

SPECIFICATION FOR STAINLESS STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING



SFA-5.4



(Identical with AWS Specification A5.4-92)

1. Scope

This specification prescribes requirements for the classification of covered stainless steel electrodes for shielded metal arc welding.¹

Chromium content of weld metal deposited by these electrodes is not less than 10.5 percent and the iron content exceeds that of any other element. For purposes of classification, the iron content shall be derived as the balance element when all other elements are considered to be at their minimum specified values.²

Note: No attempt has been made to classify all grades of filler metals within the limits of the above scope; only the more commonly used have been included.

PART A — GENERAL REQUIREMENTS

2. Classification

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

(1) Chemical composition of undiluted weld metal (Table 1)

(2) Current and position of welding (Table 2)

2.2 Materials classified under one classification may be classified under any other classification of this

specification provided they meet all the requirements for those classifications, except that a material may not be classified under more than one of the following EXXX-15, EXXX-16, EXXX-17, EXXX-25, or EXXX-26 designations.

Note: The test requirements of this specification establish minimum quality levels which will assure suitability of the electrodes for the usual applications. The guide appended to this specification describes the more common applications and suggests testing procedures for those applications which warrant tests that are beyond those included in this specification.

3. Acceptance

Acceptance³ of the material shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.⁴

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.⁵

¹ Due to possible differences in composition, core wire from a covered electrode should not be used as bare filler metal.

² This revision includes classifications for E502-XX, E505-XX and E7Cr-XX welding electrodes. These classifications also will be included in the next revision of ANSI/AWS A5.5, Specification for Low Alloy Steel Electrodes for Shielded Metal Arc Welding. They will be deleted in the first revision of this document following publication of the pending revision of the A5.5 specification.

³ See A3. Acceptance (in the Appendix) for further information on acceptance, testing of material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

⁴ AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

⁵ See A4. Certification (in the Appendix) for further information concerning certification and the test called for to meet this requirement.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR UNDILUTED WELD METAL

AWS Classification ^c	UNS Number ^d	Weight Percent ^{a,b}										
		C	Cr	Ni	Mo	Cb (Nb) plus Ta	Mn	Si	P	S	N	Cu
E209-XX ^e	W32210	0.06	20.5-24.0	9.5-12.0	1.5-3.0	—	4.0-7.0	0.90	0.04	0.03	0.10-0.30	0.75
E219-XX	W32310	0.06	19.0-21.5	5.5-7.0	0.75	—	8.0-10.0	1.00	0.04	0.03	0.10-0.30	0.75
E240-XX	W32410	0.06	17.0-19.0	4.0-6.0	0.75	—	10.5-13.5	1.00	0.04	0.03	0.10-0.30	0.75
E307-XX	W30710	0.04-0.14	18.0-21.5	9.0-10.7	0.5-1.5	—	3.30-4.75	0.90	0.04	0.03	—	0.75
E308-XX	W30810	0.08	18.0-21.0	9.0-11.0	0.75	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E308H-XX	W30810	0.04-0.08	18.0-21.0	9.0-11.0	0.75	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E308L-XX	W30813	0.04	18.0-21.0	9.0-11.0	0.75	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E308Mo-XX	W30820	0.08	18.0-21.0	9.0-12.0	2.0-3.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E308MoL-XX	W30823	0.04	18.0-21.0	9.0-12.0	2.0-3.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E309-XX	W30910	0.15	22.0-25.0	12.0-14.0	0.75	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E309L-XX	W30913	0.04	22.0-25.0	12.0-14.0	0.75	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E309Cb-XX	W30917	0.12	22.0-25.0	12.0-14.0	0.75	0.70-1.00	0.5-2.5	0.90	0.04	0.03	—	0.75
E309Mo-XX	W30920	0.12	22.0-25.0	12.0-14.0	2.0-3.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E309MoL-XX	W30923	0.04	22.0-25.0	12.0-14.0	2.0-3.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E310-XX	W31010	0.08-0.20	25.0-28.0	20.0-22.5	0.75	—	1.0-2.5	0.75	0.03	0.03	—	0.75
E310H-XX	W31015	0.35-0.45	25.0-28.0	20.0-22.5	0.75	—	1.0-2.5	0.75	0.03	0.03	—	0.75
E310Cb-XX	W31017	0.12	25.0-28.0	20.0-22.0	0.75	0.70-1.00	1.0-2.5	0.75	0.03	0.03	—	0.75
E310Mo-XX	W31020	0.12	25.0-28.0	20.0-22.0	2.0-3.0	—	1.0-2.5	0.75	0.03	0.03	—	0.75
E312-XX	W31310	0.15	28.0-32.0	8.0-10.5	0.75	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E316-XX	W31610	0.08	17.0-20.0	11.0-14.0	2.0-3.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E316H-XX	W31610	0.04-0.08	17.0-20.0	11.0-14.0	2.0-3.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E316L-XX	W31613	0.04	17.0-20.0	11.0-14.0	2.0-3.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E317-XX	W31710	0.08	18.0-21.0	12.0-14.0	3.0-4.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E317L-XX	W31713	0.04	18.0-21.0	12.0-14.0	3.0-4.0	—	0.5-2.5	0.90	0.04	0.03	—	0.75
E318-XX	W31910	0.08	17.0-20.0	11.0-14.0	2.0-3.0	6 x C, min to 1.00 max	0.5-2.5	0.90	0.04	0.03	—	0.75
E320-XX	W88021	0.07	19.0-21.0	32.0-36.0	2.0-3.0	8 x C, min to 1.00 max	0.5-2.5	0.60	0.04	0.03	—	3.0-4.0

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

SFA-5.4

TABLE 1 (CONT'D)
CHEMICAL COMPOSITION REQUIREMENTS FOR UNDILUTED WELD METAL

AWS Classification ^c	UNS Number ^d	Weight Percent ^{a,b}										
		C	Cr	Ni	Mo	Cb (Nb) plus Ta		Mn	Si	P	S	N
E320LR-XX	W88022	0.03	19.0-21.0	32.0-36.0	2.0-3.0	8 x C, min to 0.40 max		1.50-2.50	0.30	0.020	0.015	—
E330-XX	W88331	0.18-0.25	14.0-17.0	33.0-37.0	0.75	—		1.0-2.5	0.90	0.04	0.03	—
E330H-XX	W88335	0.35-0.45	14.0-17.0	33.0-37.0	0.75	—		1.0-2.5	0.90	0.04	0.03	—
E347-XX	W34710	0.08	18.0-21.0	9.0-11.0	0.75	8 x C, min to 1.00 max		0.5-2.5	0.90	0.04	0.03	—
E349-XX ^{e,f,g}	W34910	0.13	18.0-21.0	8.0-10.0	0.35-0.65	0.75-1.20		0.5-2.5	0.90	0.04	0.03	—
E383-XX	W88028	0.03	26.5-29.0	30.0-33.0	3.2-4.2	—		0.5-2.5	0.90	0.02	0.02	—
E385-XX	W88904	0.03	19.5-21.5	24.0-26.0	4.2-5.2	—		1.0-2.5	0.75	0.03	0.02	—
E410-XX	W41010	0.12	11.0-13.5	0.7	0.75	—		1.0	0.90	0.04	0.03	—
E410NiMo-XX	W41016	0.06	11.0-12.5	4.0-5.0	0.40-0.70	—		1.0	0.90	0.04	0.03	—
E430-XX	W43010	0.10	15.0-18.0	0.6	0.75	—		1.0	0.90	0.04	0.03	—
E502-XX ^h	W50210	0.10	4.0-6.0	0.4	0.45-0.65	—		1.0	0.90	0.04	0.03	—
E505-XX ^h	W50410	0.10	8.0-10.5	0.4	0.85-1.20	—		1.0	0.90	0.04	0.03	—
E630-XX	W37410	0.05	16.00-16.75	4.5-5.0	0.75	0.15-0.30		0.25-0.75	0.75	0.04	0.03	—
E16-8-2-XX	W36810	0.10	14.5-16.5	7.5-9.5	1.0-2.0	—		0.5-2.5	0.60	0.03	0.03	—
E7Cr-XX ^h	W50310	0.10	6.0-8.0	0.4	0.45-0.65	—		1.0	0.90	0.04	0.03	—
E2209-XX	W39209	0.04	21.5-23.5	8.5-10.5	2.5-3.5	—		0.5-2.0	0.90	0.04	0.03	0.08-0.20
E2553-XX	W39553	0.06	24.0-27.0	6.5-8.5	2.9-3.9	—		0.5-1.5	1.0	0.04	0.03	0.10-0.25

NOTES

- Analysis shall be made for the elements for which specific values are shown in the table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements, except iron, is not present in excess of 0.50 percent.
- Single values are maximum percentages.
- Classification suffix -XX may be -15, -16, -17, -25, or -26. See Section A8 of the Appendix for an explanation.
- SAE/ASTM Unified Number System for Metals and Alloys.
- Vanadium shall be 0.10 to 0.30 percent.
- Titanium shall be 0.15 percent max.
- Tungsten shall be from 1.25 to 1.75 percent.
- This grade also will appear in the next revision of AWS A5.5, *Specification for Low Alloy Steel Electrodes for Shielded Metal Arc Welding*. It will be deleted from A5.4 at the first revision of A5.4 following publication of the revised A5.5.

TABLE 2
TYPE OF WELDING CURRENT AND POSITION OF
WELDING

AWS Classification ^a	Welding Current ^b	Welding Position ^c
EXXX(X)-15	dcep	All ^d
EXXX(X)-25	dcep	H, F
EXXX(X)-16	dcep or ac	All ^d
EXXX(X)-17	dcep or ac	All ^d
EXXX(X)-26	dcep or ac	H, F

NOTES

- a. See Section A8, Classification as to Useability, for explanation of positions.
 b. dcep = Direct current electrode positive (reverse polarity).
 ac = Alternating current
 c. The abbreviations H and F indicate welding positions (Figure 3) as follows:
 F = Flat
 H = Horizontal
 d. Electrodes $\frac{3}{16}$ in. (4.8 mm) and larger are not recommended for welding all positions.

5. Units of Measure and Rounding-Off Procedure

5.1 U.S. customary units are the standard units of measure in this specification. The SI units are given as equivalent values to the U.S. customary units. The standard sizes and dimensions in the two systems are not identical, and for this reason, conversion from a standard size or dimension in one system will not always coincide with a standard size or dimension in 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 1000 psi for tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.⁶

⁶ ASTM standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

The tests required for each classification are specified in Table 3. The purpose of these tests is to determine the chemical composition and mechanical properties of the weld metal and the usability of the electrodes. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Section 8, Weld Test Assemblies; Section 9, Chemical Analysis; Section 10, Tension Test; and Section 11, Fillet Weld Test.

7. Retest

If any test fails to meet its requirements, that test must be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or sample or from a new test assembly or sample. For chemical analysis, retest need be only for those specific elements that failed to meet their requirement.

8. Weld Test Assemblies

8.1 Three weld test assemblies are required:

- (1) The weld pad in Figure 1 for chemical analysis of the undiluted weld metal
- (2) The groove weld in Figure 2 for mechanical properties
- (3) The fillet weld in Figure 3 for usability of the electrode

Optionally, the sample for chemical analysis may be taken from the reduced section of the fractured tension specimen or from a corresponding location (or any location above it) in the weld metal of the groove weld in Figure 2 or from the weld pad used for ferrite determination. In the case of dispute, the weld pad of Figure 1 shall be the referee method.

