

SPECIFICATION FOR CARBON AND LOW ALLOY STEEL ELECTRODES AND FLUXES FOR ELECTROSLAG WELDING



SFA-5.25



(Identical with AWS Specification A 5.25-91)

1. Scope

This specification prescribes requirements for the classification of electrodes (both solid and composite metal cored) and fluxes for electroslag welding of carbon and low alloy steels.

SECTION A — GENERAL REQUIREMENTS

2. Classification

2.1 The solid electrodes covered by this specification are classified according to the chemical composition of the electrode, as specified in Table 1.

2.1.1 The composition metal cored electrodes covered by this specification are classified according to the chemical composition of the weld metal produced by use with a specific brand name flux (i.e., manufacturer and designation) as specified in Table 2.

2.1.2 Fluxes covered by this specification are classified according to the mechanical properties of the weld metal as specified in Tables 3 and 4, when using an electrode of a particular classification.

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 using a different electrode for each. Fluxes classified as FESX2-XXX may also be classified as FESXO-XXX and FESXZ-XXX, as specifically permitted by note (a) to Table 4.

2.3 The electrodes and fluxes classified under this specification are intended for electroslag 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 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 Procedures

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), Acceptance, for further information concerning acceptance, testing of the material shipped, and 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), Certification, for further information concerning certification and the testing called for to meet this requirement.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES

AWS Classification ^c	UNS Number ^d	Weight Percent ^{a,b}											Other Elements, Total		
		C	Mn	P	S	Si	Ni	Cr	Mo	Cu ^e	Ti	Zr		Al	
Medium Manganese Classes															
EM5K-EW	K10726	0.07	0.90-1.40	0.025	0.035	0.40-0.70	—	—	—	0.35	0.05-0.15	0.02-0.12	0.05-0.15	0.50	
EM12-EW	K01112	0.06-0.15	0.80-1.25	0.035	0.035	0.10	—	—	—	0.35	—	—	—	0.50	
EM12K-EW	K01113	0.05-0.15	0.80-1.25	0.035	0.035	0.10-0.35	—	—	—	0.35	—	—	—	0.50	
EM13K-EW	K01313	0.07-0.19	0.90-1.40	0.035	0.035	0.35-0.75	—	—	—	0.35	—	—	—	0.50	
EM15K-EW	K01515	0.10-0.20	0.80-1.25	0.035	0.035	0.10-0.35	—	—	—	0.35	—	—	—	0.50	
High Manganese Classes															
EH14-EW	K11585	0.10-0.20	1.70-2.20	0.035	0.035	0.10	—	—	—	0.35	—	—	—	0.50	
Special Classes															
EWS-EW	K11245	0.07-0.12	0.35-0.65	0.035	0.040	0.22-0.37	0.40-0.75	0.50-0.80	—	0.25-0.55	—	—	—	0.50	
EH10Mo-EW	K10945	0.07-0.12	1.60-2.10	0.025	0.025	0.50-0.80	0.15	—	0.40-0.60	0.35	—	—	—	0.50	
EH10K-EW	K01010	0.07-0.14	1.40-2.00	0.025	0.030	0.15-0.30	—	—	—	—	—	—	—	0.50	
EH11K-EW	K11140	0.07-0.15	1.40-1.85	0.025	0.035	0.80-1.15	—	—	—	0.35	—	—	—	0.50	
ES-G-EW	—	—	—	—	—	—	NOT SPECIFIED ^f								0.50

NOTES:

- The electrode 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 the limit specified for "Other Elements, Total" in the last column of the table.
- Single values are maximums.
- Chemical composition requirements may be similar to those in other AWS specifications; see Table A1 in the Appendix.
- SAE/ASTM Unified Numbering System for Metals and Alloys.
- The copper limit includes copper that may be applied as a coating on the electrode.
- Composition shall be reported; the requirements are those agreed to by the purchaser and the supplier.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR
UNDILUTED WELD METAL FROM COMPOSITE METAL CORED ELECTRODES^a

AWS Classi- fication	UNS Number ^d	Weight Percent ^{b,c}										Other Elements, Total
		C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	
EWT1	W06040	0.13	2.00	0.03	0.03	0.60	—	—	—	—	—	0.50
EWT2	W20140	0.12	0.50–1.60	0.03	0.04	0.25–0.80	0.40–0.80	0.40–0.70	—	0.25–0.75	—	0.50
EWT3	W22340	0.12	1.00–2.00	0.02	0.03	0.15–0.50	1.50–2.50	0.20	0.40–0.65	—	0.05	0.50
EWT4	—	0.12	0.50–1.30	0.03	0.03	0.30–0.80	0.40–0.80	0.45–0.70	—	0.30–0.75	—	0.50
EWTG	—	NOT SPECIFIED ^e										

NOTES:

- The flux used shall be that with which the electrode is classified for mechanical properties (see Tables 3 and 4).
- 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 the limit specified for "Other Elements, Total" in the last column of the table.
- Single values are maximums.
- SAE/ASTM Unified Numbering System for Metals and Alloys.
- Composition shall be reported; the requirements are those agreed to by the purchaser and supplier.

TABLE 3
TENSION TEST REQUIREMENTS (AS-WELDED)

AWS Classification ^a	Tensile Strength		Yield Strength min ^b		Elongation (min.) Percent ^b
	psi	MPa	psi	MPa	
FES6Z-XXX	60 000	(420)	36 000	(250)	24
FES60-XXX	to	to			
FES62-XXX	80 000	(550)			
FES7Z-XXX	70 000	(490)	50 000	(350)	22
FES70-XXX	to	to			
FES72-XXX	95 000	(650)			

NOTES:

- The letters "XXX" as used in the AWS Classification column in this table refer to the electrode classification used.
- Yield strength at 0.2 percent offset and elongation in 2 in. (51 mm) gage length.

