

Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding



American Welding Society

Key Words— Filler metal specifications, low-alloy steel electrodes, carbon steel electrodes, arc welding electrodes, metal cored electrodes, electroslag welding

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Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding

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Prepared by
AWS Committee on Filler Metals

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

Classification requirements are specified for fluxes and solid and composite metal cored electrodes for electroslag welding. The requirements for electrodes include chemical composition of the electrode for solid electrodes and of weld metal for metal cored electrodes. Requirements for fluxes include the mechanical properties and soundness of weld metal taken from a groove weld made with a particular electrode using a prescribed welding procedure. Standard electrode sizes, marking, and packaging requirements are included.

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



American Welding Society

550 N.W. LeJeune Road, Miami, Florida 33126

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Foreword

(This Foreword is not a part of ANSI/AWS A5.25/A5.25M-97, *Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*, but is included for information purposes only).

This document is the first of the A5.25 specifications to use both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other, without combining in any way. In selecting rational metric units, the ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry*, and ISO 864, *Solid Wires for Gas Shielded Metal Arc Welding of Mild Steel*, are used as guides. Tables and figures make use of both U.S. Customary and SI Units, which with the application of the specified tolerances provide for interchangeability of products in both U.S. Customary and SI Units.

The current document is the second revision of this specification, as shown below:

Document Development

AWS A5.25-78	Specification for Consumables Used for Electroslag Welding of Carbon and High Strength Low Alloy Steels
ANSI/AWS A5.25-91	Specification for Carbon and Low Alloy Steel Electrodes and Fluxes for Electroslag Welding

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, Committee on Filler Metals, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding

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.

Part 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.

2.2 The composite metal cored electrodes covered by this specification are classified according to the chemical composition of the weld metal produced by use with a specific flux of a particular manufacturer and trade designation as specified in Table 2.

2.3 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.

2.4 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 FESX0-XXX and FESXZ-XXX, as specifically permitted by Note (a) to Table 4.

2.5 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 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 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each

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

2. AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

3. See Section A4 (in the Annex), 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	K1076	0.07	0.90– 1.40	0.025	0.030	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	0.030	0.030	0.10	—	—	—	0.35	—	—	—	0.50
EM12K-EW	K01113	0.05– 0.15	0.80– 1.25	0.030	0.030	0.10– 0.35	—	—	—	0.35	—	—	—	0.50
EM13K-EW	K01313	0.06– 0.16	0.90– 1.40	0.030	0.030	0.35– 0.75	—	—	—	0.35	—	—	—	0.50
EM15K-EW	K01515	0.10– 0.20	0.80– 1.25	0.030	0.030	0.10– 0.35	—	—	—	0.35	—	—	—	0.50
High-Manganese Classes														
EH14-EW	K11585	0.10– 0.20	1.70– 2.20	0.030	0.030	0.10	—	—	—	0.35	—	—	—	0.50
Special Classes														
EWS-EW	K11245	0.07– 0.12	0.35– 0.65	0.030	0.030	0.22– 0.37	0.40– 0.75	0.50– 0.80	—	0.25– 0.55	—	—	—	0.50
EA3K-EW ^f	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	0.06– 0.15	1.40– 1.85	0.025	0.030	0.80– 1.15	—	—	—	0.35	—	—	—	0.50
ES-G-EW	—	Not Specified ^g												

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 Annex.
- SAE/ASTM Unified Numbering System for Metals and Alloys.
- The copper limit includes copper that may be applied as a coating on the electrode.
- Formerly classified EH10Mo-EW in ANSI/AWS A5.25-91.
- Composition shall be reported; the requirements are those agreed to by the purchaser and the supplier.

Table 2
Chemical Composition Requirements for Weld Metal
from Composite Metal Cored Electrodes^a

AWS Classification	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
EWTG	—	Not Specified ^e										

Notes:

- The flux used, when classifying composite electrodes shall be one with which the electrode is classified for mechanical properties (see Tables 3 or 3M and 4 or 4M).
- 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
A5.25 Tension Test Requirements (As Welded)

AWS A5.25 Classification ^a	Tensile Strength	Yield Strength, min. ^b	Elongation, min. ^b
	psi	psi	percent
FES6Z-XXX	60 000		
FES60-XXX	to	36 000	24
FES62-XXX	80 000		
FES7Z-XXX	70 000		
FES70-XXX	to	50 000	22
FES72-XXX	95 000		
FES8Z-XXX	80 000		
FES80-XXX	to	60 000	20
FES82-XXX	100 000		

Notes:

- The letters “XXX” as used in the AWS A5.25 Classification column in this table refer to the electrode classification used.
- Yield strength at 0.2 percent offset and elongation in 2 in. gage length.

Table 3M
A5.25M Tension Test Requirements (As Welded)

AWS A5.25M Classification ^a	Tensile Strength	Yield Strength, min. ^b	Elongation, min. ^b
	MPa	MPa	percent
FES43Z-XXX	430		
FES432-XXX	to	250	24
FES433-XXX	550		
FES48Z-XXX	480		
FES482-XXX	to	350	22
FES483-XXX	650		
FES55Z-XXX	550		
FES552-XXX	to	410	20
FES553-XXX	700		

Notes:

- The letters “XXX” as used in the AWS A5.25M Classification column in this table refer to the electrode classification used.
- Yield strength at 0.2 percent offset and elongation in 50 mm gage length.

Table 4
A5.25 Impact Test Requirements (As Welded)^a

AWS A5.25 Classification ^b	Average Impact Strength, min. ^c ft·lbf
FES6Z-XXX	Not specified
FES7Z-XXX	Not specified
FES8Z-XXX	Not specified
FES60-XXX	15 @ 0 °F
FES70-XXX	15 @ 0 °F
FES80-XXX	15 @ 0 °F
FES62-XXX	15 @ -20 °F
FES72-XXX	15 @ -20 °F
FES82-XXX	15 @ -20 °F

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·lbf and one of the three remaining values may be lower than 15 ft·lbf, but not lower than 10 ft·lbf. The average of the three shall not be less than the 15 ft·lbf specified.

