300	149	1150	621
B2H	300	149	1150	621
B3	400	204	1275	691
B4	400	204	1275	691
B5	300	149	1150	621
B6	600	316	1375	746
B6H	600	316	1375	746
B8	600	316	1375	746
Ni1	300	149	1150	621
Ni2	300	149	1150	621
Ni3	300	149	1150	621
Ni4	300	149	1150	621
F1	300	149	1150	621
F2	300	149	1150	621
F3	300	149	1150	621
F4 ⁽⁴⁾	300	149	1050	566
F5 ⁽⁴⁾	300	149	1050	566
F6 ⁽⁴⁾	300	149	1050	566
M1 ⁽⁴⁾	300	149	1125	607
M2 ⁽⁴⁾	300	149	1125	607
M3 ⁽⁴⁾	300	149	1125	607
M4 ⁽⁴⁾	300	149	1125	607
W ⁽⁴⁾	300	149	1125	607
G	----- not specified -----			

NOTES:

- (1) These temperatures are specified for electrodes and fluxes tested and classified under this specification and are not necessarily recommendations for production use. The specific requirements for production welding shall be determined by the user. They may or may not differ from those called for here. (See also A6.3).
- (2) The preheat and interpass temperatures listed here shall be used for the test assemblies regardless of whether the electrode-flux combination is classified in the as-welded or postweld heat treated condition. They are required for purposes of uniformity and may or may not be indicative of those that might be satisfactory for fabrication of any particular weldment. The fabricator shall determine for himself what is required there. (See also A6.3).
- (3) Electrode-flux combinations classified in the postweld heat treated condition shall be heat treated for 1 hour at the temperature shown for each classification. No welding shall be done after heat treatment.
- (4) These classifications normally are used in the as-welded condition.

assemblies longer than the minimum of 12 in. (300 mm) required in Fig. 3 (see para. 8.4), shall include at least 10 in. (250 mm) of the weld, excluding the first and last inch (25 mm) 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, or with a uniform reinforcement not

exceeding $\frac{3}{32}$ in. (2.4 mm). 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 E 142, *Standard Method for Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 If the radiograph shows the following, the soundness of the weld metal meets the requirements of this specification:

(a) No cracks, no incomplete fusion, and no incomplete penetration;

(b) No slag inclusions longer than $\frac{1}{4}$ in. (6 mm) or $\frac{1}{3}$ of the thickness of the weld, whichever is greater, or no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld except when the distance between the successive inclusions exceeds six times the length of the longest inclusion in the group;

(c) No rounded indications in excess of those permitted by the radiographic standards in Fig. 4.

One inch (25 mm) of the weld, measured from each end of the test assembly, shall be disregarded for radiographic evaluation.

A rounded indication is an indication (on the radiograph) whose length is not more than three times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be of porosity or slag. Indications whose largest dimension is less than $\frac{1}{64}$ in. (0.40 mm) shall be disregarded. Test assemblies with indications larger than the large indications permitted in the radiographic standards do not meet the requirements of this specification.

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 for all electrode-flux classifications except those classified in the postweld heat-treated condition shall be aged at 200-220°F (93-104°C) for 48 ± 2 hours, then cooled in air. The specimen shall be tested in the manner described in the tension test section of 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 6.

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 7.

12.2 The five specimens shall be tested in accordance with the fracture toughness test section of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. The test temperature shall be that specified in Table 7 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-lb (20 J), and the average of the three shall not be less than the required 20 ft-lb (27 J) energy level.

