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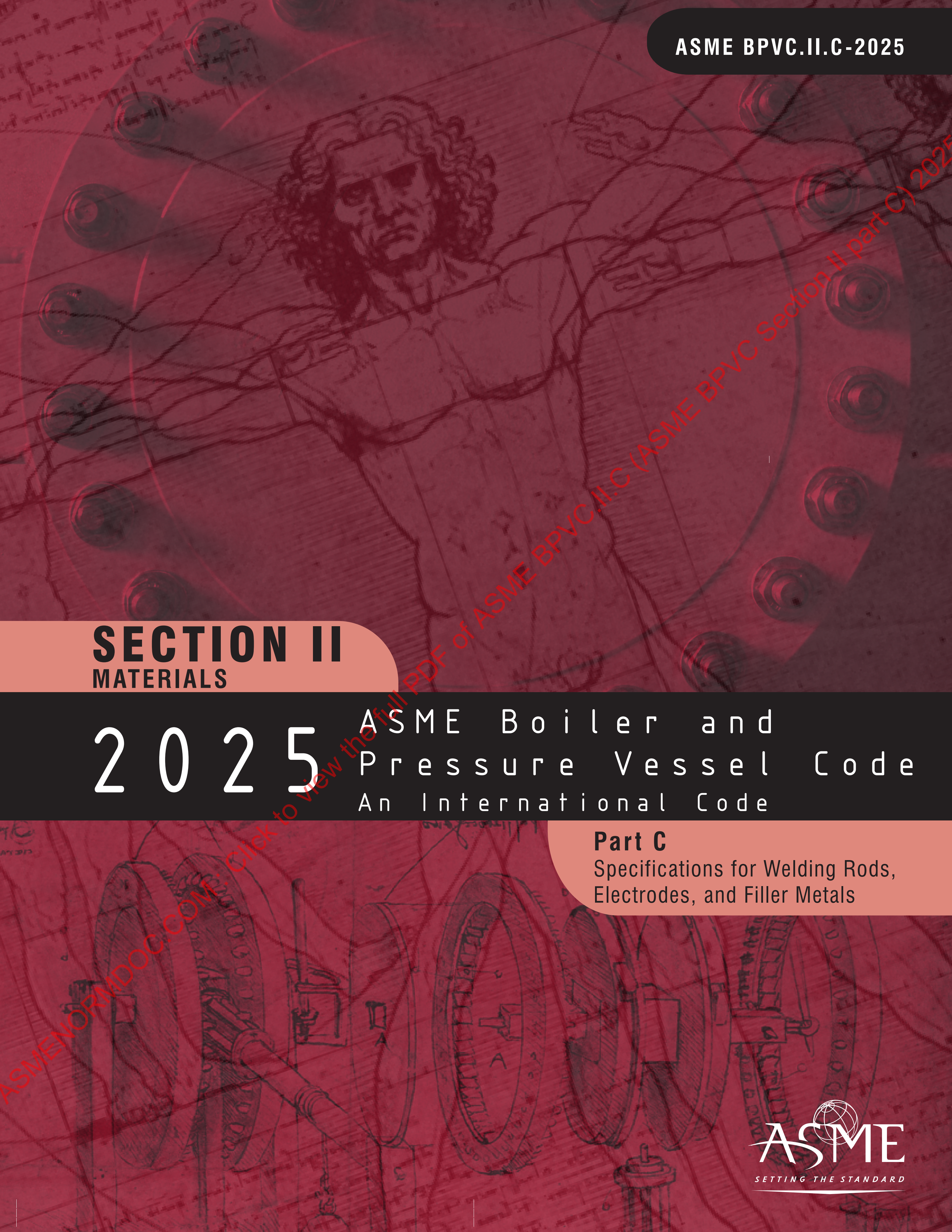

SECTION II
MATERIALS

2025 ASME Boiler and Pressure Vessel Code
An International Code

Part C
Specifications for Welding Rods, Electrodes, and Filler Metals

ASME
SETTING THE STANDARD

AN INTERNATIONAL CODE

2025 ASME Boiler & Pressure Vessel Code

2025 Edition July 1, 2025

II

MATERIALS

Part C

Specifications for Welding Rods, Electrodes, and Filler Metals

ASME Boiler and Pressure Vessel Committee
on Materials

The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

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FOREWORD*

In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Committee on Overpressure Protection (XIII)
(l) Technical Oversight Management Committee (TOMC)

Where reference is made to "the Committee" in this Foreword, each of these committees is included individually and collectively.

The Committee's function is to establish rules of safety relating to pressure integrity. The rules govern the construction** of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. For nuclear items other than pressure-retaining components, the Committee also establishes rules of safety related to structural integrity. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. The Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity and, for nuclear items other than pressure-retaining components, structural integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of components addressed by the Code. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

The Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code

* The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

** *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of the Code. Requests for revisions, new rules, Code cases, or interpretations shall be addressed to the staff secretary in writing and shall give full particulars in order to receive consideration and action (see the Correspondence With the Committee page). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in the Code, the singular shall be interpreted as the plural, and vice versa.

The words "shall," "should," and "may" are used in the Code as follows:

– *Shall* is used to denote a requirement.
– *Should* is used to denote a recommendation.
– *May* is used to denote permission, neither a requirement nor a recommendation.

STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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K. R. Bulger, *Secretary*
D. D. Dehner
P. W. Fischer
J. D. Schaefer
J. Turriff
H. D. Wehr

A5G SUBCOMMITTEE ON HARDFACING FILLER METALS

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K. R. Bulger, *Secretary*
T. A. Barnhart
F. B. Lake
P. F. Mendez
K. Meszaros
R. A. Miller
J. G. Postle
V. B. Rajan
J.-M. Tetevuide

A5H SUBCOMMITTEE ON FILLER METALS AND FLUXES FOR BRAZING

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K. R. Bulger, *Secretary*
J. Arbogast
J. Bush
D. Chalasani
W. M. Coughlan
D. Dehner
G. DeVries
P. Ditzel
S. Feldbauer
R. Gourley
M. T. Graham
T. Grostad
J. Gutierrez
T. P. Hirthe
K. Landgraf
S. Lindsey
J. Longabucco
S. McAllister
W. Miglietti
S. Nelson
T. Oyama
M. Paponetti
D. Pruchenski
S. S. Rajan
B. Schneiderman
A. E. Shapiro
L. A. Shapiro
M. Stroiczek
E. Theisen
C. M. Volpe
M. Weinstein
M. Wilson
Z. Yu
H. Zhao

A5I SUBCOMMITTEE ON TUNGSTEN ELECTRODES

K. R. Bulger, *Chair*
G. Cleveland
A. Endemann
S. Fyffe

A5K SUBCOMMITTEE ON TITANIUM AND ZIRCONIUM FILLER METALS

R. C. Sutherlin, *Chair*
S. Borrero, *Secretary*
W. Craig
B. Krueger
K. T. Tran
G. E. Trepus

A5M SUBCOMMITTEE ON CARBON AND LOW ALLOY STEEL ELECTRODES FOR FLUX CORED ARC WELDING

J. Schaeffer, *Chair*
B. A. Pletcher, *Vice Chair*
K. R. Bulger, *Secretary*
A. Boulianne
M. R. Brinkman
J. C. Bundy
D. W. Haynie
B. L. Kahut
T. C. Myers
M. F. Sinfield
T. VanLoon

A5N SUBCOMMITTEE ON CONSUMABLE INSERTS

S. Williams, *Chair*
W. J. Sperko, *Vice Chair*
K. R. Bulger, *Secretary*
R. V. Decker, Jr.
W. F. Newell
H. D. Wehr

A5O SUBCOMMITTEE ON SOLID CARBON AND LOW ALLOY STEEL ELECTRODES AND RODS FOR GAS SHIELDED ARC WELDING

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A. Boulianne
R. V. Decker, Jr.
R. J. Fox
J. Lipko
T. C. Myers
V. B. Rajan
K. Sampath
J. Schaeffer

A5P SUBCOMMITTEE ON CARBON AND LOW ALLOY STEEL ELECTRODES FOR ELECTROSLAG AND ELECTROGAS WELDING

B. A. Pletcher, *Chair*
J. S. Lee, *Vice Chair*
K. R. Bulger, *Secretary*
D. R. Bajek
D. A. Fink
K. K. Ishizaki
R. B. Turpin

A5S SUBCOMMITTEE ON GASES FOR GAS SHIELDED ARC WELDING

J. M. Zawodny, *Vice Chair*
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R. Mercer
N. Moyer
F. Rupp
J. Wallace

A5T SUBCOMMITTEE ON FILLER METAL PROCUREMENT GUIDELINES

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J. S. Lee
T. Melfi
K. Sampath

A5W SUBCOMMITTEE ON MOISTURE AND HYDROGEN

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A. Boulianne
D. A. Fink
R. J. Fox
J. S. Lee
J. Lipko
C. Miller
M. F. Sinfield
K. T. Wiest

CORRESPONDENCE WITH THE COMMITTEE

General

ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Section of the ASME Boiler and Pressure Vessel Code (BPVC) should be sent to the staff secretary noted on the Section's committee web page, accessible at https://go.asme.org/CSCommittees.

NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number to which the proposed case applies

(4) the editions of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition of the Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Inquiry Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic email confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

(d) ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

PREFACE

On January 3, 1919, ASME participated with several other organizations in a meeting to discuss the continuation of wartime research in welding. Out of that meeting, the American Welding Society was established and since that time there has been a constant and interwoven record of development by the American Welding Society and The American Society of Mechanical Engineers of the techniques of welding. Through all of these great years of growth, many of the leaders in the field of engineering had the common interest of pressure equipment design and manufacture and the development of welding as a powerful tool in that manufacture. The evolution of this cooperative effort is contained in Professor A. M. Greene's "History of the ASME Boiler Code," which was published as a series of articles in *Mechanical Engineering* from July 1952 through August 1953 and is now available from ASME in a special bound edition. The following quotation from this history based on the minutes of the Committee notes the cooperative nature of the work done in the area of welding.

"During 1919, a number of cases involving welding were referred by the Boiler Code Committee to the Subcommittee on Welding.

"As the National Welding Council was to be discontinued, a new organization was to be formed to be known as the American Welding Society with which the American Bureau of Welding was to be affiliated. This was to be a body representing the entire industry and would eliminate commercial aspects, undertake research and standardization, and act as a judicial body providing a medium for advancing the science and art of welding."

In 1935 the AWS-ASTM Joint Committee on Filler Metal was organized to provide standard specifications for welding rods, electrodes, filler metals, and fluxes for this developing U.S. industry.

In 1969 these two sponsors agreed to dissolve this joint activity and to permit the American Welding Society to assume sole responsibility for the family of welding rods, electrodes, filler metal, and flux specifications then in being.

In 1992, the ASME Board of Pressure Technology Codes and Standards endorsed the use of materials produced to other than AWS specifications. It is the intent of ASME to follow its procedures and practices currently in use to implement the adoption of material specifications of AWS and other recognized national or international organizations.

Section II, Part C contains material specifications, most of which are identical to corresponding specifications published by AWS and other recognized national or international organizations. All adopted specifications are either reproduced in the Code, where permission to do so has been obtained from the originating organization, or so referenced, and information about how to obtain them from the originating organization is provided. The ASME Committee reviews all material specifications submitted to it and if it is felt that there is any need to adapt them for Code purposes, revisions are made to them. However, there is constant liaison between ASME and AWS and other recognized national or international organizations, and there will be continuing effort to see that the specifications as produced by AWS and other recognized national or international organizations and those printed in the ASME Code are identical.

To assure that there will be a clear understanding on the part of the users of Section II, ASME publishes both the identical specifications and those amended for Code usage every 2 years.

The ASME Boiler and Pressure Vessel Code has been adopted into law by 50 states and many municipalities in the United States and by all of the Canadian provinces.

GUIDELINE ON THE APPROVAL OF NEW WELDING AND BRAZING MATERIAL CLASSIFICATIONS UNDER THE ASME BOILER AND PRESSURE VESSEL CODE

Code Policy. It is the policy of the ASME Boiler and Pressure Vessel Committee to adopt for inclusion in Section II, Part C, only such specifications as have been adopted by the American Welding Society (AWS), and by other recognized national or international organizations.

It is expected that requests for Code approval will normally be for welding and brazing materials (hereafter termed "consumables") for which there is a recognized national or international specification. For consumables made to a recognized national or international specification other than those of the AWS, the inquirer shall give notice to the standards developing organization that a request has been made to ASME for adoption of their specification under the ASME Code, and shall request that the organization to grant ASME permission to reprint the standard. For other consumables, a request shall be made to the AWS, or a recognized national or international organization, to develop a specification that can be presented to the Code Committee.

It is the policy of the ASME Boiler and Pressure Vessel Committee to consider requests to adopt new consumables for use by boiler, pressure vessel, or nuclear power plant component Manufacturers or end users. Further, such requests should be for consumables for which there is a reasonable expectation of use in a boiler, pressure vessel, or nuclear power plant component constructed to the rules of one of the Sections of this Code.

Application. The inquirer shall identify to the Committee all product forms, size ranges, and specifications for which incorporation is desired, and state whether or not the consumable is covered by patents, whether or not it is licensed, and if licensed, any limitations on its manufacture.

Weldability/Brazability. The inquirer shall furnish complete data on procedure qualification tests made in accordance with the requirements of Section IX. Such tests shall be made over the full range of base metal thickness in which the consumable is to be used. Pertinent information on deposited metal, such as effects from postweld heat treatment, susceptibility to air hardening, effects of joining processes, expected notch toughness values, and the amount of experience in use of the consumable shall be given.

Physical Changes. For new consumables, it is important to know the structural stability characteristics and the degree of retention of properties with exposure at temperature. The influence of welding or brazing and thermal treatment operations on the mechanical properties, ductility, and microstructure of the deposited metal are important, particularly where degradation in properties may occur. Where particular temperature ranges of exposure or heat treatment, cooling rates, combinations of mechanical working and thermal treatments, fabrication practices, exposure to particular environments, etc., cause significant changes in the mechanical properties, microstructure, resistance to brittle fracture, etc., it is of prime importance to call attention to those conditions that should be avoided in service or in manufacture of parts or vessels using the consumable.

Requests for Additional Data. The Committee may request additional data, including data on properties or deposited metal behavior not explicitly treated in the construction Code in which adoption is desired.

Code Case. The Code Committee will consider the issuance of an ASME Code Case, to be effective for a period of three years, permitting the treatment of a new welding or brazing material under an existing ASME Section IX grouping for qualification purposes, provided that the following conditions are met:

(a) The inquirer provides evidence that a request for coverage of the consumable in a specification has been made to the AWS or a recognized national or international organization;

(b) the consumable is commercially available and can be purchased within the proposed specification requirements;

(c) the inquirer shows that there will be a reasonable demand for the consumable by industry and that there exists an urgency for approval by means of a Code Case;

(d) the request for approval of the consumable shall clearly describe it in specification form, including applicable items as scope, process, manufacture, conditions for delivery, heat treatment, chemical and tensile requirements, testing specifications and requirements, workmanship, finish, marking, inspection, and rejection;

(e) all other requirements identified previously under Code Policy and Application apply; and

(f) the inquirer shall furnish the Code Committee with all the data specified in this Guideline.

Requirements for Requests for ASME Acceptance of Welding and Brazing Material Specifications to Recognized National or International Standards Other Than the AWS. The Committee will consider only requests in accordance with the Boiler and Pressure Vessel Committee Operating and Administrative Procedures, OP-8.6 (English language: U.S. or SI/metric units). The Committee will consider accepting specifications of recognized national or international organizations in accordance with OP-8.6 such as, but not limited to, AWS, CSA, CEN, DIN, and JIS. Consumable specifications of other than national or international organizations, such as those of consumable producers and suppliers, will not be considered for acceptance.

Requirements for Recognized National or International Specifications. Acceptable consumable specifications will be identified by date or edition. Approved edition(s) will be stated in the subtitle of the ASME specification. Minimum requirements that must be contained in a consumable specification for which acceptance is being requested include such items as name of national or international organization, scope, reference documents, process, manufacture, conditions for delivery, heat treatment, chemical and tensile requirements, testing specifications and requirements, workmanship, finish, marking, inspection, and rejection.

Publication of Recognized National or International Specifications. Specifications for which ASME has not been given permission to publish by the originating organization will be referenced on a cover sheet in appropriate Appendices in Section II, Part C, along with information xxix on where to obtain a copy of those documents. Documents that are referenced in non-AWS consumable specifications will not be published by ASME. However, information on where to obtain a copy of those documents will be maintained in Section II, Part C. Additions and exceptions to the consumable specification will be noted in the subtitle of the specification.

New Welding and Brazing Materials Checklist. To assist inquirers desiring Code coverage for new consumables, or extending coverage of existing consumables, the Committee has developed the following checklist of items that ought to be addressed by each inquiry. The Committee reserves the right to request additional data and application information when considering new consumables.

(a) Has a qualified inquirer request been provided?

(b) Has a request for either revision to existing Code requirements or for a Code Case been defined?

(c) Has a letter to the AWS been submitted requesting coverage of the new consumable in a specification, and has a copy been submitted to the Committee? Alternatively, is this consumable already covered by a specification issued by a recognized national or international organization, and has an English language version been provided?

(d) Has the Construction Code and Division coverage been identified?

(e) Have mechanical property data been submitted (ultimate tensile strength, yield strength, reduction of area, and elongation) for each intended joining process?

(f) Have toughness considerations required by the Construction Code been defined and has appropriate data been submitted?

(g) Have joining requirements been defined and has procedure qualification test data been submitted?

(h) Has influence of fabrication practices on deposited metal properties been defined?

SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(25)**, placed next to the affected area.

Page	*Location*	*Change*
v	List of Sections	Title of Section XI, Division 1 revised
vi	Foreword	Third, fourth, seventh, tenth, and eleventh paragraphs editorially revised
ix	Personnel	Updated
xxxii	AWS Personnel	Updated
1	SFA-5.01M/SFA-5.01	Revised in its entirety
25	SFA-5.02/SFA-5.02M	Revised in its entirety
43	SFA-5.1/SFA-5.1M	Revised in its entirety
113	SFA-5.3/SFA-5.3M	Revised in its entirety
343	SFA-5.10/SFA-5.10M	Revised in its entirety
425	SFA-5.12/SFA-5.12M	Revised in its entirety
447	SFA-5.13/SFA-5.13M	Revised in its entirety
481	SFA-5.14/SFA-5.14M	Revised in its entirety
511	SFA-5.15	Revised in its entirety
591	SFA-5.18/SFA-5.18M	Revised in its entirety
667	SFA-5.21/SFA-5.21M	Revised in its entirety
699	SFA-5.22/SFA-5.22M	Revised in its entirety
815	SFA-5.25/SFA-5.25M	Revised in its entirety
863	SF-5.28/SFA-5.28M	Title of para. 15 reinstated (inadvertently omitted in 2023 Edition)

CROSS-REFERENCING IN THE ASME BPVC

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) Hierarchy of Subparagraph Breakdowns

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) Cross-References to Subparagraph Breakdowns. Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The cross-references to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

WELDING AND BRAZING CONSUMABLES — PROCUREMENT OF FILLER MATERIALS AND FLUXES

SFA-5.01M/SFA-5.01

(25)

(Identical with AWS Specification A5.01M/A5.01:2019 (R2024) (ISO 14344:2010 MOD). In case of dispute, the original AWS text applies.)

Welding and Brazing Consumables— Procurement of Filler Materials and Fluxes

1. Scope

This standard identifies various information necessary for communication between a purchaser and a supplier of welding or brazing consumables. This standard, together with an AWS, ISO, or other recognized welding or brazing consumable standard, provides a method for preparing those specific details needed for welding and brazing consumable procurement which consist of the following:

(1) the welding or brazing consumable classification (selected from the pertinent AWS, ISO, or other applicable welding or brazing consumable standard),

(2) the lot class (selected from Clause 4 of this standard),

(3) the testing schedule (selected from Clause 5 of this standard).

Selection of the specific welding or brazing consumable classification, lot class, and testing schedule will depend upon the requirements of the application for which the consumable is being procured.

1.2 *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 A5.01M uses SI Units. The specification A5.01 uses U.S. Customary Units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. The standard dimensions based on either system may be used for the sizing of electrodes, packaging, or both under A5.01M or A5.01 specifications.*

2. Normative References

The following normative documents contain provisions which, through references in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest editions of the normative documents referred to apply. Members of ISO and IEC maintain registers of currently valid International Standards.

The following AWS standards are referenced in the mandatory section of this document.

AWS A3.0 M/A3.0, *Standard Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

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

The following ISO standards are referenced in the mandatory section of this document.

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

ISO 10474, Steel and steel products — Inspection documents

The following EN standard is referenced in the mandatory section of this document.

EN 10204, Metallic Products — Types of Inspection Documents

3. Terms and Definitions

In production, the components of welding or brazing consumables shall be divided into discrete quantities so that satisfactory tests with a sample from that quantity will establish that the entire quantity meets specification requirements. These quantities, known by such terms as heats, lots, blends, batches, and mixes, vary in size according to the manufacturer. For identification purposes, each manufacturer assigns a unique designation to each quantity. This designation usually consists of a series of numbers or letters, or combinations thereof, which will enable the manufacturer to determine the date and time (or shift) of manufacture, the raw materials used, and the details of the procedures used in producing the welding or brazing consumable. This designation stays with the welding or brazing consumable and can be used to identify the material later, in those cases in which identification is necessary.

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

3.1 Dry Batch. The quantity of dry ingredients mixed at one time in one mixing vessel.

NOTE: Liquid(s), such as binders, when added to a dry batch, produce a wet mix. A dry batch may be divided into homogeneous smaller quantities, in which case addition of the liquid(s) produces a corresponding number of smaller wet mixes.

3.2 Dry Blend. Two or more dry batches from which quantities of each are combined proportionately, then mixed in a mixing vessel to produce a larger quantity in which the ingredients are as uniformly dispersed as they would have been had the entire quantity been mixed together at one time in one large mixer.

NOTE: A dry blend, as in the case of a dry batch, may be used singly or divided into smaller quantities, in which case addition of liquid(s) produces a corresponding number of smaller wet mixes.

3.3 Wet Mix. The combination of liquid(s) and a dry batch, dry blend, or a portion thereof, mixed at one time in one mixing vessel.

3.4 Heat. For fully metallic consumables, or the fully metallic rod, tube, or strip used to fabricate tubular cored or covered electrodes and rods the following apply. The specific definition is dependent on the method of melting and refining of the metal:

3.4.1 The material obtained from one furnace melt, where slag-metal or gas-metal reactions occur in producing the specified alloy (e.g., open hearth, electric arc, basic oxygen, argon-oxygen processes). Mill splicing of coils from different heats is not permitted, and coils containing transition heats may not be classified in this manner.

3.4.2 An uninterrupted series of melts from one controlled batch of metals and alloying ingredients in one melting furnace under the same melting conditions, each melt conforming to the chemical composition range approved by the purchaser of the material (i.e., the producer of the welding or brazing consumable) where significant chemical reactions do not occur in producing the specified alloy (e.g., induction melting in a controlled atmosphere or in a vacuum).

3.4.3 An uninterrupted series of remelts in one furnace under the same remelting conditions using one or more consumable electrodes produced from a single heat, each remelt conforming to the chemical composition range approved by the purchaser of the material (i.e., the producer of the welding or brazing consumable) in processes involving continuous melting and casting (e.g., consumable electrode remelt).

3.5 Controlled Chemical Composition

3.5.1 Covering or core ingredients consisting of one or more wet mixes, dry batches, or dry blends that are subjected to sufficient tests to assure that all within the lot are equivalent. These tests shall include chemical analysis, the results of which shall fall within the manufacturer's acceptance limits. The identification of the test procedure and the results of the tests shall be recorded.

3.5.2 Fully metallic consumables, or the fully metallic rod, tube, or strip used to fabricate tubular cored or covered electrodes that consist of mill coils of one or more heats from which samples have been taken for chemical analysis and validated as described in this clause. Mill coils from mills that do not permit spliced-coil practice need to be sampled only on one end. Coils from mills that permit spliced-coil practice with a maximum of one splice per coil need to be sampled on both ends. Coils with more than one splice are not permitted under this definition. The results of the analysis of each sample shall be recorded and be within the manufacturer's composition limits for that material.

3.6 Lot. A unique identifying designation for a specific type and quantity of welding or brazing consumable, usually beginning with the word “lot” and followed by a series of numbers and/or letters. The lot class, as identified in Clause 4, details the requirements for grouping consumables into a single lot.

3.7 Production Schedule. A manufacturing campaign of a single lot number produced by either a single manufacturing operation or a series of manufacturing operations, any of which is uninterrupted by the production of any other product or any other lot number of the same product.

3.8 Certificate of Compliance. A statement that the product meets the requirements of the AWS, ISO, or other applicable welding or brazing consumable specification/classification.

A summary of results may be included and may be in the form of averages, ranges, or single representative values and is not necessarily from a single set of tests run at the same time, or even unique for a specific size.

3.9 Certificate of Conformance. A test report documenting that the product meets the requirements of the AWS, ISO, or other applicable welding or brazing consumable specification/classification.

The reported results shall be in the form of a single set of tests run at the same time, using representative material/product, and may be for a specific size (diameter) or for all sizes (diameters) required to be tested for classification. Actual test values for all tests required for the AWS, ISO, or other applicable welding or brazing consumable classification shall be reported and include a date showing when these actual tests were completed. The report shall not consist of averages, ranges, or single random or “representative” values. It is not usually specific to the actual material supplied.

The date when the test(s) were actually completed must be shown, but there is no requirement as to how recently they must have been completed (e.g., within 12 months of the date of the purchase order, etc.).

3.10 Certified Material Test Report (CMTR). A CMTR is a test report where there is specific reference to the tests being conducted on the actual material supplied. The CMTR may contain results of some or all of the tests required for classification, or other tests as agreed upon by the purchaser and supplier. Several examples of what these may include follow.

(1) Chemical analysis only (per each heat or lot, for the size supplied)—Schedule 3 or H per AWS A5.01M/A5.01.

(2) Tests listed in Table 2 of AWS A5.01M/A5.01 (per each heat or lot, for the size supplied)—Schedule 4 or I per AWS A5.01M/A5.01.

(3) All tests required for classification per the applicable AWS or ISO specification (per each heat or lot, for the size supplied)—Schedule 5 or J per AWS A5.01M/A5.01.

(4) Any additional tests required by the purchaser (per each heat or lot, for the size supplied)—Schedule 6 or K per AWS A5.01M/A5.01.

3.11 Material Test Report (MTR). An MTR is a report documenting the results of tests performed by the manufacturer to fulfill the requirements of the material specification. Results of tests performed to meet supplementary or special requirements specified by the purchaser may also be included on the MTR. An MTR shall identify the applicable material specification and shall include unique identification linking it to the actual material supplied. A Certificate of Conformance, Certificate of Compliance, or “Typical” Test report are not considered acceptable replacements for, or equivalent to, an MTR. A CMTR is a certified copy of an MTR.

3.12 Typical Test Report (“Typical”). A Typical Test Report is a nonstandard term which does not have a consistent definition. See Certificate of Compliance or Certificate of Conformance.

4. Lot Class

A Lot Class is a two-character designation consisting of a letter representing the form of the consumable *at its final size* and a number designating how the grouping of a quantity of consumables into a single lot is allowed. The lot class shall be selected by the purchaser from those listed below.

4.1 Fully Metallic Solid Consumables

4.1.1 Lot Class S1. The quantity of fully metallic solid welding or brazing consumables not exceeding the manufacturer's standard lot, as defined in the manufacturer's quality assurance program.

4.1.2 Lot Class S2. The quantity not exceeding 45 000 kg [100 000 lb] of one fully metallic solid welding or brazing consumable classification, size, form, and temper produced in 24 hours of consecutively scheduled production (i.e., consecutive normal work shifts) from one heat as defined in 3.4 or from controlled chemical composition material as defined in 3.5.2. *For production schedules consisting of a series of manufacturing operations, only those that significantly affect the chemical composition or operability as defined in the manufacturer's quality system are limited to the 24-hour restriction. In these cases, each of those individual manufacturing operations rather than the manufacturing campaign is subject to an independent 24-hour restriction.*

4.1.3 Lot Class S3. The quantity of one fully metallic solid welding or brazing consumable classification and one size produced in one production schedule as defined in 3.7 from one heat as defined in 3.4.

4.1.4 Lot Class S4. The quantity not exceeding 45 000 kg [100 000 lb] of one fully metallic solid welding or brazing consumable classification, size, form, and temper produced under one production schedule as defined in 3.7 from one heat as defined in 3.4 or from controlled chemical composition material as defined in 3.5.2.

4.2 Tubular Cored Electrodes and Rods

4.2.1 Lot Class T1. The quantity of tubular welding consumables not exceeding the manufacturer's standard lot, as defined in the manufacturer's quality assurance program.

4.2.2 Lot Class T2. The quantity not exceeding 45 000 kg [100 000 lb] of one tubular welding consumable classification and size produced in 24 hours of consecutively scheduled production (i.e., consecutive normal work shifts) from rod, tube, or strip from one heat as defined in 3.4 or by controlled chemical composition as defined in 3.5.2, and core ingredients from one dry batch as defined in 3.1, one dry blend as defined in 3.2, or controlled chemical composition as defined in 3.5.1. *For production schedules consisting of a series of manufacturing operations, only those that significantly affect the chemical composition or operability as defined in the manufacturer's quality system are limited to the 24-hour restriction. In these cases, each of those individual manufacturing operations rather than the manufacturing campaign is subject to an independent 24-hour restriction*.

4.2.3 Lot Class T3. The quantity of one tubular welding consumable classification and size produced from rod, tube, or strip from one heat as defined in 3.4 and core ingredients from one dry batch as defined in 3.1 or one dry blend as defined in 3.2.

4.2.4 Lot Class T4. The quantity not exceeding 45 000 kg [100 000 lb] of one tubular welding consumable classification and size produced under one production schedule as defined in 3.7 from rod, tube, or strip from one heat as defined in 3.4 or by controlled chemical composition as defined in 3.5.2, and core ingredients from one dry batch as defined in 3.1, one dry blend as defined in 3.2, or controlled chemical composition as defined in 3.5.1.

4.3 Covered Electrodes

4.3.1 Lot Class C1. The quantity of covered electrodes not exceeding the manufacturer's standard lot, as defined in the manufacturer's quality assurance program.

4.3.2 Lot Class C2. The quantity not exceeding 45 000 kg [100 000 lb] of one covered electrode welding consumable classification and size produced in 24 hours of consecutively scheduled production (i.e., consecutive normal work shifts). *For production schedules consisting of a series of manufacturing operations, only those that significantly affect the chemical composition or operability as defined in the manufacturer's quality system are limited to the 24-hour restriction. In these cases, each of those individual manufacturing operations rather than the manufacturing campaign is subject to an independent 24-hour restriction.*

4.3.3 Lot Class C3. The quantity not exceeding 45 000 kg [100 000 lb] of one covered electrode welding consumable classification and size produced under one production schedule as defined in 3.7 from core wire from one heat as defined in 3.4 or controlled chemical composition as defined in 3.5.2, and covering ingredients from one wet mix as defined in 3.3 or controlled chemical composition as defined in 3.5.1.

4.3.4 Lot Class C4. The quantity of one covered electrode welding consumable classification and size produced from core wire from one heat as defined in 3.4 and covering ingredients from one wet mix as defined in 3.3.

4.3.5 Lot Class C5. The quantity of one covered electrode welding consumable classification and size produced from core wire from one heat as defined in 3.4 and covering ingredients from one dry batch as defined in 3.1 or one dry blend as defined in 3.2.

4.4 Fluxes for Submerged Arc and Electroslag Welding

4.4.1 Lot Class F1. The quantity of flux not exceeding the manufacturer's standard lot, as defined in the manufacturer's quality assurance program.

4.4.2 Lot Class F2. The quantity of flux produced from the same combination of raw materials under one production schedule as defined in 3.7.

5. Level of Testing

Table 1 provides a summary of the levels of testing described below.

5.1 Schedule 1 or F. The level of testing shall be the manufacturer's standard. A statement, "the product supplied will meet the requirements of the applicable AWS, ISO, or other applicable welding consumable standard when tested in accordance with that standard" and a summary of the typical properties of the material, when tested in that manner, shall be supplied upon written request.

