AWS A5.23/A5.23M:2011
An American National Standard

Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

American Welding Society®

Approved American National Standard
ANSI

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Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

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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

This specification provides requirements for the classification of solid and composite carbon steel and low-alloy steel electrodes and fluxes for submerged arc welding. Electrode classification is based on chemical composition of the electrode for solid electrodes, and chemical composition of the weld metal for composite electrodes. Fluxes may be classified using a multiple pass classification system or a two-run classification system, or both, under this specification. Multiple pass classification is based on the mechanical properties and the deposit composition of weld metal produced with the flux and an electrode classified herein. Two-run classification is based upon mechanical properties only. Additional requirements are included for sizes, marking, manufacturing and packaging. The form and usability of the flux are also included. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of submerged arc fluxes and electrodes.

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

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Foreword

This foreword is not part of AWS A5.23/A5.23M:2011, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, but is included for informational purposes only.

This document is the third of the A5.23/A5.23M 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 materials — 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 U.S. Customary and SI Units.

This is the fifth revision of the document originally issued in 1976. That document was issued jointly by the American Welding Society and the American Society for Testing and Materials. The practice of issuing filler metal specifications as joint AWS/ASTM documents was discontinued shortly after the original version of this specification was issued. The 1976 version, published by AWS, was accepted by the American National Standards Institute as an ANSI standard. Subsequent revisions have become ANSI/AWS standards. *This revision includes new classifications EB23, B23, EB24, B24, ENi6 and Ni6. Classifications Ni3, Ni5, EA1TiB, EA2TiB and B9 have been modified. EB9 has been renamed as EB91 and B9 has been renamed to B91. The dual classification restriction has been deleted. Boron (B) reporting requirement has been added if intentionally added or found at a level greater than 0.0010%. Substantive changes are shown in italics font. The evolution took place as follows:*

ANSI/AWS A5.23–76, *Specification for Bare Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*; ANSI/AWS A5.23–80, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*; ANSI/AWS A5.23–90, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*; ANSI/AWS A5.23/A5.23M:1999, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*; and AWS A5.23/A5.23M:2007, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*.

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.

The welding terms used in this specification shall be interpreted in accordance with the definitions given in the latest edition of AWS A3.0, *Standard Welding Terms and Definitions*.

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Table of Contents

Page No.

Page No.

List of Tables

List of Figures

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Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel and low-alloy steel electrodes (both solid and composite) and fluxes for submerged arc welding. Multiple pass flux–electrode classifications include requirements for low-alloy weld metal composition. Two-run flux–electrode classifications, which are also permitted under this specification, have no requirements for weld metal composition. The multiple pass classification of flux–electrode combinations for carbon steel submerged arc welding is not within the scope of this specification but remains with AWS A5.17/A5.17M, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding.*

1.2 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 the nonmandatory 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 federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.23 uses U.S. Customary Units. The specification A5.23M uses SI units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing of electrodes or packaging or both under specification A5.23 or A5.23M.

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 referenced standard applies.

2.1 The following AWS standards[1] are referenced in the mandatory clauses of this document:

AWS A1.1, *Metric Practice Guide for the Welding Industry*

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*

AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

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

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, *Filler Metal Standard Sizes, Packaging and Physical Attributes*

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

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

AWS F3.2, *Ventilation Guide for Weld Fumes*

2.2 The following ANSI standard is referenced in the mandatory clauses of this document:

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*[2]

2.3 The following ASTM standards[3] are referenced in the mandatory clauses of this document:

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

ASTM A 131/A 131M, *Standard Specification for Structural Steel for Ships*

ASTM A 203/A 203M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

ASTM A 204/A 204M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum*

ASTM A 285/A 285M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength.*

ASTM A 387/A 387M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium–Molybdenum*

ASTM A 514/A 514M, *Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Quenching*

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

ASTM A 516/A 516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.*

ASTM A 517/A 517M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered*

ASTM A 533/A 533M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese–Molybdenum and Manganese–Molybdenum–Nickel*

ASTM A 537/A 537M, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon–Manganese–Silicon Steel*

ASTM A 543/A 543M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Nickel–Chromium–Molybdenum*

ASTM A 572/A 572M, *Standard Specification for High-Strength Low-Alloy Columbium–Vanadium Structural Steel*

ASTM A 588/A 588M, *Standard Specification for High-Strength Low-Alloy Structural Steel,up to 50 ksi [345 MPa] Minimum Yield Point with Atmospheric Corrosion Resistance*

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

ASTM E 350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

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

2 This ANSI standard is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.
3 ASTM standards are published by the ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959.

2.4 The following ISO standards[4] are referenced in the mandatory clauses of this document.

ISO 544, *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances, and marking*.

ISO 80000-1, *Quantities and units*

3. Classification

3.1 The submerged arc welding electrodes and fluxes covered by the A5.23 specification utilize a classification system based upon the U.S. Customary Units and are classified according to the following:

(1) The mechanical properties of the weld metal obtained from a multiple pass groove weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1 and 2.

AND/OR

The mechanical properties of the weld metal obtained from a two-run butt weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1 and 2.

Table 1
A5.23 Tension Test Requirements

Flux–Electrode Classifications[a]		Tensile Strength[b] (psi)	Yield Strength[b] (0.2% Offset) (psi)	Elongation[b] (%)
Multiple Pass Classifications	F7XX-EXX-XX	70 000–95 000	58 000	22
	F8XX-EXX-XX	80 000–100 000	68 000	20
	F9XX-EXX-XX	90 000–110 000	78 000	17
	F10XX-EXX-XX	100 000–120 000	88 000	16
	F11XX-EXX-XX	110 000–130 000	98 000	15[c]
	F12XX-EXX-XX	120 000–140 000	108 000	14[c]
	F13XX-EXX-XX	130 000–150 000	118 000	14[c]
Two-Run Classifications	F6TXX-EXX	60 000	50 000	22
	F7TXX-EXX	70 000	60 000	22
	F8TXX-EXX	80 000	70 000	20
	F9TXX-EXX	90 000	80 000	17
	F10TXX-EXX	100 000	90 000	16
	F11TXX-EXX	110 000	100 000	15
	F12TXX-EXX	120 000	110 000	14
	F13TXX-EXX	130 000	120 000	14

[a] The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter "C" will appear after the "E" as part of the classification designation when the electrode used is a composite electrode. For two-run classifications, the letter "G" will appear after the impact designator (immediately before the hyphen) to indicate that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel, as agreed between purchaser and supplier. The letter "X" used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the weld metal. See Figure 1 or 2, as applicable, for a complete explanation of the classification designators.

[b] For multiple pass classifications, the requirements listed in the table for yield strength and % elongation (in 2 in gauge length) are minimum requirements. For two-run classifications, the requirements listed for tensile strength, yield strength, and % elongation (in 1 in gauge length) are all minimum requirements.

[c] Elongation may be reduced by one percentage point for F11XX-EXX-XX, F11XX-ECXX-XX, F12XX-EXX-XX, F12XX-ECXX-XX, F13XX-EXX-XX, and F13XX-ECXX-XX weld metals in the upper 25% of their tensile strength range.

[4] ISO standards are published by the International Organization of Standardization, 1, ch. De la Voie-Creuse, Case Postale 56, CH-1211 Geneva 20, Switzerland.

Table 1M
A5.23M Tension Test Requirements

Flux–Electrode Classifications[a]		Tensile Strength[b] (MPa)	Yield Strength[b] (0.2% Offset) (MPa)	Elongation[b] (%)
Multiple Pass Classifications	F49XX-EXX-XX	490–660	400	22
	F55XX-EXX-XX	550–700	470	20
	F62XX-EXX-XX	620–760	540	17
	F69XX-EXX-XX	690–830	610	16
	F76XX-EXX-XX	760–900	680	15[c]
	F83XX-EXX-XX	830–970	740	14[c]
	F90XX-EXX-XX	900–1040	810	14[c]
Two-Run Classifications	F43TXX-EXX	430	350	22
	F49TXX-EXX	490	415	22
	F55TXX-EXX	550	490	20
	F62TXX-EXX	620	555	17
	F69TXX-EXX	690	625	16
	F76TXX-EXX	760	690	15
	F83TXX-EXX	830	760	14
	F90TXX-EXX	900	830	14

[a] The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter "C" will appear after the "E" as part of the classification designation when the electrode used is a composite electrode. For two-run classifications, the letter "G" will appear after the impact designator (immediately before the hyphen) to indicate that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel, as agreed between purchaser and supplier. The letter "X" used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the weld metal. See Figure 1M or 2M, as applicable, for a complete explanation of the classification designators.

[b] For multiple pass classifications, the requirements listed in the table for yield strength and % elongation (in 50 mm gauge length) are minimum requirements. For two-run classifications, the requirements listed for tensile strength, yield strength, and % elongation (in 25 mm gauge length) are all minimum requirements.

[c] Elongation may be reduced by one percentage point for F76-EXX-XX, F76-ECXX-XX, F83XX-EXX-XX, F83XX-ECXX-XX, F90XX-EXX-XX, and F90XX-ECXX-XX weld metals in the upper 25% of their tensile strength range.

Table 2
Impact Test Requirements

A5.23 Requirements			A5.23M Requirements		
A5.23 Impact Designator[a,b]	Maximum Test Temperature[c] (°F)	Minimum Average Energy Level	A5.23M Impact Designator[a,b]	Maximum Test Temperature[c] (°C)	Minimum Average Energy Level
0	0	20 ft·lbf	0	0	27 J
2	–20		2	–20	
4	–40		3	–30	
5	–50		4	–40	
6	–60		5	–50	
8	–80		6	–60	
10	–100		7	–70	
15	–150		10	–100	
Z	No Impact Requirements		Z	No Impact Requirements	

[a] Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate designator from this table, as indicated in Figure 1, 1M, 2, or 2M, as applicable.

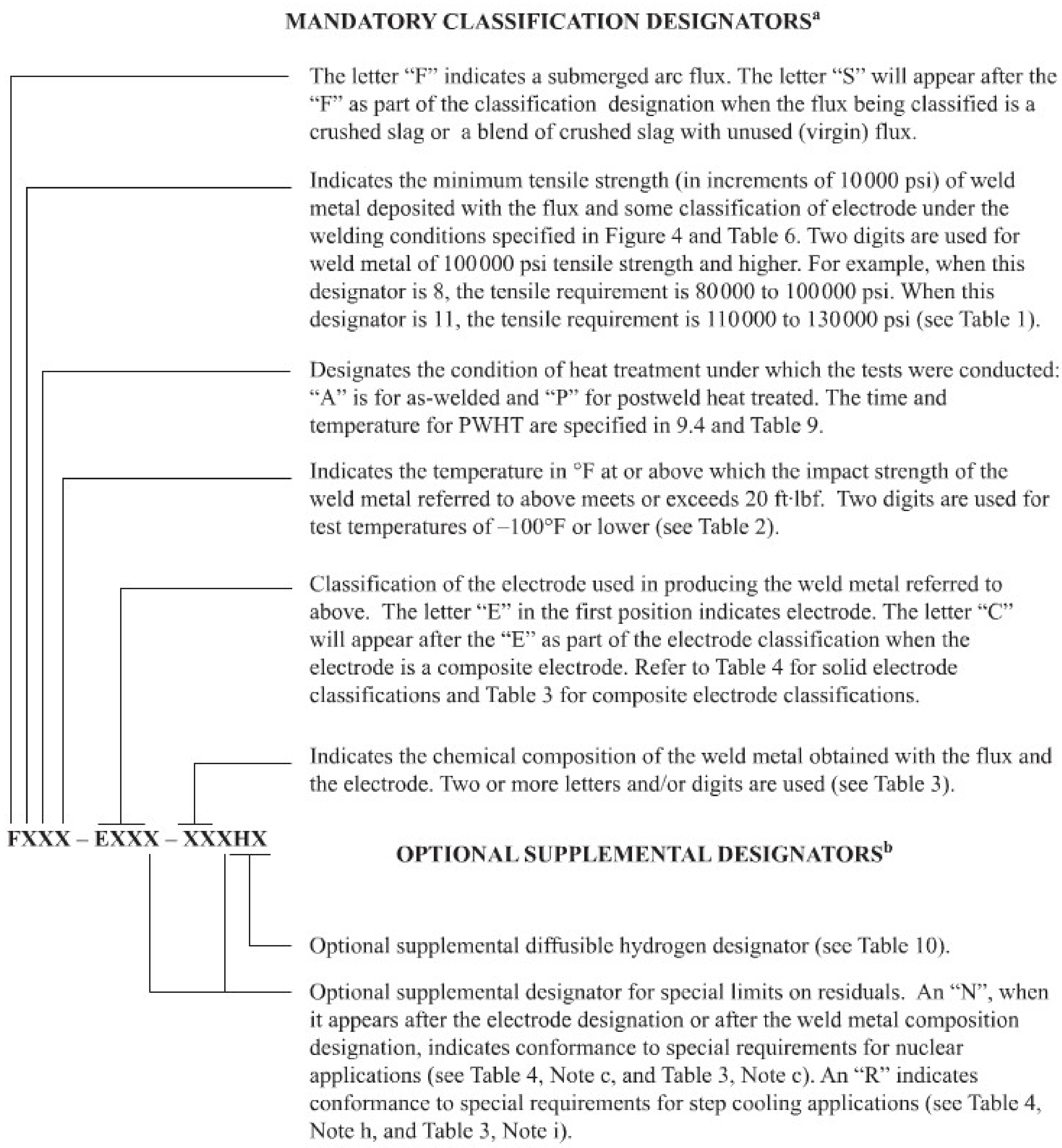
[b] When classifying flux–electrode combinations to A5.23 using U.S. Customary Units, the Impact Designator indicates the impact test temperature in °F. When classifying to A5.23M using the International System of Units (SI) the Impact Designator indicates the impact test temperature in °C. With the exception of the Impact Designator "4", a given Impact Designator will indicate different temperatures depending upon whether classification is according to A5.23 in U.S. Customary Units or according to A5.23M in the International System of Units (SI). For example, a "2" Impact Designator when classifying to A5.23 indicates a test temperature of –20°F. When classifying to A5.23M the "2" Impact Designator indicates a test temperature of –20°C, which is –4°F.

[c] Weld metal from a specific flux–electrode combination that meets the impact requirements at a given temperature also meets the requirements at all higher temperatures in this table. For example, weld metal meeting the A5.23 requirements for designator "5" also meets the requirements for designators 4, 2, 0, and Z. [Weld metal meeting the A5.23M requirements for designator "5" also meets the requirements for designators 4, 3, 2, 0, and Z].

(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 or 9.5, as applicable (and as shown in Figure 1 or 2, as applicable).

(3) For multiple pass classifications, the chemical composition of the weld metal obtained with the combination of a particular flux and a particular classification of electrode as specified in Table 3. Two-run classifications have no requirement for weld metal composition under this specification (see Figure 1 or 2, as applicable).

(4) The chemical composition of either the electrode (for solid electrodes) as specified in Table 4, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 3.



[a] The combination of these designators constitutes the flux–electrode classification.
[b] These designators are optional and do not constitute a part of the flux–electrode classification.

EXAMPLE

F9P0-EB3-B3 is a complete designation for a flux–electrode combination. It refers to a flux that will produce weld metal which, in the postweld heat-treated condition, will have a tensile strength of 90 000 to 110 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at 0°F when produced with an EB3 electrode under the conditions called for in this specification. The composition of the weld metal will meet the requirements for a B3 designation as specified in Table 3.