Table 4M
A5.25M Impact Test Requirements (As Welded)^a

AWS A5.25M Classification ^b	Average Impact Strength, min. ^c J
FES43Z-XXX	Not specified
FES48Z-XXX	Not specified
FES55Z-XXX	Not specified
FES432-XXX	20 @ -20 °C
FES482-XXX	20 @ -20 °C
FES552-XXX	20 @ -20 °C
FES433-XXX	20 @ -30 °C
FES483-XXX	20 @ -30 °C
FES553-XXX	20 @ -30 °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, FESXX3-XXX may also be classified as FESXX2-XXX and FESXXZ-XXX and FESXX2-XXX may be classified as FESXXZ-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 20 J and one of the three remaining values may be lower than 20 J, but not lower than 14 J. The average of the three shall not be less than the 20 J specified.

system must be used independently of the other without combining in any way. The specification with the designation A5.25 uses U.S. Customary Units. The specification A5.25M uses SI units. The latter are shown in appropriate columns in tables or within brackets [] when used in the text.

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 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 ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.⁴

Part 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 specific flux of a particular manufacturer and trade designation 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

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

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 FES7Z-XXX FES8Z-XXX FES43Z-XXX FES48Z-XXX FES55Z-XXX	Not Required	Not Required	Required	Required	Not Required
	FES60-XXX FES70-XXX FES80-XXX FES432-XXX FES482-XXX FES552-XXX	Not Required	Not Required	Required	Required	Required
	FES62-XXX FES72-XXX FES82-XXX FES433-XXX FES483-XXX FES553-XXX	Not Required	Not Required	Required	Required	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 one with which the electrode is classified for mechanical properties.

need be only for those specific elements that failed to meet the test requirement.

If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

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

8. Weld Test Assemblies

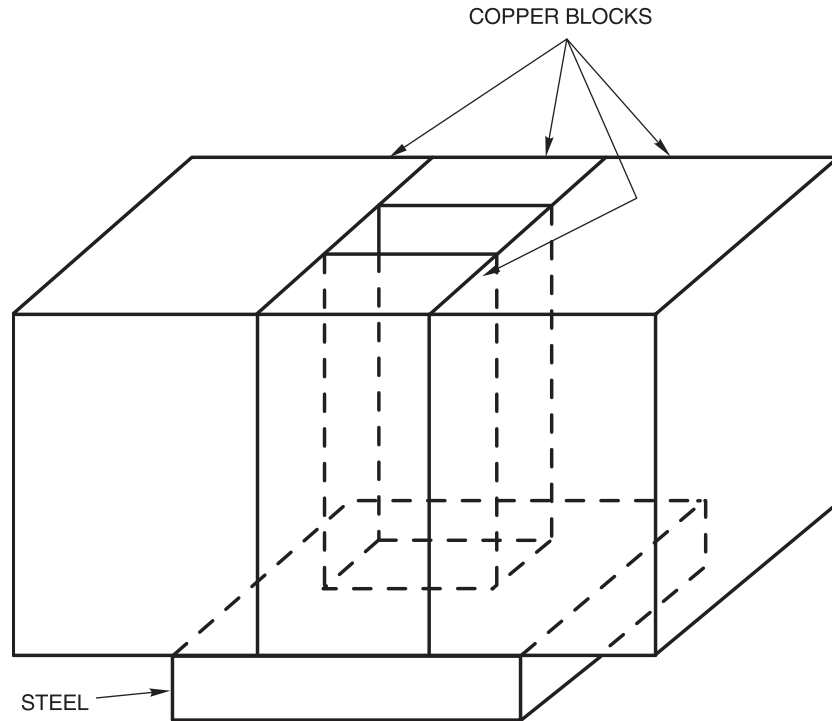
8.1 No weld test assemblies are required for classification of solid electrodes. One weld test assembly is re-

quired for classification of composite electrodes. It is the weld ingot as shown in Figure 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 Figure 2 for mechanical properties and soundness of the weld metal in the as-welded condition.

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 Figure 1.

8.4 Groove Weld for Mechanical Properties and Soundness for Flux-Electrode Combinations. A test assembly shall be chosen and welded as specified in Figure 2 using base metal of the appropriate type specified



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 in.² [25 cm²] 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] above the bottom of the ingot, and at least 2 in. [50 mm] below the crater.
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 chemical composition.

