

SPECIFICATION FOR STAINLESS STEEL ELECTRODES FOR FLUX CORED ARC WELDING AND STAINLESS STEEL FLUX CORED RODS FOR GAS TUNGSTEN ARC WELDING



SFA-5.22



(Identical with AWS Specification A5.22-95)

1. Scope

1.1 This specification prescribes requirements for the classification of stainless steel electrodes for flux cored arc welding and flux cored rods for root pass welding with the gas tungsten arc process.¹ It includes only those products whose cores contain nonmetallic ingredients comprising at least 5 wt.% of the electrode or rod.²

1.2 The chromium content of undiluted weld metal from these electrodes and rods is not less than 10.5%³ nominal 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 set at their specified minimum values.

PART A — GENERAL REQUIREMENTS

2. Classification

2.1 The welding electrodes and rods covered by this specification are classified according to the chemical

composition of the undiluted weld metal, as specified in Table 1, the position of welding, the shielding medium, and type of welding current with which they are used, as specified in Table 2.

2.2 Electrodes and rods classified under one classification may be classified under any other classification of this specification provided they meet all the requirements for those classifications. Table 3 lists a number of examples of such dual classification.

3. Acceptance

Acceptance⁴ of the material shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

4. Certification

By affixing the AWS specification⁵ and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.

¹ In ANSI/AWS A5.22-80, stainless steel classifications for 98% Argon - 2% Oxygen gas shielding existed (EXXXT-2). The combination of a slag covering and this shielding gas has been found to be inappropriate for flux cored arc welding and the EXXXT-2 Classifications have therefore been deleted from A5.22-95.

² Stainless steel products with less than 5% wt. non-metallic content are properly classified as metal cored electrodes or rods according to ANSI/AWS A5.9, *Specification for Bare Stainless Steel Welding Electrodes and Rods*.

³ This revision includes the E502T-X and E505T-X classifications. These electrodes (although they may have differing designators) will

also be included in the next revision of ANSI/AWS A5.29, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*. They will be deleted from this specification (ANSI/AWS A5.22) in the first revision following their incorporation in ANSI/AWS A5.29.

⁴ See Section A3, Acceptance (in the Annex), for further information concerning acceptance, testing of material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

⁵ See Section A4, Certification (in the Annex), for further information concerning acceptance and testing 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) + Ta	Mn	Si	P	S	N	Cu
E307TX-X	W30731	0.13	18.0-20.5	9.0-10.5	0.5-1.5	—	3.30-4.75	1.0	0.04	0.03	—	0.5
E308TX-X	W30831	0.08	18.0-21.0	9.0-11.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308LTX-X	W30835	0.04	18.0-21.0	9.0-11.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308HTX-X	W30831	0.04-0.08	18.0-21.0	9.0-11.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308MoTX-X	W30832	0.08	18.0-21.0	9.0-11.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308LMoTX-X	W30838	0.04	18.0-21.0	9.0-12.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309TX-X	W30931	0.10	22.0-25.0	12.0-14.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309LCbTX-X	W30932	0.04	22.0-25.0	12.0-14.0	0.5	0.70-1.00	0.5-2.5	1.0	0.04	0.03	—	0.5
E309LTX-X	W30935	0.04	22.0-25.0	12.0-14.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309MoTX-X	W30939	0.12	21.0-25.0	12.0-16.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309LMoTX-X	W30938	0.04	21.0-25.0	12.0-16.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309LNiMoTX-X	W30936	0.04	20.5-23.5	15.0-17.0	2.5-3.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E310TX-X	W31031	0.20	25.0-28.0	20.0-22.5	0.5	—	1.0-2.5	1.0	0.03	0.03	—	0.5
E312TX-X	W31331	0.15	28.0-32.0	8.0-10.5	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E316TX-X	W31631	0.08	17.0-20.0	11.0-14.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E316LTX-X	W31635	0.04	17.0-20.0	11.0-14.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E317LTX-X	W31735	0.04	18.0-21.0	12.0-14.0	3.0-4.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E347TX-X	W34731	0.08	18.0-21.0	9.0-11.0	0.5	8 × C min 1.0 max	0.5-2.5	1.0	0.04	0.03	—	0.5
E409TX-X*	W40931	0.10	10.5-13.5	0.60	0.5	—	0.80	1.0	0.04	0.03	—	0.5
E410TX-X	W41031	0.12	11.0-13.5	0.60	0.5	—	1.2	1.0	0.04	0.03	—	0.5
E410NiMoTX-X	W41036	0.06	11.0-12.5	4.0-5.0	0.40-0.70	—	1.0	1.0	0.04	0.03	—	0.5
E410NiTiTX-X*	W41038	0.04	11.0-12.0	3.6-4.5	0.5	—	0.70	0.50	0.03	0.03	—	0.5
E430TX-X	W43031	0.10	15.0-18.0	0.60	0.5	—	1.2	1.0	0.04	0.03	—	0.5
E502TX-X ^f	W50231	0.10	4.0-6.0	0.40	0.45-0.65	—	1.2	1.0	0.04	0.03	—	0.5
E505TX-X ^f	W50431	0.10	8.0-10.5	0.40	0.85-1.20	—	1.2	1.0	0.04	0.03	—	0.5
E307T0-3	W30733	0.13	19.5-22.0	9.0-10.5	0.5-1.5	—	3.30-4.75	1.0	0.04	0.03	—	0.5
E308T0-3	W30833	0.08	19.5-22.0	9.0-11.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308LT0-3	W30837	0.03	19.5-22.0	9.0-11.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308HT0-3	W30833	0.04-0.08	19.5-22.0	9.0-11.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308MoT0-3	W30839	0.08	18.0-21.0	9.0-11.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308LMoT0-3	W30838	0.03	18.0-21.0	9.0-12.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E308HMoT0-3	W30830	0.07-0.12	19.0-21.5	9.0-10.7	1.8-2.4	—	1.25-2.25	0.25-0.80	0.04	0.03	—	0.5
E309T0-3	W30933	0.10	23.0-25.5	12.0-14.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309LT0-3	W30937	0.03	23.0-25.5	12.0-14.0	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309LCbT0-3	W30934	0.03	23.0-25.5	12.0-14.0	0.5	0.70-1.00	0.5-2.5	1.0	0.04	0.03	—	0.5
E309MoT0-3	W30939	0.12	21.0-25.0	12.0-16.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E309LMoT0-3	W30938	0.04	21.0-25.0	12.0-16.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E310T0-3	W31031	0.20	25.0-28.0	20.0-22.5	0.5	—	1.0-2.5	1.0	0.03	0.03	—	0.5
E312T0-3	W31231	0.15	28.0-32.0	8.0-10.5	0.5	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E316T0-3	W31633	0.08	18.0-20.5	11.0-14.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E316LT0-3	W31637	0.03	18.0-20.5	11.0-14.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E316LKT0-3 ^g	W31630	0.04	17.0-20.0	11.0-14.0	2.0-3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E317LT0-3	W31737	0.03	18.5-21.0	13.0-15.0	3.0-4.0	—	0.5-2.5	1.0	0.04	0.03	—	0.5
E347T0-3	W34733	0.08	19.0-21.5	9.0-11.0	0.5	8 × C min 1.0 max	0.5-2.5	1.0	0.04	0.03	—	0.5
E409T0-3*	W40931	0.10	10.5-13.5	0.60	0.5	—	0.80	1.0	0.04	0.03	—	0.5
E410T0-3	W41031	0.12	11.0-13.5	0.60	0.5	—	1.0	1.0	0.04	0.03	—	0.5
E410NiMoT0-3	W41036	0.06	11.0-12.5	4.0-5.0	0.40-0.70	—	1.0	1.0	0.04	0.03	—	0.5
E410NiTiT0-3*	W41038	0.04	11.0-12.0	3.6-4.5	0.5	—	0.70	0.50	0.03	0.03	—	0.5
E430T0-3	W43031	0.10	15.0-18.0	0.60	0.5	—	1.0	1.0	0.04	0.03	—	0.5
E2209T0-X	W39239	0.04	21.0-24.0	7.5-10.0	2.5-4.0	—	0.5-2.0	1.0	0.04	0.03	0.08-0.20	0.5
E2553T0-X	W39533	0.04	24.0-27.0	8.5-10.5	2.9-3.9	—	0.5-1.5	0.75	0.04	0.03	0.10-0.20	1.5-2.5

(continued)

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) + Ta	Mn	Si	P	S	N	Cu
EXXXTX-G ^h		Not Specified										
R308LT1-5	W30835	0.03	18.0–21.0	9.0–11.0	0.5	—	0.5–2.5	1.2	0.04	0.03	—	0.5
R309LT1-5	W30935	0.03	22.0–25.0	12.0–14.0	0.5	—	0.5–2.5	1.2	0.04	0.03	—	0.5
R316LT1-5	W31635	0.03	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.2	0.04	0.03	—	0.5
						8 × C min						
R347T1-5	W34731	0.08	18.0–21.0	9.0–11.0	0.5	1.0 max	0.5–2.5	1.2	0.04	0.03	—	0.5

NOTES:

- a. The weld metal shall be analyzed for the specific elements in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50%.
- b. Single values shown are maximum.
- c. In this table, the "X" following the "T" refers to the position of welding (1 for all-position operation or 0 for flat or horizontal operation) and the "X" following the dash refers to the shielding medium (–1, –4, or –5) as shown in the AWS Classification column in Table 2. For information concerning the "G", see A2.3.7 and 2.3.8 of the annex. In A5.22-80, the position of welding was not included in the classification. Accordingly, electrodes classified herein as either EXXXT0-1 or EXXXT1-1 would both have been classified EXXXT-1 and so forth.
- d. ASTM/SAE Unified Number System for Metals and Alloys.
- e. Titanium—10 × C min., 1.5% max.
- f. See Footnote 3 on Page 1.
- g. This alloy is designed for cryogenic applications.
- h. See A2.3.7 and A2.3.8.

TABLE 2
REQUIRED SHIELDING MEDIUM, POLARITY, AND WELDING PROCESS

AWS Classification ^{a,b}	External Shielding Medium ^c	Welding Polarity	Welding Process
EXXXTX-1	CO ₂	DCEP	FCAW
EXXXTX-3	none (self-shielded)	DCEP	FCAW
EXXXTX-4	75–80% Argon/remainder CO ₂	DCEP	FCAW
XXXXT1-5	100% Argon	DCEN	GTAW
EXXXTX-G	Not Specified ^d	Not Specified ^d	FCAW
XXXXT1-G	Not Specified ^d	Not Specified ^d	GTAW

NOTES:

- ^a See 1.1 and its footnote 1 regarding the elimination of the EXXXT-2 classifications that existed in the previous revision of this document.
- ^b The letters "XXX" stand for the designation of the chemical composition (see Table 1). The "X" after the "T" designates the position of operation. A "0" indicates flat or horizontal operation; a "1" indicates all position operation.
- ^c The requirement for the use of specified external shielding medium shall not be construed to restrict the use of any other medium for which the electrodes are found suitable, for any application other than the classification tests.
- ^d See A2.3.7 to A2.3.9 for additional information.

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. However, suitable conversions, encompassing standard sizes of both, can be made if appropriate tolerances are applied in each case.

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi for tensile and yield strength, and to the "nearest unit" in the last

TABLE 3
EXAMPLES OF POTENTIALLY OCCURRING DUAL
CLASSIFIED ELECTRODES

Primary Classification	Alternate Classification
E308HTX-1	E308TX-1
E308LTX-1	E308TX-1
E308LT0-3	E308T0-3
E308LTX-1	E308LTX-4
E309LT1-1	E309T0-1

NOTE:

The "X" after the "T" designates the position of operation. A "0" indicates flat or horizontal operation; a "1" indicates all position operation.

TABLE 4
REQUIRED TESTS

	Chemical Analysis	Radiographic Test	Tension Test	Face Bend Test	Root Bend Test	Impact Test	Fillet Weld Test
E2XXXT0-X	Required	Required	Required	NR*	NR*	NR*	NR*
E3XXT0-X	Required	Required	Required	Required	NR*	NR*	NR*
E316LKT0-3	Required	Required	Required	Required	NR*	Required	NR*
E4XXT0-X	Required	Required	Required	NR*	NR*	NR*	NR*
E5XXT0-X	Required	Required	Required	NR*	NR*	NR*	NR*
E2XXXT1-X	Required	Required	Required	NR*	NR*	NR*	Required
E3XXT1-X	Required	Required	Required	Required	NR*	NR*	Required
E4XXT1-X	Required	Required	Required	NR*	NR*	NR*	Required
E5XXT1-X	Required	Required	Required	NR*	NR*	NR*	Required
R3XXT1-5	Required	Required	Required	NR*	Required	NR*	NR*

*Not required (See A2.3.8)

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, *Recommended Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

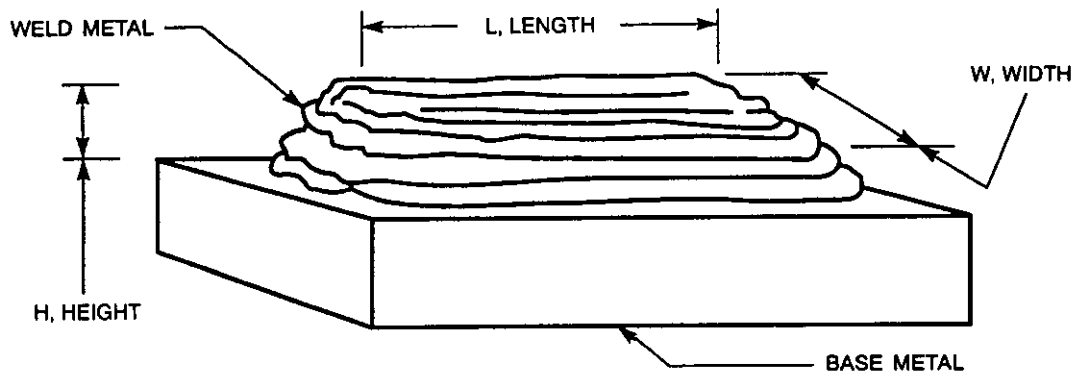
6. Summary of Tests

6.1 The tests required for each classification are specified in Table 4. The purpose of these tests is to determine the chemical composition, the mechanical properties, the usability and the soundness of the weld metal. The base metal for the weld test assemblies, the welding and testing procedures to be employed and the results required are given in Sections 8 through 14.