Source: Figure 1 of AWS A5.23/A5.23M:2007

Figure 1 — A5.23 Multiple Pass Classification System for U.S. Customary Units

MANDATORY CLASSIFICATION DESIGNATORS[a]

The letter "F" indicates a submerged arc flux. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or blend of crushed slag with unused (virgin) flux.

Two digits indicate the minimum tensile strength (in increments of 10 megapascals [MPa]) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 4 and Table 6. For example, when this designator is 55, the tensile requirement is 550 MPa to 700 MPa (see Table 1M).

Designates the condition of heat treatment in which the tests were conducted: "A" is for as-welded and "P" is for postweld heat treated. The time and temperature of the PWHT are specified in 9.4 and Table 9.

Indicates the temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J. Two digits are used for the –100°C test temperature (see Table 2).

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C" will appear after the "E" as part of the electrode classification when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

Indicates the chemical composition of the weld metal obtained with the flux and the electrode. Two or more letters and/or digits are used (see Table 3).

FXXXX – EXXX – XXXHX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental hydrogen designator (see Table 10).

Optional supplemental designator for special limits on residuals. An "N", when it appears after the electrode designation or after the weld metal composition designation, indicates conformance to special requirements for nuclear applications (see Table 4, Note c and Table 3, Note c). An "R" indicates conformance to special requirements for step cooling applications (see Table 4, Note h and Table 3, Note i).

[a] The combination of these designators constitutes the flux–electrode classification.
[b] These designators are optional and do not constitute a part of the flux–electrode classification.

EXAMPLE

F62P2-EB3-B3 is a complete designation for a flux–electrode combination. It refers to a flux that will produce weld metal which, in the postweld heat-treated condition, will have a tensile strength of 620 MPa to 760 MPa and Charpy V-notch impact strength of at least 27 J at –20°C when produced with an EB3 electrode under the conditions called for in this specification. The composition of the weld metal will meet the requirements for a B3 designation as specified in Table 3.

Source: Figure 1M of AWS A5.23/A5.23M:2007.

Figure 1M — A5.23M Multiple Pass Classification System for the International System of Units (SI)

MANDATORY CLASSIFICATION DESIGNATORS[a]

The letter "F" indicates a submerged arc welding flux. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or blend of crushed slag with unused (virgin) flux.

Indicates the minimum tensile strength (in increments of 10 000 psi) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 5 and Table 7. One or two digits may be used depending on the strength level, as indicated in Table 1. The "T" at the end of the designator identifies the classification as a two-run classification. For example, when this designator is "7T," the two-run classification tensile requirement is 70 000 psi minimum. When this designator is "10T," the tensile requirement is 100 000 psi minimum.

Designates the condition of heat treatment in which the tests were conducted: "A" for as-welded and "P" for postweld heat treated. The PWHT procedure is specified in 9.5.

Indicates the temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf. Two digits are used for test temperatures of –100 °F or lower (see Table 2).

The letter "G," when it appears in this position, indicates that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel as agreed between purchaser and supplier.

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C" will appear after the "E" as part of the electrode classification when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

FXTXXG – EXX – HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

[a] The combination of these designators constitutes the flux–electrode classification.
[b] These designators are optional and do not constitute a part of the flux–electrode classification.

EXAMPLE

F7TA4-EM12K is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EM12K electrode to weld the base plate prescribed in Table 8 in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 70 000 psi and Charpy V-Notch impact strength of at least 20 ft·lbf at –40°F.

F10TP2G-EA3 is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EA3 electrode in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the postweld heat-treated condition having a minimum tensile strength of 100 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –20°F. The "G" in the classification indicates that the base steel used is not as prescribed in Table 8 but is some other steel as agreed between purchaser and supplier

Source: Figure 2 of AWS A5.23/A5.23M:2007.

Figure 2 — A5.23 Two-Run Classification System for U.S. Customary Units

MANDATORY CLASSIFICATION DESIGNATORS[a]

The letter "F" indicates a submerged arc welding flux. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or blend of crushed slag with unused (virgin) flux.

Indicates the minimum tensile strength (in increments of 10 MPa) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 5 and Table 7. The "T" at the end of the designator identifies the classification as a two-run classification. For example, when this designator is "62T," the two-run classification tensile requirement is 620 megapascals (MPa) minimum. (See Table 1M).

Designates the condition of heat treatment in which the tests were conducted: "A" for as-welded and "P" for postweld heat treated. The PWHT procedure is specified in 9.5.

Indicates the temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J. Two digits are used for the –100°C test temperature. (see Table 2).

The letter "G," when it appears in this position, indicates that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel as agreed between purchaser and supplier.

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C" will appear after the "E" as part of the electrode classification when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

FXXTXXG – EXX – HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

[a] The combination of these designators constitutes the flux–electrode classification.
[b] These designators are optional and do not constitute a part of the flux–electrode classification.

EXAMPLES

F55TA3-EM12K is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EM12K electrode to weld the base plate prescribed in Table 8 in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 550 MPa and Charpy V-notch impact strength of at least 27 J at –30°C.

F62TP4G-EA1 is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EA1 electrode in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the postweld heat-treated condition having a minimum tensile strength of 620 MPa and Charpy V-notch impact strength of at least 27 J at –40°C. The "G" in the classification indicates that the base steel used is not as prescribed in Table 8 but is some other steel as agreed between purchaser and supplier.

Source: Figure 2M of AWS A5.23/A5.23M:2007.

Figure 2M — A5.23M Two-Run Classification System for the International System of Units (SI)

Table 3
Chemical Composition Requirements for Weld Metal[a]

Weld Metal Designation[b,c]	UNS Number[d]	Weight Percent[e,f,g]									
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other[h]
A1	W17041	0.12	1.00	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A2	W17042	0.12	1.40	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A3	W17043	0.15	2.10	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A4	W17044	0.15	1.60	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
B1	W51040	0.12	1.60	0.80	0.030	0.030	0.40–0.65	—	0.40–0.65	0.35	—
B2[i]	W52040	0.05–0.15	1.20	0.80	0.030	0.030	1.00–1.50	—	0.40–0.65	0.35	—
B2H	W52240	0.10–0.25	1.20	0.80	0.020	0.020	1.00–1.50	—	0.40–0.65	0.35	V: 0.30
B3[i]	W53040	0.05–0.15	1.20	0.80	0.030	0.030	2.00–2.50	—	0.90–1.20	0.35	—
B4	W53340	0.12	1.20	0.80	0.030	0.030	1.75–2.25	—	0.40–0.65	0.35	—
B5	W51340	0.18	1.20	0.80	0.030	0.030	0.40–0.65	—	0.90–1.20	0.35	—
B6	W50240	0.12	1.20	0.80	0.030	0.030	4.50–6.00	—	0.40–0.65	0.35	—
B6H	W50140	0.10–0.25	1.20	0.80	0.030	0.030	4.50–6.00	—	0.40–0.65	0.35	—
B8	W50440	0.12	1.20	0.80	0.030	0.030	8.00–10.00	—	0.80–1.20	0.35	—
B23	*K20857*	*0.04–0.12*	*1.00*	*0.80*	*0.015*	*0.020*	*1.9–2.9*	*0.50*	*0.30*	*0.25*	*W: 1.50–2.00* *V: 0.15–0.30* *Nb: 0.02–0.10* *B: 0.006* *Al: 0.04* *N: 0.07*
B24	*K20885*	*0.04–0.12*	*1.00*	*0.80*	*0.015*	*0.020*	*1.9–2.9*	*0.30*	*0.80–1.20*	*0.25*	*V: 0.15–0.30* *Nb: 0.02–0.10* *Ti: 0.10* *B: 0.006* *Al: 0.04* *N: 0.05*
B91	W50442	*0.08–*0.13	*1.20*[j]	0.80	0.010	0.010	*8.0–10.5*	*0.80*[j]	0.85–1.20	0.25	Nb: *0.02*–0.10 N: *0.02*–0.07 V: 0.15–0.25 Al: 0.04
F1	W21150	0.12	0.70–1.50	0.80	0.030	0.030	0.15	0.90–1.70	0.55	0.35	—
F2	W20240	0.17	1.25–2.25	0.80	0.030	0.030	—	0.40–0.80	0.40–0.65	0.35	—
F3	W21140	0.17	1.25–2.25	0.80	0.030	0.030	—	0.70–1.10	0.40–0.65	0.35	—

Table 3 (Continued)
Chemical Composition Requirements for Weld Metal[a]

Weld Metal Designation[b,c]	UNS Number[d]	Weight Percent[e,f,g] C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other[h]
F4	W20440	0.17	1.60	0.80	0.035	0.030	0.60	0.40–0.80	0.25	0.35	Ti + V + Zr: 0.03
F5	W22540	0.17	1.20–1.80	0.80	0.020	0.020	0.65	2.00–2.80	0.30–0.80	0.50	—
F6	W22640	0.14	0.80–1.85	0.80	0.020	0.030	0.65	1.50–2.25	0.60	0.40	—
M1	W21240	0.10	0.60–1.60	0.80	0.030	0.030	0.15	1.25–2.00	0.35	0.30	Ti + V + Zr: 0.03
M2	W21340	0.10	0.90–1.80	0.80	0.020	0.020	0.35	1.40–2.10	0.25–0.65	0.30	Ti + V + Zr: 0.03
M3	W22240	0.10	0.90–1.80	0.80	0.020	0.020	0.65	1.80–2.60	0.20–0.70	0.30	Ti + V + Zr: 0.03
M4	W22440	0.10	1.30–2.25	0.80	0.020	0.020	0.80	2.00–2.80	0.30–0.80	0.30	Ti + V + Zr: 0.03
M5	W21345	0.12	1.60–2.50	0.50	0.015	0.015	0.40	1.40–2.10	0.20–0.50	0.30	Ti: 0.03 V: 0.02 Zr: 0.02
M6	W21346	0.12	1.60–2.50	0.50	0.015	0.015	0.40	1.40–2.10	0.70–1.00	0.30	Ti: 0.03 V: 0.02 Zr: 0.02
Ni1	W21040	0.12	1.60[k]	0.80	0.025	0.030	0.15	0.75–1.10	0.35	0.35	Ti + V + Zr: 0.05
Ni2	W22040	0.12	1.60[k]	0.80	0.025	0.030	—	2.00–2.90	—	0.35	—
Ni3	W23040	0.12	*1.60*[k]	0.80	0.025	0.030	0.15	2.80–3.80	—	0.35	—
Ni4	W21250	0.14	1.60	0.80	0.025	0.030	—	1.40–2.10	0.10–0.35	0.35	—
Ni5	W21042	0.12	*1.60*[k]	0.80	0.025	0.030	—	0.70–1.10	0.10–0.35	0.35	—
Ni6	*W21042*	*0.14*	*1.60*[k]	*0.80*	*0.025*	*0.030*	—	*0.70–1.10*	*0.10–0.35*	*0.35*	—
W	W20140	0.12	0.50–1.60	0.80	0.030	0.035	0.45–0.70	0.40–0.80	—	0.30–0.75	—
G	As Agreed between Supplier and Purchaser										

[a] These requirements are applicable to both flux–solid electrode and flux–composite electrode combinations.
[b] The weld metal designation for composite electrodes is obtained by placing an "EC" before the appropriate electrode designation.
[c] The letter "N" when added as a suffix is an optional supplemental designator indicating that the limits on the phosphorous, vanadium, and copper are as follows: P = 0.012% max., V = 0.05% max., and Cu = 0.08% max. Additional requirements are given in 13.4. See A2.1 in Annex A for a discussion of the intended use of "N" designator electrodes.
[d] Refer to ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*
[e] The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50%.
[f] Single values are maximum.
[g] As a substitute for the weld pad in Figure 3, the sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen (see 10.2) or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 4. In case of dispute, the weld pad shall be the referee method.
[h] *Analysis for B is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.0010%.*
[i] The letter "R" when added as a suffix is an optional supplemental designator indicating that the limits on sulfur, phosphorous, copper, arsenic, tin, and antimony are as follows: S = 0.010% max., P = 0.010% max., Cu = 0.15% max., As = 0.005% max., Sn = 0.005% max., and Sb = 0.005% max. These reduced residual limits are necessary to meet the "X" factor requirements for step cooling applications.
[j] Mn + Ni = 1.40% maximum (see A7.2.3.1 in Annex A).
[k] Manganese in the Ni1, Ni2, *Ni3, Ni5, and Ni6* designated weld metals may be 1.80% maximum when the carbon is restricted to 0.10% maximum.

Table 4
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a,b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EL8[g]	K01008	0.10	0.25–0.60	0.07	0.030	0.030	—	—	—	0.35	—	—
EL8K[g]	K01009	0.10	0.25–0.60	0.10–0.25	0.030	0.030	—	—	—	0.35	—	—
EL12[g]	K01012	0.04–0.14	0.25–0.60	0.10	0.030	0.030	—	—	—	0.35	—	—
EM11K[g]	K01111	0.07–0.15	1.00–1.50	0.65–0.85	0.030	0.025	—	—	—	0.35	—	—
EM12[g]	K01112	0.06–0.15	0.80–1.25	0.10	0.030	0.030	—	—	—	0.35	—	—
EM12K[g]	K01113	0.05–0.15	0.80–1.25	0.10–0.35	0.030	0.030	—	—	—	0.35	—	—
EM13K[g]	K01313	0.06–0.16	0.90–1.40	0.35–0.75	0.030	0.030	—	—	—	0.35	—	—
EM14K[g]	K01314	0.06–0.19	0.90–1.40	0.35–0.75	0.025	0.025	—	—	—	0.35	—	Ti: 0.03–0.17
EM15K[g]	K01515	0.10–0.20	0.80–1.25	0.10–0.35	0.030	0.030	—	—	—	0.35	—	—
EH10K[g]	K01210	0.07–0.15	1.30–1.70	0.05–0.25	0.025	0.025	—	—	—	0.35	—	—
EH11K[f]	K11140	0.06–0.15	1.40–1.85	0.80–1.15	0.030	0.030	—	—	—	0.35	—	—
EH12K[g]	K01213	0.06–0.15	1.50–2.00	0.20–0.65	0.025	0.025	—	—	—	0.35	—	—
EH14[g]	K11585	0.10–0.20	1.70–2.20	0.10	0.030	0.030	—	—	—	0.35	—	—
EA1	K11222	0.05–0.15	0.65–1.00	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA1TiB	*K11020*	0.05–0.15	0.65–1.00	*0.35*	0.025	0.025	—	—	0.45–0.65	0.35	—	Ti: 0.05–0.30 B: 0.005–0.030
EA2TiB	*K11126*	0.05–0.17	0.95–1.35	*0.35*	0.025	0.025	—	—	0.45–0.65	0.35	—	Ti: 0.05–0.30 B: 0.005–0.030
EA2	K11223	0.05–0.17	0.95–1.35	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA3	K11423	0.05–0.17	1.65–2.20	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA3K	K21451	0.05–0.15	1.60–2.10	0.50–0.80	0.025	0.025	—	—	0.40–0.60	0.35	—	—
EA4	K11424	0.05–0.15	1.20–1.70	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EB1	K11043	0.10	0.40–0.80	0.05–0.30	0.025	0.025	0.40–0.75	—	0.45–0.65	0.35	—	—