5.2 Schedule 2 or G. Test results shall be supplied from any product manufactured within twelve months preceding the date of the purchase order. This shall include results of all tests required for that classification in the AWS, ISO, or other applicable welding or brazing consumable standard.

5.3 Schedule 3 or H. Chemical analysis of the specific lot of consumables shall be supplied. The analysis shall include those elements required for that classification in the AWS, ISO, or other applicable welding or brazing consumable standard.

5.4 Schedule 4 or I. Results of the tests called for in Table 2 for the specific lot of consumables shall be supplied. These tests represent a consensus of those frequently requested for consumables certification; however, they do not necessarily include all tests required for Schedule 5 or J. The tests shall be performed as prescribed for that classification in the AWS standard.

Table 1
Testing Schedules[a]

Schedule[b]	Requirements	Reference Clause	*Minimum Inspection Document Type[c]*
1 or F	The manufacturer's standard testing schedule	5.1	*2.2*
2 or G	Classification tests from product manufactured within 12 months preceding the date of the purchase order	5.2	*2.2*
3 or H	Chemical analysis of the specific lot	5.3	*3.1*
4 or I	Tests called for by Table 2, for the specific lot	5.4	*3.1*
5 or J	All tests prescribed for classification in the AWS, ISO, or other applicable welding or brazing consumable standard, for the specific lot	5.5	*3.1*
6 or K	All tests specified by the purchaser for the specific lot	5.6	*3.1*

[a] Testing shall be conducted in accordance with the applicable filler metal classification standard, unless otherwise agreed upon by purchaser and seller.
[b] Either the numeric or alphabetic designation may be used interchangeably.
[c] *Inspection document types per ISO 10474 or EN 10204. See these standards for detailed requirements.*

Table 2
Schedule 4 or I—Required Tests[a, b, c]

Product Type	Carbon Steel		Low-Alloy Steel		Stainless Steel	Nickel and Ni-Alloy	Surfacing		Cast Iron	Aluminum and Al-Alloy	Copper and Cu-Alloy	Magnesium and Mg-Alloy	Titanium and Ti-Alloy	Zirconium and Zr-Alloy	Brazing and Braze Welding Filler Metals
Covered Solid and Metal Cored (Composite) Electrodes for SMAW	(A5.1) 1, 2, 3, 4, 5[d]		(A5.5) 1, 2, 3, 4, 5[d]		(A5.4) 1	(A5.11) 1, 2, 4, 6	(A5.13) 1	(A5.21) 1	(A5.15) 1	(A5.3) 1	(A5.6) 1, 4	—	—	—	—
Bare Solid and Metal Cored (Composite) Rods and Electrodes for GTAW, PAW, GMAW, EGW	(A5.18, A5.36) 1, 2, 4	(A5.26) 1, 2, 3, 4	(A5.26) 1, 2, 3, 4	(A5.28, A5.36) 1, 2, 4	(A5.9) 1	(A5.14) 1	(A5.13) 1	(A5.21) 1	(A5.15) 1	(A5.10) 1, 4[e], 9[e]	(A5.7) 1	(A5.19) 1	(A5.16) 1	(A5.24) 1	—
Bare Solid and Metal Cored (Composite) Electrodes for SAW	(A5.17) 1		(A5.23) 1		(A5.9) 1	(A5.14) 1	—	—	—	—	—	—	—	—	—
Flux Cored Electrodes for FCAW and EGW	(A5.20, A5.36) 1, 2, 3, 4	(A5.26) 1, 2, 3, 4	(A5.26) 1, 2, 3, 4	(A5.29, A5.36) 1, 2, 3, 4	(A5.22) 1	(A5.34) 1	—	—	(A5.15) 1	—	—	—	—	—	—
Solid or Metal Cored Electrode—Flux Combinations for SAW and ESW	(A5.17) 1, 2, 3, 4	(A5.25) 1, 2, 3, 4	(A5.23) 1, 2, 3, 4	(A5.25) 1, 2, 3, 4	—	—	—	—	(A5.15) 1	—	—	—	—	—	—
Solid and Composite Rods for OFW	(A5.2) 1		(A5.2) 1		—	—	(A5.13) 1	(A5.21) 1	(A5.15) 1	(A5.10) 1, 9	(A5.7) 1	(A5.19) 1	—	—	—

(Continued)

Table 2 (Continued)
Schedule 4 or I—Required Tests[a, b, c]

Product Type	Carbon Steel	Low-Alloy Steel	Stainless Steel	Nickel and Ni-Alloy	Surfacing		Cast Iron	Aluminum and Al-Alloy	Copper and Cu-Alloy	Magnesium and Mg-Alloy	Titanium and Ti-Alloy	Zirconium and Zr-Alloy	Brazing and Braze Welding Filler Metals
Consumable Inserts	(A5.30) 1	(A5.30) 1	(A5.30) 1	(A5.30) 1	—	—	—	—	—	—	—	—	—
Bare Brazing and Braze Welding Filler Metals	—	—	—	—	—	—	—	—	—	—	—	—	(A5.8) 1
Vacuum Grade Brazing Fillers	—	—	—	—	—	—	—	—	—	—	—	—	(A5.8) 1
Brazing Metal Powders	—	—	—	—	—	—	—	—	—	—	—	—	(A5.8) 1, 8

[a] Designations in parentheses refer to the AWS filler metal specification.
[b] Tests called for in this table shall be performed only when they are required by the applicable AWS specification for the particular classification involved. Tests shall be performed in the manner prescribed by the applicable specification. Testing to one current and polarity shall be adequate.
[c] Test Designations are as follows:
1—Chemical analysis
2—Tensile
3—Impact
4—Soundness (x-ray)
5—Moisture test
6—Bend (face, side, or both)
7—Spattering characteristics
8—Sieve analysis
9—Bead-on-plate weld test
[d] Low-hydrogen electrodes only
[e] Test 4—for electrodes, Test 9—for rods

5.5 Schedule 5 or J. Results of all the tests required for classification in the AWS, ISO, or other applicable welding or brazing consumable standard for the specific lot of consumables shall be supplied.

5.6 Schedule 6 or K. In addition to, or in place of, any of the tests called for in the AWS, ISO, or other applicable welding or brazing consumable standard, the purchaser may require other tests (such as testing after a specified heat treatment). In all such cases, the purchaser shall identify on the purchase order the specific tests that are to be conducted, the procedures to be followed, the requirements that shall be met and the results to be reported for the specific lot of consumables.

Annex A (Normative)

Quality Assurance

This annex is part of this standard and includes mandatory elements for use with this standard.

A1. Manufacturer's or Supplier's Quality Assurance System

A1.1 The certification of the product is accomplished through a quality assurance program, by which the manufacturer or supplier verifies that the product meets the requirements of this specification. Such a program includes planning, documentation, surveillance, inspection, testing, and certification of the test results. It also includes control of the inspection and measuring equipment, as well as control of any nonconforming material. It involves auditing of the activities and provides for developing and implementing any corrective action that may become necessary.

A1.2 It is the responsibility of the purchaser to review the quality assurance program of the manufacturer or supplier for conformance to the purchaser's specific requirements.

A1.3 Suppliers who receive electrodes in bulk and package them for distribution, or who repackage under their own label shall as a minimum maintain an adequate control system to ensure that the package contents are traceable to the original manufacturer's records. Additional quality assurance requirements shall be as agreed between the purchaser and the supplier.

A1.4 See AWS A5.02/A5.02M, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*, for packaging information. ISO 544, *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances and markings*, could also be a suitable standard.

A2. 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 a new test assembly or sample. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

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

A3. Supplementary Requirements—Department of Defense

When specified for products used in construction for the United States Department of Defense, one or more of the following clauses may be used in contracts.

A3.1 Alloy Identity. Alloy identity procedures provide type separation through quality checks at all phases of production in the manufacture of filler metals. The test method may include chemical analysis, metal sorting devices, other approved methods, or a combination of methods. When required, alloy identity procedures shall be specified in Procurement Detail

Forms using Item III, "Other Requirements." See Tables B1 through B7 (in Annex B) for Procurement Detail Forms and examples of their use.

A3.1.1 Electrode, Rod, and Core Wire Alloy Identity. Each end of rod, wire, or strip to be spliced during processing shall be tested for alloy identity prior to rewinding, spooling, or straightening and cutting into rods or electrode core wire lengths.

A3.1.2 Single Coil. For continuous process operations where a single rod coil is drawn to finish size, straightened, and cut to length without removal from the machine, both ends of each rod coil shall be alloy identity tested immediately prior to the start of the continuous processing operation.

A3.1.3 Multiple Coils. When multiple coils are to be spliced during continuous processing operations, each end of each coil to be spliced shall be alloy identity tested at the process station just prior to splicing. In addition, the leading end of the first coil and the tail end of the last coil for each continuous process run shall be alloy identity tested.

Annex B (Informative)

Guide to Welding and Brazing Consumables—Procurement of Filler Materials and Fluxes

This annex is not part of this standard but is included for informational purposes only.

B1. Introduction

This guide is appended to the specification as a source of information; it is not mandatory and does not form a part of the specification. Its purpose is to provide descriptive information and examples that will aid in the use of AWS A5.01M/A5.01:2019 (ISO 14344:2010 MOD), *Welding and Brazing Consumables—Procurement of Filler Materials and Fluxes*.

B2. General Information

The general requirements, testing requirements and procedures, method of manufacture, identification, and packaging for filler metals are specified in the filler metal specification and are not intended to be duplicated or modified in this specification, except as the purchaser specifies. The complete list of AWS filler metal specifications including AWS A5.02/A5.02M:2007, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*, is given for reference in the back of this document.

Those specifications, used in conjunction with these Procurement Guidelines, provide a basis for specifying in a procurement document the filler metal requirements in a precise, reproducible, uniform manner.

The Procurement Detail Forms in Tables B.1 through B.5 are suggested forms intended to serve as a check list for detailing filler metal requirements for procurement. They could also serve as a basis for efficient communication between departments within an organization (*e.g.,* communication between welding or production departments and purchasing concerning the specific requirements for filler metal to be procured).

B3. Acceptance

The acceptance of welding or brazing consumables classified under AWS filler metal specifications is in accordance with the tests and requirements of the applicable filler metal specification. Any testing a purchaser requires of the supplier, for filler metal shipped in accordance with a filler metal specification, needs to be clearly stated in the purchase order according to the provisions of this specification. In the absence of any such statement in the purchase order, the supplier may ship the filler metal with whatever testing the supplier normally conducts on filler metal of that classification. Thus, the default for testing schedule is Schedule 1 or F, and the default for Lot Class is S1, T1, C1, or F1, as applicable. Testing in accordance with any other Schedule or classification to any other Lot Class must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

B4. 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 or manufacturer's certification that the product meets all of the requirements of the specification. The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that that material met the requirements of the specification. Representative material, in this case, is 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 A5.01 M/A5.01 (ISO 14344 MOD).

B5. Examples

Examples of the manner in which the Procurement Detail Forms might be used are given in Tables B.6 and B.7.

In Table B.6, the four examples demonstrate the manner in which different packaging, lot classification, supplemental designators, and testing requirements would be specified in a purchase order for 1000 lb of 3/16 in diameter E7018 electrodes. The differences are summarized below.

Example 1. The test and certification requirements specified are those the manufacturer of the electrodes uses as "standard practice" in the conduct of the manufacturer's business (see Table 1 in the body of this specification).

Example 2. Requirements include 10 lb unit packages, a -1 (read as "dash one") supplemental designator, and, for the lot supplied, a certificate showing the results of the chemical analysis, the tensile, impact, and soundness tests, and the moisture content of the covering (for low-hydrogen electrodes, as the filler metal specification requires). (See Tables 1 and 2.) The lot classification, in this case, is the manufacturer's standard lot (see 4.3.1).

Example 3. Requirements include 10 lb unit packages, an H4 supplemental designator, and, for the lot supplied, a certificate showing the results of all tests AWS A5.1 requires for the classification of E7018 electrodes. The definition of the lot classification, in this case, is given in 4.3.3.

Example 4. The requirements here are the same as in Example 3, except that the electrode length is 18 in and the supplemental designator is H4R. The lot classification is as defined in 4.3.2 and the level of testing is that which the purchaser has specified in Item III, Other Requirements. Those tests, in this case, would be the tests required for classification of the electrode, except that the mechanical property tests (strength and toughness) would be conducted on weld metal obtained from the test assembly after the assembly had been given a postweld heat treatment at 650 °C ± 15 °C [1200 °F ± 25 °F] for 12 hours with the heating and cooling rates specified in Item III, Other Requirements.

Examples 5 and 6. Table B.7 demonstrates the use of the Procurement Detail Form for listing the requirements for obtaining straight lengths (rods) and spooled (electrode) aluminum filler metal to filler metal specification AWS A5.10/A5.10M, *Welding Consumables—Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum Alloys—Classification*. Example 5 is for rods and Example 6 is for spooled electrodes. In both cases, the tests to be conducted are those called for in Table 2, as indicated by Schedule 4 or I (see Table 1 for description). The tests for aluminum rods are different from those for aluminum electrodes, but no other requirements are specified in this case.

Table B.1
Suggested Procurement Detail Form for Covered Electrodes

I.	**General**	
	A. Quantity	______________
	B. AWS Specification	______________
	C. AWS Classification	______________
	D. Supplemental Designators, if required	______________
	E. Diameter	______________
	F. Length	______________
	G. Unit Package Type and Weight	
	1. Carton	______________
	2. Can	______________
	3. Other	______________
II.	**Certification and Testing**	
	A. Lot Classification (4.3)	______________
	B. Level of Testing (5.1 through 5.6)	______________
III.	**Other Requirements**	______________

Table B.2
Suggested Procurement Detail Form for Bare Solid Electrodes and Rods

I.	**General**	
	A. Quantity	____________
	B. AWS Specification	____________
	C. AWS Classification	____________
	D. Supplemental Designators, if required	____________
	E. Diameter	____________
	F. Length (for rods)	____________
	G. Unit Package Type and Weight	
	1. Spool	____________
	2. Coil with Support	____________
	3. Coil without Support	____________
	4. Rim (reel)	____________
	5. Drum	____________
	6. Straight Lengths	____________
	7. Other	____________
II.	**Certification and Testing**	
	A. Lot Classification (4.1)	____________
	B. Level of Testing (5.1 through 5.6)	____________
III.	**Other Requirements**	____________

Table B.3
Suggested Procurement Detail Form for Flux Cored and Metal Cored Electrodes and Rods

I. General	
A. Quantity	______________________
B. AWS Specification	______________________
C. AWS Classification	______________________
D. Supplemental Designators, if required	______________________
E. Diameter	______________________
F. Unit Package Type and Weight	______________________
1. Spool	______________________
2. Coil with Support	______________________
3. Coil without Support	______________________
4. Rim (reel)	______________________
5. Drum	______________________
6. Other	______________________
II. Certification and Testing	
A. Lot Classification (4.2)	______________________
B. Level of Testing (5.1 through 5.6)	______________________
III. Other Requirements	______________________

Table B.4
Suggested Procurement Detail form for Submerged Arc Electrodes and Flux and Brazing and Braze Welding Filler Metal

	Electrode or Rod	Flux
I. General		
A. Quantity	________	________
B. AWS Specification	________	________
C. AWS Classification	________	________
D. Supplemental Designators, if required	________	________
E. Diameter	________	________
F. Unit Package Type and Weight		
1. Spool	________	________
2. Coil with Support	________	________
3. Coil without Support	________	________
4. Rim (reel)	________	________
5. Drum	________	________
6. Bag, Box, or Drum (for flux)	________	________
7. Other	________	________
II. Certification and Testing		
A. Lot Classification (4.1 and 4.4)	________	________
B. Level of Testing (5.1 through 5.6)	________	________
III. Other Requirements	________	________

Table B.5
Suggested Procurement Detail Form for Consumable Inserts

I. General	
A. Quantity[a]	________
B. AWS Specification	________
C. AWS Classification	________
D. Shape (Class)	________
E. Style	________
F. Size	________
II. Certification and Testing	
A. Lot Classification (4.1)	________
B. Level of Testing (5.1 through 5.6)	________
III. Other Requirements	________

[a] Number of pieces or meters [feet], according to the style.

Table B.6
Example of Use of the Procurement Detail Form for Covered Electrodes

	Example 1	Example 2	Example 3	Example 4
I. General				
A. Quality	1000 lbs	1000 lbs	1000 lbs	1000 lbs
B. AWS Specification	A5.1	A5.1	A5.1	A5.1
C. AWS Classification	E7018	E7018	E7018	E7018
D. Supplemental Designators		-1	H4	H4R
E. Diameter	3/16 in	3/16 in	3/16 in	3/16 in
F. Length	14 in	14 in	14 in	18 in
G. Unit Package Type and Weight				
1. Carton	50 lb			
2. Can		10 lb	10 lb	10 lb
3. Other				
II. Certification and Testing				
A. Lot Classification	C1	C1	C3	C2
B. Level of Testing	Schedule 1 or F	Schedule 4 or I	Schedule 5 or J	Schedule 6 or K
III. Other Requirements (Example No. 4 Only)	The lots of electrodes that are shipped must meet all classification test requirements of the specification. The strength and toughness of the weld metal must meet specification requirements after a postweld heat treatment at 1200 °F ± 25 °F for 12 hours. The heating and cooling rates above 600 °F shall not exceed 200 °F/hour.			

Table B.7
Example of Use of the Procurement Detail Form for Bare Solid Aluminum Electrodes and Rods

	Example 5	Example 6
I. General		
A. Quality	400 lbs	1000 lbs
B. AWS Specification	A5.10	A5.10
C. AWS Classification	R4043	ER4043
D. Diameter	3/32 in	3/64 in
E. Length	36 in	—
F. Unit Package Type and Weight		
1. Spool	—	4 in, 1 lb
2. Coil with Support	—	—
3. Coil without Support	—	—
4. Rim (reel)	—	—
5. Drum	—	—
6. Straight	5 lbs	—
II. Certification and Testing		
A. Lot Classification	Class S2	Class S2
B. Level of Testing	Schedule 4 or I	Schedule 4 or I
III. Other Requirements	None	None

Annex C (Informative)

Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard but is included for informational purposes only.

C1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

C2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. 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.

C3. General Procedure for all Requests

C3.1 Submission. All requests shall be sent to the Managing Director, AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

C3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

C3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1/D1.1M:2012) that contains the provision(s) the inquirer is addressing.

C3.4 Question(s). All requests shall be stated in the form of a question that can be answered 'yes' or 'no'. The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

C3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

C3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

C4. AWS Policy on Interpretations

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 official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

C5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the *Welding Journal*, and post it on the AWS website.

C6. 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.

Annex D (Informative)
List of Deviations from ISO 14344:2010

This annex is not part of this standard but is included for informational purposes only.

Global change: Revised organization and wording of document for simplicity and clarity. "Identification" section was removed and added to "Terms and Definitions" or "Lot Classification" sections as necessary. Various forms of fully metallic welding consumables were consolidated with no substantive changes in lot classifications and testing schedules. Removed 24 hour restriction from Lot Class C3 for consistency with other lot classifications. Defined the term "Production Schedule." Changed wording in several places from "for each lot shipped" to "for each lot supplied." *Added inspection document types and clarification of 24-hour limits*.

Added subclause 1.2.

Added Normative Annex A—*Quality Assurance*.

Added Informative Annex B—*Guide to Welding Consumables—Procurement of Filler Materials and Fluxes*.

Added Informative Annex C—*Requesting an Official Interpretation on an AWS Standard*.

Added Informative Annex D—*List of Deviations from ISO 14344:2010*.

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, A5.35	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, A5.35	A5.9, A5.22	A5.22	A5.9, A5.22, A5.39	A5.9, A5.22, A5.39	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11, A5.35	A5.14, A5.34	A5.34	A5.14, A5.34, A5.39	A5.14, A5.34, A5.39		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	

AWS Filler Metal Specifications and Related Documents

Designation	Title
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*
A4.5M/A4.5 (ISO 15792-3 MOD)	*Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*
A5.01M/A5.01 (ISO 14344 MOD)	*Welding and Brazing Consumables—Procurement of Filler Materials and Fluxes*
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 and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel 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 Electrodes for Shielded Metal Arc Welding*
A5.7/A5.7M	*Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*
A5.8M/A5.8	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M (ISO 14343 MOD)	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M (ISO 18273 MOD)	*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 (ISO 24034 MOD)	*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 and High Manganese 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*
A5.31M/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 Flux Cored and Metal Cored Welding Electrodes*
A5.35/A5.35M-AMD1	*Specification for Covered Electrodes for Underwater Wet Shielded Metal Arc Welding*
A5.39/A5.39M	*Specification for Flux and Electrode Classifications for Submerged Arc and Electroslag Joining and Surfacing of Stainless Steel and Nickel Alloys*

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SPECIFICATION FOR FILLER METAL STANDARD SIZES, PACKAGING, AND PHYSICAL ATTRIBUTES

SFA-5.02/SFA-5.02M

(25)

(Identical with AWS Specification A5.02/A5.02M:2025. In case of dispute, the original AWS text applies.)

Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes

1. Scope

1.1 This specification prescribes requirements for standard sizes and packages of welding filler metals and their physical attributes, such as product appearance and identification. *This specification does not apply to filler materials for brazing or braze welding or tungsten and oxide-dispersed tungsten electrodes.*

1.2 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. The specification with the designation A5.02 uses U.S. Customary Units. The specification A5.02M 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 sizing of filler metal or packaging.

1.3 Safety. Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

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

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. Unless otherwise defined in this document, welding terms are as defined in AWS A3.0M/A3.0. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to or revisions of any of these publications do not apply.

American Welding Society:

AWS A3.0/A3.0M, Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying

American National Standards Institute (ANSI) document:

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

ASTM International (ASTM) document:

ASTM E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

International Organization for Standardization (ISO) document:

ISO 544 *Welding consumables — Technical Delivery Conditions for Welding Filler Materials — Type of Product, Dimensions, Tolerances and Markings.*

ISO 80000-1:2022, Quantities and units — Part 1: General.

3. *Rounding Procedure*

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in B.3 of ISO 80000-1 (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. If an average value is to be compared to the specified limit, rounding shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting values for that quantity. The rounded results shall fulfill the requirements.

4. Covered Electrodes

***4*.1 Standard Sizes and Lengths.** Standard sizes (diameter of the core wire) and lengths of electrodes are shown in Table 1.

***4*.1.1** The diameter of the core wire shall not vary more than ± 0.002 in *if measured in U.S. Customary units or more than* ± 0.05 mm *if measured in SI units* from the diameter specified.

4.1.2 The length shall not vary more than ± 1/4 in *if measured in U.S. Customary units or more than* ± 10 mm *if measured in SI units* from that specified.

***4*.2 Core Wire and Covering.** The core wire and covering shall be free of defects that would interfere with the uniform deposition of the electrode. The core and covering shall be concentric to the extent that the maximum core-plus-one-covering dimension shall not exceed the minimum core-plus-one-covering dimension by more than:

(1) 7% of the mean dimension in sizes of 3/32 in [2.5 mm] and smaller

(2) 5% of the mean dimension in sizes larger than 3/32 in [2.5 mm] and smaller than 3/16 in [5 mm]

(3) 4% of the mean dimension in sizes 3/16 in [5 mm] and larger.

Concentricity may be measured by any suitable means.

***4*.3 Exposed Core**

***4*.3.1** The grip end of each electrode shall be bare (free of covering) for a distance of not less than 1/2 in [12 mm] nor more than 1-1/4 in [30 mm] for electrodes 5/32 in [4.0 mm] and smaller, and not less than 3/4 in [20 mm] nor more than 1-1/2 in [40 mm] for electrodes 3/16 in [5 mm] and larger, to provide for electrical contact with the electrode holder.

***4*.3.2** The arc end of each electrode shall be sufficiently conductive, and the covering sufficiently tapered, to permit easy striking of the arc. The length of the conductive portion (measured from the end of the core wire to the location where the full cross section of the covering is obtained) shall not exceed 1/8 in [3 mm] or the diameter of the core wire, whichever is less. Electrodes with chipped coverings near the arc end, baring the core wire no more than the lesser of 1/4 in [6 mm] or twice the diameter of the core wire, meet the requirements of this specification provided no chip uncovers more than 50% of the circumference of the core.

***4*.4 Electrode Identification.** All electrodes shall be identified as follows:

4.4.1 At least one imprint of the electrode designation (classification plus any optional designators) shall be applied to the electrode covering starting within 2-1/2 in [65 mm] of the grip end of the electrode. The prefix letter E in the classification may be omitted from the imprint.

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

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

4.4.4 When an electrode is classified as meeting the requirements of A5.X and A5.XM, both electrode designations shall be applied.

4.4.5 If allowed by the specific A5 specification *or by agreement between the supplier and the purchaser*, in lieu of imprinting, electrodes may be identified by:

(1) Attaching securely to the bare grip end of each electrode a tag bearing the classification number, or

(2) Embossing the classification number on the bare grip end of each electrode. In this case a slight flattening of the grip end will be permitted in the area of the embossing.

4.5 Packaging

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

4.5.2 Standard package *types and* weights shall be as agreed upon between purchaser and supplier.

4.5.3 Hermetically Sealed Containers. When specified for protection against atmospheric moisture during shipment and storage, electrodes shall be packaged in one of the following manners.

4.5.3.1 Rigid Metal Package. The container may be of either steel or aluminum. Each steel container shall have its sides lock-seamed and soldered or seam welded and the top and bottom mechanically seamed containing a suitable organic sealant. Aluminum containers shall be tubes formed in two sections, one flared slightly for a friction fit and the closure seam shall be sealed with a suitable pressure sensitive tape. Metal containers after loading at ambient pressure and sealing shall be capable of passing a leak test.

4.5.3.2 Vacuum *Foil* Package. High density plastic pouches laminated with a suitable metal foil vapor barrier shall be heat sealed after filling and evacuating. The pouches shall be overpacked with an outer container to protect them from damage that *may* cause loss of vacuum. Packages which *allow* the contents to be loose within the pouch do not meet the requirements of this specification.

4.5.3.3 Other Package Construction. As agreed upon between purchaser and supplier, alternate packaging for protection of electrode coverings from absorption of moisture in excess of that specified by the classification shall be demonstrated by suitable tests, such as those described *below.*

4.5.4 Leak Testing for Hermetically Sealed Containers. *Unit containers shall be immersed in water that is at a temperature of at least 50 °F [18 °C] above that of the packaged material (room temperature). The container shall be immersed so that the surface under observation is 1 in [25 mm] below the water surface and the greatest basic dimension of the container is parallel to the surface of the water. A leaker is indicated by a steady stream of bubbles emanating from the container. A container with a stream that lasts for 30 s or more does not meet the requirements of this specification.*

4.6 Marking of Packages

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

(1) AWS specification and classification designations along with applicable optional designators (year of issue may be excluded)

(2) Supplier's name and trade designation

(3) Size and net weight

(4) Lot, control, or heat number

4.6.2 The appropriate precautionary information or its equivalent, as given in ANSI Z49.1, (as a minimum) shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package. Typical examples of "warning labels" and precautionary information are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

4.6.3 *Product packaging may have applicable national or local labeling requirements, such as those specified under the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200 2012 [GHS].*

5. Bare Solid and Tubular Electrodes and Rods

*5.*1 Standard Sizes and Shapes

***5.*1.1** Standard sizes of filler metal (except strip electrodes) and straight lengths of rods and their tolerances are shown in Table 2 *and Table 2M. Table 2 provides requirements for products labeled with U.S. Customary Units (inches). Table 2M provides requirements labeled with SI Units (millimeters). For products labeled with both U.S. Customary and SI Units, compliance with both tables is required.*

***5.*1.2** Standard sizes for strip electrodes in coils are shown in Table 3 (*strip electrodes are predominantly sold only in SI Unit dimensions).*

*5.*2 Finish and Uniformity

***5.*2.1** All filler metal shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams, laps (exclusive of a longitudinal joint in flux cored or metal cored filler metal), and foreign matter that would adversely affect the welding characteristics or the properties of the weld metal.

***5.*2.2** Each continuous length of filler metal shall be from a single heat or lot of material, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the filler metal on automatic and semiautomatic equipment.

***5.*2.3** The core ingredients in flux cored and metal cored filler metal shall be distributed with sufficient uniformity throughout the length of the electrode so as not to adversely affect the performance of the electrode or the properties of the weld metal or deposited weld overlay.

***5.*2.4** A suitable protective coating may be applied to any filler metal. *Protective coatings may be* specifically restricted *or limited* by the filler metal specification *or a specific classification within a* filler metal specification.

*5.*3 Packaging

***5.*3.1** Filler metals shall be suitably packaged to protect them from damage during shipment and storage under normal conditions.

***5.*3.2** Standard package forms are straight lengths, coils with support, coils without support, spools, and drums. Standard package dimensions for each form are given in Table 4. Dimensions for standard spools are given in Figures 1A through 1D. Package forms and sizes other than these shall be as agreed upon between purchaser and supplier.

***5.*3.3** The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use, and shall be clean and dry enough to maintain the cleanliness of the filler metal.

***5.*3.4** Spools shall be designed and constructed to prevent distortion of the spool and the filler metal during normal handling and use, and shall be clean and dry enough to maintain the cleanliness of the filler metal.

***5.*3.5** As agreed upon between purchaser and supplier, alternate packaging for protection of filler metals from environmental or other conditions may be specified. This packaging may include, but not be limited to, hermetically sealed packaging as specified in *4*.5.3.

*5.*4 Winding Requirements

***5.*4.1** Filler metal on spools and in coils (including drums) shall be wound so that kinks, waves, *or* sharp bends are not encountered *and* the filler metal *is* free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be identified so it can be located readily and shall be fastened to avoid unwinding.

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

5.5 Filler Metal Identification

5.5.1 Each bare straight length filler rod shall be durably marked with identification traceable to the unique product type of the manufacturer or supplier. Suitable methods of identification *may* include stamping, coining, embossing, imprinting, flag-tagging or color coding. If color-coding is used, the choice of color shall be as agreed upon between the purchaser and supplier, and the color shall be identified on the packaging. When the AWS classification designation is used, the *E*, *R*, *or* ER may be omitted; for example, "308L" for classification "ER308L." Additional identification shall be as agreed upon between purchaser and supplier.

5.5.2 The product information and the precautionary information required in 5.6 for marking each package shall also appear on each coil, spool, and drum.

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

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

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

5.5.6 Drums shall have the information securely affixed in a prominent location on the side of the drum.

5.6 Marking of Packages

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

(1) AWS specification and classification designations along with applicable optional designators (year of issue may be excluded)

(2) Supplier's name and trade designation

(3) Size and net weight or other suitable measure of quantity

(4) Lot, control, or heat number

5.6.2 The appropriate precautionary information *or its equivalent*, as given in ANSI Z49.1 (as a minimum), shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package. Typical examples of "warning labels" and precautionary information are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

5.6.3 *Product packaging may have applicable national or local labeling requirements, such as those specified under the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200 2012 [GHS].*

Table 1
Standard Sizes and Lengths of Covered Electrodes

Standard Size		Standard Length[a,b]	
in	mm	in	mm
1/16[c]	1.6[c]	9	230
5/64[c]	2.0[c]	9 or 12	230 or 300
3/32[c]	2.4[c,d]	9, 12, or 14	230, 300, or 350
—	2.5[c]	—	300 or 350
1/8	3.2	12, 14, or 18	300, 350, or 450
5/32	4.0	14 or 18	350 or 450
3/16	4.8[d]	14 or 18	350 or 450
—	5.0	14 or 18	350 or 450
7/32[c]	5.6[c,d]	14 or 18	350 or 450
—	6.0	14 or 18	350 or 450
1/4[c]	6.4[c]	14 or 18	350 or 450
5/16[c]	8.0[c]	18	450

[a] Lengths other than these shall be as agreed upon between purchaser and supplier.
[b] In all cases, end-gripped electrodes are standard.
[c] These diameters are not standard sizes for all classifications.
[d] These metric sizes are not shown in ISO 544.