TABLE 4
IMPACT TEST REQUIREMENTS^a (AS-WELDED)

AWS Classification ^b	Average Impact Strength ^c Minimum
FES6Z-XXX	Not specified
FES7Z-XXX	Not specified
FES60-XXX	15 ft-lbs at 0°F (20J @ -18°C)
FES70-XXX	15 ft-lbs at 0°F (20J @ -18°C)
FES62-XXX	15 ft-lbs at -20°F (20J @ -29°C)
FES72-XXX	15 ft-lbs at -20°F (20J @ -29°C)

NOTES:

- A flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table. In this manner, FESX2-XXX may also be classified as FESX0-XXX and FESXZ-XXX and FESX0-XXX may be classified as FESXZ-XXX.
- The letters "XXX" used in the AWS Classification column in this table refer to the electrode classification used.
- Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 15 ft-lbs (20J) one of the three remaining values may be lower than 15 ft-lbs but not lower than 10 ft-lbs (14J). The average of the three shall not be less than the 15 ft-lbs (20J) specified.

TABLE 5
REQUIRED TESTS

Material to be Classified	AWS Classification ^a	Chemical Analysis		Radiographic Test	Tension Test	Impact Test
		Electrode	Weld Metal			
Solid Electrodes	All	Required	Not Required	Not Required	Not Required	Not Required
Composite Electrodes ^b	All	Not Required	Required	Not Required	Not Required	Not Required
Fluxes	FES6Z-XXX	Not Required	Not Required	Required	Required	Not Required
	FES60-XXX	Not Required	Not Required	Required	Required	Not Required
	FES62-XXX	Not Required	Not Required	Required	Required	Not Required
	FES7Z-XXX	Not Required	Not Required	Required	Required	Not Required
	FES70-XXX	Not Required	Not Required	Required	Required	Not Required
	FES72-XXX	Not Required	Not Required	Required	Required	Not Required

NOTES:

a. The letters "XXX" used in the AWS Classification column in this table refer to the electrode classification used.

b. The flux used when classifying composite electrodes shall be that with which the electrode is classified for mechanical properties.

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

5.2 For purposes of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1,000 psi tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method of ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.⁴

SECTION B — TESTS, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

6.1 Chemical analysis of solid electrodes is the only test required for classification of a solid electrode under this specification, as shown in Table 5.

6.2 Chemical analysis of undiluted weld metal from the composite electrode and a particular (specific brand name) flux is the only test required for classification of a composite electrode under this specification, as shown in Table 5.

6.3 The tests required for classification of each electrode/flux combination are specified in Table 5. The purpose of these tests is to determine the mechanical properties and soundness of the weld. 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 12.

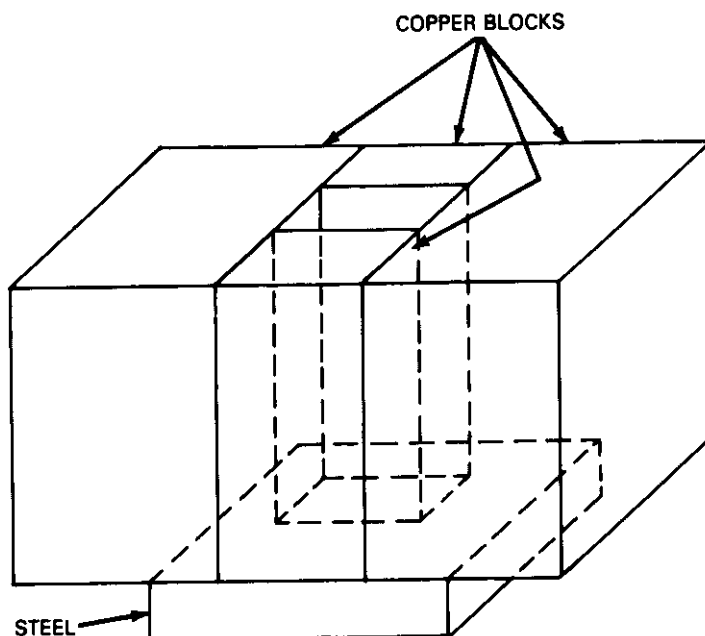
7. Retest

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. Specimens for retest may be taken from the original test assembly or from one or two new test assemblies. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement.

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 ingot as shown in Fig. 1, for chemical analysis of 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. 2 for mechanical properties and soundness of the weld metal in the as-welded condition.

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



Notes:

1. Weld ingot shall be deposited by arc welding in a water-cooled copper mold using welding conditions shown in Figure 2.
2. Weld ingot shall be of any convenient shape that provides approximately 4 sq. in. (25 sq. cm.) of weld metal cross section.
3. The weld ingot shall be started on a piece of carbon steel of sufficient size as to avoid complete fusion, and the copper mold shall be a sufficient heat sink to avoid contamination of the ingot by molten copper.
4. The sample for chemical analysis shall be taken at least 2 in. (50 mm) from the point of arc initiation and at least 1 in. (25 mm) from the end of the weld.
5. Consumable guide tubes shall be used for preparing the weld ingot if guide tubes were used in welding the groove weld test assembly, as use of consumable guide tubes will affect chemistry.