6.2 Chemical analysis is required from weld metal from each size of electrode and rod. The tests for mechanical properties and soundness are conducted on weld metal from the $\frac{1}{16}$ in. (1.6 mm) size of electrode and rod. In any case in which that size is not manufactured, the size closest to it that is manufactured shall be used for the classification tests. The bend tests are conducted on the largest size manufactured. When required by Table 4, the fillet weld tests shall be conducted on all diameters manufactured.

7. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or a new test assembly. For chemical analysis, retest need be



AWS Classification	Weld Pad Size, Minimum								Minimum Distance of Sample from Surface of Base Plate	
	Diameter		L		W		H			
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
E3XXTX-X E316LKT0-3 E4XXTX-X E5XXTX-X E2XXXTX-X	0.035	0.90	3	75	3/4	19	1/2	12.7	3/8	9.5
	0.045	1.2								
	0.052	1.3								
	1/16	1.6	3	75	3/4	19	5/8	16	1/2	12.7
	5/64	2.0								
	3/32	2.4								
	7/64	2.8	3-1/2	88	1	25	3/4	19	5/8	16
	5/64	2.0								
	0.087	2.2								
R3XXT1-5	3/32	2.4	3	75	3/4	19	3/8	10	1/4	7.0

Number of passes per layer is optional.

Notes:

- Width and thickness of the base plate may be any dimensions suitable for the electrode diameter and current use.
- The first and last inch (25 mm) of the weld length shall be disregarded. The top surface shall be removed and chemical analysis samples shall be taken from the underlying metal of the top layer of the remaining deposited metal.
- The use of copper chill bars is optional.

FIG. 1 PAD FOR CHEMICAL ANALYSIS OF UNDILUTED WELD METAL

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

8. Weld Test Assemblies

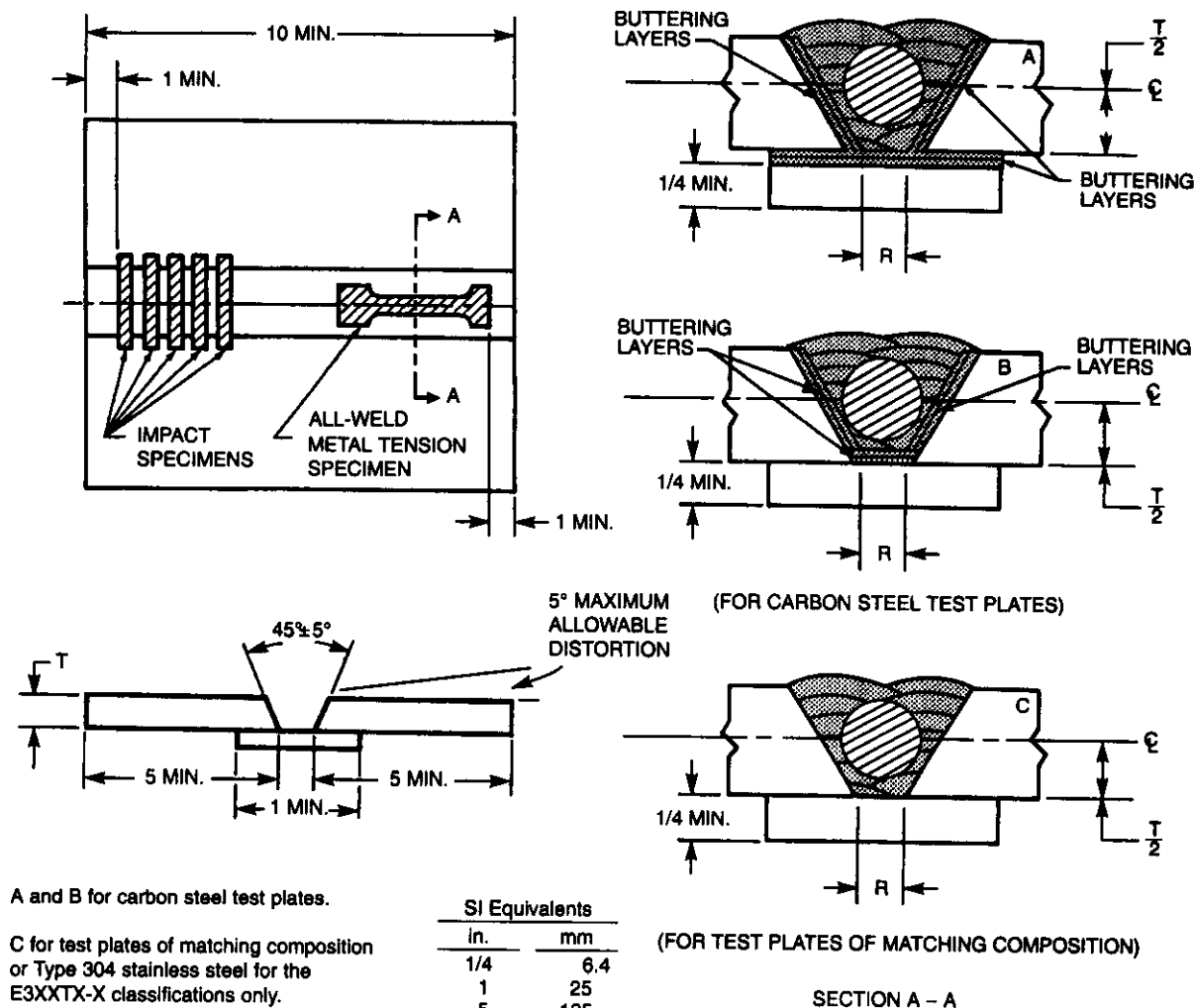
8.1 Between two and four weld test assemblies are required (according to the classification under test) for the tests specified in Table 4. They are as follows:

- The weld pad in Fig. 1 for chemical analysis of the undiluted weld metal
- The groove weld in Fig. 2 for tension, impact, and radiographic testing of the weld metal
- The groove weld in Fig. 3 for the bend test
- The fillet weld in Fig. 4 for usability of the electrode or rod

The sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the groove weld in Fig. 2, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad 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 those with 0.04 wt.% carbon or less



AWS Classification	Diameter		(T) Plate Thickness		(R) Root Openings		Recommended Passes per Layer		Recommended Number of Layers
	in.	mm	in.	mm	in.	mm	Layer 1 and 2	Layer 3 to Top	
E3XXTX-X E316LKT0-3 E4XXTX-X E5XXTX-X E2XXTX-X	0.035	0.9	1/2	12.7	3/8	9.5	1 or 2	2, 3, or 4	6 to 9
	0.045	1.2							
	0.052	1.4							
	1/16	1.6	3/4	19	3/8	9.5	1 or 2	2 or 3*	5 to 8
	5/64	2.0							
	3/32	2.4							
R3XXT1-5	7/64	2.8							
	1/8	3.2	3/4	19	3/8	9.5	1 or 2	2 or 3*	4 to 6
	5/32	4.0							
	5/64	2.0							
	0.087	2.2	1/2	12.7	1/4	6.4	1 or 2	2 or 3*	5 to 8
	3/32	2.4							

*Final layer may be 4 passes.

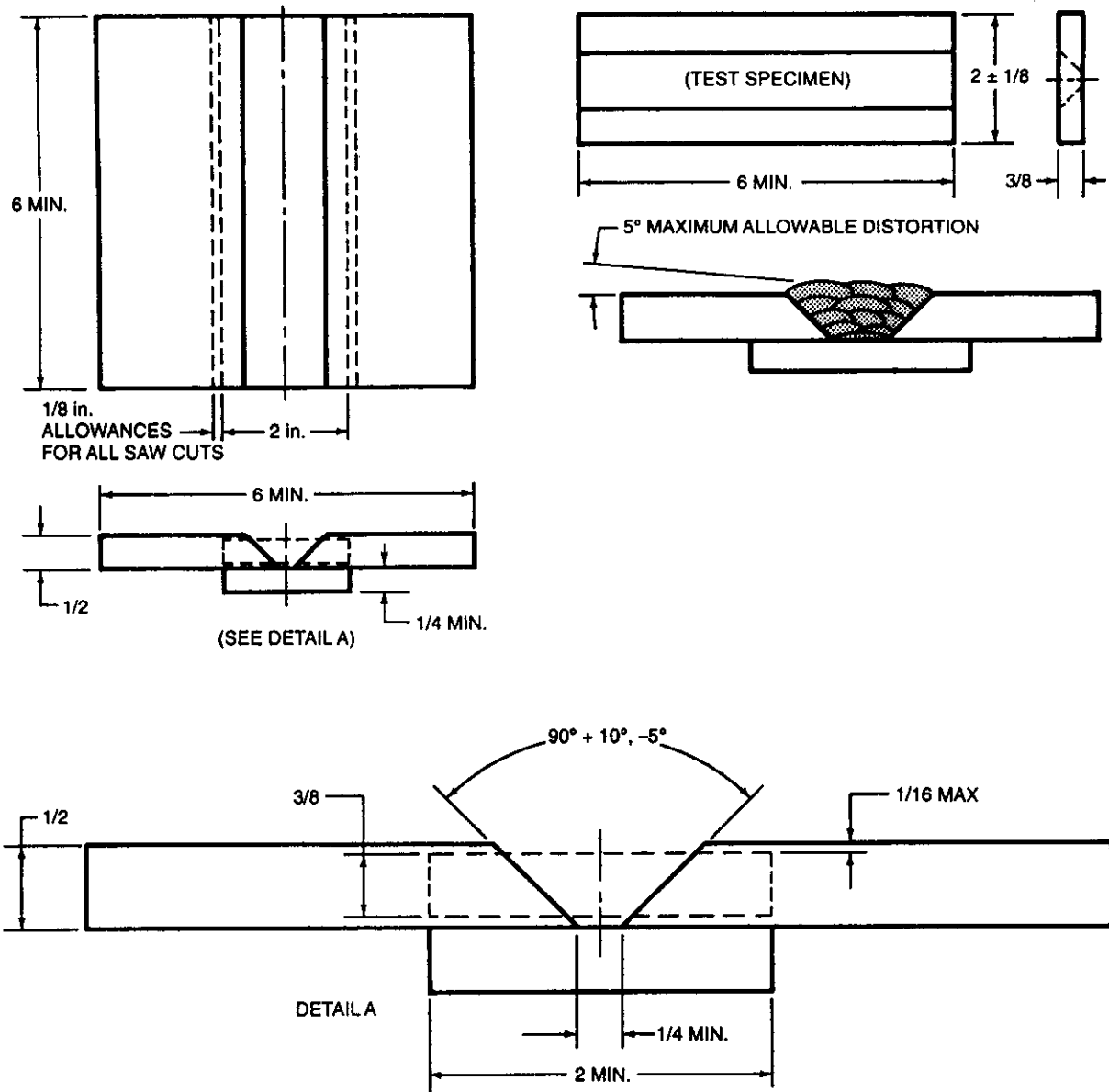
Notes:

- The dimensions for the tensile test specimen shall conform to Figure 6.
- For E316LKT0-3 test assemblies, length may be extended as needed for Charpy V-notch impact specimens.

FIG. 2 GROOVE WELD ASSEMBLY FOR TENSION, IMPACT, AND RADIOGRAPHIC TESTS

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

SFA-5.22



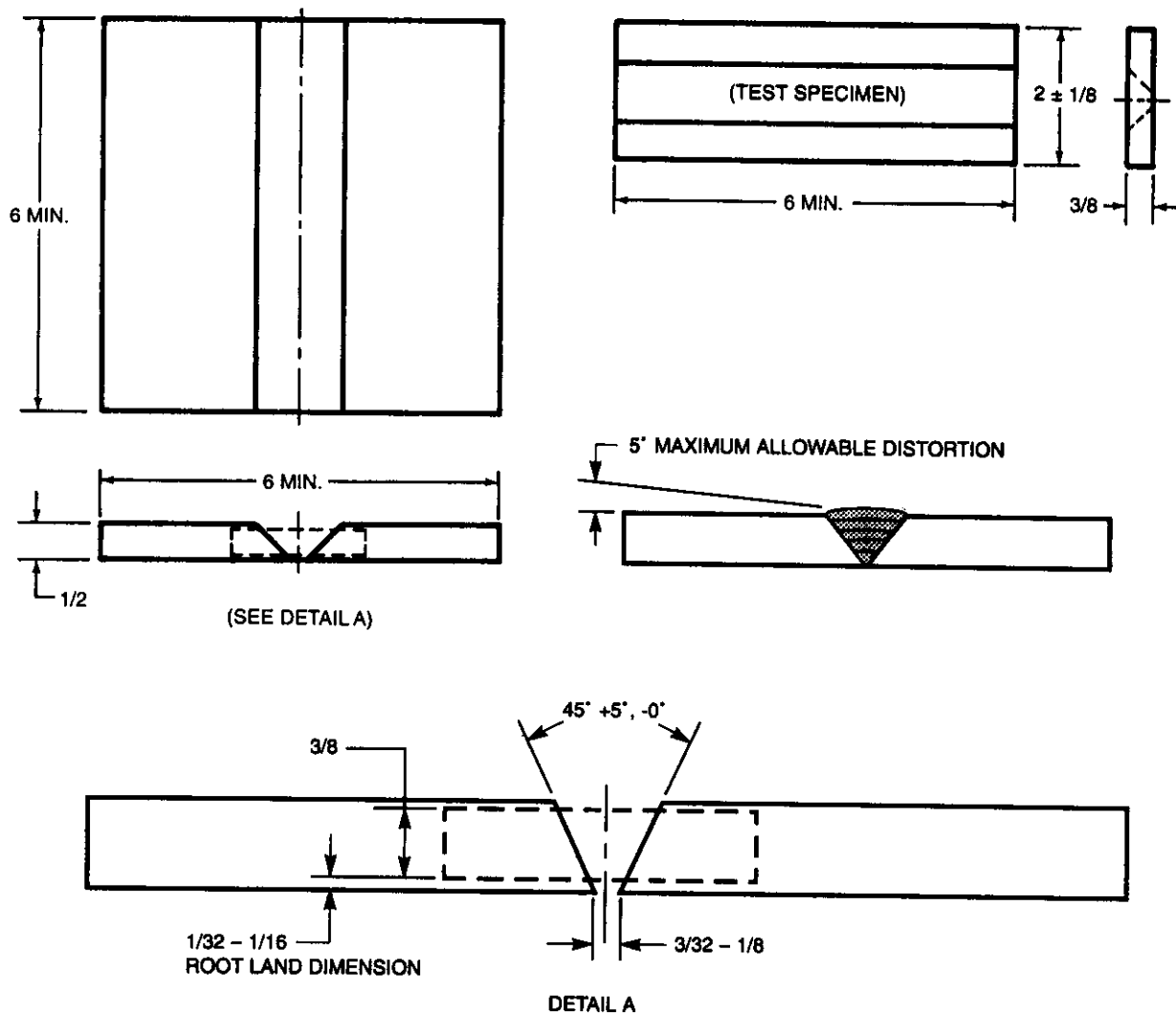
SI Equivalents	
in.	mm
1/16	1.6
1/8	3.2
1/4	6.4
3/8	9.5
1/2	12.7
1	25
2	50
6	150

All dimensions except angles are in inches.

