

Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods



American Welding Society®



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American National Standards Institute
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Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods

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Prepared by the
American Welding Society (AWS) A5 Committee on Filler Metals and Allied Materials

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

Classification and other requirements are specified for numerous grades of flux cored and metal cored stainless steel electrodes and rods.

Designations for the flux cored electrodes and rods indicate the chemical composition of the weld metal, the position of welding, and the external shielding gas required (for those classifications for which one is required). Designations for the metal cored electrodes indicate the chemical composition of the weld metal only.

The requirements include general requirements, testing and packaging. Annex A provides general application guidelines for individual alloys and other useful information about welding electrodes.



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Foreword

This foreword is not part of AWS A5.22/A5.22M: 2012, *Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*, but is included for informational purposes only.

This document is the second of the A5.22 specifications which makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore each system must be used independently of the other, without combining values in any way. In selecting rational metric units, AWS A1.1, *Metric Practice Guide for the Welding Industry*, and ISO 544: *Welding consumables — Technical delivery conditions for welding filler metals — Type of product, dimensions, tolerances and markings*, are used where suitable. Tables and figures make use of both U.S. Customary and SI Units, which, with the application of the specified tolerances, provides for interchangeability of products in both the U.S. Customary and SI Units.

New filler metal classification E2307TX-X has been added in this edition. In this edition, analysis for bismuth (Bi) is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.002%.

The first AWS specification for stainless steel electrodes for flux cored arc welding was issued in 1974 and approved by the American National Standards Institute a year later. The revision history is shown below:

AWS A5.22-74	<i>Specification for Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes</i>
ANSI W3.22-1975	
AWS A5.22-80	<i>Specification for Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes</i>
ANSI/AWS A5.22-95	<i>Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding</i>
AWS A5.22/A5.22M:2010	<i>Specification for Stainless Steel Flux Cored and Metal Cored Electrodes and Rods</i>

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A5 Committee on Filler Metals and Allied Materials, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods

1. Scope

This specification prescribes requirements for the classification of flux cored stainless steel electrodes for flux cored arc welding, flux cored stainless steel rods for root pass welding with the gas tungsten arc process, and metal cored stainless steel electrodes for gas metal arc welding, gas tungsten arc welding, plasma arc welding, submerged arc welding, and any other process to which they may be applied.¹

The chromium content of undiluted weld metal from these electrodes and rods is not less than 10.5% 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.

Safety and health issues are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clauses A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable state and federal regulations.

This specification uses both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification with the designation A5.22 uses U.S. Customary Units. The specification A5.22M uses SI Units. The latter are shown within brackets ([]) or in appropriate columns in tables. Standard dimensions based on either system may be used for sizing of filler metals or packaging or both under A5.22 or A5.22M specifications.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard referred to applies.

2.1 The following AWS standards² are referenced in the mandatory sections of this document:

AWS A5.01M/A5.01 (ISO 14344 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

AWS A5.02/A5.02M:2007, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*

AWS A5.32/A5.32M (ISO 14175:2008 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*

¹ Metal cored electrodes, currently also classified in A5.9/A5.9M, will be deleted from the next revision of that specification.

² AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

2.2 The following ANSI standard³ is referenced in the mandatory sections of this document.

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.3 The following ASTM standards⁴ are referenced in the mandatory sections of this document:

ASTM A 36/A 36M, *Standard Specification for Carbon Structural Steel*

ASTM A 240, *Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and General Applications*

ASTM A 285, *Pressure Vessel Plates, Carbon steel, Low- and Intermediate-Tensile Strength*

ASTM A 515, *Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

ASTM E 23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specification*

ASTM E 353, *Chemical Analysis of Stainless, Heat-Resisting, Maraging and Other Similar Chromium-Nickel-Iron Alloys*

ASTM E 1032, *Standard Test Methods for Radiographic Examination of Weldments*

2.4 The following ISO standard⁵ is referenced in the normative sections of this document:

ISO 80000-1, *Quantities and units*

3. Classification

The welding electrodes and rods covered by A5.22/A5.22M utilize a classification system that is independent of U.S. Customary Units and the International System of Units (SI). Classifications for the flux cored electrodes and rods indicate the chemical composition of the undiluted weld metal, as specified in Table 1FC, the position of welding, and the external shielding gas required (for those classifications for which one is required), as specified in Table 2. Classifications for the metal cored electrodes indicate the chemical composition of the undiluted weld metal only, as specified in Table 1MC.

Electrodes and rods may not be classified under more than one classification in this specification, except on the basis of carbon content and shielding gas used provided they meet all the requirements of those classifications as specified in Table 1FC and Table 1MC. More than one classification based upon any element other than carbon is not permitted. Table 3 lists a number of examples of possible dual classification.

The flux cored electrodes and rods classified under this specification are intended for flux cored arc welding and for root pass welding with the gas tungsten arc process, but this does not prohibit their use with any other process for which they are found suitable. The metal cored electrodes and rods classified under this specification are intended for gas metal arc welding, gas tungsten arc welding, plasma arc welding, and submerged arc welding, but this does not prohibit their use with any other process for which they are found suitable.

³ This ANSI standard is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

⁴ ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

⁵ ISO standards are published by International Organization of Standardization, 1, rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland.

Table 1FC
Chemical Composition Requirements for Flux Cored Electrodes for Undiluted Weld Metal

AWS Classification ^c	UNS Number ^d	Weight Percent ^{a, b}											Other ^e
		C	Cr	Ni	Mo	Nb Plus 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	—	0.75	—
E308TX-X	W30831	0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308HTX-X	W30831	0.04–0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308LTX-X	W30835	0.04	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
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	—	0.75	—
E309TX-X	W30931	0.10	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309HTX-X	W30931	0.04–0.10	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309LTX-X	W30935	0.04	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
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	—	0.75	—
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	—	0.75	—
E309LNbTX-X	W30932	0.04	22.0–25.0	12.0–14.0	0.75	0.70–1.00	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E310TX-X	W31031	0.20	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	1.0	0.03	0.03	—	0.75	—
E312TX-X	W31331	0.15	28.0–32.0	8.0–10.5	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
E316HTX-X	W31631	0.04–0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
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	—	0.75	—
E347TX-X	W34731	0.08	18.0–21.0	9.0–11.0	0.75	8 × C min. – 1.0 max.	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E347HTX-X	W34731	0.04–0.08	18.0–21.0	9.0–11.0	0.75	8 × C min. – 1.0 max.	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E409TX-X	W40931	0.10	10.5–13.5	0.60	0.75	—	0.80	1.0	0.04	0.03	—	0.75	Ti = 10 × C min. – 1.5 max.
E409NbTX-X	W40957	0.10	10.5–13.5	0.6	0.5	8 × C min. – 1.5 max.	1.2	1.0	0.04	0.03	—	0.5	—

(Continued)

Table 1FC (Continued)
Chemical Composition Requirements for Flux Cored Electrodes for Undiluted Weld Metal

AWS Classification ^c	UNS Number ^d	Weight Percent ^{a, b}											Other ^e
		C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si	P	S	N	Cu	
E410TX-X	W41031	0.12	11.0–13.5	0.60	0.75	—	1.2	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
E430TX-X	W43031	0.10	15.0–18.0	0.60	0.75	—	1.2	1.0	0.04	0.03	—	0.75	—
E430NbTX-X	W43057	0.10	15.0–18.0	0.6	0.5	0.5–1.5	1.2	1.0	0.04	0.03	—	0.5	—
E2209TX-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	0.75	—
E2307TX-X	S82371	0.04	22.5–25.5	6.5–10.0	0.8	—	2.0	1.0	0.03	0.02	0.10–0.20	0.50	—
E2553TX-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	0.10–0.25	1.5–2.5	—
E2594TX-X	W39594	0.04	24.0–27.0	8.0–10.5	2.5–4.5	—	0.5–2.5	1.0	0.04	0.03	0.20–0.30	1.5	W=1.0
EGTX-X ^g		Not Specified											
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	—	0.75	—
E308T0-3	W30833	0.08	19.5–22.0	9.0–11.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308HT0-3	W30833	0.04–0.08	19.5–22.0	9.0–11.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308LT0-3	W30837	0.04	19.5–22.0	9.0–11.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
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	—	0.75	—
E308LMoT0-3	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	—	0.75	—
E309T0-3	W30933	0.10	23.0–25.5	12.0–14.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309LT0-3	W30937	0.04	23.0–25.5	12.0–14.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
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	—	0.75	—
E309LNbT0-3	W30934	0.04	23.0–25.5	12.0–14.0	0.75	0.70–1.00	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E310T0-3	W31031	0.20	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	1.0	0.03	0.03	—	0.75	—
E312T0-3	W31231	0.15	28.0–32.0	8.0–10.5	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
E316LT0-3	W31637	0.04	18.0–20.5	11.0–14.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E316LKT0-3 ^f	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	—	0.75	—

(Continued)

Table 1FC (Continued)
Chemical Composition Requirements for Flux Cored Electrodes for Undiluted Weld Metal

AWS Classification ^c	UNS Number ^d	Weight Percent ^{a, b}											Other ^e
		C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si	P	S	N	Cu	
E317LT0-3	W31737	0.04	18.5–21.0	13.0–15.0	3.0–4.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E347T0-3	W34733	0.08	19.0–21.5	9.0–11.0	0.75	8 × C min. – 1.0 Max.	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E409T0-3	W40931	0.10	10.5–13.5	0.60	0.75	—	0.80	1.0	0.04	0.03	—	0.75	Ti = 10 × C min. – 1.5 max.
E410T0-3	W41031	0.12	11.0–13.5	0.60	0.75	—	1.0	1.0	0.04	0.03	—	0.75	—
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	—	0.75	—
E430T0-3	W43031	0.10	15.0–18.0	0.60	0.75	—	1.0	1.0	0.04	0.03	—	0.75	—
E2209T0-3	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	0.75	—
E2307T0-3	S82371	0.04	22.5–25.5	6.5–10.0	0.8	—	2.0	1.0	0.03	0.02	0.10–0.20	0.50	—
E2553T0-3	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	0.10–0.25	1.5–2.5	—
E2594T0-3	W39594	0.04	24.0–27.0	8.0–10.5	2.5–4.5	—	0.5–2.5	1.0	0.04	0.03	0.20–0.30	1.5	W = 1.0
EGTX-3 ^g		Not Specified											
R308LT1-5	W30835	0.03	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.2	0.04	0.03	—	0.75	—
R309LT1-5	W30935	0.03	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.2	0.04	0.03	—	0.75	—
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	—	0.75	—
R347T1-5	W34731	0.08	18.0–21.0	9.0–11.0	0.75	8 × C min. – 1.0 max.	0.5–2.5	1.2	0.04	0.03	—	0.75	—
RGT1-5 ^g		Not Specified											

^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 or –4) as shown in the AWS Classification column in Table 2).

^d SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System*.

^e Analysis for Bi is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.002%. See A8.1.4 for more information.

^f This alloy is designed for cryogenic applications.

^g See A2.2.7 and A2.2.8.

Notes:

1. Cb has been changed to Nb.

2. Classifications E502TX-X and E505TX-X have been moved from this revision to AWS A5.29/5.29M as new classifications E8XTX-B6/E8XTX-B6L and E8XTX-B8/E8XTX-B8L respectively.

Table 1MC
Chemical Composition Requirements for Metal Cored Electrodes for Undiluted Weld Metal

Weight Percent ^{a, b}													
AWS Classification	UNS Number ^c	C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si ^d	P	S	N	Cu	Other ^e
EC209	S20980	0.05	20.5–24.0	9.5–12.0	1.5–3.0	—	4.0–7.0	0.90	0.03	0.03	0.10–0.30	0.75	V = 0.10–0.30
EC218	S21880	0.10	16.0–18.0	8.0–9.0	0.75	—	7.0–9.0	3.5–4.5	0.03	0.03	0.08–0.18	0.75	—
EC219	S21980	0.05	19.0–21.5	5.5–7.0	0.75	—	8.0–10.0	1.00	0.03	0.03	0.10–0.30	0.75	—
EC240	S24080	0.05	17.0–19.0	4.0–6.0	0.75	—	10.5–13.5	1.00	0.03	0.03	0.10–0.30	0.75	—
EC307	S30780	0.04–0.14	19.5–22.0	8.0–10.7	0.5–1.5	—	3.30–4.75	0.30–0.65	0.03	0.03	—	0.75	—
EC308	S30880	0.08	19.5–22.0	9.0–11.0	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC308Si	S30881	0.08	19.5–22.0	9.0–11.0	0.75	—	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—
EC308H	S30880	0.04–0.08	19.5–22.0	9.0–11.0	0.50	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC308L	S30883	0.03	19.5–22.0	9.0–11.0	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC308LSi	S30888	0.03	19.5–22.0	9.0–11.0	0.75	—	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—
EC308Mo	S30882	0.08	18.0–21.0	9.0–12.0	2.0–3.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC308LMo	S30886	0.04	18.0–21.0	9.0–12.0	2.0–3.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC309	S30980	0.12	23.0–25.0	12.0–14.0	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC309Si	S30981	0.12	23.0–25.0	12.0–14.0	0.75	—	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—
EC309L	S30983	0.03	23.0–25.0	12.0–14.0	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC309LSi	S30988	0.03	23.0–25.0	12.0–14.0	0.75	—	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—
EC309Mo	S30982	0.12	23.0–25.0	12.0–14.0	2.0–3.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC309LMo	S30986	0.03	23.0–25.0	12.0–14.0	2.0–3.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC310	S31080	0.08–0.15	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC312	S31380	0.15	28.0–32.0	8.0–10.5	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC316	S31680	0.08	18.0–20.0	11.0–14.0	2.0–3.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC316Si	S31681	0.08	18.0–20.0	11.0–14.0	2.0–3.0	—	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—
EC316H	S31680	0.04–0.08	18.0–20.0	11.0–14.0	2.0–3.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC316L	S31683	0.03	18.0–20.0	11.0–14.0	2.0–3.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC316LSi	S31688	0.03	18.0–20.0	11.0–14.0	2.0–3.0	—	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—

(Continued)

Table 1MC (Continued)
Chemical Composition Requirements for Metal Cored Electrodes for Undiluted Weld Metal

AWS Classification	UNS Number ^c	Weight Percent ^{a,b}											Other ^e
		C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si ^d	P	S	N	Cu	
EC316LMn	S31682	0.03	19.0–22.0	15.0–18.0	2.5–3.5	—	5.0–9.0	0.30–0.65	0.03	0.03	0.10–0.20	0.75	—
EC317	S31780	0.08	18.5–20.5	13.0–15.0	3.0–4.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC317L	S31783	0.03	18.5–20.5	13.0–15.0	3.0–4.0	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC318	S31980	0.08	18.0–20.0	11.0–14.0	2.0–3.0	8 × C min. – 1.0 max.	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC320	N08021	0.07	19.0–21.0	32.0–36.0	2.0–3.0	8 × C min. – 1.0 max.	2.5	0.60	0.03	0.03	—	3.0–4.0	—
EC320LR	N08022	0.025	19.0–21.0	32.0–36.0	2.0–3.0	8 × C min. – 0.40 max.	1.5–2.0	0.15	0.015	0.02	—	3.0–4.0	—
EC321	S32180	0.08	18.5–20.5	9.0–10.5	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	Ti = 9 × C min. – 1.0 max.
EC330	N08331	0.18–0.25	15.0–17.0	34.0–37.0	0.75	—	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC347	S34780	0.08	19.0–21.5	9.0–11.0	0.75	10 × C min. – 1.0 max.	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—
EC347Si	S34788	0.08	19.0–21.5	9.0–11.0	0.75	10 × C min. – 1.0 max.	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—
EC383	N08028	0.025	26.5–28.5	30.0–33.0	3.2–4.2	—	1.0–2.5	0.50	0.02	0.03	—	0.70–1.50	—
EC385	N08904	0.025	19.5–21.5	24.0–26.0	4.2–5.2	—	1.0–2.5	0.50	0.02	0.03	—	1.2–2.0	—
EC409	S40900	0.08	10.5–13.5	0.6	0.50	—	0.8	0.8	0.03	0.03	—	0.75	Ti = 10 × C min. – 1.5 max.
EC409Nb	S40940	0.08	10.5–13.5	0.6	0.50	10 × C min. – 0.75 max.	0.8	1.0	0.04	0.03	—	0.75	—
EC410	S41080	0.12	11.5–13.5	0.6	0.75	—	0.6	0.5	0.03	0.03	—	0.75	—
EC410NiMo	S41086	0.06	11.0–12.5	4.0–5.0	0.4–0.7	—	0.6	0.5	0.03	0.03	—	0.75	—
EC420	S42080	0.25–0.40	12.0–14.0	0.6	0.75	—	0.6	0.5	0.03	0.03	—	0.75	—
EC430	S43080	0.10	15.5–17.0	0.6	0.75	—	0.6	0.5	0.03	0.03	—	0.75	—
EC439	S43035	0.04	17.0–19.0	0.6	0.5	—	0.8	0.8	0.03	0.03	—	0.75	Ti = 10 × C min. – 1.1 max.