8.2 Preparation of each weld test assembly shall be as prescribed in 8.3, 8.4 and 8.5. Base metal for each assembly shall conform to the following, or an equivalent:

8.2.1 The base metal shall be steel (carbon, alloy, stainless steel, or ingot iron) of 0.25 percent carbon, maximum for chemical analysis of all electrode classifications except E308L, E308MoL, E309L, E309MoL, E316L, E317L, E320LR, E383, E630, E385, and E2209. For chemical analysis of these low carbon classifications, the base metal shall be steel of 0.03 percent maximum carbon. Other steels having a carbon content of 0.25

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

SFA-5.4

TABLE 3
REQUIRED TESTS

Classification	Electrode Diameter		Type of Current ^b	Position of Welding ^a		
	in.	mm		Chemical Analysis ^c	All Weld Metal Tension Test ^d	Fillet Weld Test ^d
EXXX(X)-15	1/16	1.6	dcep	F	NR	NR
EXXX(X)-15	5/64	2.0	dcep	F	NR	NR
EXXX(X)-15	3/32	2.4	dcep	F	NR	NR
EXXX(X)-15	1/8	3.2	dcep	F	F	H, V, OH
EXXX(X)-15	5/32	4.0	dcep	F	F	H, V, OH
EXXX(X)-15	3/16	4.8	dcep	F	F	H
EXXX(X)-15	7/32	5.6	dcep	F	F	H
EXXX(X)-15	1/4	6.4	dcep	F	F	H
EXXX(X)-16, -17	1/16	1.6	ac & dcep	F	NR	NR
EXXX(X)-16, -17	5/64	2.0	ac & dcep	F	NR	NR
EXXX(X)-16, -17	3/32	2.4	ac & dcep	F	NR	NR
EXXX(X)-16, -17	1/8	3.2	ac & dcep	F	F	H, V, OH
EXXX(X)-16, -17	5/32	4.0	ac & dcep	F	F	H, V, OH
EXXX(X)-16, -17	3/16	4.8	ac & dcep	F	F	H
EXXX(X)-16, -17	7/32	5.6	ac & dcep	F	F	H
EXXX(X)-16, -17	1/4	6.4	ac & dcep	F	F	H
EXXX(X)-25	1/16	1.6	dcep	F	NR	NR
EXXX(X)-25	5/64	2.0	dcep	F	NR	NR
EXXX(X)-25	3/32	2.4	dcep	F	NR	NR
EXXX(X)-25	1/8	3.2	dcep	F	F	H
EXXX(X)-25	5/32	4.0	dcep	F	F	H
EXXX(X)-25	3/16	4.8	dcep	F	F	H
EXXX(X)-25	7/32	5.6	dcep	F	F	H
EXXX(X)-25	1/4	6.4	dcep	F	F	H
EXXX(X)-26	1/16	1.6	ac & dcep	F	NR	NR
EXXX(X)-26	5/64	2.0	ac & dcep	F	NR	NR
EXXX(X)-26	3/32	2.4	ac & dcep	F	NR	NR
EXXX(X)-26	1/8	3.2	ac & dcep	F	F	H
EXXX(X)-26	5/32	4.0	ac & dcep	F	F	H
EXXX(X)-26	3/16	4.8	ac & dcep	F	F	H
EXXX(X)-26	7/32	5.6	ac & dcep	F	F	H
EXXX(X)-26	1/4	6.4	ac & dcep	F	F	H

NOTES:

a. The abbreviations F, V, OH, and H indicate welding positions (Figure 3) as follows:

F = Flat

H = Horizontal

V = Vertical

OH = Overhead

The abbreviation NR indicates that the test is not required.

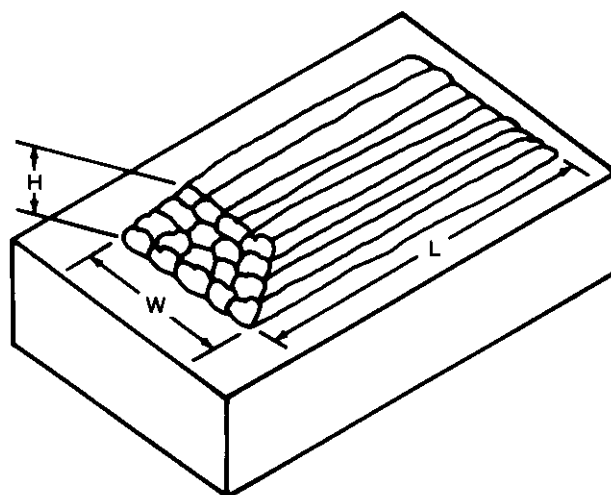
b. ac = alternating current; dcep = direct current, electrode positive (reverse polarity).

c. Where both alternating and direct current are specified, only one type of current need be used.

d. Where both alternating and direct current are specified, tests shall be made using both types of current.

SI Equivalents

in.	mm
1/16	1.6
5/64	2.0
3/32	2.4
1/8	3.2
5/32	4.0
3/16	4.8
7/32	5.6
1/4	6.4
3/8	9.5
1/2	13
5/8	16
7/8	22
1-1/2	38
2	50
2-1/2	63



Electrode Size, in.	Weld Pad Size, Minimum, in.			Minimum Distance of Sample from Surface of Base Plate, in.
	L	W	H	
1/16	1-1/2	1/2	1/2	3/8
5/64				
3/32				
1/8	2	1/2	5/8	1/2
5/32				
3/16				
7/32	2-1/2	1/2	3/4	5/8
1/4				

FIG. 1 PAD FOR CHEMICAL ANALYSIS OF UNDILUTED WELD METAL

percent maximum may be used with the further restrictions specified in 9.6.

8.2.2 For the all-weld-metal tension test, the steel to be used shall be of a matching type. Optionally, the steel may conform to one of the following specifications or their equivalents, providing two buttering layers of filler metal as shown in Figure 2, are deposited in stringer beads using electrodes of the same classification as that being classified.

(1) ASTM specification A285, *Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength, Grade C*.

(2) ASTM specification A36, *Structural Steel*.

(3) ASTM specification A515, *Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service, Grade 70*.

8.2.3 For the fillet weld test, the steel to be used shall conform to the following specifications:

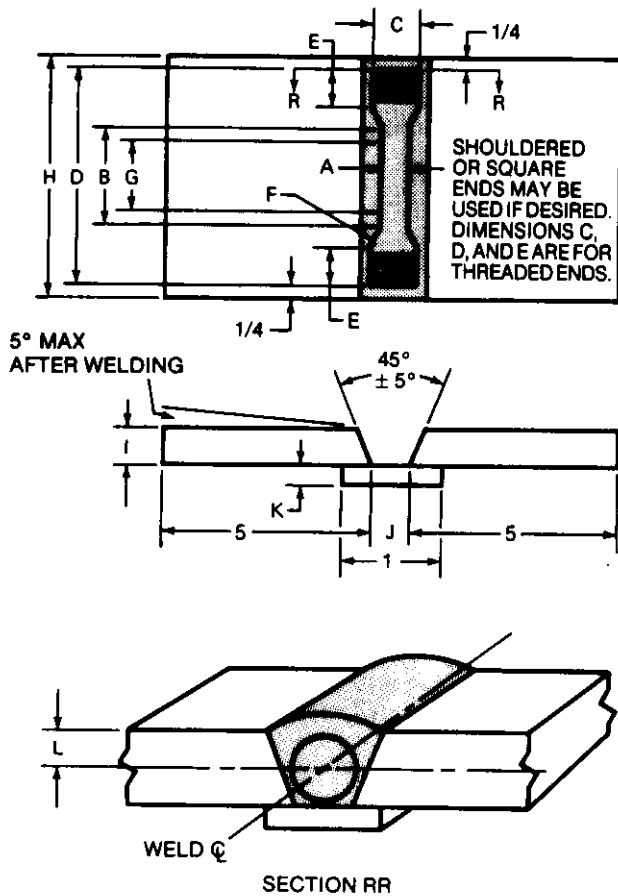
(1) For E502, E505, E7Cr electrodes—ASTM specification A285, *Pressure Vessel Plates, Carbon Steel Low- and Intermediate-Tensile Strength, Grade C*

(2) For E400 Series electrodes—ASTM specification A240, *Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Fusion-Welded Unfired Pressure Vessels, Type 410 or Type 430, A or B*

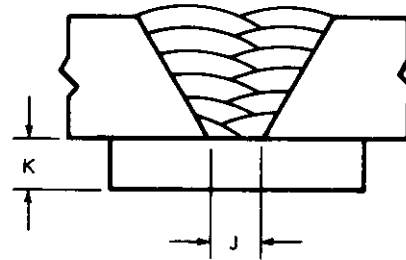
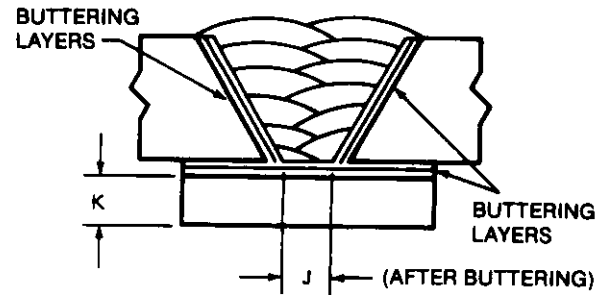
(3) For all other classifications of electrodes—ASTM specification A240, *Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Fusion-Welded Unfired Pressure Vessels, Type 304*

8.3 Weld Pad

8.3.1 A weld pad shall be prepared as specified in Figure 1 using base metal of any convenient size, of the type specified in 8.2. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position,



NOTE: ALL DIMENSIONS EXCLUDING ANGLES ARE IN INCHES.



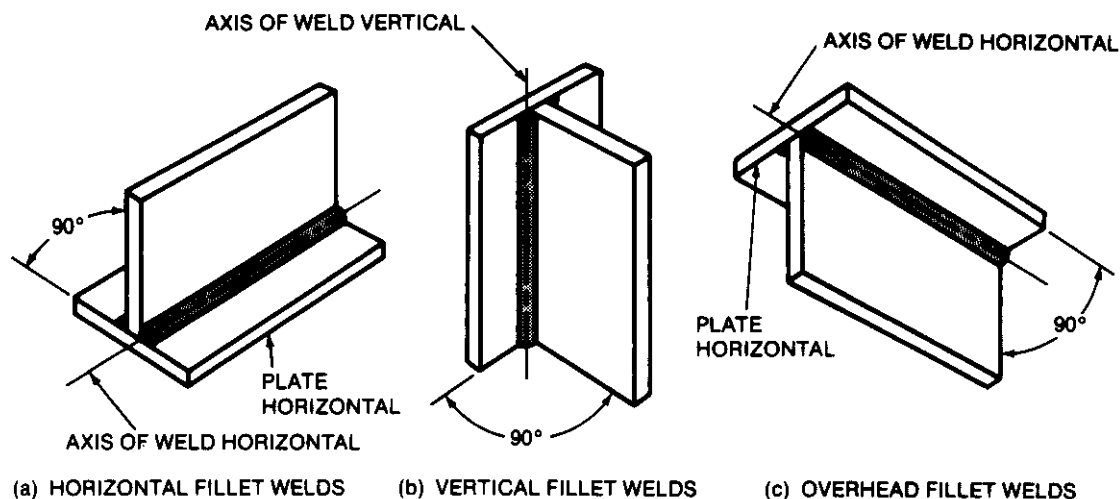
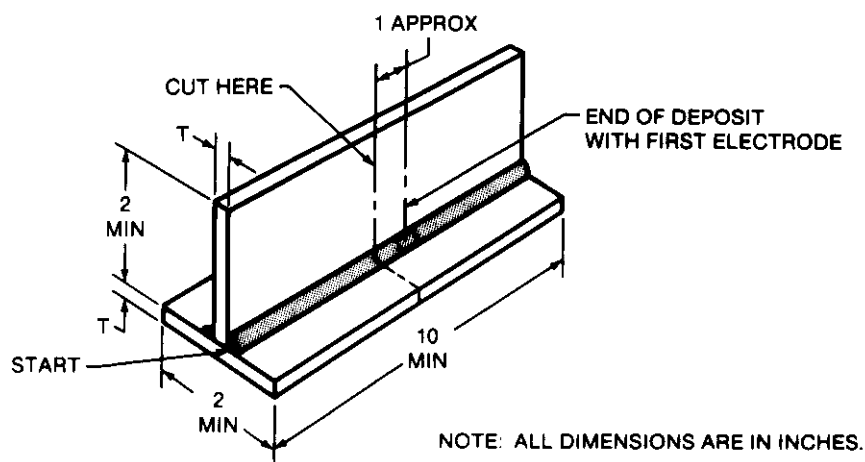
(FOR TEST PLATES OF MATCHING COMPOSITION)

Each layer or pass not to exceed 1/8 in. in thickness.
The first two layers may be deposited with one pass each.