Electrode Diameter		Suggested Passes Per Layer		Suggested Number of Layers
in.	mm	Layer 1	Layers 2 to Top	
0.035	0.90	1	2 to 3	3 to 5
0.045	1.2			
1/16	1.6			
5/64	2.0			
3/32	2.4			
7/64	2.8	1	1 to 2	2 to 4
1/8	3.2			
5/32	4.0			

*Top layer must be 2 passes minimum.

FIG. 3A GROOVE WELD ASSEMBLY FOR FACE BEND TEST



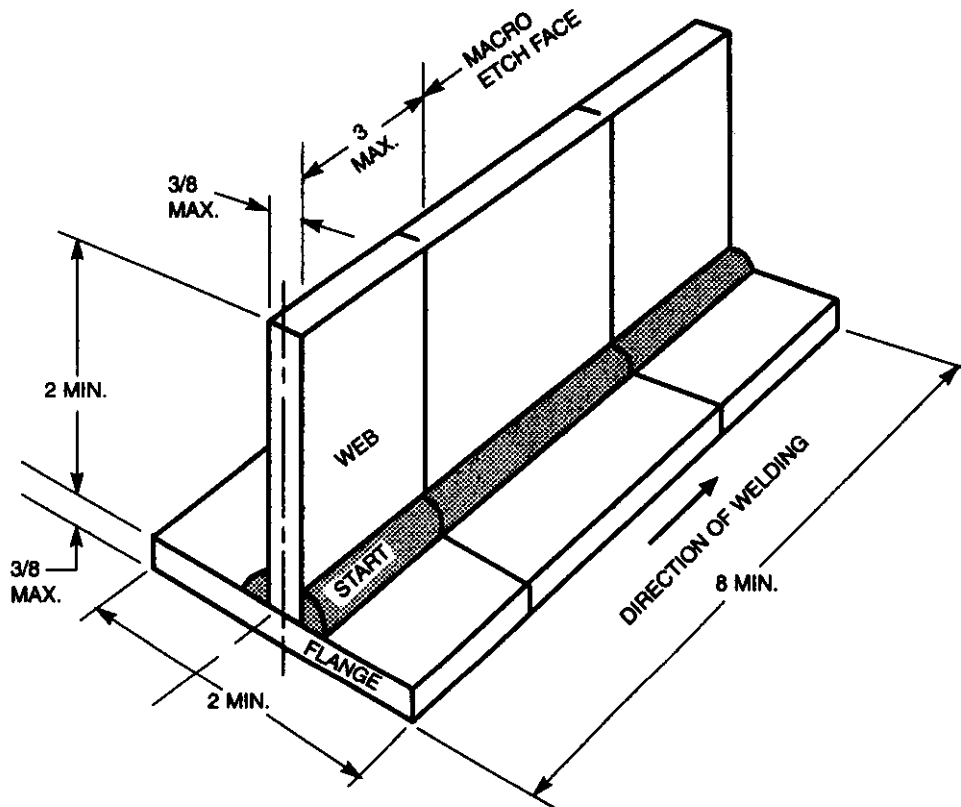
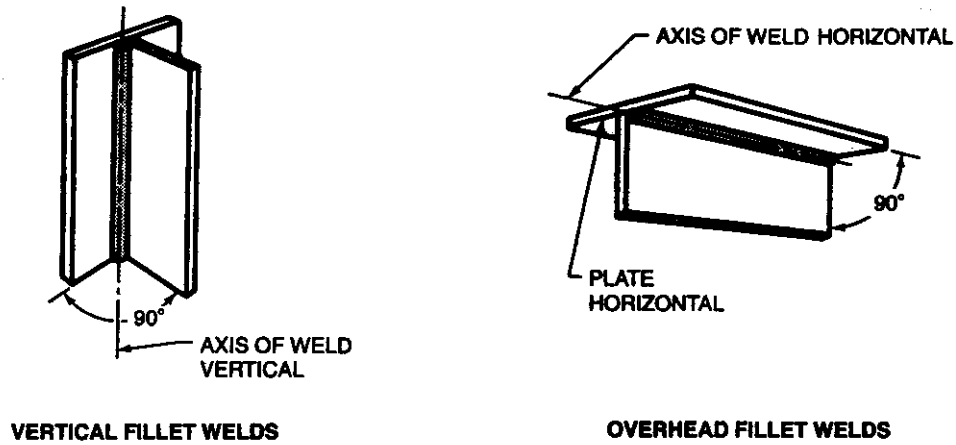
NOTE: Remove amount of material necessary to clean up root surface.
Material removed should not exceed 1/64 in. (0.4 mm).

SI Equivalents	
in.	mm
1/32	0.8
1/16	1.6
3/32	2.4
1/8	3.2
3/8	9.5
1/2	12.7
2	50
6	150

All dimensions except angles are in inches.

AWS Classification	Diameter		Passes Per Layer		
	in.	mm	Layer 1	Layers 2	Layer 3 to Completion
R3XXT1-5	{ 5/64 0.087 3/32 }	{ 2.0 2.2 2.4 }	1	1	As required

FIG. 3B GROOVE WELD ASSEMBLY FOR ROOT BEND TEST



Flange to be straight and in intimate contact with square machined edge of web member along entire length to insure maximum restraint.

NOTE: ALL DIMENSIONS EXCEPT ANGLES ARE IN INCHES.

SI Equivalents	
In.	mm
3/8	9.5
2	50
3	75
8	200

FIG. 4 PREPARATION OF FILLET WELD TEST SPECIMEN

(low-carbon classifications). For chemical analysis of these low-carbon classifications, the base metal shall be steel of 0.03 percent maximum carbon or other steels having a carbon content of 0.25 percent maximum with the further restrictions specified in 8.3.2.

8.2.2 For the all-weld-metal tension, radiographic, and impact tests, the steel to be used shall be of a matching type. Type 304 stainless steel may be used when testing any of the E3XXTX-X classifications. Optionally, the steel may conform to one of the following specifications or their equivalents, providing two buttering layers of filler metal as shown in Fig. 2, are deposited in stringer beads using electrodes or rods 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 face bend test, the base metal shall be of a matching type or Type 304 stainless steel.

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

(1) For 300 series electrodes—matching or Type 304 stainless steel

(2) For 400 or 500 series electrodes—matching or carbon steel

(3) For duplex alloy electrodes—matching or Type 304 stainless steel

8.3 Weld Pad

8.3.1 A weld pad shall be prepared as shown in Fig. 1 (except when one of the alternatives to a weld pad in 8.1 is selected). Base metal as specified in 8.2 shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple beads and multiple layers to obtain undiluted weld metal. The preheat temperature shall be not less than 60°F (16°C). The slag shall be removed after each pass. The amperage or wire feed speed and the arc voltage shall be as recommended by the manufacturer. The shielding medium and polarity shall be as specified in Table 2. The pad may be quenched in water between passes (if the pad is to be used for ferrite determination, see A6.9). The dimensions of the completed pad shall be as shown in Fig. 1, for

TABLE 5
PREHEAT AND INTERPASS TEMPERATURE
REQUIREMENTS FOR GROOVE WELD TEST
ASSEMBLIES

AWS Classification	Temperature			
	Minimum		Maximum	
	°F	°C	°F	°C
E2XXTX-X	60	16	300	150
E3XXTX-X	60	16	300	150
R3XXT1-5	60	16	300	150
E4XXTX-X*	300	150	500	260
E5XXTX-X	300	150	500	260
EXXXTX-X	Not Specified			

* Except for E410TX-X, which shall be 400°F (204°C) minimum preheat and 600°F (316°C) maximum interpass temperature.

each size of electrode or rod. Testing of this assembly shall be as specified in Section 9, Chemical Analysis.

8.3.2 The pad shall be at least four layers high. More than four layers may be required to obtain undiluted weld metal when base metal containing more than 0.03% carbon is used with the low-carbon classifications (i.e. those with the letter "L" in the designation).

8.4 Groove Weld

8.4.1 Mechanical Properties and Soundness

8.4.1.1 A test assembly shall be prepared and welded as specified in Fig. 2 and in 8.4.1.2 and 8.4.1.3, using base metal of the appropriate type specified in 8.2.2.

8.4.1.2 The test assembly shall be welded in the flat position using the shielding medium and polarity shown in Table 2, and the amperage or wire feed speed and arc voltage recommended by the manufacturer. The test assembly shall be preset or sufficiently restrained during welding to prevent warpage in excess of five degrees. A welded test assembly that has warped more than five degrees shall be discarded. Welded test assemblies shall not be straightened.

8.4.1.3 The preheat and interpass temperatures shall be as specified in Table 5. These temperatures are measured mid-length of the assembly at a distance of 1 in. (25 mm) from the centerline of the weld. These temperatures are required also for all buttering passes. After each pass, the assembly shall be allowed to cool in air (not quenched in water) to a temperature within the range specified in Table 5.

8.4.1.4 The assembly shall be tested as specified in Sections 10, 11 and 13 with or without a postweld heat treatment as specified in Table 6, for the classification under test.

8.4.2 Bend Test

8.4.2.1 A test assembly shall be prepared and welded as shown in Fig. 3A or 3B, as applicable, and specified in 8.4.2.2 through 8.4.2.4 using base metal of the appropriate type specified in 8.2.2.

8.4.2.2 The test assembly shall be welded in the flat position using the shielding medium, polarity, and welding process specified in Table 2, and the amperage or wire feed speed and arc voltage recommended by the manufacturer. The test assembly shall be present or sufficiently restrained to prevent warpage in excess of five degrees. A welded test assembly that has warped more than five degrees shall be discarded. Weld test assemblies shall not be straightened.

8.4.2.3 The preheat and interpass temperatures shall be as specified in Table 5. Those temperatures are measured mid-length of the assembly at a distance of 1 in. (25 mm) from the centerline of the weld. After each pass, the assembly shall be allowed to cool in air (not quenched in water) to a temperature within the range specified in Table 5.

8.4.2.4 The third and subsequent layers of the test assembly for R3XXT1-5 rods may be welded with a similar classification of shielded metal arc welding electrodes, flux cored electrodes or rods, metal cored electrodes or solid wire electrodes.

8.4.2.5 The assembly shall be tested as specified in Section 12, Bend Test, in the as-welded condition.

8.5 Fillet Weld

8.5.1 Fillet weld tests, when required by Table 4, shall be performed in the vertical and overhead positions. A test assembly shall be prepared and welded as shown in Fig. 4 using base metal of the appropriate type specified in 8.2.4, and using the shielding medium and polarity shown in Table 2 and the amperage or wire feed speed and arc voltage recommended by the manufacturer. Testing of the assembly shall be as specified in Section 14, Fillet Weld Test.

8.5.2 In preparing the two plates forming the test assembly, the standing member (web) shall have one edge prepared 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. When welding in the vertical position, the welding shall progress upwards.

8.5.4 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.

8.5.5 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 Flux cored electrodes and rods shall be analyzed in the form of weld metal, not filler metal.

9.2 The sample for analysis shall be taken from weld metal obtained from either the weld pad prepared according to 8.3 or one of the alternatives in 8.1 produced with the filler metal and shielding medium with which they are classified.

9.2.1 The sample for analysis of weld metal from the pad shall be taken from material above the third layer of weld metal and at least the minimum height above the base metal as specified in Fig. 1. The sample shall be free of slag and all other foreign materials. The sample may have to be taken from a higher level for weld metal from the low-carbon classifications (those with the letter "L" in the designation), when base metals containing more than 0.03% of carbon are used for the pad.

9.2.2 The sample of weld metal from the reduced section of the fractured tension test specimen, or from a corresponding location (or any location above it) in the groove weld in Fig. 2, shall be prepared for analysis by any suitable mechanical means.