Figure 1—Weld Ingot

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

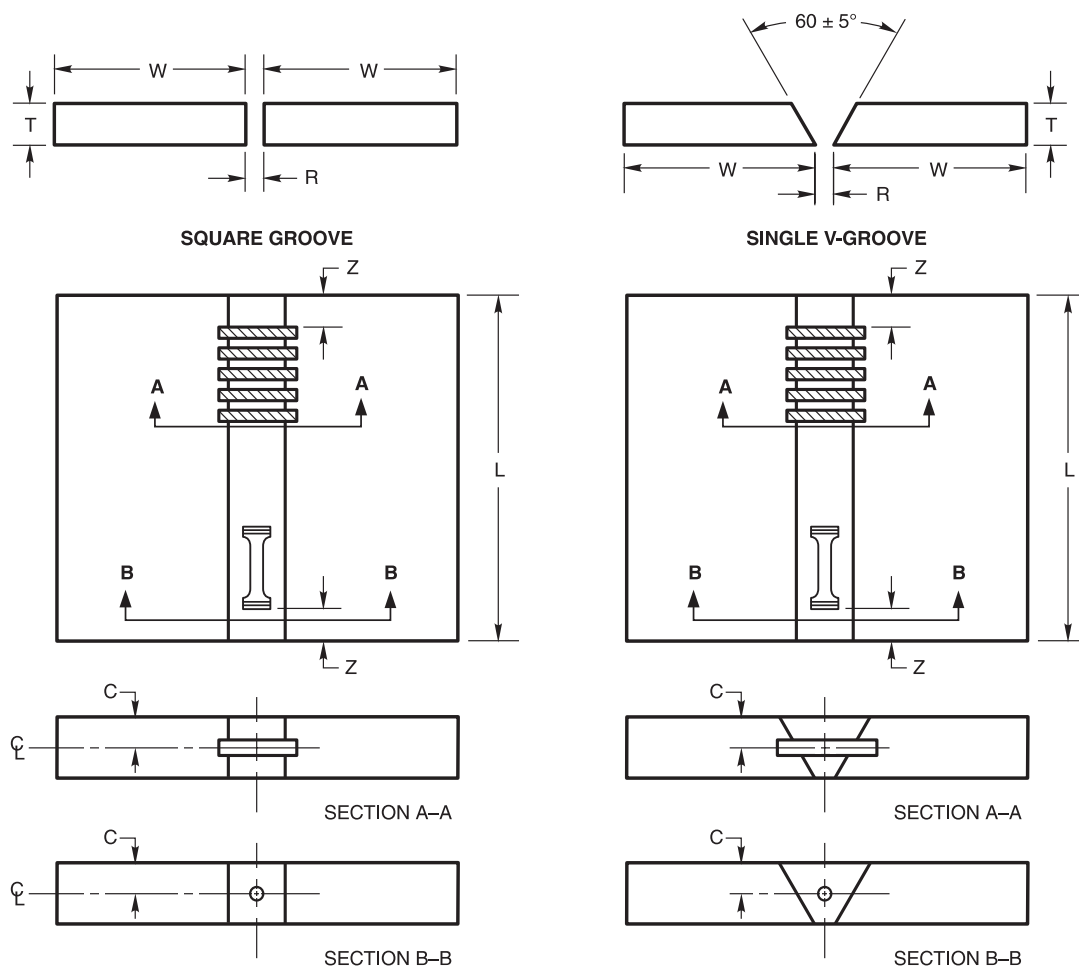
9.1 For solid electrodes, a sample of the electrode shall be prepared for chemical analysis. Solid electrodes, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the electrode is analyzed for elements other than 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 for analysis shall be taken from weld metal obtained with the

electrode and a specific flux of a particular manufacturer and trade designation with which it was classified. The sample shall come from an ingot (Figure 1). The top surface of the ingot shall be removed and discarded, and a sample for analysis shall be obtained by any appropriate mechanical means 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. 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.



Groove Type:	Square Groove		Square Groove		Single V-Groove	
Consumable Guide Tube:	Yes		No		No	
	in.	mm	in.	mm	in.	mm
Electrode Size:	3/32 or 1/8	2.4, 2.5, or 3.0	3/32 or 1/8	2.4, 2.5, or 3.0	3/32 or 1/8	2.4, 2.5, or 3.0
Dimensions:						
L, Length, min.	15	380	15	380	15	380
W, Width, min.	12	300	12	300	12	300
T, Thickness	2	50	2	50	2	25
Z, Discard, min.	2-1/2	65	2-1/2	65	2-1/2	65
R, Root Opening	1 to 1-1/4	25 to 32	1 to 1-1/4	25 to 32	1/4 min.	6 min.
C, Distance to the Center of Specimen	1/2	12.5	1/2	12.5	3/8	9.5
Current, dcep:	500 ± 50		500 ± 50		400 ± 50	
Amperes	40 ± 2		40 ± 2		40 ± 2	
Volts						

General 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.

Figure 2—Groove Weld Test Assembly for Mechanical Properties and Soundness

Table 6
Base Metals for Test Assemblies

AWS Classification		ASTM
A5.25	A5.25M	Base Metal Specification
FES6X-XXX	FES43X-XXX	ASTM A36
FES7X-XXX	FES48X-XXX	ASTM A242 Type 2 or A572 Grade 50
FES8X-XXX	FES55X-XXX	ASTM A537 Class 2, A572 Grade 60 or 65, or A633 Grade E
The following classifications are exceptions to the above general requirements:		
FESXX-EWS-EW FESXX-EWT2	FESYYY-EWS-EW FESYYY-EWT2	ASTM A588

10. Radiographic Test

10.1 The groove weld described in 8.4 and shown in Figure 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 3/32 in. [2.5 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 E142, *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 Figure 4.

In evaluating the radiograph, 2-1/2 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 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 Figure 2. The dimensions of the specimen shall be as shown in Figure 3.

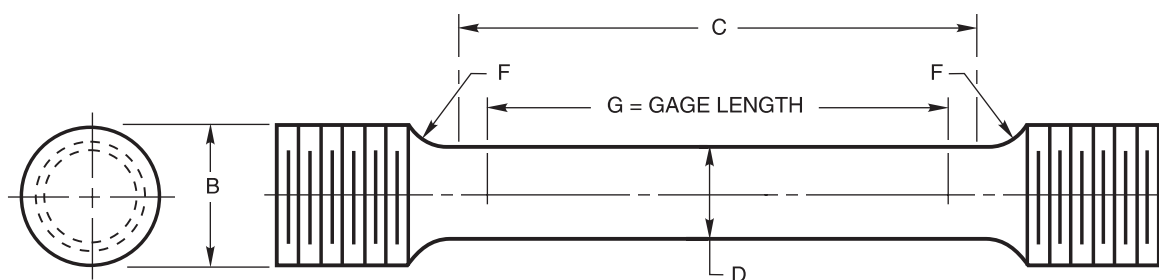
11.2 The specimen shall be tested in the manner described in the tension test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

11.3 The results of the tension test shall meet the requirements specified in Table 3, or Table 3M, as applicable.

12. Impact Test

12.1 Five Charpy V-notch impact test specimens (Figure 5) shall be machined from the test assembly shown in Figure 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 ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. The test temperature and the test results shall be those specified in Table 4 or Table 4M, as applicable, 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·lbf [20 J] energy level. One of the three may be lower, but not lower than 10 ft·lbf [14 J], and the average of the three shall be not less than the required 15 ft·lbf [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.	
12.5 ± 0.2	50.0 ± 0.1	55	20	10	123

General Notes:

1. Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
2. The diameter of the specimen within the gage length shall be slightly smaller at the center (controlling dimension) than at the ends. The difference shall not exceed one percent of the diameter.
3. When the extensometer is required to determine yield strength, 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 μin . [1.6 μm].