SI Equivalents		
	in.	mm
	0.005	0.13
	0.010	0.25
1/8	0.125	3.2
3/16	0.187	4.8
1/4	0.250	6.4
3/8	0.375	9.5
1/2	0.500	12.7
5/8	0.625	16
3/4	0.750	19.1
1	1.0	25.4
1-1/4		31.8
2		50.8
3		76
3-1/2		90
5		127
5-1/2		140

Electrode Diam., in.	Dimensions of Test Plate and Tension Test Specimens, in.											
	I	A	B	C	D, min	E, min	F, min	G	H, min	J	K	L
1/8	1/2	0.250 ± 0.005	1-1/4	3/8	3	5/8	0.18	1.000 ± 0.005	3-1/2	1/4	3/16	1/4
5/32 to 1/4 incl.	3/4	0.500 ± 0.010	2-1/4	3/4	5	1	3/8	2.000 ± 0.005	5-1/2	1/2	1/4	3/8

FIG. 2 GROOVE WELD TEST ASSEMBLY FOR TENSION TEST SPECIMEN

**(A) POSITIONS OF TEST PLATES FOR WELDING FILLET-WELD TEST SPECIMENS****(B) PREPARATION OF FILLET-WELD TEST ASSEMBLY**

Electrode Diameter Size, in.	Thickness of Plate T, in.	Position of Welding	Required Fillet Max., in.	SI Equivalents*	
1/8	1/4	{ V H and OH	1/4 3/16	in.	mm
1/8*	3/8 or 1/2	{ V H and OH	3/8 1/4	1/8	3.2
5/32	1/4 or 3/8	{ V H and OH	5/16 1/4	5/32	4.0
5/32*	1/2	{ V H and OH	1/2 5/16	3/16	4.8
3/16	3/8	H	5/16	1/4	6.4
1/4	3/8	H	3/8	5/16	8.0
*For EXXX-17 electrodes only				3/8	9.5
				1	25
				2	50
				10	250

FIG. 3 FILLET WELD TEST ASSEMBLY

TABLE 4
WELDING CONDITIONS FOR PREPARATION OF THE
GROOVE WELD

AWS Classification	Preheat and Interpass Temperature			
	Minimum		Maximum	
	°F	°C	°F	°C
E400 Series (except E410)	300	150	500	260
E500 Series	300	150	500	260
E7Cr	300	150	500	260
E410	400	204	600	315
All Others	60	16	300	150

using as short an arc length as practical and at a current as agreed upon between consumer and manufacturer. Multiple beads shall be used to obtain undiluted weld metal. The preheat temperature shall not be less than 60°F (16°C). After depositing each layer, the weld pad may be immersed in water (temperature unimportant) for approximately 30 seconds. The slag shall be removed after each pass. The completed pad shall be as shown in Figure 1 for each size of the electrode. Testing of the assembly shall be as specified in Section 9, Chemical Analysis.

8.3.2 Where both alternating and direct current are specified, only one type of current need be used.

8.4 Groove Weld

8.4.1 A test assembly shall be prepared as specified in 8.4.2, 8.4.3, and Figure 2, using base metal of the appropriate type specified in 8.2.

8.4.2 The plates shall be welded in the flat position, and they shall be preset or sufficiently restrained during welding to prevent warping more than 5 degrees. A test plate that has warped more than 5 degrees shall be discarded. Test assemblies shall not be straightened.

8.4.3 The test assembly shall be within the temperature ranges specified in Table 4 before starting each pass, including depositing of any buttering layer, as measured on the assembly at a distance of 1 in. (25 mm) from the weld at the mid-length of the test plate.

If, after any pass, the maximum temperature specified above is exceeded, plates shall be allowed to cool in air (do not cool in water) to a temperature within the range shown.

8.4.4 The assembly shall be tested in the as-welded or post weld heat-treated condition as specified in Table 5.

8.5 Fillet Weld

8.5.1 A test assembly shall be prepared and welded as shown in Figure 3, using base metal of the appropriate type specified in 8.2. The welding position and conditions shall be as specified in the fillet weld column of Table 3 for the different electrode sizes and classifications. Testing of the assembly shall be as specified in Section 11, Fillet Weld Test.

8.5.2 In preparing the two plates forming the test assembly, the standing member (web) shall have one edge machined throughout its entire length so that when the web is set upon the base plate (flange), which shall be straight and smooth, there will be intimate contact along the entire length of the joint.

8.5.3 A single-pass fillet weld shall be deposited on one side of the joint. The first electrode shall be continuously consumed to within the maximum permissible stub length of 2 in. (50 mm). Additional electrodes, if necessary, shall then be used to complete the weld for the full length of the joint, consuming each electrode completely as stated above, insofar as permitted by the length of the assembly.

8.5.4 When welding in the vertical position, the welding shall progress upwards.

8.5.5 After completing the weld on the first side of the joint, the assembly shall be cooled to room temperature [but not less than 60°F (16°C)] by any convenient means before commencing to weld on the second side (see note).

Note: If water is used as the coolant, care should be taken that it has been thoroughly removed from the joint before beginning welding on the second side.

8.5.6 The fillet weld shall be deposited on the second side of the joint with the same procedure used for the fillet weld on the first side.

9. Chemical Analysis

9.1 The top surface of the weld pad described in 8.3 and shown in Figure 1 shall be removed and discarded and a sample for analysis shall be obtained from the underlying metal by any appropriate mechanical means from the surface to be analyzed. The sample shall be free of slag.

TABLE 5
ALL-WELD-METAL MECHANICAL PROPERTY REQUIREMENTS

AWS Classification	Tensile Strength, min		Elongation min Percent	Heat Treatment
	ksi	MPa		
E209-XX	100	690	15	None
E219-XX	90	620	15	None
E240-XX	100	690	15	None
E307-XX	85	590	30	None
E308-XX	80	550	35	None
E308H-XX	80	550	35	None
E308L-XX	75	520	35	None
E308Mo-XX	80	550	35	None
E308MoL-XX	75	520	35	None
E309-XX	80	550	30	None
E309L-XX	75	520	30	None
E309Cb-XX	80	550	30	None
E309Mo-XX	80	550	30	None
E309MoL-XX	75	520	30	None
E310-XX	80	550	30	None
E310H-XX	90	620	10	None
E310Cb-XX	80	550	25	None
E310Mo-XX	80	550	30	None
E312-XX	95	660	22	None
E316-XX	75	520	30	None
E316H-XX	75	520	30	None
E316L-XX	70	490	30	None
E317-XX	80	550	30	None
E317L-XX	75	520	30	None
E318-XX	80	550	25	None
E320-XX	80	550	30	None
E320LR-XX	75	520	30	None
E330-XX	75	520	25	None
E330H-XX	90	620	10	None
E347-XX	75	520	30	None
E349-XX	100	690	25	None
E383-XX	75	520	30	None
E385-XX	75	520	30	None
E410-XX	75	450	20	a
E410NiMo-XX	110	760	15	c
E430-XX	65	450	20	d
E502-XX	60	420	20	b
E505-XX	60	420	20	b
E630-XX	135	930	7	e
E16-8-2-XX	80	550	35	None
E7Cr-XX	60	420	20	b
E2209-XX	100	690	20	None
E2553-XX	110	760	15	None

NOTES:

- Heat to 1350 to 1400°F (730 to 760°C), hold for one hour, furnace cool at a rate of 100°F (60°C) per hour to 600°F (315°C) and air cool to ambient.
- Heat to 1550 to 1600°F (840 to 870°C), hold for two hours, furnace cool at a rate not exceeding 100°F (55°C) per hour to 1100°F (595°C) and air cool to ambient.
- Heat to 1100 to 1150°F (595 to 620°C), hold for one hour, and air cool to ambient.
- Heat to 1400 to 1450°F (760 to 790°C), hold for two hours, furnace cool at a rate not exceeding 100°F (55°C) per hour to 1100°F (595°C) and air cool to ambient.
- Heat to 1875 to 1925°F (1025 to 1050°C), hold for one hour, and air cool to ambient, and then precipitation harden at 1135 to 1165°F (610 to 630°C), hold for four hours, and air cool to ambient.

9.2 Weld pads which are too hard for sample removal in the as-welded condition may be given an annealing heat treatment.

9.3 Alternatively, the sample taken from the reduced section of the fractured tension specimen or from the groove weld (see 8.1) may be prepared for analysis by any suitable mechanical means. A sample taken from the weld pad used for ferrite determination (A6.9.1 through A6.9.4) shall be taken after draw filing, and the height above the base plate for sample removal shall be consistent with the requirements of Figure 1 for the standard weld pad.

9.4 The sample shall be analyzed by accepted analytical methods. In case of dispute, the referee method shall be ASTM Standard Methods E353, *Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron-Alloys*.

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

9.6 If steels other than those that have 0.03 percent maximum carbon are used for E630, E2209, and low carbon grade electrodes,⁷ the sample shall come from material above the eighth layer.

10. Tension Test

10.1 One all-weld-metal tension test shall be machined from the groove weld described in 8.4 and shown in Figure 2.

10.2 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*.

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

11. Fillet Weld Test

11.1 The fillet weld test, when required in Table 3, shall be made in accordance with 8.5 and Figure 3. The entire face of the completed fillet weld shall be examined visually. The weld shall be free from cracks or other open defects that would affect the strength of the weld. After the visual examination, a cross section shall be taken from the portion of the weld made with the first electrode and approximately 1 in. (25 mm)

from the end of that weld bead, as shown in Figure 3. The cross-sectional surface shall be polished and etched, and then examined as required in 11.2.

11.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 4, and the leg length and the convexity shall be determined to the nearest $\frac{1}{64}$ in. (0.4 mm) by actual measurement.

11.2.1 Both fillet welds shall have penetration to or beyond the junction of the edges of the plates.

11.2.2 Both legs of the fillet weld shall be equal in length within $\frac{1}{16}$ in. (1.6 mm).

11.2.3 Convexity of each fillet weld shall be within the limits prescribed by the graph shown in Figure 4.

11.2.4 The fillet welds shall show no evidence of cracks.

11.2.5 The welds shall be reasonably free from undercutting, overlap, trapped slag, and porosity.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

12. Method of Manufacture

The welding electrodes classified according to this specification may be manufactured by any method that will produce electrodes conforming to the requirements of this specification.

13. Standard Sizes and Lengths

13.1 Standard sizes (diameter of the core wire) and lengths of electrodes shall be as shown in Table 6.

13.2 The diameter of the core wire shall not vary more than ± 0.002 in. (± 0.05 mm) from the diameter specified. The length shall not vary more than $\pm \frac{1}{4}$ in. (± 6.4 mm) from that specified.

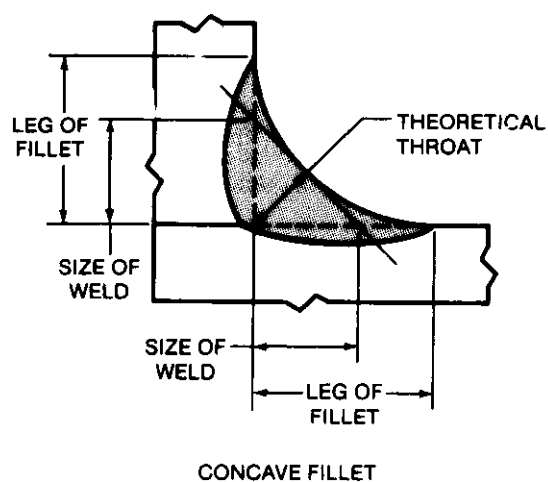
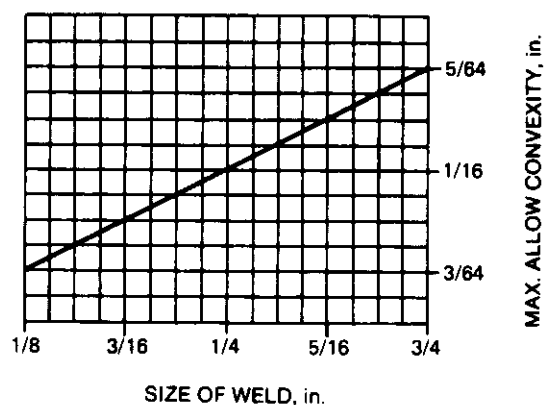
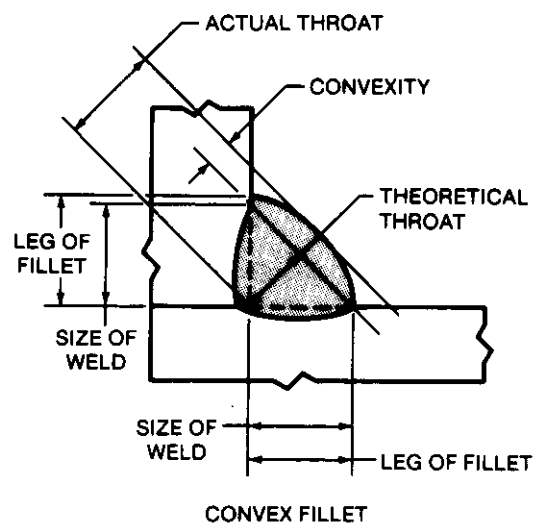
14. Core Wire and Covering

14.1 The core wire and covering shall be free of defects that would interfere with uniform deposition of the weld metal.

14.2 The core wire and the covering shall be concentric to the extent that the maximum core-plus-one-covering dimension does not exceed the minimum core-plus-one-covering dimension by more than the following:

(1) Seven percent of the mean dimension in sizes $\frac{3}{32}$ in. (2.4 mm) and smaller

⁷Low carbon electrode grades are as follows: E308L, E308MoL, E309L, E309MoL, E316L, E317L, E320LR, E383, and E385.