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

TABLE 6
TENSION TEST REQUIREMENTS

AWS Classification ^a	Tensile Strength, minimum		Elongation Percent, Min.	Postweld Heat Treatment
	ksi	MPa		
E307TX-X	85	590	30	None
E308TX-X	80	550	35	None
E308LTX-X	75	520	35	None
E308HTX-X	80	550	35	None
E308MoTX-X	80	550	35	None
E308LMoTX-X	75	520	35	None
E309TX-X	80	550	30	None
E309LCbTX-X	75	520	30	None
E309LTX-X	75	520	30	None
E309MoTX-X	80	550	25	None
E309LMoTX-X	75	520	25	None
E309LNiMoTX-X	75	520	25	None
E310TX-X	80	550	30	None
E312TX-X	95	660	22	None
E316TX-X	75	520	30	None
E316LTX-X	70	485	30	None
E317LTX-X	75	520	20	None
E347TX-X	75	520	30	None
E409TX-X	65	450	15	None
E410TX-X	75	520	20	(b)
E410NiMoTX-X	110	760	15	(c)
E410NiTiTX-X	110	760	15	(c)
E430TX-X	65	450	20	(d)
E502TX-X	60	415	20	(e)
E505TX-X	60	415	20	(e)
E308HMoT0-3	80	550	30	None
E316LKT0-3	70	485	30	None
E2209TX-X	100	690	20	None
E2553TX-X	110	760	15	None
EXXXTX-G	Not Specified			None
R308LT1-5	75	520	35	None
R309LT1-5	75	520	30	None
R316LT1-5	70	485	30	None
R347T1-5	75	520	30	None

NOTE:

- In this table, the "X" following the "T" refers to the position of welding (1 for all-position or 0 for flat or horizontal operation) and the "X" following the dash refers to the shielding medium (-1, -3 or -4) as shown in the AWS Classification.
- The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 1350 and 1400°F (732 and 760°C), held for 1 hour, then furnace cooled to 600°F (316°C) at a rate not to exceed 100°F (55°C) per hour, then cooled in air to room temperature.
- The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 1100 and 1150°F (593 and 621°C), held for 1 hour, then cooled in air to room temperature.
- The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 1400 and 1450°F (760 and 788°C), held for 4 hours, then furnace cooled to 1100°F (593°C) at a rate not to exceed 100°F (55°C) per hour, then cooled in air to room temperature.
- The weld test assembly (or blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 1550 and 1600°F (840 and 870°C) held for 2 hours, then furnace cooled to 1100°F (593°C) at a rate not to exceed 100°F (55°C) per hour, then cooled in air to room temperature.

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

10. Radiographic Test

10.1 When required in Table 4, the groove weld described in 8.4.1 and shown in Fig. 2 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding $\frac{3}{32}$ in. (2.4 mm). Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

10.2 The weld shall be radiographed in accordance with ASTM E142, *Standard Method for Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows none of the following:

- (1) cracks
- (2) incomplete fusion
- (3) incomplete penetration
- (4) rounded indications in excess of those permitted by the radiographic standards in Fig. 5A or 5B, as applicable
- (5)(a) in any 6 in. (150 mm) length of the $\frac{1}{2}$ in. (13 mm) thick test assembly: no individual slag inclusion longer than $\frac{7}{32}$ in. (5.6 mm) and a maximum total length of $\frac{7}{16}$ in. (11 mm) for all slag inclusions
- (b) in any 6 in. (150 mm) length of the $\frac{3}{4}$ in. (19 mm) thick test assembly: no individual slag inclusion in excess of $\frac{9}{32}$ in. (7.1 mm) and a maximum total length of $\frac{15}{32}$ in. (12 mm) for all slag inclusions

In evaluating the radiograph, 1 in. (25 mm) of the weld on each end of the test assembly shall be disregarded.

10.3.1 A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indications may be of porosity, or tungsten inclusions.

10.3.2 Indications whose largest dimension does not exceed $\frac{1}{64}$ in. (0.4 mm) shall be disregarded. Test assemblies with indications in excess of the sizes

permitted in the radiographic standards do not meet the requirements of this specification.

11. Tension Test

11.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in 8.4.1 and shown in Fig. 2. The dimensions of the specimen shall be as shown in Fig. 6.

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

11.3 The results of the tension test shall meet the requirements specified in Table 6.

12. Bend Test

12.1 Electrodes

12.1.1 One longitudinal face bend specimen, as required in Table 4, shall be machined from the groove weld test assembly described in 8.4.2 and shown in Fig. 3A.

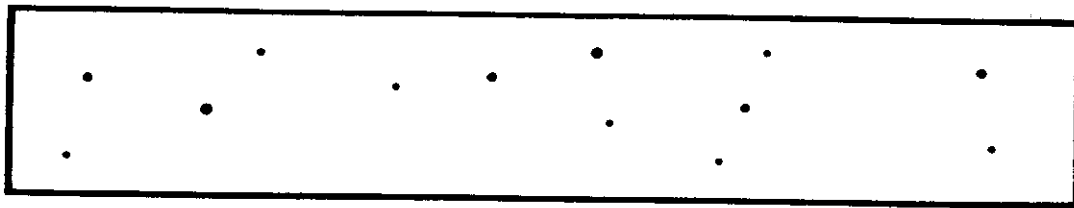
12.1.2 Backing strip and weld reinforcement shall be removed by machining. Grinding of the face surface of the specimen shall follow. The corners on the face side of the specimen shall be slightly rounded by filing or grinding. The longitudinal face bend test specimen shall be uniformly bent through 180 degrees over a radius of $\frac{3}{4}$ in. (19 mm). Typical bending jigs are shown in ANSI/AWS B4.0, *Standard Methods for the Mechanical Testing of Welds*. The specimen shall be positioned so that the face of the weld is in tension.

12.1.3 After bending, the bend test specimen shall conform to the designated radius, with appropriate allowance for springback, and the weld metal shall show no defects on the tension face greater than $\frac{1}{8}$ in. (3.2 mm).

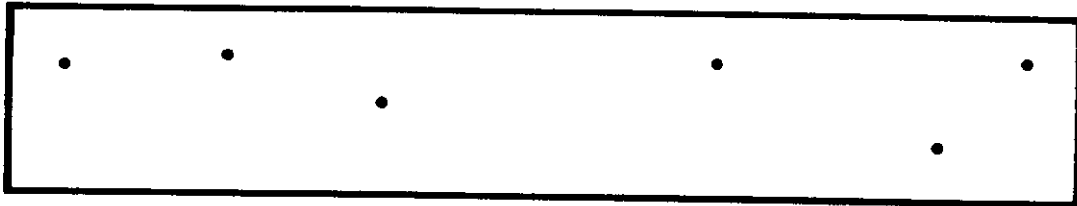
12.2 Rods

12.2.1 One longitudinal root bend specimen, as required in Table 4, shall be machined from the groove weld assembly described in 8.4.2 and shown in Fig. 3B.

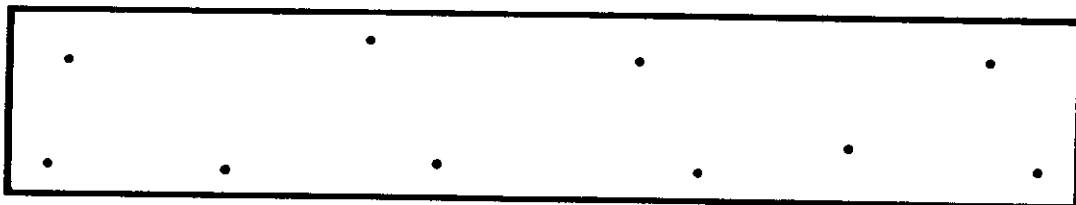
12.2.2 Weld reinforcement shall be removed by machining. Grinding of both faces of the specimen shall follow. All corners on the root side of the specimen shall be slightly rounded by filing or grinding. The longitudinal root bend specimen shall be bent uniformly through a radius of $\frac{3}{4}$ in. (19 mm). Typical bending jigs are shown in ANSI/AWS B4.0, *Standard Methods*

**(A) ASSORTED ROUNDED INDICATIONS**

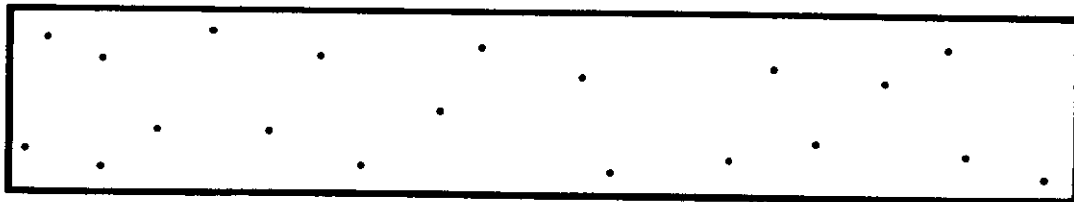
SIZE 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 13, WITH THE FOLLOWING RESTRICTIONS:
 MAXIMUM NUMBER OF LARGE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 2.
 MAXIMUM NUMBER OF MEDIUM 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 4.
 MAXIMUM NUMBER OF SMALL 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 7.

**(B) LARGE ROUNDED INDICATIONS**

SIZE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 6.

**(C) MEDIUM ROUNDED INDICATIONS**

SIZE 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 10.

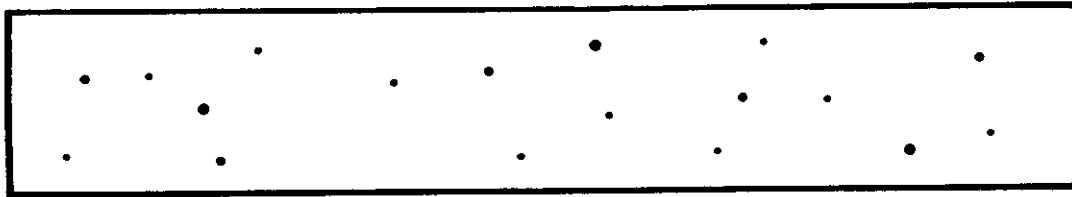
**(D) SMALL ROUNDED INDICATIONS**

SIZE 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 20.

Notes:

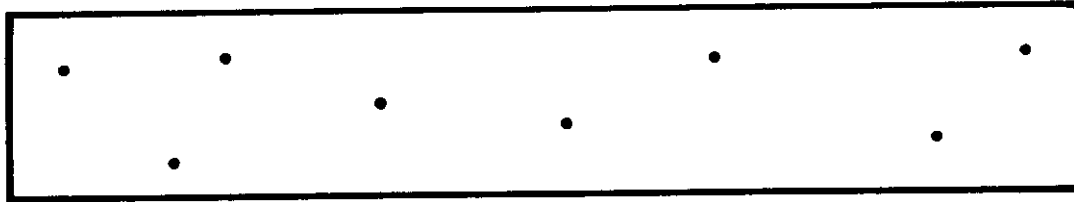
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.

FIG. 5A ROUNDED INDICATION STANDARDS FOR RADIOGRAPHIC TEST—1/2 IN. PLATE



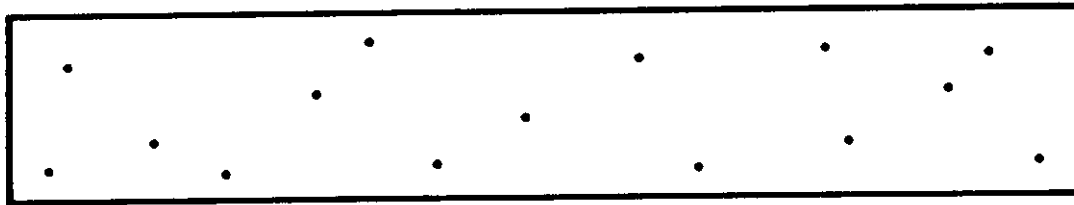
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:
MAXIMUM NUMBER OF LARGE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 10.



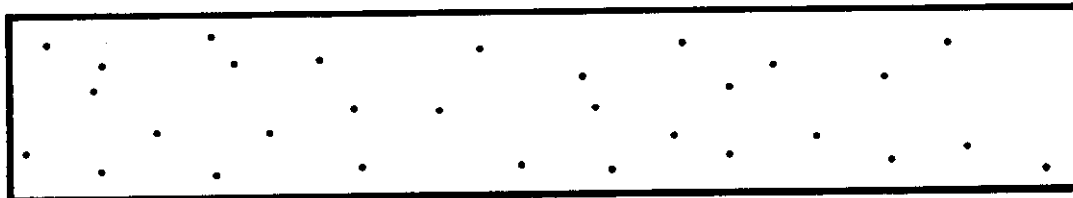
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 15.



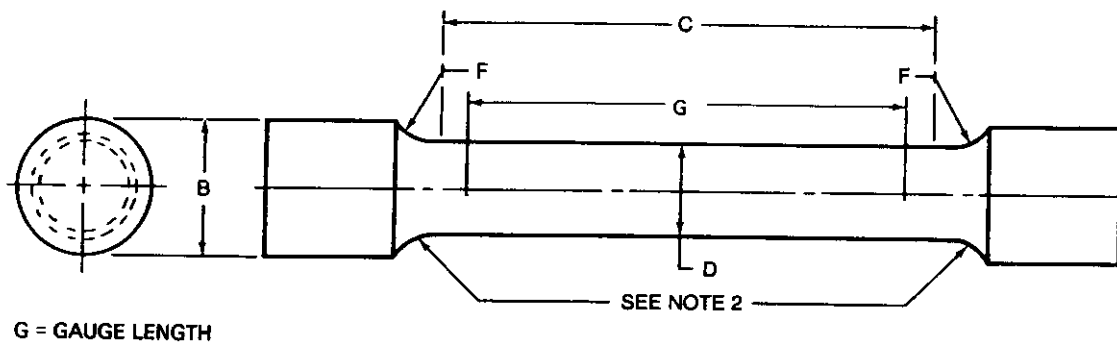
(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 30.

Notes:

1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.

FIG. 5B ROUNDED INDICATION STANDARDS FOR RADIOGRAPHIC TEST—3/4 IN. PLATE



Dimensions of Specimen, in.						
Test Assembly Thickness	D	G	C	B	F, min.	Approximate Area, in. ²
3/4	0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	0.38 (3/8)	0.2
1/2	0.250 ± 0.005	1.000 ± 0.005	1-1/4	3/8	0.18	0.05

Dimensions of Specimen, mm						
Test Assembly Thickness	D	G	C	B	F, min.	Approximate Area, mm ²
19	12.7 ± 0.25	51 ± 0.13	57	19	9.5	129
12.7	6.4 ± 0.13	25.4 ± 0.13	32	9.5	4.6	32

Notes:

1. Dimensions G and C shall be as shown, but the ends may be of any shape required to fit the testing machine, as long as the load is kept axial.
2. The diameter of the specimen within the gage length shall be slightly smaller at the center than at the ends. The difference shall not exceed one percent of the diameter.
3. The finish of the surface within the C dimension shall be no rougher than 63 μ in. (1.6 μ m).