FIG. 1 WELD INGOT

8.2 Preparation of each weld test assembly shall be as prescribed in 8.3, 8.4 and 9.2. The base metal for each assembly shall be as required in Table 6 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 9.3 and Sections 10 through 12.

8.3 Weld Ingot. An ingot shall be prepared as specified in Fig. 2.

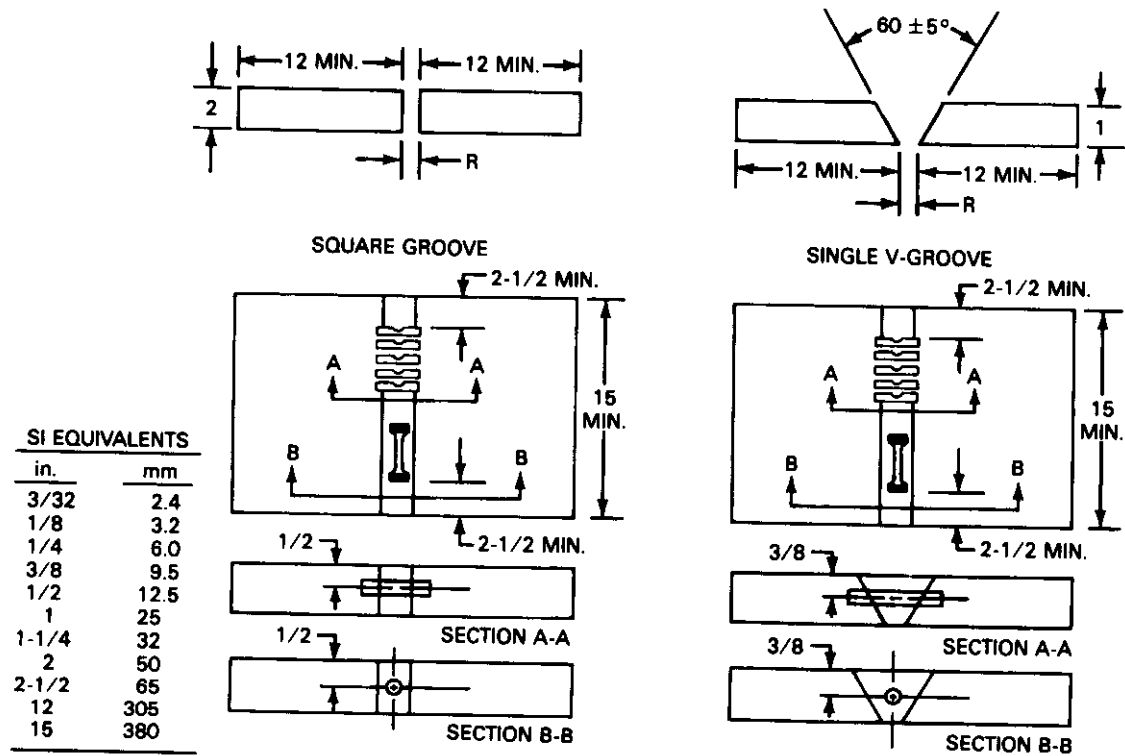
8.4 Groove Weld for Mechanical Properties and Soundness for Flux/Electrode Combinations. A test assembly shall be chosen and welded as specified in Fig. 2 using base metal of the appropriate type specified in Table 6. Testing of this assembly shall be as specified

in Sections 10 through 12. The assembly shall be tested in the as-welded condition.

9. Chemical Analysis

9.1 For solid electrodes, a sample of the electrode 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 elements other than those in the coating, the coating must be removed if its presence affects the results of the analysis for other elements.

9.2 Composite electrodes shall be analyzed in the form of undiluted weld metal, not electrode. The sample



NOTE: ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Groove Type ^a	Square groove	Square groove ^b	Single V-groove ^b
Thickness, in.	2	2	1
Consumable guide tube (nozzle)	Yes	No	No
Root opening, R, in.	1 to 1-1/4	1 to 1-1/4	1/4 min.
Electrode size, ^c in.	3/32 or 1/8	3/32 or 1/8	3/32 or 1/8
Current: deep			
Amperage	500 ± 50	500 ± 50	400 ± 50
Volts	40 ± 2	40 ± 2	40 ± 2

Notes:

- Weld test assembly shall be welded in the vertical position with upward progression.
- The test assembly shall be chosen and fixtured based on the manufacturer's recommendations. Water-cooled copper shoes shall be used except when using consumable guide tubes. For welding with consumable guide tubes, follow the manufacturer's recommendations regarding the use of water-cooled shoes. When using water cooling, the outgoing water temperature shall not exceed 180°F (82°C) near the exit point.
- If the manufacturer does not make the electrode size specified, the nearest size may be used. For sizes other than that shown, follow the manufacturer's recommended procedure.
- Welding shall begin with the assembly at room temperature, 65°F (18°C) minimum. No external heat shall be applied during welding. Run-on and run-off tabs are not required if the test assembly is of sufficient length to provide the required test specimens.
- The weld shall be completed in one pass.
- No thermal treatment shall be performed on the assembly subsequent to the completion of welding.

FIG. 2 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS

TABLE 6
BASE METAL FOR TEST ASSEMBLIES

AWS Classification	ASTM Base Metal Specification
FES6X-XXX	A36
FES7X-XXX	A242 Type 2, A441, or A572 Grade 50
FES7X-EWS-EW FES7X-EWT2 FES7X-EWT4	A588

for analysis shall be taken from weld metal obtained with the electrode (and the specific brand name flux with which it was classified). The sample shall come from an ingot (Fig. 1). The top surface of the ingot shall be removed and discarded and a sample for analysis shall be obtained from the underlying metal at a location at least 2 in. (50 mm) from the start of the ingot and at least 1 in. (25 mm) from the end by any appropriate mechanical means. The sample shall be free of slag.