SI Equivalents

in.	mm
3/64	1.2
1/16	1.6
5/64	2.0
3/32	2.4
1/8	3.2
3/16	4.8
1/4	6.4
5/16	8.0
3/8	9.5

Notes:

1. Size of fillet weld = leg length of largest inscribed isosceles right triangle.
2. Length of horizontal leg of fillet weld shall not vary more than 1/16 in. (1.6 mm) from length of vertical leg.
3. Fillet weld size, convexity, and leg lengths of fillet welds shall be determined by actual measurement (nearest 1/64 in. [0.5 mm]) on a section laid out with scribed lines shown.

FIG. 4 FILLET WELD TEST SPECIMEN

TABLE 6
STANDARD SIZES AND LENGTHS

Electrode Size (Diameter of Core Wire) ^a		Standard Lengths ^{b,c}	
in.	mm	in.	mm
1/16	1.6	9	230
5/64	2.0	9	230
3/32	2.4	9, 12, 14 ^d	230, 305, 350 ^d
1/8	3.2	14, 18 ^d	350, 460 ^d
5/32	4.0	14, 18 ^d	350, 460 ^d
3/16	4.8	14, 18 ^d	350, 460 ^d
7/32	5.6	14, 18	350, 460
1/4	6.4	14, 18	350, 460

NOTES

- Tolerance on the diameter shall be ± 0.002 in. (± 0.05 mm).
- Tolerance on length shall be $\pm 1/4$ in. (± 6.4 mm).
- Other sizes and lengths shall be as agreed upon between purchaser and supplier.
- These lengths are intended only for the EXXX-25 and EXXX-26 types.

(2) Five percent of the mean dimension in sizes 1/8 in. (3.2 mm) and 5/32 in. (4.0 mm)

(3) Four percent of the mean dimension in sizes 3/16 in. (4.8 mm) and larger

The concentricity may be measured by any suitable means.

15. Exposed Core

15.1 The grip end of each 5/32 in. (4.0 mm) and smaller electrode shall be bare (free of covering) for a distance of not less than 1/2 in. (12 mm), nor more than 1 1/4 in. (30 mm) and for larger electrodes the bare end shall be not less than 3/4 in. (19.2 mm) nor more than 1 1/2 in. (38 mm) to provide for electrical contact with the holder.

15.2 The arc end of each electrode shall be sufficiently bare and the covering sufficiently tapered to permit easy striking of the arc. The length of the bare portion (measured from the end of the core wire to the location where the full cross section of the covering is obtained) shall not exceed 1/8 in. (3 mm) or the diameter of the core wire, whichever is less. Electrodes with chipped coverings near the arc end, baring the core wire no more than the lesser of 1/4 in. (6.4 mm) or twice the diameter of the core wire, meet the requirements of this specification, provided no chip uncovers more than 50 percent of the circumference of the core.

16. Electrode Identification

All electrodes shall be identified as follows:

16.1 At least one imprint of the electrode classification shall be applied to the electrode covering within 2 1/2 in. (65 mm) of the grip end of the electrode.

16.2 The numbers and letters of the imprint shall be of bold block type and of a size large enough to be legible.

16.3 The ink used for imprinting shall provide sufficient contrast with the electrode covering so that, in normal use, the numbers and letters are legible both before and after welding.

16.4 The prefix letter "E" in the electrode classification may be omitted from the imprint.

17. Packaging

17.1 Electrodes shall be suitably packaged to protect them from damage during shipment and storage under normal conditions.

17.2 Standard package weights shall be as agreed between purchaser and supplier.

18. Marking of Packages

18.1 The following product information (as a minimum) shall be legibly marked on the outside of each unit package:

- (1) AWS specification and classification numbers (Year of issue may be excluded)
- (2) Supplier's name and trade designation
- (3) Standard size and net weight
- (4) Lot, control, or heat number

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

WARNING:

Protect yourself and others. Read and understand this information. FUMES AND GASES can be dangerous to your health. ARC RAYS can injure eyes and burn skin. ELECTRIC SHOCK can kill.

- Before use read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDS's), and your employer's safety practices.
- Keep your head out of the fumes.

- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, P.O. Box 351040, Miami, Florida 33135; *OSHA Safety and Health Standards*, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

Appendix

Guide to AWS Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

(This Appendix is not a part of ANSI/AWS A5.4-92, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, but is included for information only.)

A1. Introduction

A1.1 This specification is intended to provide both the supplier and the purchaser of covered stainless steel welding electrodes with a means of product control and a basis of acceptance through mutually acceptable, sound, standard requirements.

A1.2 This guide has been prepared as an aid to prospective users of covered stainless steel welding electrodes included in the specification to determine the classification best suited for a particular application, with due consideration to the particular requirements for that application.

A2. Classification System

A2.1 The system of classification is similar to that used in other filler metal specifications. The letter "E" at the beginning of each number indicates an electrode. The first three digits designate the classification as to its composition. (Occasionally, a number of digits other than three is used and letters may follow the digits to indicate a specific composition.) The last two digits designate the classification as to usability with respect to position of welding and type of current as described in A8. The smaller sizes of EXXX(X)-15, EXXX(X)-16, or EXXX(X)-17 electrodes [up to and including $\frac{5}{32}$ in. (4.0 mm)] included in this specification are used in all welding positions.

A2.2 The mechanical tests measure strength and ductility, qualities which are often of lesser importance than the corrosion and heat resisting properties. These mechanical test requirements, however, provide an as-

urance of freedom from weld metal flaws, such as check cracks and serious dendritic segregations which, if present, may cause failure in service.

A2.3 It is recognized that for certain applications, supplementary tests may be required. In such cases, additional tests to determine specific properties, such as corrosion resistance, scale resistance, or strength at elevated temperatures may be required as agreed upon between supplier and purchaser.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, must 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 is normally 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 must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the

product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that 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, *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 they 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. Ferrite in Weld Deposits

A6.1 Ferrite is known to be very beneficial in reducing the tendency for cracking or fissuring in weld metals; however, it is not essential. Millions of pounds of fully austenitic weld metal have been used for years and provided satisfactory service performance. Generally,

ferrite is helpful when the welds are restrained, the joints are large, and when cracks or fissures adversely affect service performance. Ferrite increases the weld strength level. Ferrite may have a detrimental effect on corrosion resistance in some environments. It also is generally regarded as detrimental to toughness in cryogenic service, and in high-temperature service where it can transform into the brittle sigma phase.

A6.2 Ferrite can be measured on a relative scale by means of various magnetic instruments. However, work by the Subcommittee for Welding of Stainless Steel of the High Alloys Committee of the Welding Research Council (WRC) established that the lack of a standard calibration procedure resulted in a very wide spread of readings on a given specimen when measured by different laboratories. A specimen averaging 5.0 percent ferrite based on the data collected from all the laboratories was measured as low as 3.5 percent by some and as high as 8.0 percent by others. At an average of 10 percent, the spread was 7.0 to 16.0 percent.

In order to substantially reduce this problem, the WRC Subcommittee published on July 1, 1972, *Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*.⁸ In 1974, the AWS extended this procedure and prepared AWS A4.2, *Standard Procedure for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Steel Weld Metal*. All instruments used to measure the ferrite content of AWS classified stainless electrode products are to be traceable to this AWS standard.

A6.3 The WRC Subcommittee also adopted the term *Ferrite Number* (FN) to be used in place of percent ferrite, to clearly indicate that the measuring instrument was calibrated to the WRC procedure. The Ferrite Number, up to 10 FN, is to be considered equal to the *percent ferrite* term previously used. It represents a good average of commercial U.S. and world practice on the percent ferrite. Through the use of standard calibration procedures, differences in readings due to instrument calibration are expected to be reduced to about ± 5 percent, or at the most, ± 10 percent of the measured ferrite value.

A6.4 In the opinion of the WRC Subcommittee, it has been impossible, to date, to accurately determine the true absolute ferrite content of weld metals.

A6.5 Even on undiluted pads, ferrite variations from pad to pad must be expected due to slight changes in

⁸ Available from the Welding Research Council, 345 East 47th Street, New York, New York 10017.

welding and measuring variables. On a large group of pads from one heat or lot and using a standard pad welding and preparation procedure, two sigma values indicate that 95 percent of the tests are expected to be within a range of approximately ± 2.2 FN at about 8 FN. If different pad welding and preparation procedures are used, these variations will increase.

A6.6 Even larger variations may be encountered if the welding technique allows excessive nitrogen pickup, in which case the ferrite can be much lower than it should be. High nitrogen pickup can cause a typical 8 FN deposit to drop to 0 FN. A nitrogen pickup of 0.10 percent will typically decrease the FN by about 8.

A6.7 Plate materials tend to be balanced chemically to have an inherently lower ferrite content than matching weld metals. Weld metal diluted with plate metal will usually be somewhat lower in ferrite than the undiluted weld metal, though this does vary depending on the amount of dilution and the composition of the base metal.

A6.8 In the E300 series electrodes, many types such as E310, E320, E320LR, E330, E383 and E385 are fully austenitic. The E316 group can be made with little or no ferrite and generally is used in that form because it has better corrosion resistance in certain media. It also can be obtained in a higher ferrite form, usually over 4 FN, if desired. The remaining E300 series electrodes can be made in low ferrite versions, but commercial practice usually involves ferrite control above 4 FN. Because of chemistry limits covering these grades and various manufacturing limits, most lots will be under 10 FN and it is unlikely to go over 15 FN commercially. E16-8-2 generally is controlled at a low ferrite level, under 5 FN; E312, E2553, and E2209 generally are quite high in ferrite, usually over 20 FN.

A6.9 When it is desired to measure ferrite content, the following procedure is recommended:

A6.9.1 Weld pads as detailed in Figure A1 are prepared as described in A6.9.2 through A6.9.4. The base plate must be Type 301, 302, or 304 conforming to ASTM Specification A167 or A240. Carbon steel may be used provided that the weld pad is built up to the minimum height specified in A6.9.2.

A6.9.2 The weld pad must be built up between two copper bars laid parallel on the base plate by depositing single weld bead layers, one on top of the other to a minimum height of $\frac{1}{2}$ in. (13 mm). The spacing between the copper bars for the size of the electrode being tested must be as specified in Figure A1. An optional welding fixture is shown in Figure

A2. If carbon steel is used as the base plate, the weld pad must be built up to a minimum height of $\frac{5}{8}$ in. (16 mm).

A6.9.3 Typical welding currents used for the size of the electrode being tested are shown in Figure A1. The arc length should be as short as practicable. The weld bead layers may be deposited with a weave, if necessary, to fill the space between the copper bars. The arc shall not be allowed to impinge on the copper bars. The welding direction should be alternated from pass to pass. The weld stops and starts must be located at the ends of the weld buildup. Each pass must be cleaned prior to depositing the next weld bead. The maximum interpass temperatures should be 200°F (95°C). Between passes, the weld pad may be cooled by quenching in water not sooner than 20 seconds after the completion of each pass. The last pass must be air cooled to below 800°F (430°C) prior to quenching in water.

A6.9.4 The completed weld pad must be draw filed to provide sufficient finished surface to make the required ferrite readings.

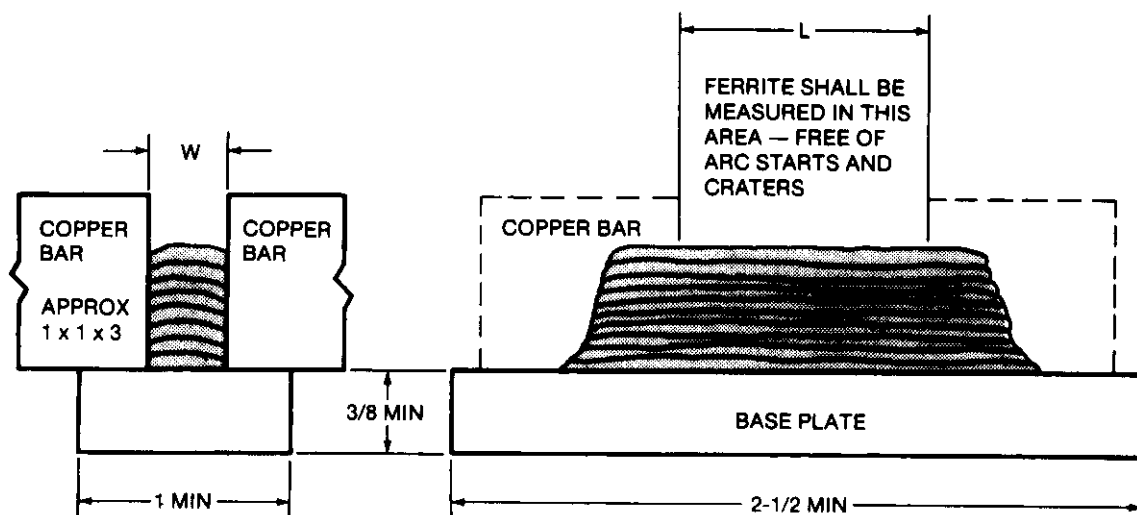
Draw filing must be performed with a 14 in. (360 mm) mill bastard file held on both sides of the weld with the long axis of the file perpendicular to the long axis of the weld. Files shall either be new or shall have been used only on austenitic stainless steel.