Table 4 (Continued)
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a,b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EB2[h]	K11172	0.07–0.15	0.45–1.00	0.05–0.30	0.025	0.025	1.00–1.75	—	0.45–0.65	0.35	—	—
EB2H	K23016	0.28–0.33	0.45–0.65	0.55–0.75	0.015	0.015	1.00–1.50	—	0.40–0.65	0.30	0.20–0.30	—
EB3[h]	K31115	0.05–0.15	0.40–0.80	0.05–0.30	0.025	0.025	2.25–3.00	—	0.90–1.10	0.35	—	—
EB5	K12187	0.15–0.23	0.40–0.70	0.40–0.60	0.025	0.025	0.45–0.65	—	0.90–1.20	0.30	—	—
EB6	S50280	0.10	0.35–0.70	0.05–0.50	0.025	0.025	4.50–6.50	—	0.45–0.70	0.35	—	—
EB6H	S50180	0.25–0.40	0.75–1.00	0.25–0.50	0.025	0.025	4.80–6.00	—	0.45–0.65	0.35	—	—
EB8	S50480	0.10	0.30–0.65	0.05–0.50	0.025	0.025	8.00–10.50	—	0.80–1.20	0.35	—	—
EB23	*K20857*	*0.05–0.12*	*1.10*	*0.50*	*0.015*	*0.015*	*1.9–3.0*	*0.50*	*0.50*	*0.10*	*0.15–0.30*	*W: 1.50–2.00 Nb: 0.02–0.10 B: 0.006 Al: 0.04 N: 0.05*
EB24	*K20885*	*0.04–0.12*	*1.00*	*0.50*	*0.015*	*0.020*	*1.9–3.0*	*0.30*	*0.80–1.20*	*0.10*	*0.15–0.30*	*Nb: 0.02–0.10 Ti: 0.10 B: 0.006 Al: 0.04 N: 0.07*
EB91	S50482	0.07–0.13	1.25[i]	0.50	0.010	0.010	8.50–10.50	1.00[i]	0.85–1.15	0.10	0.15–0.25	Nb: 0.02–0.10 N: 0.03–0.07 Al: 0.04
EF1	K11160	0.07–0.15	0.90–1.70	0.15–0.35	0.025	0.025	—	0.95–1.60	0.25–0.55	0.35	—	—
EF2	K21450	0.10–0.18	1.70–2.40	0.20	0.025	0.025	—	0.40–0.80	0.40–0.65	0.35	—	—
EF3	K21485	0.10–0.18	1.50–2.40	0.30	0.025	0.025	—	0.70–1.10	0.40–0.65	0.35	—	—
EF4	K12048	0.16–0.23	0.60–0.90	0.15–0.35	0.030	0.025	0.40–0.60	0.40–0.80	0.15–0.30	0.35	—	—
EF5	K41370	0.10–0.17	1.70–2.20	0.20	0.015	0.010	0.25–0.50	2.30–2.80	0.45–0.65	0.50	—	—
EF6	K21135	0.07–0.15	1.45–1.90	0.10–0.30	0.015	0.015	0.20–0.55	1.75–2.25	0.40–0.65	0.35	—	—
EM2[j]	K10882	0.10	1.25–1.80	0.20–0.60	0.015	0.010	0.30	1.40–2.10	0.25–0.55	0.25	0.05	Ti: 0.10 Zr: 0.10 Al: 0.10
EM3[j]	K21015	0.10	1.40–1.80	0.20–0.60	0.015	0.010	0.55	1.90–2.60	0.25–0.65	0.25	0.04	Ti: 0.10 Zr: 0.10 Al: 0.10

Table 4 (Continued)
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a,b] C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EM4[j]	K21030	0.10	1.40–1.80	0.20–0.60	0.015	0.010	0.60	2.00–2.80	0.30–0.65	0.25	0.03	Ti: 0.10 Zr: 0.10 Al: 0.10
ENi1	K11040	0.12	0.75–1.25	0.05–0.30	0.020	0.020	0.15	0.75–1.25	0.30	0.35	—	—
ENi1K	K11058	0.12	0.80–1.40	0.40–0.80	0.020	0.020	—	0.75–1.25	—	0.35	—	—
ENi2	K21010	0.12	0.75–1.25	0.05–0.30	0.020	0.020	—	2.10–2.90	—	0.35	—	—
ENi3	K31310	0.13	0.60–1.20	0.05–0.30	0.020	0.020	0.15	3.10–3.80	—	0.35	—	—
ENi4	K11485	0.12–0.19	0.60–1.00	0.10–0.30	0.020	0.015	—	1.60–2.10	0.10–0.30	0.35	—	—
ENi5	K11240	0.12	1.20–1.60	0.05–0.30	0.020	0.020	—	0.75–1.25	0.10–0.30	0.35	—	—
ENi6	*K11240*	*0.07–0.15*	*1.20–1.60*	*0.05–0.30*	*0.020*	*0.020*	—	*0.75–1.25*	*0.10–0.30*	*0.35*	—	—
EW	K11245	0.12	0.35–0.65	0.20–0.35	0.030	0.025	0.50–0.80	0.40–0.80	—	0.30–0.80	—	—
EG	Not Specified											

[a] The electrode shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50%.
[b] Single values are maximum.
[c] The letter "N", when added as a suffix to the electrode classification, is an optional supplemental designator indicating that the limits on phosphorous, vanadium, and copper are as follows: P = 0.012% max., V = 0.05% max., and Cu = 0.08% max. See A2.1 in the Annex for a discussion of the intended use of "N" designator electrodes.
[d] Refer to ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*
[e] The copper limit includes any copper coating that may be applied to the electrode.
[f] *Analysis for B is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.0010%.*
[g] This electrode is also classified under AWS A5.17/A5.17M. It is included in this specification because it can be used with an alloy flux to deposit some of the weld metals designated in Table 3. In addition, this carbon steel electrode can be used for the two-run classification of flux–electrode combinations according to the provisions of this specification.
[h] The letter "R" when added as a suffix is an optional supplemental designator indicating that the limits on sulfur, phosphorous, copper, arsenic, tin, and antimony are as follows: S = 0.010% max., P = 0.010% max., Cu = 0.15% max., As =0.005% max., Sn = 0.005% max., and Sb = 0.005% max. These reduced residual limits are necessary to meet "X" factor requirements for step cooling applications.
[i] See A7.2.3.1 in Annex A for a discussion of the B91 alloy and recommendation regarding the Mn + Ni level achieved in the weld deposit. See also Note j of Table 3 for limits on the Mn + Ni content of the B91 weld deposit.
[j] The composition ranges of classifications with the "EM" prefix are intended to conform to the ranges of similar electrodes in the military specifications.

3.1M The submerged arc welding electrodes and fluxes covered by the A5.23M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the following:

(1) The mechanical properties of the weld metal obtained from a multiple pass groove weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1M and 2.

AND/OR

The mechanical properties of the weld metal obtained from a two-run butt weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1M and 2.

(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 or 9.5, as applicable (and as shown in Figure 1M or 2M, as applicable).

(3) For multiple pass classifications, the chemical composition of the weld metal obtained with the combination of a particular flux and a particular classification of electrode as specified in Table 3. Two-run classifications have no requirement for weld metal composition under this specification (see Figure 1M or 2M, as applicable).

(4) The chemical composition of either the electrode (for solid electrodes) as specified in Table 4 or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 3.

3.2 Flux–electrode combinations may be classified under A5.23 with U.S. Customary Units, under A5.23M using the International System of Units (SI), or both. Flux–electrode combinations classified under both A5.23 and A5.23M must meet all requirements for classification under each system. The classification systems are shown in Figures 1 and 1M (multiple pass) and in Figures 2 and 2M (two-run).

3.3 The electrodes and fluxes classified under this specification are intended for submerged arc welding, but that is not to prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance[5] of the electrodes and fluxes shall be in accordance with the provisions of AWS A5.01 or the tests and requirements of this specification.

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[6]

6. Rounding-Off Procedure

For purposes of determining compliance 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, Part 1: General (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 1 000 psi (1 ksi) for tensile or yield strength for A5.23 [to the nearest 10 MPa for tensile or yield strength for A5.23M] 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 for the classification under test.

7. Summary of Tests

7.1 Electrodes. Chemical analysis of the electrode is the only test required for classification of a solid electrode under this specification. The chemical analysis of the rod stock from which the solid electrode is made may also be used provided the electrode manufacturing process does not alter the chemical composition. For composite electrodes, chemical analysis of the weld metal produced with the composite electrode and a particular flux is required.

7.2 Fluxes. The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the mechanical properties and soundness of the weld metal. The base metal for test assemblies, the preparations of the test samples, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 14.

7.3 Flux classification is based upon a 5/32 in [4.0 mm] electrode size as standard. If this size electrode is not manufactured, the closest size shall be used for classification tests (see Table 6, Note d, and Table 7, Note d).

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[5] See A3 in Annex A for further information concerning acceptance, testing of the material shipped, and AWS A5.01.
[6] See A4 in Annex A for further information concerning certification and the testing called for to meet this requirement.

Table 5
Tests Required for Classification

AWS Classification	Chemical Analysis: Electrode	Chemical Analysis: Weld Metal	Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
All Solid Electrodes	Required	Not Required	Not Required	Not Required	Not Required	Not Required
All Composite Electrodes	Not Required	Required	Not Required	Not Required	Not Required	Not Required
All Flux–Solid or Composite Electrode Multiple Pass Classifications	Not Required	Required	Required	Required	Required[a]	(Note b)
All Flux–Solid or Composite Electrode Two-Run Classifications	Not Required	Not Required	Required	Required	Required[a]	(Note b)

[a] When the "Z" impact designator (no impact requirement – Table 2) is used, the Impact Test is not required.
[b] Diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Clauses A3 and A9 in Annex A).

Table 6
Welding Parameters for Multiple Pass Groove Weld Test Assembly

Welding Conditions for Solid Electrodes[a,b,c]

Electrode Size[d] in	Electrode Size[d] mm	Welding Current (amperes)[f]	Arc Voltage (volts)	Electrode Extension[g] in	Electrode Extension[g] mm	Travel Speed ipm (±1)	Travel Speed mm/sec. (±0.5)	Current Type[h]	Preheat and Interpass Temperatures
1/16	1.6	250–350	26–29	1/2 to 3/4	13–19	12	5.0	AC or DC either polarity	Refer to Table 9 for the Preheat and Interpass Temperatures Applicable to the Weld Metal Being Classified
5/64	2.0	300–400	26–29	1/2 to 3/4	13–19	13	5.5		
3/32	2.4	350–450	27–30	3/4 to 1–1/4	19–32	14	6.0		
—	2.5	350–450	27–30	3/4 to 1–1/4	19–32	14	6.0		
7/64	2.8	400–500	27–30	3/4 to 1–1/4	19–32	14	6.0		
—	3.0	400–500	27–30	1 to 1–1/2	25–38	15	6.5		
1/8	3.2	425–525	27–30	1 to 1–1/2	25–38	15	6.5		
5/32	4.0	475–575	27–30	1 to 1–1/2	25–38	16	7.0		
3/16	4.8[e]	525–625	27–30	1 to 1–1/2	25–38	17	7.0		
—	5.0	550–650	27–30	1 to 1–1/2	25–38	17	7.0		
7/32	5.6[e]	575–675	28–31	1–1/4 to 1–3/4	32–44	18	7.5		
—	6.0	625–725	28–31	1–1/4 to 1–3/4	32–44	19	8.0		
1/4	6.4[e]	700–800	28–32	1–1/2 to 2	38–50	20	8.5		

[a] Values specified in inches or ipm apply to A5.23. Values specified in mm or mm/sec apply to A5.23M.
[b] These welding conditions are intended for machine or automatic welding with straight progression (no weaving). Welding shall be performed in the flat position. The first layer shall be produced in either 1 or 2 passes. All other layers shall be produced in 2 or 3 passes per layer except the last, which shall be produced in 2, 3, or 4 passes. The completed weld shall be at least flush with the surface of the test plate.
[c] Welding conditions for composite electrodes shall be as agreed between purchaser and supplier.
[d] Classification is based on the properties of weld metal with 5/32 in [4.0 mm] electrodes or the closest size manufactured, if 5/32 in [4.0 mm] is not manufactured. The conditions given for sizes other than 5/32 in [4.0 mm] are to be used when classification is based on those sizes, or when they are required for lot acceptance testing under AWS A5.01 (unless otherwise specified by the purchaser).
[e] 4.8 mm, 5.6 mm, and 6.4 mm are not included as standard sizes in ISO 544:2003.
[f] Lower currents may be used for the first layer.
[g] The electrode extension is the contact tube-to-work distance. When an electrode manufacturer recommends a contact tube-to-work distance outside the range shown, that recommendation shall be followed ±1/4 in [6.5 mm].
[h] In case of dispute, DCEP (direct current electrode positive) shall be used as the referee current.

Table 7
Welding Parameters for Two-Run Weld Test Assembly[a,b]

Electrode Diameter		Procedure	Preheat/Interbead	Heat Input[d]
in	mm	Type[c]	Temperature	(each pass)
5/32[e]	4.0[e]	DCEP (single electrode) or AC (single electrode) or DCEP lead, AC trail (tandem) or AC lead, AC trail (tandem)	212°F [115°C] Maximum	55–80 kJ/in [2.2–3.1 kJ/mm]

[a] The test assembly shall be welded in the flat position in two runs, one from each side. The welding procedures shall be in conformance with the requirements of this table and shall be consistent with accepted welding practice. The procedure used shall ensure adequate tie-in of the weld beads made from each side. The requirements listed apply to both solid electrodes and composite electrodes.

[b] These welding conditions are intended for machine or automatic welding with straight progression (no weaving).

[c] Single electrode procedures with either DCEP (direct current, electrode positive) or AC (alternating current) or two-electrode tandem procedures (DCEP/AC or AC/AC) may be used for classification purposes. The procedure type used shall be the same for both weld passes. In case of dispute, DCEP shall be used as the referee current.

[d] The calculation to be used for heat input is:

$$\text{(1) Heat Input (kJ/in)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (in/min)} \times 1000} \quad \text{or} \quad \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (in)} \times 1000}$$

or

$$\text{(2) Heat Input (kJ/mm)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (mm/min)} \times 1000} \quad \text{or} \quad \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (mm)} \times 1000}$$

For two-wire tandem procedures the heat input is the arithmetic sum of the heat inputs calculated for each electrode.

[e] Classification is based upon the properties of the weld made with 5/32 in [4.0mm] electrodes or the closest size manufactured, if 5/32 in [4.0 mm] is not manufactured. An alternate electrode diameter may also be required, in some cases, for lot acceptance testing under AWS A5.01, unless other conditions are specified by the purchaser. The heat input requirements specified above for 5/32 in [4.0 mm] shall be used when using alternate diameters of electrode.

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. Material, specimens, or samples for retest may be taken from the original test assembly or sample or from one or two new test assemblies or samples. 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.