(Continued)

Table 1MC (Continued)
Chemical Composition Requirements for Metal Cored Electrodes for Undiluted Weld Metal

Weight Percent ^{a, b}													
AWS Classification	UNS Number ^c	C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si ^d	P	S	N	Cu	Other ^e
EC439Nb	S43035	0.04	17.0–20.0	0.6	0.5	8 × C min. – 0.75 max.	0.8	0.8	0.03	0.03	—	0.75	Ti = 0.10 – 0.75
EC446LMo	S44687	0.015	25.0–27.5	f	0.75–1.50	—	0.4	0.4	0.02	0.02	0.015	f	—
EC630	S17480	0.05	16.00–16.75	4.5–5.0	0.75	0.15–0.30	0.25–0.75	0.75	0.03	0.03	—	3.25–4.00	—
EC19–10H	S30480	0.04–0.08	18.5–20.0	9.0–11.0	0.25	0.05	1.0–2.0	0.30–0.65	0.03	0.03	—	0.75	Ti = 0.05
EC16-8-2	S16880	0.10	14.5–16.5	7.5–9.5	1.0–2.0	—	1.0–2.0	0.30–0.65	0.03	0.03	—	0.75	—
EC2209	S39209	0.03	21.5–23.5	7.5–9.5	2.5–3.5	—	0.50–2.00	0.90	0.03	0.03	0.08–0.20	0.75	—
EC2553	S39553	0.04	24.0–27.0	4.5–6.5	2.9–3.9	—	1.5	1.0	0.04	0.03	0.10–0.25	1.5–2.5	—
EC2594	S32750	0.03	24.0–27.0	8.0–10.5	2.5–4.5	—	2.5	1.0	0.03	0.02	0.20–0.30	1.5	W = 1.0
EC33-31	R20033	0.015	31.0–35.0	30.0–33.0	0.5–2.0	—	2.00	0.50	0.02	0.01	0.35–0.60	0.3–1.2	—
													Co = 16.0–21.0 W = 2.0–3.5 Nb = 0.30 Ta = 0.30–1.25 Al = 0.10–0.50 Zr = 0.001–0.100 La = 0.005–0.100 B = 0.02
EC3556	R30556	0.05–0.15	21.0–23.0	19.0–22.5	2.5–4.0	—	0.50–2.00	0.20–0.80	0.04	0.015	0.10–0.30	—	
ECG ^g		Not Specified											

^a Analysis shall be made for the elements for which specific values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total, excluding iron, does not exceed 0.50%.

^b Single values shown are maximum percentages.

^c SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System*.

^d For special applications, electrodes may be purchased with less than the specified silicon content.

^e Analysis for Bi is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.002%. See A8.1.4 for more information.

^f Total of Ni + Cu is 0.5 wt % maximum.

^g See A2.2.7 and A2.2.8.

Note: Classifications EC502 and EC505 have been discontinued. Classifications ECB6 and E80C-B6, which are similar to EC502, have been added to AWS A5.23 and AWS A5.28 respectively. Classifications ECB8 and E80C-B8, which are similar to EC505, have been added to AWS A5.23 and AWS A5.28, respectively.

Table 2
Required Shielding Medium, Polarity, and Welding Process

AWS Classification ^a	External Shielding Gas ^b	Welding Polarity	Welding Process
EXXXTX-1	CO ₂ ^d	DCEP	FCAW
EXXXTX-3	none (self-shielded)	DCEP	FCAW
EXXXTX-4	75%–80% Argon/remainder CO ₂ ^e	DCEP	FCAW
RXXXT1-5	100% Argon ^f	DCEN	GTAW
EXXXTX-G	Not Specified ^c	Not Specified ^c	FCAW
RXXXT1-G	Not Specified ^c	Not Specified ^c	GTAW
ECXXX	Argon with up to 2% O ₂ ^g	DCEP	GMAW
	100% Argon ^f	DCEN	GTAW

^a 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. Refer to Figure A.1 and Clause A2 for a complete description of this classification system.

^b The requirement for the use of a specified external shielding gas 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.

^c See A2.2.7 to A2.2.9 for additional information.

^d AWS A5.32/A5.32M Class C1.

^e AWS A5.32/A5.32M Class M21.

^f AWS A5.32/A5.32M Class I1.

^g AWS A5.32/A5.32M Class I1 or M13.

Table 3
Examples of Potentially Occurring Dual Classified Electrodes

Primary Classification	Alternate Classification
E308HT1-1	E308T1-1
E308LT0-1	E308T0-1
E308LT0-3	E308T0-3
E308LT1-1	E308LT1-4
EC308L	EC308

4. Acceptance

Acceptance⁶ of the material shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.⁷

⁶ See Annex Clause A3 for further information concerning acceptance, testing of material shipped, and AWS A5.01M/A5.01 (ISO 14344 MOD).

⁷ See Annex Clause A4 for further information concerning acceptance and testing called for to meet this requirement.

6. Rounding-Off Procedure

For the purpose of determining conformance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E 29 or ISO 80000-1, Annex B, Rule A (the results are the same). If the measured values are obtained by equipment calibrated in units other than those of the specified limit, the measured values shall be converted to the units of the specified limit before rounding off. If an average value is to be compared to the specified limit, rounding off shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi for tensile strength for U.S. Customary Unit standard [to the nearest 10 MPa for tensile strength for S.I. Unit standard] and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded-off results shall fulfill the requirements of the appropriate table for the classification under test.

7. Summary of Tests

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 [Clauses 9 through 15](#).

Chemical analysis is required for each size of electrode and rod. The tests for mechanical properties and soundness are conducted on weld metal from the 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 the largest size and smallest size manufactured.

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

In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the weld test assembly or test specimen(s) or test sample(s), or in conducting the

Table 4
Required Tests

Classification ^a	Chemical Analysis	Radiographic Test	Tension Test	Face Bend Test	Root Bend Test	Impact Test	Fillet Weld Test
E2XXXT0-X	Required	Required	Required	NR ^b	NR ^b	NR ^b	NR ^b
E3XXT0-X	Required	Required	Required	Required	NR ^b	NR ^{b,c}	NR ^b
E316LKT0-3	Required	Required	Required	Required	NR ^b	Required	NR ^b
E4XXT0-X	Required	Required	Required	NR ^b	NR ^b	NR ^b	NR ^b
E2XXXT1-X	Required	Required	Required	NR ^b	NR ^b	NR ^b	Required
E3XXT1-X	Required	Required	Required	Required	NR ^b	NR ^{b,c}	Required
E4XXT1-X	Required	Required	Required	NR ^b	NR ^b	NR ^b	Required
R3XXT1-5	Required	Required	Required	NR ^b	Required	NR ^b	NR ^b
ECXXX	Required	NR ^b	NR ^b	NR ^b	NR ^b	NR ^b	NR ^b

^a In the table, the “X” at the end of the “EXXXT0-X” classifications refers to the shielding medium (-1, -3, -4, or -G) the “X” at the end of the “EXXXT1-X” classifications refers to the shielding medium (-1, -4, or -G).

^b NR = not required (see A2.2.8)

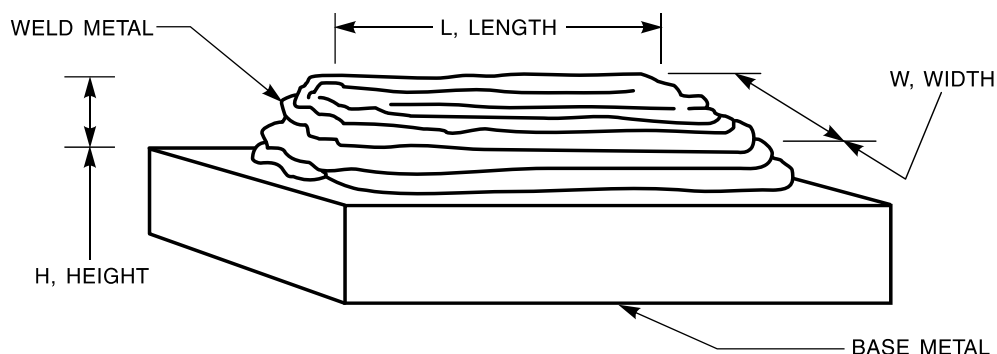
^c Impact testing is required when the optional supplemental designator “J” is added to the classification. See Figure A.1.

test, the test shall be considered invalid, without regard to whether the test was actually completed, or whether test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9. Test Assemblies

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

- (1) The weld pad in Figure 1 for chemical analysis of undiluted weld metal, or a fused sample of a metal cored electrode
- (2) The groove weld in Figure 2 for tension, impact, and radiographic testing of the weld metal
- (3) The groove weld in Figure 3A for the face bend test, or Figure 3B for the root bend test
- (4) The fillet weld in Figure 4 for usability of the electrode



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 E2XXXTX-X ECXXX ^a	0.035	0.9								
	0.045	1.2	3	75	3/4	19	1/2	13	3/8	10
	0.052	1.4								
	1/16	1.6	3	75	3/4	19	5/8	16	1/2	13
	5/64	2.0								
	3/32	2.4	3-1/2	88	1	25	3/4	19	5/8	16
	7/64	2.8								
R3XXT1-5	5/64	2.0								
	0.087	2.2	3	75	3/4	19	3/8	10	1/4	7
	3/32	2.4								

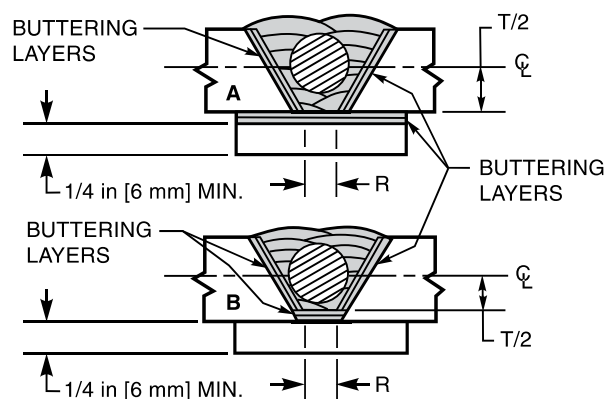
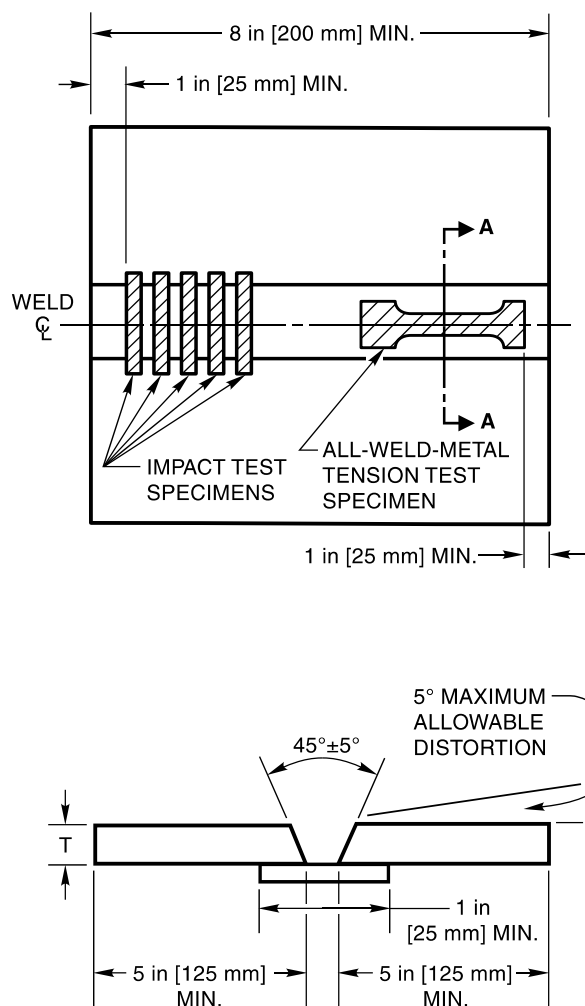
^a Refer to 10.2 for alternative to the pad for chemical analysis.

Notes:

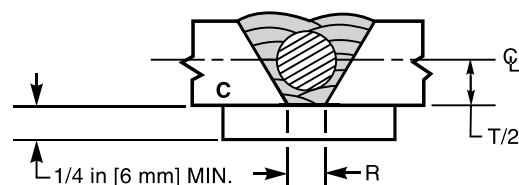
1. Number of passes per layer is optional.
2. Width and thickness of the base plate may be any dimension suitable for the electrode diameter and current in use.
3. The first and last inch (25 mm) of the weld length shall be disregarded. The top surface shall be removed and chemical analysis samples shall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

Source: Adapted from AWS A5.22-95 (R2005)—Errata.

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal



**BUTTERING CONDITIONS FOR
CARBON STEEL TEST PLATE ASSEMBLY**



**MATCHING COMPOSITION FOR
STAINLESS STEEL TEST PLATE ASSEMBLY**

**BUTTERING CONDITIONS AND
TENSION SPECIMEN LOCATION**

SECTION A-A

DIAGRAM A AND DIAGRAM B FOR CARBON STEEL TEST PLATES. DIAGRAM C FOR TEST PLATES OF MATCHING COMPOSITION OF TYPE 410, 430A, OR 430B FOR THE E4XXTX-X CLASSIFICATIONS ONLY AND TYPES 304 OR 304L FOR THE REMAINDER.

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 E2XXTX-X	0.035	0.9	1/2	12	3/8	10	1 or 2	2, 3, or 4	6 to 9
	0.045	1.2							
	0.052	1.4							
	1/16	1.6	3/4	20	3/8	10	1 or 2	2 or 3 ^a	5 to 8
	5/64	2.0							
	3/32	2.4							
	7/64	2.8							
R3XXT1-5	1/8	3.2	3/4	20	3/8	10	1 or 2	2 or 3 ^a	4 to 6
	5/32	4.0							
	5/64	2.0							
	0.087	2.2	1/2	12	1/4	6	1 or 2	2 or 3 ^a	5 to 8
	3/32	2.4							

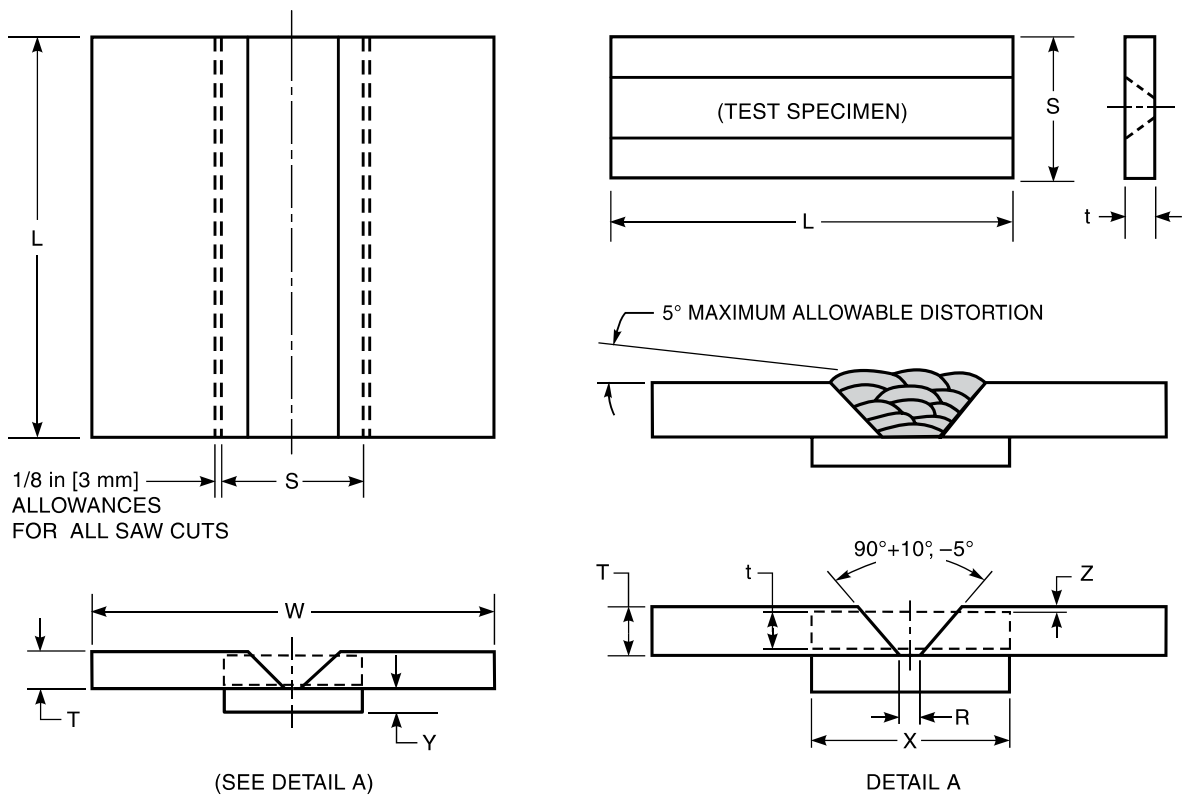
^a Final layer may be 4 passes.