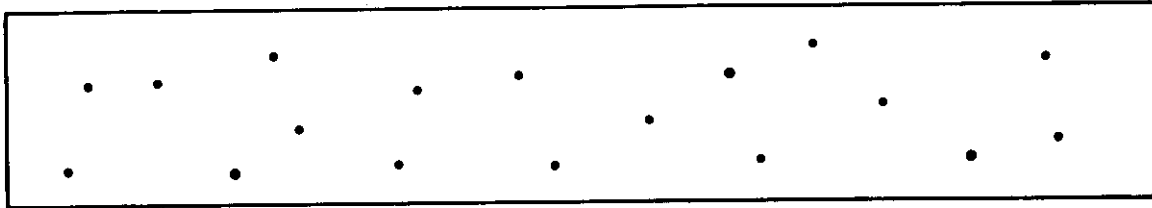
12.4 For classifications with the "N" (nuclear) designation, three additional specimens shall be prepared. These specimens shall be tested at room temperature. Two of the three shall equal or exceed 75 ft-lb (102 J), and the third shall be not lower than 70 ft-lb (95 J). The average of the three shall equal or exceed 75 ft-lb (102 J).

13. Diffusible Hydrogen Test

13.1 For each electrode-flux combination to be identified by a diffusible hydrogen designator, that combination shall be tested according to one of the methods given in ANSI/AWS A4.3, *Standard Procedures for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. The electrode and flux may be baked to reduce their moisture content before testing. When this is done, the baking time and temperature shall be noted on the test report. The diffusible hydrogen designator may be added to the classification designation according to the average test value as compared to the requirements of Table 8.

13.2 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of moisture per pound of dry air (1.43 g of moisture per kg of dry air) at the time of welding. The actual atmospheric conditions shall be reported along with the average value for the test according to ANSI/AWS A4.3.

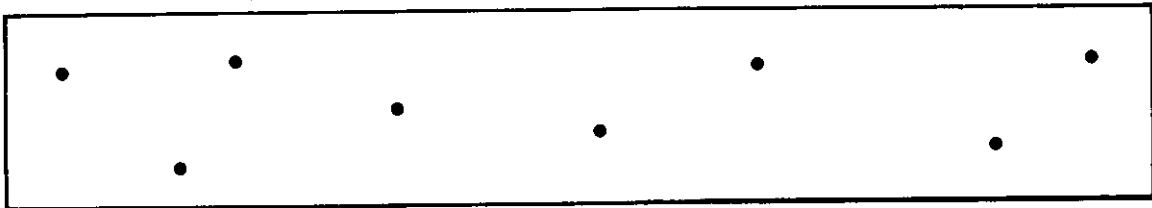
13.3 When the absolute humidity equals, or exceeds, the reference condition for preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided that actual test results satisfy the diffusible hydrogen



(A) ASSORTED ROUNDED INDICATIONS

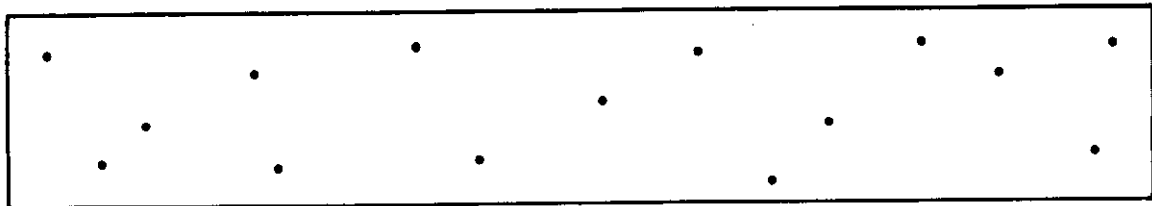
SIZE PERMITTED IS 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm).
NUMBER PERMITTED IN ANY 6 in. (150 mm) OF WELD IS 18, WITH THE FOLLOWING
RESTRICTIONS:

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.



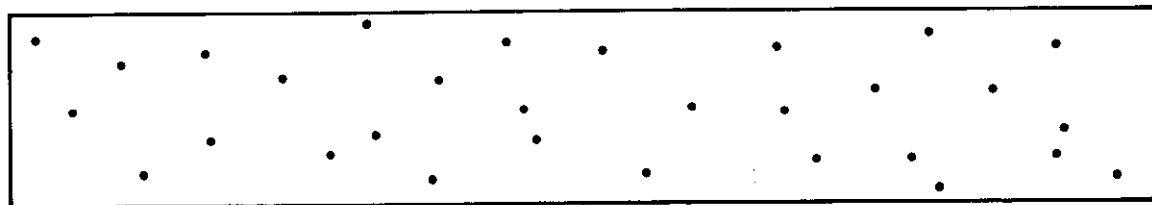
(B) LARGE ROUNDED INDICATIONS

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.