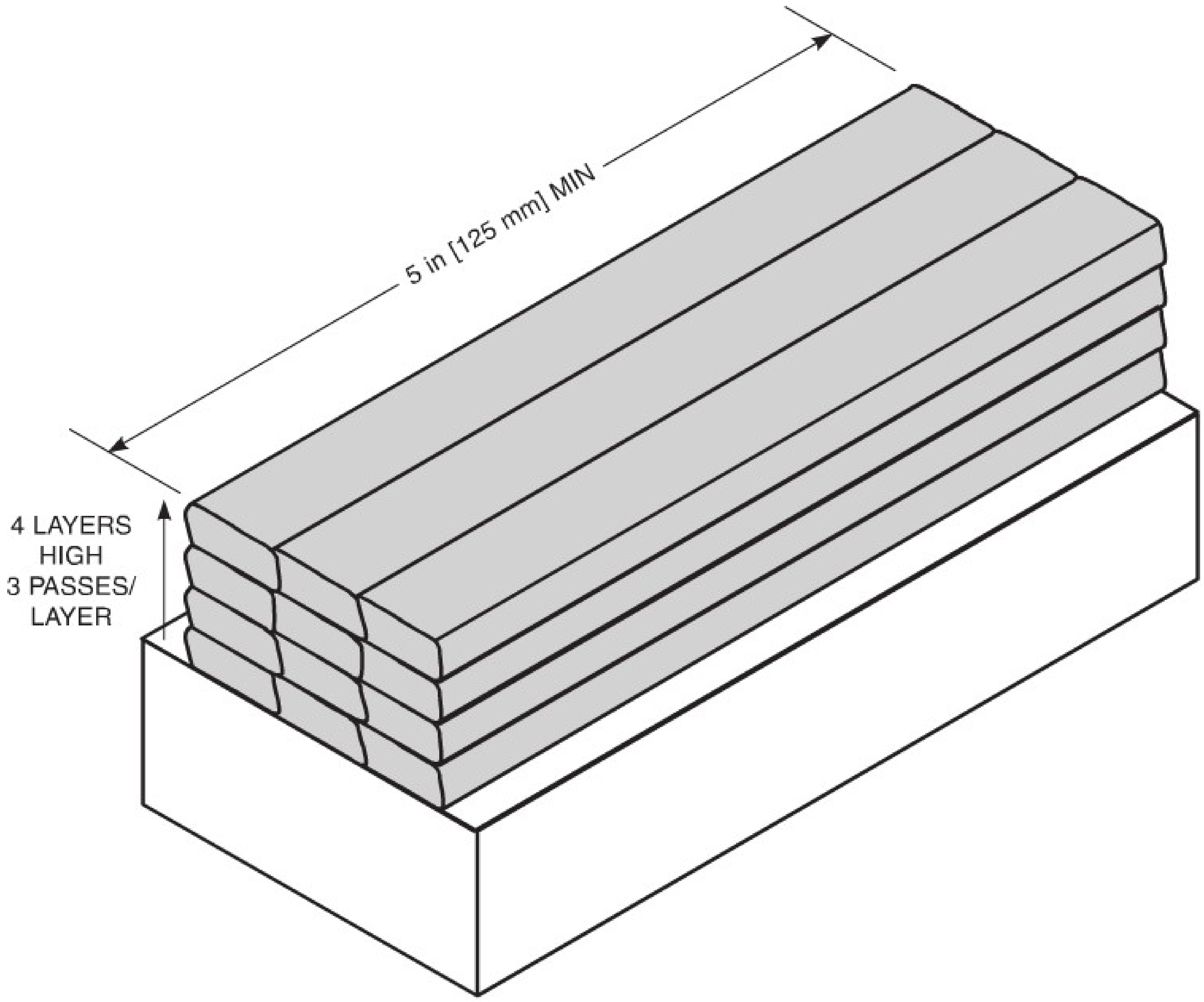
In the event that, during preparation or after the completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the weld test assembly or test specimen(s) or in conducting the test, the test shall be considered invalid, without regard to whether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

9. Weld Test Assemblies

9.1 Requirements for Classification

9.1.1 Classification of Solid Electrodes. No weld test assembly is required for classification of solid electrodes.

9.1.2 Classification of Composite Electrodes. The chemical analysis of weld metal produced with the composite electrode and a particular flux is required for classification of a composite electrode under this specification. The weld test assembly, shown in Figure 3, is used to meet this requirement for the classification of composite electrodes. Figure 3 is



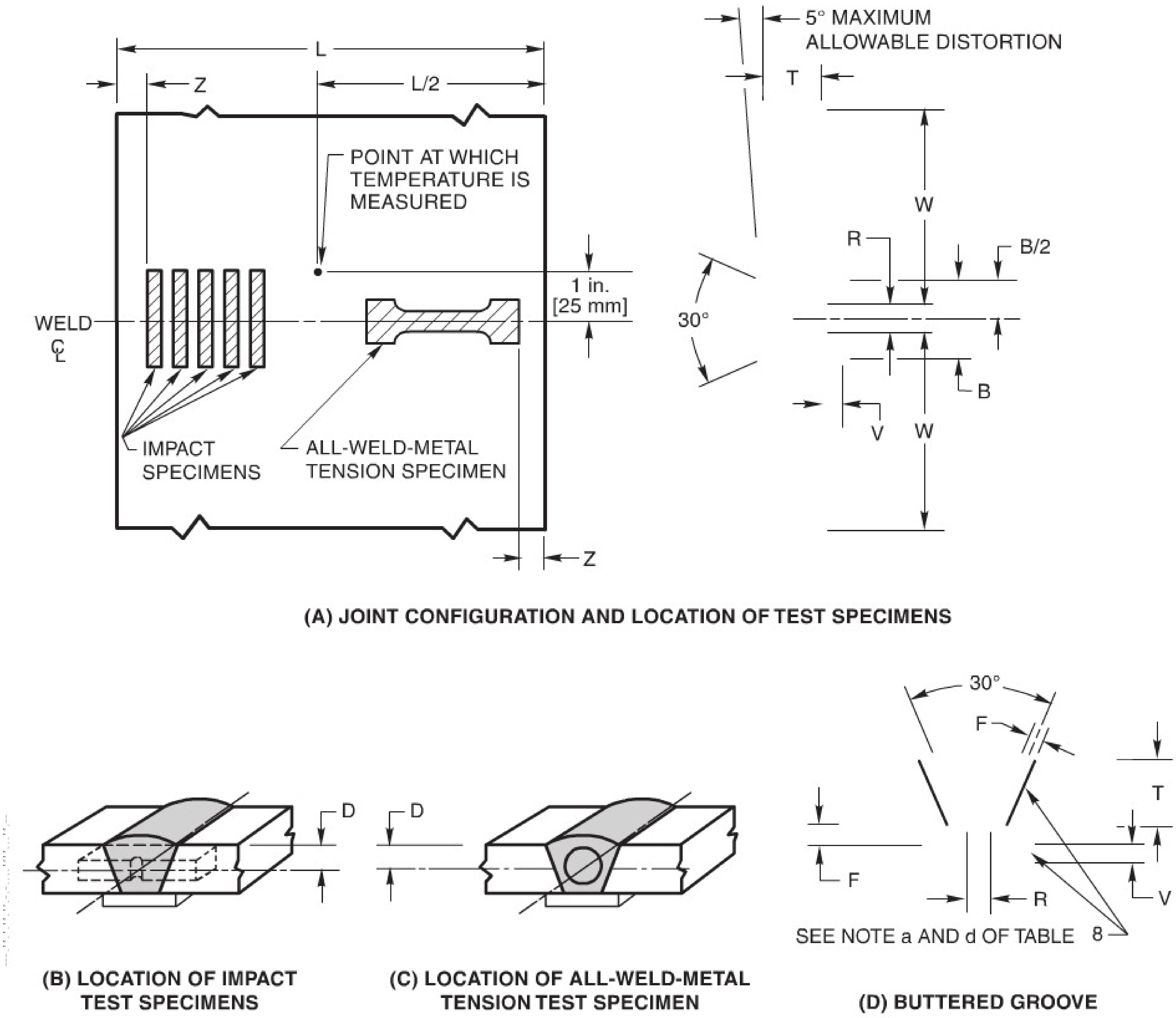
Notes:
1. Width, thickness, and length of the base metal plate may be any dimensions suitable for the electrode diameter and welding procedure. The base plate shall be of the type specified in Table 8 for the applicable weld metal designation.
2. Weld beads shall be deposited without oscillation. The welding conditions shall be in accordance with the welding parameters specified in Table 6 for the multiple pass groove weld.
3. The first and last 2 in [50 mm] of the weld length shall be discarded. The top surface shall be removed, and chemical analysis shall be taken from the underlying metal of the fourth layer of the weld pad.

Source: Figure 3 of AWS A5.23/A5.23M:2007.

Figure 3 — Weld Pad for Chemical Analysis of Weld Metal

the weld pad test assembly for chemical analysis of weld metal. The welding parameters for the multiple pass groove weld, as specified in Table 6, shall be used for the weld pad. As an alternative to the weld pad, the sample for chemical analysis of composite electrode weld metal may be taken from the groove weld in Figure 4. Note g of Table 3 allows the sample for chemical analysis in the case of a composite electrode to be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 4. In case of dispute, the weld pad shall be the referee method.

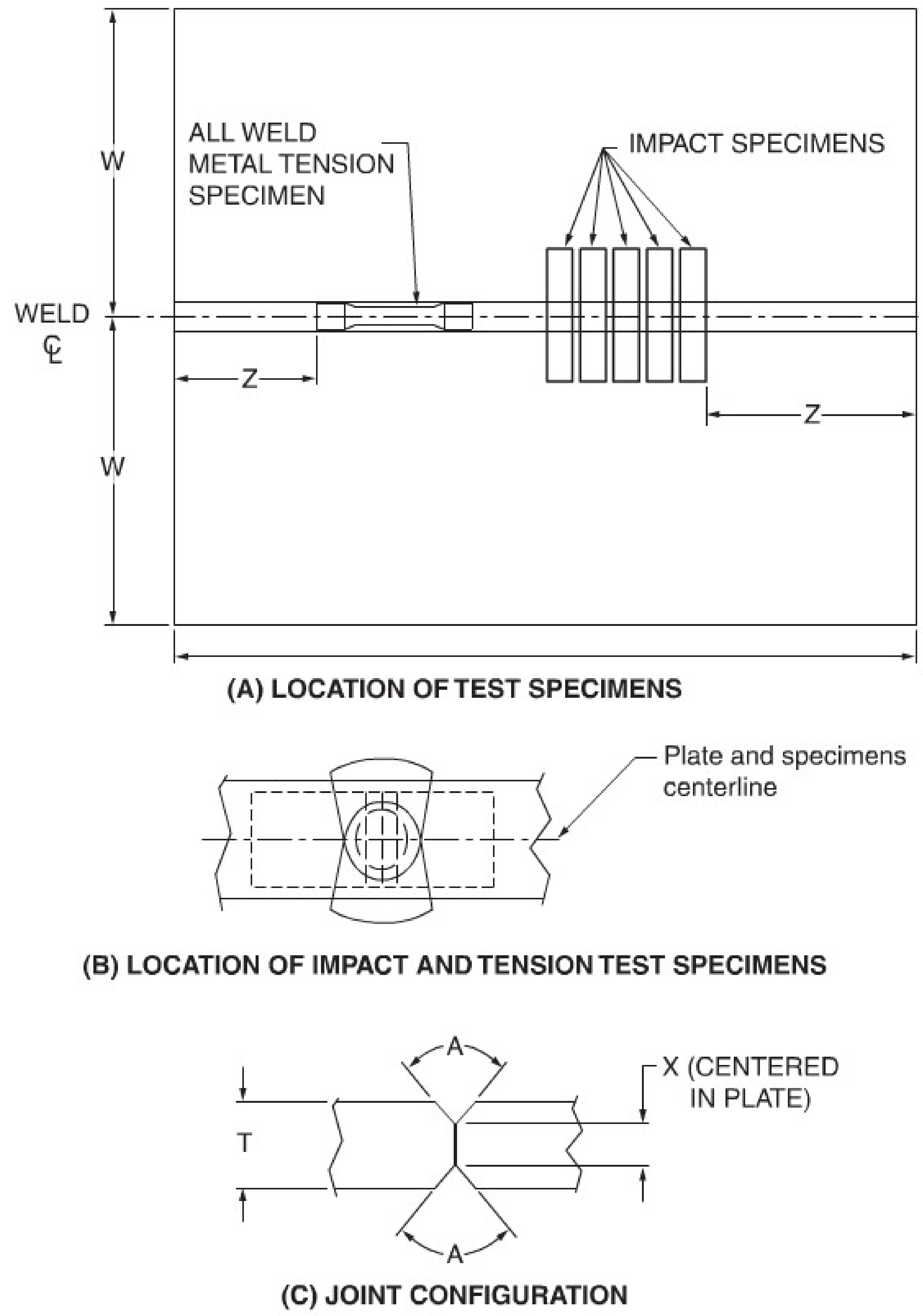
9.1.3 Classification of Flux–Electrode Combinations. One groove weld test assembly is required for each multiple pass classification of a flux–solid electrode combination or a flux–composite electrode combination. This is the groove weld in Figure 4 for mechanical properties and soundness of weld metal. A second test assembly, the weld pad in Figure 3, is required for chemical analysis of the weld metal. However, Note g to Table 3 allows the sample for chemical analysis to be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 4, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method. One butt weld test assembly is required for each two-run



LETTER	DIMENSIONS	in	mm
L	Length (min)	12	305
T	Thickness	1 ± 1/16	25 ± 1.5
W	Width (min)	5	127
D	Specimen Center	3/8 ± 1/32	9.5 ± 1.0
B	Backup Width (min)	2	50
R	Root Opening	1/2 ± 1/16	13 ± 1.5
Z	Discard (min)	1	25
V	Backup Thickness:		
	Without buttering (min)	1/2	13
	With buttering (min)	3/8	9.5
F	Buttering Thickness (min)	1/8	3.2

Source: Figure 4 of AWS A5.23/A5.23M:2007.

Figure 4 Multiple Pass Groove Weld Test Assembly



Dimension	Description		
A	Bevel angel (max.)	90°	90°
L	Length (min.)	12 in	300 mm
T	Thickness	1/2 in ± 1/16 in	12 mm ± 1.5 mm
W	Width (min.)	5 in	125 mm
X	Land (min.)	3/16 in	5 mm
Z	Discard (min.)	1 in	25 mm

Source: Figure 5 of AWS A5.23/A5.23M:2007.

Figure 5 Two-Run Weld Test Assembly

classification of a flux–solid electrode combination or flux–composite electrode combination. This is the two-run weld test assembly in Figure 5 for mechanical properties and soundness of weld metal.

9.2 Preparation. Preparation of each weld test assembly shall be as prescribed in 9.3, 9.4, and 9.5. The base metal for the weld pad, the multiple pass groove weld, and the two-run weld assemblies, shall be as required in Table 8 according to the tests to be conducted and shall meet the requirements of the appropriate ASTM specification shown in Table 8, or an equivalent specification. Testing of the assemblies shall be as prescribed in Clauses 10 through 13.