Notes:

1. The tensile test specimen shall be located such that its centerline to be T/2 above any buttering, if used, otherwise on the centerline of the plate. Its dimensions shall be as specified in 12.1, and AWS B4.0 [AWS B4.0M].
2. For test assemblies requiring impact testing, the length shall be extended as needed for Charpy V-notch impact specimens, which shall be located as shown in Figure 6.

Source: Modified adoption of Figure 2 from AWS A5.1/A5.1M:2004 (ERRATA/REPRINT), and Figure 2 from AWS A5.4/A5.4M:2006.

Figure 2—Groove Weld Test Assembly for Tension, Impact, and Radiographic Tests

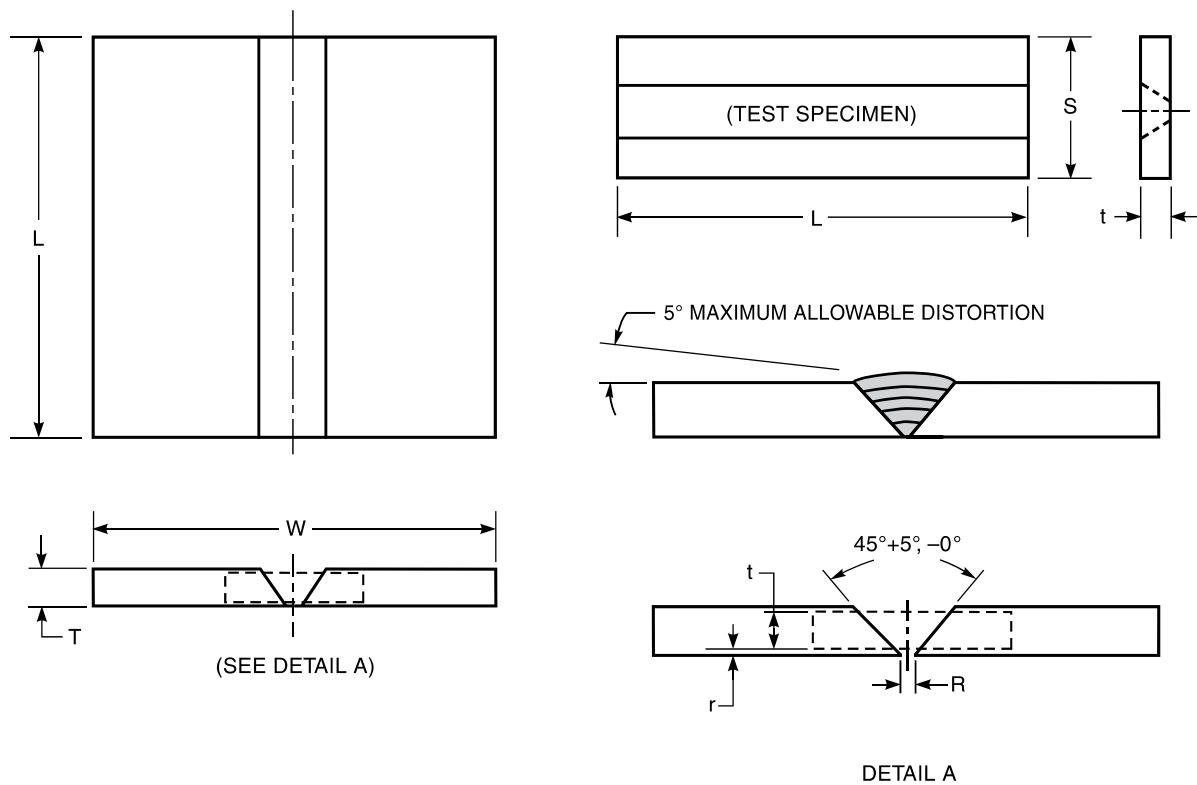


DIMENSIONS			
		in	mm
L	Length	6 min.	150 min.
R	Root opening	1/4 min.	6 min.
S	Specimen Width	2 ± 1/8	50 ± 3
T	Thickness	1/2	12
t	Specimen Thickness	3/8 min.	9.5 min.
W	Width	6 min.	150 min.
X	Backing Bar Width	2 max.	50 max.
Y	Backing Bar Thickness	1/4 min.	6 min.
Z	Specimen Location	1/16 min.	1.5 min.

Electrode Diameter		Recommended Passes Per Layer		Recommended Number of Layers
in	mm	Layer 1	Layers 2 to Top ^a	
0.035	0.9	1	2 to 3	3 to 5
0.045	1.2			
0.052	1.4			
1/16	1.6			
5/64	2.0			
3/32	2.4	1	1 to 2	2 to 4
7/64	2.8			
1/8	3.2			
5/32	4.0			

^a Top layer must be 2 passes minimum.
Source: Modified adoption of Figure 3 from AWS A5.34/A5.34M:2007.

Figure 3A—Groove Weld Test Assembly for Face Bend Test



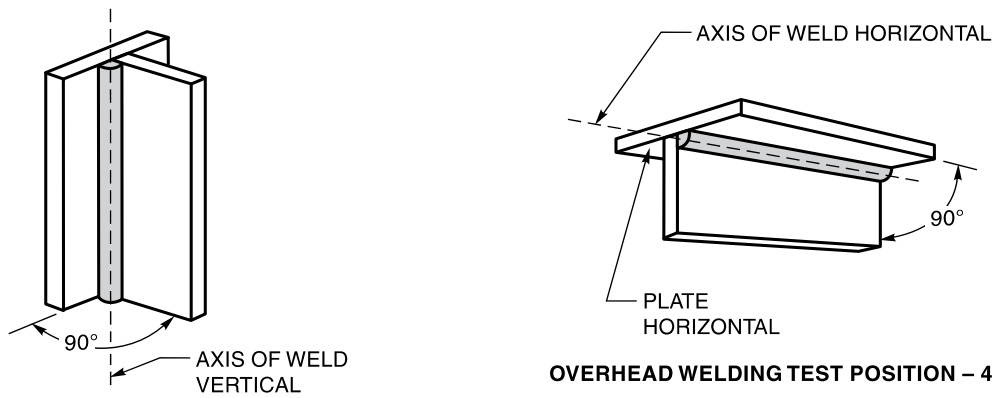
Note: Remove amount of material necessary to clean up root surface. Material removed should not exceed 1/64 in [0.4 mm].

DIMENSIONS					
		in	mm		
L	Length	6 min.	150 min.		
S	Specimen Width	2 ± 1/8	50 ± 3		
R	Root Opening	3/32 to 1/8	2.4 to 3.2		
r	Root Land	1/32 to 1/16	0.8 to 1.6		
T	Thickness	1/2	12		
t	Specimen Thickness	3/8 min.	9.5 min.		
W	Width	6 min.	150 min		

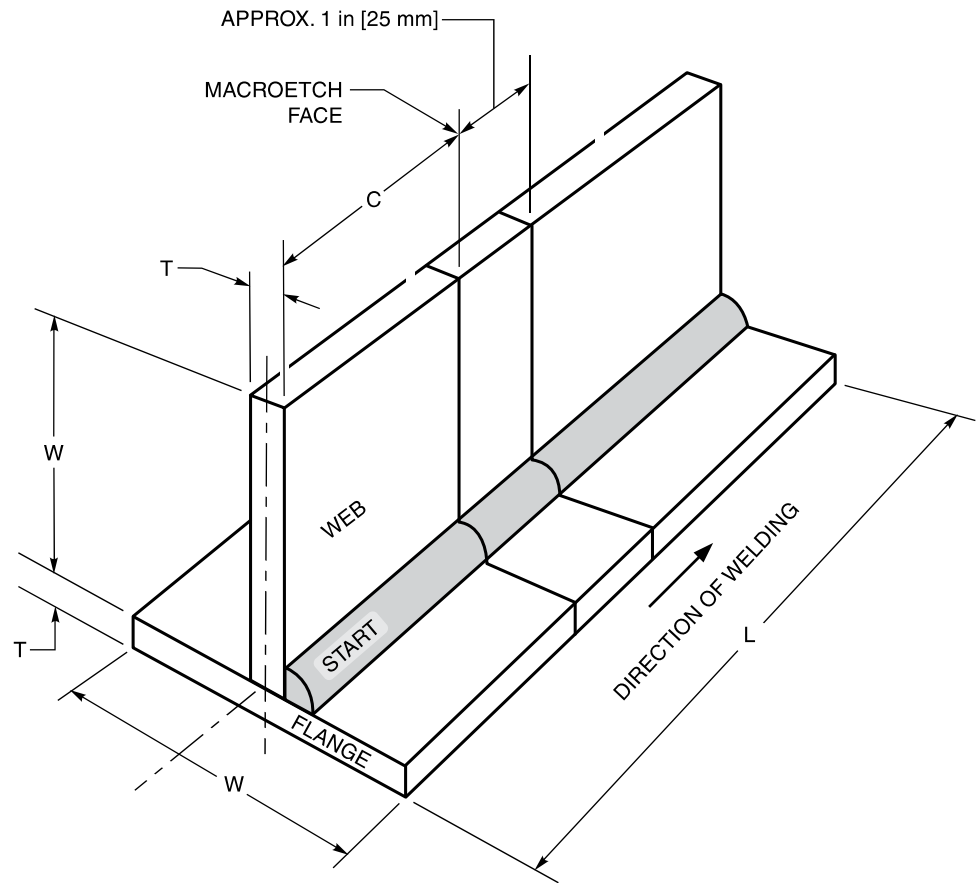
Diameter			Passes per Layer		
AWS Classification	in	mm	Layer 1	Layer 2	Layer 3 to Completion
R3XXT1-5	5/64	2.0	1	1	As required
	0.087	2.2			
	3/32	2.4			

Source: Modified adoption of Figure 3 from AWS A5.34/A5.34M:2007.

Figure 3B—Groove Weld Test Assembly for Root Bend Test



VERTICAL WELDING TEST POSITION – 3F



DIMENSION		in	mm
L	Length	8 min.	200 min.
C	Length to Cut	3 max.	75 max.
T	Thickness	3/8 max.	10 max.
W	Width	2 min.	50 min.

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

Source: Modified adoption of Figure 4 from AWS A5.34/A5.34M:2007.

Figure 4—Preparation of Fillet Weld Test Specimen

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 Figure 2, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

9.2 Preparation of each weld test assembly shall be as prescribed in 9.3, 9.4, and 9.5. Base metal for each assembly shall conform to the following or an equivalent:

9.2.1 For the chemical analysis pad, the base metal to be used shall be carbon steel, low-alloy steel, or stainless steel of 0.25% carbon maximum for all classifications of electrodes and rods except for classifications with up to 0.04% carbon maximum. For chemical analysis of these low carbon classifications, the base metal shall be steel of 0.03% carbon maximum. Other steels having a carbon content of 0.25% maximum may be used with the further restrictions in 9.3.2 and 10.1.2.

9.2.2 For all-weld-metal tension and radiographic tests, the steel to be used shall be of a matching type or either of the following:

- (1) For E4XXTX-X and E4XXT0-3 classifications—ASTM A 240, Types 410, 430A, or 430B
- (2) For all other classifications—ASTM A 240, Types 304 or 304L

Optionally, the steel may conform to one of the following specifications or their equivalents, provided two buttering layers of the filler metal, as shown in Figure 2, are deposited in stringer beads using electrodes of the same classification, or an equivalent classification of AWS A5.4/A5.4M, as that being classified:

ASTM A 36, ASTM A 285, or ASTM A 515

9.2.3 For the bend test, if required, and for the fillet weld test, if required, the steel to be used shall be of a matching type or either of the following:

- (1) For E4XXTX-X classifications—ASTM A 240, Types 410, 430A, or 430B
- (2) For all other electrode/rod classifications—ASTM A 240, Types 304 or 304L

9.3 Weld Pad

9.3.1 A weld pad shall be prepared as shown in Figure 1 (except when one of the alternatives to a weld pad in 9.1 or one of the methods given in 10.2 is selected). Base metal as specified in 9.2 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 [15°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 Figure 1, for each size of electrode or rod. Testing of this assembly shall be as specified in Clause 10.

9.3.2 The pad shall be at least four layers high. At least nine layers shall be required to obtain undiluted weld metal when base metal containing more than 0.03% carbon is used with the low-carbon classifications.

9.4 Groove Weld

9.4.1 For Mechanical Properties and Soundness

9.4.1.1 As required by Table 4, a test assembly shall be prepared and welded as specified in Figure 2 and in 9.4.1.2 and 9.4.1.3 using base metal of the appropriate type specified in 9.2.

9.4.1.2 The test assembly shall be welded in the flat position using the process, 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 5°. A welded test assembly that has warped more than 5° shall be discarded. Welded test assemblies shall not be straightened.

9.4.1.3 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 also

Table 5
Preheat and Interpass Temperature Requirements for Groove Weld Test Assemblies

AWS Classification ^a	Temperature			
	Minimum		Maximum	
	°F	°C	°F	°C
E2XXTX-X	60	15	300	150
E3XXTX-X	60	15	300	150
R3XXT1-5	60	15	300	150
E4XXTX-X ^b	300	150	500	260
EXXXTX-G	Not Specified			

^a 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.

^b Except for E410TX-X, which shall be 400°F [205°C] minimum preheat and 600°F [315°C] maximum interpass temperature.

required 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.

9.4.1.4 The assembly shall be tested as specified in Clauses 11, 12, and 14 with or without a postweld heat treatment as specified in Table 6, for the classification under test.

9.4.2 Bend Test

9.4.2.1 As required by Table 4, a test assembly shall be prepared and welded as shown in Figure 3A or 3B, as applicable, and specified in 9.4.2.2 through 9.4.2.4 using base metal of the appropriate type specified in 9.2.

9.4.2.2 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 preset or sufficiently restrained to prevent warpage in excess of 5°. A welded test assembly that has warped more than 5° shall be discarded. Weld test assemblies shall not be straightened.

9.4.2.3 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.

9.4.2.4 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.

9.4.2.5 The assembly shall be tested as specified in Clause 13, in the as-welded condition.

9.5 Fillet Weld

9.5.1 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 Figure 4 using base metal of the appropriate type specified in 9.2, 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 Clause 15.

9.5.2 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.

9.5.3 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.

Table 6
Tension Test Requirements

AWS Classification ^a	Tensile Strength, min.		Elongation, min.	Postweld Heat Treatment
	ksi	MPa	Percent	
E307TX-X	85	590	30	None
E308TX-X	80	550	30	None
E308HTX-X	80	550	30	None
E308LTX-X	75	520	30	None
E308MoTX-X	80	550	30	None
E308LMoTX-X	75	520	30	None
E309TX-X	80	550	30	None
E309HTX-X	80	550	30	None
E309LNbTX-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
E316HTX-X	75	520	30	None
E316LTX-X	70	485	30	None
E317LTX-X	75	520	20	None
E347TX-X	75	520	30	None
E347HTX-X	75	520	30	None
E409TX-X	65	450	15	None
E409NbTX-X	65	450	15	(d)
E410TX-X	75	520	20	(b)
E410NiMoTX-X	110	760	15	(c)
E430TX-X	65	450	20	(d)
E430NbTX-X	65	450	13	(d)
E2209TX-X	100	690	20	None
E2307TX-X	100	690	20	None
E2553TX-X	110	760	15	None
E2594TX-X	110	760	15	None
E316LKT0-3	70	485	30	None
E308HMoT0-3	80	550	30	None
EGTX-X	Not Specified			
R308LT1-5	75	520	30	None
R309LT1-5	75	520	30	None
R316LT1-5	70	485	30	None
R347T1-5	75	520	30	None

^a 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.

^b Heat to 1350°F to 1400°F [730°C to 760°C], hold for one hour (–0, +15 minutes), furnace cool at a rate not exceeding 200°F [110°C] per hour to 600° F [315°C] and air cool to ambient.

^c Heat to 1100°F to 1150°F [595°C to 620°C], hold for one hour (–0, +15 minutes), and air cool to ambient.