Table 2
Standard Sizes and Tolerances of Solid and Tubular Bare Wires[a]

Nominal Diameter (in)	Solid Wire for GMAW or GTAW[b]	Solid Wire for SAW or EGW or ESW	Cast Electrodes or Rods[c]	Tubular Cored Wire for All Processes and All Wire for Hardfacing	Tungsten Carbide (WC) Rods[c]	Copper and Copper-Alloy Electrodes and Rods
0.020	0.019–0.021	—	—	—	—	0.018–0.022
0.025	0.024–0.026	—	—	—	—	—
0.030	0.029–0.031	—	—	0.028–0.032	—	0.028–0.032
0.035	0.034–0.036	—	—	0.033–0.037	—	0.033–0.037
0.045	0.044–0.046	—	—	0.043–0.047	—	0.043–0.047
3/64	0.045–0.049	—	—	0.045–0.049	—	—
0.052	0.050–0.054	—	—	0.050–0.054	—	—
1/16	0.060–0.064	0.060–0.064	—	0.060–0.064	—	0.060–0.064
0.068	0.066–0.070	0.066–0.070	—	0.065–0.071	—	—
0.072	0.070–0.074	0.070–0.074	—	0.069–0.075	—	—
5/64	0.076–0.080	0.076–0.080	—	0.075–0.081	—	0.076–0.080
3/32	0.092–0.096	0.092–0.096	0.074–0.114	0.091–0.097	—	0.092–0.096
7/64	0.106–0.112	0.106–0.112	—	0.106–0.112	—	—
1/8	0.122–0.128	0.122–0.128	0.105–0.145	0.122–0.128	0.062–0.188	0.123–0.127
5/32	—	0.152–0.160	0.136–0.176	0.152–0.160	0.093–0.219	0.154–0.158
3/16	—	0.184–0.192	0.168–0.208	0.184–0.192	0.125–0.251	0.186–0.190
7/32	—	0.215–0.223	—	0.215–0.223	—	—
1/4	—	0.246–0.254	0.220–0.280	0.246–0.254	0.187–0.313	0.248–0.252
5/16	—	0.308–0.316	0.282–0.342	0.308–0.316	0.249–0.375	—
3/8	—	—	—	—	0.312–0.438	—

[a] Dashes indicate a non-standard size. Dimensions, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.
[b] Bare straight lengths shall be 18.0 in (±0.5 in) or 36.0 in (±0.5 in).
[c] Lengths shall be as agreed upon between the manufacturer and the purchaser.

Table 2M
Standard Sizes and Tolerances of Solid and Tubular Bare Wires[a]

Nominal Diameter (mm)	Solid Wire for GMAW or GTAW[b]	Solid Wire for SAW or EGW or ESW	Cast Electrodes or Rods[c,d]	Tubular Cored Wire for All Processes and All Wire for Hardfacing	Tungsten Carbide (WC) Rods[c,d]	Copper and Copper-Alloy Electrodes and Rods
0.5	0.47–0.51	—	—	—	—	0.47–0.51
0.6	0.57–0.61	—	—	—	—	0.57–0.61
0.8	0.76–0.81	—	—	0.75–0.82	—	0.76–0.81
0.9	0.86–0.91	—	—	0.85–0.92	—	0.86–0.91
1.0	0.96–1.01	0.96–1.04	—	0.95–1.02	—	0.96–1.01
1.2	1.16–1.21	1.16–1.24	—	1.15–1.22	—	1.16–1.21
1.4	1.36–1.41	1.36–1.44	—	1.35–1.42	—	1.36–1.41
1.6	1.56–1.61	1.56–1.64	—	1.54–1.62	—	1.56–1.61
1.8	1.76–1.81	1.76–1.84	—	1.74–1.82	—	1.76–1.81
2.0	1.96–2.01	1.96–2.04	—	1.94–2.02	—	1.96–2.01
2.4	2.36–2.41	2.36–2.44	1.89–2.91	2.34–2.42	—	2.36–2.41
2.5	2.46–2.51	2.46–2.54	—	2.44–2.52	—	2.46–2.51
2.8	2.73–2.81	2.76–2.84	—	2.74–2.82	—	2.73–2.81
3.0	2.93–3.01	2.94–3.06	—	2.93–3.02	—	2.93–3.01
3.2	3.13–3.21	3.14–3.26	2.69–3.71	3.13–3.22	1.6–4.8	3.13–3.21
4.0	3.93–4.01	3.94–4.06	3.49–4.51	3.93–4.02	2.4–5.6	3.93–4.01
4.8	—	4.74–4.86	4.29–5.31	4.73–4.82	—	—
5.0	—	4.94–5.06	—	4.92–5.02	3.4–6.6	—
5.6	—	5.54–5.66	—	5.52–5.62	—	—
6.0	—	5.94–6.06	—	5.92–6.02	—	—
6.4	—	6.34–6.46	5.64–7.16	6.32–6.42	4.8–8.0	—
8.0	—	7.94–8.06	7.24–8.76	7.92–8.02	6.4–9.6	—
9.5	—	—	—	—	7.9–11.1	—

[a] Dashes indicate a non-standard size. Dimensions, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.
[b] Bare straight lengths shall be 450 mm (± 12 mm), 500 mm (± 12 mm), 900 mm (± 12 mm), or 1000 mm (± 12 mm).
[c] Lengths shall be as agreed upon between the manufacturer and the purchaser.
[d] These products are not covered in ISO 544.

Table 3
Standard Sizes of Strip Electrodes

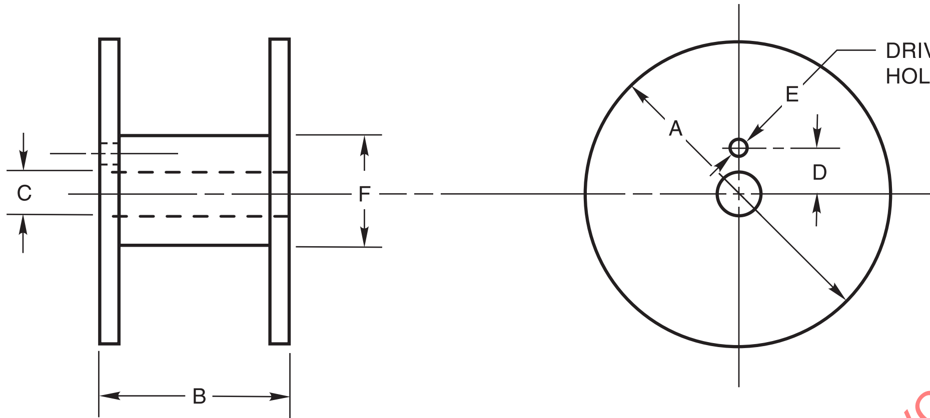
Width, mm	Thickness, mm
30	0.5
60	0.5
90	0.5
120	0.5

Notes:
1. Other sizes shall be as agreed upon between purchaser and supplier.
2. Strip electrodes shall not vary more than ± 0.2 mm in width and more than ± 0.05 mm in thickness.
3. *The edge of the strip electrodes (camber) shall not deviate from a straight line by more than 12 mm in any 2.5 m length.*

Table 4
Standard Packages[a, b]

Type of Package	Width		Inside Diameter		Outside Diameter, Max.	
	in	mm[b]	in	mm[b]	in	mm[b]
Coils with Support	2-1/2 max.	—	12 ± 1/8	—	17	—
	—	64, +0, –15	—	300, +15, –0	—	435
	3 max.	75 max.	6-3/4 ±1/8	170 ±3	12	—
	4-5/8 max.	—	12 ±1/8	—	18	—
	—	100, +10, –5	—	300, +15, –5	—	450
	5 max.	—	24	—	32	—
	—	120, +10, –5	—	600, +20, –0	—	800
Coils without support	As agreed upon between purchaser and supplier					
Spools	See Figures 1A, 1B, and 1C				4	100
					8	200
					12	300
					13.5	340
					14	350
					22	560
					24	610
					30	760
Drums	Not applicable				15.5	400
					20	500
					23	600

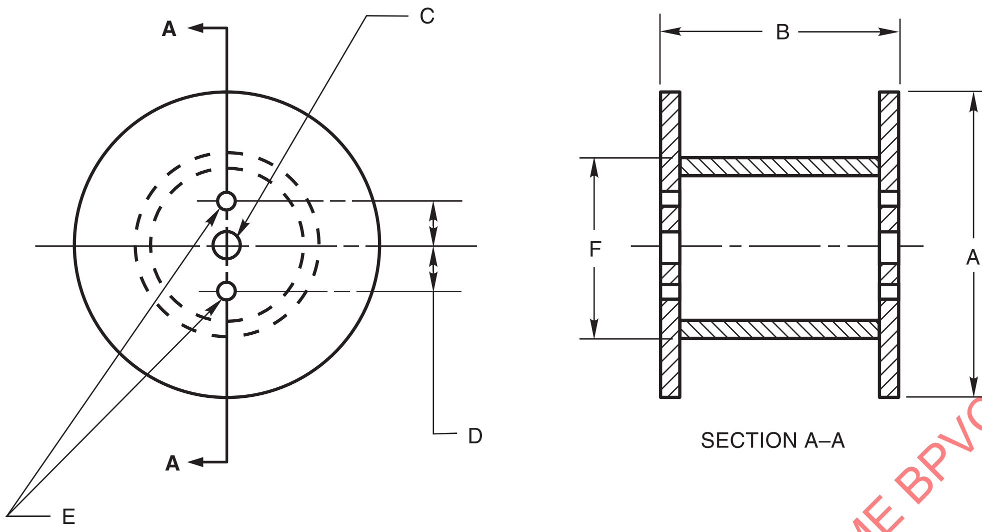
[a] Dimensions, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.
[b] Shaded values in the metric columns are as specified in ISO 544 for coils both with and without supports.



		4 in [100 mm] Spools		8 in [200 mm] Spools		12 in [300 mm] Spools		14 in [350 mm] Spools	
	DIMENSIONS	in	mm	in	mm	in	mm	in	mm
A	Diameter, max. (Note 4)	4.0	102	8.0	203	12	305	14	355
B	Width Tolerance	1.75 ±0.03	45 +0, –2	2.16 ±0.03	55 +0, –3	4.0 ±0.06	103 +0, –3	4.0 ±0.06	103 +0, –3
C	Diameter Tolerance	0.63 +0.01, –0	16.5 +1, –0	2.03 +0.06, –0	50.5 +2.5, –0	2.03 +0.06, –0	50.5 +2.5, –0	2.03 +0.06, –0	50.5 +2.5, –0
D	Distance Between Axes Tolerance	— —	— —	1.75 ±0.02	44.5 ±0.5	1.75 ±0.02	44.5 ±0.5	1.75 ±0.02	44.5 ±0.5
E	Diameter (Note 3) Tolerance	— —	— —	0.44 +0, –0.06	10 +1, –0	0.44 +0, –0.06	10 +1, –0	0.44 +0, –0.06	10 +1, –0

Notes:
1. Outside diameter of barrel, dimension F, shall be such as to permit proper feeding of the electrode.
2. Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside of the diameter of the barrel being less than the inside diameter of the flanges.
3. Holes are provided on each flange, but they need not be aligned. No driving holes required for 4 in [100 mm] spools.
4. Metric dimensions and tolerances conform to ISO 544, except that "A" specifies ± tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

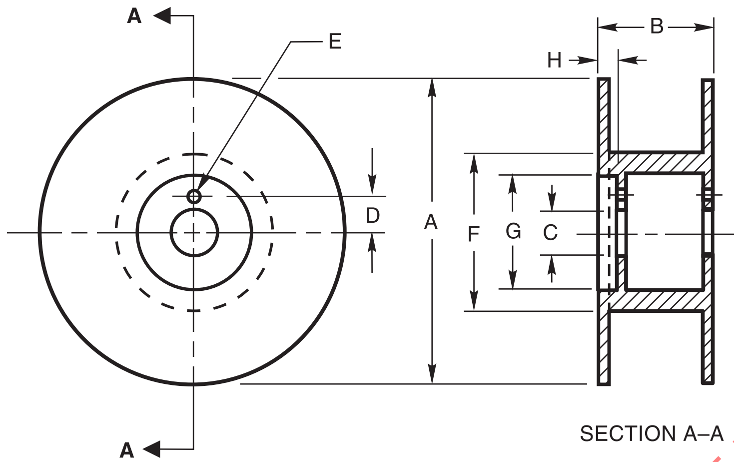
Figure 1A—Dimensions of 4 in, 8 in, 12 in, and 14 in [100 mm, 200 mm, 300 mm, and 350 mm] Spools



		DIMENSIONS					
		22 in [560 mm] Spools		24 in [610 mm] Spools		30 in [760 mm] Spools	
		in	mm	in	mm	in	mm
A	Diameter, max. (Note 4)	22	560	24	610	30	760
B	Width, max.	12	305	13.5	345	13.5	345
C	Diameter Tolerance	1.31 +0.13, –0	35.0 ±1.5	1.31 +0.13, –0	35.0 ±1.5	1.31 +0.13, –0	35.0 ±1.5
D	Distance, Center-to-Center Tolerance	2.5 ±0.1	63.5 ±1.5	2.5 ±0.1	63.5 ±1.5	2.5 ±0.1	63.5 ±1.5
E	Diameter (Note 3) Tolerance	0.69 +0, –0.06	16.7 ±0.7	0.69 +0, –0.06	16.7 ±0.7	0.69 +0, –0.06	16.7 ±0.7

Notes:
1. Outside diameter of barrel, dimension F, shall be such as to permit proper feeding of the electrode.
2. Inside diameter of barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside diameter of the barrel being less than the inside diameter of the flanges.
3. Two holes are provided on each flange and shall be aligned on both flanges with the center hole.
4. Metric dimensions and tolerances conform to ISO 544, except that "A" specifies ± tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

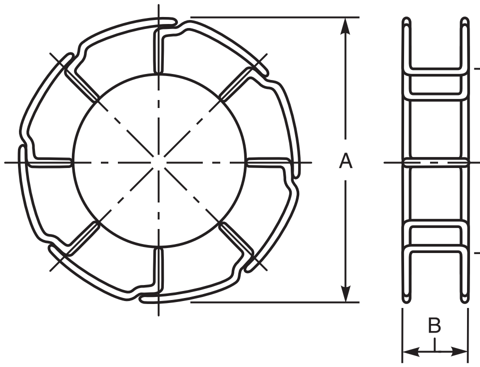
Figure 1B—Dimensions of 22 in, 24 in, and 30 in [560 mm, 610 mm, and 760 mm] Spools (Reels)



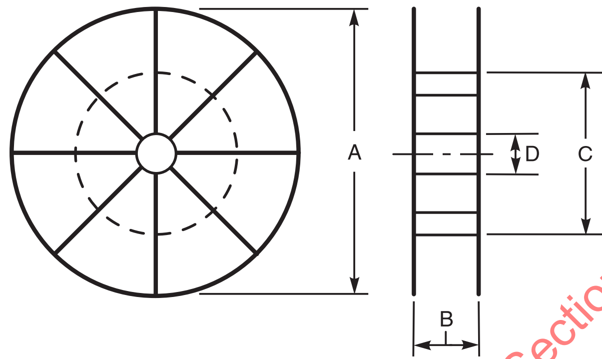
DIMENSIONS			
		in	mm
A	Diameter Tolerance	13.50 +0, –0.06	342 ±2
B	Width Tolerance	5.13 ±0.06	130 ±2
C	Diameter Tolerance	2.03 +0.06, –0	50.5 +2.5, –0
D	Distance Between Axes Tolerance	1.75 ±0.02	44.5 ±0.5
E	Diameter Tolerance	0.44 +0, –0.06	10 +1, –0
F	Diameter Tolerance	7.0 ±0.03	177.5 ±1.0
G	Diameter Tolerance	5.0 ±0.03	127 ±0.8
H	Recess Tolerance	1.13 +0.12, –0	31 ±2

Note: Holes are provided on each flange, but they need not be aligned.

Figure 1C—Dimensions of 13-1/2 in [340 mm] Spools (for Al and Mg Alloys Only)



BASKET RIM (B)



BASKET SPOOL (BS)

DIMENSIONS							
		Basket Rim		Basket Rim		Basket Spool	
		in	mm	in	mm	in	mm
A	Diameter Tolerance	11.7 ±0.1	300 +0, –5	17.7 max.	450 max.	12.0 +0, –0.4	300 ±5
B	Width Tolerance	4.0 ±0.06	103 +0, –3	4 +0.06, –0.18	100 ±3	4.0 ±0.06	103 +0, –3
C	Diameter Tolerance	7.0 +0.2, –0	180 ±2	12.0 +0, –0.4	300 ±5	7.44 ±0.02	189 ±0.5
D	Bore Diameter	—	—	—	—	2.03 +0.06, –0	50.5 +2.5, –0

Figure 1D—Dimensions of Basket Rims and Basket Spools

Annex A (Informative)

Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard but is included for informational purposes only.

A1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

A2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. 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.

A3. General Procedure for all Requests

A3.1 Submission. All requests shall be sent to the Managing Director, AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

A3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

A3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

A3.4 Question(s). All requests shall be stated in the form of a question that can be answered 'yes' or 'no'. The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

A3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

A3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

A4. AWS Policy on Interpretations

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 official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

A5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the *Welding Journal*, and post it on the AWS website.

A6. 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.

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, A5.35	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, A5.35	A5.9, A5.22	A5.22	A5.9, A5.22, A5.39	A5.9, A5.22, A5.39	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11, A5.35	A5.14, A5.34	A5.34	A5.14, A5.34, A5.39	A5.14, A5.34, A5.39		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	

AWS Filler Metal Specifications and Related Documents

Designation	Title
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-ADD1	*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*
A4.5M/A4.5 (ISO 15792-3 MOD)	*Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*
A5.01M/A5.01 (ISO 14344 MOD)	*Welding Consumables—Procurement of Filler Materials and Fluxes*
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 and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel 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 Electrodes for Shielded Metal Arc Welding*
A5.7/A5.7M	*Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*
A5.8M/A5.8	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M (ISO 14343 MOD)	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M (ISO 18273 MOD)	*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 (ISO 24034 MOD)	*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 and High Manganese 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*
A5.31M/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 Flux Cored and Metal Cored Welding Electrodes*
A5.35/A5.35M-AMD1	*Specification for Covered Electrodes for Underwater Wet Shielded Metal Arc Welding*
A5.39/A5.39M	*Specification for Flux and Electrode Combinations for Submerged Arc and Electroslag Joining and Surfacing of Stainless Steel and Nickel Alloys*

SPECIFICATION FOR CARBON STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.1/SFA-5.1M

(25)

(Identical with AWS Specification A5.1/A5.1M:2025. In case of dispute, the original AWS text applies.)

Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel electrodes for shielded metal arc welding of carbon steels.

1.2 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 material properties. The specification designated A5.1 uses U.S. Customary Units. The specification designated A5.1M uses SI Units. The latter units are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under either the A5.1 or the A5.1M specification.

1.3 Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Some safety and health information can be found in Annex A, Clauses A5 and A10.

Safety and health information is available from the following sources:

American Welding Society:

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

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies.

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to or revisions of any of these publications do not apply.

American Welding Society (AWS) documents:

AWS A3.0M/A3.0, Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying

AWS A4.3 ADD1, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

AWS A4.4M, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coatings*

AWS A4.5M/A4.5, Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld

AWS A5.01M/A5.01, *Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes*

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

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

American National Standards Institute (ANSI) document:

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

ASTM International (ASTM) document*s*:

ASTM A29/A29M, Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought

ASTM A36/A36M, Standard Specification for Carbon Structural Steel

ASTM A131/A131M, Standard Specification for Structural Steel for Ships

ASTM A283/A283M, Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates

ASTM A285/A285M, Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength

ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

ASTM E350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*

ASTM E2033, Standard Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)

ASTM E2698, Standard Practice for Radiographic Examination Using Digital Detector Arrays

International Organization for Standardization (ISO) document:

ISO 80000-1, Quantities and units — Part 1: General.

3. Classification

3.1 The welding electrodes covered by the A5.1 and A5.1M specifications utilize a classification system (shown in Figure 1) based upon U.S. Customary Units and the International System of Units (SI), respectively, and are classified according to:

(1) Type of current (Table 1)

(2) Type of covering (Table 1)

(3) Welding position (Table 1)

(4) Mechanical properties of the weld metal in the as-welded condition (Tables 4 and 5)

3.2 Electrodes classified under one classification shall not be classified under any other classification in this specification, except as herein noted. *Electrodes classified as E60-G [E43-G] or E70-G [E49-G] may also be classified as any other classification provided that the electrode meets all of the requirements of both classifications.* E7018M [E4918M] electrodes may also be classified as E7018 [E4918] provided that the electrode meets all of the requirements of both classifications.

3.3 Electrodes may be classified under A5.1 using U.S. Customary Units or under A5.1M using the International System of Units (SI), or they may be classified under both systems. Electrodes classified under either classification system must meet all requirements for classification under that system. The classification system is shown in Figure 1.

4. Acceptance

Acceptance of the welding electrodes shall be in accordance with the provisions of AWS A5.01M/A5.01. See A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01M/A5.01.

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. See A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

6. Rounding Procedure

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in Clause B.3 of ISO 80000-1 (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. If an average value is to be compared to the specified limit, rounding 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 and yield strength for A5.1, to the nearest 10 MPa for tensile and yield strength for A5.1M, and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities.

7. Summary of Tests

The tests required for each classification are specified in Table 2. The purpose of these tests is to determine the chemical composition, mechanical properties, soundness of the weld metal, the usability of the electrode, and the moisture content of the low-hydrogen electrode covering. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 16. The supplemental tests for absorbed moisture (see Clause 17) and for diffusible hydrogen (see Clause 18) are not required for classification of electrodes (see Note h of Table 2).

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or sample or from a new test assembly or sample. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

In the event that, during preparation or after completion of any test, it is clearly determined that specified or proper procedures were not followed in preparing the weld test assembly 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 One or more of the following weld test assemblies are required for classification testing. They are:

(1) The weld pad in Figure *2* for chemical analysis of the weld metal.

(2) The groove weld in Figure *3* for mechanical properties and soundness of the weld metal for all classifications except E6022 [E4322] and E7018M [E4918M].

(3) The fillet weld in Figure *4* for the usability of the electrode.

(4) The groove weld in Figure *6* for transverse tensile and longitudinal bend tests for welds made with the E6022 [E4322] single pass electrode.

(5) The groove weld in Figure 5 *to be used in place of (2) above*, for mechanical properties and soundness of the weld metal for E7018M [E4918M] electrodes.

The sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) along the weld centerline of the weld metal in the groove weld in Figure *3* or Figure 5, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

9.2 Preparation of each weld test assembly shall be as specified in 9.3 through 9.5. The base metal for each assembly shall be as required in Table 7 and shall meet the requirements of the ASTM specification shown there or a chemically equivalent specification. Electrodes other than low-hydrogen electrodes shall be tested without conditioning. Low-hydrogen electrodes, if they have not been adequately protected against moisture pickup in storage, shall be held at a temperature within the range 500 °F to 800 °F [260 °C to 430 °C] for a minimum of one hour prior to testing. Testing of assemblies shall be as prescribed in Clauses 10 through 15.

9.3 Weld Pad. A weld pad shall be prepared as specified in Figure 2, except when one of the alternatives in 9.1 (taking the sample from the broken tension test specimen or from a corresponding location or any location above it along the weld centerline in the weld metal of the groove weld in Figure *3* or Figure 5) is selected. Base metal of any convenient size, of the type specified in Table *7* shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is to be deposited shall be clean. The pad shall be welded in the flat position with multiple layers, to obtain undiluted weld metal.

The preheat temperature shall not be less than 60 °F [15 °C] and the interpass temperature shall not exceed 300 °F [150 °C]. The slag shall be removed after each pass. The pad may be quenched in water between passes, *but must be dry before the start of the next pass*. The dimensions of the completed pad shall be as shown in Figure *2*. Testing of this assembly shall be as specified in Clause 10, Chemical Analysis.

9.4 Groove Weld

9.4.1 Mechanical Properties and Soundness. A test assembly shall be prepared and welded as specified in Figure *3* or Figure 5, using base metal of the appropriate type specified in Table *7*. *Welding shall use each type of current and position as specified in Table 2.*

Prior to welding, the assembly may be preset to yield a welded joint 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 within 5 degrees of plane. A completed welded test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assembly is prohibited.

Preheat and interpass temperatures shall be as specified in Figure 3 or 5. Testing of this assembly shall be as specified in Clauses 11, 12, and 14. The assembly shall be tested in the as-welded condition.

9.4.2 Transverse Tension and Longitudinal Bend Tests. A test assembly shall be prepared and welded as specified in Figure *6* using base metal of the appropriate type specified in Table *7*. Testing of this assembly shall be as specified in 12.5 and Clause 13. The assembly shall be tested in the as-welded condition.

9.5 Fillet Weld. *One or more* test assemblies shall be prepared and welded as specified in Table *8* and shown in Figure *4* using base metal of the appropriate type as specified in Table *7*. The welding positions shall be as specified in Table *8* and *Figure 7*, according to the size and classification of the electrode. Testing of the assembly shall be as specified in *AWS A4.5M/A4.5*.

10. Chemical Analysis

10.1 The sample for analysis shall be taken from weld metal produced with the electrode. The sample shall be taken from a weld pad or the reduced section of the fractured tension test specimen (Figure 3 or 5) or from a corresponding location *or any location along the weld centerline above it of the* groove weld in Figure *3* or 5. Areas where arc starts or craters exist shall be avoided.

The top surface of the pad described in 9.3 and shown in Figure *2* shall be removed and discarded and a sample for analysis shall be obtained from the underlying metal of this same top layer by any means *that will not affect the chemical composition*. The sample shall be free of slag and shall be taken from metal that is at least 1/4 in [6 mm] from the original base metal surface *as specified in Figure 2*.

The sample from the reduced section of the fractured tension test specimen or from a corresponding location (or any location along the weld centerline above it) in the groove weld in Figure *3* or 5 shall be prepared for analysis by any suitable means *that will not affect the chemical composition*.

10.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E350.

10.3 The results of the analysis shall meet the requirements of Table *6* for the classification of electrode under test.

11. Radiographic Test

11.1 When required in Table *2*, the groove weld described in 9.4.1 and shown in Figure *3* or 5 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 reasonably 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] below the original base metal surface, in order to facilitate backing and/or 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 one of the following*. The quality level of inspection shall be 2-2T.

(1) Film Radiology: ASTM E1032.

(2) Computed Radiology (CR): ASTM E2033 and the requirements of ASTM E1032, except where CR differs from film. The term film, as used within ASTM E1032, applicable to performing radiography in accordance with ASTM E2033, refers to phosphor imaging plate.

(3) Digital Radiology (DR): ASTM E2698 and the requirements of ASTM E1032, except where DR differs from film. The term film, as used within ASTM E1032, applicable to performing radiography in accordance with ASTM E2698, refers to digital detector array (DDA).

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, and

(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 *8A (Grade 1), Figure 8B (Grade 2), or Figure 8C (Grade 3)*, according to the grade specified in Table *3*.

In evaluating the radiograph, one inch [25 mm] of the weld on each end of the test assembly shall be disregarded.

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

The indication may be of porosity or slag. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications larger than the large indications permitted in the radiographic standards do not meet the requirements of this specification.

12. Tension Test

12.1 For all electrodes except E6022 [E4322], one all-weld-metal tension test specimen as specified in the Tension Test clause of AWS B4.0 shall be machined from the groove weld described in Clause 9 and shown in Figure *3* or *5*. For specimens machined from 3/4 in [20 mm] or thicker weld assemblies, the all-weld-metal tension test specimen shall have a nominal diameter of 0.500 in [12.5 mm]. *For specimens machined from 1/2 in [12.5 mm] thick weld assemblies, the all-weld-metal tension test specimen shall have a nominal diameter of 0.250 in [6.5 mm]. The nominal gauge length-to-diameter ratio shall be 4:1 in each case*.

12.2 After machining, but before testing, the specimen for all electrodes except the low hydrogen classifications may be aged at a temperature not to exceed 220 °F [105 °C] for up to 48 hours, then allowed to cool to room temperature. Refer to Annex A, A6.3 for a discussion on the purpose of aging. *In case of dispute, aging the tensile specimen shall be the referee method. No aging shall be performed prior to radiographic examination. The purchaser may, by mutual agreement with the supplier, have the thermal aging of specimens prohibited for all mechanical testing done to Schedule I or J of AWS A5.01M/A5.01*.

12.3 The tension test specimens shall be tested in the manner described in the Tension Test clause of AWS B4.0.

12.4 The results of the tension test shall meet the requirements specified in Table *4*.

12.5 For E6022 [E4322], one transverse rectangular tension test specimen as specified in the Tension Test clause of AWS B4.0, shall be machined from the test assembly described in 9.4.2 and shown in Figure *6*. The transverse rectangular tensile specimen shall be a full-thickness specimen machined transverse to the weld with a nominal reduced section width of 1.50 in [38 mm].

13. Bend Test

13.1 One longitudinal face bend specimen, as required in Table 2, shall be machined from the groove weld test assembly described in 9.4.2 and shown in Figure *6*. The nominal length of the specimen shall be 6 in [150 mm], the nominal width of the specimen shall be 1.50 in [38 mm], and the nominal thickness shall be 0.25 in [6mm]. Other dimensions shall be as specified in the Bend Test clause of AWS B4.0.

13.2 After machining, but before testing, the specimen may be aged at a temperature not to exceed 220 °F [105 °C] for up to 48 hours, then allowed to cool to room temperature. Refer to Annex A, A6.3 for a discussion on the purpose of aging.

13.3 The specimen shall be tested in the manner described in the Bend Test clause of AWS B4.0, by bending it uniformly through 180° over a 3/4in [19 mm] radius in any suitable jig, as specified in AWS B4.0. Positioning of the face bend specimen shall be such that the weld face of the last side welded shall be in tension.

13.4 Each specimen, after bending, shall conform to the 3/4 in [19 mm] radius, with an appropriate allowance for spring-back, and the weld metal shall not contain openings in excess of 1/8 in [3 mm] on the convex surface.

14. Impact Test

14.1 Five full-size Charpy V-notch impact test specimens shall be machined from the test assembly shown in Figure *3* or 5, for those classifications for which impact testing is required in Table *2*. The Charpy V-notch specimens shall have the notched and struck surfaces 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 machined 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 *10X* magnification. The correct location of the notch shall be verified by etching before or after machining.

14.2 The five specimens shall be tested in accordance with the Fracture Toughness Test clause of AWS B4.0. The test temperature shall be at or below the temperature specified in Table *5*, for the classification under test. The actual temperature used shall be listed on the certification documentation when issued.

14.3 In evaluating the results *for all except E7018M [E4918M]*, 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 the single value indicated in Table 5*, and the average of the three shall be not less than the required *average* energy level.

14.4 In evaluating the results for E7018M [E4918M], all five impact values shall be included. At least four of the five shall equal, or exceed, the specified 50 ft·lbf [67 J] energy level. One of the five may be lower than that, but not lower than 40 ft·lbf [54 J]. The average of the five results shall be not less than the required 50 ft·lbf [67 J] energy level.

15. Fillet Weld Test

15.1 The fillet weld test assembly, when required in Table *2*, shall be made in accordance with the requirements of 9.5, and Figure *4 and AWS A4.5M/A4.5. There shall be no indication of cracks and the weld shall be reasonably free of undercut, overlap, trapped slag, and surface porosity. After the visual examination, the fillet weld size, leg lengths and convexity shall be measured using the methods of AWS A4.5M/A4.5. Fillet weld measurements shall meet the requirements of Table 8, and Table 9 for convexity and permissible difference in the length of the legs.*

15.2 *A minimum of 10 in [250 mm] of the test assembly shall be broken longitudinally through the fillet weld by a force exerted as shown in AWS A4.5M/A4.5. Cutting of the test assembly into two or more lengths before fracture is permitted, but a sufficient number of segments shall be fractured such that a minimum of 10 in [250 mm] is examined. When necessary, to facilitate fracture through the fillet, one or more of the procedures listed in AWS A4.5M/A4.5 may be used.*

Tests in which the weld metal pulls out of the base metal during bending are invalid. Specimens in which this occurs shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of the specimens required for retest in Clause 8 does not apply.