9.3 Weld Pad. For composite electrodes or for any flux–electrode multiple pass classification, a weld pad shall be prepared as specified in Figure 3, except when either alternative in 9.1.2 or 9.1.3 is selected. Base metal of any convenient

Table 8
Base Metals for Test Assemblies

Classification Type	Weld Metal Designation	Base Metal: ASTM Standard[a,b]	Base Metal: UNS Number[c]
	A1, A2, A3, and A4	A204 Grade A	K11820
	B2, B2H, and B5	A387 Grade 11	K11789
	B3 and B4	A387 Grade 22	K21590
	B6 and B6H	A387 Grade 5	S50200
	B8	A387 Grade 9	S50400
	B23	*See Note a*	*See Note a*
	B24	*See Note a*	*See Note a*
	B91	A387 Grade 91	S50460
	F1, *F2, F3*, and F4	A537 Class 1 or 2, or A 533 (any type or grade in this specification)	K12437, K12521, K12539, K12529, K12554
	F5 and F6	A514 or A517 (any type or grade in this specification	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, or K21650
Multiple Pass Classifications	M1, M2, M3, M4, M5, and M6	A514 or A517 (any type or grade in this specification), or A543 Type B or C	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, K21650, or K42339
	Ni1	A516 Grade 60, 65, or 70, A537 Class 1 or 2	K02100, K02403, K02700, or K12437
	Ni2	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, or K22103
	Ni3	A203 Grade D or E	K31718 or K32018
	Ni4, Ni5, and *Ni6*	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, K22103
	W	A572 or A588 (any type or in this specification)	K02303, K02304, K02305, K02306, K11430, K12040, K12043, or K11538
	G	(Note d)	
Two-Run Classifications[e]	Not Applicable	A131 Grade AH36 A516 Grade 70	K11852 K02700

[a] For multiple pass flux–electrode classifications, ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70 may be used for any weld metal classification in this specification. In that case, the groove faces and the contacting face of the backing shall be buttered as shown in Figure 4, using a flux–electrode combination of the same weld metal composition as that specified for the combination being tested, or using an electrode of the specified composition classified in another AWS low-alloy steel filler metal specification. Alternately, for the indicated weld metal classification, the corresponding base metals may be used for weld test assemblies without buttering. In case of dispute, buttered A36 shall be the referee material.

[b] Chemically equivalent steels in other U.S. customary grades or in any metric grades, whose properties are expressed in SI units, may also be used.

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

[d] For the "G" classification (multiple pass flux–electrode classifications only), ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70 may be used; however, the groove weld faces and the contacting face of the backing shall be buttered as shown in Figure 4, using either the flux–electrode combination being classified or using a matching composition in another AWS low-alloy filler metal specification. Alternatively, base metal for which the flux–electrode combination is recommended by the manufacturer can be used for this test.

[e] Base metal different from that prescribed in this table may be used for two-run classification purposes, as agreed between supplier and purchaser. This substitution of base metal is indicated by the addition of a "G" to the classification as indicated in Figures 2 and 2M.

size, and of the type specified in Table 8, shall be used as the base metal 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, three passes per layer, four layers high. For classifying composite electrodes, the flux for which the composite electrode is intended shall be used. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 300°F [150°C]. The welding parameters for the groove weld, as specified in Table 6, shall be used. The slag shall be removed after each pass. The pad may be quenched in water between passes but shall be dry before the start of each pass. Testing of this assembly shall be as specified in Clause 10, Chemical Analysis.

9.4 Groove Weld for Multiple Pass Classifications

9.4.1 For mechanical properties and soundness testing for the multiple pass classification of a flux–electrode combination, a test assembly shall be prepared and welded as specified in Figure 4 and Table 6 using base metal of the appropriate type specified in Table 8. Prior to welding, the assembly may be preset so that the welded joint will be sufficiently flat after welding to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5° of plane. A welded test assembly that is more than 5° out of plane shall be discarded. Straightening of the test assembly is prohibited. Testing shall be as specified in Clauses 10 through 13, with the assembly in either the as-welded or the postweld heat-treated condition, according to the classification of the weld metal (See Figures 1 and 1M).

9.4.1.1 When postweld heat treatment (PWHT) is required, the heat treatment shall be applied to the test assembly before the specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination.

9.4.1.2 Any multiple pass groove weld test assembly to be heat treated shall be heat treated at the temperature specified in Table 9 for the applicable weld metal designation. The furnace shall be at a temperature not higher than 600°F [315°C] when the test assembly is placed in it. The temperature of the test assembly shall be raised at a rate of 150°F to 500°F [85°C to 280°C] per hour to the holding temperature specified in Table 9. This temperature shall be maintained for 1 hour (–0, +15 minutes), except when as indicated in Note e of Table 9.

9.4.1.3 The test assembly shall then be allowed to completely cool in the furnace at a rate not greater than 350°F [200°C] per hour or may be removed from the furnace when the temperature of the furnace has reached 600°F [315°C] and allowed to further cool in still air.

Table 9
Preheat, Interpass, and Postweld Heat Treatment Temperatures for Multiple Pass Classifications[a,b]

Weld Metal Designation	Preheat and Interpass Temperature[c]		Postweld Heat Treatment Temperature[d]	
	°F	°C	°F	°C
A1, A2, A3, A4, B1, B5, Ni1, Ni2, Ni3, Ni4, Ni5, *Ni6*, F1, F2, F3	300 ± 25	150 ± 15	1150 ± 25	620 ± 15
B2, B2H	300 ± 25	150 ± 15	1275 ± 25	690 ± 15
B3, B4	400 ± 25	205 ± 15	1275 ± 25	690 ± 15
B6, B6H, B8	400 ± 100	205 ± 50	1375 ± 25	745 ± 15
B91	500 ± 100	260 ± 50	1400 ± 25[e]	760 ± 15[e]
B23, B24	*425 ± 50*	*210 ± 20*	*1365 ± 25[e]*	*740 ± 15[e]*
F4[f], F5[f], F6[f]	300 ± 25	150 ± 15	1050 ± 25	565 ± 15
M1[f], M2[f], M3[f], M4[f], M5[f], M6[f], W[f]	300 ± 25	150 ± 15	1125 ± 25	605 ± 15
G	Not Specified			

[a] These temperatures are specified for fluxes and electrodes tested and classified under this specification and are not necessarily for production use. The specific requirements for production welding shall be determined by the user. They may or may not differ from those called for here (see A8 in Annex A).

[b] The preheat, interpass, and postweld heat treatment temperatures, as applicable, for multiple pass flux–electrode classifications are listed for specific weld metal compositions as shown (see 9.4). For two-run classifications the preheat and interpass temperatures are specified in Table 7, and the post-weld heat treatment requirements are given in 9.5.

[c] The preheat and interpass temperatures listed here shall be used for the test assemblies regardless of whether the flux–electrode combination is classified in the as-welded or postweld heat-treated condition. They are required for purposes of uniformity and may or may not be indicative of those that might be satisfactory for fabrication of any particular weldment. The fabricator shall determine what is required for the application (see also A8 in Annex A).

[d] Unless noted otherwise, weld metal specimens for flux–electrode combinations classified in the postweld heat-treated condition shall be heat treated for 1 hour at the temperature shown for that classification (see 9.4).

[e] PWHT at specified temperature for 2 hours –0, +15 minutes.

[f] These classifications are normally used in the as-welded condition.

9.5 Butt Weld for Two-Run Classifications

9.5.1 For mechanical properties and soundness testing for the two-run classification of a flux–electrode combination, a test assembly shall be prepared and welded as specified in Figure 5 and Table 7 using base metal of the appropriate type specified in Table 8. Prior to welding, the assembly may be preset such that the welded joint will be sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint sufficiently flat after welding. Straightening of the test assembly is prohibited. Testing shall be as specified in Clauses 11 through 13, with the assembly in either the as-welded or postweld heat-treated condition, according to the classification of the weld metal (see Figures 2 and 2M).

9.5.1.1 When PWHT is required, the heat treatment shall be applied to the test assembly before the specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination.

9.5.1.2 Any two-run butt weld test assembly to be heat treated shall be heat treated at 1150°F ± 25°F [620°C ± 15°C] for 30 minutes (–0, +7 minutes). The furnace shall be at a temperature not higher than 600°F [315°C] when the test assembly is placed in it. The temperature of the test assembly shall be raised at a rate of 150°F to 500°F [85°C to 280°C] per hour. The above PWHT procedure also applies to FXTPXG-EXX flux–electrode classifications unless otherwise specified by the purchaser.

9.5.1.3 The test assembly shall then be allowed to completely cool in the furnace at a rate not greater than 350°F [200°C] per hour or may be removed from the furnace when the temperature of the furnace has reached 600°F [315°C] and allowed to further cool in still air.

9.6 Diffusible Hydrogen. In those cases in which an optional supplemental diffusible hydrogen designator is to be added to the flux–electrode classification designation, four diffusible hydrogen test assemblies shall be prepared, welded, and tested as specified in Clause 14, Diffusible Hydrogen Test.

10. Chemical Analysis

10.1 For solid electrodes, a sample of the electrode, or the rod stock from which it is made, shall be prepared for chemical analysis. Solid electrodes, when analyzed for elements that are present in a coating (e.g., copper flashing), shall be analyzed without removing the coating. When the electrode is analyzed for elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for other elements. Rod stock analyzed for elements not in the coating may be analyzed prior to reducing the rod to the finished electrode diameter and applying the coating.

10.2 For composite electrodes and for the multiple pass classification of flux–electrode combinations, the sample for analysis shall be taken from the weld pad in Figure 3, from the reduced section of the fractured tension test specimen in Figure 4, or from a corresponding location (or any location above it) in the weld metal in the butt weld in Figure 4. Weld metal from the butt weld used for two-run classification (Figure 5) may not be used for the purpose of classifying composite electrodes.

The top surface of the pad described in 9.3 and shown in Figure 3 shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal of the fourth layer of the weld pad by any appropriate mechanical means. The sample shall be free of slag. The sample shall be taken at least 3/8 in [10 mm] from the nearest surface of the base metal. The sample 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 4 shall be prepared for analysis by any suitable mechanical means.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be the procedure in the latest edition of ASTM E 350.

10.4 For solid electrodes, the results of the electrode analysis shall meet the requirements of Table 4 for the classification of electrode under test. For composite electrodes and for the multiple pass classification of flux–electrode combinations, the results of the weld metal analysis shall meet the requirements of Table 3 for the applicable weld metal designation.

11. Radiographic Test

11.1 The groove weld for multiple pass classifications described in 9.4 and shown in Figure 4 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 [2.5 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 or buildup removal, or both. The thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] so that the thickness of the prepared radiographic test specimen equals at least the thickness of the base metal minus 1/16 in [1.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

The butt weld for two-run classifications described in 9.5 and shown in Figure 5 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, both ends of the test joint may be trimmed off to remove run-on and run-off tabs, if any, and any excess weld joint material and the surfaces of both weld beads may be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 mm]. 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 buildup removal. The thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] so that the thickness of the prepared radiographic test specimen equals at least the thickness of the base metal minus 1/16 in [1.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

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:

(1) no cracks, no incomplete fusion, and no incomplete penetration;

(2) no slag inclusions longer than 1/4 in [6 mm] or 1/3 of the thickness of the weld, whichever is greater, or no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld except when the distance between the successive inclusions exceeds six times the length of the longest inclusion in the group; and

(3) no rounded indications in excess of those permitted by the radiographic standards in Figure 6.

In evaluating the radiograph for the multiple pass groove weld, 1 in [25 mm] of the weld on each end of the test assembly shall be disregarded. For the two-run butt weld, evaluation shall be made on a 10 in [250 mm] continuous length, as a minimum.

11.3.1 The alternative method of evaluation involves calculation of the total area of the rounded indications as they appear on the radiograph. This total area, in any 6 in [150 mm] of the weld, shall not exceed 6% of the thickness of the test assembly.

11.3.2 A rounded indication is an indication (on the radiograph) whose length is no more than 3 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 indication may be of porosity or slag inclusions.

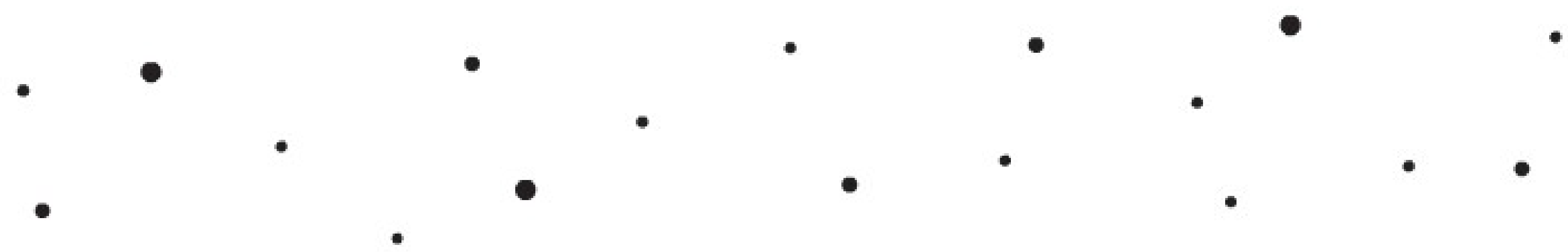
11.3.3 The total area of the rounded indications for the alternative method shall not exceed the values given in Note 3 to the radiographic standards (Figure 6A through 6D). Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications larger than the large indications permitted in the radiographic standards do not meet the requirements of this specification.

12. Tension Test

12.1 For multiple pass classifications, one all-weld metal tension test specimen, as specified in the Tension Tests clause of AWS B4.0 or B4.0M, shall be machined from the groove weld described in 9.4 and shown in Figure 4. The tensile specimen shall have a nominal diameter of 0.500 in [12.5 mm] and a nominal gage length to diameter ratio of 4:1.

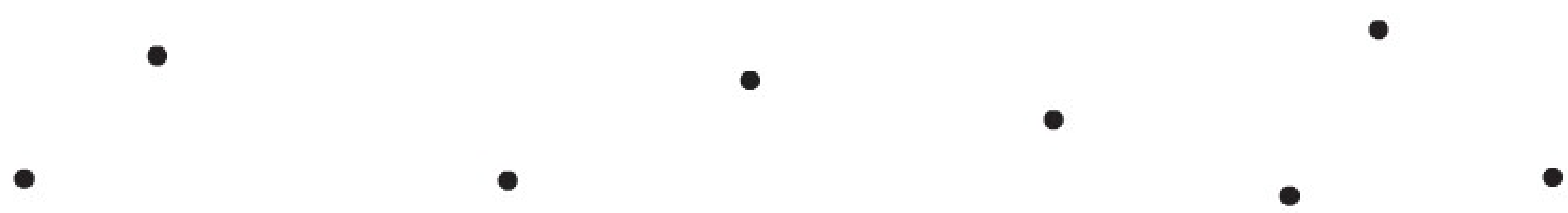
12.1.1 For flux–electrode combinations classified in the postweld heat treated condition, the weld metal shall be heat-treated as shown in Table 9 before final machining of the specimen (refer to 9.4.1.1).

12.1.2 After machining, but before testing, the specimen for all flux–electrode classifications, except those classified in the postweld heat-treated condition, may be aged at temperatures up to 220°F [105°C] for up to 48 hours, then allowed to cool to room temperature (refer to A9.5 in the Annex A for a discussion on the purpose of aging).