9.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM Standard Method E350, *Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*.

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

10. Radiographic Test

10.1 The groove weld described in 8.4 and shown in Fig. 2 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, both surfaces of the weld may 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 The soundness of the weld metal meets the requirements of this specification if the radiograph shows no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Fig. 4.

In evaluating the radiograph, $2\frac{1}{2}$ in. (65 mm) of the weld on each end of the test assembly shall be disregarded.

A rounded indication is an indication (on the radiograph) whose length is no 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 does not exceed $\frac{1}{64}$ in. (0.4 mm) shall be disregarded. Test assemblies with indications greater than the largest 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 8.4 and shown in Fig. 2. The dimensions of the specimen shall be as shown in Fig. 3.

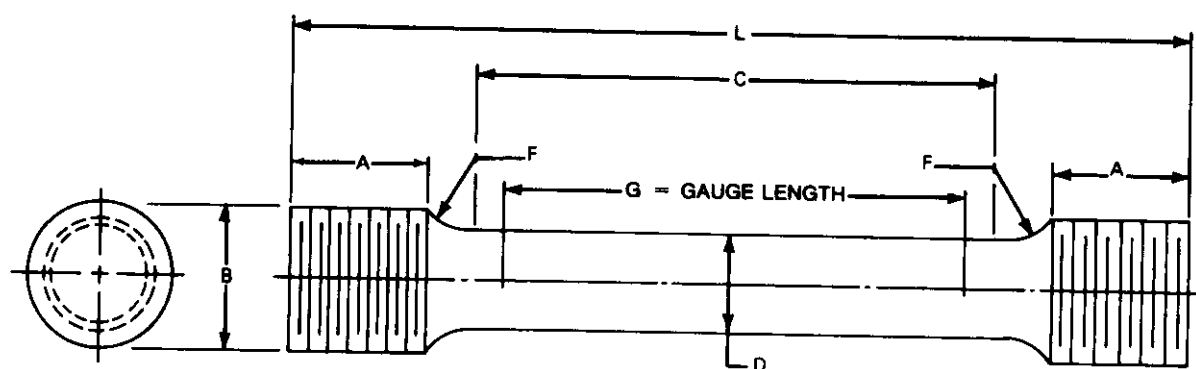
11.2 The specimen shall be tested in the manner described in the tension test section of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

11.3 The results of the tension test shall meet the requirements specified in Table 3.

12. Impact Test

12.1 Five Charpy V-notch impact test specimens (Fig. 5) shall be machined from the test assembly shown in Fig. 2, for those flux-electrode classifications for which impact testing is required in Table 5. 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 and the test results shall be those specified in Table 4, for the classification under test.

12.2 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 15 ft-lb (20 J) energy level. One of the three may be lower, but not lower than 10 ft-lb (14 J), and the average of the three shall be not less than the required 15 ft-lb (20 J) energy level.



Dimensions of Specimen, in.					Approximate Area, in. ²
D	G	C	B	F, min.	
0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	0.375	0.2

Dimensions of Specimen, mm					Approximate Area, mm ²
D	G	C	B	F, min.	
12.7 ± 0.25	50.8 ± 0.13	57	19	9.5	130

Notes:

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

FIG. 3 TENSION TEST SPECIMEN

SECTION C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

13. Method of Manufacture

The welding materials 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 different package forms (coils with support, coils without support, spools and drums) are shown in Table 7.

14.2 Finish and Uniformity

14.2.1 All electrodes shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams or laps (exclusive of the longitudinal joint in cored electrodes), and foreign matter that would adversely affect

the welding characteristics, the operation of the welding equipment or the properties of the weld metal.

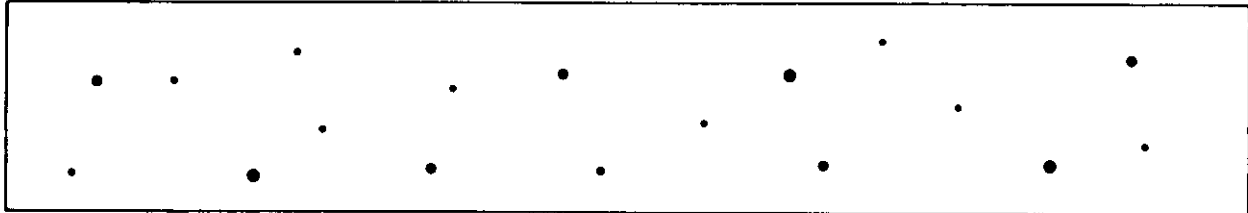
14.2.2 Each continuous length of electrode shall be from a single lot of material, and welds, when present shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic equipment.

14.2.3 The 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 may be applied to any of the electrodes in this specification.