^d Heat to 1400°F to 1450°F [760°C to 790°C], hold for two hours (–0, +15 minutes), furnace cool at a rate not exceeding 100°F [55°C] per hour to 1100°F [595°C] and air cool to ambient.

10. Chemical Analysis

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

10.1.1 The sample for analysis shall be taken from weld metal obtained from either the weld pad prepared according to 9.3 or one of the alternatives in 9.1 produced with the filler metal and shielding medium with which they are classified.

10.1.2 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 Figure 1. The sample shall be free of slag and all other foreign materials. The sample shall come from above the eighth layer for weld metal from the low-carbon classifications when base metals containing more than 0.03% carbon are used for the pad.

10.1.3 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 Figure 2, shall be prepared for analysis by any suitable mechanical means.

10.2 Metal cored electrodes may be sampled for chemical analysis by the following methods:

(1) Gas tungsten arc welding may be used to melt a sample to result in a button (or slug) of sufficient size for analytical use.

(2) Other processes that melt a sample under a vacuum or inert atmosphere that result in a cast button (slug) may be used to produce a specimen for analysis.

(3) Gas metal arc welding with argon with up to 2% oxygen gas shielding may also be used to produce a homogeneous deposit for analysis. In this case, the weld pad shall be produced to the requirements for producing a flux core weld pad deposit.

These methods must be utilized in such a manner that no dilution of the base metal or mold occurs to contaminate the fused sample. Copper molds often are used to minimize the effects of dilution by the base metal or mold.

Special care must be exercised to minimize such dilution effects when testing low carbon filler metals.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be that found in ASTM E 353.

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

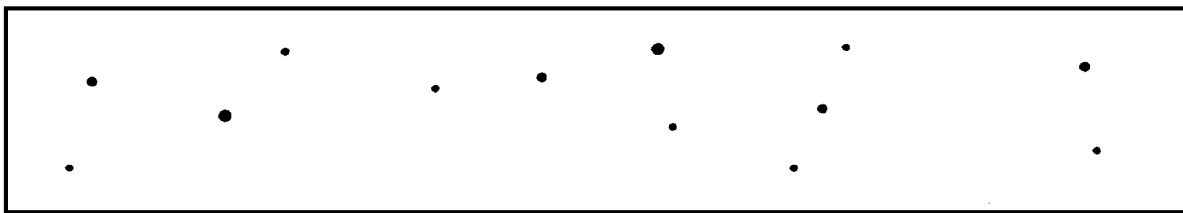
11. Radiographic Test

11.1 When required in Table 4, the groove weld described in 9.4.1 and shown in Figure 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 3/32 in [2.4 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 1032. The quality level of inspection shall be 2-2T.

11.3 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 Figure 5A or 5B, as applicable

**(A) ASSORTED ROUNDED INDICATIONS**

SIZE 1/64 in TO 1/16 in [0.4 mm TO 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 TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 2.

MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 4.

MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 7.

**(B) LARGE ROUNDED INDICATIONS**

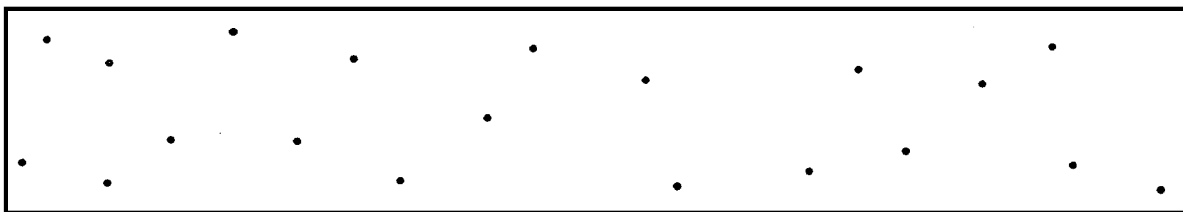
SIZE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.

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

**(C) MEDIUM ROUNDED INDICATIONS**

SIZE 1/32 in TO 3/64 in [0.8 mm TO 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 TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH.

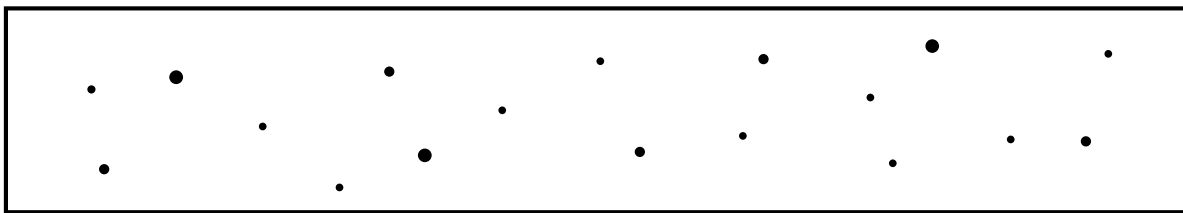
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 20.

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.

Source: AWS A5.4/A5.4M:2006, Figure 5A.

Figure 5A—Rounded Indication Standards for Radiographic Test—1/2 in [12 mm] Plate

**(A) ASSORTED ROUNDED INDICATIONS**

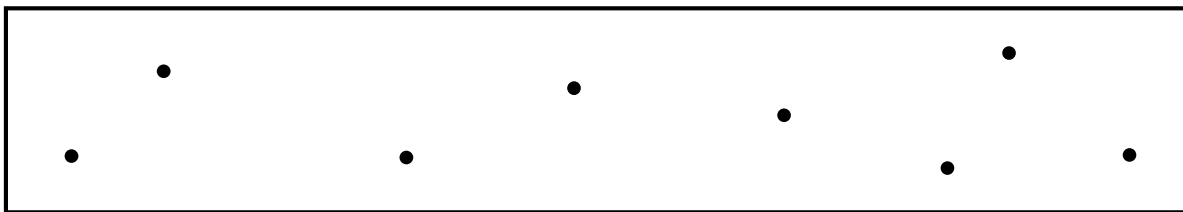
SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.

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

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

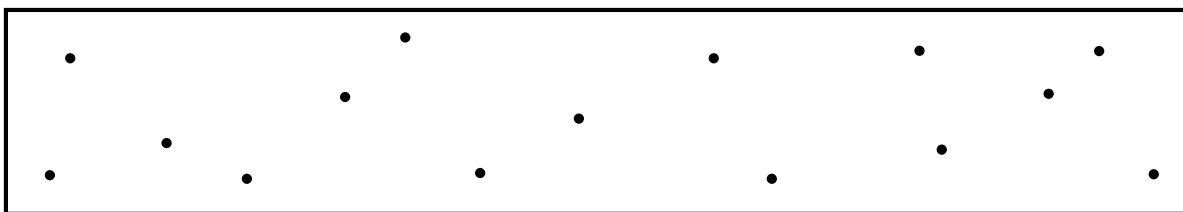
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.

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

**(B) LARGE ROUNDED INDICATIONS**

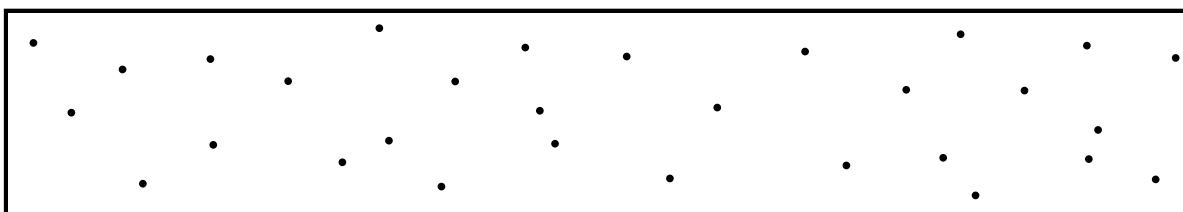
SIZE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.

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

**(C) MEDIUM ROUNDED INDICATIONS**

SIZE 1/32 in TO 3/64 in [0.8 mm TO 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 TO 1/32 in [0.4 mm TO 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.

Source: AWS A5.4/A5.4M:2006, Figure 5B.

Figure 5B—Rounded Indication Standards for Radiographic Test—3/4 in [20 mm] Plate

(5)(a) in any 6 in [150 mm] length of the 1/2 in [13 mm] thick test assembly: no individual slag inclusion longer than 7/32 in [5.6 mm] and a maximum total length of 7/16 in [11 mm] for all slag inclusions.

(5)(b) in any 6 in [150 mm] length of the 3/4 in [20 mm] thick test assembly: no individual slag inclusion in excess of 9/32 in [7.1 mm] and a maximum total length of 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.

11.3.1 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.

11.3.2 Indications whose largest dimension does not exceed 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.

12. Tension Test

12.1 One all-weld-metal tension test specimen, as specified in the Tension Test section of AWS B4.0 or B 4.0M, shall be machined from the groove weld described in 9.4.1 and shown in Figure 2. The all-weld-metal tension test specimen shall have a gage length-to-diameter ratio of 4:1.

The specimen shall be tested in the manner described in the tension test section of AWS B4.0 or B4.0M. The 1/2 in [12 mm] plate uses a 0.250 in [6 mm] tension specimen, while the 3/4 in [20 mm] plate uses a 0.500 in [13 mm] specimen.

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

13. Bend Test

13.1 Electrodes

13.1.1 One longitudinal face bend specimen, as required in Table 4, shall be machined from the groove weld test assembly described in 9.4.2 and shown in Figure 3A.

13.1.2 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° over a radius of 3/4 in [19 mm]. Typical bending jigs are shown in AWS B4.0 or B4.0M. The specimen shall be positioned so that the face of the weld is in tension.

13.1.3 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 1/8 in [3.2 mm].

13.2 Rods

13.2.1 One longitudinal root bend specimen, as required in Table 4, shall be machined from the groove weld assembly described in 9.4.2 and shown in Figure 3B.

13.2.2 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 180° over a radius of 3/4 in [19 mm]. Typical bending jigs are shown in AWS B4.0 or B4.0M. The specimen shall be positioned so that the root of the weld is in tension.

13.2.3 After bending, the bend test specimen shall conform to the designated radius, with appropriate allowance for spring-back, and the weld metal shall show no defects on the tension face greater than 1/8 in [3.2 mm].

14. Impact Test

When specified in Table 4, five full size, 0.394 in $\times$ 0.394 in, [10 mm $\times$ 10 mm] Charpy V-notch impact specimens (see Figure 6) shall be machined from the test assembly (see Note 2 of Figure 2).

The five specimens shall be tested at a temperature of -320°F [-196°C] in accordance with the impact test section of AWS B4.0 or AWS B4.0M.

Lateral expansion shall be measured in accordance with ASTM E 23. In evaluating the test results, the highest and lowest lateral expansion values shall be disregarded. The remaining three impact specimens shall exhibit lateral expansion of 0.015 in [0.38 mm] minimum when tested at -320°F [-196°C].

15. Fillet Weld Test

15.1 The fillet weld test, when required in Table 4, shall be made in accordance with 9.5 and Figure 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 Figure 4. The cross-sectional surface shall be ground smooth and etched, and then examined as required in 15.2.

15.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 7, and the leg length and the convexity shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement.

15.2.1 The fillet weld shall have penetration to or beyond the junction of the edges of the plates.

15.2.2 The legs and convexity of the fillet weld shall be within the limits prescribed in Figure 7.

15.2.3 The fillet weld shall show no evidence of cracks.

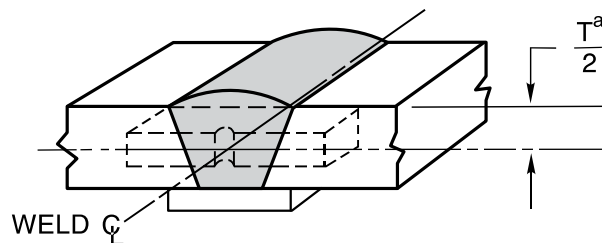
15.2.4 The weld shall be reasonably free from undercutting, overlap, trapped slag, and porosity.

16. 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.

17. Standard Sizes

17.1 Standard sizes for filler metal in the different package forms (straight lengths, coils with support, coils without support, spools, and drums) are as specified in AWS A5.02/A5.02M.

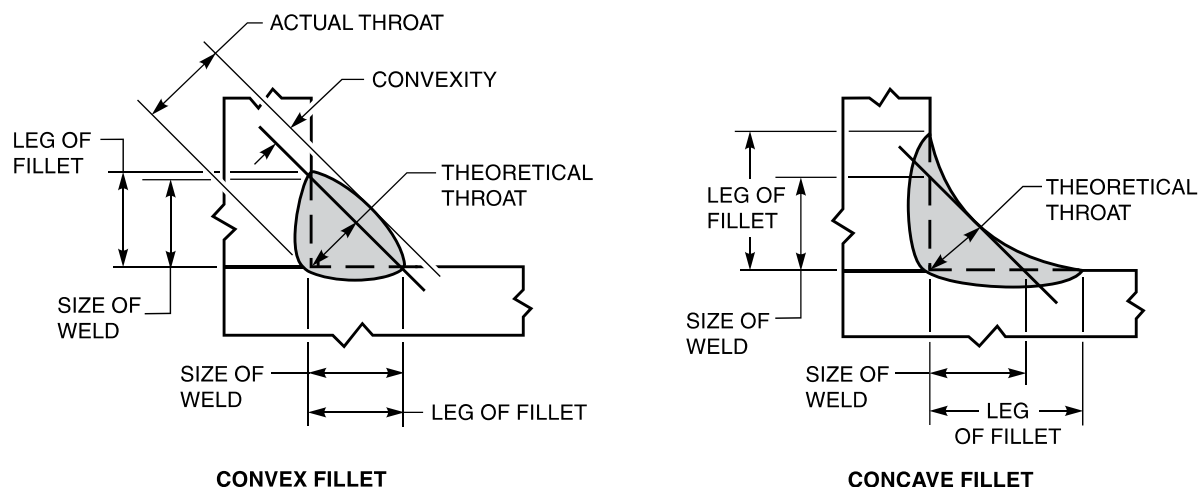


^a If buttering is used in preparation of the test plate (see Figure 2) the $T/2$ dimension may need to be reduced to assure that none of the buttering becomes part of the notch area of the impact specimen.

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

Source: Figure A.4 of AWS A5.4/A5.4M:2006.

Figure 6—Orientation and Location of Impact Test Specimen



Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in	mm	in	mm	in	mm
1/8 or less	3.0 or less	5/64	2.0	1/32	1.0
9/64	3.5	5/64	2.0	3/64	1.0
5/32	4.0	5/64	2.0	3/64	1.0
11/64	4.5	5/64	2.0	1/16	1.5
3/16	5.0	5/64	2.0	1/16	1.5
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	2.5
1/4	6.5	5/64	2.0	3/32	2.5
17/64	6.5	3/32	2.5	7/64	3.0
9/32	7.0	3/32	2.5	7/64	3.0
19/64	7.5	3/32	2.5	1/8	3.0
5/16	8.0	3/32	2.5	1/8	3.0
21/64	8.5	3/32	2.5	9/64	3.5
11/32	8.5	3/32	2.5	9/64	3.5
23/64	9.0	3/32	2.5	5/32	4.0
3/8 or more	9.5 or more	3/32	2.5	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 [0.5 mm]) on a section laid out with scribed lines shown.

Source: Figure 6 of AWS A5.34/A5.34M:2007.

Figure 7—Fillet Weld Test Specimen and Dimensional Requirements

18. Finish and Uniformity

18.1 Finish and uniformity shall be as specified in 4.2 of AWS A5.02/A5.02M.

19. Standard Package Forms

19.1 Standard package forms are straight lengths, coils with support, coils without support, spools, and drums. Standard package dimensions and weights and other requirements for each form shall be as specified in 4.3 of AWS A5.02/A5.02M.

20. Winding Requirements

20.1 Winding requirements shall be as specified in 4.4.1 of AWS A5.02/A5.02M.

20.2 The cast and helix of filler metal shall be as specified in 4.4.2 of AWS A5.02/A5.02M.

21. Filler Metal Identification

21.1 Filler metal identification, including marking of bare straight lengths of filler rod, product information, and the precautionary information, shall be as specified in 4.5 of AWS A5.02/A5.02M.

22. Packaging

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

23. Marking of Packages

23.1 The product information (as a minimum) that shall be legibly marked so as to be visible from the outside of each unit package shall be as specified in 4.6.1 of AWS A5.02/A5.02M.

23.2 The appropriate precautionary information as given in ANSI Z49.1 (as a minimum) or its equivalent, shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package.

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Annex A (Informative)

Guide to AWS Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods

This annex is not part of AWS A5.22/A5.22M:2012, *Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*, but is included for informational 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. Appropriate base metal specifications are referenced 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 includes welding rods classified as R3XXT1-5. 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.