FIG. 6 TENSION TEST SPECIMEN

for *Mechanical Testing of Welds*. The specimen shall be positioned so that the root of the weld is in tension.

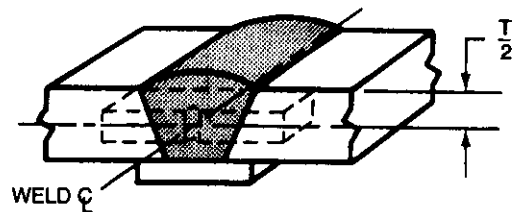
12.2.3 After bending, the bend test specimen shall conform to the designated radius, with appropriate allowance for springback, and the weld metal shall show no defects on the tension face greater than $\frac{1}{8}$ in. (3.2 mm).

13. Impact Test (E316LKT0-3 Electrodes Only)

13.1 Five full size, 0.394 in. by 0.394 in. (10 mm by 10 mm) Charpy V-notch impact specimens (see Fig. 7) shall be machined from the test assembly (see Fig. 2) for testing of E316LKT0-3 electrodes.

13.2 The five specimens shall be tested at a temperature of -320°F (-196°C) in accordance with the impact test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

13.3 Lateral expansion shall be measured in accordance with ASTM E23, *Test Methods for Notched Bar*



Note: Specimen size to be in accordance with ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

FIG. 7 ORIENTATION AND LOCATION OF IMPACT TEST SPECIMEN

Impact Testing of Metallic Materials. In evaluating the test results, the highest and lowest lateral expansion values shall be disregarded. The remaining three impact specimens shall exhibit a lateral expansion of 0.015 in. (0.4 mm) minimum when tested at -320°F (-196°C).

14. Fillet Weld Test

14.1 The fillet weld test, when required in Table 4, shall be made in accordance with 8.5 and Fig. 4. 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 as shown in Fig. 4. The cross-sectional surface shall be polished and etched, and then examined as required in 14.2.

14.2 Scribe lines shall be placed on the prepared surface, as shown in Fig. 8, and the leg length and the convexity shall be determined to the nearest $\frac{1}{64}$ in. (0.4 mm) by actual measurement.

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

14.2.2 The legs and convexity of each fillet weld shall be within the limits prescribed in Fig. 8.

14.2.3 The fillet welds shall show no evidence of cracks.

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

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

15. Method of Manufacture

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

16. Standard Sizes

Standard sizes for electrodes and rods are shown in Table 7.

17. Finish and Uniformity

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

17.2 Each continuous length of filler metal shall be from a single lot of material. Welds, when present, shall have been made so as not to interfere with the

uniform, uninterrupted feeding of the filler metal on automatic and semiautomatic equipment.

17.3 Core ingredients shall be distributed with sufficient uniformity throughout the length of the electrode or rod so as not to adversely affect performance or properties of the weld metal.

18. Standard Package Forms

18.1 Standard package forms are straight lengths, coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Tables 8 and 9. Package forms, sizes and weights other than these shall be as agreed upon between purchaser and supplier.

18.2 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

18.3 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal (see Figs. 9, 10, and 11).

19. Winding Requirements

19.1 The filler metal shall be wound so that kinks, waves, sharp bends, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be accessible and secured to avoid unwinding.

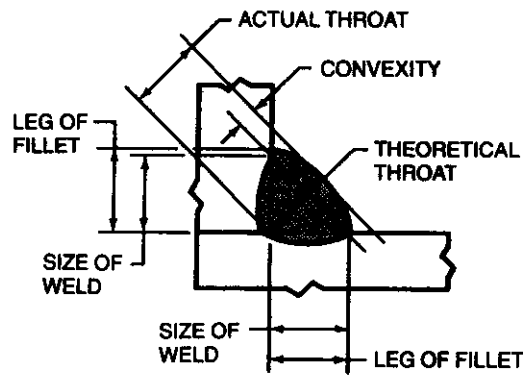
19.2 The cast and helix of filler metal in coils, spools, and drums shall be such that the filler metal will feed in an uninterrupted manner in automatic and semiautomatic equipment.

20. Filler Metal Identification

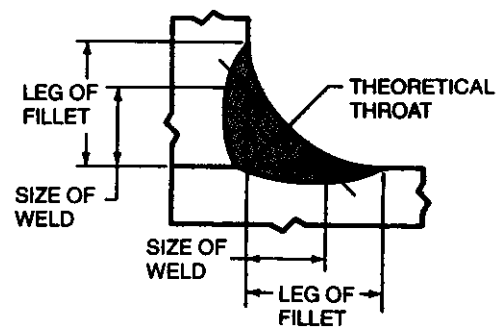
20.1 The product information and the precautionary information required in Section 21, Marking of Packages, shall also appear on each coil, spool, and drum.

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

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



CONVEX FILLET



CONCAVE FILLET

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in.	mm	in.	mm	in.	mm
1/8 or less	3.0	5/64	2.0	1/32	0.8
9/64	3.5	5/64	2.0	3/64	1.2
5/32	4.0	5/64	2.0	3/64	1.2
11/64	4.5	5/64	2.0	1/16	1.6
3/16	5.0	5/64	2.0	1/16	1.6
13/64	5.0	5/64	2.0	5/64	2.0
7/32	5.5	5/64	2.0	5/64	2.0
15/64	6.0	5/64	2.0	3/32	2.4
1/4	6.5	5/64	2.0	3/32	2.4
17/64	6.5	3/32	2.4	7/64	2.8
9/32	7.0	3/32	2.4	7/64	2.8
19/64	7.5	3/32	2.4	1/8	3.2
5/16	8.0	3/32	2.4	1/8	3.2
21/64	8.5	3/32	2.4	9/64	3.6
11/32	8.5	3/32	2.4	9/64	3.6
23/64	9.0	3/32	2.4	5/32	4.0
3/8 or more	9.5	3/32	2.4	5/32	4.0

Notes:

1. Size of fillet weld = leg length of largest inscribed isosceles right triangle.
2. Fillet weld size, convexity, and leg lengths of fillet welds shall be determined by actual measurement (nearest 1/64 [0.4 mm]) on a section laid out with scribed lines shown.

FIG. 8 FILLET WELD TEST SPECIMEN AND DIMENSIONAL REQUIREMENTS

TABLE 7
STANDARD ELECTRODE AND ROD SIZES AND TOLERANCES^a

Package Form	Diameter		Tolerance	
	in.	mm	in.	mm
Coils with Support, Spools	0.035	0.9	±0.002	±0.05
	0.045	1.2		
	0.052	1.4		
	1/16	(0.062)		
Coils without Support Coils with Support Drums Spools	5/64	(0.078)	±0.003	±0.08
	3/32	(0.094)		
	7/64	(0.109)		
	1/8	(0.125)		
	5/32	(0.156)		
Straight Lengths ^b	5/64	(0.078)	±0.003	±0.08
	0.087	2.2		
	3/32	(0.094)		

NOTES:

a. Other sizes and forms shall be as agreed upon between the purchaser and supplier.

b. Length shall be 36 in. +0, -1/2 in. (915 mm +0, -13 mm).

TABLE 8
STANDARD DIMENSIONS FOR COILS, WITH AND WITHOUT SUPPORT, AND DRUMS

Coils						Drums	
Without Support		With Support					
Inside Diameter of Coil		Inside Diameter of Liner		Width of Wound Electrode, Max.		Outside Diameter	
in.	mm	in.	mm	in.	mm	in.	mm
12	300	12 ± 1/8	300 ± 3	4 5/8	120	15 1/2	400
22 1/2	570					20	500
						23	600

NOTE:

Other forms shall be as agreed upon between purchaser and supplier.

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

20.5 Drums shall have the information securely affixed to the side of the drum.

20.6 Identification of individual welding rods in straight lengths is not a requirement of this specification, but may be done as agreed upon between the purchaser and supplier.

21. Packaging

Filler metal shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

22. Marking of Packages

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

TABLE 9
PACKAGING REQUIREMENTS^a

Type of Package	Package Size		Net Weight of Electrode ^b	
	in.	mm	lb	kg
Coils Without Support	As specified by purchaser ^c		As specified by purchaser ^c	
Coils With Support (see below)	ID	6 $\frac{3}{4}$	170	14
	ID	12	300	25, 30, 50, and 60
				11, 14, 23, and 27
Spools	OD	4	100	1 $\frac{1}{2}$ and 2 $\frac{1}{2}$
	OD	8	200	10, 15, and 22
	OD	12	300	25, 30, and 35
	OD	14	350	50 and 60
	OD	22	550	250
	OD	24	600	300
	OD	30	750	600 and 750
Drums	OD	15 $\frac{1}{2}$	400	As specified by purchaser ^c
	OD	20	500	As specified by purchaser ^c
	OD	23	575	300 and 600

Coils with Support—Standard Dimensions and Weights^a

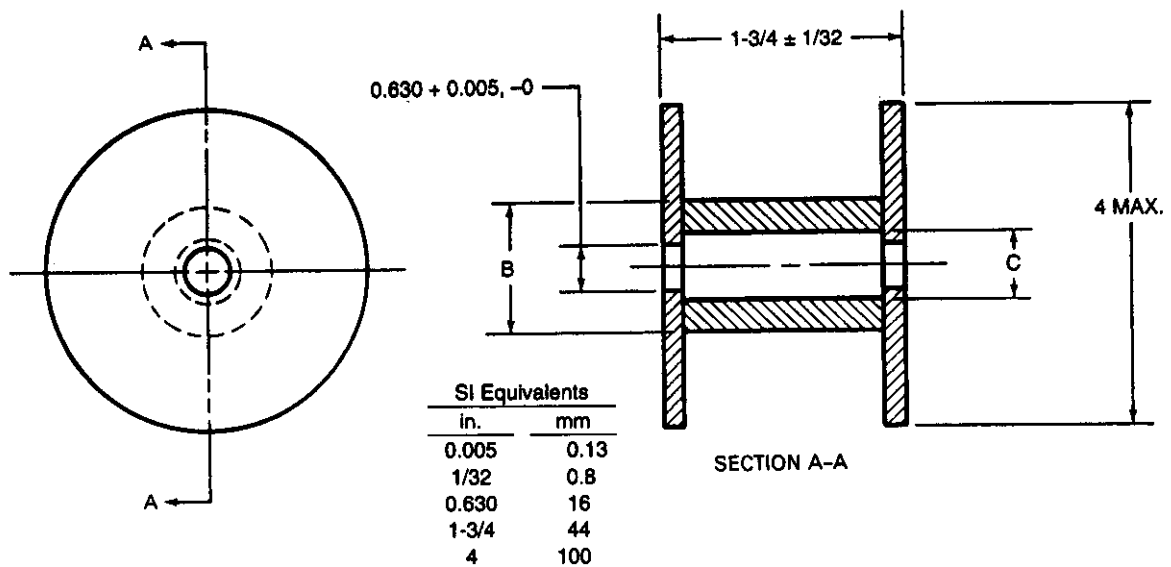
		Coil Dimensions				
		Coil Net Weight ^b		Inside Diameter of Liner		Width of Wound Electrode, max.
Electrode Size		lb	kg	in.	mm	in.
All		14	6.4	6 $\frac{3}{4}$ $\pm$ $\frac{1}{8}$	170 $\pm$ 3	3
		25 and 30	11 and 14	12 $\pm$ $\frac{1}{8}$	300 $\pm$ 3	2 $\frac{1}{2}$ or 4 $\frac{5}{8}$
		50 and 60	23 and 27	12 $\pm$ $\frac{1}{8}$	300 $\pm$ 3	4 $\frac{5}{8}$

NOTES:

^a Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser.

^b Tolerance on net weight shall be ± 10 percent.

^c As agreed between supplier and purchaser.

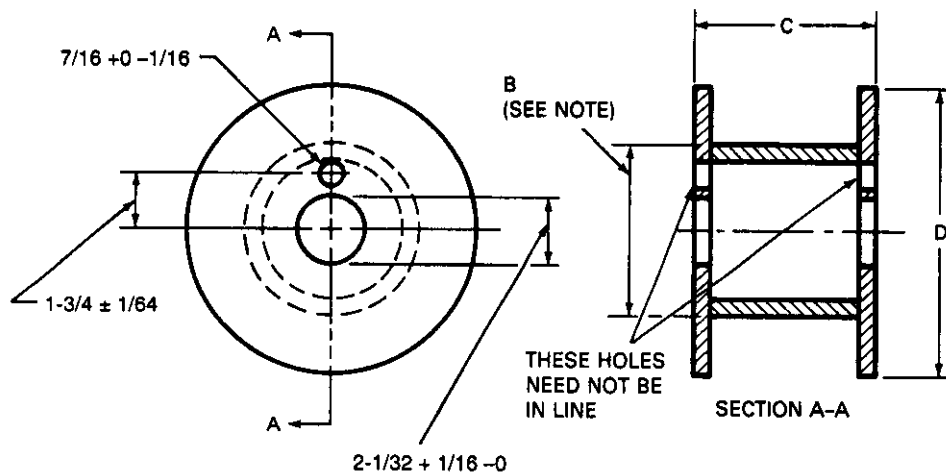


All dimensions except angles are in inches.

Notes:

1. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.
2. Dimension C, inside diameter of barrel, shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside diameter of the barrel being less than the inside diameter of the flanges.