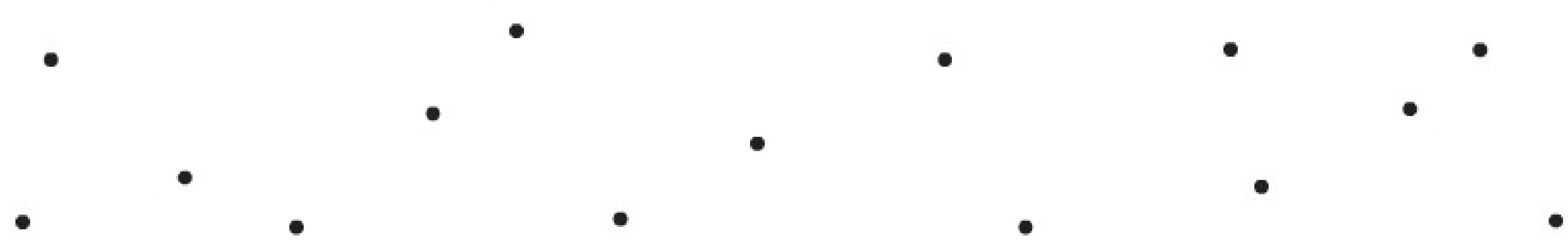
(A) ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 18,
WITH THE FOLLOWING RESTRICTIONS:
LARGE : 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] = 3 PERMITTED.
MEDIUM: 1/32 inTO 3/64 in [0.8 mm TO 1.2 mm] = 5 PERMITTED.
SMALL: 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] = 10 PERMITTED.



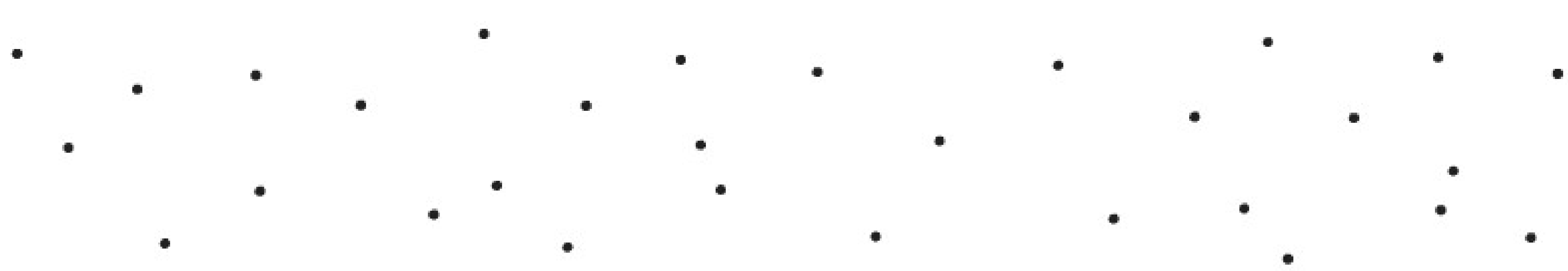
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 15.



(D) SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 30.

Notes:
1. The chart which is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used for determination of conformance with this specification. Rounded indications smaller than 1/64 in [0.4 mm] shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those usually encountered in general fabrication. They are equivalent to the Grade 1 standards of AWS A5.1/A5.1M.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.0150 in^2 [10 mm^2] in any 6 in [150 mm] of weld.

Source: Figure 6 of AWS A5.23/A5.23M:2007.

Figure 6 Radiographic Standards for Rounded Indications

12.1.3 The specimen shall be tested in the manner described in the Tension Test clause of the latest edition of AWS B4.0 or B4.0M.

12.1.4 The results of the tension test shall meet the requirements specified in Table 1 or Table 1M, as applicable.

12.2 For two-run classifications, one longitudinal tension test specimen, as specified in the Tension Test clause of AWS B4.0 or B4.0M, shall be machined from the butt weld described in 9.5 and shown in Figure 5. The tensile specimen shall have a nominal diameter of 0.250 in [6.0 mm] and a nominal gage length to diameter ratio of 4:1. The reduced section of the longitudinal tensile specimen shall be located entirely within the weld zone.

12.2.1 For flux–electrode combinations classified in the postweld heat-treated condition, the weld metal shall be heat treated as shown in 9.5.1.2 and 9.5.1.3 before final machining of the specimen.

12.2.2 After machining, but before testing, the specimen for all flux–electrode classifications, except those classified in the postweld heat-treated condition, may be aged at temperatures up to 220°F [105°C] for up to 48 hours, then allowed to cool to room temperature. If the specimen is aged, that fact, together with the manner of aging, shall be recorded on the test certificate. Refer to A9.5 in Annex A for a discussion on the purpose of aging.

12.2.3 The specimen shall be tested in the manner described in the Tension Test clause of AWS B4.0 or B4.0M.

12.2.4 The results of the tension test shall meet the requirements specified in Table 1 or Table 1M, as applicable.

13. Impact Test

13.1 Five full-size Charpy V-Notch impact specimens, as specified in the Fracture Toughness Test clause of AWS B4.0 or B4.0M, shall be machined from the test assembly shown in Figure 4 or 5, as applicable, for those classifications for which impact testing is required in Table 5. The Charpy V-Notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree. The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50× magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the fracture toughness test clause of AWS B4.0 or B4.0M. The test temperature shall be that as specified in Table 2 for the classification under test.

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft·lbf [20 J], and the average of the three shall be not less than the required 20 ft·lbf [27 J] energy level.

13.4 For classification with the "N" (nuclear) designation, three additional specimens shall be prepared. These specimens shall be tested at room temperature. Two of the three shall equal or exceed 75 ft·lbf [102 J], and the third shall not be lower than 70 ft·lbf [95 J]. The average of the three shall equal or exceed 75 ft·lbf [102 J].

14. Diffusible Hydrogen Test

14.1 Each flux–electrode combination to be identified by an optional supplemental diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results which satisfy the requirements of Table 10, the appropriate diffusible hydrogen designator may be added to the end of the classification.

14.2 The welding procedure shown in Table 6 for the multiple pass groove weld test assembly shall be used for the diffusible hydrogen test. The travel speed, however, may be increased up to a maximum of 28 in/min [12 mm/s]. This adjustment in travel speed is permitted in order to establish a weld bead width that is appropriate for the specimen. The flux, electrode, or both, may be baked before testing to restore the moisture content to the as-manufactured condition. When this is done, the baking time and temperature shall be noted on the test report. The manufacturer of the flux, electrode, or both, should be consulted for their recommendation regarding the time and temperature for restoring their products to the as-manufactured condition.

Table 10
Diffusible Hydrogen Requirements[a]

AWS A5.23/A5.23M Flux–Electrode Classifications	Optional Supplemental Diffusible Hydrogen Designator[b]	Average Diffusible Hydrogen, Maximum[c] (ml/100 g Deposited Metal)
All	H16	*16*
	H8	*8*
	H4	*4*
	H2	*2*

[a] The diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Clauses A3 and A9 in Annex A).
[b] This designator is added to the end of the flux–electrode classification (see Figure 1, 1M, 2, or 2M, as applicable).
[c] Flux–electrode combinations meeting the requirements for an H2 designator also meet the requirements for H4, H8, and H16. Flux–electrode combinations meeting requirements for an H4 designator also meet the requirements for H8 and H16. Flux–electrode combinations meeting the requirements for an H8 designator also meet the requirements for H16.

14.3 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of ten (10) grains of moisture/lb [1.43 g/kg] of dry air at the time of welding. The actual atmospheric conditions shall be reported along with the average diffusible hydrogen value for the test according to AWS A4.3.

14.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the actual test results for a flux–electrode combination meet the requirements for the lower or lowest hydrogen designator, as specified in Table 10, the flux–electrode combination also meets the requirements for all higher designators in Table 10 without need to retest.

15. Method of Manufacture

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

15.1 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as crushed slag. Crushed slag and blends of crushed slag with the original brand of unused (virgin) flux may be classified as welding flux under this specification. When classifying a blend of crushed slag with virgin flux, the ratio of the blend mixture shall not vary from nominal by more than 10% of the minor component. For example, a nominal blend of 40% crushed slag with 60% virgin flux shall contain at least 36%, but no more than 44% crushed slag. The classification of more than one blend ratio of crushed slag with the original brand of unused (virgin) flux is permitted under this specification. In each case, however, the nominal blend ratio shall be noted on the packaging or on the corresponding lot certificate, as applicable (see A6.1.4 in Annex A).

16. Electrode Requirements

16.1 Standard Sizes. Standard sizes for electrodes in the different package forms (coils with support, coils without support, spools, and drums) are as specified in AWS A5.02/A5.02M.

16.2 Finish and Uniformity

16.2.1 Finish and uniformity shall be specified in sub-clause 4.2 of AWS A5.02/A5.02M:2007.

16.3 Standard Package Forms

16.3.1 Standard package forms are 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 sub-clause 4.3 of AWS A5.02/A5.02M:2007. Package forms and sizes other than these shall be as agreed between purchaser and supplier.

16.4 Winding Requirements

16.4.1 Winding requirements shall be as specified in sub-sub-clause 4.4.1 of AWS A5.02/A5.02M:2007.

16.4.2 The cast and helix of the electrode shall be as specified in sub-sub-clause 4.4.2 of AWS A5.02/A5.02M:2007.

16.5 Electrode Identification

16.5.1 The product information and the precautionary information shall be as specified in sub-clause 4.5 of AWS A5.02/A5.02M:2007.

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

16.7 Marking of Packages

16.7.1 The product information (as a minimum) shall be as specified in sub-sub-clause 4.6.1 of AWS A5.02/A5.02M:2007. (For flux–composite electrode classifications, the trade designation of the flux (or fluxes) with which its weld metal composition meets the requirements of Table 3 shall be included.

17. Flux Requirements

17.1 Form and Particle Size. Flux shall be granular in form and shall be capable of flowing freely through the flux feeding tubes, valves, and nozzles of standard submerged arc welding equipment. Particle size is not specified here, but, when it is addressed, it shall be a matter of agreement between the purchaser and the supplier.

17.2 Usability. The flux shall permit the production of uniform, well shaped beads that merge smoothly with each other and the base metal. Undercut, if any, shall not be so deep or so widespread that a subsequent bead will not remove it.

17.3 Packaging

17.3.1 Flux shall be suitably packaged to ensure against damage during shipment.

17.3.2 Flux, in its original unopened container, shall withstand storage under normal conditions for at least six months without damage to its welding characteristics or the properties of the weld. Heating of the flux to assure dryness may be necessary when the very best properties (of which the materials are capable) are required. For specific recommendations, consult the manufacturer.

17.4 Marking of Packages

17.4.1 The product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package shall be specified as in sub-sub-clause 4.6.1 of AWS A5.02/A5.02M:2007:

(1) AWS specification and classification along with the applicable optional, supplemental designator(s) (year of issue may be excluded). For flux–composite electrode classifications the trade designation of the composite electrode shall be indicated. It is not required that all of the classifications published for the flux (with different electrodes, with and without PWHT, etc.) be included on the packaging.

(2) Supplier's name, trade designation, and country of manufacture: In the case of crushed slags (or blends of crushed slag with virgin flux), the crusher (or crusher/blender), not the original producer, shall be considered the supplier. Crushed slag or a blend of crushed slag with virgin flux shall have a unique trade designation that clearly differentiates it from the original virgin flux used in its manufacture (see also A6.1.4 in the Annex A).

(3) Net weight.

(4) Lot, control, or heat number.

(5) Particle size, if more than one particle size of flux of that trade designation is produced.

17.4.2 The appropriate precautionary information as given in ANSI Z49.1, latest edition (as a minimum), or its equivalent, shall be prominently displayed in legible print on all packages of flux.

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Annex A (Informative)

Guide to AWS Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

This annex is not part of AWS A5.23/A5.23M:2011, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, but is included for informational purposes only.

A1. Introduction

The purpose of this guide is to correlate the electrode and flux classifications with their intended applications so the specification can be used effectively. Appropriate base metal specifications are referred to 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 flux or electrode is suitable.

A2. Classification System

A2.1 Classification of Electrodes. The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" (or "EC" for composite electrodes) at the beginning of each classification designation stands for electrode. The remainder of the designation indicates the chemical composition of the electrode or, in the case of composite electrodes, the chemical composition of the weld metal obtained with a particular flux (see Figure 1, 1M, 2, or 2M, as applicable).

For solid carbon steel electrodes, the letter "L" after the "E" indicates that the solid electrode is comparatively low in manganese content. The letter "M" after the "E" indicates medium manganese content, while the letter "H" after the "E" indicates comparatively high manganese content. The one or two digits following the manganese designator indicate the nominal carbon content of the electrode. Note that the above indicators of manganese and carbon content are not applicable to solid low-alloy steel electrodes. For solid low-alloy steel electrodes, one or two letters after the "E" are used to indicate the general alloy type. Subsequent digits identify the specific classification. The letter "K," which appears as a suffix in some designations, indicates that the electrode is made from a heat of silicon-killed steel. Solid carbon and low-alloy steel electrodes are classified only on the basis of their chemical composition, as specified in Table 4 of this specification.

A composite electrode is indicated by the letter "C" after the "E" and a numeric or alphanumeric suffix. The composition of a composite electrode may include metallic elements in the core material that are also present as oxides, fluorides, etc., of those same elements. Therefore, the chemical analysis of a composite electrode may not be directly comparable to an analysis made on a solid electrode. For this reason, the composition of composite electrodes is not used for classification purposes under this specification, and the user is referred to weld metal composition (Table 3) with a particular flux, rather than to electrode composition.

As examples, consider the following electrode designations: EL12, EM12K, EB3, EM3, and ECB3. As in other specifications, the prefix "E" designates an electrode. The EL12 and EM12K are solid carbon steel electrodes and the EB3 and EM3 are solid low-alloy steel electrodes. Their compositions are given in Table 4. The ECB3, however, is a composite electrode as indicated by the "C" after the "E." Composite electrodes are classified by the composition of the weld metal produced with a specific flux as shown in Table 3. An ECB3 electrode, therefore, is a composite electrode which, when used with a particular flux, will produce weld metal meeting the requirements for a B3 deposit as shown in Table 3.

The letter "N" when added as a suffix is an optional supplemental designator indicating that the electrode is intended for certain very special welds in nuclear applications. These welds are found in the core belt region of the reactor vessel. This region is subject to intense neutron radiation, and it is necessary, therefore, that the phosphorus, vanadium, and copper contents of this weld metal be limited in order to resist neutron radiation-induced embrittlement. It is also necessary that the weld metal have a high upper-shelf energy level in order to withstand some embrittlement, yet remain serviceable over the years. These electrodes are not required elsewhere; however, they could be used where that weld metal with an exceptionally high upper-shelf energy level is required.

A2.2 "G" Classification

A2.2.1 This specification includes electrode classified as "EG" (or "ECG"). The "G" indicates that the electrode is of a *general* classification. It is *general* because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent, in establishing this classification, is to provide a means by which electrodes that differ in one respect or another (e.g., chemical composition) from all other classifications (meaning that the composition of the electrode—in the case of the example—does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful electrode—one that otherwise would have to wait for a revision of the specification—to be classified immediately, under the existing specification. This means, then, that two electrodes—each bearing the same "G" classification—may be quite different in some certain respects (e.g., chemical composition, again).

A2.2.2 For the two-run classification a "G" is used in the classification designation when, as agreed between the supplier and purchaser, a difference in base material from that specified is used for qualification. See second example in Figures 2 and 2M.

A2.2.3 The point of difference (although not necessarily the amount of that difference) between an electrode of a "G" classification and an electrode 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 welding flux or electrode. It indicates that 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 flux or electrode 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 (ISO 14344 MOD), in the purchase order.