15.3 The fractured surfaces shall be examined. They shall be free of cracks *and shall be reasonably free of porosity and trapped slag*. Incomplete fusion at the root of the weld shall not exceed 20% of the total length of the weld. *Slag beyond the root of the joint shall not be considered incomplete fusion.* There shall be no continuous length of incomplete fusion greater than one inch [25 mm] as measured along the weld axis, except for electrodes of E6012 [E4312], E6013 [E4313], and E7014 [E4914] classifications. Fillet welds made with electrodes of these classifications may exhibit incomplete *fusion at the root* through the entire weld length. They may also exhibit incomplete fusion *at the weld face*, which shall at no point exceed 25% of the smaller leg of the fillet weld.

16. Moisture Test

16.1 The moisture content of the covering of the electrode, when required in Table *2*, shall be determined by any suitable method. In case of dispute, the method described in AWS A4.4M shall be the referee method.

16.2 The electrodes shall be tested without conditioning, unless the manufacturer recommends otherwise. *Conditioning can be considered to be any special preparation or procedure, such as baking the electrode.* If the electrodes are conditioned, that fact, along with the method used for conditioning and the time and temperature involved in the conditioning, shall be noted on the *Certificate of Conformance*. The moisture content shall not exceed the limit specified in Table 10, for the classification under test.

17. Absorbed Moisture Test

17.1 In order for a low-hydrogen electrode to be designated as low-moisture-absorbing, with the optional supplemental "R" suffix designator, or classified as E7018M [E4918M], sufficient electrodes shall be exposed to an environment of 80 °F [27 °C] and 80 percent relative humidity (RH) for a period of not less than nine hours by any suitable method. In case of dispute, the exposure method described in 17.2 through 17.6 shall be the referee method.

The moisture content of the electrode covering on the low-moisture-absorbing, low-hydrogen electrodes (for example, E7015R [E4915R], E7016R [E4916R], E7016-1R [E4916-1R], E7018R [E4918R], E7018-1R [E4918-1R], E7018M [E4918M], E7028R [E4928R], E7048R [E4948R]) shall be determined by any suitable method. In case of dispute, the method described in AWS Specification A4.4M shall be the referee method. The moisture content of the exposed covering shall not exceed the maximum specified moisture content for the designated electrode and classification in Table 10.

17.2 An electrode sample of each size of E7018M [E4918M] or the smallest and the largest sizes of "R" designated electrode shall be exposed. If the electrodes are conditioned prior to exposure, that fact, along with the method used for conditioning, and the time and temperature involved in conditioning, shall be noted on the certificate of conformance. Conditioning of electrodes after exposure is not permitted.

17.3 The electrode sample shall be exposed in a suitably calibrated and controlled environmental chamber for a minimum of nine hours at 80 °F to 85 °F, [27 °C to 30 °C] and 80% to 85% relative humidity.

17.4 The environmental chamber shall meet the following design requirements:

(1) The apparatus shall be an insulated humidifier which produces the temperature of adiabatic saturation through regenerative evaporation or vaporization of water.

(2) The apparatus shall have an average air speed of 100 fpm to 325 fpm [0.5 m/s to 1.7 m/s] within the envelope of air surrounding the covered electrode.

(3) The apparatus shall have a drip-free area where the covered electrode up to 18 in [450 mm] in length can be positioned with length as perpendicular as practical to the general air flow.

(4) The apparatus shall have a calibrated means of continuously measuring and recording the dry bulb temperature and either the wet bulb temperature or the differential between the dry bulb and wet bulb temperature over the period of time required.

(5) The apparatus shall have an air speed of at least 900 fpm [4.5 m/s] over the wet bulb sensor unless the wet bulb sensor can be shown to be insensitive to air speed or has a known correction factor that will provide for an adjusted wet bulb reading equal to the temperature of adiabatic saturation.

(6) The apparatus shall have the wet bulb sensor located on the suction side of the fan so that there is an absence of heat radiation on the sensor.

17.5 The exposure procedure shall be as follows:

(1) The electrode sample, in previously unopened packages or from a reconditioned lot shall be brought to a temperature, –0 °F, +10 °F [*–0 °C,* +6 °C] above the dew point *of the chamber at the time of loading*.

(2) The electrode sample shall be loaded into the chamber without delay after the packages are opened. *Or, in the case of a reconditioned lot, the sample shall be loaded without delay once conditioning is complete and the sample reaches the temperature prescribed in 17.5 (1).*

(3) The electrodes shall be placed in the chamber in a vertical or horizontal position on 1 in [25 mm] centers, with the length of the electrode as perpendicular as practical to the general air flow.

(4) Time, temperature, and humidity shall be continuously recorded for the period that the electrodes are in the chamber.

(5) Counting of the exposure time shall start when the required temperature and humidity in the chamber are established.

(6) At the end of the exposure time, the electrodes shall be removed from the chamber and a sample of the electrode covering taken for moisture determination, as specified in Clause 16, Moisture Test.

17.6 The manufacturer shall control other test variables *which are not defined, but which must be controlled* to ensure a greater consistency of results.

18. Diffusible Hydrogen Test

18.1 The smallest and largest sizes of an electrode to be identified by an optional supplemental diffusible hydrogen designator and all sizes of E7018M [E4918M], shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results that satisfy the requirements of Table 11, the appropriate diffusible hydrogen designator may be added at the end of the classification.

18.2 Testing shall be done without conditioning of the electrode, unless the manufacturer recommends otherwise. *Conditioning can be considered to be any special preparation or procedure, such as baking the electrode.* If the electrodes are conditioned, that fact, along with the method used for conditioning, and the time and temperature involved in the conditioning shall be noted on the *Certificate of Conformance*.

18.3 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. See A8.1.4 in Annex A. The actual atmospheric conditions shall be reported along with the average value for the tests, according to AWS A4.3.

18.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assemblies, 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. If the actual test results for an electrode meet the requirements for the lower or lowest hydrogen designator, as specified in Table 11, the electrode also meets the requirements for all higher hydrogen designators in Table 11 without need to retest.

19. Method of Manufacture

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

20. Standard Sizes and Lengths

Standard sizes (diameter of the core wire) and lengths of electrodes *and their respective tolerances are as specified in AWS A5.02/A5.02M*.

21. Core Wire and Covering

Requirements for the core wire and covering, including concentricity requirements, are as specified in AWS A5.02/A5.02M.

22. Exposed Core

22.1 *Requirements for the grip end of each electrode are as specified in AWS A5.02/A5.02M.*

22.2 *Requirements for the arc end of each electrode are as specified in AWS A5.02/A5.02M.*

23. Electrode Identification

23.1 *All electrodes shall be identified (imprinted) as specified in AWS A5.02/A5.02M.*

23.2 *In lieu of imprinting, electrodes may be identified by the alternate methods specified in AWS A5.02/A5.02M.*

23.3 *In the case of electrodes that have two classifications, in accordance with 3.2 or 3.3, whether the method of identification in 23.1 or 23.2 is chosen, it is at the manufacturer's discretion to identify electrodes with either of the classifications or both of the classifications. Purchaser can specify a preference for identification using AWS A5.01M/A5.01.*

24. Packaging

Electrodes shall be packaged *as specified in AWS A5.02/A5.02M.* E7018M [E4918M] electrodes shall be packaged in hermetically sealed containers. These containers shall be capable of passing the test specified *in AWS A5.02/A5.02M for hermetically sealed containers*.

25. Marking of Packages

25.1 The product information *specified in AWS A5.02/A5.02M (as a minimum)* shall be legibly marked on the outside of each unit package.

25.2 The appropriate precautionary information as given in ANSI Z49.1 (as a minimum) or its equivalent shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package. Typical examples of "warning labels" and precautionary information are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

Table 1
Electrode Classification

AWS Classification		Type of Covering	Type of Current[a]	Welding Position Capability[b]
A5.1	[A5.1M]			
E6010	[E4310]	High cellulose sodium	DCEP	F, V[c], OH[c], H
E6011	[E4311]	High cellulose potassium	AC, DCEP	F, V[c], OH[c], H
E6012	[E4312]	High titania sodium	AC, DCEN	F, V[c], OH[c], H
E6013	[E4313]	High titania potassium	AC, DCEP, DCEN	F, V[c], OH[c], H
E6018[e]	[E4318[e]]	Low-hydrogen potassium, iron powder	AC, DCEP	F, V[d], OH[d], H
E6019	[E4319]	Iron oxide titania potassium	AC, DCEP, DCEN	F, V[c], OH[c], H
E6020	[E4320]	High iron oxide	AC, DCEN	H-fillet
			AC, DCEP, DCEN	F
E6022[f]	[E4322[f]]	High iron oxide	AC, DCEN	F, H-fillet
E6027	[E4327]	High iron oxide, iron powder	AC, DCEN	H-fillet
			AC, DCEP, DCEN	F
E7014	[E4914]	Iron powder, titania	AC, DCEP, DCEN	F, V[d], OH[d], H
E7015	[E4915]	Low-hydrogen sodium	DCEP	F, V[d], OH[d], H
E7016[e]	[E4916[e]]	Low-hydrogen potassium	AC, DCEP	F, V[d], OH[d], H
E7018[e]	[E4918[e]]	Low-hydrogen potassium, iron powder	AC, DCEP	F, V[d], OH[d], H
E7018M	[E4918M]	Low-hydrogen iron powder	DCEP	F, V[d], OH[d], H
E7024[e]	[E4924[e]]	Iron powder, titania	AC, DCEP, DCEN	H-fillet, F
E7027	[E4927]	High iron oxide, iron powder	AC, DCEN	H-fillet
			AC, DCEP, DCEN	F
E7028[e]	[E4928[e]]	Low-hydrogen, potassium, iron powder	AC, DCEP	H-fillet, F
E7048	[E4948]	Low-hydrogen, potassium, iron powder	AC, DCEP	F, OH, H, V-down[d]
E60-G	*[E43-G]*	*As agreed between purchaser and supplier*		
E70-G	*[E49-G]*	*As agreed between purchaser and supplier*		

[a] The term "DCEP" refers to direct current electrode positive (dc, reverse polarity). The term "DCEN" refers to direct current electrode negative (dc, straight polarity). The term "AC" indicates alternating current.
[b] The abbreviations "F, H, H-fillet, V, V-down, and OH" indicate the welding positions as follows: F = Flat, H = Horizontal, H-fillet = Horizontal fillet, V = vertical, progression upwards, V-down = Vertical, progression downwards, OH = Overhead.
[c] For electrodes 3/16 in [5.0 mm] and under.
[d] For electrodes 5/32 in [4.0 mm] and under.
[e] Electrodes with supplemental elongation, notch toughness, absorbed moisture, and diffusible hydrogen requirements may be further identified as shown in Tables 4, 5, 10, and 11.
[f] Electrodes of the E6022 [E4322] classification are intended for single-pass welds only.

Table 2
Required Tests[a]

AWS Classification A5.1 [A5.1M]	Current and Polarity[b, c]	Electrode Size in [mm]	All-Weld Metal Tests: Chemical Analysis[d]	All-Weld Metal Tests: Radio-graphic Test[d]	All-Weld Metal Tests: Tension Test[d]	All-Weld Metal Tests: Impact Test[d]	Fillet Weld Test	Electrode Covering Moisture Test
E6010 [E4310]	DCEP	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32, 3/16 [4.0, 4.8, 5.0]	R	R	R	R	V & OH	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	R	H-fillet	NR
		5/16 [8.0]	NR	R	R	NR	NR	NR
E6011 [E4311]	AC and DCEP	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32, 3/16 [4.0, 4.8, 5.0]	R	R	R	R	V & OH	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	R	H-fillet	NR
		5/16 [8.0]	NR	R	R	NR	NR	NR
E6012 [E4312]	AC and DCEN	1/16 to 1/8 [1.6 to 3.2] inc.	NR	NR	NR	NR	NR	NR
		5/32, 3/16 [4.0, 4.8, 5.0]	R	NR	R	NR	V & OH	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4, 5/16 [6.0, 6.4, 8.0]	R	NR	R	NR	H-fillet	NR
E6013 [E4313]	AC, DCEP, and DCEN	1/16 to 1/8 [1.6 to 3.2] inc.	NR	NR	NR	NR	NR	NR
		5/32, 3/16 [4.0, 4.8, 5.0]	R	R	R	NR	V & OH	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4, 5/16 [6.0, 6.4, 8.0]	R	R	R	NR	H-fillet	NR
E6018 [E4318]	AC and DCEP	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R	R	V & OH	R
		3/16 [4.8, 5.0]	NR	R	R	R	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	R	H-fillet	R
		5/16 [8.0]	NR	R	R	NR	NR	NR
E6019 [E4319]	AC, DCEP, and DCEN	5/64 to 1/8 [2.0 to 3.2] inc.	NR	NR	NR	NR	NR	NR
		5/32, 3/16 [4.0, 4.8, 5.0]	R[g]	R[g]	R[g]	R[g]	V & OH	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4, 5/16 [6.0, 6.4, 8.0]	R[g]	R[g]	R[g]	R[g]	H-fillet	NR
E6020 [E4320]	AC, DCEP, and DCEN	1/8 [3.2]	NR	NR	NR	NR	NR	NR
		5/32, 3/16 [4.0, 4.8, 5.0]	R	R	R	NR	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	NR	H-fillet	NR
		5/16 [8.0]	NR	R	R	NR	NR	NR

(Continued)

Table 2 (Continued)
Required Tests[a]

AWS Classification A5.1 [A5.1M]	Current and Polarity[b,c]	Electrode Size in [mm]	All-Weld Metal Tests: Chemical Analysis[d]	All-Weld Metal Tests: Radio-graphic Test[d]	All-Weld Metal Tests: Tension Test[d]	All-Weld Metal Tests: Impact Test[d]	Fillet Weld Test	Electrode Covering Moisture Test I
E6022 [E4322]	AC and DCEN	1/8 [3.2]	NR	NR	R[f]	NR	NR	NR
		5/32 to 7/32 [4.0 to 5.6] inc.	NR	NR	R[f]	NR	NR	NR
E6027 [E4327]	AC, DCEP, and DCEN	1/8 [3.2]	NR	NR	NR	NR	NR	NR
		5/32, 3/16 [4.0, 4.8, 5.0]	R[g]	R[g]	R[g]	R[g]	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R[g]	R[g]	R[g]	R[g]	H-fillet	NR
		5/16 [8.0]	NR	R[g]	R[g]	NR	NR	NR
E7014 [E4914]	AC, DCEP, and DCEN	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R	NR	V & OH	NR
		3/16 [4.8, 5.0]	NR	R	R	NR	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	NR	H-fillet	NR
		5/16 [8.0]	NR	R	R	NR	H-fillet	NR
E7015 [E4915]	DCEP	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R	R	V & OH	R
		3/16 [4.8, 5.0]	NR	R	R	R	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	R	H-fillet	R
		5/16 [8.0]	NR	R	R	NR	NR	NR
E7016 [E4916]	AC and DCEP	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R	R	V & OH	R
		3/16 [4.8, 5.0]	NR	R	R	R	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	R	H-fillet	R
		5/16 [8.0]	NR	R	R	NR	NR	NR
E7018 [E4918]	AC and DCEP	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R	R	V & OH	R
		3/16 [4.8, 5.0]	NR	R	R	R	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	R	H-fillet	R
		5/16 [8.0]	NR	R	R	NR	NR	NR
E7018M [E4918M]	AC and DCEP	3/32 to 5/32 [2.4 to 4.0] inc.	R	R (Vertical)	R (Vertical)	R (Vertical)	NR	R[h]
		3/16 to 5/16 [4.8 to 8.0] inc.	R	R	R	R	NR	R[h]

(Continued)

Table 2 (Continued)
Required Tests[a]

AWS Classification A5.1 [A5.1M]	Current and Polarity[b,c]	Electrode Size in [mm]	All-Weld Metal Tests: Chemical Analysis[d]	All-Weld Metal Tests: Radio-graphic Test[d]	All-Weld Metal Tests: Tension Test[d]	All-Weld Metal Tests: Impact Test[d]	Fillet Weld Test	Electrode Covering Moisture Test I
E7024 [E4924]	AC, DCEP, and DCEN	3/32, 1/8 [2.4, 2.5, 3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R	R[g,i]	H-fillet	NR
		3/16 [4.8, 5.0]	NR	R	R	R[g,i]	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R	R[g,i]	H-fillet	NR
		5/16 [8.0]	NR	R	R	NR	NR	NR
E7027 [E4927]	For H-fillet, AC and DCEN For flat position, AC, DCEP, and DCEN	1/8 [3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R[g]	R	H-fillet	NR
		3/16 [4.8, 5.0]	NR	R	R[g]	R[g]	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R[g]	R[g]	H-fillet	NR
		5/16 [8.0]	NR	R	R[g]	NR	NR	NR
E7028 [E4928]	AC and DCEP	1/8 [3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R[g]	R	H-fillet	R
		3/16 [4.8, 5.0]	NR	R	R[g]	R	H-fillet	NR
		7/32 [5.6]	NR	NR	NR	NR	NR	NR
		1/4 [6.0, 6.4]	R	R	R[g]	R	H-fillet	R
		5/16 [8.0]	NR	R	R[g]	NR	NR	NR
E7048 [E4948]	AC and DCEP	1/8 [3.2]	NR	NR	NR	NR	NR	NR
		5/32 [4.0]	R	R	R	R	V-down & OH	R
		3/16 [4.8, 5.0]	NR	R	R	R	V-down & H-fillet	NR
E60-G [E43-G]	*As agreed upon between Purchaser and Supplier*		*R*	*NR*	*R*	*NR*	*NR*	*NR*
E70-G [E49-G]	*As agreed upon between Purchaser and Supplier*		*R*	*NR*	*R*	*NR*	*NR*	*NR*

[a] "R" indicates that the test is required. "NR" indicates that the test is not required.
[b] The term "DCEP" refers to direct current electrode positive (dc, reverse polarity). The term "DCEN" refers to direct current electrode negative (dc, straight polarity). The term "AC" refers to alternating current.
[c] When DCEP and DCEN are shown, only DCEN need be tested.
[d] See Clause 10, 11, 12, or 14, as applicable.
[e] The moisture test given in Clause 16 is the required test for moisture content of the covering. Optional, supplemental tests for absorbed moisture and diffusible hydrogen are included in Clauses 17 and 18.
[f] An all-weld-metal tension test is not required for E6022 [E4322] electrodes. Instead, a transverse tension test (see 12.5) and a longitudinal guided bend test (see Clause 13) are required for classification of 5/32 in, 3/16/in, and 7/32 in [4.0 mm, 5.0 mm, and 6.0 mm] E6022 [E4322] electrodes.
[g] Electrodes longer than 18 in [450 mm] will require a double length test assembly in accordance with Note 1 of Figure 3 to ensure uniformity of the entire electrode.
[h] The Absorbed Moisture Test (Clause17) and Diffusible Hydrogen Test (Clause 18) are required for all sizes of E7018M [E4918M].
[i] Electrodes identified as E7024-1 [E4924-1] shall be impact tested (see Table 5).

Table 3
Radiographic Soundness Requirements

AWS Classification A5.1 [A5.1M]	Radiographic Standard[a, b]
E6018 [E4318], E6019 [E4319], E6020 [E4320], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], and E7048 [E4948]	Grade 1
E6010 [E4310], E6011 [E4311], E6013 [E4313], E6027 [E4327], E7014 [E4914], E7027 [E4927], and E7028 [E4928]	Grade 2
E7024 [E4924]	*Grade 3*
E6012 [E4312] and E6022 [E4322]	Not Specified
E60-G [E43-G] and E70-G [E49-G]	*Not Specified*

[a] See Figure 8.
[b] The radiographic soundness obtainable under industrial conditions employed for various electrode classifications is discussed in A6.10.1 in Annex A.

Table 4
Tension Test Requirements[a, b]

AWS Classification A5.1 [A5.1M]	Tensile Strength (minimum) ksi [MPa]	Yield Strength[c] (minimum) ksi [MPa]	Percent Elongation[d] (minimum)
E6010 [E4310]	60 [430]	48 [330]	22
E6011 [E4311]	60 [430]	48 [330]	22
E6012 [E4312]	60 [430]	48 [330]	22
E6013 [E4313]	60 [430]	48 [330]	22
E6018 [E4318]	60 [430]	48 [330]	22
E6019 [E4319]	60 [430]	48 [330]	22
E6020 [E4320]	60 [430]	48 [330]	22
E6022 [E4322][e]	60 [430]	Not Specified	Not Specified
E6027 [E4327]	60 [430]	48 [330]	22
E60-G [E43-G]	*60 [430]*	*48 [330]*	*17*
E7014 [E4914]	70 [490]	58 [400]	17
E7015 [E4915]	70 [490]	58 [400]	22
E7016 [E4916]	70 [490]	58 [400]	22
E7018 [E4918]	70 [490]	58 [400]	22
E7018M [E4918M]	(g)	53–72 [370–500][h]	24
E7024 [E4924]	70 [490]	58 [400]	17[f]
E7027 [E4927]	70 [490]	58 [400]	22
E7028 [E4928]	70 [490]	58 [400]	22
E7048 [E4948]	70 [490]	58 [400]	22
E70-G [E49-G]	*70 [490]*	*58 [400]*	*17*

[a] See Table 2 for sizes to be tested.
[b] Requirements are to be in the as-welded condition with aging as specified in 12.2.
[c] Yield strength at 0.2% offset.
[d] Elongation percentage in 4x diameter length.
[e] A transverse tensile test, as specified in 12.5 and a longitudinal guided bend test, as specified in Clause 13 are required.
[f] Weld metal from electrodes identified as E7024-1 [E4924-1] shall have elongation of 22% minimum.
[g] Tensile strength of this weld metal is a nominal 70 ksi [490 MPa]
[h] For 3/32 in [2.4 mm] electrodes, the maximum yield strength shall be 77 ksi [530 MPa].

Table 5
Charpy V-Notch Impact Requirements

AWS Classification A5.1 [A5.1M]	Classifications with Optional, Supplemental "-1" Impact Designator	Acceptance Criteria[a, b]	
		Average (minimum)	Single Value (minimum)
E6010 [E4310]	—	20 ft·lbf at –20 °F [27 J at –30 °C]	15 ft·lbf at –20 °F [20 J at –30 °C]
E6011 [E4311]	—		
E6018 [E4318]	—		
E6027 [E4327]	—		
E7015 [E4915]	—		
E7016 [E4916]	—		
E7018 [E4918]	—		
E7027 [E4927]	—		
E7048 [E4948]	—		
	E7016-1 [E4916-1]	20 ft·lbf at –50 °F [27 J at –45 °C]	15 ft·lbf at –50 °F [20 J at –45 °C]
	E7018-1 [E4918-1]		
E7018M [E4918M][b]	—	50 ft·lbf at –20 °F[b] [67 J at –30 °C]	40 ft·lbf at –20 °F[b] [54 J at –30 °C]
E6019 [E4319]	—	20 ft·lbf at 0 °F [27 J at –20 °C]	15 ft·lbf at 0 °F [20 J at –20 °C]
E7028 [E4928]	—		
	E7024-1 [E4924-1]		
E6012 [E4312]	—	Not Specified	Not Specified
E6013 [E4313]	—		
E6020 [E4320]	—		
E6022 [E4322]	—		
E7014 [E4914]	—		
E7024 [E4924]	—		
E60-G [E43-G]		*Not Specified*	*Not Specified*
E70-G [E49-G]			

[a] Both the highest and lowest test values obtained shall be disregarded in computing the average. Two of the remaining three values shall equal or exceed 20 ft·lbf [27 J].
[b] For the E7018M classification all five values obtained shall be used in computing the average. Four of the five values shall equal or exceed 50 ft·lbf [67 J].

Table *6*
Chemical Composition Requirements for Weld Metal

<table>
<tr><th rowspan="2">AWS Classification A5.1 [A5.1M]</th><th rowspan="2">UNS[c] Number</th><th colspan="11">Weight Percent[a, b]</th></tr>
<tr><th>C</th><th>Mn</th><th>Si</th><th>P</th><th>S</th><th>Ni</th><th>Cr</th><th>Mo</th><th>V</th><th>Combined Limit for Mn + Ni + Cr + Mo + V</th><th>Other Specified Elements</th></tr>
<tr><td>E6010 [E4310]</td><td>W06010</td><td rowspan="7">0.20</td><td rowspan="7">1.20</td><td rowspan="7">1.00</td><td rowspan="7">N.S.</td><td rowspan="7">N.S.</td><td rowspan="7">0.30</td><td rowspan="7">0.20</td><td rowspan="7">0.30</td><td rowspan="7">0.08</td><td rowspan="7">N.S.</td><td>—</td></tr>
<tr><td>E6011 [E4311]</td><td>W06011</td><td>—</td></tr>
<tr><td>E6012 [E4312]</td><td>W06012</td><td>—</td></tr>
<tr><td>E6013 [E4313]</td><td>W06013</td><td>—</td></tr>
<tr><td>E6019 [E4319]</td><td>W06019</td><td>—</td></tr>
<tr><td>E6020 [E4320]</td><td>W06020</td><td>—</td></tr>
<tr><td>E6027 [E4327]</td><td>W06027</td><td>—</td></tr>
<tr><td>E6018 [E4318]</td><td>W06018</td><td>0.03</td><td>0.60</td><td>0.40</td><td>0.025</td><td>0.015</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>N.S.</td><td>—</td></tr>
<tr><td>E60-G [E43-G]</td><td></td><td colspan="10">N.S.</td><td>—</td></tr>
<tr><td>E7015 [E4915]</td><td>W07015</td><td>0.15</td><td>1.25</td><td>0.90</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.50</td><td>—</td></tr>
<tr><td>E7016 [E4916]</td><td>W07016</td><td>0.15</td><td>1.60</td><td>0.75</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.75</td><td>—</td></tr>
<tr><td>E7018 [E4918]</td><td>W07018</td><td>0.15</td><td>1.60</td><td>0.75</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.75</td><td>—</td></tr>
<tr><td>E7014 [E4914]</td><td>W07014</td><td>0.15</td><td>1.25</td><td>0.90</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.50</td><td>—</td></tr>
<tr><td>E7024 [E4924]</td><td>W07024</td><td>0.15</td><td>1.25</td><td>0.90</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.50</td><td>—</td></tr>
<tr><td>E7027 [E4927]</td><td>W07027</td><td>0.15</td><td>1.60</td><td>0.75</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.75</td><td>—</td></tr>
<tr><td>E7028 [E4928]</td><td>W07028</td><td>0.15</td><td>1.60</td><td>0.90</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.75</td><td>—</td></tr>
<tr><td>E7048 [E4948]</td><td>W07048</td><td>0.15</td><td>1.60</td><td>0.90</td><td>0.035</td><td>0.035</td><td>0.30</td><td>0.20</td><td>0.30</td><td>0.08</td><td>1.75</td><td>—</td></tr>
<tr><td>E7018M [E4918M]</td><td>W07018</td><td>0.12</td><td>0.40 to 1.60</td><td>0.80</td><td>0.030</td><td>0.020</td><td>0.25</td><td>0.15</td><td>0.35</td><td>0.05</td><td>N.S.</td><td>—</td></tr>
<tr><td>E70-G [E49-G]</td><td></td><td colspan="10">N.S.</td><td>—</td></tr>
</table>

[a] *The filler metal shall be analyzed for the specific elements for which values are shown in this table. In addition to that, analysis* is required to be reported for boron (B) if intentionally added, or if it is known to be present at levels greater than 0.0010%. *Additionally, if the presence of unspecified 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 maximums. N.S. means not specified.

[c] SAE/ASTM Unified Numbering System for Metals and Alloys.

Table 7
Base Metal for Weld Test Assemblies

AWS Classification	Type	ASTM Specification[a]	UNS Number[b]
All	Carbon Steel	A131 Grade B	K02102
		A285 Grade A	K01700
		A285 Grade B	K02200
All except E7018M [E4918M]	Carbon Steel	A285 Grade C	K02801
		A283 Grade D	K02702
		A36	K02600
		A29 Grade 1015	G10150
		A29 Grade 1020	G10200

[a]Equivalent steel may be used.
[b]SAE/ASTM Unified Numbering System for Metals and Alloys.

Table 8
Requirements for Preparation of Fillet Weld Test Assemblies

AWS Classification[a]		Electrode				Plate Size[b]				Position of Welding	Size of Fillet Weld	
		Size		Length		Thickness (T)		Length (L) min.[c]				
A5.1	A5.1M	in	mm	in	mm	in	mm	in	mm		in	mm
E6010 E6011	E4310 E4311	3/32	2.4, 2.5	12	300	1/8	3	10	250	V & OH	5/32 max.	4 max.
		1/8	3.2	14	350	3/16	5	12	300	V & OH	3/16 max.	5 max.
		5/32	4.0	14	350	3/8	10	12	300	V & OH	1/4 max.	6 max.
		3/16	4.8, 5.0	14	350	3/8	10	12	300	V & OH	5/16 max.	8 max.
		7/32	5.6	14 or 18	350 or 450	1/2	12	12 or 16[c]	300 or 400[c]	H	1/4 min.	6 min.
		1/4 5/16	6.0, 6.4 8.0	18	450	1/2	12	16	400	H	1/4 min.	6 min.
E6012, E6013, E6019	E4312, E4313, E4319	1/16–5/64	1.6–2.0	12	300	1/8	3	6	150	V & OH	1/8 max.	3 max.
		3/32	2.4, 2.5	12	300	1/8	3	10	250	V & OH	1/8 max.	3 max.
		1/8	3.2	14	350	3/16	5	12	300	V & OH	3/16 max.	5 max.
		5/32	4.0	14	350	3/8	10	12	300	V & OH	1/4 max.	6 max.
		3/16	4.8, 5.0	14	350	1/2	12	12	300	V & OH	3/8 max.	10 max.
		7/32	5.6	14 or 18	350 or 450	1/2	12	12 or 16[c]	300 or 400[c]	H	1/4 min.	6 min.
		1/4	6.0, 6.4	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.
		5/16	8.0	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.
E7014	E4914	3/32	2.4, 2.5	12	300	1/8	3	12	300	V & OH	5/32 max.	4 max.
		1/8	3.2	14	350	3/16	5	12	300	V & OH	3/16 max.	5 max.
		5/32	4.0	14	350	3/8	10	12	300	V & OH	5/16 max.	8 max.
		3/16	4.8, 5.0	14	350	3/8	10	12	300	H	1/4 min.	6 min.
		7/32	5.6	14 or 18	350 or 450	3/8	10	12 or 16[c]	300 or 400[c]	H	1/4 min.	6 min.
		1/4	6.0, 6.4	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.
		5/16	8.0	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.

(Continued)

Table 8 (Continued)
Requirements for Preparation of Fillet Weld Test Assemblies

AWS Classification[a]		Electrode				Plate Size[b]				Position of Welding	Size of Fillet Weld	
		Size		Length		Thickness (T)		Length (L) min.[c]				
A5.1	A5.1M	in	mm	in	mm	in	mm	in	mm		in	mm
E7015 E7016	E4915 E4916	3/32	2.4, 2.5	12	300	1/8	3	10	250	V & OH	5/32 max.	4 max.
		1/8	3.2	14	350	1/4	6	12	300	V & OH	3/16 max.	5 max.
		5/32	4.0	14	350	3/8	10	12	300	V & OH	5/16 max.	8 max.
		3/16	4.8, 5.0	14	350	3/8	10	12	300	H	3/16 min.	5 min.
		7/32	5.6	14 or 18	350 or 450	1/2	12	12 or 16[c]	300 or 400[c]	H	1/4 min.	6 min.
		1/4	6.0, 6.4	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.
		5/16	8.0	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.
E6018 E7018	E4318 E4918	3/32	2.4, 2.5	12	300	1/8	3	10 or 12[d]	250 or 300[d]	V & OH	3/16 max.	5 max.
		1/8	3.2	14	350	1/4	6	12	300	V & OH	1/4 max.	6 max.
		5/32	4.0	14	350	3/8	10	12	300	V & OH	5/16 max.	8 max.
		3/16	4.8, 5.0	14	350	3/8	10	12	300	H	1/4 min.	6 min.
		7/32	5.6	14 or 18	350 or 450	1/2	12	12 or 16[c]	300 or 400[c]	H	1/4 min.	6 min.
		1/4	6.0, 6.4	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.
		5/16	8.0	14 or 18	350 or 450	1/2	12	16	400	H	5/16 min.	8 min.
E6020	E4320	1/8	3.2	14	350	1/4	6	12	300	H	1/8 min.	3 min.
		5/32	4.0	14	350	3/8	10	12	300	H	5/32 min.	4 min.
		3/16	4.8, 5.0	14 or 18	350 or 450	3/8	10	12 or 16[c]	300 or 400[c]	H	3/16 min.	5 min.
		7/32	5.6	18 or 28	450 or 700	1/2	12	16	400	H	1/4 min.	6 min.
		1/4	6.0, 6.4	18 or 28	450 or 700	1/2	12	16	400	H	5/16 min.	8 min.
		5/16	8.0	18 or 28	450 or 700	1/2	12	16	400	H	5/16 min.	8 min.