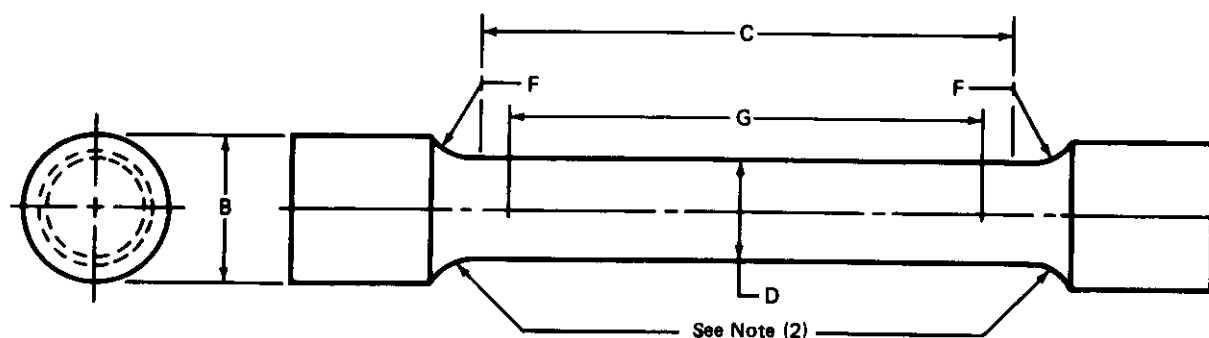
(D) SMALL ROUNDED INDICATIONS

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.

NOTES:

- (1) The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications smaller than 1/64 in. (0.40 mm) shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
- (2) 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 ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

FIG. 4 RADIOGRAPHIC STANDARDS FOR ROUNDED INDICATIONS



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 ± 0.2	50.8 ± 0.1	57	19	9.5	130

NOTES:

- (1) Dimensions G and C shall be as shown, but the ends may be of any shape required to fit the testing machine as long as the load is kept 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).

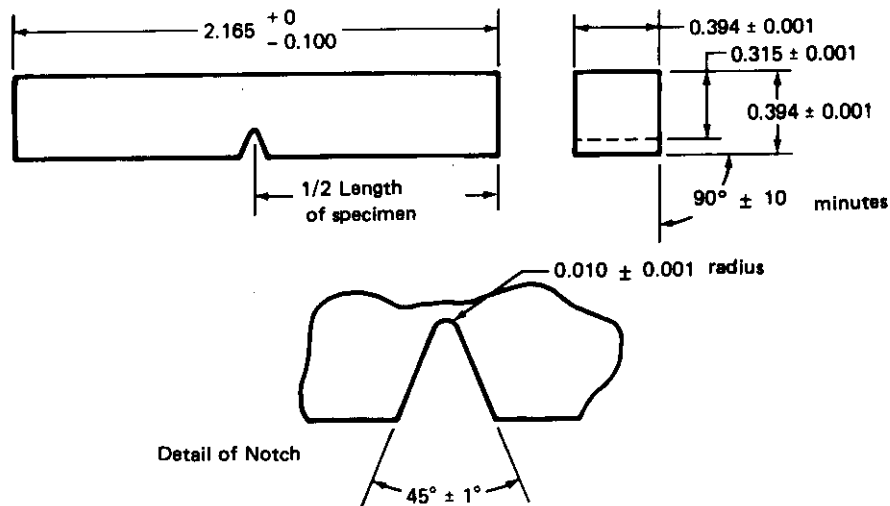
FIG. 5 TENSION TEST SPECIMEN

TABLE 6
TENSION TEST REQUIREMENTS

Electrode-Flux Combination Classification ⁽¹⁾	Tensile Strength		Yield Strength Minimum ⁽²⁾		Elongation % min. ⁽²⁾
	psi	MPa	psi	MPa	
F7XX-EXX-XX	70 000– 95 000	480–660	58 000	400	22
F8XX-EXX-XX	80 000–100 000	550–690	68 000	470	20
F9XX-EXX-XX	90 000–110 000	620–760	78 000	540	17
F10XX-EXX-XX	100 000–120 000	690–830	88 000	610	16
F11XX-EXX-XX	110 000–130 000	760–900	98 000	680	15 ⁽³⁾
F12XX-EXX-XX	120 000–140 000	830–970	108 000	750	14 ⁽³⁾