Figure 3—Tension Test Specimen

Part 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 the 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 elec-

trodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment or the properties of the weld metal.

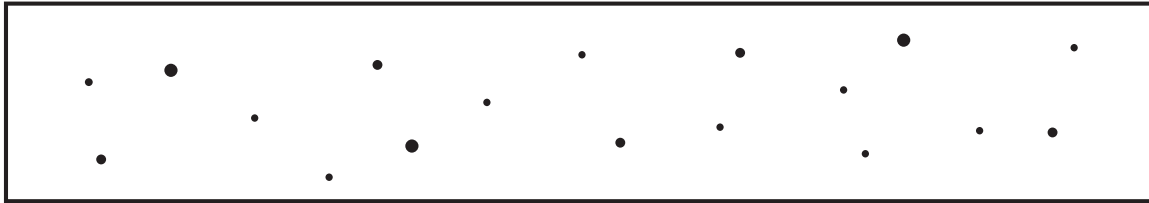
14.2.2 Each continuous length of electrode shall be from a single lot of material, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic equipment.

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 package dimensions and weights for each form are given in Table 8 and Figure 6. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.



(A) ASSORTED ROUNDED INDICATIONS

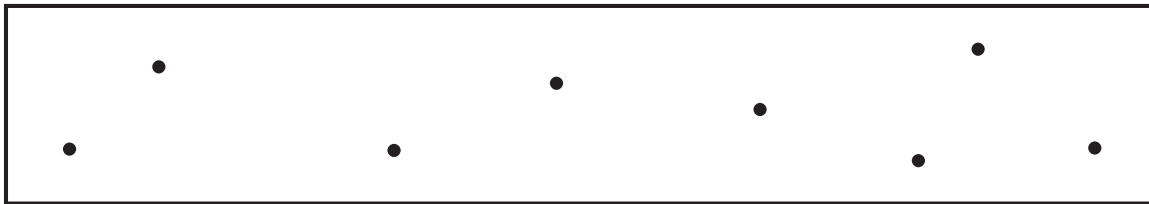
SIZE 1/64 in. TO 1/16 in. [0.4 TO 1.6 mm] DIAMETER OR IN LENGTH.

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

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

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

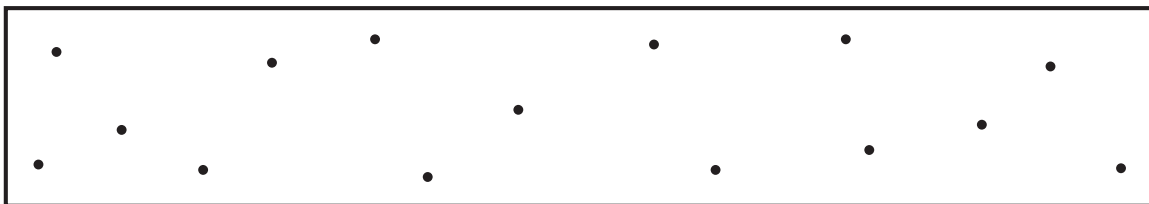
MAXIMUM NUMBER OF SMALL 1/64 TO 1/32 in. [0.4 TO 0.8 mm] DIAMETER AND/OR LENGTH INDICATIONS = 10.



(B) LARGE ROUNDED INDICATIONS

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

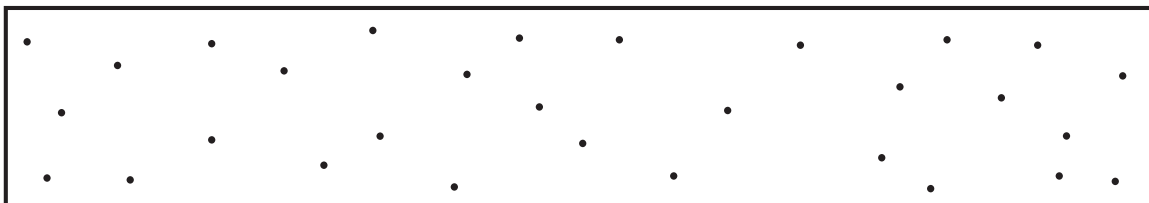
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

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

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



(D) SMALL ROUNDED INDICATIONS

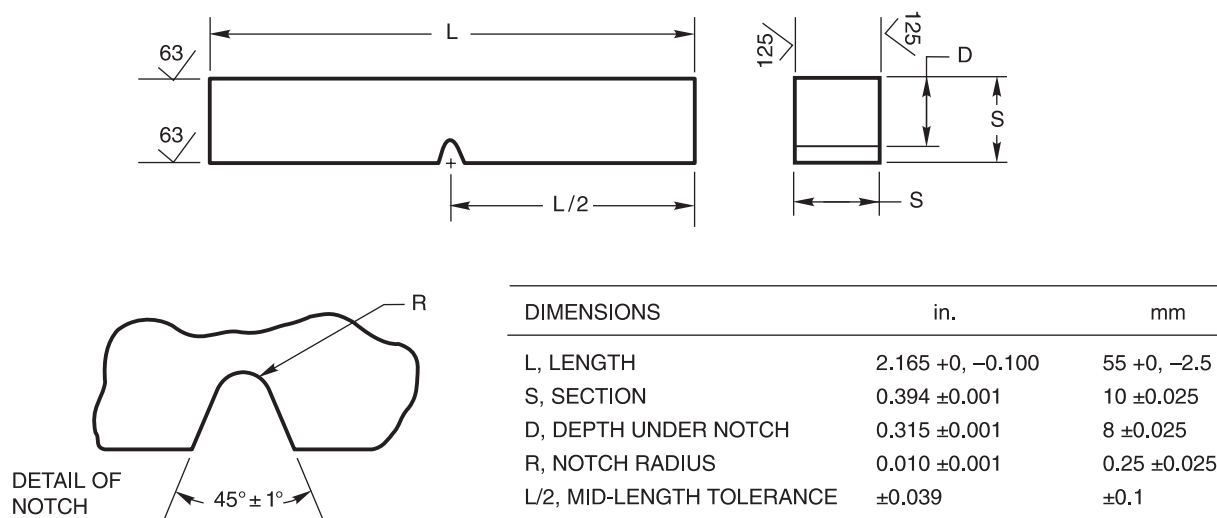
SIZE 1/64 TO 1/32 in. [0.4 TO 0.8 mm] DIAMETER AND/OR LENGTH.