Filing must be accomplished by smooth draw filing strokes (one direction only) along the length of the weld while applying a firm downward pressure. Cross filing, i.e., filing in two different directions, shall not be permitted. The finished surface must be smooth with all traces of weld ripple removed and must be continuous in length where measurements are to be taken. The width of the prepared surface shall not be less than $\frac{1}{8}$ in. (3 mm).

A6.9.5 A total of six ferrite readings must be taken on the filed surface along the longitudinal axis of the weld pad with an instrument calibrated in accordance with the procedures specified in ANSI/AWS A4.2, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal* (latest edition).

A6.9.6 The six readings obtained must be averaged to a single value for conversion to Ferrite Number.

A6.10 The ferrite content of welds may be calculated from the chemical composition of the weld deposit. This can be done from one of several constitution diagrams. These are the WRC-1988 Diagram (Figure



NOTE: ALL DIMENSIONS ARE IN INCHES.

Electrode Diameter, in.	Welding Current Amperes ^a -15, -16, -17, -25, -26	Approximate Dimensions of Deposit, in.		SI Equivalents	
		W	L	in.	mm
1/16	35-50	0.25	1-1/4	1/16	1.6
5/64	45-60	0.25	1-1/4	5/64	2.0
3/32	65-90	0.3	1-1/2	3/32	2.4
1/8	90-120	0.4	1-1/2	1/8	3.2
5/32	120-150	0.5	1-1/2	5/32	4.0
3/16	160-200	0.6	1-1/2	3/16	4.8
7/32	200-240	0.7	1-1/2	7/32	5.6
1/4	240-280	0.7	1-1/2	1/4	6.4
				0.25	6.4
				0.3	7.6
				3/8	9.5
				0.4	10
				0.5	13
				0.6	15
				0.7	18
				1	25
				1-1/4	32
				1-1/2	38
				2-1/2	64
				3	76

a. Recommended welding current will vary widely depending on the type of core wire employed. Consult the manufacturer for specific recommendations. Welding current used to produce the test specimen should be reported.

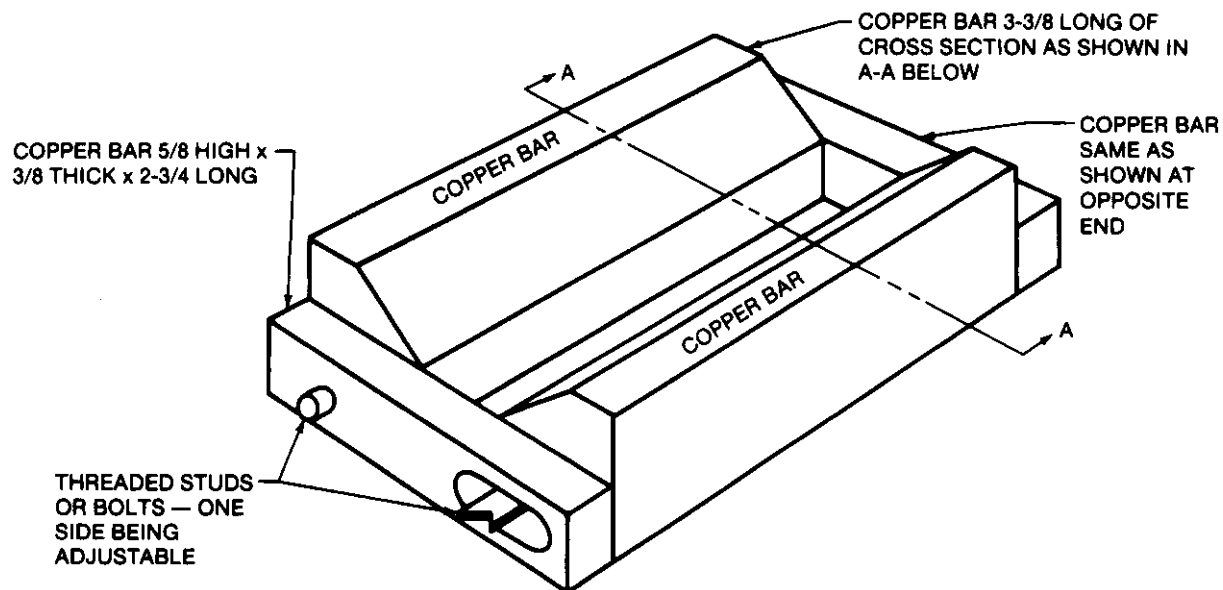
FIG. A1 WELD PAD FOR FERRITE TEST

A3), the Espy Diagram (Figure A4), and the DeLong Diagram (Figure A5). There may be a wide range of results obtained from one diagram to another. The following paragraphs give some explanation of the differences among these diagrams and their recommended applications.

A6.10.1 WRC-1988 Diagram (Figure A3) predicts ferrite in Ferrite Number (FN).⁹ This diagram is the

⁹ McCowan, C. N., Stewart, T. A., and Olson, D. L. "Stainless steel weld metal prediction of ferrite." Bulletin 342. New York: Welding Research Council, April 1989.

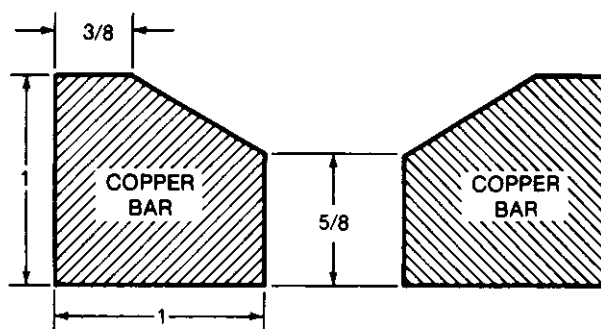
newest of the diagrams mentioned. Studies within the WRC Subcommittee on Welding of Stainless Steel and within Commission II of the International Institute of Welding show a closer agreement between measured and predicted ferrite using this diagram than when using the DeLong Diagram. It should be noted that predictions of the WRC-1988 Diagram are independent of silicon and manganese contents because these elements were not found to have statistically significant effects. The WRC-1988 Diagram is preferred for "300" series stainless steels and for duplex stainless alloys. It may not be applicable to compositions having greater



NOTE: ALL DIMENSIONS ARE IN INCHES.

SI Equivalents	
in.	mm
5/32	4.0
3/16	4.8
3/8	9.5
5/8	16
1	25
2-3/4	70
3-3/8	85

TYPE 1
FOR 5/32 DIAM ELECTRODES AND SMALLER



THIS DESIGN ALLOWS INCREASED VISIBILITY,
MAKING IT EASIER TO HOLD A SHORT ARC LENGTH.

CROSS SECTION A-A

TYPE 2
FOR 3/16 & LARGER DIAM WELDING ELECTRODES
AND FOR ANY PADS ON CARBON STEEL BASE PLATE

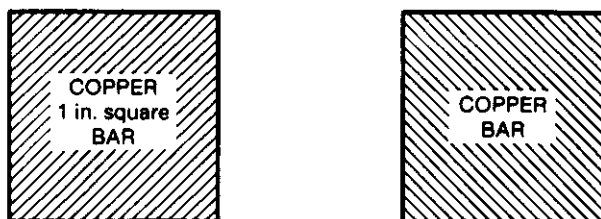


FIG. A2 OPTIONAL WELDING FIXTURE FOR WELDING FERRITE TEST PADS

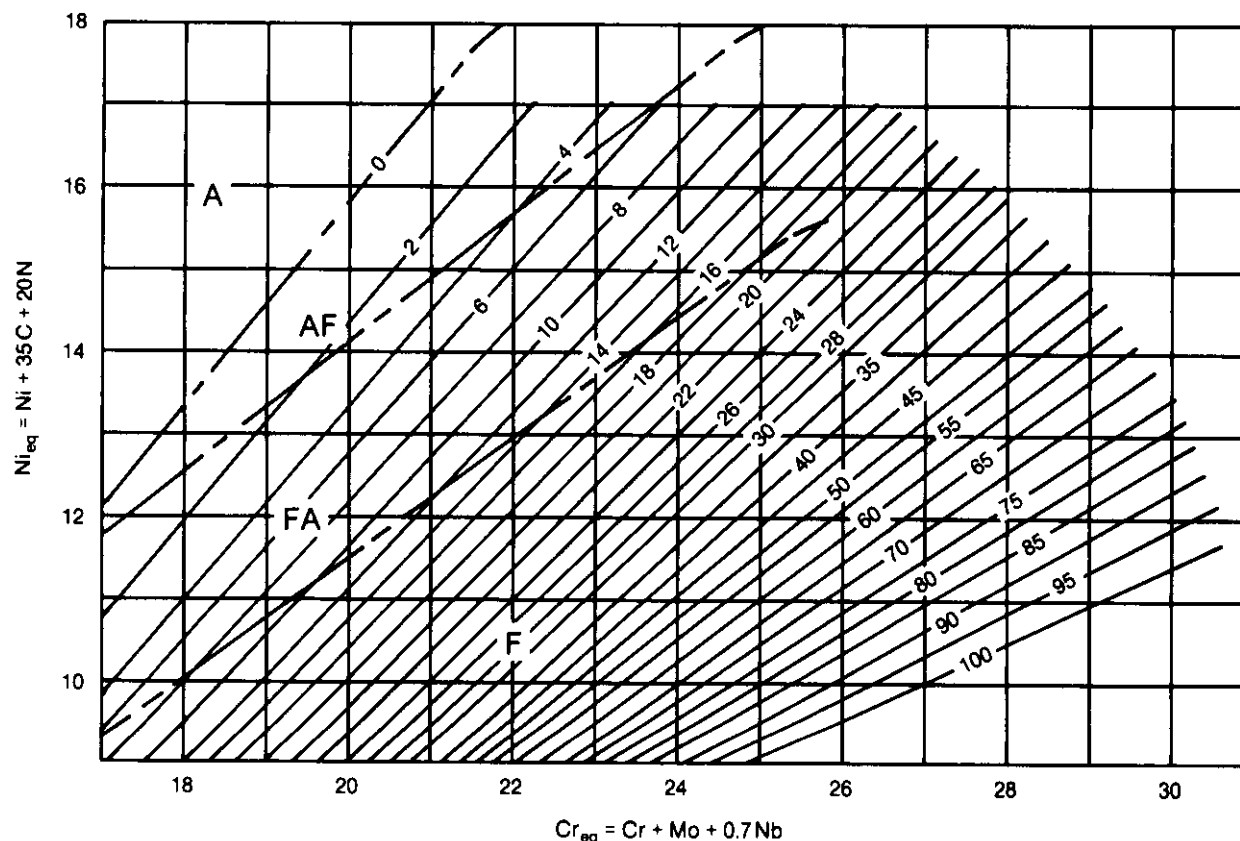


FIG. A3 WRC-1988 (FN) DIAGRAM FOR STAINLESS STEEL WELD METAL

than 0.2 percent of nitrogen and greater than 10 percent of manganese.

A6.10.2 Espy Diagram calculates the percent ferrite (Figure A4) rather than FN of deposits of the "200" series (see A2.1) having manganese levels up to 15 percent and nitrogen contents up to 0.35 percent (nitrogen-strengthened austenitic stainless steels).¹⁰

A6.10.3 DeLong Diagram¹¹ is a modified Schaeffler Diagram¹² predicting the Ferrite Number (FN) up to a maximum of 18 FN. The diagram includes the nitrogen level into the calculation to predict the FN. The DeLong modifications to the Schaeffler Diagram provide a better correlation between the calculated and measured ferrite content of the weld metal, therefore, the Schaeffler Diagram is not shown in this specification. The new

WRC-1988 Diagram, see Figure A3, is the most accurate and preferred diagram for predicting the ferrite in "300" series stainless steel weld metals. Future publications of this specification may not include the DeLong Diagram.

A6.10.4 The differences between measured and calculated ferrite are somewhat dependent on the ferrite level of the deposit, increasing as the ferrite level increases. The agreement between the calculated and measured ferrite values is also strongly dependent on the quality of the chemical analysis. Variations in the results of the chemical analyses encountered from laboratory to laboratory can have significant effects on the calculated ferrite value, changing it as much as 4 to 8 FN.