14.3 Standard Package Forms

14.3.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard



(A) ASSORTED POROSITY AND/OR INCLUSIONS

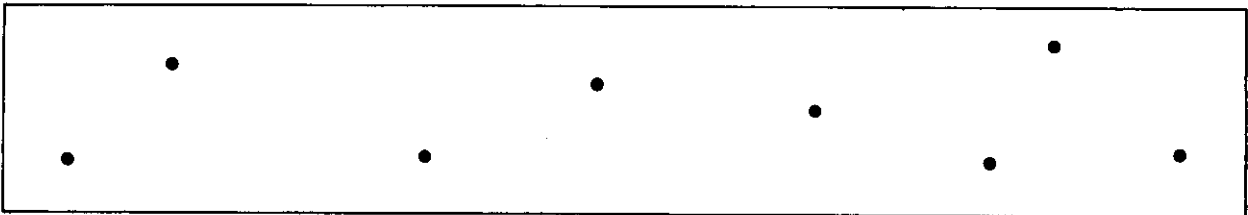
Size $1/64$ in. (0.4 mm) to $1/16$ in. (1.6 mm) diameter or in length

Maximum number of indications in any 6 in. (150 mm) of weld = 18, with the following restrictions:

Maximum number of large $3/64$ in. (1.2 mm) to $1/16$ in. (1.6 mm) diameter and/or length indications = 3

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

Maximum number of small $1/64$ in. (0.4 mm) to $1/32$ in. (0.8 mm) diameter and/or length indications = 10



(B) LARGE POROSITY AND/OR INCLUSIONS

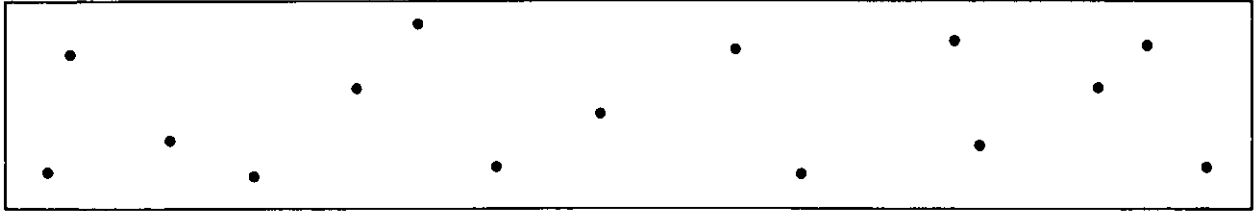
Size $3/64$ in. (1.2 mm) to $1/16$ in. (1.6 mm) diameter and/or length

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

Notes:

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

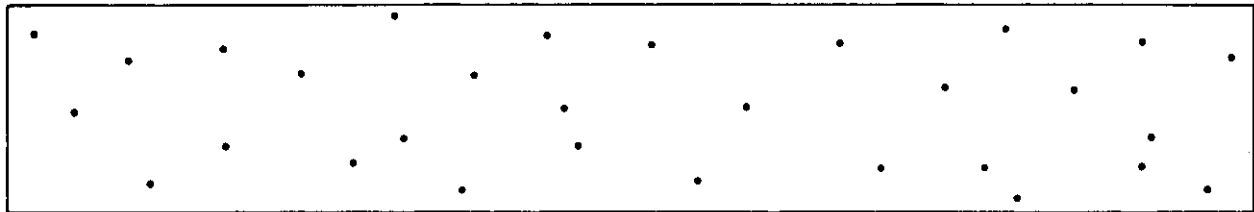
FIG. 4 RADIOGRAPHIC ACCEPTANCE STANDARDS



(C) MEDIUM POROSITY AND/OR INCLUSIONS

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

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



(D) SMALL POROSITY AND/OR INCLUSIONS

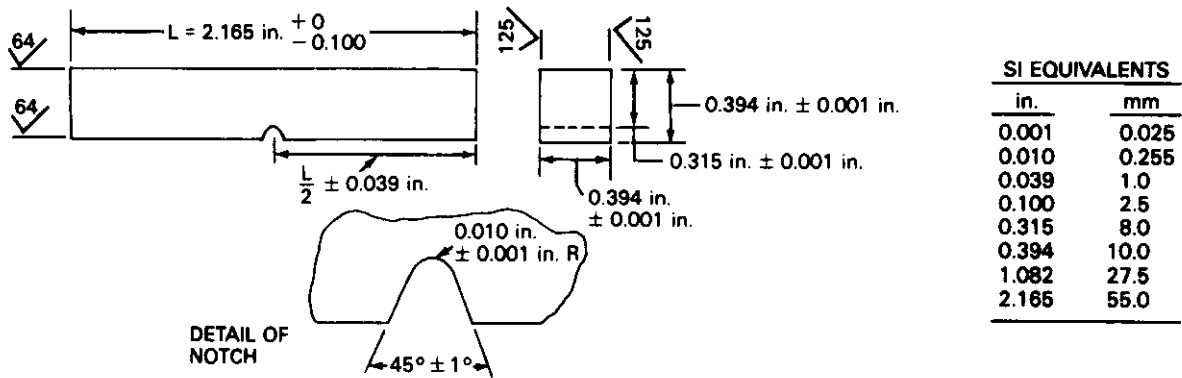
Size 1/64 in. (0.4 mm) to 1/32 in. (0.8 mm) diameter and/or length

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

Notes:

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

FIG. 4 RADIOGRAPHIC ACCEPTANCE STANDARDS (CONT'D)



Notes:

1. The notched surface and the surface to be struck shall be parallel within 0.002 in. (0.05 mm) and have at least $64 \mu\text{in.}$ ($1.6 \mu\text{m}$) finish. The other two surfaces shall be square with the notched or struck surface within ± 10 minutes of the degree and have at least $125 \mu\text{in.}$ ($3.2 \mu\text{m}$) finish.
2. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.
3. The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at minimum 50 times magnification on either a shadowgraph or a metallograph.
4. The correct location of the notch shall be verified by etching before or after machining.
5. 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. 5 CHARPY V-NOTCH IMPACT TEST SPECIMEN