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

General Notes:

1. In using these standards the chart which is most representative of the size of the porosity and/or inclusions present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications smaller than 1/64 in. [0.4 mm] shall be disregarded.

Figure 4—Radiographic Acceptance Standards



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 63 μ in. [1.6 μ m] finish. The other two surfaces shall be square with the notched or struck surface within ± 10 minutes of a degree and have at least 125 μ in. [3.2 μ 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 (+).

Figure 5—Charpy V-Notch Impact Test Specimen

Table 7
Standard Sizes*

Standard Package Forms	A5.25				A5.25M		
	Diameter		Tolerance		Diameter		Tolerance
	in.	Solid in.	Cored in.		mm	Solid mm	Cored mm
Coils with support, Coils without support, Drums, and Spools	1/16	0.062	±0.002	±0.002	1.6	±0.05	±0.05
	5/64	0.078	±0.002	±0.003	2.0	±0.05	±0.08
	3/32	0.094	±0.002	±0.003	2.4	±0.05	±0.08
					2.5	±0.05	±0.08
	1/8	0.120	±0.003	±0.003	3.0	±0.08	±0.08
		0.125	±0.003	±0.003	3.2	±0.08	±0.08
	5/32	0.156	±0.003	±0.003	4.0	±0.08	±0.08

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

Table 8
Standard Package Dimensions and Weights^a

Type of Package	Package Size OD ^d		Net Weight of Electrode ^b			
	in.	mm	lb		kg	
Coils without support	Not specified ^c		Not specified ^c			
Spools	12 14 22 24 30	300 350 560 610 760	25, 30, and 35 50 and 60 250 300 600, 750, and 1000		10 and 15 20 and 25 100 150 250, 350, and 450	
Drums	15-1/2 20 23	400 500 600	Not specified ^c Not specified ^c 300 and 600 150 and 300			
Coils with Support—Standard Dimensions and Weights						
Electrode Size	Coil Net Weight ^b		Coil Dimensions			
			Inside Diameter of Lining		Width of Wound Electrodes	
	lb	kg	in.	mm	in., max.	mm, max.
All	50, 60, and 65 150 and 200	20, 25, and 30 75 and 100	12 ± 1/8 23-1/2 ± 1/4	300 +3, -10 600 +3, -10	4-5/8 5	120 125

Notes:

a. Package sizes, dimensions, 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. OD = outside diameter.

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.

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 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 on the side of the drum.

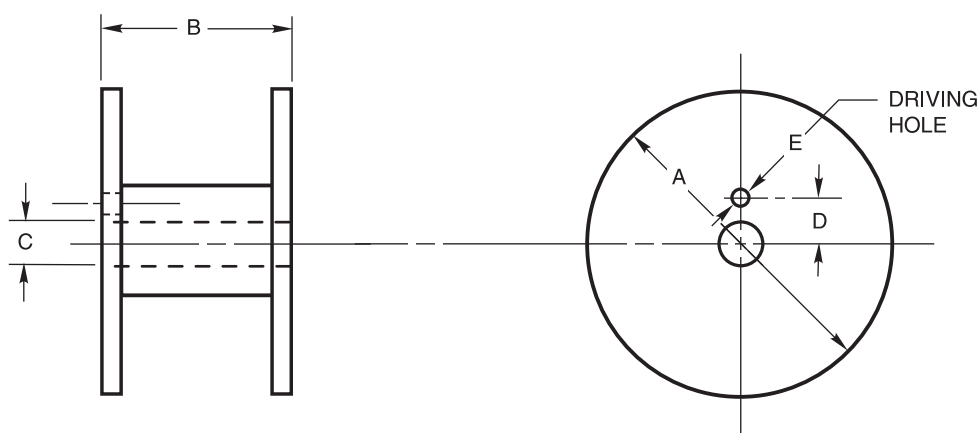
14.6 Packaging. Electrodes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

14.7 Marking of Packages

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

(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



DIMENSIONS

		12 in. [300 mm] Spools		14 in. [350 mm] Spools	
		in.	mm	in.	mm
A	Diameter, max.	12	300	14	350
B	Width	4.0 ± 0.06	$103 -3, +0$	4.0 ± 0.06	$103 -3, +0$
C	Diameter	$2.03 -0, +0.06$	$50.5 -0, +2.5$	$2.03 -0, +0.06$	$50.5 -0, +2.5$
D	Distance Between Axes	1.75 ± 0.02	44.5 ± 0.5	1.75 ± 0.02	44.5 ± 0.5
E	Diameter (Note 3)	0.44 ± 0.06	$10 -0, +1$	0.44 ± 0.06	$10 -0, +1$

General Notes:

1. Outside diameter of barrel shall be such as to permit feeding of the filler metals.
2. Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside of the diameter of the barrel being less than the inside diameter of the flanges.
3. Holes are provided on each flange, but they need not be aligned.

Figure 6A—Dimensions of 12 and 14 in. [300 and 350 mm] Standard Spools

tion 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.