¹⁰ Espy, R. H. "Weldability of nitrogen-strengthened stainless steels." *Welding Journal*, 61(5): 149s-156s, 1982.

¹¹ DeLong, W. T. (1974 Adams Lecture) "Ferrite in austenitic stainless steel weld metal." *Welding Journal*, 53(7): 273s to 286s, 1974.

¹² Schaeffler, A. E. *Metal Progress* (56): 680-680B.

A7. Description and Intended Use of Filler Metals

A7.1 E209. The nominal composition (wt.%) of this weld metal is 22 Cr, 11 Ni, 5.5 Mn, 2 Mo, and 0.20

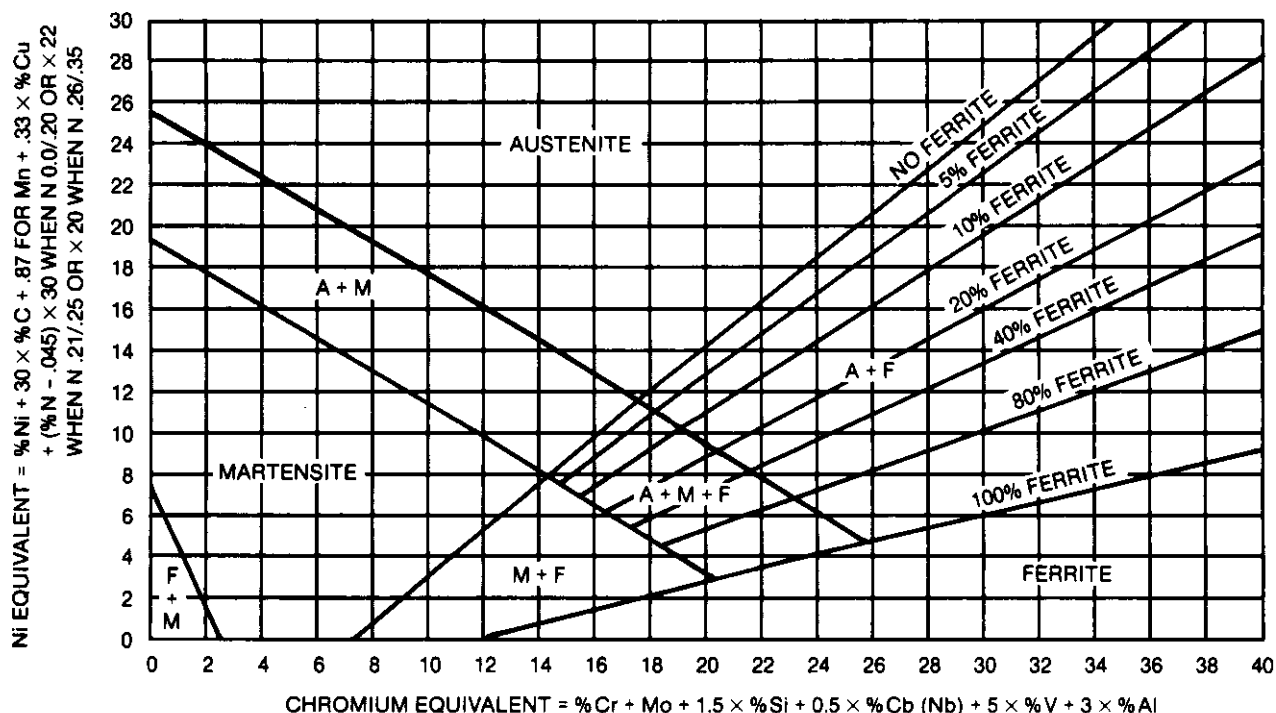


FIG. A4 ESPY PERCENT FERRITE DIAGRAM FOR STAINLESS WELD METAL

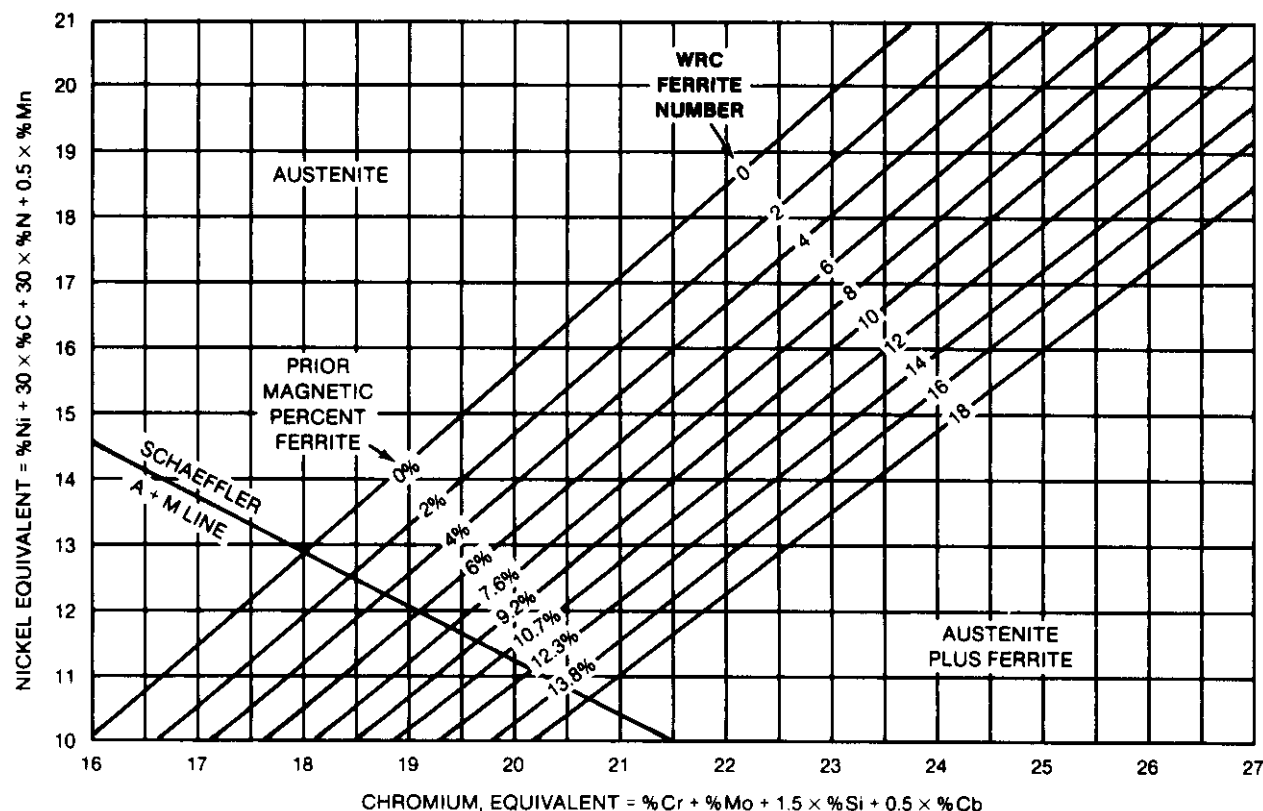
N. Electrodes of this composition are most often used to weld AISI Type 209 (UNS S20910) base metals. The alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength with good toughness over a wide range of temperatures. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increasing resistance to intergranular corrosion. Nitrogen alloying coupled with the molybdenum content provides superior resistance to pitting and crevice corrosion in aqueous chloride-containing media. Type E209 electrodes have sufficient total alloy content for use in joining dissimilar alloys, like mild steel and the stainless steels and also for direct overlay on mild steel for corrosion applications.

A7.2 E219. The nominal composition (wt.%) of this weld metal is 20 Cr, 6 Ni, 9 Mn, and 0.20 N. Electrodes of this composition are most often used to weld AISI Type 219 (UNS S21900) base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength with good toughness over a wide range of temperatures. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby, increases

resistance to intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. The E219 electrodes have sufficient total alloy content for use in joining dissimilar alloys, like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications.

A7.3 E240. The nominal composition (wt.%) of this weld metal is 18 Cr, 5 Ni, 12 Mn, and 0.02 N. Electrodes of this composition are most often used to weld AISI Type 240 and 241 base metals. These alloys are nitrogen-strengthened austenitic stainless steels exhibiting high strength with good toughness over a wide range of temperatures. Significant improvement in resistance to wear in particle-to-metal and metal-to-metal (galling) applications is a desirable characteristic when compared to the more conventional austenitic stainless steels like Type 304. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increasing resistance to intergranular corrosion.

Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. In addition, weldments in alloys AISI 240 and



Calculate the nickel and chromium equivalents from the weld metal analysis. If nitrogen analysis of the weld metal is not available, assume 0.06% for GTA and covered electrode, or 0.08% for GMA weld metals. If the chemistry is accurate the diagram predicts the WRC Ferrite Number within plus or minus 3 in approximately 90% of the tests for the 308, 309, 316 and 317 families.

FIG. A5 DELONG (FN) DIAGRAM FOR STAINLESS STEEL WELD METAL

AISI 241 when compared to Type 304, exhibit improved resistance to transgranular stress corrosion cracking in hot aqueous chloride-containing media. The E240 electrodes have sufficient total alloy content for use in joining dissimilar alloys, like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion and wear applications.

A7.4 E307. The nominal composition (wt.%) of this weld metal is 19 Cr, 9.8 Ni, 4 Mn. Electrodes of this composition are used primarily for moderate strength welds with good crack resistance between dissimilar steels such as austenitic manganese steel and carbon steel forgings or castings.

A7.5 E308. The nominal composition (wt.%) of this weld metal is 19 Cr, and 10 Ni. Electrodes of this composition are most often used to weld base metal

of similar composition such as AISI Types 301, 302, 304, and 305.

A7.6 E308H. These electrodes are the same as E308 except that the allowable carbon content has been restricted to the higher portion of the E308 range. Carbon content in the range of 0.04-0.08 provides higher tensile and creep strengths at elevated temperatures. These electrodes are used for welding Type 304H base metal.

A7.7 E308L. The composition of the weld metal is the same as E308, except for the restricted carbon content. The 0.04 percent max carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium)

or titanium. A carbon content of 0.04 percent max has been shown to be adequate in weld metal, even though it is recognized that similar base metal specifications require a 0.03 percent limitation. This low carbon alloy, however, is not as strong at elevated temperature as the columbium-stabilized alloys or 304H.

A7.8 E308Mo. These electrodes are the same as E308, except for the addition of molybdenum. E308Mo electrodes are recommended for welding ASTM CF8M stainless steel castings, as they match the base metal with regard to chromium, nickel, and molybdenum. They may also be used for welding wrought materials such as Type 316 stainless when increased ferrite is desired beyond that attainable with E316 electrodes.

A7.9 E308MoL. These electrodes are recommended for welding ASTM CF3M stainless steel castings, as they match the base metal with regard to chromium, nickel, and molybdenum. E308MoL electrodes may also be used for welding wrought materials such as Type 316L stainless when increased ferrite is desired beyond that attainable with E316L electrodes.

A7.10 E309. The nominal composition (wt.%) of this weld metal is 23.5 Cr, 13 Ni. Electrodes of this composition are commonly used for welding similar alloys in wrought or cast form. They are used for welding dissimilar metals, such as joining Type 304 to carbon steel, welding the clad side of Type 304 clad steels, and applying stainless steel sheet linings to carbon steel shells. Occasionally, they are used to weld Type 304 and similar base metals where severe corrosion conditions exist requiring higher alloy weld metal.

A7.11 E309L. The composition of this weld metal is the same as that deposited by E309 electrodes, except for the restricted carbon content. The 0.04 percent max carbon content of these weld deposits reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium) and titanium. This low carbon alloy, however, is not as strong at elevated temperature as the columbium-stabilized alloys or high carbon content Type 309 deposits.

A7.12 E309Cb. The composition of this weld metal is the same as Type 309, except for the addition of columbium (niobium) and a reduction in the carbon limit. The columbium (niobium) provides resistance to carbide precipitation and thus increases intergranular corrosion resistance and also provides higher strength in elevated temperature service. E309Cb electrodes are

used also for welding Type 347 clad steels or for the overlay of carbon steel.

A7.13 E309Mo. The composition of this weld metal is the same as that deposited by E309 electrodes, except for the addition of molybdenum and a small reduction in the carbon limit. These electrodes are used for welding Type 316 clad steels or for the overlay of carbon steels.

A7.14 E309MoL. The composition of this weld metal is the same as that deposited by E309Mo electrodes, except for the restricted carbon content. The lower carbon content of the weld metal reduces the possibility of intergranular corrosion.

A7.15 E310. The nominal composition (wt.%) of this weld metal is 26.5 Cr, 21 Ni. Electrodes of this composition are most often used to weld base metals of similar composition.