TABLE 7
STANDARD SIZES*

Standard Package Form	Diameter		Tolerance	
	in.	mm	in.	mm
Coils with support	$\frac{1}{16}$ (.062)	1.6	± 0.002	± 0.05
Coils without support	$\frac{3}{64}$ (.078)	2.0	± 0.003	± 0.08
	$\frac{3}{32}$ (.094)	2.4		
	.120	3.0		
Drums	$\frac{1}{8}$ (.125)	3.2	± 0.004	± 0.10
Spools	$\frac{5}{32}$ (.156)	4.0		

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

package dimensions and weights for each form are given in Table 8 and Fig. 6. 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 Spools shall be designed and constructed to prevent distortion of the electrode during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

TABLE 8
STANDARD PACKAGE DIMENSIONS AND WEIGHTS^a

Type of Package	Package Size		Net Weight of Electrode ^b	
	in.	mm	lb	kg
Coils without support	(c)		(c)	
Coils with support (See below)	12	300 ID ^d	50, 60 and 65	23, 27 and 30
	23½	600 ID	150 and 200	68 and 91
Spools	12	300 OD ^d	25, 30, 35, and 44	11, 14, 16, and 20
	14	360 OD	50 and 60	23 and 27
	22	560 OD	250	110
	24	610 OD	300	140
	30	760 OD	600 and 750	270 and 340
Drums	15½	400 OD	(c)	
	20	500 OD	(c)	
	23	600 OD	300 and 600	140 and 270

Coils with Support — Standard Dimensions and Weight^a

Electrode Size	Coil Net Weight ^b		Coil Dimensions			
			Inside Dia. of Lining		Width of Wound Electrode	
	lb	kg	in.	mm	in. max.	mm. max.
All	50, 60, and 65	23, 27 and 30	12 ± ⅛	305 ± 3	4⅝	120
	150 and 200	68 and 91	23½ ± ¼	600 ± 6	5	125

NOTES:

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

14.4 Winding Requirements

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

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

14.5 Electrode Identification

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

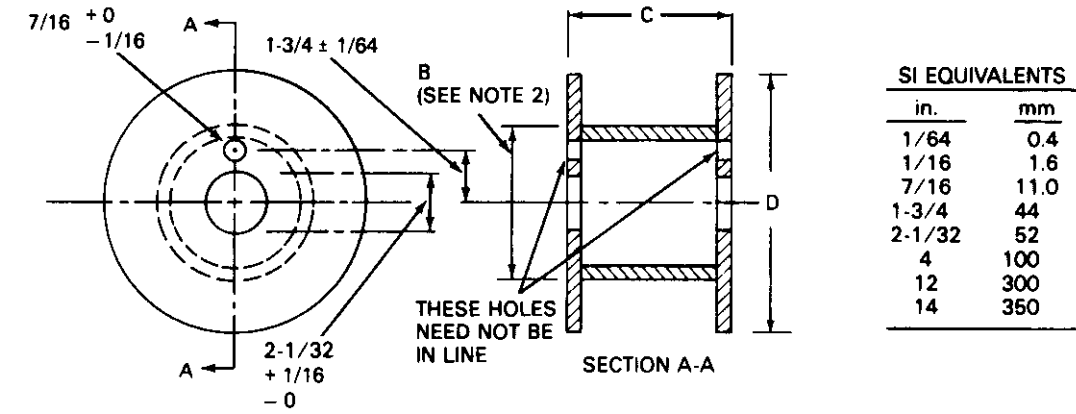
14.5.2 Coils without support shall have a tag containing this information securely attached to the electrode at the inside end of the coil.

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

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

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

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

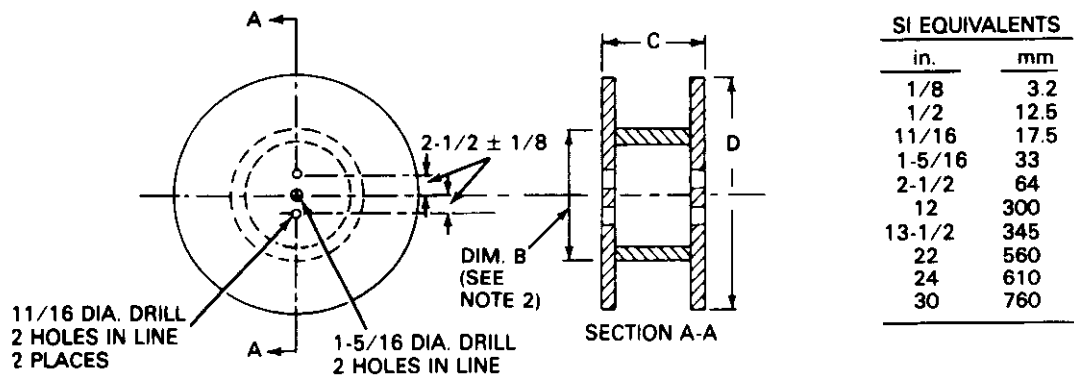


Dimensions		
Spool size in.	C in.	D, maximum in.
12	4 ± 1/16	12
14	4 ± 1/16	14

Notes:

1. All dimensions are in inches.
2. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrodes.

FIG. 6A DIMENSIONS OF 12 AND 14 IN. STANDARD SPOOLS



Dimensions		
Spool size in.	D in.	C, maximum in.
22	22 ± 1/2	12
24	24 ± 1/2	13-1/2
30	30 ± 1/2	13-1/2

Notes:

1. All dimensions are in inches.
2. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrode.

FIG. 6B DIMENSIONS OF 22, 24, AND 30 IN. STANDARD SPOOLS

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.