The metal cored electrodes previously classified according to AWS A5.9/A5.9M have been included in this specification, in agreement with worldwide classification of metal cored electrodes in the same specifications as flux cored electrodes. By far the most popular metal cored electrodes are the EC409 type and similar ferritic stainless steel alloys. These are commonly used for single pass welding on thin wall tubing, as in automobile exhaust systems. Since these are mainly used in single pass welding, mechanical properties are not specified for such electrodes. Future revision of AWS A5.9/A5.9M will delete these classifications from that standard.

A2. Classification System

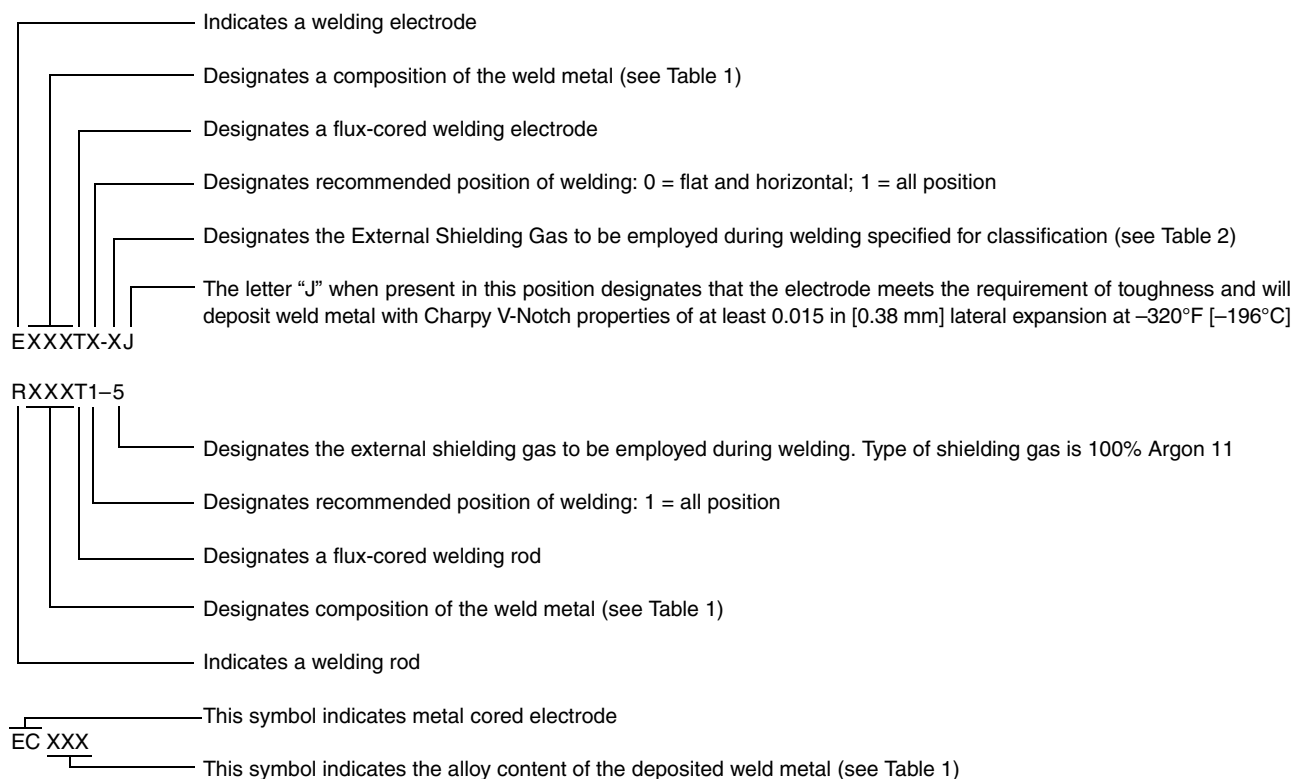
A2.1 The system for identifying the electrode and rod classifications in this specification follows the standard pattern used in other AWS filler metal specifications.

A2.2 The letter “E” at the beginning of each classification designation stands for electrode, and the letter “R” indicates a welding rod. The letters “EC” indicate a metal cored electrode. Figure A.1 is a graphical explanation of the system.

A2.2.1 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 low-carbon content in the deposit. The letter “H” denotes carbon content in the upper part of the range that is specified for the corresponding standard alloy type.

If a “G” is used for the chemical composition designator, it signifies that the chemical composition and mechanical properties are not specified and are as agreed upon between supplier and purchaser. Refer to A2.2.7 for a further explanation of the “G” classification and its implications.

A2.2.2 The letter “K” in the E316LKT0-3 classification, or the optional supplemental designator “J” for other classifications, signifies that weld metal deposited by these electrodes is designed for cryogenic applications.



Source: AWS A5.22-95 (R2005): Errata, Figure A.1.

Figure A.1—Classification Systems

A2.2.3 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 is shielded by the atmosphere and slag generated by the flux core. The letter "G" signifies that the shielding medium is not specified and is agreed upon between the purchaser and supplier. Refer to A2.2.7 for a further explanation of the "G" classification and its implications.

A2.2.4 Significance of the position indicators is summarized as follows:

- (1) E XXXT0-X Designates a welding electrode designed for welding in the flat or horizontal positions.
- (2) E XXXT1-X Designates a welding electrode designed for welding in all positions.
- (3) R3XXT1-5 Designates a welding rod designed for welding in all positions.

A2.2.5 As shown in Table 2, the shielding designation for a particular classification indicates the external shielding gas to be employed for classification of the electrode/rod. This does not exclude the use of alternate gas mixtures as agreed upon between the 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.

A2.2.6 While mechanical property tests are required for classification of the electrodes or rods in this specification (see Table 4), the classification designation does not identify the mechanical property test requirements. Refer to Table 6 for mechanical property requirements. Also note that mechanical properties are not a requirement for the EC classifications.

A2.2.7 This specification includes filler metals classified EGTX-X, EXXXXTX-G, RGT1-5 and ECG. The “G” indicates that the filler metal is of a “general” classification. It is general because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing these classifications is to provide a means by which filler metals that differ in one respect or another (chemical composition or shielding gas) from all other classifications (meaning that the composition of the filler metal or shielding gas does not meet that 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 or shielding gas).

A2.2.8 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 AWS A5.01M/A5.01) in the purchase order.

A2.2.9 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 AWS A5 Committee on Filler Metals and Allied Materials recommends that the manufacturer still request 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 AWS A5 Committee on Filler Metals and Allied Materials or the AWS Subcommittee involved 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. In particular, the request needs to include:

(a) All classification requirements as given for existing classifications, such as chemical composition ranges, mechanical property requirements, and possibly test requirements.

(b) Any testing conditions for conducting the tests used to demonstrate that the product meets the classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)

(c) Information on Descriptions and Intended Use, which parallels that for existing classifications, for that clause of the Annex.

A request for a new classification without the above information will be considered incomplete. The Secretary will return the request for further information.

(3) The request should be sent to the Secretary of the AWS A5 Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will do the following:

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

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

(c) Send a copy of the request to the Chair of the AWS A5 Committee on Filler Metal and Allied Materials and the Chair of the particular Subcommittee involved.

(d) File the original request.

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

(4) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chair 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 Chair of the AWS A5 Committee on Filler Metals and Allied Materials for action.

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

A2.3 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table A.1 shows those in comparable classifications in ISO 17633, *Welding consumables — Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels — Classification*, along with classification for similar covered electrode classifications in AWS A5.4/A5.4M and similar bare wire classifications in AWS A5.9/A5.9M. To understand the international designation system, refer to Tables 9A and 9B and the annex of AWS document IFS:2002, *International Index of Welding Filler Metal Classifications*. These tables also show many of the classifications used in comparable national specifications from industrial regions in the world.

A2.4 ISO 17633 was first published in 2004. A revision published in 2010 updated the shielding gas designations to those of the 2008 revision of ISO 14175. It is a cohabitation standard, providing for classification according to the system preferred in Europe or according to the system used by AWS and countries around the Pacific Rim. The “A-side” of the ISO standard indicates chemical composition directly in the designation, as in the “T 19 12 3L R M21 3” classification where the T indicates a tubular cored electrode, the 19 indicates % Cr, 12 indicates % Ni, 3 indicates % Mo, L indicates low carbon, R indicates a rutile slag system, M21 indicates use with argon-carbon dioxide mixed shielding gas and the last 3 indicates flat and horizontal position welding. The same electrode, classified according to the B-side of the ISO standard, would be designated TS316L-F M21 0 where T indicates a tubular cored electrode, S indicates stainless steel, 316L is the traditional AWS alloy designation, F indicates a flux cored electrode, M21 indicates argon-carbon dioxide mixed shielding gas, and 0 indicates flat and horizontal position welding. The same electrode, according to AWS A5.22, would be classified as E316LT0-4. In the future, AWS may adopt the ISO standard.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01(ISO 14344 MOD), as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of AWS A5.01M/A5.01(ISO 14344 MOD). 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.

Table A.1
Comparison of A5.22/A5.22M Classifications with
AWS A5.4/A5.4M, AWS A5.9/A5.9M, and ISO 17633

AWS A5.22/A5.22M	AWS A5.4/A5.4M ^a	AWS A5.9/A5.9M	ISO 17633-A ^b	ISO 17633-B ^c
E307TX-X	E307-XX	ER307	—	TS307 F X X
E308TX-X	E308-XX	ER308, ER308Si	—	TS308 F X X
E308HTX-X	E308H-XX	ER308H, ER19-10H	—	TS308H F X X
E308LTX-X	E308L-XX	ER308L, ER308LSi	T 19 9 L X X X	TS308L F X X
E308MoTX-X	E308Mo-XX	ER308Mo	—	TS308Mo F X X
E308LMoTX-X	E308LMo-XX	ER308LMo	—	TS308LMo F X X
E309TX-X	E309-XX	ER309, ER309Si	—	TS309 F X X
E309HTX-X	E309H-XX	—	—	—
E309LTX-X	E309L-XX	ER309L, ER309LSi	T 23 12 L X X X	TS309L F X X
E309MoTX-X	E309Mo-XX	ER309Mo	—	TS309Mo F X X
E309LMoTX-X	E309LMo-XX	ER309LMo	T 23 12 2 L X X X	TS309LMo F X X
E309LNiMoTX-X	—	—	—	—
E309LNbTX-X	—	—	—	TS309LNb F X X
E310TX-X	E310-XX	ER310	T 25 20 X X X	TS310 F X X
E312TX-X	E312-XX	ER312	T 29 9 X X X	TS312 F X X
E316TX-X	E316-XX	ER316, ER316Si	—	TS316 F X X
E316HTX-X	E316H-XX	ER316H	—	TS316H F X X
E316LTX-X, E316LKT0-3	E316L-XX	ER316L, ER316LSi	T 19 12 3 L X X X	TS316L F X X
E317LTX-X	E317L-XX	ER317L	T 19 13 4 N L X X X	TS317L F X X
E347TX-X	E347-XX	ER347, ER347Si	T 19 9 Nb X X X	TS347 F X X
E347HTX-X	—	—	—	—
E409TX-X	—	ER409	T 13 Ti X X X	TS409 F X X
E409NbTX-X	E409Nb-XX	ER409Nb	—	TS409Nb F X X
E410TX-X	E410-XX	ER410	T 13 X X X	TS410 F X X
E410NiMoTX-X	E410NiMo-XX	ER410NiMo	T 13 4 X X X	TS410NiMo F X X
E430TX-X	E430-XX	ER430	T 17 X X X	TS430 F X X
E430NbTX-X	E430Nb-XX	—	—	TS430Nb F X X
E2209TX-X	E2209-XX	ER2209	T 22 9 3 N L X X X	TS2209 F X X
E2307TX-X	E2307-XX*	ER2307	T 23 7 N L	—
E2553TX-X	E2553-XX	ER2553	—	—
E2594TX-X	E2594-XX, E2595-XX	ER2594	—	—
EGTX-X	—	—	T Z X X X	—
R308LT1-5	E308L-XX	ER308L	—	TS308L R I I
R309LT1-5	E309L-XX	ER309L	—	TS309L R I I
R316LT1-5	E316L-XX	ER316L	—	TS316L R I I
R347T1-5	E347-XX	ER347	—	TS347 R I I
EC209	E209-XX	EC209	—	—
EC218	—	EC218	—	—
EC219	E219-XX	EC219	—	—
EC240	E240-XX	EC240	—	—
EC307	E307-XX	EC307	—	—
EC308	E308-XX	EC308	—	—
EC308Si	E308-XX	EC308Si	—	—
EC308H	E308H-XX	EC308H	—	—
EC308L	E308L-XX	EC308L	T 19 9 L M X X	TS308L M X X
EC308LSi	E308L-XX	EC308LSi	T 19 9 L M X X	—
EC308Mo	E308Mo-XX	EC308Mo	—	TS308Mo M X X
EC308LMo	E308LMo-XX	EC308LMo	—	—
EC309	E309-XX	EC309	—	—
EC309Si	E309-XX	EC309Si	—	—
EC309L	E309L-XX	EC309L	T 23 12 L M X X	TS309L M X X

(Continued)

Table A.1 (Continued)
Comparison of A5.22/A5.22M Classifications with
AWS A5.4/A5.4M, AWS A5.9/A5.9M, and ISO 17633

AWS A5.22/A5.22M	AWS A5.4/A5.4M ^a	AWS A5.9/A5.9M	ISO 17633-A ^b	ISO 17633-B ^c
EC309LSi	E309L-XX	EC309LSi	T 23 12 L M X X	—
EC309Mo	E309Mo-XX	EC309Mo	—	—
EC309LMo	E309LMo-XX	EC309LMo	T 23 12 2 L M X X	TS309LMo M X X
EC310	E310-XX	EC310	T 25 20 M X X	—
EC312	E312-XX	EC312	T 29 9 M X X	—
EC316	E316-XX	EC316	—	—
EC316Si	E316-XX	EC316Si	—	—
EC316H	E316H-XX	EC316H	—	—
EC316L	E316L-XX	EC316L	T 19 12 3 L M X X	TS316L M X X
EC316LSi	E316L-XX	EC316LSi	T 19 12 3 L M X X	—
EC316LMn	E316LMn-XX	EC316LMn	—	—
EC317	E317-XX	EC317	—	—
EC317L	E317L-XX	EC317L	T 19 13 4 N M X X	—
EC318	E318-XX	EC318	—	—
EC320	E320-XX	EC320	—	—
EC320LR	E320LR-XX	EC320LR	—	—
EC321	—	EC321	—	—
EC330	E330-XX	EC330	—	—
EC347	E347-XX	EC347	T 19 9 Nb M X X	TS347 M X X
EC347Si	E347-XX	EC347Si	T 19 9 Nb M X X	—
EC383	E383-XX	EC383	—	—
EC385	E385-XX	EC385	—	—
EC409	—	EC409	T 13 Ti M X X	TS409 M X X
EC409Nb	E409Nb-XX	EC409Nb	—	TS409Nb M X X
EC410	E410-XX	EC410	T 13 M X X	TS410 M X X
EC410NiMo	E410NiMo-XX	EC410NiMo	T 13 4 M X X	TS410NiMo M X X
EC420	—	EC420	—	—
EC430	E430-XX	EC430	T 17 M X X	TS430 M X X
EC439	—	EC439	—	—
EC439Nb	—	—	—	—
EC446LMo	—	EC446LMo	—	—
EC630	E630-XX	EC630	—	—
EC19-10H	E308H-XX	EC19-10H	—	—
EC16-8-2	E16-8-2-XX	EC16-8-2	—	—
EC2209	E2209-XX	EC2209	T 22 9 3 N L M X X	—
EC2553	E2553-XX	EC2553	—	—
EC2594	E2594-XX, E2595-XX	EC2594	—	—
EC33-31	E33-31-XX	EC33-31	—	—
EC3556	—	EC3556	—	—
ECG	—	—	T Z M X X	—

*Expected to be included in next editions.

^a In the AWS A5.4/A5.4M classification designations, “-XX” stands for the coating type. -15 means DC current only, all-position welding. -16 means AC or DC current, all-position welding. -17 means AC or DC current, all-position welding but allows for a wider weave in the vertical position. -26 means AC or DC current, flat and horizontal positions only.

^b In the ISO 17633-A classification designations, the last three symbols (where X stands for any symbol) indicate, respectively, the type of electrode core (R means rutile, slow freezing; P means rutile, fast freezing; M means metal core; U means self-shielding; Z means an unspecified type), the shielding gas for classification (M21 means argon plus 15% to 25% CO₂; C means CO₂; M13 means argon plus up to 3% oxygen; and NO means no shielding gas), and position of welding (1 means all positions including vertical down; 2 means all positions except vertical down; 3 means flat and horizontal only; 4 means flat only; and 5 means flat, horizontal and vertical down).