NOTES:

- (1) The letter "X" used in various places in the classification in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, the classification of the electrode, and the chemical composition of the weld metal (see Fig. 1).
- (2) Yield strength at 0.2 percent offset, and elongation in 2 in. (51 mm) gage length.
- (3) Elongation may be reduced by one percentage point for F11XX-EXX-XX, F11XX-ECXX-XX, F12XX-EXX-XX, and F12XX-ECXX-XX weld metals in the upper 25 percent of their tensile strength range.



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

GENERAL NOTES:

- All dimensions except angles are in inches.
- The notched surface and the surface to be struck shall be parallel within 0.002 in. The other two surfaces shall be square with the notched and struck surfaces within ± 10 minutes of a degree.
- The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edges of the specimen within one degree.
- The dimensions of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum of 50 times magnification on a shadowgraph, metallograph, or optical comparator.
- The correct location of the notch shall be verified by etching before or after machining.
- If a specimen does not break upon being struck, the value for energy absorbed shall be reported as the capacity of the impact testing machine followed by a plus sign (+).

FIG. 6 CHARPY V-NOTCH IMPACT TEST SPECIMEN

TABLE 7
IMPACT TEST REQUIREMENTS^{(1) (2)}

Digit	Test Temperature		Average Energy Level, Minimum
	°F	°C	
Z	Not Specified		Not Required
0	0	-18	20 ft-lbs (27 J)
2	-20	-29	"
4	-40	-40	"
5	-50	-46	"
6	-60	-51	"
8	-80	-62	"
10	-100	-73	"
15	-150	-101	"

NOTES:

- Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification (Table 6) the appropriate digit from the table above (Table 7), as indicated in Fig. 1. Weld metal from a specific electrode-flux 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).
- Weld metals with the "N" suffix shall also have a Charpy V-notch energy level of at least 75 ft-lbs (102 J) at 70°F (21°C).

TABLE 8
DIFFUSIBLE HYDROGEN REQUIREMENTS⁽¹⁾

AWS Electrode- Flux Combination Classification	Optional Supplemental Diffusible Hydrogen Designator ^{(1) (2)}	Average Diffusible Hydrogen, Maximum (m/100g Deposited Metal) ⁽³⁾
All	H16	16.0
All	H8	8.0
All	H4	4.0

NOTES:

(1) See Note (3) to Table 3.

(2) This designator is added to the end of the complete electrode-flux classification designation. For example, a weathering steel electrode-flux combination meeting a maximum diffusible hydrogen of 8.0 ml/100g of deposited metal might be designated F8A2-EW-WH8.

(3) Some classifications may not meet the lower average diffusible hydrogen levels (H8 and H4).

requirements for a given designator, as specified in Table 8.

PART C — MANUFACTURER, IDENTIFICATION, AND PACKAGING

14. Method of Manufacture

The welding 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.

15. Electrode Requirements

15.1 Standard Sizes. Standard sizes for electrodes in the different package forms (coils with support, coils without support, and drums) are shown in Table 9.

15.2 Finish and Uniformity

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

15.2.2 Each continuous length of filler metal shall be from a single heat or lot of material. Welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the filler metal on automatic and semiautomatic equipment.

15.2.3 Core ingredients in composite filler metal 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.

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

15.3 Standard Package Forms

15.3.1 Standard package forms are coils with support, coils without support, and drums. Standard package dimensions and weights for each form are given in Table 10. Package forms, sizes, and weights other than these shall be as agreed upon between purchaser and supplier.