(1) AWS Specification and Classification (year of issue may be excluded)

(2) Supplier's name and trade designation. In the case of a composite metal cored electrode, the trade designation of the flux (or fluxes) with which it meets the requirements of Table 2.

(3) Size and net weight

(4) Lot, control, or heat number

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

- 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 corrective 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

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

electroslag welding equipment. Particle size is not specified in this specification, 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 the base metal. The molten slag shall have electrical properties suitable for electroslag operation.

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 to obtain the very best operation and properties of which the materials are capable. When drying (reconditioning) is necessary, the supplier should be consulted for a recommended procedure.

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.

(1) AWS specification and classification for the appropriate flux-electrode combination (year of issue may be excluded)

(2) Supplier's name and trade designation (brand name)

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

(4) Net weight

(5) Lot or control number

(6) Particle size, if more than one size is produced

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.

- 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.

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

SFA-5.25

- Use enough ventilation, exhaust at the arc, or both to keep fumes and gases away from your breathing zone and the general area.
- Wear corrective 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

Appendix

Guide to AWS Classification of Carbon and Low Alloy Steel Electrodes and Fluxes for Electroslag Welding

(This Appendix is not a part of ANSI/AWS A5.25-91, *Specification for Carbon and Low Alloy Steel Electrodes and Fluxes for Electroslag Welding*, but is included for information purpose only.)

A1. Introduction

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

A2. Classification System

A2.1 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 metal cored electrodes, of the undiluted weld metal obtained with a particular flux. See Fig. A1.

The letter "M" indicates that the solid electrode is of a medium manganese content, while the letter "H" would indicate 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-killed steel. The designation for a solid wire is followed by the suffix "EW." 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 letters "WT"

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.

A comparison of solid electrode classifications in this specification and those of other specifications is shown in Table A1.

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

As examples of flux classifications, consider the following:

FES60-EH14-EW

FES72-EWT2

The prefix "FES" designates a flux for electroslag welding. This is followed by a single digit representing the minimum tensile strength required of the weld metal in 10 000 psi (see Table 3).

The digit that follows is 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 15 ft-lb (20 J) Charpy V-notch impact strength [except for the letter "Z," which indicates that no impact strength requirement is specified (see Table 4)]. These mechanical property designators are followed by the designation of the electrode used in classifying the flux (see Tables 1 and 2). The suffix (EM12-EW, EH10K-EW, EWT2, etc.) included after the first hyphen refers to the electrode classification with which the

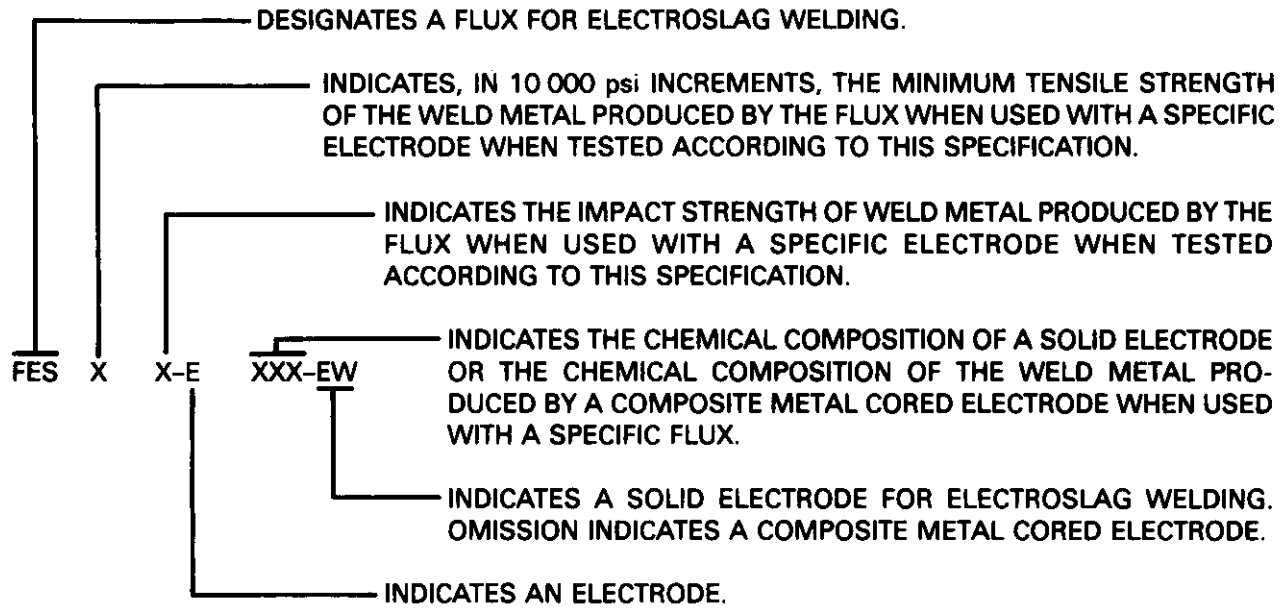


FIG. A1 CLASSIFICATION SYSTEM

TABLE A1
COMPARISON OF A5.25-91 CLASSIFICATIONS AND CLASSIFICATIONS IN OTHER
AWS SPECIFICATIONS

AWS A5.25-91 Classification	Similar Classifications*			
	AWS A5.17-89	AWS A5.18-79	AWS A5.23-90	AWS A5.28-79
EM5K-EW	—	ER70S-2	—	—
EM12-EW	EM12	—	—	—
EM12K-EW	EM12K	—	EM12K	—
EM13K-EW	EM13K	ER70S-3	—	—
EM15K-EW	EM15K	—	—	—
EH14-EW	EH14	—	—	—
EWS-EW	—	—	EW	—
EH10Mo-EW	—	—	EA3K	ER80S-D2
EH10K-EW	—	—	—	—
EH11K-EW	EH11K	ER70S-6	—	—

* Classifications are similar, but not necessarily identical in composition.