(Continued)

Table 8 (Continued)
Requirements for Preparation of Fillet Weld Test Assemblies

AWS Classification[a]		Electrode				Plate Size[b]				Position of Welding	Size of Fillet Weld	
		Size		Length		Thickness (T)		Length (L) min.[c]				
A5.1	A5.1M	in	mm	in	mm	in	mm	in	mm		in	mm
E6027 E7024 E7027 E7028	E4327 E4924 E4927 E4928	3/32[e]	2.4, 2.5[e]	14	350	1/4	6	10	250	H	5/32 min.	4 min.
		1/8	3.2	14	350	1/4	6	12	300	H	5/32 min.	4 min.
		5/32	4.0	14	350	3/8	10	12	300	H	3/16 min.	6 min.
		3/16	4.8, 5.0	14 or 18	350 or 450	3/8	10	12 or 16[c]	300 or 400[c]	H	1/4 min.	6 min.
		7/32	5.6	18 or 28	450 or 700	1/2	12	16 or 26[f]	400 or 650[f]	H	1/4 min.	6 min.
		1/4	6.0, 6.4	18 or 28	450 or 700	1/2	12	16 or 26[f]	400 or 650[f]	H	5/16 min.	8 min.
		5/16	8.0	18 or 28	450 or 700	1/2	12	16 or 26[f]	400 or 650[f]	H	5/16 min.	8 min.
E7048	E4948	1/8	3.2	14	350	1/4	6	12	300	V-down & OH	1/4 max.	6 max
		5/32	4.0	14 or 18	350 or 450	3/8	10	12	300	V-down & OH	5/16 max.	8 max
		3/16	4.8, 5.0	14 or 18	350 or 450	3/8	10	12 or 16	300 or 400	H &V-down	1/4 min.	6 min.

[a] See Figure 4. Any classification test can be conducted with either USC or SI thickness plate.
[b] When the end of the bead with the first electrode will be less than 4 in [100 mm] from the end of the test assembly, a starting tab or a longer test assembly shall be used.
[c] For 14 in [350 mm] electrodes, the minimum length of the test assembly shall be 12 in [300 mm]; for 18 in [450 mm] electrodes, the minimum length of the test assembly shall be 16 in [400 mm].
[d] For 12 in [300 mm] electrodes, the minimum length of the test assembly shall be 10 in [250 mm]; for 14 in [350 mm] electrodes, the minimum length of the test assembly shall be 12 in [300 mm].
[e] E7024 [E4924] only.
[f] For 18 in [450 mm] electrodes, the minimum length of the test assembly shall be 16 in [400 mm]; for 28 in [700 mm] electrodes, the minimum length of the test assembly shall be 26 in [650 mm].

Table 9
Dimensional Requirements for Fillet Weld Usability Test Specimens

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in	mm	in	mm	in	mm
1/8 or less	3 or less	*1/16*	*2*	1/32	1
5/32	4	*1/16*	*2*	*1/16*	*2*
3/16	—	1/16	—	1/16	—
—	5	—	2	—	2
7/32	5	1/16	2	*3/32*	*2*
1/4	6	1/16	2	3/32	2
9/32	7	1/16	2	*1/8*	*3*
5/16	8	*3/32*	*2*	1/8	3
11/32	9	*3/32*	*2*	*5/32*	*4*
3/8 or more	*10 or more*	*3/32*	*2*	5/32	*4*

Table 10
Moisture Content Limits for Electrode Coverings

<table>
<tr><th rowspan="2">AWS Classification A5.1 [A5.1M]</th><th rowspan="2">Electrode Designation[a] A5.1 [A5.1M]</th><th colspan="2">Limit of Moisture Content (maximum % by weight)</th></tr>
<tr><th>As-Received or Conditioned[b]</th><th>As-Exposed[c]</th></tr>
<tr><td>E6018 [E4318]</td><td>E6018 [E4318]</td><td rowspan="8">0.6</td><td rowspan="8">Not Specified</td></tr>
<tr><td>E7015 [E4915]</td><td>E7015 [E4915]</td></tr>
<tr><td>E7016 [E4916]</td><td>E7016 [E4916]</td></tr>
<tr><td>E7016 [E4916]</td><td>E7016-1 [E4916-1]</td></tr>
<tr><td>E7018 [E4918]</td><td>E7018 [E4918]</td></tr>
<tr><td>E7018 [E4918]</td><td>E7018-1 [E4918-1]</td></tr>
<tr><td>E7028 [E4928]</td><td>E7028 [E4928]</td></tr>
<tr><td>E7048 [E4948]</td><td>E7048 [E4948]</td></tr>
<tr><td>E6018 [E4318]</td><td>E6018R [E4318R]</td><td rowspan="8">0.3</td><td rowspan="8">0.4</td></tr>
<tr><td>E7015 [E4915]</td><td>E7015R [E4915R]</td></tr>
<tr><td>E7016 [E4916]</td><td>E7016R [E4916R]</td></tr>
<tr><td>E7016 [E4916]</td><td>E7016-1R [E4916-1R]</td></tr>
<tr><td>E7018 [E4918]</td><td>E7018R [E4918R]</td></tr>
<tr><td>E7018 [E4918]</td><td>E7018-1R [E4918-1R]</td></tr>
<tr><td>E7028 [E4928]</td><td>E7028R [E4928R]</td></tr>
<tr><td>E7048 [E4948]</td><td>E7048R [E4948R]</td></tr>
<tr><td>E7018M [E4918M]</td><td>E7018M [E4918M]</td><td>0.1</td><td>0.4</td></tr>
</table>

[a] AWS classification with optional, supplemental designators applied.
[b] As-received or conditioned electrode coverings shall be tested as specified in Clause 16, Moisture Test.
[c] As-exposed electrode coverings shall have been exposed to a moist environment as specified in Clause 17, Absorbed Moisture Test, before being tested as specified in Clause 16.

Table 11
Diffusible Hydrogen Limits for Weld Metal

AWS Classification A5.1 [A5.1M]	Diffusible Hydrogen Designator	Diffusible Hydrogen Content Average mL/100g Deposited Metal (maximum)
E7018M [E4918M]	None	4
E6018 [E4318]	H16, H8, or H4	16 (for H16) 8 (for H8) 4 (for H4)
E7015 [E4915]		
E7016 [E4916]		
E7018 [E4918]		
E7028 [E4928]		
E7048 [E4948]		

Mandatory Classification Designators[a]

E XX YY
E XX YY M
E XX XX – X HZ R

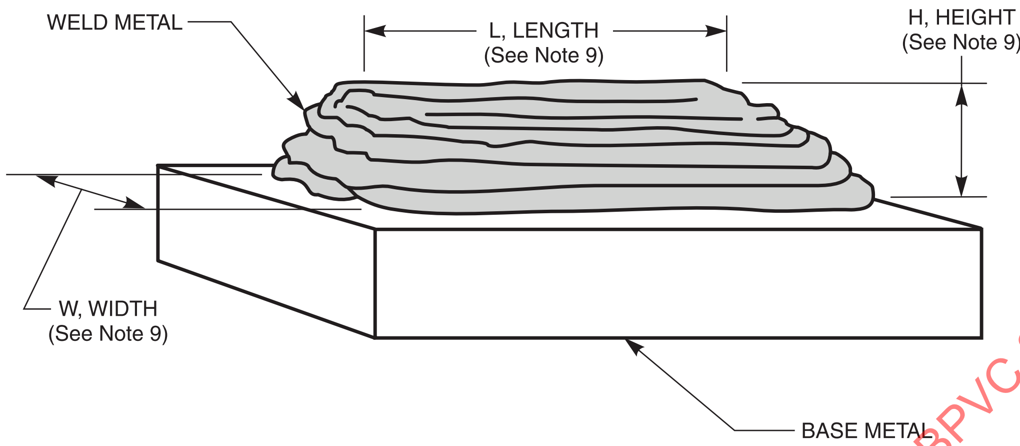
- **E** — Designates an electrode. This designator may be deleted from the product imprint required for identification of the electrode.
- **XX** — Two digits are used for AWS A5.1 to designate in ksi, or for A5.1M to designate in MPa divided by 10, the minimum tensile strength of the weld metal produced in accordance with the test assembly preparation procedure of this specification (see Table 4). Example: E7018 is an electrode with a tensile strength of 70,000 psi. [E4918 is an electrode with a tensile strength of 490 MPa].
- **YY** — Designates the welding position in which electrodes are usable, the type of covering and the kind of current for which the electrodes are suitable (see Table 1). Example: In the E7018 [E4918] classification referenced above, the "18" designates a low-hydrogen, basic coated iron powder electrode capable of welding in all positions using either ac or dc electrode positive. *These two digits may be omitted and replaced by "-G."*
- **M** — Designates an electrode EXX18M [EXX18M] intended to meet most requirements for military specifications (greater toughness, yield strength, and elongation) (see Tables 4 and 5). Example: E7018M [E4918M].

Optional Supplemental Designators[b]

- **R** — Designates that the electrode meets the requirements of the absorbed moisture test (an optional supplemental test for all low hydrogen electrodes (see Table 10). Example: E7018R [E4918R].
- **HZ** — Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low-hydrogen electrodes) for electrodes in the as received or conditioned state, with an average diffusible hydrogen content not exceeding "Z" mL/100 g of deposited metal, where "Z" is 4, 8, or 16 (see Table 11). Example: E7018H8 [E4918H8]. In this case, the electrode will give a maximum of 8 mL of hydrogen per 100 g of deposited metal when tested in accordance with this specification.
- **X** — Designates that the electrode (E7016, E7018, or E7024) [E4916, E4918, or E4924] meets the requirements for improved toughness-and ductility in the case of E7024 [E4924]—Optional supplemental test requirements are shown in Table 4 (note f) and Table 5.

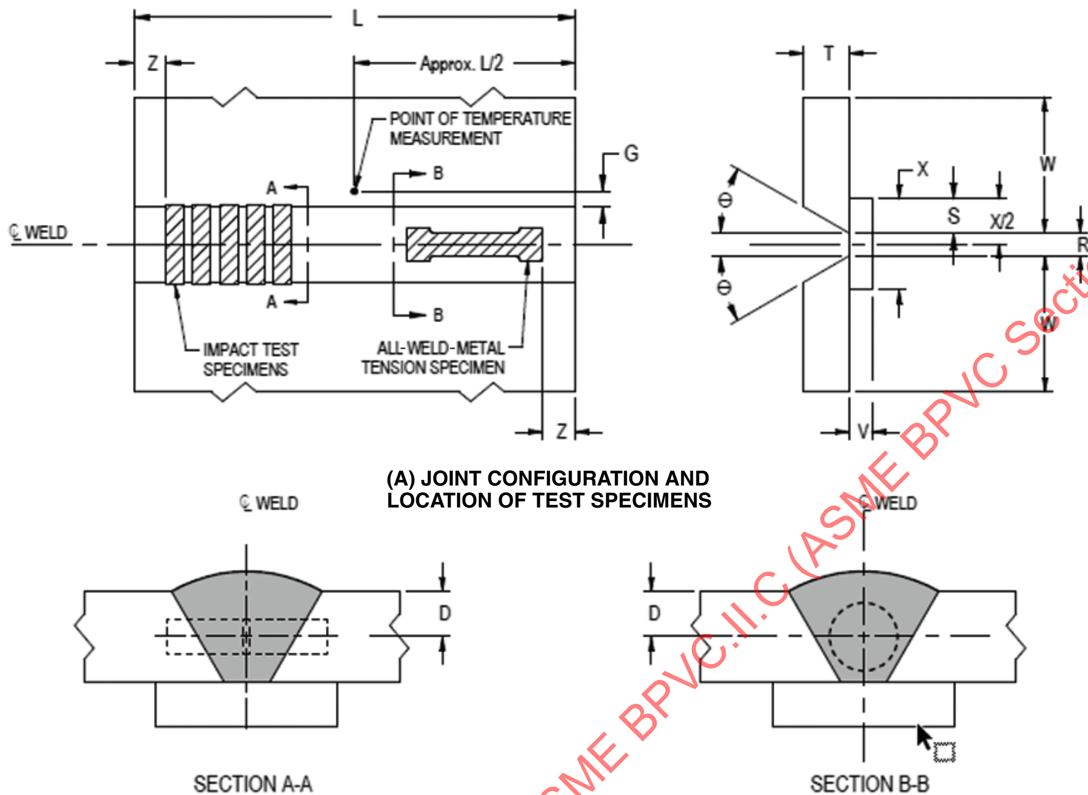
[a] The combination of these designators constitutes the electrode classification.
[b] These designators are optional and do not constitute a part of the electrode classification.

Figure 1—Order of Electrode Mandatory and Optional Supplemental Designators



Notes:
1. Base metal of any convenient size, of the type specified in Table 7, shall be used as the base for the weld pad.
2. The surface of the base metal on which the filler metal is to be deposited shall be clean.
3. The pad shall be welded in the flat position with successive layers to obtain undiluted weld metal.
4. One pad shall be welded for each type of current shown in Table 2 except for those classifications identified by note c in Table 2.
5. The number and size of the beads will vary according to the size of the electrode and the width of the weave, as well as the amperage employed. The width of each weld pass in each weld layer shall be no more than 2-1/2 times the diameter of the core wire.
6. The preheat temperature shall not be less than 60 °F [15 °C] and the interpass temperature shall not exceed 300 °F [150 °C].
7. The slag shall be removed after each pass.
8. The test assembly may be quenched in water between passes to control interpass temperature, but must be dry before welding resumes.
9. The minimum completed pad size shall be at least four layers in height (H) with length (L) and width (W) sufficient to perform analysis. The sample for analysis shall be taken from weld metal that is at least 1/4 in [6 mm] above the original base metal surface.

Figure 2—Pad for Chemical Analysis of Undiluted Weld Metal



(A) JOINT CONFIGURATION AND LOCATION OF TEST SPECIMENS

(B) LOCATION OF IMPACT TEST SPECIMENS

(C) LOCATION OF ALL-WELD-METAL TENSION TEST SPECIMEN

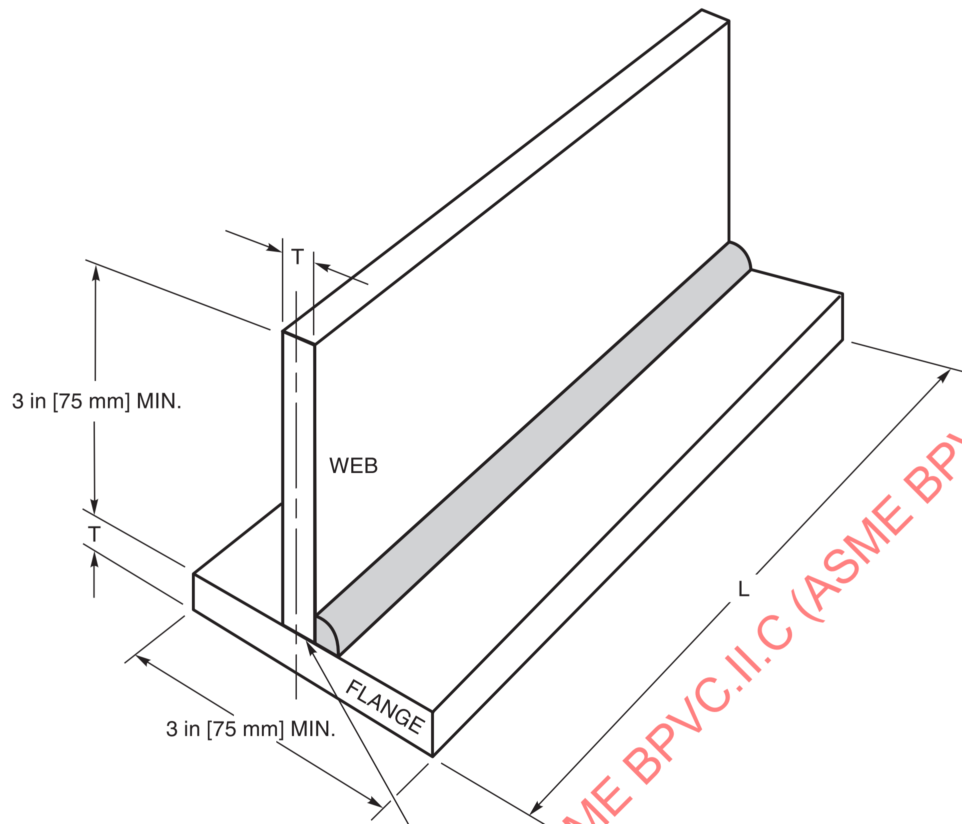
Dimension	Description	A5.1						
		Electrode Size, in						
		3/32	1/8	5/32	3/16	7/32	3/4	5/16
G	Point of Temperature Measurement, Offset from Groove Edge, in	1/4 to 1/2						
L	Length, min., in (See Note 1)	10						
S	Backing Overlap, min., in	1/4						
V	Backing Thickness, min., in	1/4						
W	Width, min., in	5						
X	Backing Width, min., in	R + 1/2						
Z	Discard, min., in	1						
T	Nominal Plate Thickness, in	1/2 ± 1/32	1/2 ± 1/32	3/4 ± 1/32	3/4 ± 1/32	3/4 ± 1/32	1 ± 1/32	1-1/4 ± 1/32
D	Specimen Center, in	1/4 ± 1/32	1/4 ± 1/32	3/8 ± 1/32	3/8 ± 1/32	3/8 ± 1/32	1/2 ± 1/32	5/8 ± 1/32
R	Root Opening, in	3/8 –0, +1/16	1/2 –0, +1/16	5/8 –0, +1/16	3/4, –0, +1/16	7/8, –0, +1/16	1, –0, +1/16	1-1/8, –0, +1/16
Θ	Bevel Angle, degrees	10, +2.5, –0						
	Passes per Layer	2	2	2	2	2	2	2
	Total Layers	Not Specified	5 to 7	7 to 9	6 to 8	6 to 8	9 to 11	10 to 12

Figure 3—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using All Electrode Classifications Except E6022 [E4322] and E7018M [E4918M] Electrodes

Dimension	Description	A5.1M					
		Electrode Size, mm					
		2.5	3.2	4	4.5, 5.0	6	8
G	Point of Temperature Measurement, Offset from Groove Edge, mm	6 to 13					
L	Length, min., mm (See Note 1)	250					
S	Backing Overlap, min., mm	6					
V	Backing Thickness, min., mm	6					
W	Width, min., mm	125					
X	Backing Width, min., mm	R + 12					
Z	Discard, min, mm	25					
T	Nominal Plate Thickness, mm	12 ± 1	12 ± 1	20 ± 1	20 ± 1	25 ± 1	30 ± 1
D	Specimen Center, mm	6 ± 1	6 ± 1	10 ± 1	10 ± 1	12 ± 1	16 ± 1
R	Root Opening, mm	10 –0, +1	13 –0, +1	16 –0, +1	19 –0, +1	25 –0, +1	28 –0, +1
Θ	Bevel Angle, degrees	10, *+2.5, –0*					
	Passes per Layer	2	2	2	2	2	2
	Total Layers	Not Specified	5 to 7	7 to 9	6 to 8	9 to 11	10 to 12

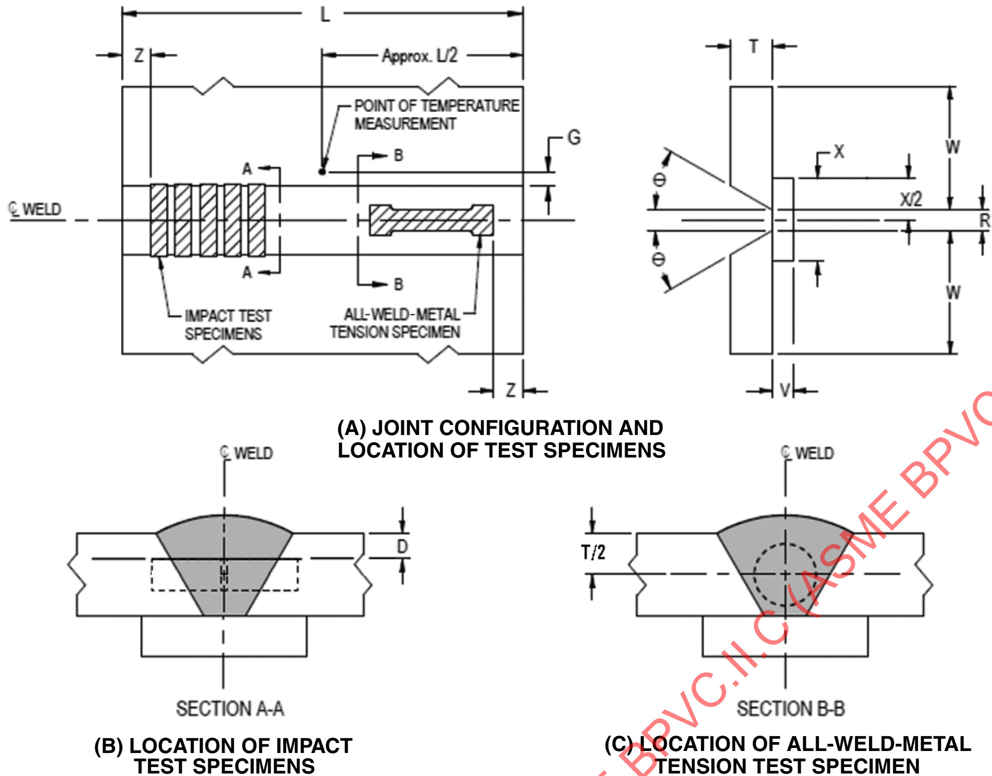
Notes:
1. For electrodes longer than 18 in [450 mm], a 20 in [500 mm] long test assembly shall be welded.
2. The surfaces to be welded shall be clean.
3. Base metal shall be as specified in Table 7.
4. Prior to welding, the assembly may be preset to yield a welded joint sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 degrees of plane. A completed welded test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assembly is prohibited.
5. Welding shall be in the flat position, using each type of current specified in Table 2 except for classifications identified by Note c in Table 2.
6. The preheat temperature shall be 225 °F [105 °C] minimum. The interpass temperature shall not be less than 225 °F [105 °C] nor more than 350 °F [175 °C].
7. For electrode size larger than 1/8 in [3.2 mm] the joint root may be seal welded with 3/32 or 1/8 in [2.5 or 3.2 mm] electrodes using stringer beads.
8. In addition to the stops and starts at the ends, each pass shall contain a stop and start in between the ends.
9. The completed weld shall be at least flush with the surface of the test plate.

Figure 3 (Continued)—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using All Electrode Classifications Except E6022 [E4322] and E7018M [E4918M] Electrodes



Notes:
1. See Table 8 for values of T and L.
2. Base metal shall be as specified in Table 7.
3. The surfaces to be welded shall be clean.
4. One assembly shall be welded for each position specified in Table 8 and shown in Figure 7 using each type of current and polarity specified in Table 2.
5. The preheat shall be 60 °F [15 °C] minimum.
6. A single pass fillet weld shall be made on one side of the joint. The first electrode shall be consumed to a stub length of no greater than 2 in [50 mm].
7. Progression in the vertical position shall be upwards, except the E7048 [E4948] classification where progression shall be downward.
8. Weld cleaning shall be limited to slag chipping, brushing and needle scaling. Grinding or filing of the final weld surface is prohibited.
9. The tests shall be conducted without postweld heat treatment.

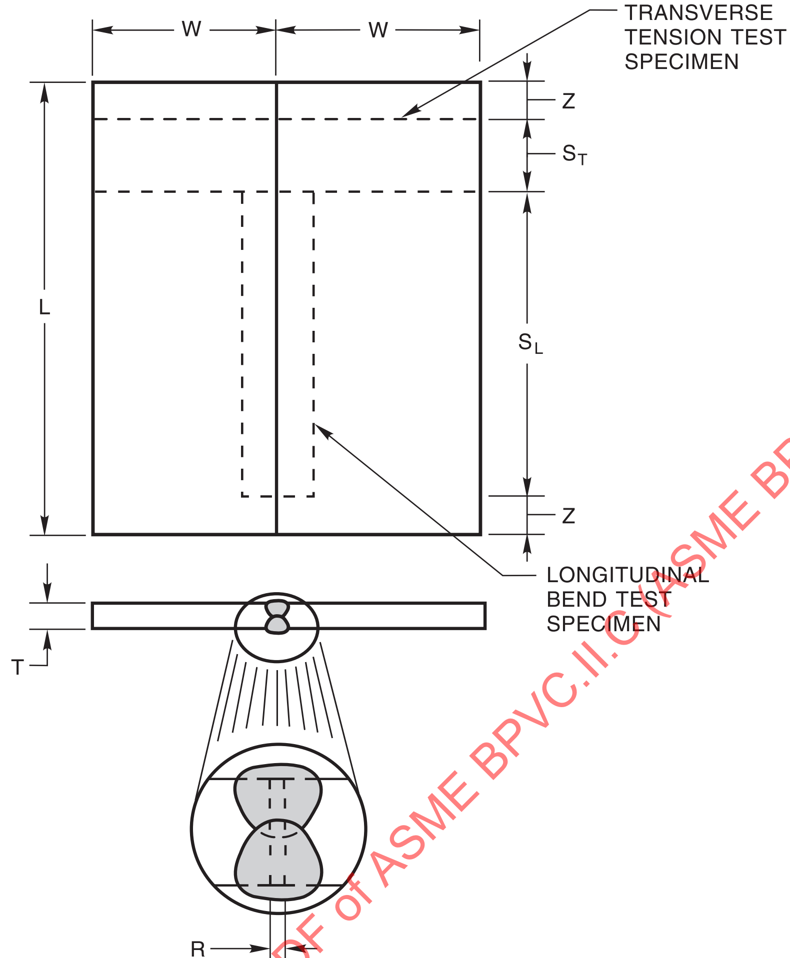
Figure 4—Fillet Weld Test Assembly for Usability of the Electrode



Dimension	Description	A5.1 E7018M						A5.1M E4918M				
		Electrode Size, in						Electrode Size, mm				
		3/32	1/8	5/32	3/16	7/32	1/4	2.5	3.2	4	5	6
D	Nominal CVN Location	1/8						3.2				
G	Point of Temperature Measurement, Offset from Groove Edge	1/4 to 1/2						6 to 13				
L	Length, min.	10						250				
V	Backing Thickness, min.	1/4						6				
W	Width, min.	5						125				
X	Backing Width, min.	3/4						20				
Z	Discard, min.	1						25				
T	Plate Thickness, min.	3/4						20				
R	Root Opening, min.	1/4						6				
Θ	Bevel Angle, degrees	30 *–0°, +5°*										
	Total Layers	See Note 6										

Notes:
1. Dimensions in inches are applicable to A5.1. Dimensions in mm are applicable to A5.1M.
2. Base metal shall be as specified in Table 7. The surfaces to be welded shall be clean.
3. Prior to welding, the assembly may be preset to yield a welded joint 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 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.
4. The assembly shall be welded in the vertical position with progression upward for electrodes 5/32 in [4.0 mm] and less in size, and in the flat position for electrodes 3/16 in [5.0 mm] and greater in size, using the type of current specified in Table 2 for the electrode and welding technique recommended by the electrode manufacturer.
5. The preheat temperature and the interpass temperature shall be 200 °F to 250 °F [90 °C to 120 °C].
6. The welding heat input shall be 30 kJ/in to 40 kJ/in [1.2 kJ/mm to 1.6 kJ/mm] for the 3/32 in [2.5 mm] size electrodes and 50 kJ/in to 60 kJ/in [2.0 kJ/mm to 2.4 kJ/mm] for the 1/8 in [3.2 mm] size and larger electrodes.
7. In addition to the stops and starts at the ends, each pass shall contain a stop and start in between the ends.
8. The completed weld shall be at least flush with the surface of the test plate. Maximum weld reinforcement shall be 3/16 in [5.0 mm]. Peening of weld beads is not permitted.

Figure 5—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using E7018M [E4918M] Electrodes



Minimum Length (L) in [mm]	Minimum Width (W) in [mm]	Maximum Root Opening (R) in [mm]	Transverse Specimen (S_T) in [mm]	Longitudinal Specimen (S_L) in [mm]	Thickness (T) in [mm]	Minimum Discard (Z) in [mm]
10 [250]	4 [100]	1/16 [1.6]	2 [50]	6 [150]	1/4 [6]	1 [25]

Notes:
1. Dimensions in inches are applicable to A5.1. Dimensions in mm are applicable to A5.1M.
2. Base metal shall be as specified in Table 7. The surfaces to be welded shall be clean.
3. Prior to welding, the assembly may be preset to yield a welded joint 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 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.
4. The assembly shall be welded in the flat position, using the type of current specified in Table 2.
5. The preheat temperature shall be 60 °F [15 °C] min. The interpass temperature shall not exceed 350 °F [180 °C].
6. In addition to the stops and starts at the ends, each pass shall contain a stop and start in between the ends.
7. Back gouging may be done to ensure sound weld metal through the entire thickness of test assembly.
8. The completed weld shall be at least flush with the surface of the test plate.

Figure 6—Test Assembly for Transverse Tension and Longitudinal Guided Bend Tests for Welds Made with E6022 [E4322] Electrodes

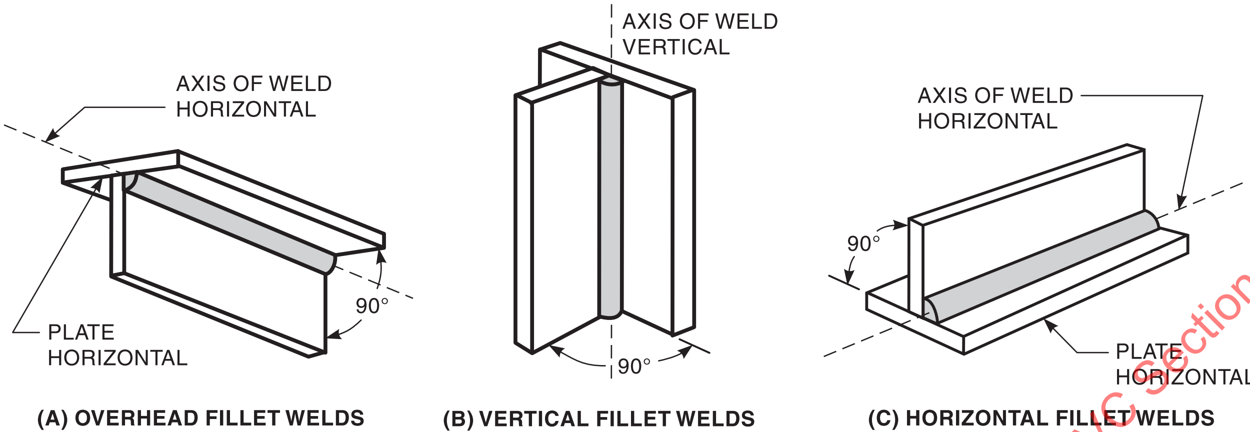
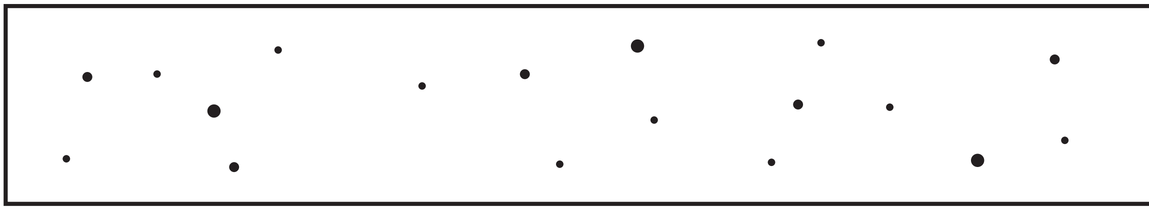
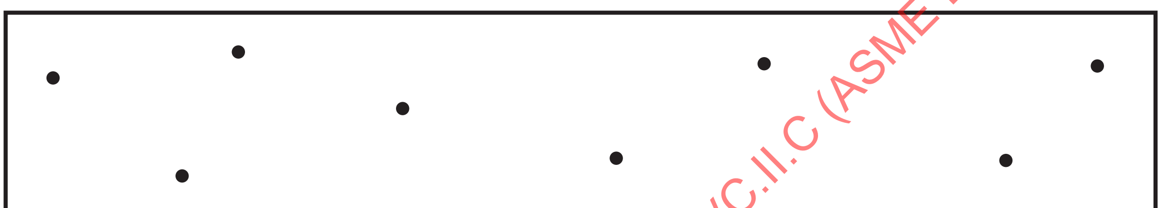


Figure 7—Welding Positions for Fillet Weld Test Assemblies



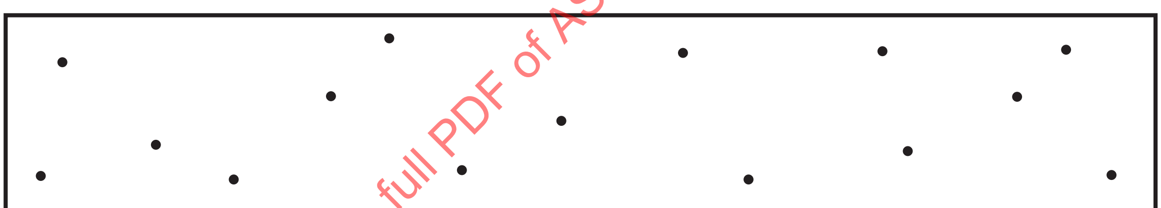
(A) ASSORTED ROUNDED INDICATIONS

SIZE: 1/64 in [0.4 mm] to 1/16 in [1.6 mm] in diameter or in length.
Maximum number of indications in any 6 in [150mm] of weld is 18, with the following restrictions:
Maximum number of large (3/64 in [1.2 mm] to 1/16 in [1.6 mm] in diameter or length) indications is 3, and
Maximum number of medium (1/32 in [0.8 mm] to 3/64 in [1.2 mm] in diameter of in length) indications is 5, and
Maximum number of small (1/64 in [0.4 mm] to 1/32 in [0.8 mm] in diameter or in length) indications is 10.