^c In the ISO 17633-B classification designations, the last three symbols (where X stands for any symbol) indicate, respectively, the type of electrode or rod (F means flux cored; M means metal cored; and R means a rod for GTAW), the shielding gas for classification (M21 means argon plus 20% to 25% CO₂; C means CO₂; M13 means argon plus up to 3% oxygen; I1 means 100% argon; NO means no shielding gas; and G means an unspecified shielding gas), and position of welding (0 means flat and horizontal only, 1 means all positions).

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 AWS A5.01M/A5.01(ISO 14344 MOD).

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 clause on ventilation in that document. See also AWS F3.2, *Ventilation Guide for Weld Fume*, for more detailed descriptions of ventilation options.

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% ferrite based on the data collected from all the laboratories was measured as low as 3.5% by some and as high as 8.0% by others. At an average of 10%, the spread was 7.0% to 16.0%. In order to substantially reduce this problem, the WRC Subcommittee published *Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*⁸ on July 1, 1972.

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 % 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 “% ferrite” term previously used. It represents a good average of commercial U.S. and world

⁸ Welding Research Council, P.O. Box 201547, Shaker Heights, OH 44120.

practice on the % ferrite. Through the use of standard calibration procedures, differences in readings due to instrument calibration are expected to be reduced to about $\pm 5\%$, or at the most, $\pm 10\%$ 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.

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% 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% 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 normally austenitic (types 3XX) filler metals, many types, such as filler metals of types 310, 320, 320LR, 330, 383, and 385, are fully austenitic. The filler metals of type 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 normally austenitic (types 3XX) filler metals can be made in low-ferrite versions, but commercial practice usually involves ferrite control above 4 FN. Because of chemical composition limits covering these grades and various manufacturing limits, most lots will be under 10 FN and are unlikely to go over 15 FN commercially. Filler metals of types 312, 2209, 2553, and 2594 generally are quite high in ferrite, usually over 30 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 9.3, 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 Figure 1 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 A 167 or A 240, or carbon steel. If the base plate contains more than 0.03% carbon and is used for the low-carbon classifications (classifications with up to 0.04% carbon maximum), then the pad shall have a minimum of nine 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 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 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 measurable length between start and stop on the last two layers must be 2 in [50 mm] minimum. The weld layers used for the buildup may be deposited with a weave. The amperage or wire feed speed, the arc voltage, and the contact tip to workpiece distance 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 [425°C] prior to quenching in water.

The weld deposit can be built up 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 1/8 in [3 mm].

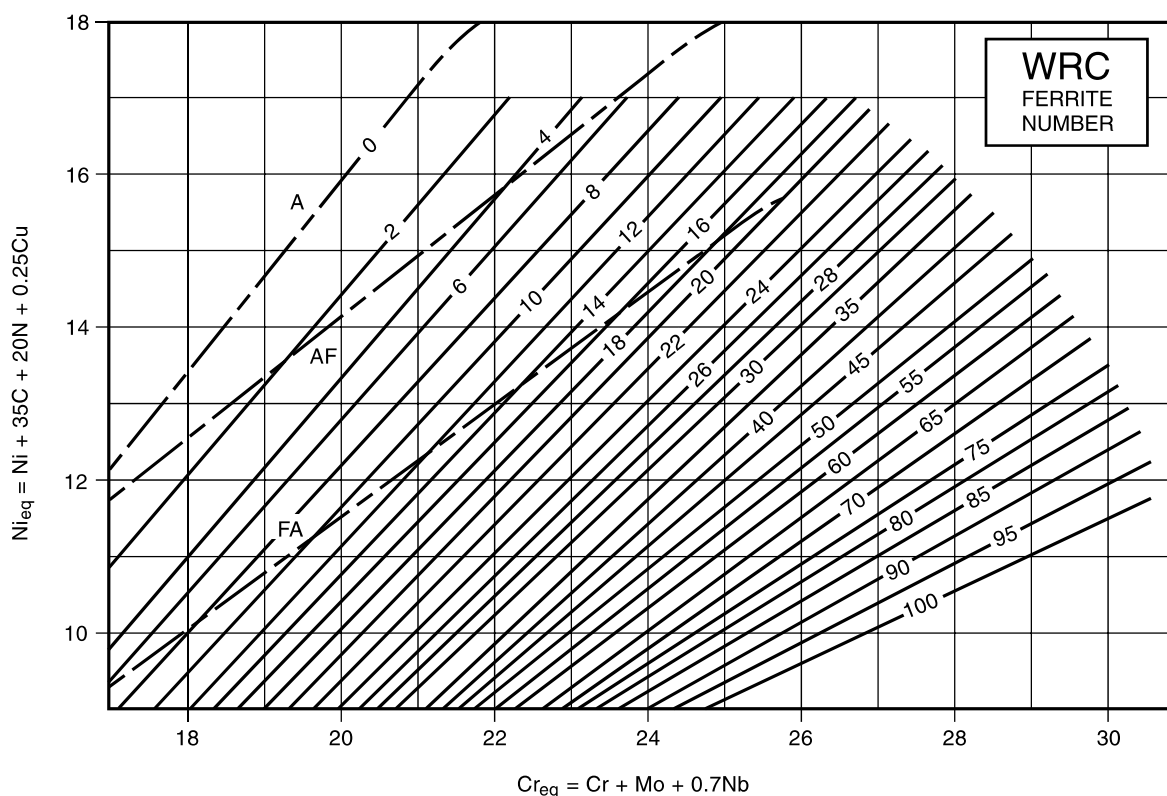
The surface can be prepared by draw filing using a mill bastard file held on both sides of the weld with the long axis of the file perpendicular to the long axis of the weld. Files shall either be new or shall have only been used on austenitic stainless steel. Filing must be accomplished by smooth draw-filing strokes (one direction only) along the length of the weld while applying a firm downward pressure. If the ferrite content is 30 FN or greater, the surface must be ground to a 600 grit [P1200] finish.

A6.9.5 A minimum of six ferrite readings must be taken on the filed or ground surface along the longitudinal axis of the weld pad with an instrument calibrated in accordance with the procedures specified in AWS A4.2M (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal* (latest edition). The six or more readings obtained must be averaged to give the final result.

A6.10 The ferrite content of welds may be calculated from the chemical composition of the weld deposit. This can be done from the WRC-1992 Diagram⁹ (Figure A.2) which predicts ferrite in Ferrite Number (FN). It is a slight modification of the WRC-1988 Diagram¹⁰ to take into account the effect of copper originally proposed by Lake. Studies within the WRC Subcommittee on Welding Stainless Steel and within Commission II of the International Institute of Welding show a closer agreement between measured and predicted ferrite contents using the WRC-1988 Diagram than when using the previously used DeLong Diagram. The WRC-1992 Diagram may not be applicable to compositions greater

⁹ Kotecki, D. J. and Siewert, T. A., "WRC-1992 Constitution Diagram for Stainless Steel Weld Metals: A Modification of the WRC-1988 Diagram." *Welding Journal* 71(5): 171-s–178-s (1992).

¹⁰ McCowan, C. N., Siewert, T. A., and Olson, D. L. 1989. WRC Bulletin 342, Stainless Steel Weld Metal: Prediction of Ferrite Content, Welding Research Council.



Source: AWS A5.4/A5.4M:2006, Figure A.3.

Figure A.2—WRC-1992 Diagram for Stainless Steel Weld Metal

than 0.3% nitrogen, 1% silicon, or greater than 10% manganese. For stainless steel compositions not alloyed with Cu, the predictions of the 1988 and 1992 diagrams are identical.

The differences between measured and calculated ferrite are somewhat dependent on the ferrite level of the deposit, increasing the ferrite level increases the variance. 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. Ferrite and Compositional Concerns for ECXXX Metal Cored Electrodes

A7.1 The welding process used and the welding conditions and technique have a significant influence on the chemical composition and the ferrite content of the weld deposit in many instances. These influences must be considered by the user if the weld deposit must meet specific chemical or Ferrite Number limits. The purpose of A7.2.1 through A7.2.3 is to present some general information on the effect of common arc welding processes on the chemical composition and the ferrite content of weld deposits made with filler metal classified in this specification.

A7.2 The chemical composition of a given weld deposit has the capability of providing an approximately predictable Ferrite Number for the undiluted deposit, as described in A6.10, with the limitations discussed here. However, important changes in the chemical compositions can occur from wire to deposit as described in A7.2.1 through A7.2.3.

A7.2.1 Gas Tungsten Arc Welding. This welding process involves the least change in the chemical composition from wire to deposit, and hence produces the smallest difference between the ferrite content calculated from the wire analysis and that measured on the undiluted deposit. There is some loss of carbon in gas tungsten arc welding—about half of the carbon content above 0.02%. Thus, a wire of 0.06% carbon will typically produce a deposit of 0.04% carbon. There is also some nitrogen pickup—a gain of 0.02%. The change in other elements is not significant in the undiluted weld metal.

A7.2.2 Gas Metal Arc Welding. For this process, typical carbon losses are low, only about one quarter those of the gas tungsten arc welding process. However, the typical nitrogen pick up is much higher than in gas tungsten arc welding, and it should be estimated at about 0.04% (equivalent to about 3 or 4 FN loss) unless specific measurements on welds for a particular application establish other values. Nitrogen pickup in this process is very dependent upon the welding technique and may go as high as 0.15% or more. This may result in little or no ferrite in the weld deposits of filler metals such as EC 308 and EC 309. Some slight oxidation plus volatilization losses may occur in manganese, silicon, and chromium contents.

A7.2.3 Submerged Arc Welding. Submerged arc welds show variable gains or losses of alloying elements, or both depending on the flux used. All fluxes produce some changes in the chemical composition as the electrode is melted and deposited as weld metal. Some fluxes deliberately add alloying elements such as niobium (columbium) and molybdenum; others are very active in the sense that they deplete significant amounts of certain elements that are readily oxidized, such as chromium. Other fluxes are less active and may contain small amounts of alloys to offset any losses and thereby, produce a weld deposit with a chemical composition close to the composition of the electrode. If the flux is active or alloyed, changes in the welding conditions, particularly voltage, will result in significant changes in the chemical composition of the deposit. Higher voltages produce greater flux/metal interactions and, for example, in the case of an alloy flux, greater alloy pickup. When close control of ferrite content is required, the effects of a particular flux/electrode combination should be evaluated before any production welding is undertaken due to the effects as shown in Table A.2.

A7.3 Bare solid filler metal wire, unlike covered electrodes and bare composite cored wires, cannot be adjusted for ferrite content by means of further alloy additions by the electrode producer, except through the use of flux in the submerged arc welding process. Thus, if specific FN ranges are desired, they must be obtained through wire chemical composition selection. This is further complicated by the changes in the ferrite content from wire to deposit caused by the welding process and techniques, as previously discussed.

A7.4 In the 300 series filler metals, the compositions of the bare filler metal wires in general tend to cluster around the midpoints of the available chemical ranges. Thus, the potential ferrite for the 308, 308L, and 347 wires is approximately

Table A.2
Variations of Alloying Elements for Submerged Arc Welding

Element	Typical Change from Wire to Deposit
Carbon	Varies. On “L” grades, usually a gain: +0.01% to +0.02%; on non-L grades, usually a loss: up to –0.02%.
Silicon	Usually a gain: +0.3% to +0.6%.
Chromium	Usually a loss, unless a deliberate addition is made to the flux: –0.5% to –3.0%.
Nickel	Little change, unless a deliberate addition is made to the flux.
Manganese	Varies: –0.5% to +0.5%.
Molybdenum	Little change, unless a deliberate addition is made to the flux.
Niobium	Usually a loss, unless a deliberate addition is made to the flux: –0.1% to –0.5%.

10 FN, for the 309 wire approximately 12 FN, and for the 316 and 316L wires approximately 5 FN. Around these mid-points, the ferrite contents may be ± 7 FN or more, but the chemical compositions of these filler metals will still be within the chemical limits specified in this specification.

A7.5 In summary, the ferrite potential of a filler metal afforded by this chemical composition will, except for a few instances in submerged arc welding, be modified downward in the deposit due to changes in the chemical composition which are caused by the welding process and the technique used.

A8. Description and Intended Use of Electrodes and Rods

A8.1 Composition Considerations

A8.1.1 The chemical composition requirements for these electrodes and rods are patterned after those of AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, and AWS A5.9/A5.9M, *Specification for Bare Stainless Steel Electrodes and Rods* (see Table A.1).

A8.1.2 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. The EXXXT0-3 deposits usually have 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 usually have higher Cr/Ni ratios than those of the EXXXTX-1 and EXXXTX-4 deposits.

Since the atmosphere generated by E316LKT0-3 electrodes more efficiently shields 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.

A8.1.3 The chemical composition requirements for metal cored electrodes are identical to those which were previously in the AWS A5.9/A5.9M specification. The most common use of metal cored electrodes is for single pass welds on thin wall tubing used in automotive exhaust systems. These are most commonly the ferritic stainless steel compositions 409, 409Nb, 430, and 439. Because they are used almost exclusively single pass, mechanical properties depend strongly upon the composition of the base metal. Accordingly, mechanical properties are not specified for these compositions.

A8.1.4 Bismuth (Bi) in Flux Cored Stainless Steel Electrodes. For many years, bismuth in one form or another has been added to the core ingredients of many, but by no means all, stainless steel flux cored electrodes for the purpose of improved slag release. In such electrodes, the weld metal typically retains about 0.02% (200 ppm) of bismuth. Bismuth is a surface active element which, under prolonged exposure to temperatures above about 750°F [400°C], can segregate to grain boundaries and promote premature failure under sustained tensile loading. Accordingly, stainless steel electrodes containing bismuth additions should not be used for such high temperature service or postweld heat treatment

above about 900°F [500°C]. Instead, stainless steel flux cored electrodes providing no more than 0.002% (20 ppm) Bi in the weld metal should be specified. For further information, see Welding Research Council Bulletin 460 High Temperature Cracking and Properties of Stainless Steel Flux Cored Welds and Effects of Bismuth¹¹ and International Institute of Welding Document IX-1873-97, *Effect of Bismuth on Reheat Cracking Susceptibility in Type 308 FCAW Weld Metal*.

A8.2 Intended Use of Flux Cored Electrodes and Rods. In the following, the final X of the classification refers to -1, -3, or -4.

A8.2.1 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.

A8.2.2 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.

A8.2.3 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 wt % 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.

A8.2.4 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 corrosion due to carbide precipitation without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, is not as strong at elevated temperature as the E308 and niobium stabilized alloys.

A8.2.5 E308MoTX-X. The composition of this weld metal is the same as that of E308TX-X weld metal, except for the addition of 2 wt %–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 316 when ferrite content higher than attainable with E316TX-X electrodes is desired.

A8.2.6 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 may also be used for welding wrought metals such as type 316L stainless when ferrite content higher than attainable with E316LTX-X electrodes is desired.

A8.2.7 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.

A8.2.8 E309HTX-X. The composition of this weld metal is the same as that of E309TX-X except for carbon content which is at the high end of the range, 0.04%–0.10%. Carbon content in this range provides higher tensile and creep strength at elevated temperatures. This together with a lower ferrite content makes these electrodes suitable for the welding of 24 Cr 12 Ni wrought and cast grades for corrosion and oxidation resistance. High carbon castings to ACI's HH grade should be welded with an electrode that is similar to the casting composition.

A8.2.9 E309LTX-X. The composition of the 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 niobium or titanium. This low carbon alloy, however, is not as strong at elevated temperature as Type 309 or the niobium stabilized modification. A primary application of this alloy is the first layer cladding of carbon steel if no niobium additions are required.

¹¹ WRC documents are published by Welding Research Council, P.O. Box 201547, Shaker Heights, OH 44120.

¹² CF8M and CF3M are designations of ASTM A 351, *Standard Specification for Steel Castings, Austenitic, for Pressure-Containing Parts*.

A8.2.10 E309MoTX-X. The composition of this weld metal is the same as that of E309TX-X weld metal, except for the addition of 2 wt %–3 wt % molybdenum. These electrodes are used to join stainless steel to carbon and low-alloy steels for service below 600°F [315°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 deposit is approximately 18 FN.

A8.2.11 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 deposit is approximately 20 FN.

A8.2.12 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 (approximately 20 FN). This chemistry is required by the pulp and paper industry for joining applications.

A8.2.13 E309LNbTX-X. The composition of this weld metal is the same as E309LTX-X weld metal, except for the addition of 0.7 wt % to 1.0 wt % Nb. These electrodes are used to overlay carbon and low-alloy steels and produce a niobium stabilized first layer on such overlays.