15.3.2 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 filler metal.

15.3.3 Drums shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

15.4 Winding Requirements

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

15.4.2 The cast and helix of the electrode in coils and drums shall be such that the electrode will feed

TABLE 9
STANDARD ELECTRODE SIZES AND TOLERANCES⁽¹⁾

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

NOTE:

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

TABLE 10
STANDARD DIMENSIONS AND WEIGHTS⁽¹⁾

Electrode Size ⁽²⁾		Net Weight of Coil ⁽³⁾		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	12 ± 1/8	305 ± 3	2 1/2	65	or	17 1/2	440
"	"	50	23	"	"	4 5/8	120		17	430
"	"	60	27	"	"				"	"
"	"	65	30	"	"					
3/32-1/4	2.4-6.4	100	45	(4)		5	125		31 1/2	800
"	"	150	68	"		"	"		"	"
"	"	200	91	"		"	"		"	...
Coils without Support										
1/16-1/4	1.6-6.4	----- as agreed between purchaser and supplier -----								
Drums										
1/16-1/4	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 upon between purchaser and supplier.

(5) Drum diameters are nominal, not maximum.

in an uninterrupted manner on automatic and semiautomatic equipment.

15.5 Electrode Identification

15.5.1 The product information and the precautionary information required in para. 15.7 for marking each package shall appear also on each coil and drum.

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

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

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

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

15.7 Marking of Packages

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

15.7.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of welding 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 INFORMATION

16. Flux Requirements

16.1 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.

16.2 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 weld pass will not remove it.

16.3 Packaging

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

16.3.2 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.

16.4 Marking of Packages

16.4.1 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 designation (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 of the flux, is the supplier. See also Appendix A6.1.5);

- (c) Net weight;
- (d) Lot, control, or heat number;
- (e) Particle size, if more than one particle size of flux of that trade designation is produced;
- (f) The trade designation of each composite electrode with which the flux manufacturer has classified the flux, if applicable.

16.4.2 All packages of flux shall be marked as required in para. 15.7.2 for the electrodes.

Appendix A

Guide to AWS Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

(This Appendix is not a part of ANSI/AWS A5.23-90, *Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, but is 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 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 undiluted weld metal obtained with a particular flux. See Fig. 1.

As examples, consider the following: EL12, EM12K, EB3, EM3, and ECB3.

The prefix "E" designates an electrode, as in other specifications. For the EL12 and EM12K classifications, the system given in ANSI/AWS A5.17 is used, and the same chemical composition is required for these carbon steel electrodes as for those classifications in ANSI/AWS A5.17. The EB3 and EM3 electrodes are solid electrodes whose compositions are shown as electrode compositions in Table 1. The letter "C" in ECB3 indicates that the electrode is a composite electrode. Such electrodes are classified by the composition of

the weld metal produced with a specific flux. Such compositions are given in Table 2 of this Specification. The composition of the weld metal is specified for composite electrodes because there is no standard method of analyzing the electrode itself.

The addition of the letter "N" as a suffix to a classification indicates that the electrode is intended for certain very special welds in nuclear applications. These welds are found in the core belt region of the reactor vessel. This region is subject to intense neutron radiation, and it is necessary, therefore, that the phosphorus, vanadium, and copper contents of this weld metal be limited in order to resist neutron radiation-induced embrittlement. It is also necessary that the weld metal have a high shelf energy level in order to withstand some embrittlement, yet remain serviceable over the years. These electrodes are not required elsewhere; however, they could be used anywhere that weld metal with an exceptionally high shelf energy level is required. Coating of "N" electrodes with copper or copper-bearing material is prohibited.

A2.2 "G" Classification and the Use of "Not Specified" and "Not Required"

A2.2.1 This specification includes filler metals classified as EG or ECG. The "G" indicates that the filler metal is of a "general" classification. It is "general" because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent, in establishing this classification, is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal — in the case

of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal — one that otherwise would have to await a revision of the specification — to be classified immediately, under the existing specification. This means, then, that two filler metals — each bearing the same “G” classification — may be quite different in some certain respect (chemical composition, again, for example).