FIG. 9 DIMENSIONS OF STANDARD 4 IN. (100 MM) SPOOL

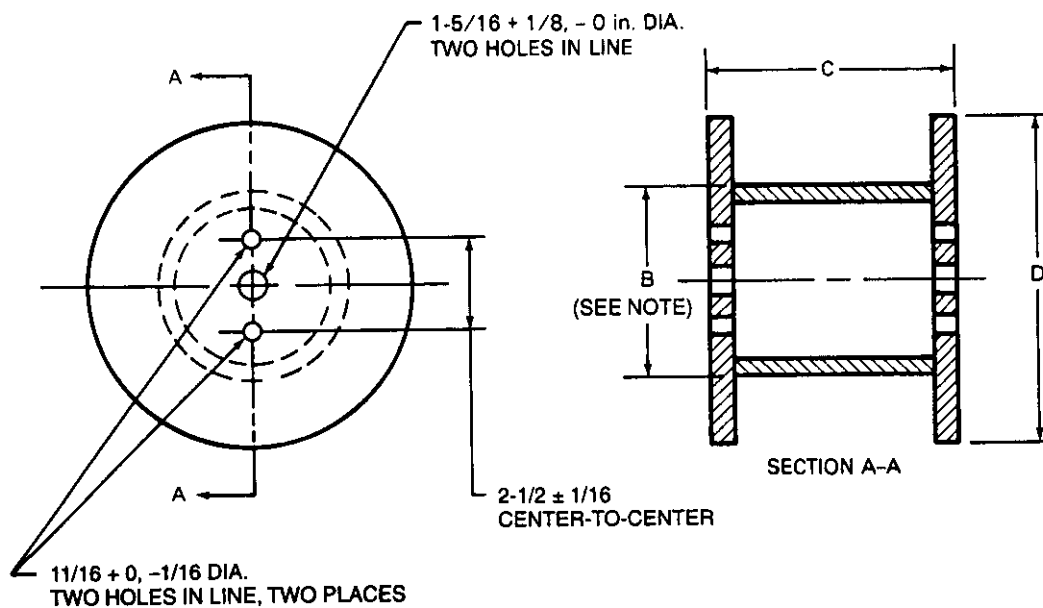


All dimensions except angles are in inches.

Spool Size		C Dimension		D Dimension (maximum)		SI Equivalents	
in.	mm	in.	mm	in.	mm	in.	mm
8	200	$2-5/32 \pm 1/32$	55 ± 1	8	205	1/64	0.4
8	200	$2-7/8 \pm 1/16$	75 ± 2	8	205	1/16	1.6
12	300	$4 \pm 1/16$	100 ± 2	12	305	7/16	11
14	350	$4 \pm 1/16$	100 ± 2	14	355	1-3/4	44
						2-1/32	52

Note: Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrode.

FIG. 10 DIMENSIONS OF STANDARD 8, 12, AND 14 IN. (200, 300 AND 350 MM) SPOOLS



All dimensions except angles are in inches.

Spool Size		D Dimension		Maximum C Dimension		SI Equivalents	
in.	mm	in.	mm	in.	mm	in.	mm
22	550	$22 \pm \frac{1}{2}$	550 ± 12.7	12	300	$\frac{1}{16}$	1.6
24	600	$24 \pm \frac{1}{2}$	600 ± 12.7	$13\frac{1}{2}$	338	$\frac{1}{8}$	3
30	750	$30 \pm \frac{1}{2}$	770 ± 12.7	$13\frac{1}{2}$	338	$\frac{11}{16}$	18
						$\frac{1-5}{16}$	33
						$2\frac{1}{2}$	63

Note: Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrode.

FIG. 11 DIMENSIONS OF 22, 24, AND 30 IN. (550, 600, AND 750 MM) SPOOLS

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

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

WARNING:

Protect yourself and others.

Read and understand this information.

FUMES AND GASES can be hazardous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can kill.

- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch electrical parts.
- See American National Standard Z49.1, *Safety in Welding, Cutting, and Allied Processes* published by the American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126; OSHA Safety and Health Standards, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

Annex

Guide to AWS Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding

(This Annex is not a part of A5.22-95, *Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding*, but is included for information purposes only.)

A1. Introduction

The purpose of this guide is to correlate the electrode and rod classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable. This specification now includes welding rods classified as RXXXT1-5. These are flux cored welding rods which can be used for GTAW of the root pass of stainless steel pipe without the use of a back shielding gas. Previous editions of A5.22 only included flux cored welding electrodes.

A2. Classification System

A2.1 The system for identifying the electrode and rod classifications in this specification follows the standard pattern used in other AWS filler metal specifications.

A2.2 The letter "E" at the beginning of each classification designation stands for electrode, and the letter "R" indicates a welding rod. The three or four digit number such as 308 designates the chemical composition. The following letter "T" indicates that the product is a flux cored electrode or rod. The "1" or "0" following the "T" indicates the recommended position of operation. Inclusion of "K" in the designator signifies that the material has been designed for cryogenic service. Figure A1 is graphical explanation of the system.

A2.3 Since the electrodes and rods are classified according to the chemical composition of the weld metal and the external shielding medium required for the classification tests, additional symbols are employed, following the "E" or "R" in the classification designations.

A2.3.1 The chemical composition is identified by a three-digit or four-digit number, and, in some cases, additional chemical symbols and the letters "L" or "H." The numbers generally follow the pattern of the AISI numbering system for heat- and corrosion-resisting steels; however, there are exceptions. In some classifications additional chemical symbols are used to signify modifications of basic alloy types. The letter "L" denotes a low-carbon content in the deposit. The letter "H" denotes a carbon content in the upper part of the range that is specified for the corresponding standard alloy type.

A2.3.2 The letter "K" in the E316LKT0-3 classification signifies that weld metal deposited by these electrodes is designed for cryogenic applications.

A2.3.3 Following the chemical composition designation comes the letter "T," which signifies that the product is a flux cored electrode or rod. Following the "T" is a 1 or 0 indicating the recommended position of welding. Following the position indicator and a dash, are the numerals "1," "3," "4," or "5" or the letter "G." The numerals "1," "4," and "5" identify the shielding gas required for classification of the electrode or rod. The numeral "3" signifies that an external shielding gas is not employed and that the weld puddle

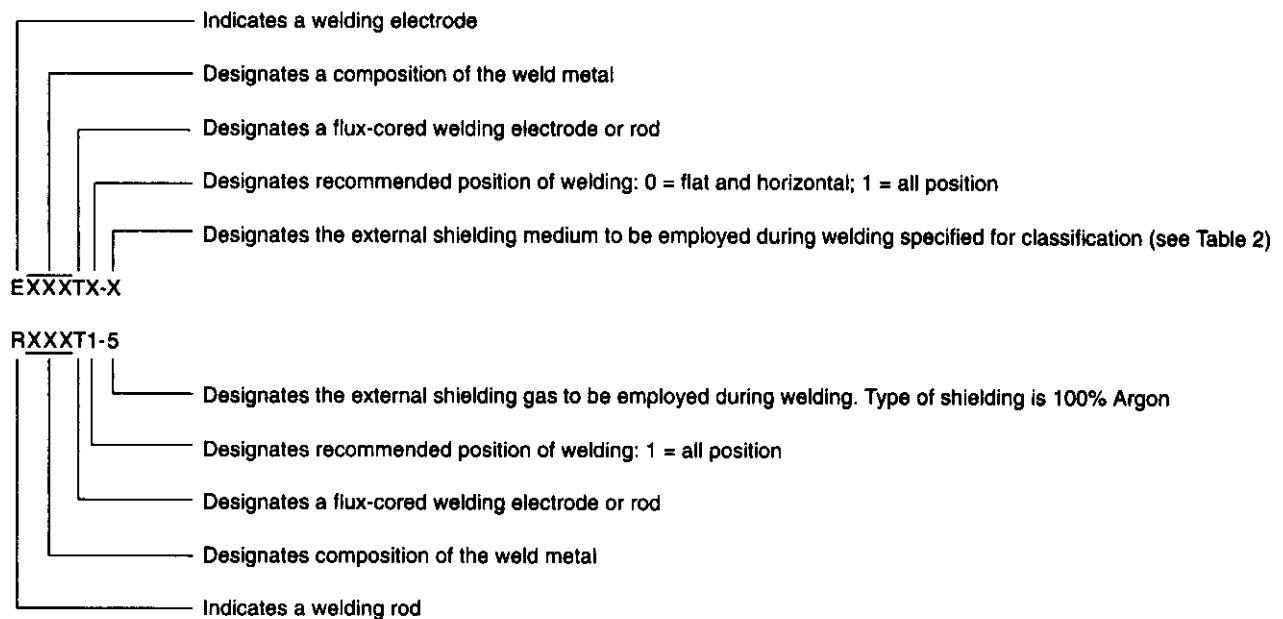


FIG. A1 CLASSIFICATION SYSTEM

is shielded by the atmosphere and slag generated by the flux core. The letter "G" signifies that the shielding medium, chemical composition, and mechanical properties are not specified and are as agreed upon between supplier and purchaser. For rods, the letter "G" signifies that the shielding medium is not specified and is as agreed upon between the purchaser and the manufacturer. Refer to A2.3.7 for a further explanation of the "G" classification and its implications.

A2.3.4 Significance of the position indicators is summarized as follows:

(a) EXXXT0-X Designates a welding electrode designed to weld in the flat or horizontal position.

(b) EXXXT1-X Designates a welding electrode designed for welding in all positions.

(c) RXXXT1-5 Designates a welding rod designed for welding in all positions.

A2.3.5 The shielding designations, denoting shielding from the core materials as well as from any externally applied gas, are shown in Table 2. This does not exclude the use of alternate gas mixtures as agreed upon between purchaser and supplier. The use of alternate gas mixtures may have an effect on welding characteristics, deposit composition, and mechanical properties of the weld, such that classification requirements may not be met.

A2.3.6 While mechanical property tests are required for classification of the electrodes or rods in this specification (see Table 6), the classification system does not identify the test requirements.

A2.3.7 This specification includes filler metals classified EXXXTX-G. The "G" indicates that the filler metal is of a *general* classification. It is general because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing this classification is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications, (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal—one that otherwise would have to await a revision of the specification—to be classified immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some certain respect (chemical composition, again, for example).

A2.3.8 The point of difference (although not necessarily the amount of that difference) between filler

metal of a "G" classification and filler metal of a similar classification without the "G" (or even with it, for that matter) will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

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

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

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

A2.3.9 Request for Filler Metal Classification

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

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

(3) The request should be sent to the Secretary of the Filler Metal Committee at AWS Headquarters.

Upon receipt of the request, the Secretary will do the following:

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

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

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

(d) File the original request.

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

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

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

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, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01.

In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing he normally conducts 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 the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. *Certification* is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may, or may not, have been conducted.

The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" 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 involved
- (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, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section relating to 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 have 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*.⁶

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 the latest revision of 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 stainless steel weld metals.

⁶ Welding Research Council, 345 East 47th Street, New York, New York 10017

A6.5 Even on undiluted pads, ferrite variations from pad to pad must be expected due to slight changes in 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 to 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.⁷ The E316 group can be made with little or no ferrite when required for improved corrosion resistance in certain media, and in high temperature and cryogenic applications where ferrite can be detrimental. 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 are likely 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 The same weld pads, as detailed in 8.3, may be used to measure the ferrite level, provided the last two or three layers are prepared as described in A6.9.3 and A6.9.4. Otherwise, the pads shall be made as detailed on Fig. A1 and prepared as described in A6.9.2 through A6.9.4. The base plate may be of Type 301, 302, or 304 conforming to ASTM Specification

A167 or A240, or carbon steel. If the base plate contains more than 0.03% carbon and is used for the low-carbon classifications (those with the letter "L" in the designation), then the pad shall have a minimum of four layers. This is required to assure a low-carbon weld metal deposit.

A6.9.2 The weld pad must be built to a minimum height of $\frac{1}{2}$ in. (13 mm) when using Type 301, 302, or 304 base plate. When using a carbon steel base, the weld pad must have a minimum height of $\frac{5}{8}$ in. (16 mm) to eliminate dilution effects.

A6.9.3 The pad must be welded in the flat position using multiple layers, with at least the last 2 layers deposited using stringer beads. The weld layers used for the buildup may be deposited with a weave. The amperage or wire feed speed and the arc voltage shall be as recommended by the manufacturer of the electrode. The shielding medium, polarity and welding process shall be as shown in Table 2. Each pass must be cleaned prior to depositing the next pass. 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. 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 two layers must have a maximum interpass temperature of 300°F (150°C). The last pass must be air cooled to below 800°F (427°C) prior to quenching in water.

The weld deposit can be buildup between two copper bars laid parallel on the base plate. The spacing between the copper bars is dependent on the size of the electrode and the type or size of welding gun used. Care must be taken to make sure the arc does not impinge on the copper bars resulting in copper dilution in the weld metal.

A6.9.4 The completed weld pad must have the surface prepared so that it is smooth with all traces of weld ripple removed and must be continuous in length where measurements are to be taken. This can be accomplished by any suitable means providing the surface is not heated in excess during the machining operation (excessive heating may affect the final ferrite reading). The width of the prepared surface shall not be less than $\frac{1}{8}$ in. (3 mm).

The surface can be prepared by draw filing using a 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 only been used on austenitic stainless steel. Filing must be accomplished by smooth draw-filing strokes (one

⁷ Some of the grades of electrodes listed here are not in this document, but are contained in ANSI/AWS A5.4 or ANSI/AWS A5.9.