A8.2.14 E310TX-X. The nominal composition (wt %) of this weld metal is 26.5 Cr and 21 Ni. These electrodes are most often used to weld base metals of similar compositions.

A8.2.15 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.

A8.2.16 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.

A8.2.17 E316HTX-X. The composition of this weld metal is the same as that of E316TX-X except for carbon content which is in the high end of the range, 0.04 wt % 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 316H base metal.

A8.2.18 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 niobium or titanium. This low-carbon alloy, however, is not as strong at elevated temperatures as the niobium stabilized alloys.

A8.2.19 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 (0.04 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 niobium or titanium. This low-carbon alloy, however, may not be so strong at elevated temperatures as the niobium stabilized alloys or Type 317.

A8.2.20 E347TX-X. The nominal composition (wt %) of this weld metal is 19.5 Cr and 10 Ni with 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 stainless steel base metals of similar composition stabilized either with niobium or titanium.

Although niobium is the stabilizing element usually specified in 347 alloys, it should be recognized that tantalum may also be present. Tantalum and niobium are almost equally effective in stabilizing carbon and in providing high-temperature strength. The usual commercial practice is to report niobium as the sum of the niobium plus tantalum. Crack sensi-

tivity of the weld may increase substantially, if dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit.

A8.2.21 E347HTX-X. The composition of this weld metal is the same as that of E347TX-X, except for carbon content which is at the high end of the range, 0.04 wt % 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 347H base metal.

A8.2.22 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.

A8.2.23 E409NbTX-X. This classification is the same as E409TX-X, except that niobium is used instead of titanium to achieve similar results. Applications are the same as for E409TX-X filler metals.

A8.2.24 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 occurs in valve seats and other valve parts.

A8.2.25 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.

A8.2.26 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.

A8.2.27 E430NbTX-X. The composition of this weld metal is very similar to that deposited by E430 electrodes, except for the addition of niobium. The weld deposit is a ferritic microstructure with fine grains. Preheat and postweld heat treatment are required to achieve welds of adequate ductility for many engineering purposes. These electrodes are used for the welding of Type 430 stainless steel. They are also used for the first layer in the welding of Type 405 and 410 clad steels.

A8.2.28 E2209TX-X. The nominal composition (wt %) of this weld metal is 22 Cr, 8.5 Ni, 3.5 Mo, and 0.15 N. 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. If post weld annealing is required, this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A8.2.29 E2307TX-X. *The nominal composition (wt %) of this weld metal is 24 Cr, 8.5 Ni, and 0.15 N. Electrodes of this classification are used for welding lean duplex stainless steel such as UNS S32101 and S32304. Weld metal deposited by these electrodes has a “duplex” microstructure consisting of an austenite-ferrite matrix. Weld metal deposited with E2307 filler metal combines increased tensile strength and improved resistance to stress corrosion cracking as compared to those properties in 308L weld metal.*

A8.2.30 E2553TX-X. The nominal composition (wt %) of this weld metal is 25.5 Cr, 9.5 Ni, 3.4 Mo, 2 Cu, and 0.18 N. 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

¹³ CA6NM is a designation of ASTM A 352, *Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service.*

strengths with improved resistance to pitting corrosion and stress corrosion cracking. If postweld annealing is required, this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A8.2.31 E2594TX-X. The nominal composition (wt %) of this classification is 25.5 Cr, 9.3 Ni, 3.5 Mo, and 0.25 N. The sum of the $\text{Cr} + 3.3 (\text{Mo} + 0.5 \text{W}) + 16 \text{N}$, known as the Pitting Resistance Equivalent Number (PRE_N), is at least 40, thereby allowing the weld metal to be called a “superduplex stainless steel.” This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride containing environments. It is designed for the welding of superduplex stainless steels UNS S32750 and S32760 (wrought) and for UNS J93380 and J93404 (cast). It can also be used for the welding of UNS S32550, J93370, and J93372 when not subject to sulfurous or sulfuric acids in service. It can also be used for the welding of low alloy steels to duplex stainless steels as well as to weld ‘standard’ duplex stainless steels such as UNS S32205 and J92205 although the weld metal impact toughness may be inferior to that from E2209TX-X electrodes. If postweld annealing is required, this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A8.2.32 E308HMoT0-3. The composition of this weld metal is the same as that of E308MoTX-X, except that the carbon content is higher than the E308MoT0-3 range. The higher carbon content provides higher strength at elevated temperatures. The primary use of this electrode is for the welding of armor steel.

A8.2.33 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 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.

A8.2.34 R308LT1-5. The nominal composition (wt %) of this weld metal is 18.5 Cr and 10 Ni with carbon held to 0.03% maximum. This flux cored rod is used primarily for root pass welding of Type 304 or 304L stainless steel joints when an 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.

A8.2.35 R309LT1-5. The nominal composition (wt %) of this weld metal is 23.5 Cr and 13 Ni with carbon held to 0.03% maximum. This flux cored filler rod is used primarily for the root pass welding of carbon steel to austenitic stainless steel when inert gas backing purge is either not possible or not desirable. The high Cr and Ni content allow dilution with carbon steel while still producing a weld metal with sufficient alloy to provide stable austenite with a little ferrite despite normal dilution from the carbon steel side of the joint. 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.

A8.2.36 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 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.

A8.2.37 R347T1-5. The nominal composition (wt %) of this weld metal is 19.5 Cr and 10 Ni with Nb added as a stabilizer. This flux cored filler rod is used primarily for the root pass welding of Types 321 and 347 stainless steel 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.

A8.3 Intended Use of Metal Cored Electrodes

A8.3.1 EC209. The nominal composition (wt %) of this classification is 22 Cr, 11 Ni, 5.5 Mn, 2 Mo, and 0.20 N. Filler metals of this classification are most often used to weld UNS S20910 base metal. This alloy is a nitrogen-strengthened,

austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperatures. Weldments in the as-welded condition using this filler metal are not subject to carbide precipitation. Nitrogen alloying reduces the tendency for carbon diffusion and thereby increases resistance to intergranular corrosion.

The EC209 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications when used with the gas metal arc welding process.

The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.2 EC218. The nominal composition (wt %) of this classification is 17 Cr, 8.5 Ni, 8 Mn, 4 Si, and 0.13 N. Filler metals of this classification are most often used to weld UNS S21800 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperature. Nitrogen alloying in this base composition results in significant improvement in wear resistance in particle-to-metal and metal-to-metal (galling) applications when compared to the more conventional austenitic stainless steels such as Type 304. The EC218 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.3 EC219. The nominal composition (wt %) of this classification is 20 Cr, 6 Ni, 9 Mn, and 0.20 N. Filler metals of this classification are most often used to weld UNS S21900 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperatures.

Weldments made using this filler metal are not subject to carbide precipitation in the as-welded condition. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increases resistance to intergranular corrosion.

The EC219 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosive applications when used with the gas metal arc welding process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.4 EC240. The nominal composition (wt %) of this classification is 18 Cr, 5 Ni, 12 Mn, and 0.20 N. Filler metal of this classification is most often used to weld UNS S24000 and UNS S24100 base metals. These alloys are nitrogen-strengthened austenitic stainless steels exhibiting high strength and good toughness over a wide range of temperatures. Significant improvement of wear resistance in particle-to-metal and metal-to-metal (galling) applications is a valuable characteristic when compared to the more conventional austenitic stainless steels such as Type 304. Nitrogen alloying reduces the tendency toward intergranular carbide precipitation in the weld area by inhibiting carbon diffusion thereby reducing the possibility for intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. In addition, weldments in Type 240 exhibit improved resistance to transgranular stress corrosion cracking in hot aqueous chloride-containing media. The EC240 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.5 EC307. The nominal composition (wt %) of this classification is 21 Cr, 9.5 Ni, 4 Mn, and 1 Mo. Filler metals of this classification are used primarily for moderate-strength welds with good crack resistance between dissimilar steels such as austenitic manganese steel and carbon steel forgings or castings.

A8.3.6 EC308. The nominal composition (wt %) of this classification is 21 Cr and 10 Ni. Commercial specifications for filler and base metals vary in the minimum alloy requirements; consequently, the names 18-8, 19-9, and 20-10 are often associated with filler metals of this classification. This classification is most often used to weld base metals of similar composition, in particular, Type 304.

A8.3.7 EC308Si. This classification is the same as EC308, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces

low ferrite or fully austenitic weld metal, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.8 EC308H. This classification is the same as EC308, except that the allowable carbon content has been restricted to the higher portion of the 308 range. Carbon content in the range of 0.04–0.08 provides higher strength at elevated temperatures. This filler metal is used for welding 304H base metal.

A8.3.9 EC308L. This classification is the same as EC308, except for the carbon content. Low carbon (0.03% maximum) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. Strength of this low-carbon alloy, however, is less than that of the niobium-stabilized alloys or Type 308H at elevated temperatures.

A8.3.10 EC308LSi. This classification is the same as EC308L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.11 EC308Mo. This classification is the same as EC308, except for the addition of molybdenum. It is used for welding ASTM CF8M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for welding wrought materials such as Type 316 (UNS31600) stainless when ferrite content in excess of that attainable with the EC316 classification is desired.

A8.3.12 EC308LMo. This classification is used for welding ASTM CF3M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for welding wrought materials such as Type 316L stainless when a ferrite in excess of that attainable with EC316L is desired.

A8.3.13 EC309. The nominal composition (wt %) of this classification is 24 Cr and 13 Ni. Filler metals of this classification are commonly used for welding similar alloys in wrought or cast form. Occasionally, they are used to weld Type 304 and similar base metals where severe corrosion conditions exist requiring higher alloy weld metal. They are also used in dissimilar metal welds, such as joining Type 304 to carbon steel, welding the clad side of Type 304 clad steels, and applying stainless steel sheet linings to carbon steel shells.

A8.3.14 EC309Si. This classification is the same as EC309, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.3.15 EC309L. This classification is the same as EC309, except for the carbon content. Low carbon (0.03% max.) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. Strength of this low-carbon alloy, however, may not be as great at elevated temperatures as that of the niobium-stabilized alloys or EC309.

A8.3.16 EC309LSi. This classification is the same as EC309L, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.17 EC309Mo. This classification is the same as EC309, except for the addition of 2.0% to 3.0% molybdenum to increase its pitting corrosion resistance in halide-containing environments. The primary application for this filler metal is surfacing of base metals to improve their corrosion resistance. The EC309Mo is used to achieve a single-layer overlay with a chemical composition similar to that of a 316 stainless steel. It is also used for the first layer of multilayer overlays with filler metals such as EC316 or EC317 stainless steels. Without the first layer of 309Mo, elements such as chromium and molybdenum might be reduced to unacceptable levels in successive layers by dilution from the base metal. Other applications include the welding of molybdenum-containing stainless steel linings to carbon steel shells, the joining of carbon steel base metals which had been clad with a molybdenum-containing stainless steel, and the joining of dissimilar base metals such as carbon steel to Type 304 stainless steel, for service below 600°F [315°C].

A8.3.18 EC309LMo. This classification is the same as an EC309Mo, except for lower maximum carbon content (0.03%). Low-carbon contents in stainless steels reduce the possibility of chromium carbide precipitation and thereby increase weld metal resistance to intergranular corrosion. The EC309LMo is used in the same type of applications as the

EC309Mo, but where excessive pickup of carbon from dilution by the base metal, where intergranular corrosion from carbide precipitation, or both are factors to be considered in the selection of the filler metal. In multilayer overlays, the low carbon EC309LMo is usually needed for the first layer in order to achieve low carbon contents in successive layers with filler metals such as EC316L or EC317L.

A8.3.19 EC310. The nominal composition (wt %) of this classification is 26.5 Cr and 21 Ni. Filler metal of this classification is most often used to weld base metals of similar composition.

A8.3.20 EC312. The nominal composition (wt %) of this classification is 30 Cr and 9 Ni. Filler metal of this classification was originally designed to weld cast alloys of similar composition. It also has been found to be valuable in welding dissimilar metals such as carbon steel to stainless steel, particularly those grades high in nickel. This alloy gives a two-phase weld deposit with substantial percentages of ferrite in an austenite 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.

A8.3.21 EC316. The nominal composition (wt %) of this classification is 19 Cr, 12.5 Ni, and 2.5 Mo. This filler metal is used for welding Type 316 and similar alloys. It has been used successfully in certain applications involving special base metals for high-temperature service. The presence of molybdenum provides creep resistance at elevated temperatures and pitting resistance in a halide atmosphere.

Rapid corrosion of EC316 weld metal may occur when the following three factors co-exist:

- (1) The presence of a continuous or semi-continuous network of ferrite in the weld metal microstructure
- (2) A composition balance of the weld metal giving a chromium-to-molybdenum ratio of less than 8.2 to 1
- (3) Immersion of the weld metal in a corrosive medium. Attempts to classify the media in which accelerated corrosion will take place by attack on the ferrite phase have not been entirely successful. Strong oxidizing and mildly reducing environments have been present where a number of corrosion failures were investigated and documented. The literature should be consulted for latest recommendations.

A8.3.22 EC316Si. This classification is the same as EC316, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.23 EC316H. This filler metal is the same as EC316, except that the allowable carbon content has been restricted to the higher portion of the 316 range. Carbon content in the range of 0.04 wt % to 0.08 wt % provides higher strength at elevated temperatures. This filler metal is used for welding 316H base metal.

A8.3.24 EC316L. This classification is the same as EC316, except for the carbon content. Low carbon (0.03% maximum) in this filler metal reduces the possibility of intergranular chromium carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This filler metal is primarily used for welding low-carbon molybdenum-bearing austenitic alloys. This low-carbon alloy, however, is not as strong at elevated temperature as the niobium-stabilized alloys or Type EC316H.

A8.3.25 EC316LSi. This classification is the same as EC316L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity is somewhat higher than that of lower silicon content weld metal.

A8.3.26 EC316LMn. The nominal composition (wt %) of this classification is 19 Cr, 15 Ni, 7 Mn, 3 Mo, and 0.2 N. This is a fully austenitic alloy with a typical ferrite content of 0.5 FN maximum. One of the primary uses of this filler metal is for joining similar and dissimilar cryogenic steels for applications down to -452°F (-269°C). This filler metal also exhibits good corrosion resistance in acids and seawater, and is particularly suited for corrosion conditions found in urea synthesis plants. It is also nonmagnetic. The high Mn content of the alloy helps to stabilize the austenitic microstructure and aids in hot cracking resistance.

A8.3.27 EC317. The nominal composition (wt %) of this classification is 19.5 Cr, 14 Ni, and 3.5 Mo, somewhat higher than EC316. It is usually used for welding alloys of similar composition. EC317 filler metal is utilized in severely corrosive environments where crevice and pitting corrosion are of concern.

A8.3.28 EC317L. This classification is the same as EC317, except for the carbon content. Low carbon (0.03% maximum) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, may not be as strong at elevated temperature as the niobium-stabilized alloys or Type 317.

A8.3.29 EC318. This composition is identical to EC316, except for the addition of niobium. Niobium provides resistance to intergranular chromium carbide precipitation and thus increased resistance to intergranular corrosion. Filler metal of this classification is used primarily for welding base metals of similar composition.

A8.3.30 EC320. The nominal composition (wt %) of this classification is 20 Cr, 34 Ni, 2.5 Mo, and 3.5 Cu, with Nb added to provide resistance to intergranular corrosion. Filler metal of this classification is primarily used to weld base metals of similar composition for applications where resistance to severe corrosion involving a wide range of chemicals, including sulfuric and sulfurous acids and their salts, is required. This filler metal can be used to weld both castings and wrought alloys of similar composition without postweld heat treatment. A modification of this classification without niobium is available for repairing castings which do not contain niobium, but with this modified composition, solution annealing is required after welding.

A8.3.31 EC320LR (Low Residuals). This classification has the same basic composition as EC320; however, the elements C, Si, P, and S are specified at lower maximum levels and the Nb and Mn are controlled within narrower ranges. These changes reduce the weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals. Consequently, welding practices typically used for austenitic stainless steel weld metals containing ferrite can be used in bare filler metal welding processes such as gas tungsten arc and gas metal arc welding. EC320LR filler metal has been used successfully in submerged arc overlay welding, but it may be prone to cracking when used for joining base metal by the submerged arc process. EC320LR weld metal has a lower minimum tensile strength than EC320 weld metal.

A8.3.32 EC321. The nominal composition (wt %) of this classification is 19.5 Cr and 9.5 Ni, with titanium added. The titanium acts in the same way as niobium in Type 347 in reducing intergranular chromium carbide precipitation and thus increasing resistance to intergranular corrosion. The filler metal of this classification is used for welding chromium-nickel stainless steel base metals of similar composition, using an inert gas shielded process. It is not suitable for use with the submerged arc process because only a small portion of the titanium will be recovered in the weld metal.