A2.2.4 Request for Filler Metal Classification

(1) When a flux or electrode cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that flux or electrode. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the A5 Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that flux or electrode, as long as the flux or electrode is of commercial significance.

(2) A request to establish a new electrode classification must be a written request, and it needs to provide sufficient detail to permit the A5 Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the 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 and mechanical property requirements.

(b) Any 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.

(d) *Actual test data for all tests required for classification according to the requirements of the specification for a minimum of two production heats/lots must be provided. In addition, if the filler metal specification is silent regarding mechanical properties, test data submitted shall include appropriate weld metal mechanical properties from a minimum of two production heats/lots.*

(e) A request for a new classification without the above information will be considered incomplete. The Secretary will return the request to the requester for further information.

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

(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 A5 Committee on Filler Metals 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 Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner," and the Secretary shall report these to the Chair of the 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 AWS A5 Committee on Filler Metals and Allied Materials 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 used in ISO 14171, ISO 24598, and ISO 26304 for comparison with comparable classifications in this specification. To understand the published international designation system, refer to Tables 7A, 7B, and 7C and the Annex of AWS publication IFS:2002, *International Index of Welding Filler Metal Classifications.* National specifications from many industrial countries are also found in Tables 7A, 7B, and 7C of that publication.

A2.4 Classification of Fluxes. Fluxes are classified on the basis of the mechanical properties of the weld metal they produce, with a certain classification of electrode, under the specific test conditions called for in this specification. Multiple pass flux–electrode classifications also have requirements for weld metal composition. Two-run flux–electrode classifications have no requirements for weld deposit composition under this specification (refer to Figure 1, 1M, 2, or 2M, as applicable).

A2.4.1 It should be noted that flux of any specific trade designation may have many classifications. The number is limited only by the number of different electrode classifications and the condition of heat treatment (as-welded and postweld heat treated) with which the flux can meet the classification requirements. The flux marking lists at least one and may list all classifications to which the flux conforms. It should also be noted that the specific usability (or operating) characteristics of the various fluxes of the same classification may differ in one respect or another.

A2.4.2 Solid electrodes having the same classification are usually interchangeable when used with a specific flux. Composite electrodes may not be.

A3. Acceptance

Acceptance of all fluxes and electrodes classified under this specification is in accordance with the tests and requirements of this specification. Any testing a purchaser requires of the supplier, for fluxes or electrodes shipped in accordance with this specification, needs to 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 flux or electrode with whatever testing the supplier normally conducts on flux or electrode of that classification, as specified in Schedule

Table A.1
Comparison of Solid Electrode Designations[a]

AWS A5.23/A5.23M Classification	ISO 14171[b] Designation	ISO 24598[c] Designation	ISO 26304[d] Designation			
	ISO 14171-A	ISO 14171-B	ISO 24598-A	ISO 24598-B	ISO 26304-A	ISO 26304-B
EL8[e]	S1	(SU11)	—	—	—	—
EL8K[e]	S1Si1	SU12	—	—	—	—
EL12[e]	S1	SU11	—	—	—	—
EM11K[e]	—	SU25	—	—	—	—
EM12[e]	S2	SU22	—	—	—	—
EM12K[e]	S2Si	SU21	—	—	—	—
EM13K[e]	S2Si2	SU25	—	—	—	—
EM14K[e]	—	SU24	—	—	—	—
EM15K[e]	S2Si	(SU21)	—	—	—	—
EH10K[e]	S3Si	SU32	—	—	—	—
EH11K[e]	—	SU31	—	—	—	—
EH12K[e]	S4Si	SU42	—	—	—	—
EH14[e]	—	SU41	—	—	—	—
EA1	—	SU1M3	(SMo)	SU1M3	—	—
EA1TiB	—	—	—	—	—	—
EA2	S2Mo	SU2M3	SMo	SU2M3	—	—
EA3	S4Mo	SU4M3	—	SU4M3	—	—
EA3K	—	SU4M31	—	SU4M32	—	—
EA4	S3Mo	SU3M3	SMnMo	SU3M3	—	—
EB1	—	—	—	SUCM	—	—
EB2	—	—	SCrMo1	SU1CM	—	—
EB2H	—	—	—	SU1CMVH	—	—
EB3	—	—	SCrMo2	SU2C1M	—	—
EB5	—	—	—	SUC1MH	—	—
EB6	—	—	SCrMo5	SU5CM	—	—
EB6H	—	—	—	SU5CMH	—	—
EB8	—	—	SCrMo9	SU9C1M	—	—
EB23	—	—	—	—	—	—
EB24	—	—	—	—	—	—
EB91	—	—	—	SU9C1MV	—	—
EF1	—	—	—	—	S2Ni1Mo	SUN2M2
EF2	—	—	—	—	—	SUN1M3
EF3	—	—	—	—	—	SUN2M33
EF4	—	—	—	—	—	SUN1C1M1
EF5	—	—	—	—	—	SUN5CM3
EF6	—	—	—	—	—	SUN4C1M3
EM2	—	—	—	—	—	SUN3M2
EM3	—	—	—	—	—	SUN4C1M2
EM4	—	—	—	—	—	SUN5C1M3
ENi1	S2Ni1	SUN2	—	—	—	—
ENi1K	—	SUN21	—	—	—	—
ENi2	—	SUN5	—	—	—	—
ENi3	S2Ni3	SUN7	—	—	—	—
ENi4	—	SUN4M1	—	—	—	SUN4M1
ENi5	—	SUN2M1	—	—	—	SUN2M1
ENi6	—	—	—	—	—	—
EW	SUNCC1	—	—	—	—	—

[a] The requirements for the equivalent classifications shown are not necessarily identical in every respect.

[b] ISO 14171, *Welding consumables – Wire electrodes and wire-flux combinations for submerged arc welding of non alloy and fine grain steels – Classification*, is a cohabitation document providing classification utilizing a system based upon the yield strength and the average impact energy for

all-weld metal of 47J (ISO 14171-A), or utilizing a system based upon the tensile strength and the average impact energy for all-weld metal of 27J (ISO 14171-B).

[c] ISO 24598 *Welding consumables – Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of creep-resisting steels – Classification*, is a cohabitation document. The classification according to system A is mainly based on EN 12070. The classification according to system B is mainly based upon standards used around the Pacific Rim.

[d] ISO 26304, *Welding consumables – Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of high strength steels – Classification*, is a cohabitation document. The classification according to system A is mainly based on EN 14295. The classification according to system B is mainly based upon standards used around the Pacific Rim.

[e] These solid wire electrode classifications also appear in AWS A5.17/A5.17M.

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 (and optional supplemental designators, if applicable) 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 the requirements of the specification. The only testing requirement implicit in this *certification* is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that that material met the requirements of the specification. (Representative material, in this case, is material from any production run of that classification using the same formulation.) *Certification* is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the *certification* required by the specification is the classification test of *representative material* cited above and the Manufacturer's Quality Assurance Program in AWS A5.01M/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. They are:

(1) dimensions of the space in which the welding is done (with special regard to the height of the ceiling);

(2) number of welders and welding operators working in that space;

(3) rate of evolution of fumes, gases, or dust, according to the materials and processes used;

(4) the proximity of the welders or welding operators to the fumes, as these fumes issue from the welding zone, and to the gases and dusts in the space in which they are working; and

(5) the ventilation provided to the space in which the welding is done.

A5.2 American National Standard ANSI Z49.1, 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. Further details about ventilation can be found in AWS F3.2.

A.6 Description and Intended Use

A6.1 Types of Flux. Submerged arc welding fluxes are granular, fusible mineral compounds of various proportions and quantities, manufactured by any of several different methods. In addition, some fluxes may contain intimately mixed metallic ingredients to deoxidize the weld pool. Any flux is likely to produce weld metal of somewhat different composition from that of the electrode used with it due to chemical reactions in the arc and sometimes to the presence of metallic ingredients in the flux. A change in the arc voltage during welding will change the quantity of flux interacting with a given quantity of electrode and may, therefore, change the composition of the weld metal. This latter change provides a means of describing fluxes as "neutral," "active," or "alloy."

A6.1.1 Neutral Fluxes. Neutral fluxes are those which will not produce any significant change in the weld metal chemical analysis as a result of a large change in the arc voltage and, thus, the arc length. The primary use for neutral fluxes is in multiple pass welding, especially when the base metal exceeds 1 in [25 mm] in thickness. Note the following considerations concerning neutral fluxes:

(1) Since neutral fluxes contain little or no deoxidizers, they must rely on the electrode to provide deoxidation. Single-pass welds with insufficient deoxidation on heavily oxidized base metal may be prone to porosity, centerline cracking, or both.

(2) While neutral fluxes do maintain the chemical composition of the weld metal even when the voltage is changed, it is not always true that the chemical composition of the weld metal is the same as the chemical composition of the electrode used. Some neutral fluxes decompose in the heat of the arc and release oxygen, resulting in a lower carbon value in the weld metal than the carbon content of the electrode itself. Some neutral fluxes contain manganese silicate which can decompose in the heat of the arc and add some manganese and silicon to the weld metal even though no metallic manganese or silicon was added to these particular fluxes. These changes in the chemical composition of the weld metal are fairly consistent, even when there are large changes in voltage.

(3) Even when a neutral flux is used to maintain the weld metal chemical composition through a range of welding voltages, weld properties such as strength level and impact properties can change because of changes in other welding parameters such as depth of fusion, heat input, and number of passes.

A6.1.2 Active Fluxes. Active fluxes are those which contain small amounts of manganese, silicon, or both. These deoxidizers are added to the flux to provide improved resistance to porosity and weld cracking caused by contaminants on or in the base metal. The primary use for active fluxes is to make single-pass welds, especially on oxidized base metal. Note the following considerations concerning active fluxes:

(1) Since active fluxes do contain some deoxidizers, the manganese, silicon, or both in the weld metal will vary with changes in arc voltage. An increase in manganese or silicon increases the strength and hardness of the weld metal in multiple pass welds but may lower the impact properties. For this reason, the voltage may need to be more tightly controlled for multiple pass welds with active fluxes than when using neutral fluxes.

(2) Some fluxes are more active than others. This means they offer more resistance to porosity due to base metal surface oxides in single-pass welds than a flux which is less active, but may pose more problems in multiple pass welding.

A6.1.3 Alloy Fluxes. Alloy fluxes are those which can be used with a carbon steel electrode to make alloy weld metal. The alloys for the weld metal are added as ingredients in the flux. As with active fluxes, where the recovery of manganese and silicon is affected significantly by arc voltage, so with alloy fluxes, the recovery of alloy elements from the flux is affected significantly by the arc voltage. With alloy fluxes, the manufacturer's recommendations should be closely followed if desired weld metal compositions are to be obtained. The use as a welding flux of crushed slags generated from alloy flux is not recommended.

A6.1.4 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as a *crushed slag*. This is different from a recycled flux which was never fused into a slag and can often be collected from a clean surface and reused without crushing. Crushed slags and blends of crushed slag with unused (virgin) flux may be classified as a welding flux under this specification, but shall not be considered to be the same as a virgin flux. Although it is possible to crush and reuse submerged arc slag as a welding flux, the crushed slag, regardless of any addition of virgin flux to it, is a new and chemically different flux. This is because the slag formed during submerged arc welding does not have the same chemical composition or welding characteristics as the virgin flux. Its composition is affected by the composition of the original flux, chemical reactions which occur due to the welding arc, the base metal and electrode compositions, and the welding parameters.

Blends of crushed slag with the original brand of virgin flux from which it was generated cannot be assumed to conform to the classification of either component, even when both the crushed slag and virgin flux conform to the same classification (except for the "S" designator). It shall be the responsibility of the crusher or fabricator partner, who performs the blending, to verify that any intended blend of crushed slag with the original brand of virgin flux is in full conformance with the classification requirements of this specification.

As with any flux product, the manufacturer (crusher) shall follow a detailed processing procedure with controlled input material, preparation, crushing, and blending, which will ensure that a standard quality of output welding flux product is attained that meets the requirements for the classification.

A6.1.4.1 Closed Loop Crushed Slags. Slag generated by a fabricator from a specific brand of flux under controlled welding conditions, segregated at all points during collection and processing from other sources of slag or contaminants, crushed by the fabricator or another crushing organization, possibly blended with a specific virgin flux and returned to the same fabricator for use as a welding flux, is defined as closed loop crushed slag.

Closed-loop crushed slags or blends of closed-loop crushed slag with the original brand of virgin flux ensure better control of input material by virtue of the inherent partnering of the fabricator with the crusher. In some instances, these partners may be one and the same. If blending of crushed slag with virgin flux is done, changes in the original brand of virgin flux or in the blending ratio can affect the quality of the final product.

A6.2 Wall Neutrality Number. The Wall Neutrality Number (N) is a convenient relative measure of flux neutrality. The Wall Neutrality Number addresses fluxes and electrodes for welding carbon steel with regard to the weld metal manganese and silicon content. It does not address alloy fluxes. For a flux–electrode combination to be considered neutral, it should have an N value of 35 or lower. The lower the number, the more neutral the flux.

Determination of the Wall Neutrality Number can be done in accordance with the following:

(1) A weld pad of the type shown in Figure 3 is welded with the flux–electrode combination being tested. The welding parameters shall be as specified in Table 6 for the groove weld test assembly for the diameter of electrode being used.

(2) A second weld pad is welded using the same parameters, except that the arc voltage is increased by 8 volts.

(3) The top surface of each of the weld pads is ground or machined smooth to clean metal. Samples sufficient for analysis are removed by machining. Weld metal is analyzed only from the top (fourth) layer of the weld pad. The samples are analyzed separately for silicon and manganese.

(4) The Wall Neutrality Number depends on the change in silicon, regardless of whether it increases or decreases, and on the change in manganese, regardless of whether it increases or decreases. The Wall Neutrality Number is the absolute value (ignoring positive or negative signs) and is calculated as follows:

$$N = 100\,(|\,\Delta\,\%Si\,| + |\,\Delta\,\%Mn\,|)$$

where

$\Delta\%Si$ = Difference in silicon content of the two pads and

$\Delta\%Mn$ = Corresponding difference in manganese content.

A7. Description and Intended Use of Electrodes

A7.1 Choice of Electrodes. In choosing an electrode classification for submerged arc welding, the most important considerations are the mechanical properties expected of the weld metal, the requirements for weld metal composition, whether the weld is to be single pass or multiple pass, the cleanliness and composition of the steel to be welded, and the type of flux to be used. It is important to note that the mechanical properties obtained on a one-run or two-run weld are often quite different than those obtained on a multiple pass weld made with the same flux and electrode. For that reason, a two-run flux–electrode classification option is included in this specification to provide for an alternate classification system based upon welding conditions that more closely reflect limited pass applications. The AWS A5.23/A5.23M specification (instead of the AWS A5.17/A5.17M specification) was selected for the inclusion of a two-run classification system because, for these types of applications, it is common commercial practice to use a low-alloy electrode for the welding of carbon steel to enhance the weld metal mechanical properties. For example, an EA1 molybdenum-bearing electrode is routinely used in pipemills to improve the strength level and impact properties of the two-run welds made to manufacture pipe. In addition, the strength level requirements for two-run welds such as used for the manufacture of pipe can be significantly higher than those shown in A5.17/A5.17M and are more consistent with the strength levels included in A5.23/A5.23M.