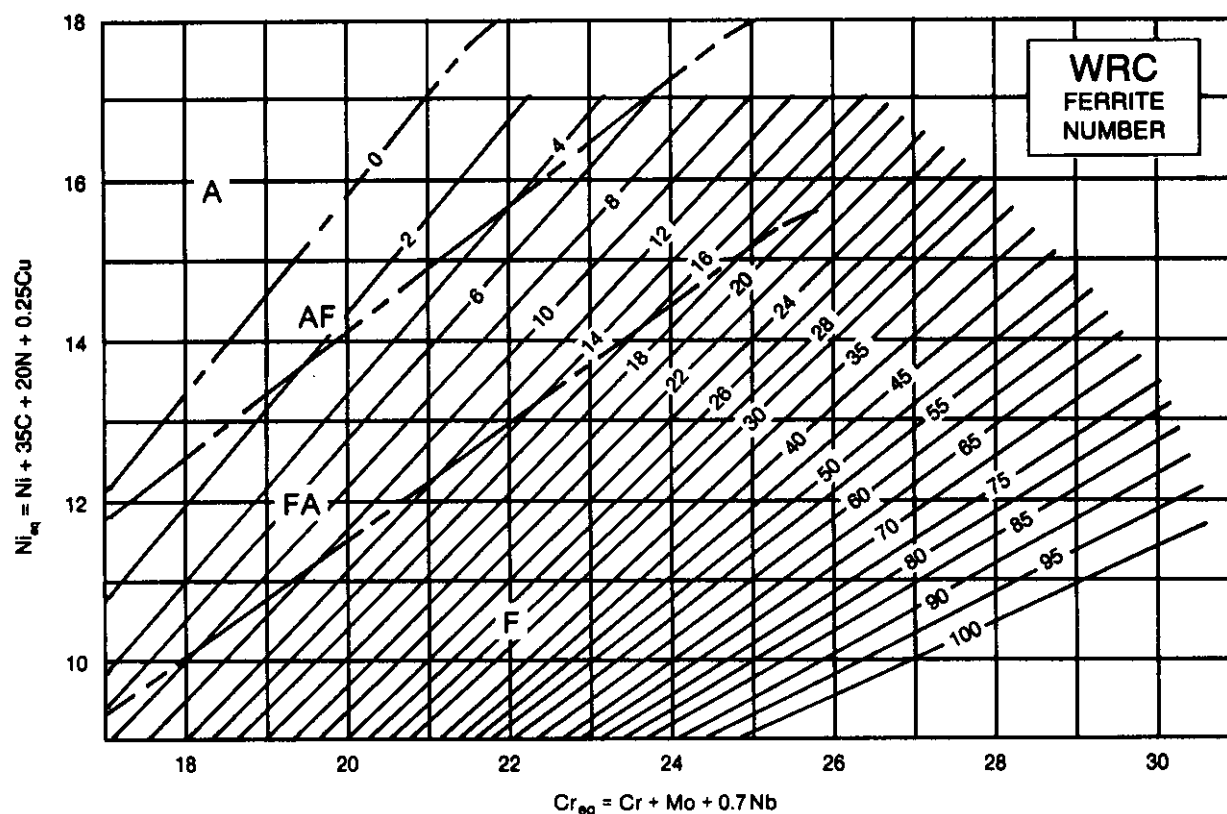


FIG. A2 WRC—WRC-1992 (FN) DIAGRAM FOR STAINLESS STEEL WELD METAL

direction only) along the length of the weld while applying a firm downward pressure.

A6.9.5 A minimum 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 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-1992 (Fig. A2), the Espy Diagram (Fig. A3), and the DeLong Diagram (Fig. A4). 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-1992 Diagram⁸ (Fig. A2) predicts ferrite in Ferrite Number (FN). This diagram is the 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-1992 Diagram are independent of silicon and manganese contents because these elements were not found to have statistically significant effects. The WRC-1992 Diagram is preferred for "300" series stainless steels and for duplex stainless alloys. It may not be applicable to compositions having greater

⁸ D. J. Kotecki, T. A. Siewert, "WRC-1992 Constitution Diagram for Stainless Steel Weld Metals: A Modification of the WRC-1988 Diagram." *Welding Journal* 71[5] 171s-178s (1992).

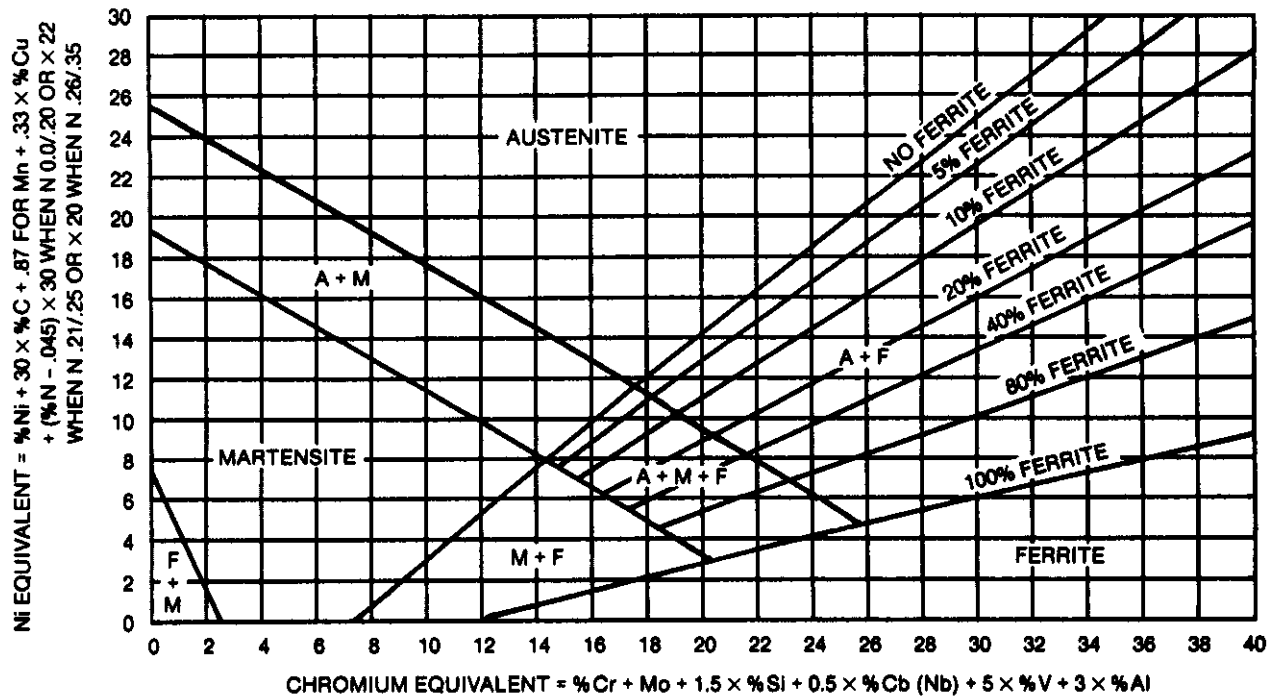


FIG. A3 ESPY PERCENT FERRITE DIAGRAM FOR STAINLESS WELD METAL

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

A6.10.2 Espy Diagram⁹ (Fig. A3) calculates the percent ferrite 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 (i.e., nitrogen-strengthened austenitic stainless steels).

A6.10.3 DeLong Diagram¹⁰ (Fig. A4) is a modified Schaeffler Diagram¹¹ predicting the Ferrite Number (FN) up to a maximum of 18 FN. The diagram includes the nitrogen level in 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 1992 Diagram (see Fig. A2) 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.

A7. Description and Intended Use of Electrodes and Rods

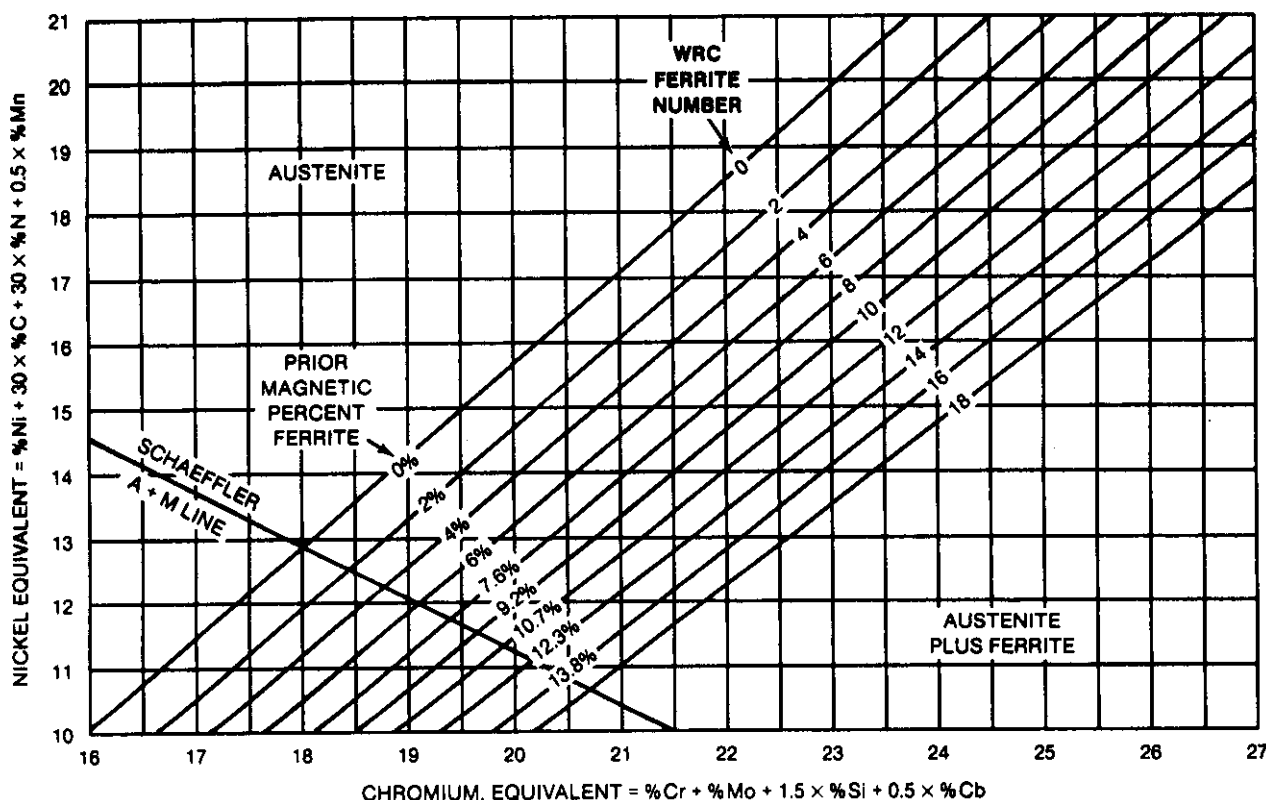
A7.1 Composition Considerations

A7.1.1 The chemical composition requirements for these electrodes and rods are patterned after those of ANSI/AWS A5.4, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, and ANSI/AWS A5.9, *Specification for Bare Stainless Steel Electrodes and Rods*.

⁹ R. H. Espy, "Weldability of Nitrogen-Strengthened Stainless Steels," *Welding Journal* 61[5] 149s-156s, 1982.

¹⁰ W. T. DeLong, 1974 Adams Lecture; "Ferrite in Austenitic Stainless Steel Weld Metal," *Welding Journal* 53[7] 273-s to 286-s (1974).

¹¹ A. E. Schaeffler, *Metal Progress*, 56, 680-680B.



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. A4 DeLONG (FN) DIAGRAM FOR STAINLESS STEEL WELD METAL

A7.1.2 The chemical composition requirements of the EXXXTX-1 and EXXXTX-4 classifications are very similar. The requirements of the EXXXT0-3 classifications are different from those of the previous two because self-shielding with a slag system alone is not as effective as shielding with a combination of a slag system and an external shielding gas. The EXXXT0-3 deposits, therefore, usually have a higher nitrogen content. This means that, in order to control the ferrite content of the weld metal, the chemical compositions of the EXXXT0-3 deposits must have different Cr/Ni ratios than those of EXXXTX-1 and EXXXTX-4 deposits.

Since the atmosphere generated by E316LKT0-3 electrodes more efficiently shield the arc from nitrogen pickup than that produced by other EXXXT0-3 electrodes, the Cr/Ni ratio can be the same as for EXXXTX-1 deposits without a loss of ferrite control.

A7.2 Intended Use of Electrodes and Rods

A7.2.1 E307TX-X. The nominal composition (wt.%) of this weld metal is 19 Cr, 9.7 Ni, 1.0 Mo and 4 Mn. These electrodes are used primarily for moderate strength welds with good crack resistance between dissimilar steels, such as welding austenitic manganese steel to carbon steel forgings or castings.

A7.2.2 E308TX-X. The nominal composition (wt.%) of this weld metal is 19.5 Cr and 10 Ni. Electrodes of this classification are most often used to weld base metal of similar composition such as AISI Types 301, 302, 304, 305, and 308.

A7.2.3 E308LTX-X. The composition of this weld metal is the same as that of E308TX-X, except for carbon content. By specifying low carbon in this alloy, it is possible to obtain resistance to intergranular corro-

sion due to carbide precipitation without the use of stabilizers such as columbium (niobium) or titanium. This low-carbon alloy, however, is not as strong at elevated temperature as the E308 and columbium (niobium)-stabilized alloys.

A7.2.4 E308HTX-X. The composition of this weld metal is the same as that of E308TX-X except for carbon content which is in the high end of the range, 0.04 to 0.08 wt.%. Carbon content in this range provides higher tensile and creep strength at elevated temperatures. These electrodes are used primarily for welding type 304H base metal.

A7.2.5 E308MoTX-X. The composition of this weld metal is the same as that of E308TX-X weld metal, except for the addition of 2–3 wt.% molybdenum. This electrode is recommended for welding CF8M stainless steel castings, as it matches the base metal with regard to chromium, nickel, and molybdenum.¹² This grade may also be used for welding wrought metals such as Type 316L when a ferrite content higher than attainable with E316LTX-X electrodes is desired.

A7.2.6 E308HMoT0-3. The composition of this weld metal is the same as that of E308MoTX-X, except that the carbon content has been restricted to the higher portion of the range. The higher carbon content provides higher strength at elevated temperatures.

A7.2.7 E308LMoTX-X. The composition of this weld metal is the same as that of E308MoTX-X weld metal, except for the lower carbon content. These electrodes are recommended for welding CF3M stainless steel castings, to match the base metal with regard to chromium, nickel, and molybdenum. This grade also may be used for welding wrought metals such as type 316L stainless when ferrite content higher than attainable with E316LTX-X electrodes is desired.

A7.2.8 E309TX-X. The nominal composition (wt.%) of this weld metal is 23.5 Cr and 13 Ni. Electrodes of this classification commonly are used for welding similar alloys in wrought or cast forms. They are used in welding dissimilar metals, such as joining Type 304 to mild steel, welding the stainless steel side of Type 304 clad steels, and applying stainless steel sheet linings to carbon steel sheets. Occasionally, they are used to weld Type 304 base metals where severe corrosion conditions exist that require higher alloy content weld metal.