A7.16 E310H. The composition of this weld metal is the same as that deposited by E310 electrodes, except that carbon ranges from 0.35 to 0.45 percent. These electrodes are used primarily for welding or repairing high alloy heat and corrosion resistant castings of the same general composition which are designated as Type HK by the Alloy Castings Institute. The alloy has high strength at temperatures over 1700°F (930°C). It is not recommended for high sulfur atmospheres or where severe thermal shock is present. Long time exposure to temperatures in the approximate range of 1400 to 1600°F (760 to 870°C) may induce formation of sigma and secondary carbides which may result in reduced corrosion resistance, reduced ductility, or both.

A7.17 E310Cb. The composition of this weld metal is the same as that deposited by E310 electrodes, except for the addition of columbium (niobium) and a reduction in carbon limit. These electrodes are used for the welding of heat resisting castings, Type 347 clad steels, or the overlay of carbon steels.

A7.18 E310Mo. The composition of this weld metal is the same as that deposited by E310 electrodes, except for the addition of molybdenum and a reduction in carbon limit. These electrodes are used for the welding of heat resisting castings, Type 316 clad steels, or for the overlay of carbon steels.

A7.19 E312. The nominal composition (wt.%) of this weld metal is 30 Cr, 9 Ni. These electrodes were originally designed to weld cast alloys of similar composition. They have been found to be valuable in welding dissimilar metals, especially if one of them is a stainless steel, high in nickel. This alloy gives a two-

phase weld deposit with substantial amounts of ferrite in an austenitic matrix. Even with considerable dilution by austenite-forming elements, such as nickel, the microstructure remains two-phase and thus highly resistant to weld metal cracks and fissures. Applications should be limited to service temperature below 800°F (420°C) to avoid formation of secondary brittle phases.

A7.20 E316. The nominal composition (wt.%) of this weld metal is 18.5 Cr, 12.5 Ni, 2.5 Mo. These electrodes are used for welding Type 316 and similar alloys. They have been used successfully in certain applications involving special base metals for high-temperature service. The presence of molybdenum provides creep resistance at elevated temperatures. Rapid corrosion of Type 316 weld metal may occur when the following three factors co-exist:

(1) The presence of a continuous or semicontinuous network of ferrite in the weld metal microstructure

(2) A composition balance of the weld metal giving a chromium-to-molybdenum ratio of less than 8.2 to 1

(3) Immersion of the weld metal in a corrosive medium

Attempts to classify the media in which accelerated corrosion will take place by attack on the ferrite phase have not been entirely successful. Strong oxidizing and mildly reducing environments have been present where a number of corrosion failures were investigated and documented. The literature should be consulted for latest recommendations.

A7.21 E316H. These electrodes are the same as E316, except that the allowable carbon content has been restricted to the higher portion of the E316 range. Carbon content in the range of 0.04 to 0.08 provides higher tensile and creep strengths at elevated temperatures. These electrodes are used for welding 316H base metal.

A7.22 E316L. This composition is the same as E316, except for the restricted carbon content. The 0.04 percent max carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium) or titanium. These electrodes are used principally for welding low carbon, molybdenum-bearing austenitic alloys. Tests have shown that 0.04 percent carbon limit in the weld metal gives adequate protection against intergranular corrosion in most cases. This low carbon alloy, however, is not as strong at elevated temperatures as Type E316H.

A7.23 E317. The alloy content of weld metal deposited by these electrodes is somewhat higher than that

of E316 electrodes, particularly in molybdenum. These electrodes are usually used for welding alloys of similar composition and are utilized in severely corrosive environments (such as those containing halogens) where crevice and pitting corrosion are of concern.

A7.24 E317L. The composition of this weld metal is the same as that deposited by E317 electrodes, except for the restricted carbon content. The 0.04 percent max carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium) or titanium. This low carbon alloy, however, is not as strong at elevated temperatures as the columbium (niobium) stabilized alloys or the standard Type 317 weld metal with a higher carbon content.

A7.25 E318. The composition of this weld metal is the same as that deposited by E316 electrodes, except for the addition of columbium (niobium). Columbium (niobium) provides resistance to intergranular carbide precipitation and thus increased resistance to intergranular corrosion. These electrodes are used primarily for welding base metals of similar composition.

A7.26 E320. The nominal composition (wt.%) of this weld metal is 20 Cr, 34 Ni, 2.5 Mo, 3.5 Cu, with Cb (Nb) added to improve resistance to intergranular corrosion. These electrodes are primarily used to weld base metals of similar composition for applications where resistance to severe corrosion is required for a wide range of chemicals including sulfuric and sulfurous acids and their salts. These electrodes can be used to weld both castings and wrought alloys of similar composition without postweld heat treatment.

A modification of this grade without columbium (niobium) is available for repairing castings which do not contain columbium. With this modified composition, solution annealing is required after welding.

A7.27 E320LR (Low Residuals). Weld metal deposited by E320LR electrodes has the same basic composition as that deposited by E320 electrodes; however, the elements C, Si, P, and S are specified at lower maximum levels, and Cb (Nb) and Mn are controlled within narrower ranges. These changes reduce the weld metal fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals. Consequently, welding practices typically used to deposit ferrite-containing austenitic stainless steel weld metals can be used. Type 320LR weld metal has a lower minimum tensile strength than Type 320 weld metal.

A7.28 E330. The nominal composition (wt.%) of this weld metal is 35 Ni, 15.5 Cr. These electrodes are commonly used where heat- and scale-resisting properties above 1800°F (980°C) are required. However, high sulfur environments may adversely effect performance at elevated temperature. Repairs of defects in alloy castings and the welding of castings and wrought alloys of similar composition are the most common applications.

A7.29 E330H. The composition of this weld metal is the same as that deposited by E330 electrodes, except that carbon ranges from 0.35 to 0.45 percent. These electrodes are used primarily for the welding and repairing of high alloy heat and corrosion resistant castings of the same general composition which are designated HT by the Alloy Castings Institute. This composition can be used to 2100°F (1150°C) in oxidizing atmospheres and at 2000°F (1090°C) in reducing atmospheres. However, high sulfur environments may adversely affect performance at elevated temperature.

A7.30 E347. The nominal composition (wt.%) of this weld metal is 19.5 Cr, 10 Ni with Cb (Nb) or Cb (Nb) plus Ta added as a stabilizer. Either of these additions reduces the possibility of intergranular chromium carbide precipitation and thus increases resistance to intergranular corrosion.

These electrodes are usually used for welding chromium-nickel alloys of similar composition stabilized either with columbium (niobium) or titanium. Electrodes depositing titanium as a stabilizing element are not commercially available because titanium is not readily transferred across the arc in shielded metal arc welding. Although columbium (niobium) is the stabilizing element usually specified in Type 347 alloys, it should be recognized that tantalum also is present. Tantalum and columbium (niobium) are almost equally effective in stabilizing carbon and in providing high-temperature strength. This specification recognizes the usual commercial practice of reporting columbium (niobium) as the sum of columbium (niobium) plus tantalum. If dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit, crack sensitivity of the weld may increase substantially.

Some applications, especially those involving high-temperature service, are adversely affected if the ferrite content is too high. Consequently, a high ferrite content should not be specified unless tests prove it to be absolutely necessary.

A7.31 E349. The nominal composition (wt.%) of this weld metal is 19.5 Cr, 9 Ni, 1 Cb(Nb), 0.5 Mo, 1.4 W. These electrodes are used for welding steels

of similar composition such as AISI Type 651 or 652. The combination of columbium (niobium), molybdenum, and tungsten with chromium and nickel gives good high-temperature rupture strength. The chemical composition of the weld metal results in an appreciable content of ferrite which increases the crack resistance of the weld metal.

A7.32 E383. The nominal composition (wt.%) of this weld metal is 28 Cr, 31.5 Ni, 3.7 Mo, 1 Cu. These electrodes are used to weld base metal of a similar composition to itself and to other grades of stainless steel. Type E383 weld metal is recommended for sulphuric and phosphoric acid environments.

The elements C, Si, P, and S are specified at low maximum levels to minimize weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals.

A7.33 E385. The nominal composition (wt.%) of this weld metal is 20.5 Cr, 25 Ni, 5 Mo, 1.5 Cu. These electrodes are used primarily for welding of Type 904L materials for the handling of sulphuric acid and many chloride-containing media. E385 electrodes also may be used to join Type 317L material where improved corrosion resistance in specific media is needed. E385 electrodes also can be used for joining Type 904L base metal to other grades of stainless. The elements C, Si, P and S are specified at lower maximum levels to minimize weld metal hot cracking and fissuring (while maintaining corrosion resistance) frequently encountered in fully austenitic weld metals.

A7.34 E410. This 12 Cr alloy is an air-hardening steel. Preheat and postheat treatments are required to achieve welds of adequate ductility for many engineering purposes. The most common application of these electrodes is for welding alloys of similar compositions.

They are also used for surfacing of carbon steels to resist corrosion, erosion, or abrasion.

A7.35 E410NiMo. These electrodes are used for welding ASTM CA6NM castings or similar materials, as well as light gage Type 410, 410S, and 405 base metals. Weld metal deposited by these electrodes are modified to contain less chromium and more nickel than weld metal deposited by E410 electrodes. The objective is to eliminate ferrite in the microstructure, as ferrite has a deleterious effect on mechanical properties of this alloy. Final postweld heat treatment should not exceed 1150°F (620°C). Higher temperatures may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A7.36 E430. The weld metal deposited by these electrodes contains between 15 and 18 Cr (wt.%). The composition is balanced by providing sufficient chromium to give adequate corrosion resistance for the usual applications and yet retain sufficient ductility in the heat-treated condition to meet the mechanical requirements of the specification. (Excessive chromium will result in lowered ductility.) Welding with E430 electrodes usually requires preheat and postheat. Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A7.37 E502. The nominal composition (wt.%) of this weld metal is 5 Cr, 0.5 Mo. These electrodes are used for welding base metal of similar composition, usually in the form of pipe or tubing. The alloy is an air-hardening material; therefore, when welding with these electrodes, preheat and postweld heat treatment are required.

A7.38 E505. The nominal composition (wt.%) of this weld metal is 9 Cr, 1 Mo. These electrodes are used for welding base metal of similar composition, usually in the form of pipe or tubing. The alloy is an air-hardening material and, therefore, when welding with these electrodes, preheat and postweld heat treatment are required.

A7.39 E630. The nominal composition (wt.%) of these electrodes is 16.4 Cr, 4.7 Ni, 3.6 Cu. These electrodes are primarily designed for welding ASTM A564, Type 630, and some other precipitation-hardening stainless steels. The weld metal is modified to prevent the formation of ferrite networks in the martensite microstructure which could have a deleterious effect on mechanical properties. Dependent on the application and weld size, the weld metal may be used either as-welded, welded and precipitation hardened, or welded, solution treated and precipitation hardened.

A7.40 E16-8-2. The nominal composition (wt.%) of this weld metal is 15.5 Cr, 8.5 Ni, 1.5 Mo. These electrodes are used primarily for welding stainless steel, such as Types 16-8-2, 316, and 347, for high-pressure, high-temperature piping systems. The weld deposit usually has a Ferrite Number no higher than 5 FN. The deposit also has good hot ductility properties which offer relative freedom from weld or crater cracking even under high-restraint conditions. The weld metal is usable in either the as-welded or solution-treated condition. These electrodes depend on a very carefully balanced chemical composition to develop their fullest properties. Corrosion tests indicate that Type 16-8-2 weld metal may have less corrosion resistance than

Type 316 base metal depending on the corrosive media. Where the weldment is exposed to severe corrosives, the surface layers should be deposited with a more corrosion resistant weld metal.

A7.41 E7Cr. The nominal composition (wt.%) of this weld metal is 7 Cr, 0.5 Mo. These electrodes are primarily used in welding base metal of similar composition. The 7 Cr base metal usually is furnished as tubing, pipe, or casting. This alloy is an air-hardening material and requires the use of both preheat and postweld heat treatment for satisfactory welding and service.

A7.42 E2209. The nominal composition (wt.%) of this weld metal is 22.5 Cr, 9.5 Ni, 3 Mo, 0.15 N. Electrodes of this composition are used primarily to weld duplex stainless steels which contain approximately 22 percent of chromium. Weld metal deposited by these electrodes has "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2209 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking.

A7.43 E2553. The nominal composition (wt.%) of this weld metal is 25.5 Cr, 7.5 Ni, 3.5 Mo, 2 Cu and 0.17 N. These electrodes are used primarily to weld duplex stainless steels which contain approximately 25 percent of chromium. Weld metal deposited by these electrodes has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2553 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking.

A8. Classification as to Usability

A8.1 Five basic usability classifications are provided in this specification, as shown in Table 2.