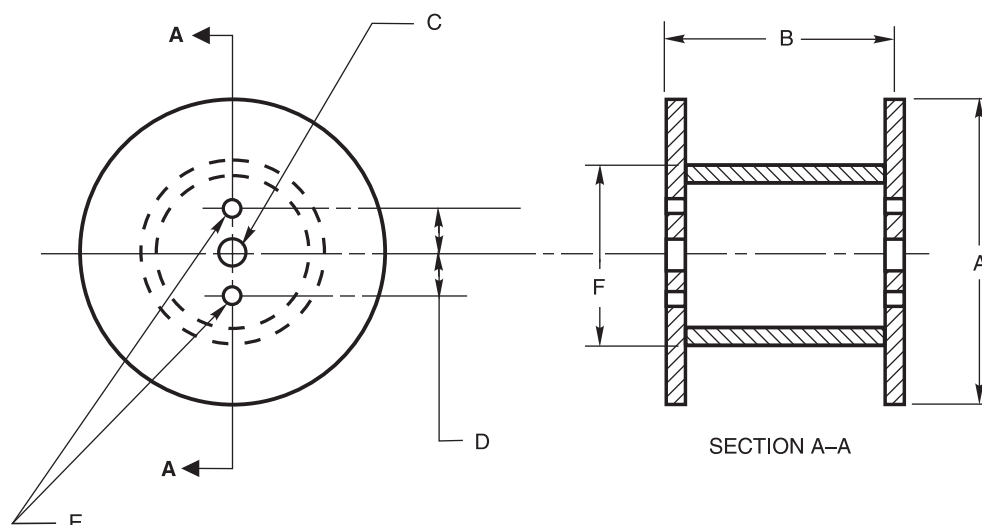
FUMES AND GASES can be hazardous to your health.

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 correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; 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



DIMENSIONS

		22 in. [560 mm] Spools		24 in. [610 mm] Spools		30 in. [760 mm] Spools	
		in.	mm	in.	mm	in.	mm
A	Diameter, max.	22	560	24	610	30	760
B	Width, max.	12	305	13.5	345	13.5	345
C	Diameter	1.31 +0.13, -0	35.0 ± 1.5	1.31 +0.13, -0	35.0 ± 1.5	1.31 +0.13, -0	35.0 ± 1.5
D	Distance, Ctr. to Ctr.	2.5 ± 0.1	63.5 ± 1.5	2.5 ± 0.1	63.5 ± 1.5	2.5 ± 0.1	63.5 ± 1.5
E	Diameter (Note 3)	0.69 +0, -0.06	16.7 ± 0.7	0.69 +0, -0.06	16.7 ± 0.7	0.69 +0, -0.06	16.7 ± 0.7

General Notes:

1. Outside diameter of barrel, dimension F, shall be such as to permit feeding of the filler metals.
2. Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside of the diameter of the barrel being less than the inside diameter of the flanges.
3. Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

Figure 6B—Dimensions of 22, 24, and 30 in. [560, 610, and 760 mm] Standard Spools (Reels)

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 weld 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

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

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be hazardous 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 correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and *OSHA Safety and Health Standards*, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402.

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Annex

Guide to AWS Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding

(This Annex is not a part of ANSI/AWS A5.25/5.25M-97, *Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*, but is included for information only.)

A1. Introduction

The purpose of this annex is to correlate the electrode and flux 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 weld metal obtained with a particular flux. See Figure 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 particular classification of electrode, under the specific test conditions called for in this specification.

For example, consider the following flux classifications:

FES60-EH14-EW

FES72-EWT2

The prefix “FES” designates a flux for electroslag welding. In the case of the designations for A5.25, this is followed by a single digit representing the minimum tensile strength required of the weld metal in units of 10 000 psi (see Table 3); for the designations for A5.25M, the FES is followed by two digits (43, 48, or 55), representing the minimum tensile strength in units of 10 MPa (see Table 3M).

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-lbf [20 J] Charpy V-notch impact strength