A certain minimum weld metal manganese content is necessary to avoid centerline cracking. This minimum depends upon restraint of the joint and upon the weld metal composition. In the event that centerline cracking is encountered, especially with a low manganese electrode (see Table 4) and neutral flux, a change to a higher manganese electrode, a change to a more active flux, or both, may eliminate the problem.

Certain fluxes, generally considered to be neutral, tend to remove carbon and manganese to a limited extent and to replace these elements with silicon. With such fluxes, a silicon-killed electrode is often not necessary though it may be used. Other fluxes add no silicon and may, therefore, require the use of a silicon-killed electrode for proper wetting and freedom from porosity. The flux manufacturer should be consulted for electrode recommendations suitable for a given flux.

In welding single-pass fillet welds, especially on scaly base metal, it is important that the flux, electrode, or both, provide sufficient deoxidation to avoid unacceptable porosity. Silicon is a more powerful deoxidizer than manganese. In such applications, use of a silicon-killed electrode or of an active flux, or both, may be essential. Again, manufacturer's recommendations should be consulted.

Composite electrodes are generally designed for a specific flux. The flux identification is required (see 16.7.1) to be marked on the electrode package. Before using a composite electrode with a flux not indicated on the electrode package markings, the electrode producer should be contacted for recommendations. A composite electrode might be chosen for a higher melting rate and lower depth of fusion at a given current level than would be obtained under the same conditions with a solid electrode.

A7.2 Chemical Composition. For the welding of low-alloy steel, the chemical composition of the weld metal produced is often the primary consideration for electrode selection. Together with appropriate heat treatments, each composition can achieve a wide range of corrosion resistance and mechanical properties at various service temperatures. It is usually desirable for weld metal to match the chemical composition and the mechanical properties of the base metal as closely as possible. In fact, many of the electrodes classified to this specification have been developed for specific base-metal grades or classes. If an optimum match is not possible, engineering judgment together with weld testing may be required to select the most suitable electrodes. Table 3 provides detailed weld metal chemical composition requirements. Tables 1, 1M, and 2 list the mechanical properties of the weld metal in the as-welded condition or in the postweld heat-treated condition when the weldment is subjected to the PWHT requirements in Table 9. It should be noted that changes in welding variables or heat treatment can be expected to affect the mechanical properties. However, except for the effects of dilution, the chemical composition can be expected to remain reasonably unchanged.

The electrode classification identifies the chemical composition of the electrode. The following paragraphs highlight the differences between these electrodes and electrode groups and indicate typical applications.

A7.2.1 EL8, EL8K, EL12, EM11K, EM12, EM12K, EM13K, EM14K, EM15K, EH10K, EH11K, EH12K, and EH14 (Carbon Steel) Electrodes. These electrodes are carbon steel electrodes which vary from one another in their carbon, manganese, and silicon contents. An electrode from this group is selected for use with a particular flux to provide the best combination of these elements to meet application requirements. These requirements can include (but are not limited to) resistance to cracking and porosity, welding characteristics, welding speed, bead appearance, and weld metal mechanical properties. The EM14K electrodes also contain small additions of titanium, although they are considered carbon steel electrodes. The titanium functions to improve strength and toughness under certain conditions of high heat input welding or PWHT. The manufacturer should be consulted for specific recommendations.

A7.2.2 EA1, EA2, EA3, EA3K, and EA4 (C-Mo Steel) Electrodes. These electrodes are similar to the medium manganese and high manganese carbon steel electrodes shown above except that 0.5% molybdenum is added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance. Typical applications include the welding of C-Mo steel base metals such as ASTM A 204 plate and ASTM A335-P1 pipe. Electrodes of this type are particularly useful in developing impact strength on single-pass welds such as are used in the manufacture of line pipe.

A7.2.3 EB1, EB2, EB2H, EB3, EB5, EB6, EB6H, EB8, *EB23*, *EB24, and EB91* (Cr-Mo Steel) Electrodes. These electrodes produce weld metal that contains between 0.5% and *10.5%* chromium and between 0.5% and 1% molybdenum. They are designed to produce weld metal for high-temperature service.

The letter "R" when added as a suffix to the EB2 or EB3 electrode classification or to the B2 or B3 weld metal designation is an optional supplemental designator indicating that the electrode will meet the reduced residual limits necessary to meet "X" factor requirements for step cooling applications.

Since all Cr-Mo weld deposits will air harden in still air, both preheat and postweld heat treatment are required for most applications.

A7.2.3.1 *EB91 (previously EB9) is a* 9% Cr–1% Mo electrode modified with niobium (columbium) and vanadium designed to provide improved creep strength, and oxidation and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.

In addition to the classification requirements of this specification, impact toughness and high-temperature creep strength properties should be determined. Due to the influence of various levels of carbon and niobium (columbium), specific values and testing must be agreed to by the purchaser and supplier.

Thermal treatment of the *B91* alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation into martensite (M_f) is relatively low; therefore, upon completion of welding and before PWHT, it is recommended that the weldment be allowed to cool below 200°F [93°C] to maximize transformation to martensite. The maximum allowable temperature for PWHT is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To aid in allowing for an adequate PWHT, the restriction of Mn + Ni has been imposed (see Table 3, Note j). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

A7.2.4 EF4, EF5, and EF6 (Cr-Ni-Mo Steel) Electrodes. These electrodes use a combination of Cr, Ni, and Mo to develop the strength levels and notch toughness required for a number of high-strength, low-alloy or microalloyed structural steels.

A7.2.5 EM2, EM3, and EM4 (High-Strength, Low-Alloy Steel) Electrodes. These electrodes may contain a combination of Cr, Ni, Mo, Ti, Zr, and Al. They are intended to produce high-strength deposits meeting 100 000 psi [690 MPa], 110 000 psi [760 MPa], or 120 000 psi [830 MPa] minimum tensile requirements to weld steels such as HY80 and HY100. They are most typically used for weldments not subject to PWHT.

A7.2.6 ENi1, ENi1K, ENi2, and ENi3 (Ni Steel) Electrodes. These electrodes have been designed to produce weld metal with increased strength without being hardenable or with increased notch toughness at temperatures as low as –100°F (–73°C) or lower. They have been specified with nickel contents which fall into three nominal levels of 1% Ni, 2.5% Ni, and 3.5% Ni. With carbon levels of up to 0.12%, strength increases and weld deposits can meet 80 000 psi [550 MPa] minimum tensile-strength requirements. However, with lower levels of carbon, low-temperature toughness improves to match the base-metal properties of nickel steels such as ASTM A 203 Gr. E, ASTM A 352 LC3 and LC4 classifications.

Many low-alloy steels require PWHT to stress relieve the weld or temper the weld metal and heat-affected zone to achieve increased ductility. It is often acceptable to exceed the PWHT holding temperatures shown in Table 9. However, for many applications, nickel steel weld metal can be used without PWHT. If PWHT is to be specified for a nickel steel weldment, the holding temperature should not exceed the maximum temperature given in Table 9 for the classification considered since nickel steels can be embrittled at higher temperatures.

A7.2.7 ENi4, ENi5, *ENi6*, EF1, EF2, and EF3 (Ni-Mo Steel) Electrodes. These electrodes contain between 0.5% and 2% nickel and between 0.25% and 0.5% molybdenum. They are typically used for the welding of high-strength, low-alloy or microalloyed structural steels where a combination of strength and good notch toughness is required.

A7.2.8 EW (Weathering Steel) Electrode. This electrode has been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels. These special properties are achieved by the addition of about 0.5% copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, some chromium and nickel additions are also made. This electrode is used to weld the typical weathering steels such as ASTM A 242 and ASTM A 588.

A7.2.9 EG (General Low-Alloy Steel) Electrodes. These electrodes are described in A2.2. These electrode classifications may be either modifications of other discrete classifications or totally new classifications. Purchaser and user should obtain from the supplier the description and intended use for any EG electrode.

A8. Mechanical Properties of Submerged Arc Welds

Tables 1, 1M, and 2 (as applicable) of this specification list the mechanical properties required of weld metal for both the multiple pass and two-run flux–electrode classifications. The mechanical properties are determined from specimens prepared according to the procedures called for in this specification. The multiple pass procedure (for multiple pass flux–electrode classifications) minimizes dilution from the base metal and provides a finer grain structure due to the reheating of the deposited metal by subsequent weld passes. Therefore, this classification procedure more accurately reflects the properties of the undiluted weld metal from each flux–electrode classification. The two-run procedure (for two-run flux–electrode classifications) more accurately reflects the properties of as-deposited weld metal made with a particular flux and electrode under conditions of high base plate dilution.

In use, the electrodes and fluxes are handled separately, and either of them may be changed without changing the other. For this reason, a classification system with standardized test methods is necessary to relate the fluxes and electrodes to the properties of their weld metal. Chemical reactions between the molten portion of the flux and electrode, and dilution by the base metal all affect the composition of the weld metal.

The specific mechanical properties of a weld are a function of its chemical composition, cooling rate, and PWHT. High-amperage, single-pass welds have a greater depth of fusion and, hence, greater dilution by the base metal than lower current, multiple pass welds. Moreover, large, single-pass welds solidify and cool more slowly than the smaller weld beads of multiple pass welds. Furthermore, the succeeding passes of a multiple pass weld subject the weld metal of previous passes to a variety of temperature and cooling cycles that alter the metallurgical structure of different portions of those beads. For these reasons, the properties of a single-pass weld may be significantly different from those of a multiple pass weld made with the same electrode and flux.

The weld metal properties in this specification are determined in either the as-welded condition or after a PWHT, or both. For multiple pass classifications tested in the postweld heat-treated condition ("P" designator, see Figure 1 or 1M, as applicable) the PWHT procedure is as indicated in Table 9 and 9.4. For two-run classifications tested in the postweld heat-treated condition ("P" designator, see Figure 2 or 2M, as applicable) the PWHT procedure is as indicated in 9.5. Most of the weld metals are suitable for service in either condition, but the specification cannot cover all of the conditions that such weld metal may encounter in fabrication or service. For this reason, the classifications in this specification require that the weld metals be produced and tested under certain specific conditions.

Procedures employed in practice may require voltage, amperage, type of current, number of welding arcs, and travel speeds that are considerably different from those required in this specification. In addition, differences encountered in electrode size, electrode composition, electrode extension, joint configuration, preheat temperature, interpass temperature, and PWHT can have a significant effect on the properties of the weld. Within a particular electrode classification, the electrode composition can vary sufficiently to produce variations in the mechanical properties of the weld deposit in both the as-welded and PWHT conditions.

For multiple pass welds, PWHT times in excess of the time used for multiple pass classification purposes in this specification (conventionally, 20 hours to 30 hours for very thick sections) may have a major influence on the strength and toughness of the weld metal. The user needs to be aware of this and of the fact that the mechanical properties of carbon steel weld metal produced with other procedures may differ from the properties required by Tables 1, 1M, and 2 of this specification, as applicable.

A9. Diffusible Hydrogen Test

A9.1 The submerged arc welding process is generally considered to be a low-hydrogen welding process. However, as the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in the root beads), and toe or underbead cracks in the heat-affected zone. It may be appropriate to evaluate the diffusible hydrogen produced during welding with the flux–electrode combination. This specification has, therefore, included the use of optional designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3.

A9.2 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values from those indicated by the designator. Moisture from the air, distinct from that in the flux or electrode, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. Some air will mix with the flux cover and add its moisture to the other sources of diffusible hydrogen. It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. The use of a reference atmospheric condition during the welding of the hydrogen test assembly is necessitated because the arc is always imperfectly shielded. The reference atmospheric condition of 10 grains of moisture per lb [1.5 grams of moisture per kilogram] of dry air is equivalent to 10% relative humidity at 68 °F [20 °C]. A flux–electrode combination meeting the H4 requirements under the reference atmospheric conditions may not do so under conditions of high humidity at the time of welding.

A9.3 Fluxes (and composite electrodes) can be contaminated by the condensation of moisture from the atmosphere and, in some cases, can absorb significant moisture if stored in a humid environment in damaged or open packages, or especially if unprotected for long periods of time. In the worst cases of high humidity, even overnight exposure of unprotected flux (or composite electrode) can lead to a significant increase of diffusible hydrogen. In the event the flux (or composite electrode) has been exposed, the manufacturer should be consulted regarding probable damage to low-hydrogen characteristics and possible reconditioning of the flux (or composite electrode). Solid electrodes can also be contaminated under the same conditions. In this case, the moisture contamination is on the surface. It is recommended that electrodes exhibiting visible surface rust be discarded.

A9.4 Not all classifications may be available in the H16, H8, H4, or H2 diffusible hydrogen levels. The manufacturer of a given flux (or composite electrode) should be consulted for availability of products meeting these limits.

A9.5 Aging of Tensile Specimens. Weld metals may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases toward its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. This specification permits the aging of the tensile test specimens at elevated temperatures up to 220 °F [105 °C] for up to 48 h before subjecting them to tension testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrode deposits, especially when testing high-strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds.

A10. General Safety Considerations

A10.1 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 A10.2, ANSI Z49.1, and applicable federal and state regulations.

A10.2 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.

A10.3. AWS Safety and Health Fact Sheets Index (SHF)[7]

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*

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

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 Valve 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

Annex B (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS A5.23/A5.23M: 2011, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, 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	A5.20	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28	A5.29	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless Steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11	A5.14	A5.34	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	*Filler Metal Comparison Charts*
IFS	*International Index of Welding Filler Metal Classifications*
UGFM	*User's Guide to Filler Metals*
A4.2M (ISO 8249 MOD)	*Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*
A4.3	*Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*
A4.4M	*Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*
A5.01M/A5.01 (ISO 14344 MOD)	*Procurement Guidelines for Consumables — Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*
A5.02/A5.02M	*Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*
A5.1/A5.1M	*Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*
A5.2/A5.2M	*Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding*
A5.3/A5.3M	*Specification for Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding*
A5.5/A5.5M	*Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*
A5.6/A5.6M	*Specification for Copper and Copper-Alloy for Shielded Metal Arc Welding Electrodes*
A5.7/A5.7M	*Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes*
A5.8/A5.8M	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M	*Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods*
A5.11/A5.11M	*Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*
A5.12M/A5.12 (ISO 6848 MOD)	*Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*
A5.13/A5.13M	*Specification for Surfacing Electrodes for Shielded Metal Arc Welding*
A5.14/A5.14M	*Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*
A5.15	*Specification for Welding Electrodes and Rods for Cast Iron*
A5.16/A5.16M	*Specification for Titanium and Titanium Alloy Welding Electrodes and Rods*
A5.17/A5.17M	*Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.18/A5.18M	*Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.19	*Specification for Magnesium Alloy Welding Electrodes and Rods*
A5.20/A5.20M	*Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*
A5.21/A5.21M	*Specification for Bare Electrodes and Rods for Surfacing*
A5.22/A5.22M	*Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*
A5.23/A5.23M	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.24/A5.24M	*Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods*
A5.25/A5.25M	*Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*
A5.26/A5.26M	*Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*
A5.28/A5.28M	*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.29/A5.29M	*Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*
A5.30/A5.30M	*Specification for Consumable Inserts*
A5.31	*Specification for Fluxes for Brazing and Braze Welding*
A5.32M/A5.32 (ISO 14175 MOD)	*Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*
A5.34/A5.34M	*Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding*

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