A8.2 The type of covering applied to a core wire to make a shielded metal arc welding electrode determines the usability characteristics of the electrode. The following discussion of covering types is based upon terminology commonly used by the industry; no attempt has been made to specifically define the composition of the different covering types.

A8.3 Usability Designation -15. The electrodes are usable with dcep (electrode positive) only. While use with alternating current is sometimes accomplished, they are not intended to qualify for use with this type of current. Electrode sizes $\frac{5}{32}$ in. (4.0 mm) and smaller may be used in all positions of welding.

A8.4 Usability Designation -16. The covering for these electrodes generally contains readily ionizing elements, such as potassium, in order to stabilize the arc for welding with ac. Electrode sizes $\frac{5}{32}$ in. (4.0 mm) and smaller may be used in all positions of welding.

A8.5 Usability Designation -17. The covering of these electrodes is a modification of the -16 covering in that considerable silica replaces some of the titania of the -16 covering. Since both the -16 and the -17 electrode coverings permit ac operation, both covering types were classified as -16 in the past because there was no classification alternative until this revision of ANSI/AWS A5.4. However, the operational differences between the two types have become significant enough to warrant a separate classification.

On horizontal fillet welds, electrodes with a -17 covering tend to produce more of a spray arc and a finer rippled weld-bead surface than do those with the -16 coverings. A slower freezing slag of the -17 covering also permits improved handling characteristics when employing a drag technique. The bead shape on horizontal fillets is typically flat to concave with -17 covered electrodes as compared to flat to slightly convex with -16 covered electrodes. When making fillet welds in the vertical position with upward progression, the slower freezing slag of the -17 covered electrodes requires a slight weave technique to produce the proper bead shape. For this reason, the minimum leg-size fillet that can be properly made with a -17 covered electrode is larger than that for a -16 covered electrode. While these electrodes are designed for all-position operation, electrode sizes $\frac{3}{16}$ in. (4.8 mm) and larger are not recommended for vertical or overhead welding.

A8.6 Usability Designation -25. This slag system is very similar in composition and operating characteristics to that of the -15 designation, and so that description also applies here. The electrode differs from the -15 type in that the core wire may be of a substantially different composition, such as mild steel, that may require a much higher welding current. The additional alloys necessary to obtain the required analysis are contained in the covering which will be of greater diameter than the corresponding -15 type. These electrodes are recommended for welding only in the flat and horizontal positions.

A8.7 Usability Designation -26. This slag system is very similar in composition and operating characteristics to that of the -16 designation, and so that description also applies here. The electrode differs from the -16 type in that the core wire may be of a substantially different composition such as mild steel that may require

a much higher welding current. The additional alloys necessary to obtain the required analysis are contained in the covering which will be of much larger diameter than the corresponding -16 type. These electrodes are recommended for welding only in the flat and horizontal positions.

A9. Special Tests

A9.1 Although welds made with electrodes covered by this specification are commonly used in corrosion- or heat-resisting applications, it is not practical to require tests for corrosion or scale resistance on welds or weld metal specimens. Such special tests which are pertinent to the intended application may be conducted as agreed upon between supplier and purchaser. This section is included for the guidance of those who desire to specify such special tests.

A9.2 Corrosion or scaling tests of joint specimens have the advantage that the joint design and welding procedure can be made identical to those being used in fabrication. They have the disadvantage of being a test of the combined properties of the weld metal, the heat-affected zone of the base metal, and the unaffected base metal. Furthermore, it is difficult to obtain reproducible data if a difference exists between the corrosion or oxidation rates of the various metal structures (weld metal, heat-affected zone, and unaffected base metal). Test samples cannot be readily standardized if welding procedure and joint design are to be considered variables. Joint specimens for corrosion tests should not be used for qualifying the electrode but may be used for qualifying welding procedures using approved materials.

A9.3 All-weld-metal specimens for testing corrosion or scale resistance are prepared by following the procedure outlined for the preparation of pads for chemical analysis (see Section 9.). The pad size should be at least $\frac{3}{4}$ in. (19 mm) in height by $2\frac{1}{2}$ in. (65 mm) wide by $1 + \frac{5}{8}n$ in. ($25 + 16n$ mm) long, where n represents the number of specimens required from the pad. Specimens measuring $\frac{1}{2} \times 2 \times \frac{1}{4}$ in. ($13 \times 50 \times 6.4$ mm) are machined from the top surface of the pad in such a way that the 2 in. (50 mm) dimension of the specimen is parallel to the $2\frac{1}{2}$ in. (65 mm) width dimension of the pad and the $\frac{1}{2}$ in. (13 mm) dimension is parallel to the length of the pad.

A9.4 The heat treatments, surface finish, and marking of the specimens prior to testing should be in accordance with standard practices for tests of similar alloys in the wrought or cast forms. The testing procedure should correspond to the ASTM G4, *Standard Method for*

Conducting Corrosion Tests in Plant Equipment or ASTM A262, Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels.

A9.5 Tests for mechanical properties of joint specimens may be desired when the intended application involves the welding of dissimilar metals. Procedures for the mechanical testing of such joints should be in accordance with the latest edition of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

A9.6 Tests of joint specimens may be influenced by the properties of the base metal and welding procedures and may not provide adequate tests of the weld metal. Such tests should be considered as tests for qualifying welding procedures using approved materials rather than tests for qualifying the electrodes.

A9.7 Where fabrication codes require tests of welds in heat-treated conditions other than those specified in Table 2, all-weld-metal tests of heat-treated specimens may be desired. For the preparation of such specimens, the procedures outlined in Section 10, Tension Test and Section 11, Fillet Weld Test, should be followed.

A9.8 Fully austenitic stainless steel weld metals are known to possess excellent toughness at cryogenic temperatures such as -320°F (-196°C). An example of this is the successful use of E310 (which deposits fully austenitic weld metal) to join 9 percent nickel steel for use in cryogenic service. To ensure freedom from brittle failure, Section VIII of the *ASME Boiler and Pressure Vessel Code* requires weldments intended for cryogenic service be qualified by Charpy V-notch testing. The criterion for acceptability is the attainment of a lateral expansion opposite the notch of not less than 15 mils (0.38 mm) for each of three specimens. In general, fully austenitic stainless steel weld metals such as Types 310, 320, 320LR, and 330 can be expected to meet the 15 mils (0.38 mm) requirement at -320°F (-196°C).

A9.9 Austenitic stainless steel weld metals of lower alloy content than those noted above usually are not fully austenitic but contain some delta ferrite. It has been found that such weld metals require judicious compositional balances to meet the 15 mils (0.38 mm) lateral expansion criteria even at moderately low temperatures such as -150°F (-100°C).

A9.10 Electrode classifications which can be used if special attention is given to the weld deposit composition content to maximize toughness are E308L-XX, E309L-XX, and E316L-XX. Published studies of the effect

of composition changes on weldment toughness properties for these types have shown the following:

A9.10.1 Both carbon and nitrogen contents have strong adverse effects on weld metal toughness so that their contents should be minimized. Low carbon weld metals with a nitrogen content below 0.06 percent are preferred.

A9.10.2 Nickel appears to be the only element whose increased content in weld metal improves weld metal toughness.

A9.10.3 Delta ferrite is harmful; therefore, minimizing ferrite in weld metal (3 FN max) is recommended. Weld metal free of ferrite (fully austenitic) is preferred; the more austenitic, the better.

A9.10.4 Fully austenitic E316L weld metal appears to be the preferred composition because of the ease in achieving ferrite-free weld metal, while compositionally conforming to AWS A5.4 and retaining crack resistance.

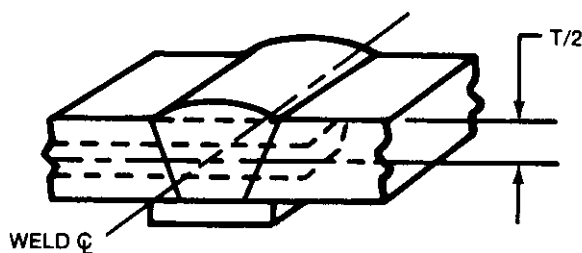
A9.10.5 Lime covered electrodes tend to produce weldments having slightly superior lateral expansion values for Charpy V-notch impact specimens than titania covered electrodes when weld metal composition factors are essentially the same. This appears to be due to two factors:

A9.10.5.1 Lime coated SMAW electrodes usually provide better protection from nitrogen incursion into the weld metal than that provided by titania coated electrodes. Nitrogen, as noted above, has significantly adverse effects on weld toughness.

A9.10.5.2 Lime coated SMAW electrodes appear to produce weld metals of lower oxygen levels or inclusion population (i.e., cleaner weld metal), or both. The above suggestions are particularly important when the intended application involves very low temperatures such as -320°F (-196°C).

A9.11 Limited SMAW electrode weld metal data have indicated that welding in the vertical position, as compared to flat position welding, does not reduce toughness properties, providing good operator's technique is employed.

A9.12 Where cryogenic service [below -150°F (-100°C)] is intended, it is recommended that each lot of electrodes be qualified with Charpy V-notch impact tests. When such tests are required, the test specimens must be taken from a test plate prepared in accordance with Figure 2. The impact specimens must be located



NOTE: SPECIMEN SIZE TO BE IN ACCORDANCE WITH ANSI/AWS B4.0, *STANDARD METHODS FOR MECHANICAL TESTING OF WELDS*.

FIG. A6 ORIENTATION AND LOCATION OF IMPACT SPECIMEN

in the test plate as shown in Figure A6. The specimens must be prepared and tested in accordance with the impact test sections of the latest edition of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. The test temperature must be selected on the basis of intended service.

A10. Safety Considerations

A10.1 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 head covering to protect the head 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 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 flame. 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 work pieces 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 are for more detailed information on personal protection:

(1) American National Standards Institute. ANSI/ASC Z49.1, *Safety in welding and cutting* (published by the American Welding Society). Miami, FL: American Welding Society.

(2) ———. ANSI/ASC Z87.1, *Practice for occupational and educational eye and face protection*. New York: American National Standards Institute.¹³

(3) ———. ANSI/ASC Z41.1, *Safety-toe footwear*. New York: American National Standards Institute.

(4) Occupational Safety and Health Administration. *Code of federal regulations*, Title 29 Labor, Chapter XVII, Part 1910. Washington, D.C.: U.S. Government Printing Office.¹⁴

A10.2 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 workpiece should not be mistaken for a ground connection.

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 connec-

¹³ ANSI documents are available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

¹⁴ OSHA documents are available from U.S. Government Printing office, Washington, D.C., 20402.

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

Recognized safety standards such as ANSI/ASC Z49.1, *Safety in Welding and Cutting*, and NFPA No. 70, *National Electrical Code* available from National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, should be followed.

A10.3 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 alike 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 filler metal and base metal, welding process, current level, arc length, and other factors.

The possible effects of over-exposure 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, Chapter XVII Part 1910.

(2) The recommended threshold limit values for these fumes and gases may be found in the ACGIH, *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*.¹⁵

(3) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*.¹⁶

A10.4 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 non-ionizing (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.

A10.4.1 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.

A10.4.2 Non-Ionizing Radiation. The intensity and wave lengths of non-ionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composi-

¹⁵ ACGIH documents are available from the American Conference of Governmental Industrial Hygienists, 6550 Glenway Avenue, Building D-5, Cincinnati, OH 45211.

¹⁶ AWS documents are available from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135.

tion, 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 when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of non-ionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by non-ionizing 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*, published by American National Standards Institute. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect a passerby from incidental exposure.

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

(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.

A10.4.3 Ionizing radiation information sources include:

ANSI/AWS F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting* and the Manufacturer's product information literature.

A10.4.4 The following include non-ionizing radiation information sources:

(1) American National Standards Institute. ANSI Z136.1, *Safe use of lasers*. New York, NY: American National Standards Institute.

(2) ———. ANSI/ASC Z49.1, *Safety in welding and cutting*. (published by AWS) Miami, FL: American Welding Society.

(3) ———. ANSI/ASC Z87.1, *Practice for occupational and educational eye and face protection*. New York, NY: American National Standards Institute.

(4) Hinrichs, J. F. "Project committee on radiation—summary report." *Welding Journal*. January 1978.

(5) Moss, C. E. and Murray, W. E. "Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting." *Welding Journal*. September 1979.

(6) Moss, C. E. "Optical radiation transmission levels through transparent welding curtains." *Welding Journal*. March 1979.

(7) "Optical radiation levels produced by air-carbon arc cutting processes." *Welding Journal*. March 1980.

(8) National Technical Information Service. Non-Ionizing 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. ADA-033768.

(9) ———. Non-Ionizing 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. ADA-043023.