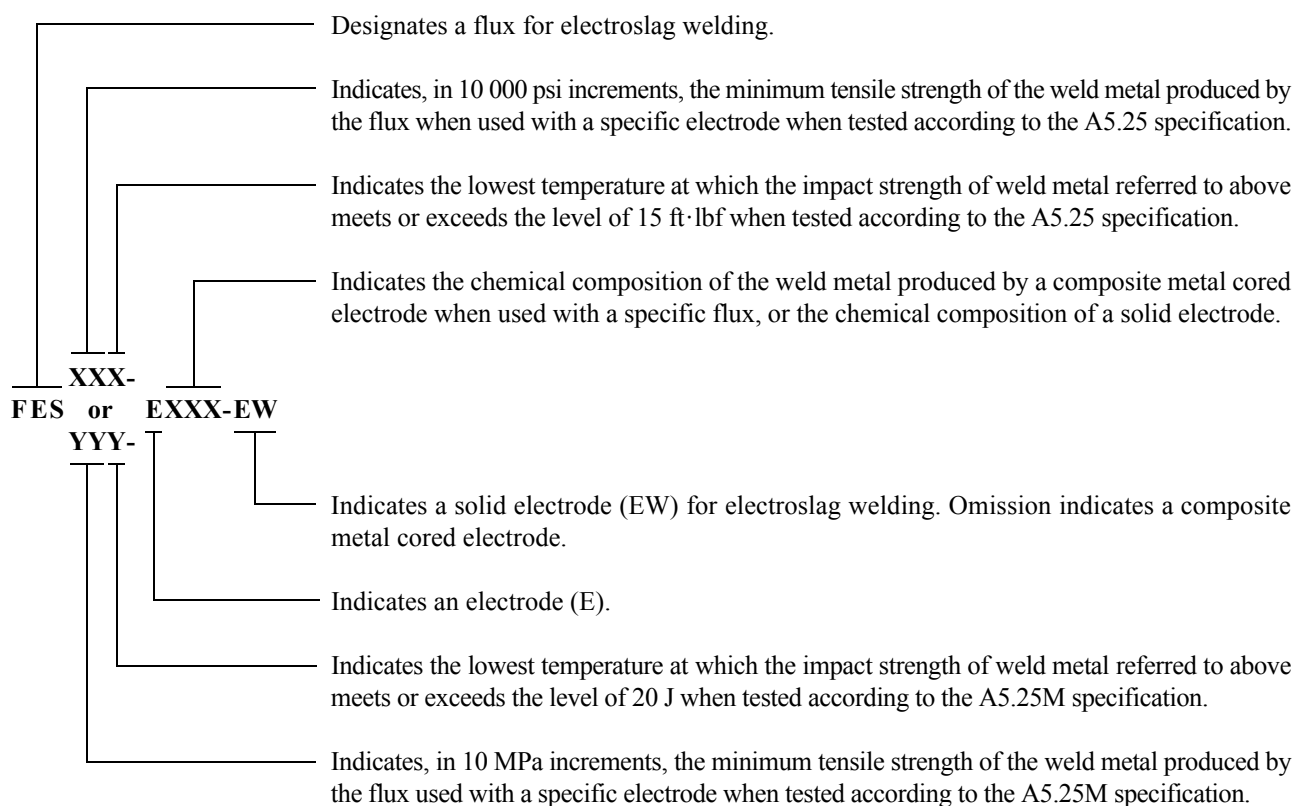


Figure A1—Classification System

Table A1
Comparison of A5.25/A5.25M-97 Classifications and
Classifications in Other AWS Specifications and Proposed ISO Designations

AWS A5.25/A5.25M Classification	Similar Classifications ^a					Proposed ISO Designation ^b
	AWS A5.17	AWS A5.18	AWS A5.23	AWS A5.26	AWS A5.28	
EM5K-EW	—	ER70S-2	—	EGXXS-2	—	S2134
EM12-EW	EM12	—	—	—	—	S2000
EM12K-EW	EM12K	—	EM12K	—	—	S2010
EM13K-EW	EM13K	ER70S-3	--	EGXXS-3	—	S2030
EM15K-EW	EM15K	—	—	—	—	S2210
EH14-EW	EH14	—	—	—	—	S4200
EWS-EW	—	—	EW	—	—	S1000-W
EA3K-EW ^c	—	—	EA3K	EGXXS-D2	ER80S-D2	S3020-A3
EH10K-EW	—	—	—	—	—	—
EH11K-EW	EH11K	ER70S-6	—	EGXXS-6	—	S3031

Notes:

a. Classifications are similar, but not necessarily identical in composition:

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

ANSI/AWS A5.18, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

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

ANSI/AWS A5.26, *Specification for Carbon and Low Alloy Steel Electrodes for Electrode Gas Welding*

ANSI/AWS A5.28, *Specification for Low Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

b. IIW Doc. XII-1232-91 (also see Section A2.5)

c. Formerly classified as EH10Mo-EW in AWS A5.25-91.

(except for the letter “Z,” which indicates that no impact strength requirement is specified in 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 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 package 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).

A2.3.2 Request for Filler Metal Classification

(1) When a filler metal cannot be classified according to some classification other than a “G” classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the “G” classification, the Committee on Filler Metals recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

(2) A request to establish a new filler metal classification must be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate to satisfy the need. The request needs to state the variables and their limits for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

(3) The request should be sent to the Secretary of the Committee on Filler Metals at AWS Headquarters. Upon receipt of the request, the Secretary will do the following:

(a) Assign an identifying number to the request. This number will include the date the request was received.

(b) Confirm receipt of the request and give the identification number to the person who made the request.

(c) Send a copy of the request to the Chair of the Filler Metal Committee and the Chair of the particular Subcommittee involved.

(d) File the original request.

(e) Add the request to the log of outstanding requests.

(4) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a “timely manner,” and the Secretary shall report these to the Chair of the Committee on Filler Metals for action.

(5) The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each Committee on Filler Metals meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A2.4 Terms ‘Not Specified’ and ‘Not Required.’ 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 (re-

sults) 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 of that product. The purchaser and supplier also will have to establish with that supplier just what the specific testing procedure and the acceptance requirements are to be for that test. The purchaser may want to incorporate that information (via ANSI/AWS A5.01, in the purchase order.

A2.5 An international system, for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for the type of filler metal. In that system, the initial letter “S” designates a mild or low-alloy steel wire, followed by a four-digit number. If the filler metal is a metal cored wire, the initial letter is “C;” if a flux-cored wire, the initial letter is “T.”

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, as the specification states.

Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/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 ANSI/AWS A5.01. 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

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 ANSI/AWS A5.01.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators 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 ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes* (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 on Health Protection and Ventilation of that document.

A6. Welding Considerations

A6.1 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 starting an arc beneath a layer of granular welding flux. 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.

A6.2 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.

A6.3 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.

A6.4 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.

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 percent of base metal.

A6.5 The standard joint preparation is a square groove in a butt joint. Joint preparations other than square grooves in butt joints can be used.

A6.6 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 into the weld pool as the pool rises, supplying additional filler metal.

In some applications, the guide tubes are covered with a flux 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.

The effect of the consumable guide tube generally is to dilute the alloy content of the weld metal. Consumable guide tubes are not classified per this specification;

therefore, weld-metal strength and toughness should be tested by the user.

A6.7 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.

A6.8 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 (HAZ) are subject to no subsequent weld thermal cycles, such as is common with conventional multipass arc welding of thick materials. The weld metal is characterized by large unrefined dendrites. The relatively wide HAZ is characterized by large grains. The as-welded mechanical properties of the weld and HAZ may therefore be somewhat lower than that of the base metal.

This specification requires a minimum of 15 ft-lbf [20 J] at the specified temperature while most other AWS filler metal specifications require 20 ft-lbf [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.