A2.2.2 The point of difference (although not necessarily the amount of the difference) referred to above will be readily apparent from the use of the words “not required” and “not specified” in the specification. The use of these words is as follows:

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

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

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a filler metal to that classification. When a purchaser wants the information provided by that test, in order to consider a particular product of that classification for a certain application, the customer will have to arrange for that information with the supplier of that product. The customer will also have to establish with that supplier just what the testing procedure and the acceptance requirements are to be, for that test. The customer may want to incorporate that information (via ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*) in the purchase order.

A2.3 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 Part B of this specification.

As examples of flux classifications, consider the following:

F7PO-EL12-A1
F8A6-ENi3-Ni3
F10PZ-ECB3-B3
F9 A2-ECM1-M1

The prefix “F” designates a flux. This is followed by one or two digits representing the minimum tensile

strength required of the weld metal in 10 000 psi (69 MPa).

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 metal 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 7).

These mechanical property designations are followed by the designation of the electrode used in classifying the flux (see Table 1). The suffix included after the first hyphen (EL12, ENi3, ECB3, or ECM1) refers to the electrode classification (solid electrodes from Table 1 or composite electrodes from Table 2) with which the flux will produce weld metal that meets the specified mechanical properties when tested as called for in the specification. The suffix after the second hyphen refers to the weld metal composition (Table 2) without regard to whether the electrode was solid or composite.

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 marking of the flux package 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 ANSI/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, should be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule

F, Table 1, of the ANSI/AWS A5.01-87, *Filler Metal Procurement Guidelines*. Testing in accordance with any other schedule in that Table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall 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 has actually conducted the test required by the specification on material that is representative of that being shipped, and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

A5. Ventilation During Welding

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

- (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 used;
- (d) The proximity of the welders or welding operators to the fumes as the fumes issue from the welding zone, and to the gases and dust in the space in which they are working;
- (e) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard Z49.1, *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 drawn particularly to the section of that document on Health Protection and Ventilation.

A6. Welding Considerations

A6.1 Types of Fluxes. Submerged arc welding fluxes are granular, fusible mineral compounds of various proportions manufactured by any of several different methods. In addition, some fluxes may contain intimately mixed metallic ingredients to deoxidize the weld pool or add alloy elements, or both. 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," "active," or "alloy."

A6.1.1 Neutral Fluxes. Neutral fluxes are defined as those which will not produce any significant change in the weld metal manganese and silicon content 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 plate exceeds 1 in. (25 mm) in thickness.

The following considerations concerning neutral fluxes should be noted:

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

(b) While neutral fluxes do maintain the composition of the weld metal even when the voltage is changed, it is not always true that the composition of the weld metal deposit is the same as the composition of the electrode used. Some neutral fluxes break down 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 composition from the electrode used to the weld metal obtained are fairly consistent even when there are large changes in voltage.

(c) Even when a neutral flux is used to maintain the weld metal 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.

(d) While a flux may be neutral with respect to manganese and silicon, it may not be neutral with respect to active alloy elements, most notably chromium. Some, but not all, neutral fluxes tend to reduce the chromium content of the weld metal as compared to that of the electrode. An electrode of somewhat higher chromium content than the intended weld metal may be necessary in such cases. Note that the EB3 chromium range for solid electrodes in Table 1 is higher than the corresponding weld metal chromium range in Table 2.

A6.1.2 Active Fluxes. Active fluxes are those which contain small amounts of manganese, or 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 weld, especially on oxidized plate.

The following considerations concerning active fluxes should be noted:

(a) Since active fluxes do contain some deoxidizers, the manganese and silicon in the weld metal will vary with changes in arc voltage. An increase in manganese or silicon increases the strength level of the weld metal, but may lower the impact properties. For this reason, voltage shall 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 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 carbon steel electrodes to make alloy weld metal. The alloys for the weld metal are added as ingredients in the flux. As with active fluxes, the recovery of manganese and silicon is affected significantly by arc voltage, so with alloy fluxes the recovery of alloy elements from the flux is affected significantly by the arc voltage. With alloy fluxes, the manufacturer's recommendations should be closely followed if desired alloy weld metal compositions are to be obtained.