AWS A5.17-89, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*

AWS A5.18-79, *Specification for Carbon Steel Filler Metals for Gas Shielded Arc Welding*

AWS A5.23-90, *Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*

AWS A5.28-79, *Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding*

flux will produce 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 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 metal cored 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.

A2.3 "G" Classification

A2.3.1 This specification includes filler metals classified as ES-G-EW or EWTG. The letter "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).

A2.4 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 must be conducted in order to classify a filler metal (or a welding flux). It indicates that test is not required because the requirements (results) for the test have not been specified for that particular classification. Restating the case, when

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

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this Specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing normally is 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 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 tests required by the specification on material that is representative of that being shipped and that 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 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:

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

A5.2 American National Standard Z49.1, *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. Definition and General Description

Electroslag welding is a process producing coalescence of metals with molten slag which melts the filler metal and the surfaces of the workpiece to be welded. The process is initiated by an arc which heats the slag. The arc is then extinguished by the conductive slag which is kept molten by its resistance to electric current passing between the electrode and the workpiece. The weld pool is shielded by this slag which covers the full cross-section of the joint as welding progresses. The joint is generally welded in a single pass.

A6.1 Principles of Operation (Conventional Method)

A6.1.1 The process is initiated by starting an arc beneath a layer of granular welding flux. As soon as a sufficiently thick layer of hot molten slag is formed, all arc action stops and current passes from the electrode to the workpiece through the conductive slag. Heat generated by the resistance to the current through the molten slag is sufficient to fuse the edges of the workpiece and melt the welding electrode.

Since no arc exists, the welding action is quiet and spatter-free. The liquid metal coming from the filler metal and the fused base metal collects in a pool beneath the slag bath and slowly solidifies to form the weld.

A6.1.2 Because of the necessity to contain the large volume of molten slag and weld metal produced in electroslag welding, the process is used for welding in the vertical position. Water-cooled or solid copper backing shoes are usually used on each side of the joint to retain the molten metal and slag pool and to act as a mold to cool and shape the weld faces. The copper backing shoes are normally moved upward on the plate surfaces as welding progresses.

A6.1.3 The entire assembly — including electrode, copper shoes, wire-feeding mechanism, controls, and oscillator — generally moves vertically during operation. The length of vertical travel is unlimited and is dependent upon the design of the equipment used.

A6.1.4 Because of the uniform heat distribution throughout the plate thickness during welding, electroslag welds are virtually free of axial or transverse distortion; however, the joint may contract. The weld interface contour is a function of the welding voltage, current and slag pool depth. The weld metal usually consists of approximately 30 to 50% of base metal.

A6.1.5 The standard joint preparation is a square groove in a butt joint. Joint preparations other than square grooves in butt joints can be used.

A6.2 Principles of Operation (Consumable Guide Method)

A6.2.1 The consumable guide method uses a metal tube extending the full length of the weld joint to guide the electrode to the welding zone. The molds and all wire-feeding equipment remain stationary, with the electrode being the only moving part. The guide tube melts in the weld pool as the pool rises, supplying additional filler metal.

A6.2.2 A flux coating is sometimes provided on the outside of the consumable guide to insulate the tube if it should contact the base metal or copper backing shoes. The coating also helps to replenish flux that solidifies on the surface of the copper shoes forming the weld face contour. The flux coating thus helps to maintain a level of molten slag adequate to provide resistance heating and to protect the weld pool from atmospheric contamination. The manufacturer should be consulted for specific recommendations regarding consumable guide tubes.

A6.2.3 The effect of the consumable guide tube generally is to dilute the alloy content of the weld metal. For this reason, weld metal strength and toughness should be determined.

A6.3 The specification requires the use of certain base metals for classification purposes. This does not signify any restriction on the application of the process for joining other base metals, but rather provides a means for obtaining reproducible results. Electroslag welding is a "high dilution" process, meaning that the base metal forms a significant portion of the weld metal. The type of base metal, especially given the wide variety of available low alloy structural steels, will influence the mechanical and other properties of the joint. Weld procedure qualification tests, as distinguished from filler metal classification tests, should be used for assessing the properties of welds for a given application.

A6.4 Electroslag welding is a high deposition process for thick plates. Since it usually is operated as a single

pass process, the weld metal and heat-affected zone are subject to no subsequent weld thermal cycles, such as is common with arc welding of thick materials. The weld metal is characterized by large unrefined dendrites. The relatively wide heat-affected zone is characterized by large grains. The as-welded mechanical properties may therefore be somewhat lower than that of the base metal. This specification requires a minimum of 15 ft-lb (20 J) at the specified temperature while most other AWS filler metal specifications require 20 ft-lb (27 J). Considerable improvement in mechanical properties can be effected by a postweld heat treatment. Subcritical stress relieving heat treatments are generally less effective for electroslag welding than for arc welding. For this reason, many code requirements require an austenitizing, or normalizing, postweld heat treatment.