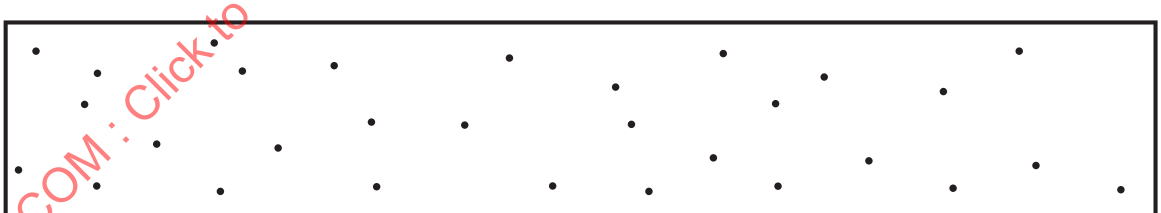
(B) LARGE ROUNDED INDICATIONS

SIZE: 3/64 in [1.2 mm] to 1/16 in [1.6 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE: 1/32 in [0.8 mm] to 3/64 in [1.2 mm] in diameter of in length. Maximum number of indications in any 6 in [150 mm] of weld is 15.

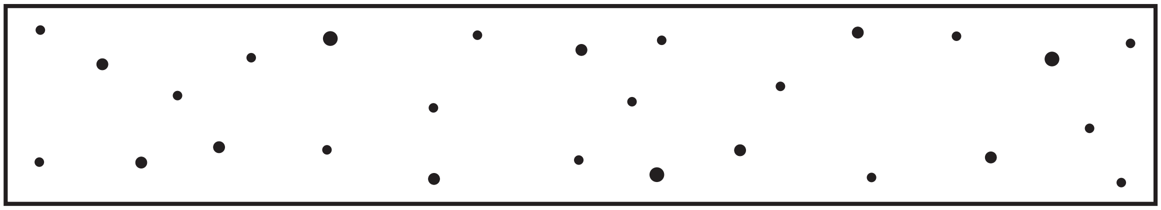


(D) SMALL ROUNDED INDICATIONS

SIZE: 1/64 in [0.4 mm] to 1/32 in [0.8 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 30.

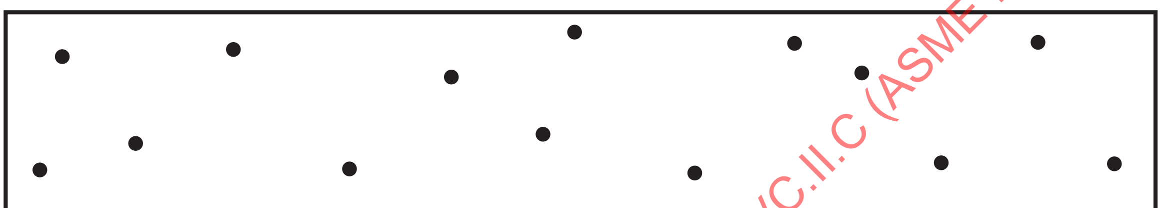
Notes:
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph, shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specially made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded.

Figure 8A—Radiographic Acceptance Standards for Rounded Indications (Grade 1)



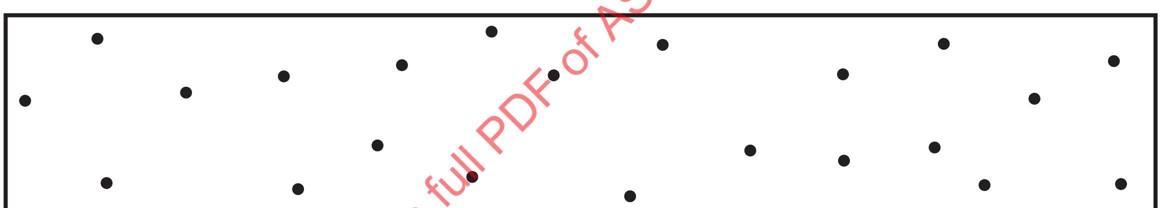
(E) ASSORTED ROUNDED INDICATIONS

SIZE: 1/64 in [0.4 mm] to 5/64 in [2.0 mm] in diameter or in length.
Maximum number of indications in any 6 in [150 mm] of weld is 27, with the following restrictions:
Maximum number of large (1/16 in [1.6 mm] to 5/64 in [2.0 mm] in diameter or in length) indications is 3, and
Maximum number of medium (3/64 in [1.2 mm] to 1/16 in [1.6 mm] in diameter of in length) indications is 8, and
Maximum number of small (1/64 in [0.4 mm] to 3/64 in [1.2 mm] in diameter or in length) indications is 16.



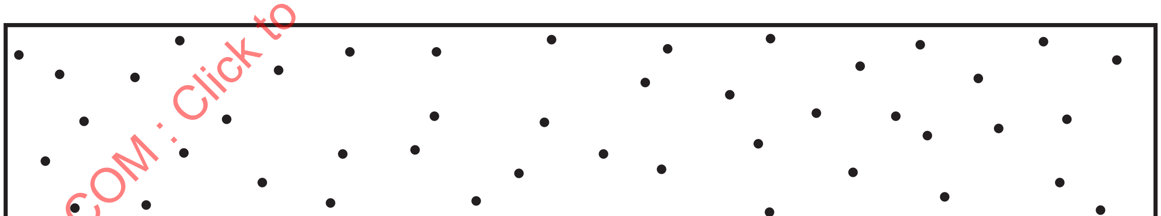
(F) LARGE ROUNDED INDICATIONS

SIZE: 1/16 in [1.6 mm] to 5/64 in [2.0 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 14.



(G) MEDIUM ROUNDED INDICATIONS

SIZE: 3/64 in [1.2 mm] to 1/16 in [1.6 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 22.

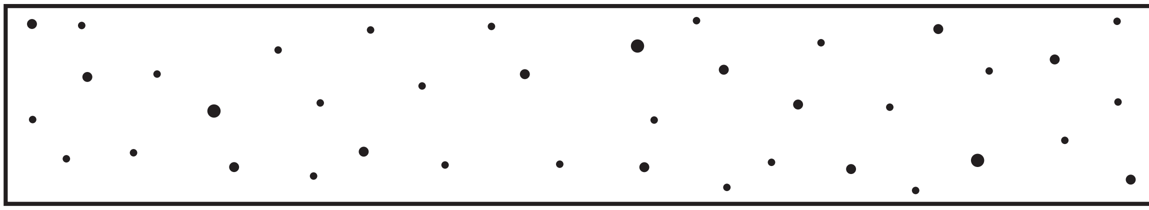


(H) SMALL ROUNDED INDICATIONS

SIZE: 1/64 in [0.4 mm] to 3/64 in [1.2 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 44.

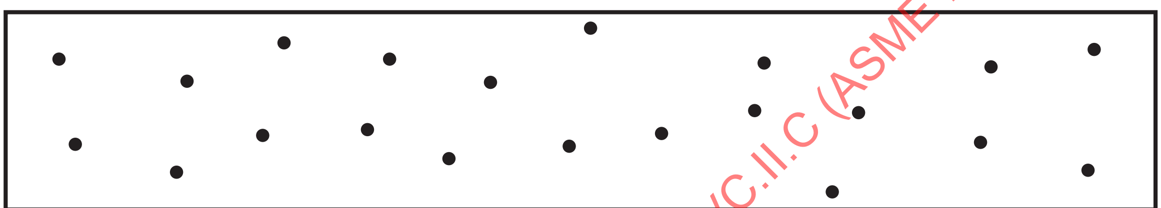
Notes:
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph, shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specially made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded.

Figure 8B—Radiographic Acceptance Standards for Rounded Indications (Grade 2)



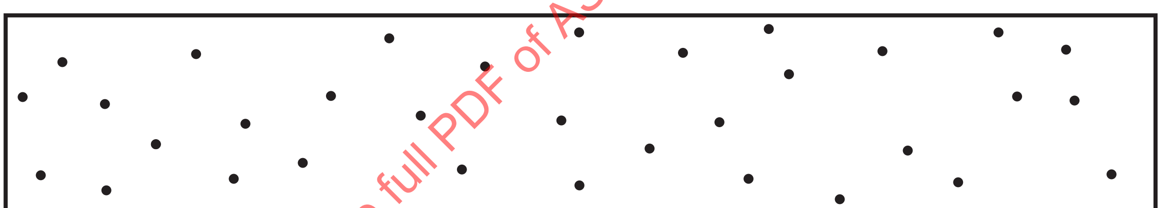
(I) ASSORTED ROUNDED INDICATIONS

SIZE: 1/64 in [0.4 mm] to 5/64 in [2.0 mm] in diameter or in length.
Maximum number of indications in any 6 in [150mm] of weld is 39, with the following restrictions:
Maximum number of large 1/16 in [1.6 mm] to 5/64 in [2.0 mm] is 3, and
Maximum number of medium 3/64 in [1.2 mm] to 1/16 in [1.6 mm] is 12, and
Maximum number of small 1/64 in [0.4 mm] to 3/64 in [1.2 mm] is 24.



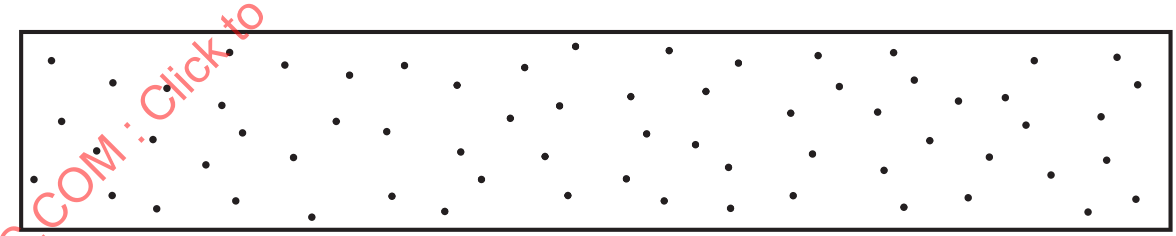
(J) LARGE ROUNDED INDICATIONS

SIZE: 1/16 in [1.6 mm] to 5/64 in [2.0 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 21.



(K) MEDIUM ROUNDED INDICATIONS

SIZE: 3/64 in [1.2 mm] to 1/16 in [1.6 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 33.



(L) SMALL RONDED INDICATIONS

SIZE: 1/64 in [0.4 mm] to 3/64 in [1.2 mm] in diameter or in length. Maximum number of indications in any 6 in [150 mm] of weld is 66.

Figure 8C—Radiographic Acceptance Standards for Rounded Indications (Grade 3)

Annex A (Informative)

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

This annex is not part of this standard, but is included for informational purposes only.

A1. Introduction

The purpose of this guide is to correlate the electrode 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 base metals for which each filler metal is suitable.

A2. Classification System

A2.1 The system for identifying the electrode classification in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix letter "E" at the beginning of each classification stands for electrode. The first two digits, 60 [43], for example, designate tensile strength of at least 60 ksi [430 MPa] of the weld metal, welded in accordance with the test assembly preparation clause of this specification. The third digit designates position usability that will allow satisfactory welds to be produced with the electrode. In this document, the classification in U.S. Customary Units is followed by the SI Unit classification in brackets.

Thus, the "1," as in E6010 [E4310], means that the electrode is usable in all positions (flat, horizontal, vertical, and overhead). The "2," as in E6020 [E4320] designates that the electrode is suitable for use in the flat position and for making fillet welds in the horizontal position. The "4," as in E7048 [E4948], designates that the electrode is suitable for use in vertical welding with downward progression and for other positions (see Table 1). The last two digits taken together designate the type of current with which the electrode can be used and the type of covering on the electrode, as listed in Table 1.

A2.2 Optional designators are also used in this specification in order to identify electrodes that have met the mandatory classification requirements and certain supplementary requirements as agreed to between the supplier and the purchaser. A "-1" designator following classification identifies an electrode which meets optional supplemental impact requirements at a lower temperature than required for the classification (see Table 5). An example of this is the E7024-1 [E4924-1] electrode which meets the classification requirements of E7024 [E4924] and also meets the optional supplemental requirements for toughness and improved elongation of the weld metal (see Note f to Table 4).

Certain low-hydrogen electrodes also may have optional designators. An optional supplemental designator "HZ" following the four digit classification designators or following the "-1" optional supplemental designator, if used, indicates an average diffusible hydrogen content of not more than "Z" mL/100g of deposited metal when tested in the "as-received" or conditioned state in accordance with AWS A4.3. Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 11, are also understood to be able to meet any higher hydrogen limits even though these are not necessarily designated along with the electrode classification. Therefore, as an example, an electrode designated as "H4" also meets "H8" and "H16" requirements without being designated as such. See Clause 18, Diffusible Hydrogen Test, and Table 11.

A letter “R” is a designator used with the low-hydrogen electrode classifications. It is used to identify electrodes that have been exposed to a humid environment for a given length of time and tested for moisture absorption in addition to the standard moisture test required for classification of low-hydrogen electrodes (see Clause 17 and Table 10).

A2.3 “G” Classification

A2.3.1 This specification includes filler metals classified as EXX-G. The last “G” indicates that the filler metal is of a *general* classification. It is *general* because the filler metal may not meet all requirements for any other classification. The purpose is to allow a useful filler metal to receive a classification before the specification is revised.

One filler metal of a “G” classification is not interchangeable with another filler metal of the same classification.

This specification contains provisions for the E60-G and E70-G [E43-G and E49-G] classifications.

A2.3.2 The point of difference between a particular filler metal of a “G” classification and all other filler metals of a similar classification with or without the “G” may be further clarified from the use of the words “not required” and “not specified” in the specification. The use of these words is as follows:

“Not Required” is used in those areas of the specification that specify the tests that must be conducted in order to classify a welding material. It indicates that that test is not required because the results for the particular test are not a requirement for that particular classification. When a test is “not required”, it is not necessary to conduct the corresponding test in order to classify a filler metal to that classification. When a purchaser wants the information provided by that test in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of the product. The purchaser will have to establish with that supplier just what the testing procedure and the acceptance requirements are to be for that test. The purchaser may want to incorporate that information (via AWS A5.01M/A5.01) in the purchase order.

“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. If the required results from a specific test are listed as “not specified” but the test in question is shown as “required” then the test results must be reported.

A2.3.3 Request for Filler Metal Classification. When a filler metal cannot be classified other than as a “G” classification, a manufacturer may request that a new classification be established. The manufacturer shall do this using the following procedure:

(1) A request to establish a new filler metal classification must be submitted in writing. The request needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials and the relevant Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, or if neither is necessary. In particular, the request needs to include:

(a) Declaration that the new classification will be offered for sale commercially;

(b) All classification requirements as given for existing classifications, such as, chemical composition ranges, mechanical property requirements, and usability test requirements;

(c) Any conditions for conducting the tests used to demonstrate that the filler metal meets the classification requirements (It would be sufficient, for example, to state that welding conditions are the same as for other classifications);

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

(e) 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 specification is silent regarding mechanical properties, test data submitted shall include appropriate weld metal mechanical properties from a minimum of two production heats/lots.

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

(2) In order to comply with the AWS Policy on Patented Items, Trademarks, and Restraint of Trade, if the proposed new classification is patented, if a patent is pending for it, or if there is any intention to apply for a patent, the requester

shall disclose this. In these cases, the patent holder must allow the use of this technology, such as by license. The Secretary will provide examples of acceptable wording to the patent holder, as required.

(3) The request should be sent to the Secretary of the Committee on Filler Metals and Allied Materials at AWS Headquarters for processing.

A2.3.4 *After the new classification is established, the –G classification may be retained for a period of time to allow for users to transition existing documents to the new classification.*

A2.4 International Classification System. An international system for designating welding filler metals has been developed by ISO. A complete series of ISO standards for filler metals and allied materials, including the vast majority of AWS classifications, but not all, has now been published. Some of these ISO standards have a single way of classification, like AWS standards. A number of the ISO standards dealing with steels are cohabitation standards. A cohabitation standard specifies two parallel systems, roughly corresponding to the European system (the "A" side) and the AWS system (the "B" side). In each case, the "B" side is usually similar to the AWS designation.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 as the specification states. Any testing a purchaser requires of the supplier, for material 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. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of AWS A5.01M/A5.01. 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 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 of the requirements of the specification. The only testing requirement implicit in this *certification* is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. *Certification* is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been made. 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 as defined in AWS A5.01M/A5.01.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding. They are:

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

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

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

(4) The proximity of welders and welding operators to the fumes, as these fumes issue from the welding zone, and to the gases and dust 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. See also AWS F3.2, *Ventilation Guide for Weld Fume* for more detailed descriptions of ventilation options.

A6. Welding Considerations

A6.1 Weld metal properties may vary widely, according to size of the electrode and amperage used, size of the weld beads, base metal thickness, joint geometry, preheat and interpass temperatures, surface condition, base metal composition, dilution, etc. Because of the profound effect of these variables, a test procedure was chosen for this specification that would represent good welding practice and minimize variation of the most potent of these variables.

A6.2 It should be recognized, however, that production practices may be different. The differences encountered may alter the properties of the weld metal. For instance, interpass temperatures may range from subfreezing to several hundred degrees. No single temperature or reasonable range of temperatures can be chosen for classification tests which will be representative of all of the conditions encountered in production work.

Properties of production welds may vary accordingly, depending on the particular welding conditions. Weld metal properties may not duplicate, or even closely approach, the values listed and prescribed for test welds. For example, ductility in single-pass welds in thick base metal made outdoors in cold weather without adequate preheating may drop to little more than half that required herein and normally obtained. This does not indicate that either the electrodes or the welds are below standard. It indicates only that the particular production conditions are more severe than the test conditions prescribed by this specification.

A6.3 Hydrogen is another factor to be considered in welding. Weld metals, other than those from low-hydrogen electrodes (*E6018 [E4318],* E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7028 [E4928], and E7048 [E4948]) contain significant quantities of hydrogen for some period of time after they have been made. Most of this hydrogen gradually escapes. After two to four weeks at room temperature or 24 hours to 48 hours at 200 °F to 220 °F [90 °C to 105 °C], most of it has escaped. As a result of this change in hydrogen content, ductility of the weld metal increases towards its inherent value, while yield, tensile and impact *properties* remain relatively unchanged.

This specification permits aging of the weld plate or test specimens of cellulosic electrodes at up to 220 °F [105 °C] for up to 48 hours before subjecting them to tension testing. This is done to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrodes, 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.

A6.4 When weldments are given a postweld heat treatment, the temperature and time at temperature are very important. The tensile and yield strengths are generally decreased as postweld heat treatment temperatures and time at temperature are increased.

A6.5 Welds made with electrodes of the same classification and the same welding procedure will have significantly different tensile and yield strengths in the as-welded and postweld heat-treated conditions. Comparison of the values for as-welded and postweld heat-treated (1150 °F [620 °C] for one hour) weld metal will show the following:

A6.5.1 The tensile strength of the postweld heat-treated weld metal will be approximately 5 ksi [35 MPa] lower than that of the weld metal in the as-welded condition.

A6.5.2 The yield strength of the postweld heat-treated weld metal will be approximately 10 ksi [70 MPa] lower than that of the weld metal in the as-welded condition.

A6.6 Conversely, postweld heat-treated welds made with the same electrodes and using the same welding procedure except for variation in interpass temperature and postweld heat treatment time, can have almost identical tensile and yield strengths. As an example, almost identical tensile and yield strengths may be obtained in two welds, one using an interpass temperature of 300 °F [150 °C] and postweld heat-treated for 1 hour at 1150 °F [620 °C], and the other using an interpass temperature of 212 °F [100 °C] and postweld heat-treated for 10 hours at 1150 °F [620 °C].

A6.7 Electrodes which meet all the requirements of any given classification may be expected to have similar characteristics. Certain minor differences continue to exist from one brand to another due to differences in preferences that exist regarding specific operating characteristics. Furthermore, the only differences between the present E60XX and E70XX [E43XX and E49XX] classifications are the differences in chemical composition and mechanical properties of the weld metal, as shown in Tables 4, 5, and 6. In many applications, electrodes of either E60XX or E70XX [E43XX or E49XX] classifications may be used.

A6.8 Since the electrodes within a given classification have similar operating characteristics and mechanical properties, the user can limit the study of available electrodes to those within a single classification after determining which classification best suits the particular requirements.

A6.9 This specification does not establish values for all characteristics of the electrodes falling within a given classification, but it does establish values to measure those of major importance. In some instances, a particular characteristic is common to a number of classifications and testing for it is not necessary. In other instances, the characteristics are so intangible that no adequate tests are available. This specification does not necessarily provide all the information needed to determine which classification will best fulfill a particular need. The information included in Annex Clause A7 regarding typical applications for each classification supplements information given elsewhere in the specification and is intended to provide assistance in making electrode selections. However, it must be noted that it is the fabricator's responsibility to ensure that the electrode selected will satisfy all of the performance requirements for the intended applications under the specific fabrication conditions in use.

A6.10 Some important tests for measuring major electrode characteristics are as follows:

A6.10.1 Radiographic Test. Nearly all of the carbon steel electrodes covered by this specification are capable of producing welds that meet most radiographic soundness requirements. However, if incorrectly applied, unsound welds may be produced by any of the electrodes. For electrodes of some classifications, the radiographic requirements in Figure 8 are not necessarily indicative of the average radiographic soundness to be expected in production use. Electrodes of the E6010 [E4310], E6011 [E4311], E6019 [E4319], and E6020 [E4320] classifications can be expected to produce acceptable radiographic results.

Under certain conditions, notably in welding long, continuous joints in relatively thick base metal, low-hydrogen electrodes of the E7015 [E4915], E7016 [E4916], E7018 [E4918], and E7018M [E4918M] classifications will often produce even better results. On the other hand, in joints open to the atmosphere on the root side, at the ends of joints, in joints with many stops and starts, and in welds on small diameter pipe or in small, thin, irregularly shaped joints, the low-hydrogen electrodes tend to produce welds of poor radiographic soundness. For the shielded metal arc process, E6013 [E4313] electrodes usually produce the best radiographic soundness in welding small, thin parts.

E6027 [E4327], E7024 [E4924], and E7028 [E4928] electrodes produce welds which may be either quite good or rather inferior in radiographic soundness. The tendency seems to be in the latter direction. Of all types, the E6022 [E4322] and E6012 [E4312] electrodes generally produce welds with the least favorable radiographic soundness.

A6.10.2 Fillet Weld Test This test is included as a means of demonstrating the usability of an electrode. The test is concerned with the appearance of the weld (i.e., weld face contour and smoothness, undercut, overlap, size, and resistance to cracking). It also provides an excellent and inexpensive method of determining the adequacy of fusion at the weld root (one of the important considerations for an electrode). Test results may be influenced by the level of welder skill.

A6.10.3 Toughness. Charpy V-notch impact requirements are included in the specification. All classifications of electrodes in the specification can produce weld metal of sufficient toughness for many applications. The inclusion of impact requirements for certain electrode classifications allows the specification to be used as a guide in selecting electrodes where low- temperature toughness is required. There can be considerable variation in the weld-metal toughness unless particular attention is given to the welding procedure and the preparation and testing of the specimens. The impact energy values are for Charpy V-notch specimens and should not be confused with values obtained with other toughness tests.

A6.11 Electrode Covering Moisture Content and Conditioning

A6.11.1 Hydrogen can have adverse effects on welds in some steels under certain conditions. One source of this hydrogen is moisture in the electrode coverings. For this reason, the proper storage, treatment, and handling of electrodes are necessary.

A6.11.2 Electrodes are manufactured to be within acceptable moisture limits, consistent with the type of covering and strength of the weld metal. They are then normally packaged in a container, which has been designed to provide the degree of moisture protection considered necessary for the type of covering involved.

A6.11.3 If there is a possibility that the noncellulosic covered electrodes may have absorbed excessive moisture, they may be reconditioned by rebaking. Some electrodes require rebaking at a temperature as high as 800 °F [425 °C] for approximately 1 to 2 hours. The manner in which the electrodes have been produced and the relative humidity and temperature conditions under which the electrodes are stored determine the proper length of time and temperature used for conditioning. Some typical storage and drying conditions are included in Table A1.

A6.11.4 Cellulosic coverings for E6010 [E4310] and E6011 [E4311] electrodes need moisture levels of approximately 3% to 7% for proper operation. Therefore, storage or conditioning above ambient temperature may dry these electrodes too much and adversely affect their operation (see Table A1).

A6.12 Core Wire. The core wire for all the electrodes in this specification is usually a mild steel having a typical composition which may differ significantly from that of the weld metal produced by the covered electrode.

A6.13 Coverings

A6.13.1 Electrodes of some classifications have substantial quantities of iron and other metal powders added to their coverings. (Use of the term "iron powder" herein is intended to include metal powders added to the coating for alloying of the weld metal.) The iron powder fuses with the core wire as the electrode melts, and is deposited as part of the weld metal, just as is the core wire and other metals in the covering. Relatively high currents can be used since a considerable portion of the electrical energy passing through the electrode is used to melt the thicker covering containing iron powder. The result is that more weld metal may be obtained from a single electrode with iron powder in its covering than from a single electrode of the same size without iron powder.

A6.13.2 Due to the thick covering and deep cup produced at the arcing end of the electrode, iron powder electrodes can be used very effectively with a "drag" technique. This technique consists of keeping the electrode covering in contact with the workpiece at all times, which makes for easy handling. However, a technique using a short arc length is preferable if the 3/32 in [2.5 mm] or 1/8 in [3.2 mm] electrodes are to be used in other than flat or horizontal fillet welding positions or for making groove welds.

A6.13.3 The E70XX [E49XX] electrodes were included in this specification to recognize the higher strength levels obtained with many of the iron powder and low hydrogen electrodes, as well as to recognize the industry demand for electrodes with 70 ksi [490 MPa] minimum tensile strength. Unlike the E70XX-X [E49XX-X] classifications in AWS A5.5/A5.5M, these electrodes do not contain deliberate alloy additions, nor are they required to meet minimal tensile properties after postweld heat treatment.

A6.13.4 E70XX [E49XX] low-hydrogen electrodes have mineral coverings which are high in limestone and other ingredients that are low in moisture and hence produce weld deposits "low in hydrogen content." Low-hydrogen electrodes were developed for welding low-alloy high-strength steels, some of which were high in carbon content. Electrodes with other than low-hydrogen coverings may produce "hydrogen-induced cracking" in those steels. These underbead cracks occur in the base metal, usually just below the weld bead. Weld metal cracks may also occur.

Low-hydrogen electrodes should be used when welding high-sulfur or enameling steels. Other electrodes are likely to cause porosity and/or cracks in high-sulfur steels. With enameling steels, the hydrogen that escapes after welding with other than low-hydrogen electrodes produces holes in the enamel.

Some extra-low hydrogen (H4) electrode coatings may be prone to reduced operability and producing unacceptable porosity. The unacceptable condition is usually associated with varying or excessive arc length and is highly dependent on operator skill level.

A6.14 Welding Parameters. Appropriate parameters vary by product, polarity, welding position, etc. The electrode manufacturer should be consulted for recommended parameters.

A7. Description and Intended Use of Electrodes

A7.1 E6010 [E4310] Classification

A7.1.1 E6010 [E4310] electrodes are characterized by a deeply penetrating, forceful, spray type arc and readily removable, thin, friable slag which may not seem to completely cover the weld bead. Fillet welds usually have a relatively flat weld face and have a rather coarse, unevenly spaced ripple. The coverings are high in cellulose, usually exceeding 30% by weight. The other materials generally used in the covering include titanium dioxide, metallic deoxidizers such as ferromanganese, various types of magnesium or aluminum silicates, and liquid sodium silicate as a binder. Because of their covering composition, these electrodes are generally described as the high-cellulose sodium type.

A7.1.2 These electrodes are recommended for all welding positions, particularly on multiple pass applications in the vertical and overhead welding positions and where welds of good soundness are required. They frequently are selected for joining pipe and generally are capable of welding in the vertical position with either uphill or downhill progression.

A7.1.3 The majority of applications for these electrodes is in joining carbon steel. However, they have been used to advantage on galvanized steel and on some low-alloy steels. Typical applications include shipbuilding, buildings, bridges, storage tanks, piping, and pressure vessel fittings. Since the applications are so widespread, a discussion of each is impractical. Sizes larger than 3/16 in [5.0 mm] generally have limited use in other than flat or horizontal-fillet welding positions.

A7.1.4 These electrodes have been designed for use with dcep (electrode positive). The maximum amperage that can generally be used with the larger sizes of these electrodes is limited in comparison to that for other classifications due to the high spatter loss that occurs with high amperage.

A7.2 E6011 [E4311] Classification

A7.2.1 E6011 [E4311] electrodes are designed to be used with ac current and to duplicate the usability characteristics and mechanical properties of the E6010 [E4310] classification. Although also usable with dcep (electrode positive), a decrease in joint penetration will be noted when compared to the E6010 [E4310] electrodes. Arc action, slag, and fillet weld appearance are similar to those of the E6010 [E4310] electrodes.

A7.2.2 The coverings are also high in cellulose and are described as the high-cellulose potassium type. In addition to the other ingredients normally found in E6010 [E4310] coverings, small quantities of calcium and potassium compounds usually are present.

A7.2.3 Sizes larger than 3/16 in [5.0 mm] generally have limited use in other than flat or horizontal-fillet welding positions.

A7.3 E6012 [E4312] Classification

A7.3.1 E6012 [E4312] electrodes are characterized by low penetrating arc and dense slag, which completely covers the bead. This may result in incomplete root penetration in fillet welded joints. The coverings are high in titania, usually exceeding 35% by weight, and usually are referred to as the "titania" or "rutile" type. The coverings generally also contain small amounts of cellulose and ferromanganese, and various siliceous materials such as feldspar and clay with sodium silicate as a binder. Also, small amounts of certain calcium compounds may be used to produce satisfactory arc characteristics on dcen (electrode negative).