All of the aforementioned postweld heat treatments (*i.e.*, subcritical stress relief, austenitizing, normalizing) may have a pronounced effect on weld metal mechanical properties, both strength levels and Charpy V-notch toughness. The strength levels of the heat-treated weld deposit can be expected to be lower than those in the as-welded condition. For this reason, the user is cautioned to conduct actual tests to determine the effect of the heat treatment on the mechanical properties obtained.

A7. Discontinued Classifications

The following classification has been discontinued over the life of this specification:

<u>Discontinued Classification</u>	<u>Last Published</u>
EH10Mo-EW	1991
EWT4	1991

A8. Safety Considerations

A8.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a protective head covering should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles, or the equivalent, to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flames. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection.

Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load; disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (*Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.*)

The following sources provide more detailed information on personal protection:

(1) American National Standards Institute. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York: American National Standards Institute.⁵

(2) —. ANSI/ASC Z41.1, *Safety-Toe Footwear*. New York: American National Standards Institute.

5. ANSI standards may be obtained from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

(3) American Welding Society. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, Fla.: American Welding Society.⁶

(4) OSHA. *Code of Federal Regulations*, Title 29—Labor, Chapter XVII, Part 1910. Washington, D.C.: U.S. Government Printing Office.⁷

A8.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead; it is used only to complete the welding circuit. A separate connection is required to ground the workpiece.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform.

Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be

6. AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

7. OSHA standards may be obtained from the U.S. Government Printing Office, Washington, D.C. 20402.

avoided; the injured area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance, if necessary.

Recognized safety standards should be followed, such as ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and NFPA No. 70, *National Electrical Code*.⁸

A8.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management, welders, and other personnel should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the electrode and base metal, welding process, current level, arc length, and other factors.

The possible effects of overexposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air and cause asphyxiation. One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from your breathing zone and the general area.

In some cases, natural air movement will provide enough ventilation. Where ventilation may be questionable, air sampling should be used to determine if corrective measures should be applied.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(1) The permissible exposure limits required by OSHA can be found in *Code of Federal Regulations*, Title 29—Labor, Chapter XVII Part 1910.

(2) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH).⁹

8. NFPA documents are available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

9. ACGIH documents are available from the American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1634.

(3) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*.

A8.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as x-rays), or nonionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

A8.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A8.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base-metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc welding when used properly), laser beam welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(1) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(2) Exposed skin should be protected with adequate gloves and clothing as specified ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

(3) Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. (*Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.*)

(4) Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

(5) Safety glasses with UV-protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.

A8.4.3 Ionizing radiation information sources include the following:

(1) American Welding Society F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*.

(2) Manufacturer's product information literature.

A8.4.4 Nonionizing radiation information sources include the following:

(1) American National Standards Institute. ANSI/ASC Z136.1, *Safe Use of Lasers*. New York, N.Y.: American National Standards Institute.

(2) ——. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York, N.Y.: American National Standards Institute.

(3) American Welding Society. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, Fla.: American Welding Society.

(4) Hinrichs, J. F. "Project committee on radiation—summary report." *Welding Journal* 57(1):62-s to 65-s, 1978.

(5) Marshall, W. J., Sliney, D. H., *et al.* "Optical radiation levels produced by air carbon arc cutting processes." *Welding Journal* 59(3):43-s to 46-s, 1980.

(6) Moss, C. E., and Murray, W. E. "Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting." *Welding Journal* 58(9):37-s to 46-s, 1979.

(7) Moss, C. E. "Optical radiation transmission levels through transparent welding curtains." *Welding Journal* 58(3):69-s to 75-s, 1979.

(8) National Technical Information Service. Nonionizing radiation protection special study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*. Springfield, Va.: National Technical Information Service.¹⁰

(9) National Technical Information Service. Nonionizing radiation protection special study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*. Springfield, Va.: National Technical Information Service.

10. National Technical Information documents are available from the National Technical Information Service, Springfield, VA 22161.

AWS Filler Metal Specifications by Material and Welding Process

	OFW	SMAW	GTAW GMAW PAW	FCAW	SAW	ESW	EGW	Brazing
Carbon Steel	A5.2	A5.1	A5.18	A5.20	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28	A5.29	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless Steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11	A5.14		A5.14			A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.13, A5.21	A5.13, A5.21	A5.13, A5.21					
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

AWS Designation	Title
FMC	Filler Metal Comparison Charts
UGFM	Users Guide for Filler Metals
A4.2	Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal
A4.3	Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding
A5.01	Filler Metal Procurement Guidelines
A5.1	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
A5.2	Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding
A5.3	Specification for Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding
A5.4	Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding
A5.5	Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
A5.6	Specification for Covered Copper and Copper Alloy Arc Welding Electrodes
A5.7	Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes
A5.8	Specification for Filler Metals for Brazing and Braze Welding
A5.9	Specification for Bare Stainless Steel Welding Electrodes and Rods
A5.10	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
A5.11	Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding
A5.12	Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting
A5.13	Specification for Solid Surfacing Welding Rods and Electrodes
A5.14	Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods
A5.15	Specification for Welding Electrodes and Rods for Cast Iron
A5.16	Specification for Titanium and Titanium Alloy Welding Electrodes and Rods
A5.17	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
A5.18	Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.19	Specification for Magnesium Alloy Welding Electrodes and Rods
A5.20	Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
A5.21	Specification for Composite Surfacing Welding Rods and Electrodes
A5.22	Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding
A5.23	Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
A5.24	Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods
A5.25	Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding
A5.26	Specification for Carbon and Low-Alloy Steel Electrodes for Electrode Gas Welding
A5.28	Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.29	Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding
A5.30	Specification for Consumable Inserts
A5.31	Specification for Fluxes for Brazing and Braze Welding
A5.32	Specification for Welding Shielding Gases

For ordering information, contact the AWS Order Department, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126. Telephones: (800) 334-9353, (305) 443-9353, ext. 280; FAX (305) 443-7559.