A6.1.4 Wall Neutrality Number. The Wall Neutrality Number is a convenient relative measure of flux neutrality. The Wall Neutrality Number addresses carbon steel weld metals with regard to their 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 total change in silicon, regardless of whether it increases or decreases, and the total change in manganese, regardless of whether it increases 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:

ΔSi = is the difference in silicon content of the two pads and

ΔMn = is the corresponding difference in manganese content.

A6.1.5 Recrushed Slags. The slag formed during submerged arc welding does not have the same chemical composition as unused (virgin) flux. Its composition is affected by the composition of the original flux, the base metal plate and electrode composition, and 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 should not be considered to be the same as the virgin flux. Such flux should be provided with its own marking (see para. 16.4) using the crusher's name and trade designation.

A6.2 Choice of Electrodes. In choosing an electrode classification for submerged arc welding of a low alloy steel, the most important considerations are the

manganese, silicon, and alloy content in the electrode, the effect of the flux on recovery of manganese, silicon, and alloy elements in the weld metal, whether the weld is to be single pass or multi-pass, and the mechanical properties expected of the weld metal.

A certain minimum weld metal manganese content is necessary to avoid longitudinal centerline cracking. This minimum depends upon restraint of the joint, upon welding procedure and resulting bead shape, and upon the weld metal composition. In the event that longitudinal 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 fillets, especially on base metal that has scale, 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 an active flux, or both, may be essential. Again manufacturer's recommendations should be consulted.

Table 4 lists numerous weld metal classifications and corresponding base metals that are suitable for use with these weld metals for preparing the weld test assembly for classification of an electrode-flux combination. This gives some indication of electrodes suitable for joining these base metals. However, the entries in Table 4 should not be considered as recommendations for joining these base metals. Likewise, the absence of a correspondence in Table 4 between a weld metal classification and a base metal should not be considered a recommendation against using a particular weld metal to join a particular base metal. The steel producer, the electrode producer, and the flux producer may all be able to make appropriate recommendations and should be consulted.

Composite electrodes are generally designed for a specific flux. That flux identification is required (para. 15.7.1) 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

less 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 6 and 7 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 the weld metal they produce. 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 metal produced in 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 the temperature called for in Table 5) 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 specifications 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 very 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 low alloy steel weld metal produced with other procedures may differ from the properties required by Tables 6 and 7 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 and electrode in a dry condition. In submerged arc welding with low alloy steel electrodes and fluxes classified in this specification, weld metal or heat-affected zone cracking associated with diffusible hydrogen tends to become more of a problem with increasing weld metal strength, increasing heat-affected zone hardness, increasing diffusible hydrogen content, decreasing preheat and interpass temperature, and decreasing time at or above the interpass temperature during and after welding. This cracking is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal centerline cracks

(especially in root beads), and toe or underbead cracks in the heat-affected zone.

Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-induced cracking, it may be desirable to measure the diffusible hydrogen content resulting from a particular electrode-flux combination. Accordingly, the use of optional designators for diffusible hydrogen is introduced to indicate the maximum average value obtained under a clearly defined test condition in ANSI/AWS A4.3, *Standard Procedures for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.

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

The use of a reference atmospheric condition during welding is necessitated because the arc always is imperfectly shielded. Moisture from the air, distinct from that in the electrode or flux, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining a suitable depth of flux cover [normally 1 to 1½ in. (25 to 38 mm)] in front of the electrode during welding. Nevertheless, some air will mix with the flux cover and add its moisture to the other sources of diffusible hydrogen. It is possible for this extra diffusible hydrogen to significantly affect the outcome a diffusible hydrogen test. For this reason, it is appropriate to specify a reference atmospheric condition. The reference atmospheric condition of 10 grains of moisture per pound (1.43 grams per kilogram) of dry air is equivalent to 10 percent relative humidity at 68°F (20°C).