A8.3.33 EC330. The nominal composition (wt %) of this classification is 35.5 Ni and 16 Cr. Filler metal of this type is commonly used where heat and scale resisting properties above 1800°F (980°C) are required, except in high-sulfur environments, as these environments may adversely affect elevated temperature performance. Repairs of defects in alloy castings and the welding of castings and wrought alloys of similar composition are the most common applications.

A8.3.34 EC347. The nominal composition (wt %) of this classification is 20 Cr and 10 Ni, with Nb added as a stabilizer. The addition of niobium reduces the possibility of intergranular chromium carbide precipitation and thus susceptibility to intergranular corrosion. The filler metal of this classification is usually used for welding chromium-nickel stainless steel base metals of similar composition stabilized with either Nb or Ti. Although Nb is the stabilizing element usually specified in Type 347 alloys, it should be recognized that tantalum (Ta) is also present. Ta and Nb are almost equally effective in stabilizing carbon and in providing high-temperature strength. If dilution by the base metal produces a low ferrite or fully austenitic weld metal, the crack sensitivity of the weld may increase substantially.

A8.3.35 EC347Si. This classification is the same as EC347, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.36 EC383. The nominal composition (wt %) of this classification is 27.5 Cr, 31.5 Ni, 3.7 Mo, and 1 Cu. Filler metal of this classification is used to weld UNS N08028 base metal to itself, or to other grades of stainless steel. EC383 filler metal is recommended for sulfuric and phosphoric acid environments. The elements C, Si, P, and S are specified at low maximum levels to minimize weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals.

A8.3.37 EC385. The nominal composition (wt %) of this classification is 20.5 Cr, 25 Ni, 4.7 Mo, and 1.5 Cu. ER385 filler metal is used primarily for welding of ASTM B 625, B 673, B 674, and B 677 (UNS N08904) materials for the handling of sulfuric acid and many chloride containing media. EC385 filler metal may also be used to join Type 317L material where improved corrosion resistance in specific media is needed. EC385 filler metal may be used for joining UNS N08904 base metals to other grades of stainless steel. The elements C, S, P, and Si are specified at lower maximum levels to minimize weld metal hot cracking and fissuring (while maintaining corrosion resistance) frequently encountered in fully austenitic weld metals.

A8.3.38 EC409. This 12 Cr alloy (wt %) differs from Type 410 material because it has a ferritic microstructure. The titanium addition forms carbides to improve corrosion resistance, increase strength at high temperature, and promote the ferritic microstructure. EC409 filler metals may be used to join matching or dissimilar base metals. The greatest usage is for applications where thin stock is fabricated into exhaust system components.

A8.3.39 EC409Nb. This classification is the same as EC409, except that niobium is used instead of titanium to achieve similar results. Oxidation losses across the arc generally are lower. Applications are the same as those of EC409 filler metals.

A8.3.40 EC410. This 12 Cr alloy (wt %) is an air-hardening steel. Preheat and postweld heat treatments are required to achieve welds of adequate ductility for many engineering purposes. The most common application of filler metal of this type is for welding alloys of similar composition. It is also used for deposition of overlays on carbon steels to resist corrosion, erosion, or abrasion.

A8.3.41 EC410NiMo. The nominal composition (wt %) of this classification is 12 Cr, 4.5 Ni, and 0.55 Mo. It is primarily designed for welding ASTM CA6NM castings or similar material, as well as light-gauge 405, 410, and 410S base metals. Filler metal of this classification is modified to contain less chromium and more nickel to eliminate ferrite in the microstructure as it has a deleterious effect on mechanical properties. Final postweld heat treatment should not exceed 1150°F [620°C], as higher temperatures may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A8.3.42 EC420. This classification is similar to EC410, except for slightly higher chromium and carbon contents. EC420 is used for many surfacing operations requiring corrosion resistance provided by 12% chromium along with somewhat higher hardness than weld metal deposited by EC410 electrodes. This increases wear resistance.

A8.3.43 EC430. This is a 16 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 filler metal of the EC430 classification usually requires preheating and postweld heat treatment.

Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A8.3.44 EC439. This is an 18 wt % Cr alloy that is stabilized with titanium. EC439 provides improved oxidation and corrosion resistance over EC409 in similar applications. Applications are the same as those of EC409 filler metals where thin stock is fabricated into exhaust system components.

A8.3.45 EC439Nb. This classification is the same as EC439, except that niobium is used instead of titanium to achieve similar results. Oxidation loss across the arc for Nb is generally lower than Ti loss in EC439. Applications for EC439Nb filler metal are generally similar to EC439. Its major use is in automotive exhaust systems components.

A8.3.46 EC446LMo. The nominal composition (wt %) of this classification (formerly listed as EC26-1) is 26 Cr and 1 Mo. It is used for welding base metal of the same composition with inert gas shielded welding processes. Due to the high purity of both base metal and filler metal, cleaning of the parts before welding is most important. Complete coverage by shielding gas during welding is extremely important to prevent contamination by oxygen and nitrogen. Nonconventional gas shielding methods (leading, trailing, and back shielding) often are employed.

A8.3.47 EC630. The nominal composition (wt %) of this classification is 16.4 Cr, 4.7 Ni, and 3.6 Cu. The composition is designed primarily for welding ASTM A 564 Type 630 and some other precipitation-hardening stainless steels. The composition is modified to prevent the formation of ferrite networks in the martensitic microstructure which have a deleterious effect on mechanical properties. Dependent on the application and weld size, the weld metal may be used as-welded; welded and precipitation hardened; or welded, solution treated, and precipitation hardened.

A8.3.48 EC19-10H. The nominal composition (wt %) of this classification is 19 Cr and 10 Ni and is similar to ER308H, except that the chromium content is lower and there are additional limits on Mo, Nb, and Ti. This lower limit of Cr and additional limits on other Cr equivalent elements allows a lower ferrite range to be attained. A lower ferrite level in the weld metal decreases the chance of sigma embrittlement after long-term exposure at temperatures in excess of 1000°F [540°C]. This filler metal should be used in conjunction with welding processes and other welding consumables which do not deplete or otherwise significantly change the amount of chromium in the weld metal. If used with submerged arc welding, a flux that neither removes nor adds chromium to the weld metal is highly recommended.

This filler metal also has the higher carbon level required for improved creep properties in high-temperature service. The user is cautioned that actual weld application qualification testing is recommended in order to be sure that an acceptable weld metal carbon level is obtained. If corrosion or scaling is a concern, special testing, as outlined in Clause A10, Special Tests, should be included in application testing.

A8.3.49 EC16-8-2. The nominal composition (wt %) of this classification is 15.5 Cr, 8.5 Ni, and 1.5 Mo. Filler metal of this classification is used primarily for welding stainless steel such as types 16-8-2, 316, and 347 for high-pressure, high-temperature piping systems. The weld deposit usually has a Ferrite Number no higher than 5 FN. The deposit also has good hot-ductility properties which offer greater freedom from weld or crater cracking even under restraint conditions. The weld metal is usable in either the as-welded condition or solution-treated condition. This filler metal depends on a very carefully balanced chemical composition to develop its fullest properties. Corrosion tests indicate that the 16-8-2 weld metal may have less corrosion resistance than 316 base metal, depending on the corrosive media. Where the weldment is exposed to severe corrodants, the surface layers should be deposited with a more corrosion-resistant filler metal.

A8.3.50 EC2209. The nominal composition (wt %) of this classification is 22.5 Cr, 8.5 Ni, 3 Mo, and 0.15 N. Filler metal of this classification is used primarily to weld duplex stainless steels which contain approximately 22% chromium such as UNS S31803 and S32205. Deposits of this alloy have “duplex” microstructures consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting.

A8.3.51 EC2553. The nominal composition (wt %) of this classification is 25.5 Cr, 5.5 Ni, 3.4 Mo, 2 Cu, and 0.2 N. Filler metal of this classification is used primarily to weld duplex stainless steels UNS S32550 which contain approximately 25% chromium. Deposits of this alloy have a “duplex” microstructure consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting.

A8.3.52 EC2594. The nominal composition (wt %) of this classification is 25.5 Cr, 9.2 Ni, 3.5 Mo, and 0.25 N. The sum of the Cr + 3.3(Mo + 0.5 W) + 16 N, known as the Pitting Resistance Equivalent Number (PREN), is at least 40, thereby allowing the weld metal to be called a ‘superduplex stainless steel’. This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride-containing environments. It is designed for the welding of superduplex stainless steels UNS S32750 and 32760 (wrought), and UNS J93380 and J93404 (cast). It can also be used for the welding of UNS S32550, J93370, and J93372 when not subject to sulfurous or sulfuric acids in service. It can also be used for welding carbon and low alloy steels to duplex stainless steels as well as to weld ‘standard’ duplex stainless steel such as UNS S32205 and J92205, especially for root runs in pipe.

A8.3.53 EC33-31. The nominal composition (wt %) of this classification is 33 Cr, 31Ni, and 1.6 Mo, with low carbon. The filler metal is used for welding nickel-chromium-iron alloy (UNS R20033) to itself and to carbon steel, and for weld overlay on boiler tubes. The weld metal is resistant to high temperature corrosive environments of coal fired power plant boilers.

A8.3.54 EC3556. The nominal composition (wt %) of this classification is 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, and 2.5 W. Filler metal of this classification is used for welding 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W (UNS R30556) base metal to itself, for joining steel to other nickel alloys, and for surfacing steel by the gas tungsten arc, gas metal arc, and plasma arc welding processes. The filler metal is resistant to high-temperature corrosive environments containing sulfur. Typical specifications for 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W base metal are ASTM B 435, B 572, B 619, B 622, and B 626 (UNS R30556).

A9. Special Tests

A9.1 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. For impact testing at any temperature, the requirements of Impact Test (Clause 14) for specimen type and size should be followed. AWS A5.01M/A5.01 contains provisions for ordering such tests. This clause 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 AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*. 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 9.4 should be used.

A9.2 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 purchaser and supplier. This subclause is included for the guidance of those who desire such special tests.

A9.2.1 Corrosion or scaling tests of joint specimens have the advantage that the joint design and welding procedure can be made identical to those being used in fabrication. 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.

A9.2.2 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 Clause 9). The pad size should be at least 3/4 in [19 mm] in height by 2-1/2 in [65 mm] wide by 1 + n5/8 in [25 + n16 mm] long, where “n” represents the number of specimens required from the pad. Specimens measuring 1/2 × 2 × 1/4 in [13 × 51 × 6.4 mm] are machined from the top surface of the pad in such a way that the 2 in [51 mm] dimension of the specimen is parallel to the 2-1/2 in [65 mm] width dimension of the pad and the 1/2 in [13 mm] dimension is parallel to the length of the pad.

A9.2.3 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 ASTM G 4, *Standard Method for Conducting Corrosion Tests in Plant Equipment*, or ASTM A 262, *Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels*.

A10. Discontinued Classifications

The classifications that have been discontinued are listed in Table A.3 along with the year in which they were last included in this specification.

A11. General Safety Considerations

A11.1 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clause A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A11.2, ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*,¹⁴ and applicable federal and state regulations.

A11.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at <http://www.aws.org>. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

¹⁴ ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Table A.3
Discontinued Classifications

Classification	Year of Last Publication
EXXXT-2	1980
E309LCbTX-X ^a	1995
E410NiTiTX-X	1995
E410NiTiT0-3	1995
E502TX-X ^b	1995
E505TX-X ^b	1995

^a E309LCbTX-X is now E309LNbTX-X.

^b Classifications E502TX-X and E505TX-X have been moved from this revision to AWS A5.29/5.29M as new classifications E8XTX-B6/E8XTX-B6L and E8XTX-B8/E8XTX-B8L, respectively.

A11.3 AWS Safety and Health Fact Sheets Index (SHF)¹⁵

No. Title

- 1 *Fumes and Gases*
- 2 *Radiation*
- 3 *Noise*
- 4 *Chromium and Nickel in Welding Fume*
- 5 *Electrical Hazards*
- 6 *Fire and Explosion Prevention*
- 7 *Burn Protection*
- 8 *Mechanical Hazards*
- 9 *Tripping and Falling*
- 10 *Falling Objects*
- 11 *Confined Spaces*
- 12 *Contact Lens Wear*
- 13 *Ergonomics in the Welding Environment*
- 14 *Graphic Symbols for Precautionary Labels*
- 15 *Style Guidelines for Safety and Health Documents*
- 16 *Pacemakers and Welding*
- 17 *Electric and Magnetic Fields (EMF)*
- 18 *Lockout/Tagout*
- 19 *Laser Welding and Cutting Safety*
- 20 *Thermal Spraying Safety*
- 21 *Resistance Spot Welding*
- 22 *Cadmium Exposure from Welding & Allied Processes*
- 23 *California Proposition 65*
- 24 *Fluxes for Arc Welding and Brazing: Safe Handling and Use*
- 25 *Metal Fume Fever*
- 26 *Arc Viewing Distance*
- 27 *Thoriated Tungsten Electrodes*
- 28 *Oxyfuel Safety: Check Valves and Flashback Arrestors*
- 29 *Grounding of Portable and Vehicle Mounted Welding Generators*
- 30 *Cylinders: Safe Storage, Handling, and Use*
- 31 *Eye and Face Protection for Welding and Cutting Operations*
- 33 *Personal Protective Equipment (PPE) for Welding & Cutting*
- 34 *Coated Steels: Welding and Cutting Safety Concerns*
- 36 *Ventilation for Welding & Cutting*
- 37 *Selecting Gloves for Welding & Cutting*

¹⁵ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Annex B (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS A5.22/A5.22M:2012, *Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*, but is included for informational purposes only.

B1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

B2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

B2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

B2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

B2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

B4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

B5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The *AWS Board Policy Manual* requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

AWS Filler Metal Specifications by Material and Welding Process

	OFW	SMAW	GTAW GMAW PAW	FCAW	SAW	ESW	EGW	Brazing
Carbon Steel	A5.2	A5.1	A5.18, A5.36	A5.36	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28, A5.36	A5.36	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless Steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11	A5.14	A5.34	A5.14	A5.14		A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

Designation	Title
FMC	<i>Filler Metal Comparison Charts</i>
IFS	<i>International Index of Welding Filler Metal Classifications</i>
UGFM	<i>User's Guide to Filler Metals</i>
A4.2M (ISO 8249 MOD)	<i>Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal</i>
A4.3	<i>Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding</i>
A4.4M	<i>Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings</i>
A4.5M/A4.5 (ISO 15792-3 MOD)	<i>Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld</i>
A5.01M/A5.01 (ISO 14344 MOD)	<i>Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes</i>
A5.02/A5.02M	<i>Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes</i>
A5.1/A5.1M	<i>Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding</i>
A5.2/A5.2M	<i>Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding</i>
A5.3/A5.3M	<i>Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding</i>
A5.4/A5.4M	<i>Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding</i>
A5.5/A5.5M	<i>Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding</i>
A5.6/A5.6M	<i>Specification for Copper and Copper-Alloy Electrodes for Shielded Metal Arc Welding</i>
A5.7/A5.7M	<i>Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes</i>
A5.8/A5.8M	<i>Specification for Filler Metals for Brazing and Braze Welding</i>
A5.9/A5.9M	<i>Specification for Bare Stainless Steel Welding Electrodes and Rods</i>
A5.10/A5.10M	<i>Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods</i>
A5.11/A5.11M	<i>Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding</i>
A5.12M/A5.12 (ISO 6848 MOD)	<i>Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting</i>
A5.13/A5.13M	<i>Specification for Surfacing Electrodes for Shielded Metal Arc Welding</i>
A5.14/A5.14M	<i>Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods</i>
A5.15	<i>Specification for Welding Electrodes and Rods for Cast Iron</i>
A5.16/A5.16M	<i>Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods</i>
A5.17/A5.17M	<i>Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding</i>
A5.18/A5.18M	<i>Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding</i>
A5.19	<i>Specification for Magnesium Alloy Welding Electrodes and Rods</i>
A5.21/A5.21M	<i>Specification for Bare Electrodes and Rods for Surfacing</i>
A5.22/A5.22M	<i>Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods</i>
A5.23/A5.23M	<i>Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding</i>
A5.24/A5.24M	<i>Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods</i>
A5.25/A5.25M	<i>Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding</i>
A5.26/A5.26M	<i>Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding</i>
A5.28/A5.28M	<i>Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding</i>
A5.30/A5.30M	<i>Specification for Consumable Inserts</i>
A5.31	<i>Specification for Fluxes for Brazing and Braze Welding</i>
A5.32M/A5.32 (ISO 14175 MOD)	<i>Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes</i>
A5.34/A5.34M	<i>Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding</i>
A5.36/A5.36M	<i>Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding</i>

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