A7.2.9 E309LTX-X. The composition of this weld metal is the same as E309TX-X, except for the carbon content. By specifying low carbon in this alloy, it is possible to obtain resistance to intergranular corrosion due to carbide precipitation without the use of stabilizers such as columbium (niobium) or titanium. This low carbon alloy, however, is not as strong at elevated temperature as Type 309 or the columbium (niobium)-stabilized modification. A primary application of this alloy is the first layer cladding of carbon steel if no columbium additions are required.

A7.2.10 E309MoTX-X. The composition of this weld metal is the same as that of E309TX-X weld metal, except for the addition of 2–3 wt.% of molybdenum. These electrodes are used to join stainless steel to carbon and low-alloy steels for service below 600°F (316°C), and for overlaying of carbon and low-alloy steels. The presence of molybdenum provides pitting resistance in a halide environment and helps provide high temperature ductility in dissimilar joints. The ferrite level for this electrode is approximately 18 FN.

A7.2.11 E309LMoTX-X. The composition of this weld metal is the same as E309MoTX-X weld metal, except for the lower carbon content. These electrodes are used to join stainless steel to carbon and low-alloy steels for service below 600°F (316°C), and for overlaying of carbon and low-alloy steels. The presence of molybdenum provides pitting resistance in a halide environment and helps provide high temperature ductility in dissimilar joints. The ferrite level for this electrode is approximately 20 FN.

A7.2.12 E309LNiMoTX-X. The composition of this weld metal is essentially the same as E309LMoTX-X except for the lower chromium and higher nickel content. The purpose of this modification is to achieve a lower deposit ferrite content (typically 8–12 FN) when compared to E309LMoTX-X (typically 16–20 FN). This chemistry is required by the pulp and paper industry for joining applications. The lower ferrite content leads to better corrosion resistance due to a decreased potential for chromium-nitride precipitation.

A7.2.13 E309LCbTX-X. The composition of this weld metal is the same as E309LTX-X weld metal, except for the addition of 0.7 to 1.0 wt.% of Cb (Nb). These electrodes are used to overlay carbon and low alloy steels and produce a columbium (niobium) stabilized first layer on such overlays.

A7.2.14 E310TX-X. The nominal composition (wt.%) of this weld metal is 26.5 Cr and 21 Ni. These

¹²CF8M and CF3M are designations of ASTM A351, *Specification for Steel Castings, Austenitic, for High Temperature Service*.

electrodes are most often used to weld base metals of similar compositions.

A7.2.15 E312TX-X. The nominal composition (wt.%) of this weld metal is 30 Cr and 9 Ni. These electrodes most often are used to weld dissimilar metal compositions of which one component is 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.

A7.2.16 E316TX-X. The nominal composition (wt.%) of this weld metal is 18.5 Cr, 12.5 Ni, and 2.5 Mo. Electrodes of this classification usually are used for welding similar alloys (about 2 wt.% molybdenum). These electrodes have been used successfully in applications involving special alloys for high-temperature service. The presence of molybdenum provides increased creep resistance at elevated temperatures and pitting resistance in a halide environment.

A7.2.17 E316LTX-X. The composition of this weld metal is the same as E316TX-X electrodes, except for the lower carbon content. By specifying low carbon in this alloy, it is possible to obtain resistance to intergranular corrosion due to carbide precipitation 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.

A7.2.18 E316LKT0-3. The composition of this weld metal is the same as E316LTX-X. These electrodes, however, are "self-shielding" and are used primarily for welding stainless steels for cryogenic service. Although the nominal chromium, nickel, and molybdenum content of E316LKT0-3 filler metal is essentially the same as the other E316 grades, special attention is given to it in order to maximize low-temperature toughness. Minimizing the content of carbon and nitrogen improves the toughness. Low nitrogen content is achieved by providing a more efficient slag system than is employed with EXXXT0-3 self-shielding electrodes. Delta ferrite in the weld metal has an adverse effect on toughness; therefore, the chemical composition of the weld metal is balanced to provide a low maximum ferrite content (3 FN or less). Fully austenitic weld metal is preferred from a toughness standpoint; however, it is recognized that the tendency for weld metal fissuring is greater in fully austenitic weld metals.

A7.2.19 E317LTX-X. The nominal composition (wt.%) of this weld metal is 19.5 Cr, 13 Ni, and 3.5 Mo. These electrodes usually are used for welding alloys of similar composition and are usually limited to severe corrosion applications. Low carbon (0.03 wt.% maximum) in this filler metal reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as columbium or titanium. This low-carbon alloy, however, may not be so strong at elevated temperatures as the columbium (niobium) stabilized alloys or Type 317.

A7.2.20 E347TX-X. The nominal composition (wt.%) of this weld metal is 19.5 Cr and 10 Ni with Cb (Nb) added as a stabilizer. The alloy is often referred to as a stabilized Type 308 alloy, indicating that it normally is not subject to intergranular corrosion from carbide precipitation. Electrodes of this classification usually are used for welding chromium-nickel steel base metals of similar composition stabilized either with columbium (niobium) or titanium.

Although columbium (niobium) is the stabilizing element usually specified in 347 alloys, it should be recognized that tantalum also may be present. Tantalum and columbium (niobium) are almost equally effective in stabilizing carbon and in providing high-temperature strength. The usual commercial practice is to report columbium (niobium) as the sum of the columbium plus tantalum. Crack sensitivity of the weld may increase substantially, if dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit.

A7.2.21 E409TX-X. The nominal composition (wt.%) of this weld metal is 12 Cr with Ti added as a stabilizer. These electrodes, which produce a ferritic microstructure, often are used to weld base metal of similar composition.

A7.2.22 E410TX-X. This 12 Cr (wt.%) alloy is an air-hardening steel and, therefore, requires preheat and postheat treatments in order to achieve welds of adequate ductility for most engineering purposes. The most common application of electrodes of this classification is for welding alloys of similar composition. They also are used for surfacing of carbon steels to resist corrosion, erosion, or abrasion, such as that which occur in valve seats and other valve parts.

A7.2.23 E410NiMoTX-X. The nominal composition (wt.%) of this weld metal is 11.5 Cr, 4.5 Ni, and 0.55 Mo. This electrode generally is used to weld

CA6NM castings or similar materials.¹³ These electrodes are modified to contain less chromium and more nickel to eliminate ferrite in the microstructure, as ferrite has a deleterious effect on mechanical properties. Postweld heat treatment in excess of 1150°F (620°C) may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A7.2.24 E410NiTiTX-X. The nominal composition (wt.%) of this weld metal is 11.5 Cr and 4 Ni with Ti added as a stabilizer. These electrodes generally are used to weld base metals of similar composition.

A7.2.25 E430TX-X. This is a nominal 16.5 (wt.%) Cr alloy. 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. (Excessive chromium will result in lower ductility.)

Welding with E430TX-X electrodes may produce a partially hardened microstructure that requires preheating and a postweld heat treatment. Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A7.2.26 E502TX-X. The nominal composition (wt.%) of this weld metal is 5 Cr and 0.55 Mo. Electrodes of this classification are used for welding base metal of similar composition, usually in the form of a pipe or tube. This alloy is air-hardening. Therefore, preheating and postweld heat treatment are strongly recommended.

A7.2.27 E505TX-X. The nominal composition (wt.%) of this weld metal is 9.2 Cr and 1.0 Mo. Electrodes of this classification are used for welding base metal of similar composition, usually in the form of a pipe or tube. The alloy is air-hardening and therefore, preheating and postweld heat treatment are strongly recommended.

A7.2.28 E2209TX-X. The nominal composition (wt.%) of this weld metal is 22 Cr, 8.5 Ni, and 3.5 Mo. This electrode is used to join duplex stainless steel base metals containing approximately 22 wt.% chromium. The microstructure of the weld deposit consists of a mixture of austenite and ferrite. Because of the two-phase structure, the alloy is one of the family of duplex stainless steel alloys. The alloy has good resistance to stress corrosion cracking and pitting corrosion attack.

A7.2.29 E2553TX-X. The nominal composition (wt.%) of this weld metal is 25.5 Cr, 9.5 Ni, and 3.4 Mo. This electrode is used to join duplex stainless steel base metals containing approximately 25 wt.% chromium. The microstructure of the weld deposit consists of a mixture of austenite and ferrite. Because of the two-phase microstructure, this alloy is one of the family of duplex stainless steel alloys. Duplex stainless steels combine high tensile and yield strengths with improved resistance to pitting corrosion and stress corrosion cracking.

A7.2.30 R308LT1-5. The nominal composition (wt.%) of this weld metal is 18.5 Cr, and 10 Ni with C held to 0.03 maximum. This flux cored rod is used primarily for root pass welding of Type 304 or 304L stainless steel piping joints when an inert gas backing purge is either not possible or not desirable. This rod can only be used with the GTA process, but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A7.2.31 R309LT1-5. The nominal composition (wt.%) of this weld metal is 23.5 Cr, and 13 Ni with C held to 0.03 maximum. This flux cored filler rod is used primarily for the root pass welding of carbon steel pipe to austenitic stainless steel pipe when inert gas backing purge is either not possible or not desirable. The high Cr and Ni content allows dilution with carbon steel while still producing a weld metal with sufficient alloy to resist corrosion. This rod can only be used with the GTA process but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A7.2.32 R316LT1-5. The nominal composition (wt.%) of this weld metal is 18.5 Cr, 13 Ni, and 2.5 Mo with C held to 0.03 maximum. This flux cored filler rod is used primarily for the root pass welding of Type 316 or 316L stainless steel piping joints when inert gas backing purge is either not possible or not desirable. This rod can only be used with the GTAW process but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A7.2.33 R347T1-5. The nominal composition (wt.%) of this weld metal is 19.5 Cr and 10 Ni with

¹³ CA6NM is a designation of ASTM Specification A352, *Specification for Steel Castings, Ferritic and Martensitic, for Pressure Containing Parts, Suitable for Low Temperature Service.*

Cb(Nb) and Ta added as stabilizers. This flux cored filler rod is used primarily for the root pass welding of Type 347 stainless steel piping joints when inert gas backing purge is either not possible or not desirable. This rod can only be used with the GTAW process but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A8. Special Tests

A8.1 Mechanical Properties. It is recognized that supplementary tests may be required for certain applications. In such cases, tests to determine specific properties such as strength at elevated or cryogenic temperatures may be required. ANSI/AWS A5.01 contains provisions for ordering such tests. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

Tests 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 ANSI/AWS B4.0. Tests of joint specimens may be influenced by the properties of the base metal and may not provide adequate tests of the weld metal. Such tests should be considered as tests for qualifying the electrodes or rods. Where fabrication codes require testing welds in heat-treated conditions other than those specified in Table 6, all-weld-metal tests of heat-treated specimens may be desired. For the preparation of such specimens the procedures outlined in 8.4 should be used.

A8.2 Corrosion or Scaling Tests. Although welds made with electrodes or rods covered by this specification commonly are 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 pertinent to the intended application may be conducted as agreed upon between the manufacturer and the purchaser. This section is included for the guidance of those who desire such special tests.

A8.2.1 Corrosion or scaling tests of joining specimens have the advantage that the joint design and welding procedure can be made identical to those being used in fabrication. However the user must be aware that these are tests of the combined properties of the weld metal, the heat-affected zone of the base metal, and the unaffected base metal. It is difficult to obtain

reproducible data when 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 procedures.

A8.2.2 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 $1 + n\frac{5}{8}$ in. ($25 + n16$ 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.

A8.2.3 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. Safety Considerations

A9.1 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 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 the equivalent, to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any

combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flames. Aprons, cape sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered.

Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot 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 references are for more detailed information on personal protection:

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

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

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

(4) OSHA, *Code of Federal Regulations*, Title 29—Labor, Chapter XVII, Part 1910. Washington, D.C.: U. S. Government Printing Office.¹⁴

A9.2 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 workpieces should be grounded. The workpiece lead is not a ground lead; it is used only to complete the welding circuit. A separate connection is required to ground the workpiece.

The correct cable size should be used since sustained overloading will cause cable failure and can result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity.

To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned OFF. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be 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, Cutting, and Allied Processes* and NFPA No. 70, *The National Electrical Code* should be followed.¹⁵

A9.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management, welders, and other personnel should be aware of the effects of these fumes and gases. The amount and composition of these

¹⁴ OSHA standards may be obtained from the U. S. Government Printing Office, Washington, D.C. 20402.

¹⁵ NFPA documents are available from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

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

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

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

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

(2) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment* published by the American Conference of Governmental Industrial Hygienists (ACGIH).¹⁶

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

A9.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

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

A9.4.1 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.

A9.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base-metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by 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*. 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 in ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

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

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

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

A9.4.3 Ionizing radiation information sources include the following:

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

(2) Manufacturer's product information literature.

A9.4.4 Nonionizing radiation information sources include:

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

¹⁶ ACGIH documents are available from the American Conference of Governmental Industrial Hygienists, Kemper Woods Center, 1330 Kemper Meadow Drive, Cincinnati, OH 45240.

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

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

(4) Hinrichs, J. F. "Project Committee on Radiation-Summary Report." *Welding Journal* 57 (January 1978):62-65.

(5) Marshall, W. J., Sliney, D. H., and others. "Optical Radiation Levels Produced by Air-Carbon Arc Cutting Processes." *Welding Journal* 59 (March 1980):43-46.

(6) Moss, C. E. and Murray, W. E. "Optical Radiation Levels Produced in Gas Welding, Torch Brazing, and Oxygen Cutting." *Welding Journal* 58 (September 1979):37-46.

(7) Moss, C. E. "Optical Radiation Transmission Levels Through Transparent Welding Curtains." *Welding Journal* 58 (March 1979):69s-75s.

(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.¹⁷

(9) National Technical Information Service. 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.

¹⁷ National Technical Information documents are available from the National Technical Information Service, Springfield, VA 22161.