A7.3.2 Fillet welds tend to have a convex weld face with smooth even ripples in the horizontal welding position, and widely spaced rougher ripples in the vertical welding position which become smoother and more uniform as the size of the weld is increased. Ordinarily, a larger size fillet must be made in the vertical and overhead welding positions using E6012 [E4312] electrodes compared to welds with E6010 [E4310] and E6011 [E4311] electrodes of the same diameter.

A7.3.3 The E6012 [E4312] electrodes are all-position electrodes and usually are suitable for welding in the vertical welding position with either the upward or downward progression. However, more often the larger sizes are used in the flat and horizontal welding positions rather than in the vertical and overhead welding positions. The larger sizes are often used for single pass, high-speed, high current fillet welds in the horizontal welding position. Their ease of handling, good fillet weld face, and ability to bridge wide root openings under conditions of poor fit, and to withstand high amperages make them very well suited to this type of work. The electrode size used for vertical and overhead position welding is frequently one size smaller than would be used with an E6010 [E4310] or E6011 [E4311] electrode.

A7.3.4 Weld metal from these electrodes is generally lower in ductility and may be higher in yield strength (1 ksi to 2 ksi [7 MPa to 14 MPa]) than weld metal from the same size of either the E6010 [E4310] or E6011 [E4311] electrodes.

A7.4 E6013 [E4313] Classification

A7.4.1 E6013 [E4313] electrodes, although very similar to the E6012 [E4312] electrodes, have distinct differences. Their flux covering makes slag removal easier and gives a smoother arc transfer than E6012 [E4312] electrodes. This is particularly the case for the small diameters 1/16 in, 5/64 in, and 3/32 in [1.6 mm, 2.0 mm, and 2.5 mm]. This permits satisfactory operation with lower open-circuit ac voltage. E6013 [E4313] electrodes were designed specifically for light sheet metal work. However, the larger diameters are used on many of the same applications as E6012 [E4312] electrodes and provide low penetrating arc. The smaller diameters provide a less penetrating arc than is obtained with E6012 [E4312] electrodes. This may result in incomplete penetration in fillet welded joints.

A7.4.2 Coverings of E6013 [E4313] electrodes contain rutile, cellulose, ferromanganese, potassium silicate as a binder, and other siliceous materials. The potassium compounds permit the electrodes to operate with ac at low amperages and low open-circuit voltages.

A7.4.3 E6013 [E4313] electrodes are similar to the E6012 [E4312] electrodes in usability characteristics and bead appearance. The arc action tends to be quieter and the bead surface smoother with a finer ripple. The usability characteristics of E6013 [E4313] electrodes vary slightly from brand to brand. Some are recommended for sheet metal applications where their ability to weld satisfactorily in the vertical welding position with downward progression is an advantage.

Others, with a more fluid slag, are used for horizontal fillet welds and other general purpose welding. These electrodes produce a flat fillet weld face rather than the convex weld face characteristic of E6012 [E4312] electrodes. They are also suitable for making groove welds because of their concave weld face and easily removable slag. In addition, the weld metal is definitely freer of slag and oxide inclusions than E6012 [E4312] weld metal and exhibits better soundness. Welds with the smaller diameter E6013 [E4313] electrodes often meet the Grade 1 radiographic requirements of this specification.

A7.4.4 E6013 [E4313] electrodes usually cannot withstand the high amperages that can be used with E6012 [E4312] electrodes in the flat and horizontal welding positions. Amperages in the vertical and overhead positions, however, are similar to those used with E6012 [E4312] electrodes.

A7.5 E7014 [E4914] Classification

A7.5.1 E7014 [E4914] electrode coverings are similar to those of E6012 [E4312] and E6013 [E4313] electrodes, but with the addition of iron powder for obtaining higher deposition efficiency. The covering thickness and the amount of iron powder in E7014 [E4914] are less than in E7024 [E4924] electrodes (see A7.10).

A7.5.2 The iron powder also permits the use of higher amperages than are used for E6012 [E4312] and E6013 [E4313] electrodes. The amount and character of the slag permit E7014 [E4914] electrodes to be used in all positions.

A7.5.3 The E7014 [E4914] electrodes are suitable for welding carbon and low alloy steels. Typical weld beads are smooth with fine ripples. Joint penetration is approximately the same as that obtained with E6012 [E4312] electrodes (see A7.3.1), which is advantageous when welding over a wide root opening due to poor fit. The face of fillet welds tends to be flat to slightly convex. The slag is easy to remove. In many cases, it removes itself.

A7.6 Low-Hydrogen Electrodes

A7.6.1 Electrodes of the low-hydrogen classifications E6018 [E4318], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7028 [E4928], and E7048 [E4948]) are made with inorganic coverings that contain minimal moisture. The covering moisture test such as specified in AWS A4.4M, converts hydrogen-bearing compounds in any form in the covering into water vapor that is collected and measured. The test thus assesses the potential hydrogen available from an electrode covering. All low-hydrogen electrodes, in the as-manufactured condition or after conditioning, are expected to meet a maximum covering moisture limit of 0.6% or less, as required in Table 10.

A7.6.2 The relative potential of an electrode to contribute to diffusible hydrogen in the weld metal can be assessed more directly, but less conveniently, by the diffusible hydrogen test, as specified in Clause 18. The results of this test, using electrodes in the as-manufactured condition or after conditioning, permit the addition of an optional supplemental diffusible hydrogen designator to the classification designation according to Table 11.

A7.6.3 In order to maintain low-hydrogen electrodes with minimal moisture in their coverings, these electrodes should be stored and handled with considerable care. Electrodes which have been exposed to humidity may absorb considerable moisture and their low-hydrogen character may be lost. Then conditioning can restore their low-hydrogen-character (see Table A.1).

A7.6.4 Low-hydrogen electrode coverings can be designed to resist moisture absorption for a considerable time in a humid environment. The absorbed moisture test (see Clause 17) assesses this characteristic by determining the covering moisture after nine hours exposure to 80 °F [27 °C], 80% relative humidity air. If, after this exposure, the covering moisture does not exceed 0.4%, then the optional supplemental designator, "R," may be added to the electrode classification designation, as specified in Table 10.

A7.6.5 E7015 [E4915] Classification (Low Hydrogen)

A7.6.5.1 E7015 [E4915] electrodes are low-hydrogen electrodes to be used with dcep (electrode positive). The slag is chemically basic.

A7.6.5.2 E7015 [E4915] electrodes are commonly used for making small welds on thick base metal, since the welds are less susceptible to cracking. They are also used for welding high-sulfur and enameling steels. Welds made with E7015 [E4915] electrodes on high-sulfur steels may produce a very tight slag and a very rough or irregular bead appearance in comparison to welds with the same electrodes in steels of normal sulfur content.

A7.6.5.3 The arc of E7015 [E4915] electrodes is moderately penetrating. The slag is heavy, friable, and easy to remove. The weld face is convex, although a fillet weld face may be flat.

A7.6.5.4 E7015 [E4915] electrodes up to and including the 5/32 in [4.0 mm] size are used in all welding positions. Larger electrodes are used for groove welds in the flat welding position and fillet welds in the horizontal and flat welding positions.

A7.6.5.5 Amperages for E7015 [E4915] electrodes are higher than those used with E6010 [E4310] electrodes of the same diameter. The shortest possible arc length should be maintained for best results with E7015 [E4915] electrodes. This reduces the risk of porosity. The necessity for preheating is reduced; therefore, better welding conditions are provided.

A7.6.6 E7016 [E4916] Classification

A7.6.6.1 E7016 [E4916] electrodes have all the characteristics of E7015 [E4915] electrodes, plus the ability to operate on ac. The core wire and coverings are very similar to those of E7015 [E4915], except for the use of a potassium silicate binder or other potassium salts in the coverings to facilitate their use with ac. Most of the preceding discussion on E7015 [E4915] electrodes applies equally well to the E7016 [E4916] electrodes. The discussion in A6.13.4 also applies.

A7.6.6.2 Electrodes designated as E7016-1 [E4916-1] have the same usability and weld metal composition as E7016 [E4916] electrodes except that the manganese content is set at the high end of the range. They are intended for welds requiring a lower transition temperature than is normally available from E7016 [E4916] electrodes.

A7.6.7 E6018 [E4318] and E7018 [E4918] Classifications

A7.6.7.1 E7018 [E4918] electrode coverings are similar to E7015 [E4915] coverings, except for the addition of a relatively high percentage of iron powder. The coverings on these electrodes are slightly thicker than those of the E7016 [E4916] electrodes.

A7.6.7.2 E7018 [E4918] low-hydrogen electrodes can be used with either ac or dcep. They are designed for the same applications as the E7016 [E4916] electrodes. As is common with all low-hydrogen electrodes, a short arc length should be maintained at all times.

A7.6.7.3 In addition to their use on carbon steel, the E7018 [E4918] electrodes are also used for joints involving high-strength, high-carbon, or low-alloy steels (see also A6.13). The fillet welds made in the horizontal and flat welding positions have a slightly convex weld face, with a smooth and finely rippled surface. The electrodes are characterized by a smooth, quiet arc, very low spatter, and medium arc penetration. E7018 [E4918] electrodes can be used at high travel speeds.

A7.6.7.4 Electrodes designated as E7018-1 [E4918-1] have the same usability and weld metal composition as E7018 [E4918] electrodes, except that the manganese content is set at the high end of the range. They are intended for welds requiring a lower transition temperature than is normally available from E7018 [E4918] electrodes.

A7.6.7.5 E6018 [E4318] electrodes possess operating and mechanical property characteristics similar to E7018 [E4918] except at a lower strength level. The electrode covering and low hydrogen characteristics are also similar. This electrode is desirable where matching or undermatching weld deposit is required. Electrodes that meet this classification may also be suitable for buffer layer application in cladding operations.

A7.6.8 E7018M [E4918M] Classification

A7.6.8.1 E7018M [E4918M] electrodes are similar to E7018-1H4R [E4918-1H4R] electrodes, except that the testing for mechanical properties and for classification is done on a groove weld that has a 60° included angle and, for electrodes up to 5/32 in [4.0mm], welded in the vertical position with upward progression. The impact test results are evaluated using all five test values and higher values are required at –20 °F [–30 °C]. The maximum allowable moisture-in-coating values in the "as-received" or reconditioned state are more restrictive than that required for E7018R [E4918R]. This classification closely corresponds to MIL-7018-M in the United States military standard MIL-E-22200/10 specification, with the exception that the absorbed moisture limits on the electrode covering and the diffusible hydrogen limits on the weld metal are not as restrictive as those in MIL-E-22200/10.

A7.6.8.2 E7018M [E4918M] is intended to be used with dcep type current in order to produce the optimum mechanical properties. However, if the manufacturer desires, the electrode may also be classified as E7018 [E4918] provided all the requirements of E7018 [E4918] are met.

A7.6.8.3 In addition to their use on carbon steel, the E7018M [E4918M] electrodes are used for joining carbon steel to high-strength low-alloy steels and higher carbon steels. Fillet welds made in the horizontal and flat welding positions have a slightly convex weld face, with a smooth and finely rippled surface. The electrodes are characterized by a smooth, quiet arc, very low spatter, and medium arc penetration.

A7.6.9 E7028 [E4928] Classification

A7.6.9.1 E7028 [E4928] electrodes are very much like the E7018 [E4918] electrodes. However, E7028 [E4928] electrodes are suitable for fillet welds in the horizontal welding position and groove welds in the flat welding position only, whereas E7018 [E4918] electrodes are suitable for all positions.

A7.6.9.2 The E7028 [E4928] electrode coverings are much thicker. They make up approximately 50% of the weight of the electrodes. The iron content ofE7028 [E4928] electrodes is higher (approximately 50% of the weight of the coverings). Consequently, on fillet welds in the horizontal position and groove welds in the flat welding position, E7028 [E4928] electrodes give a higher deposition rate than the E7018 [E4918] electrodes for a given size of electrode.

A7.6.10 E7048 [E4948] Classification. Electrodes of the E7048 [E4948] classification have the same usability, composition, and design characteristics as E7018 [E4918] electrodes, except that E7048 [E4948] electrodes are specifically designed for exceptionally good vertical welding with downward progression (see Table 1).

A7.7 E6019 [E4319] Classification

A7.7.1 E6019 [E4319] electrodes, although very similar to E6013 and E6020 [E4313 and E4320] electrodes in their coverings, have distinct differences. E6019 [E4319] electrodes, with a rather fluid slag system, provide deeper arc penetration and produce weld metal that meets a 22% minimum elongation requirement, meets the Grade 1 radiographic standards, and meets an average impact *energy* of 20 ft·lbf [27J] when tested at 0 °F [–20 °C].

A7.7.2 E6019 [E4319] electrodes are suitable for multipass welding of up to 1 in [25 mm] thick steel. They are designed for use with ac, dcen, or dcep. While 3/16 in [5.0 mm] and smaller diameter electrodes can be used for all welding positions (except vertical welding position with downward progression), the use of larger diameter electrodes should be limited to the flat or horizontal fillet welding positions. When welding in the vertical welding position with upward progression, weaving should be limited to minimize undercut.

A7.8 E6020 [E4320] Classification

A7.8.1 E6020 [E4320] electrodes have a high iron oxide covering. They are characterized by a spray type arc, produce a smooth and flat or slightly concave weld face, and have an easily removable slag.

A7.8.2 A low viscosity slag limits their usability to horizontal fillets and flat welding positions. With arc penetration ranging from medium to deep (depending upon welding current), E6020 [E4320] electrodes are best suited for thicker base metal.

A7.9 E6022 [E4322] Classification. Electrodes of the E6022 [E4322] classification are recommended for single-pass, high-speed, high-current welding of groove welds in the flat welding position, lap joints in the horizontal welding position, and fillet welds on sheet metal. The weld face tends to be more convex and less uniform, especially since the welding speeds are higher. *The common usage of E6022 is for burn-thru spot welding, such as connecting floor decking to beams. These electrodes provide deep penetration with little slag interference with the arc.*

A7.10 E7024 [E4924] Classification

A7.10.1 E7024 [E4924] electrode coverings contain large amounts of iron powder in combination with ingredients similar to those used in E6012 and E6013 [E4312 and E4313] electrodes. The coverings on E7024 [E4924] electrodes are very thick and usually amount to about 50% of the weight of the electrode, resulting in higher deposition efficiency.

A7.10.2 The E7024 [E4924] electrodes are well suited for making fillet welds in the flat or horizontal position. The weld face is slightly convex to flat, with a very smooth surface and a very fine ripple. These electrodes are characterized by a smooth, quiet arc, very low spatter, and low arc penetration. They can be used with high travel speeds. Electrodes of these classifications can be operated on ac, dcep, or dcen.

A7.10.3 Electrodes designated as E7024-1 [E4924-1] have the same general usability characteristics as E7024 [E4924] electrodes. They are intended for use in situations requiring greater ductility and a lower transition temperature than normally is available from E7024 [E4924] electrodes. *These electrodes have less stringent radiographic requirements than other classifications*.

A7.11 E6027 [E4327] Classification

A7.11.1 E6027 [E4327] electrode coverings contain large amounts of iron powder in combination with ingredients similar to those found in E6020 [E4320] electrodes. The coverings on E6027 [E4327] electrodes are also very thick and usually amount to about 50% of the weight of the electrode.

A7.11.2 The E6027 [E4327] electrodes are designed for fillet or groove welds in the flat welding position with ac, dcep, or dcen, and will produce a flat or slightly concave weld face on fillet welds in the horizontal position with either ac or dcen.

A7.11.3 E6027 [E4327] electrodes have a spray-type arc. They will operate at high travel speeds. Arc penetration is medium. Spatter loss is very low. E6027 [E4327] electrodes produce a heavy slag which is honeycombed on the underside. The slag is friable and easily removed.

A7.11.4 Welds produced with E6027 [E4327] electrodes have a flat to slightly concave weld face with a smooth, fine, even ripple, and good wetting along the sides of the joint. The weld metal may be slightly inferior in radiographic soundness to that from E6020 [E4320] electrodes. High amperages can be used, since a considerable portion of the electrical energy passing through the electrode is used to melt the covering and the iron powder it contains. These electrodes are well suited for thicker base metal.

A7.12 E7027 [E4927] Classification. E7027 [E4927] electrodes have the same usability and design characteristics as E6027 [E4327] electrodes, except they are intended for use in situations requiring slightly higher tensile and yield strengths than are obtained with E6027 [E4327] electrodes. They must also meet chemical composition requirements (see Table 6). In other respects, all previous discussions for E6027 [E4327] electrodes also apply to E7027 [E4927] electrodes.

A8. Special Tests

It is recognized that supplementary tests may be necessary for certain applications. In such cases, tests to determine specific properties such as hardness, corrosion resistance, mechanical properties at elevated or cryogenic temperatures, wear resistance, and suitability for welding different carbon and low-alloy steels, may be required. AWS A5.01M/A5.01 contains provisions for ordering such tests. This clause is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed upon between the purchaser and supplier.

A8.1 Diffusible Hydrogen Test.

A8.1.1 Hydrogen-induced cracking of weld metal or the heat affected zone generally is not a problem with carbon steels containing 0.3% or less carbon, or with lower-strength alloy steels. However, the electrodes classified in this specification are sometimes used to join higher carbon steels or low-alloy, high-strength steels where hydrogen-induced cracking may be a serious problem.

A8.1.2 Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-induced cracking, it may be desirable to measure the diffusible hydrogen content resulting from welding with a particular electrode. 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.

A8.1.3 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

A8.1.4 The use of a reference atmospheric condition during welding is necessitated because the arc is subject to atmospheric contamination due to imperfect shielding. Moisture from the air, distinct from that in the electrode, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining as short an arc length as possible consistent with a steady arc. Experience has shown that the effect of arc length is minor at the H16 level, but can be very significant at the H4 level. An electrode meeting the H4 requirements under the reference atmospheric conditions may not do so under conditions of high humidity at the time of welding, especially if a long arc length is maintained.

A8.1.5 Low-hydrogen electrodes 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 exposure of unprotected electrodes for as little as two hours can lead to a significant increase of diffusible hydrogen. In the event the electrodes have been exposed, the manufacturer should be consulted regarding probable damage to low hydrogen characteristics and possible reconditioning of the electrodes.

A8.1.6 Not all classifications may be available in H16, H8, and H4 diffusible hydrogen levels. The manufacturer of a given electrode should be consulted for availability of products meeting these limits.

A8.2 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 properties remain relatively unchanged. The A5.1 and A5.1M specifications permit the aging of the test specimens or weld test assembly for non-low hydrogen electrodes at elevated temperatures not exceeding 220 °F [105 °C] for up to 48 hours before cooling them to room temperature and subjecting them to testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to narrow the variation in the test results.

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. It should be kept in mind that aging test assemblies may not remove as much diffusible hydrogen as aging the individual specimens. The purchaser may, by mutual agreement with the supplier, have the thermal aging of specimens prohibited for all mechanical testing done to schedule I or J of AWS A5.01M/A5.01.

A8.3 Absorbed Moisture Test. The development of low-hydrogen electrode coverings that resist moisture absorption during exposure to humid air is a more recent improvement in covered electrode technology. Not all commercial low-hydrogen electrodes possess this characteristic. To assess this characteristic, the absorbed moisture test described in Clause 17 was devised. The exposure conditions selected for the test are arbitrary. Other conditions may yield quite different results.

A task group of the AWS A5A Subcommittee evaluated this test and concluded that it can successfully differentiate moisture resistant electrodes from those which are not. The task group also observed considerable variability of covering moisture results after exposure of electrodes in cooperative testing among several laboratories. The precision of the test is such that, with moisture resistant electrodes from a single lot, the participating laboratories could observe exposed covering moisture values ranging, for example, from 0.15% or less, to 0.35% or more. The task group concluded that the variability was due to both variations in the exposure conditions and the variability inherent in the application of the moisture test procedure. Therefore, it is not realistic to set a limit for covering moisture of exposed moisture resistant electrodes lower than 0.4% at that time.

A9. Discontinued Classifications

Some classifications have been discontinued from one revision of this specification to another. This results either from changes in commercial practice or changes in the classification system used in the specification. The classifications that have been discontinued are listed in Table A.2, along with the year in which they were last included in the specification.

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 AWS Safety and Health Fact Sheets and ANSI Z49.1 and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets 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.

Table A.1
Typical Storage and Drying Conditions for Covered Arc Welding Electrodes

AWS Classification		Storage Conditions[a, b]		Drying Conditions[c]
A5.1	A5.1M	Ambient Air	Holding Ovens	
E6010, E6011	E4310, E4311	Ambient Temperature	Not Recommended	
E6012, E6013, E6019, E6020, E6022, E6027, E7014, E7024, E7027	E4312, E4313, E4319, E4320, E4322, E4327, E4914, E4924, E4927	80 °F ± 20 °F [30 °C ± 10 °C] 50% max. relative humidity	20 °F to 40 °F [10 °C to 20 °C] above ambient temperature	275 °F ± 25 °F [135 °C ± 15 °C] 1 hour at temperature
E6018, E7015, E7016, E7018, E7028 E7018M, E7048	E4318, E4915, E4916, E4918, E4928, E4918M, E4948	Not Recommended	50 °F to 250 °F [30 °C to 140 °C] above ambient temperature	500 °F to 800 °F [260 °C to 425 °C] 1 to 2 hours at temperature
E60-G, E70-G	*E43-G, E49-G*	*Manufacturer should be consulted for specific storage and drying recommendations*	*Manufacturer should be consulted for specific storage and drying recommendations*	*Manufacturer should be consulted for specific storage and drying recommendations*

[a] After removal from manufacturer's packaging.
[b] Some of these electrode classifications may be designated as meeting low moisture absorbing requirements. This designation does not imply that storage in ambient air is recommended.
[c] Because of inherent differences in covering composition, the manufacturers should be consulted for the exact drying conditions.

Table A.2
Discontinued Electrode Classifications[a]

AWS Classification	Last A5.1 (ASTM A-233) Publication Date	AWS Classification	Last A5.1 (ASTM A-233) Publication Date
E4511	1943	E9030	1945
E4521	1943	E10010[b]	1945
E7010[b]	1945	E10011[b]	1945
E7011[b]	1945	E10012	1945
E7012	1945	E10020	1945
E7020[b]	1945	E10030	1945
E7030	1945	E4510	1958
E8010[b]	1945	E4520	1958
E8011[b]	1945	E6014	1958
E8012	1945	E6015	1958
E8020[b]	1945	E6016	1958
E8030	1945	E6018[c]	1958
E9010[b]	1945	E6024	1958
E9011[b]	1945	E6028	1958
E9012	1945	E6030	1958
E9020	1945		

[a] See Clause A9 for information on discontinued classifications.
[b] These electrode classifications were transferred from the ASTM A233-45T to the new AWS A5.5-48T. They were later discontinued from that specification and replaced with the new "G" classifications in order to permit a single classification system with weld metal chemical composition requirements in AWS A5.5-58T.
[c] This classification was reintroduced in the 2004 revision of AWS A5.1/A5.1M with revised classification requirements.

Annex B (Informative)

Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard but is included for informational purposes only.

B1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

B2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. 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.

B3. General Procedure for all Requests

B3.1 Submission. All requests shall be sent to the Managing Director, AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

B3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

B3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

B3.4 Question(s). All requests shall be stated in the form of a question that can be answered 'yes' or 'no'. The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

B3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

B3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

B4. AWS Policy on Interpretations

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 official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

B5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the *Welding Journal*, and post it on the AWS website.

B6. 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.

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, A5.35	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, A5.35	A5.9, A5.22	A5.22	A5.9, A5.22, A5.39	A5.9, A5.22, A5.39	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11, A5.35	A5.14, A5.34	A5.34	A5.14, A5.34, A5.39	A5.14, A5.34, A5.39		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	

AWS Filler Metal Specifications and Related Documents

Designation	Title
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*
A4.5M/A4.5 (ISO 15792-3 MOD)	*Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*
A5.01M/A5.01 (ISO 14344 MOD)	*Welding Consumables—Procurement of Filler Materials and Fluxes*
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 and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel 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 Electrodes for Shielded Metal Arc Welding*
A5.7/A5.7M	*Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*
A5.8M/A5.8	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M (ISO 14343 MOD)	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M (ISO 18273 MOD)	*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 (ISO 24034 MOD)	*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 and High Manganese 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*
A5.31M/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 Flux Cored and Metal Cored Welding Electrodes*
A5.35/A5.35M-AMD1	*Specification for Covered Electrodes for Underwater Wet Shielded Metal Arc Welding*
A5.39/A5.39M	*Specification for Flux and Electrode Combinations for Submerged Arc and Electroslag Joining and Surfacing of Stainless Steel and Nickel Alloys*

SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL RODS FOR OXYFUEL GAS WELDING

SFA-5.2/SFA-5.2M

(Identical with AWS Specification A5.2/A5.2M:2018. In case of dispute, the original AWS text applies.)

Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon and low-alloy steel rods for oxyfuel gas welding.

1.2 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 material properties. The specification designated A5.2 uses U.S. Customary Units. The specification designated A5.2M uses SI Units. The latter units are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under A5.2 and A5.2M specifications.

1.3 *Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Some safety and health information can be found in Annex Clauses A5 and A10.*

Safety and Health information is available from the following sources:

American Welding Society:

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

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable federal and state regulations.

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

2.1 The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

2.2 The following AWS standards are referenced in the normative clauses of this document:

(1) AWS A3.0M/A3.0, *Standard Welding Terms and Definitions; Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

(2) A5.01M/A5.01 (ISO 14344 MOD), *Welding Consumables—Procurement of Filler Metals and Fluxes*

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

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

2.3 The following ANSI standard is referenced in the normative clauses of this document:

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

2.4 The following ASTM standards are referenced in the normative clauses of this document:

(1) ASTM A36/A36M, *Standard Specification for Carbon Structural Steel*

(2) ASTM A285/A285M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

(3) ASTM A514/A514M, *Standard Specification for High–Yield–Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding*

(4) ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(5) ASTM E350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

2.5 The following ISO standard is referenced in the normative clauses of this document:

(1) ISO 544, *Welding consumables—Technical delivery conditions for welding filler materials and fluxes—Type of product, dimensions, tolerances and markings*

(2) ISO 80000-1, *Quantities and Units—Part 1: General (Corrected by ISO 80000–1:2009/Cor 1:2011)*

3. Classification

3.1 The welding rods covered by this A5.2 specification utilize a classification system based on U.S. Customary Units and are classified according to the mechanical properties of the weld metal in the as-welded condition, as shown in Table 1.

3.1M The welding rods covered by this A5.2M specification utilize a classification system based on the International System of Units (SI) and are classified according to the mechanical properties of the weld metal in the as-welded condition, as shown in Table 1.

3.2 Welding rods classified under one classification shall not be classified under any other classification in this specification. A welding rod may be classified under both A5.2 and A5.2M providing it meets the requirements of both specifications.

3.3 The welding rods classified under this specification are intended for oxyfuel gas welding, but that is not to prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance[1] of the welding rods shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

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

Table 1
Tension Test Requirements

AWS Classification		Minimum Tensile Strength[a]		Elongation in 1 in [25 mm] Percent, Min.
A5.2	A5.2M	ksi	MPa	
R45	RM30	Not Specified		Not Specified
R60	RM40	60	400	20
R65	RM45	65	450	16
R100	RM69	100	690	14
R(X)XX-G[b]	RMXX-G[c]	(X)XX[b]	XX[c]	Not Specified

[a] Specimens shall be tested in the as-welded condition.
[b] For specification A5.2, classifications R(X)XX-G should be based on minimum tensile strength of all-weld-metal tension test of the test assembly, expressed in multiples of 1000 psi. These designators shall be limited to 45, 60, 65, and 100.
[c] For specification A5.2M, classification RMXX-G shall be based on minimum tensile strength of all-weld-metal tension test of the test assembly, expressed in multiples of 10 MPa. These designators shall be limited to 30, 40, 45, and 69.

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.[2]

6. Rounding Procedure

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in Clause B.3 of ISO 80000-1 (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. If an average value is to be compared to the specified limit, rounding shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi (1 ksi) for tensile strength for A5.2, and to the nearest 10 MPa for tensile strength for A5.2M, and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded results shall fulfill the requirements for the classification under test.

7. Summary of Tests

The tests required for each classification are specified in Table 2. The purpose of these tests is to determine the chemical composition of the welding rod and the mechanical properties of the weld metal. The base metal for the preparation of test samples, the testing procedures to be employed, and the results required are given in Clauses 9 through 11.

Table 2
Required Tests

AWS Classification		Chemical Analysis	Tension Test
A5.2	A5.2M		
R45	RM30	Required	Not required
R60	RM40	Required	Required
R65	RM45	Required	Required
R100	RM69	Required	Required
R(X)XX-G	RMXX-G	Not required	Required

[2] See Annex Clause A4 for further information concerning certification and the testing called for to meet this requirement.

8. Retest

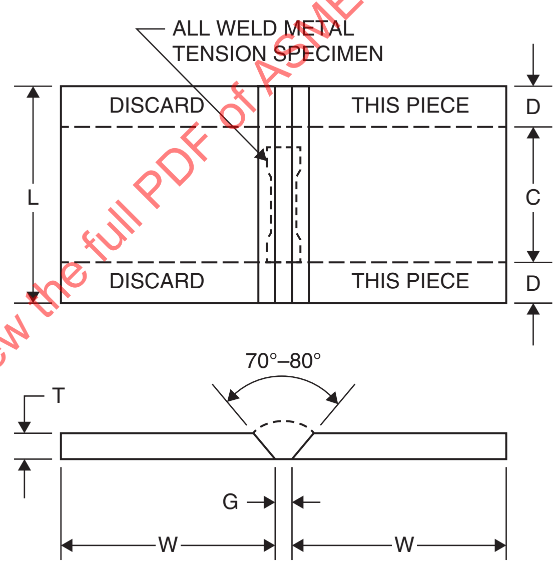
If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens or samples for retest may be taken from the original test assembly or sample, or from a new test assembly or sample. For chemical analysis, the retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

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

9. Weld Test Assembly

9.1 Except for the R45 [RM30] classification, one weld test assembly is required. It is the groove weld for mechanical properties in Figure 1.

9.2 Preparation of the weld test assembly shall be as specified in Figure 1. The base metal for the assembly shall be as required in Table 3 and shall meet the requirements of the appropriate ASTM specification shown there or an equivalent specification. Testing of the assembly shall be as prescribed in Clause 11.



Dimension	in	mm
L, min.	5	125
W, min.	5	125
T, nominal	3/8	10
D, min.	1	25
C, min.	2–1/2	65
G	1/8 to 5/32	3 to 4

Figure 1—Groove Weld Test Assembly for Mechanical Properties

Table 3
Base Metal Required for Test Assemblies

AWS Classification		Base Metal		
A5.2	A5.2M	Type	ASTM Specification	UNS Number[a]
R60	RM40	Carbon Steel	A36, A285, grade C, or equivalent	K02600
R65	RM45	Carbon Steel	A36, A285, grade C, or equivalent	K02600
R100	RM69	Low-Alloy Steel	Any grade of A514 or equivalent	K11630
R(X)XX-G	RMXX-G	Material shall have tensile strength and chemical composition similar to that of the rod being classified.		

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

9.3 A test assembly shall be prepared as specified in 9.2. It shall be preheated to between 60°F [15°C] and 200°F [95°C], and the assembly shall be welded using a 3/32 in or 1/8 in [2.5 mm or 3.2 mm] diameter welding rod, and using a maximum of five layers. No layer shall exceed 1/8 in [3 mm] in thickness. The filler metal shall be deposited using backhand welding with a neutral or slightly reducing flame. After welding each layer, the assembly shall be allowed to cool in still air until the interpass temperature drops below 350°F [180°C] before proceeding with the next layer. The joint shall be completely welded without treatment of the reverse side (root surface). Maximum weld reinforcement shall be 1/8 in [3 mm]. After the last pass has been completed, the assembly shall be allowed to cool in still air to ambient temperature. The assembly shall be tested in the as-welded condition.

10. Chemical Analysis

10.1 A sample of the welding rod or the rod stock from which it is made shall be prepared for chemical analysis. Welding rod, when analyzed for elements that are present in the coating (e.g., copper flashing), shall be analyzed without removing the coating. When the welding rod is analyzed for elements other than those in the coating, the coating must be removed if its presence affects the results of the analysis for the other elements. Rod stock analyzed for elements not in the coating may be analyzed prior to applying the coating.

10.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E350.

10.3 The results of the analysis shall meet the requirements of Table 4 for the classification of the rod under test.

11. Tension Test

11.1 One all-weld-metal tension test specimen, as specified in the Tension Test Clause of AWS B4.0 or B4.0M, shall be machined from the groove weld described in Clause 9 and shown in Figure 1. The all-weld-metal tension test specimen shall have a nominal diameter of 0.250 in [6.5 mm] and a nominal gage length-to-diameter ratio of 4:1.

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

11.3 The results of the tension test shall meet the requirements specified in Table 1.

12. Method of Manufacture

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

Table 4
Chemical Composition Requirements for Welding Rods and Rod Stock

AWS Classification		UNS Number[a]	Amount, wt %[b]									
A5.2	A5.2M		C	Mn	Si	P	S	Cu	Cr	Ni	Mo	Al
R45	RM30	K00045	0.08	0.50	0.10	0.035	0.040	0.30	0.20	0.30	0.20	0.02
R60	RM40	K00060	0.15	0.90 to 1.40	0.10 to 0.35	0.035	0.035	0.30	0.20	0.30	0.20	0.02
R65	RM45	K00065	0.15	0.90 to 1.60	0.10 to 0.70	0.035	0.035	0.30	0.40	0.30	0.20	0.02
R100	RM69	K12147	0.18 to 0.23	0.70 to 0.90	0.20 to 0.35	0.025	0.025	0.15	0.40 to 0.60	0.40 to 0.70	0.15 to 0.25	0.02
R(X)XX-G[c]	RMXX-G[d]	Not Specified										

[a] SAE HS-1086/ASTM DS-56 *Metals & Alloys in the Unified Numbering System*.
[b] Single values are maxima.
[c] Designators "(X)XX" correspond to minimum tensile strength of weld metal in ksi. See Note "b" of Table 1.
[d] Designators "XX" correspond to minimum tensile strength of weld metal in multiples of 10 MPa. See Note "c" of Table 1.

13. Standard Sizes and Lengths

Standard sizes and lengths for welding rods shall be as shown in Table 5.

14. Finish and Uniformity

14.1 All welding rods shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams, laps, and foreign matter that would adversely affect the welding characteristics or the properties of the weld metal.

14.2 A suitable protective coating may be applied to any welding rod in this specification.

14.3 The welding rods may be coated with the minimum amount of oil necessary to prevent rusting, but not sufficient to adversely affect weld properties, except that oil is not permitted when copper or other suitable coatings are used to prevent rusting.

15. Filler Metal Identification

Each bare straight length filler rod shall be durably marked with identification traceable to the unique product type of the manufacturer or supplier. Suitable methods of identification could include stamping, coining, embossing, imprinting, flag-tagging, or color coding. (If color coding is used, the choice of color shall be as agreed upon between the purchaser and supplier, and the color shall be identified on the packaging.) When the AWS classification is used for identification, it shall be used in its entirety; for example, "R65" or "RM45" would be used for an R65 [RM45] welding rod. Additional identification shall be as agreed upon between the purchaser and supplier.

16. Packaging

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

Table 5
Standard Filler Metal Sizes[a]

Standard Package Form	Diameter			Tolerance	
	A5.2 (in)		A5.2M (mm)	in	mm
Straight lengths[b]	1/16	(0.062)	1.6	± 0.002	±0.05
	3/32	(0.094)	2.4		
	—	(0.098)	2.5		
	1/8	(0.125)	3.2		
	5/32	(0.156)	4.0		
	3/16	(0.188)	4.8[c]		
	—	(0.197)	5.0		
	—	(0.236)	6.0		
	1/4	(0.250)	6.4[c]		

[a] Other sizes may be supplied as agreed upon between the purchaser and supplier.
[b] The standard length of the welding rod shall be 36 in +0, –1/2 in [900 mm +15 mm, –0 mm]. Other lengths may be supplied as agreed upon between the purchaser and supplier.
[c] All sizes in mm are standard in ISO 544 except 4.8 mm and 6.4 mm.

17. Marking of Packages

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

(1) AWS Specification and classification designations (year of issue may be excluded)

(2) Supplier's name and trade designation

(3) Size and net weight

(4) Lot, control, or heat number.

17.2 The appropriate precautionary information[3] 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 welding rods, including individual unit packages enclosed within a larger package.

[3] Typical examples of "warning labels" *and precautionary information* are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

Annex A (Informative)
Guide to AWS Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding

This annex is not part of this standard, but is included for informational purposes only.

A1. Introduction

The purpose of this guide is to correlate the rod 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 correlations are intended only as examples rather than complete listings of the materials for which each filler metal is suitable.

A2. Classification System

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

A2.2 The prefix "R [RM]" designates a rod. For A5.2, the numbers (45, 60, 65, and 100) indicate the required minimum tensile strength, as a multiple of 1000 psi, of the weld metal in a test weld made in accordance with specification A5.2. Similarly, for A5.2M, the numbers (30, 40, 45, and 69) indicate the required minimum tensile strength, as a multiple of 10 MPa, of the weld metal in a test weld made in accordance with specification A5.2M.

A2.3 "G" Classification

A2.3.1 This specification includes filler metals classified as R(X)XX-G [RMXX-G]. The "G" indicates that the filler metal is of a *general* classification. It is general because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing this classification is to provide a means by which filler metals that differ in one respect or another (e.g., chemical composition) from all other classifications (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal—one that otherwise would have to await a revision of the specification—to be classified immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some certain respect (e.g., chemical composition).

A2.3.2 The point of difference (although not necessarily the amount of that difference) referred to above will be readily apparent from the use of the words *not required* and *not specified* in the specification. The use of these words is as follows:

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

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

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a filler metal to that classification. When a purchaser wants the information provided by that test in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of that product. The purchaser will also have to establish with that supplier just what the testing procedure and the acceptance requirements are to be, for that test. They may want to incorporate that information (via AWS A5.01M/A5.01 (ISO 14344 MOD) in the purchase order.

A2.4 Request for Filler Metal Classification

(1) When a filler metal cannot be classified other than as a "G" classification, a manufacturer may request that a new classification be established. The manufacturer shall do this using the following procedure:

If a manufacturer elects to use a "G" classification, the AWS A5 Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a new classification be established, as long as the filler metal is commercially available.

(2) A request to establish a new filler metal classification must be submitted in writing. The request needs to provide sufficient detail to permit the AWS A5 Committee on Filler Metals and Allied Materials and the relevant Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, or if neither is necessary. In particular, the request needs to include:

(a) A declaration that the new classification will be offered for sale commercially;

(b) All classification requirements as given for existing classifications, such as, chemical composition ranges, mechanical property requirements, and usability test requirements;

(c) Any conditions for conducting the tests used to demonstrate that the filler metal meets the classification requirements (it would be sufficient, for example, to state that welding conditions are the same as for other classifications);

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

(e) 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 specification is silent regarding mechanical properties, test data submitted shall include appropriate weld metal mechanical properties from a minimum of two production heats/lots.

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

(3) In order to comply with the AWS Policy on Patented Items, Trademarks, and Restraint of Trade, if the proposed new classification is patented, if a patent is pending for it, or if there is any intention to apply for a patent, the requester shall disclose this. The affected classification shall be identified in all drafts and eventually the published standard identifying the patent owner. The requester shall also provide written assurance to AWS that:

[Name of the requester] has filed a patent application [patent application number] for alloy [classification number]. [Name of the requester] does not hold and does not currently intend holding any essential patent claims.

or

[Name of the quester] has filed a patent application [patent application number] for alloy [classification number]. [Name of the requester] will make a license available to such essential patent claims to applicants desiring to utilize the license for the purpose of implementing the standard. The license will be under reasonable terms and conditions that are demonstrably free of any unfair discrimination.

or

[Name of the quester] has filed a patent application [patent application number] for alloy [classification number]. [Name of the requester] will make a license available to such essential patent claims to applicants desiring to utilize the license for the purpose of implementing the standard. The license will be without compensation and under reasonable terms and conditions that are demonstrably free of any unfair discrimination.

[Name of the requester] indicates that the patent holder (or third party authorized to make above assurances on its behalf) will include in any documents transferring ownership of patents subject to the assurance, provisions sufficient to

ensure that the commitments in the assurance are binding on the transferee, and that the transferee will similarly include appropriate provisions in the event of future transfers with the goal of binding each successor-in-interest.

[Name of the requester] indicates that it is intended to be binding on successors-in-interest regardless of whether such provisions are included in the relevant transfer documents.

The status for the patent shall be checked before publication of the document and the patent information included in the document will be updated as appropriate.

Neither AWS, nor the AWS Committee on Filler Metals and Allied Materials, nor the relevant Subcommittee is required to consider the validity of any patent or patent application.

The published standard shall include a note as follows:

NOTE: The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, no position is taken with respect to the validity of any such claim(s) or of any patent rights in connection therewith. If a patent holder has filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, then details may be obtained from the standards developer.

(4) The request should be sent to the Secretary of the AWS A5 Committee on Filler Metals and Allied Materials at AWS Headquarters.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344 MOD), as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, 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 material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of AWS A5.01M/A5.01 (ISO 14344 MOD). Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification. The only testing requirement implicit in this *certification* is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped, and that material met the requirements of the specification. Representative material, in this case, is 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 made. 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:

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

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

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

(4) The proximity of 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

(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. *See also AWS F3.2*, Ventilation Guide for Weld Fume, *for more detailed descriptions of ventilation options.*

A6. Welding Considerations

A6.1 The test assembly required in this specification is welded according to established techniques of the oxyfuel gas welding process.

A6.2 The oxyfuel gas supplied to the torch should be adjusted to give a neutral or slightly reducing flame. This assures the absence of the oxidizing flame that could adversely influence weld quality. The extent of the excess fuel gas is measured by the length of the streamer (the so-called "feather") of unburned fuel gas visible at the extremity of the inner cone. This streamer should measure about 1/8 to 1/4 the length of the inner cone of the flame. Excessively long streamers should be avoided, since they may add carbon to the weld metal.

A6.3 In forehand welding, the torch flame points ahead in the direction of welding, and the welding rod precedes the torch flame. To distribute the heat and molten weld metal, it is necessary to use opposing oscillating motions for the flame and welding rod. This may cause excessive melting of the base metal and mixing of base metal and weld metal. Weld metal properties may be altered.

A6.4 In backhand welding, the torch flame points back at the molten metal, and the welding rod is interposed between the flame and molten metal. There is significantly less manipulation of the flame, the welding rod, and the molten metal. Therefore, a backhand weld is more likely to approach the chemical composition of undiluted weld metal.

A7. Description and Intended Use of Carbon and Low-Alloy Steel Rods

A7.1 Oxyfuel gas welding rods have no coverings to influence usability of the rod. Thus, the ability to weld in the vertical or overhead position is essentially a matter of welder skill and can be affected to some degree by the chemical composition of the rod.

A7.2 Class R45 [RM30] welding rods are used for the oxyfuel gas welding of steels, where the minimum tensile strength requirement of the steel does not exceed 45 ksi [300 MPa]. Class R45 [RM30] rods have a low carbon steel composition.

A7.3 Class R60 [RM40] welding rods are used for the oxyfuel gas welding of carbon steels, where the minimum tensile strength requirement of the steel does not exceed 60 ksi [400 MPa]. Class R60 [RM40] rods have a carbon steel composition.

A7.4 Class R65 [RM45] welding rods are used for the oxyfuel gas welding of carbon and low-alloy steels, where the minimum tensile strength requirement of the steel does not exceed 65 ksi [450 MPa]. Class R65 [RM45] welding rods may have either a low-alloy or an unalloyed carbon steel composition.

A7.5 Class R100 [RM69] welding rods are used for the oxyfuel gas welding of low-alloy steels, where the minimum tensile strength requirement of the steel does not exceed 100 ksi [690 MPa] in the as-welded condition. Users are cautioned that response of the weld metal and base metal to postweld heat treatment may be different.

A8. Special Tests

It is recognized that supplementary tests may be required for certain applications. In such cases, tests to determine specific properties such as corrosion resistance, mechanical properties at elevated or cryogenic temperatures, wear resistance, and suitability for welding combinations of dissimilar metals may be required. AWS A5.01M/A5.01 (ISO 14344 MOD) contains provisions for ordering such tests, which may be conducted as agreed upon between the purchaser and supplier.

A9. Discontinued Classifications

Some classifications have been discontinued from one revision of this specification to another. Discontinued classifications result from changes in commercial practice or changes in the classification system used in the specification. The classifications that have been discontinued are listed in Table A.1, along with the year in which they were last included in the specification.

Table A.1
Discontinued Classifications

AWS Classification	Last Published Date
GA 50	1946
GA 60	1946
GA 65	1946
GB 45	1946
GB 60	1946
GB 65	1946
RG 45	1969
RG 60	1969
RG 65	1969

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 A10.3, 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 https://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)

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*

9 *Tripping and Falling*
10 *Falling Objects*
11 *Confined Spaces*
12 *Contact Lens Wear*
13 *Ergonomics in the Welding Environment*
14 *Graphic Symbols for Precautionary Labels*
15 *Style Guidelines for Safety and Health Documents*
16 *Pacemakers and Welding*
17 *Electric and Magnetic Fields (EMF)*
18 *Lockout/Tagout*
19 *Laser Welding and Cutting Safety*
20 *Thermal Spraying Safety*
21 *Resistance Spot Welding*
22 *Cadmium Exposure from Welding & Allied Processes*
23 *California Proposition 65*
24 *Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25 *Metal Fume Fever*
26 *Arc Viewing Distance*
27 *Thoriated Tungsten Electrodes*
28 *Oxyfuel Safety: Check Valves and Flashback Arrestors*
29 *Grounding of Portable and Vehicle Mounted Welding Generators*
30 *Cylinders: Safe Storage, Handling, and Use*
31 *Eye and Face Protection for Welding and Cutting Operations*
33 *Personal Protective Equipment (PPE) for Welding and Cutting*
34 *Coated Steels: Welding and Cutting Safety Concerns*
35 *Welding Safety in Education and Schools*
36 *Ventilation for Welding and Cutting*
37 *Selecting Gloves for Welding and Cutting*
38 *Respiratory Protection Basics for Welding Operations*
40 *Asbestos Hazards Encountered in the Welding and Cutting Environment*
41 *Combustible Dust Hazards in the Welding and Cutting Environment*

Annex B (Informative)
Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard, but is included for informational purposes only.

B1. Introduction

The following procedures are here to assist standards users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

B2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. 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.

B3. General Procedure for all Requests

B3.1 Submission. All requests shall be sent to the Managing Director, Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

B3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

B3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

B3.4 Question(s). All requests shall be stated in the form of a question that can be answered "yes" or "no". The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

B3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

B3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

B4. AWS Policy on Interpretations

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 official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

B5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the *Welding Journal*, and post it on the AWS website.

B6. 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.

SPECIFICATION FOR ALUMINUM AND ALUMINUM-ALLOY ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.3/SFA-5.3M

(25)

(Identical with AWS Specification A5.3/A5.3M:2023. In case of dispute, the original AWS text applies.)

Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of aluminum and aluminum-alloy electrodes for shielded metal arc welding.

1.2 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 A5.3 uses U.S. Customary Units. The specification A5.3M 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 sizing electrodes, packaging or both under A5.3 or A5.3M specifications.

1.3 Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Some safety and health information can be found in Annex A, Clauses A5 and A10.

Safety and health information is available from the following sources:

American Welding Society:

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

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. Unless otherwise defined in this document, welding terms are as defined in AWS A3.0M/A3.0. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

2.1 American Welding Society (AWS) documents:

(1) AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

(2) AWS A5.01M/A5.01, *Welding Consumables—Procurement of Filler Metals and Fluxes*

(3) AWS A5.02/A5.02M, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*

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

2.2 American National Standards Institute (ANSI) document:

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

2.3 ASTM International (ASTM) documents:

(1) ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(2) ASTM E34, *Standard Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys*

(3) ASTM B209, *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate*

2.4 International Organization for Standardization (ISO) document:

(1) ISO 80000-1:2022, Quantities and units—Part 1: General

3. Classification

3.1 The electrodes covered by the A5.3/A5.3M specification are classified using a system that is independent of U.S. Customary Units and the International System of Units (SI). Classification is according to the chemical composition of the core wire, as specified in Table 1 and mechanical properties of a groove weld.

3.2 An electrode classified under one classification shall not be classified under any other classification in this specification.

4. Acceptance

Acceptance of the electrode shall be in accordance with the provisions of AWS A5.01M/A5.01 and the tests and requirements of this specification. See A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01M/A5.01.

Table 1
Chemical Composition Requirements for Core Wire

AWS Classification	UNS Designation[c]	Weight Percent[a,b]								Other Elements		
		Si	Fe	Cu	Mn	Mg	Zn	Ti	Be	Each	Total	Al
E1100	A91100	(d)	(d)	0.05–0.20	0.05	—	0.10	—	*0.0003*	0.05	0.15	99.00 min[e]
E3003	A93003	0.6	0.7	0.05–0.20	1.0–1.5	—	0.10	—	*0.0003*	0.05	0.15	Remainder
E4043	A94043	4.5–6.0	0.8	0.30	0.05	0.05	0.10	0.20	*0.0003*	0.05	0.15	Remainder
EG	—	*As Agreed between Supplier and Purchaser*										

[a] The core wire, or the stock from which it is made, 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 work, the amount of those elements shall be determined to ensure that they do not exceed the limits specified for "Other Elements."
[b] Single values are maximum, except where otherwise specified.
[c] SAE-HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System*.
[d] Silicon plus iron shall not exceed 0.95%.
[e] The aluminum content for unalloyed aluminum is the difference between 100% and the sum of all other metallic elements present in amounts of 0.010% or more each, expressed to the second decimal before determining the sum.

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. See A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

6. Rounding Procedure

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in Clause B.3 of ISO 80000-1 (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. If an average value is to be compared to the specified limit, rounding shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi (1 ksi) for tensile strength for A5.3 [to the nearest 5 MPa for tensile strength for A5.3M] and to the nearest unit in the last right-hand place of figures used for expressing the limiting values for other quantities. The rounded results shall fulfil the requirements for the classification under test.

7. Summary of Tests

The tests required for each classification are specified in Table 2. The purpose of these tests is to determine the chemical composition of the core wire and the mechanical properties of the weldment. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 12.

Table 2
Required Tests

AWS Classification	Electrode Size		Chemical Analysis[a]	Tension Test[b]	Bend Test[c,d]
	in	mm			
All classifications	3/32	2.4	Required	Not Required[e]	Not Required[e]
	—	2.5	Required	Not Required[e]	Not Required[e]
	1/8	3.2	Required	Not Required[e]	Not Required[e]
	5/32	4.0	Required	Required[f]	Required[f]
	3/16	4.8	Required	Not Required[e]	Not Required[e]
	—	5.0	Required	Not Required[e]	Not Required[e]
	—	6.0	Required	Required[g]	Required[g]
	1/4	6.4	Required	Required[g]	Required[g]
	5/16	8.0	Required	Not Required[e]	Not Required[e]
	3/8	9.5	Required	Not Required[e]	Not Required[e]

[a] Chemical analysis of the core wire or the stock from which it is made.
[b] See Clause 11.
[c] See Clause 12.
[d] *For electrodes classified as EG, bend testing shall be as agreed upon between the supplier and the purchaser and may be omitted.*
[e] If the product is not produced in the sizes listed for required tensile tests and bend tests, then the size closest but not greater than the size specified to be tested, shall be subject to the required tests.
[f] Electrodes 5/32 in [4.0 mm] and smaller shall be classified on the basis of the results obtained with the 5/32 in [4.0 mm] size of the same classification.
[g] Electrodes 3/16 in [4.8 mm] and larger shall be classified on the basis of the results obtained with the 1/4 in [6.0 mm or 6.4 mm] size of the same classification.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens 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 completion of any test, it is clearly determined that specified or proper procedures were not followed in preparing the weld test assembly or test specimens or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed, or whether the test results met, or failed to meet, the requirement. That test shall be repeated, following the proper specified procedures. In this case the requirement for doubling the number of test specimens does not apply.

9. Weld Test Assembly

9.1 One weld test assembly is required as specified in Table 2. It is the groove weld in Figure 1 [1M] for mechanical properties and soundness (bend) testing.

9.2 A test assembly shall be prepared and welded as specified in Figure 1 [1M], and Table 2 using base metal of the appropriate type specified in Table 3. The test assembly shall be preheated to a temperature between 350 °F and 400 °F [175 °C and 200 °C], and shielded metal arc (SMAW) welded from one side. Welding shall be in the flat position, and the assembly shall be restrained or preset to prevent warpage in excess of 5°. An assembly that is warped more than 5° out of plane shall be discarded. Test assemblies shall not be straightened. Testing of this assembly shall be as specified in Clauses 11 and 12. The assembly shall be tested in the as-welded condition.

10. Chemical Analysis

10.1 A sample of the core wire or the stock from which it is made shall be prepared for chemical analysis.

10.2 The sample shall be analyzed by accepted analytical methods. In case of dispute, the referee method shall be ASTM E34.

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

11. Tension Test

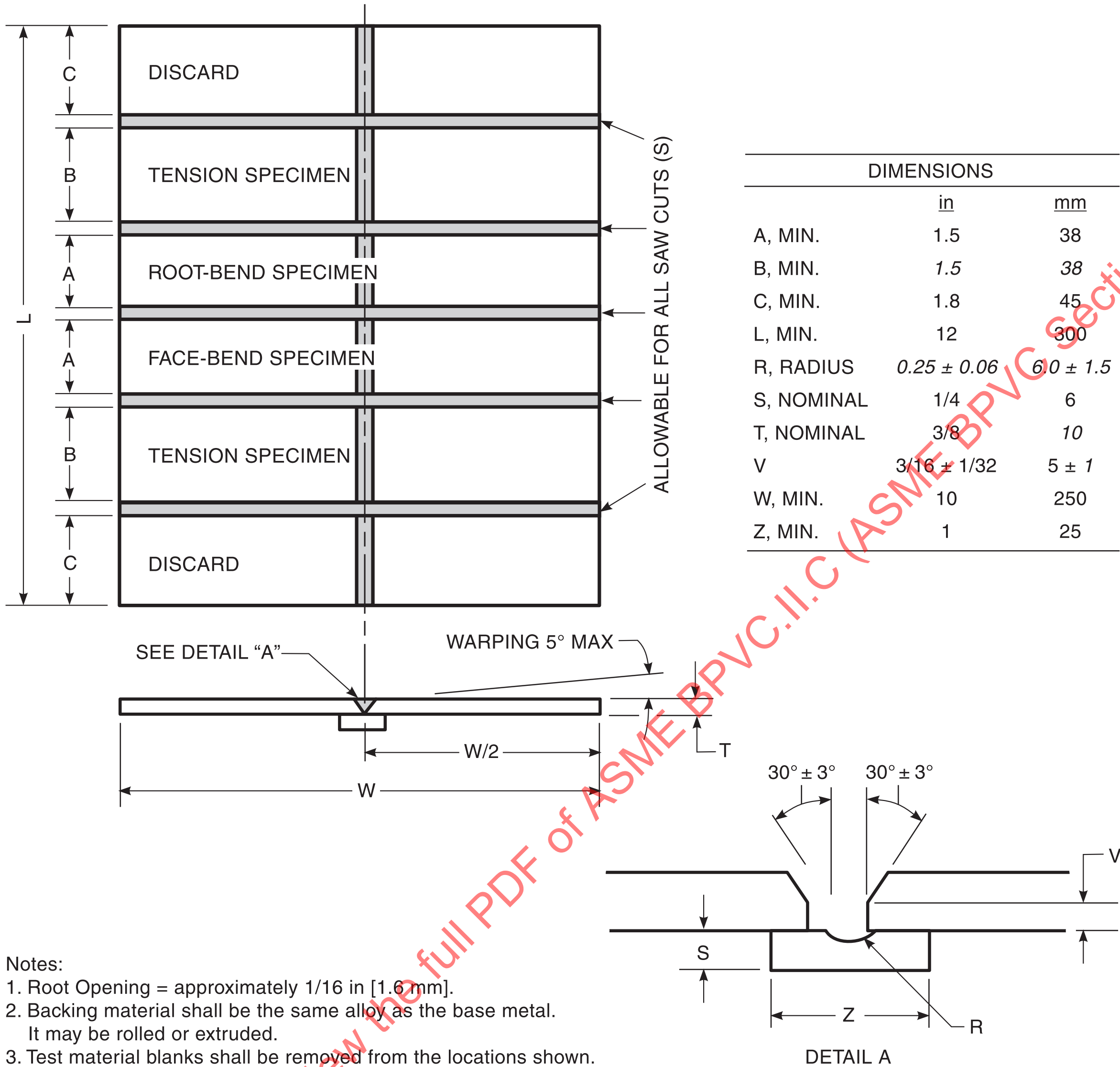
11.1 Two transverse rectangular tension test specimens shall be machined from the groove weld described in Clause 9 and shown in Figure 1 [1M]. The dimensions of the specimens shall be as specified in the tension test section of AWS B4.0. All dimensions shall be the same as shown in the AWS B4.0 figure for transverse rectangular tension test specimens (plate) except the reduced section radius shall be 2 in [50 mm].

11.2 The specimens shall be tested in the manner described in the tension test clause of AWS B4.0.

11.3 The results of both of the tension tests shall meet the requirements specified in Table 4.

12. Bend Test

12.1 One transverse face and one transverse root bend specimen, as required in Table 2, shall be machined from the groove weld test assembly described in Clause 9 and shown in Figure 1 [1M]. The dimensions of these bend specimens shall be the same as those shown in the bend test section of AWS B4.0, in the figure for transverse face and transverse root-bend specimens (plate).



DIMENSIONS	in	mm
A, MIN.	1.5	38
B, MIN.	1.5	38
C, MIN.	1.8	45
L, MIN.	12	300
R, RADIUS	0.25 ± 0.06	6.0 ± 1.5
S, NOMINAL	1/4	6
T, NOMINAL	3/8	10
V	3/16 ± 1/32	5 ± 1
W, MIN.	10	250
Z, MIN.	1	25

Notes:
1. Root Opening = approximately 1/16 in [1.6 mm].
2. Backing material shall be the same alloy as the base metal. It may be rolled or extruded.
3. Test material blanks shall be removed from the locations shown.

Figure 1 [1M]—Groove Weld Test Assembly for Mechanical Properties

Table 3
Base Metal for Test Assemblies

Electrode	Base Metal		
AWS Classification	**Aluminum Alloy[a]**	**ASTM Specification**	**UNS Designation**
E1100	1100	B209	A91100
E3003, E4043	3003[b]	B209	A93003
EG	*As Agreed between Supplier and Purchaser[c]*		

[a] Aluminum Association, Inc. registration numbers.
[b] When welding 3003 with E4043 electrodes, 3003-0 (annealed temper) plate is preferred.
[x] Base metal for which the electrode is recommended by the manufacturer may be used.

Table 4
Tension Test Requirements

AWS Classification	Tensile Strength, min.[a] psi	Tensile Strength, min.[a] MPa
E1100	12 000	80
E3003	14 000	95
E4043	14 000	95
EG	*As Agreed between Supplier and Purchaser*	

[a] Fracture may occur in either the base metal or the weld metal.

12.2 The specimens shall be tested in the manner described in the Bend Test clause of AWS B4.0 by bending them uniformly through 180° over a 1-1/4 in [32 mm] radius using any suitable jig, as specified in the Bend Test clause of AWS B4.0. Positioning of the face-bend specimen shall be such that the face of the weld is in tension. Positioning of the root-bend specimen shall be such that the root of the weld is in tension. For both types of transverse bend specimen, the weld shall be at the center of the bend.

12.3 Each specimen, after bending, shall conform to the 1-1/4 in [32 mm] radius, with an appropriate allowance for spring back, and the weld metal shall show no crack or other open defect exceeding 1/8 in [3.2 mm] measured in any direction on the convex surface, when examined with the unaided eye. Cracks that occur on the corners of a specimen during testing and which show no evidence of inclusions or other fusion-type discontinuities shall be disregarded.

13. Method of Manufacture

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

14. Standard Sizes and Lengths

14.1 Standard sizes (diameter of the core wire) and lengths of electrodes and their respective tolerances are specified in AWS A5.02/A5.02M.

15. Core Wire and Covering

15.1 Requirements for the core wire and covering, including concentricity requirements are specified in AWS A5.02/A5.02M.

15.2 The coverings shall be such that they are not readily damaged by ordinary handling and the coverings shall not blister when heated to 400 °F [200 °C]. They shall be consumed uniformly during welding, and they also shall not blister or melt back from the core wire. The flux residue they produce shall be readily removable.

16. Exposed Core

16.1 Requirements for the grip end of each electrode are specified in AWS A5.02/A5.02M.

16.2 Requirements for the arc end of each electrode are specified in AWS A5.02/A5.02M.

17. Electrode Identification

17.1 All electrodes shall be identified (imprinted) as specified in AWS A5.02/A5.02M.

17.2 In lieu of imprinting, electrodes may be identified by the alternate methods specified in AWS A5.02/A5.02M.

18. Packaging

Electrodes shall be packaged as specified in AWS A5.02/A5.02M.

19. Marking of Packages

19.1 The product information specified in AWS A5.02/A5.02M (as a minimum) shall be legibly marked on the outside of each unit package.

19.2 The appropriate precautionary information as given in ANSI Z49.1 (as a minimum) or its equivalent shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package. Typical examples of "warning labels" and precautionary information are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

Annex A (Informative)

Guide to AWS Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding

This annex is not a part of this standard but is included for informational purposes only.

A1. Introduction

The purpose of this guide is to correlate the electrode 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 filler metal is suitable.

A2. Classification System

A2.1 The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix letter E at the beginning of each classification designation stands for electrode. The numerical portion of the designation in this specification conforms to the Aluminum Association registration for the composition of the core wire used in the electrode.

A2.2 "G" Classification

A2.2.1 This specification includes filler metals classified as EG. 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 (chemical composition, for example) 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 await a revision of the specification—to be classified immediately, under the existing specification. This means that two electrodes—each bearing the same "G" classification—may be quite different in some certain respect (chemical composition, again, for example).

A2.2.2 The point of difference (although not necessarily the amount of that difference) between electrodes of a "G" classification and electrodes 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 Required is used in those areas that specify the tests that must be conducted in order to classify an electrode. The words indicate that there is no requirement for that test for that particular classification. When a test is "not required," it is not necessary to conduct the test in order to classify an 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) in the purchase order.

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. If the results from a specific test are listed as "not specified" but the test in question is shown as "required" then the test result must be reported.

A2.2.3 Request for Filler Metal Classification. When a filler metal cannot be classified other than as a "G" classification, a manufacturer may request that a new classification be established. The manufacturer shall do this using the following procedure:

(1) A request to establish a new electrode classification must be submitted in writing. The request needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials and the relevant Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, or if neither is necessary. In particular, the request needs to include:

(a) A declaration that the new classification will be offered for sale commercially.

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

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

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

(e) 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.

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

(2) In order to comply with the AWS Policy on Patented Items, Trademarks, and Restraint of Trade, if the proposed new classification is patented, if a patent is pending for it, or if there is any intention to apply for a patent, the requester shall disclose this. In these cases, the patent holder must allow the use of this technology, such as by license. The Secretary will provide examples of acceptable wording to the patent holder, as required.

(3) The request should be sent to the Secretary of the AWS A5 Committee on Filler Metals and Allied Materials at AWS Headquarters for processing.

A3. Acceptance

Acceptance of electrodes classified under this specification is in accordance with AWS A5.01M/A5.01. Any testing a purchaser requires of the supplier for material shipped in accordance with this specification shall be clearly stated in the purchase order. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F of AWS A5.01M/A5.01. Testing in accordance with any other Schedule shall be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or of placing the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

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

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders are exposed during welding. They are:

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

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

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

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

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

A5.2 American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the Clause on Ventilation in that document. See also AWS F3.2M/F3.2, *Ventilation Guide for Weld Fume*, for more detailed descriptions of ventilation options.

A6. Welding Considerations

A6.1 Welding aluminum by the shielded metal arc process is a well-established practice. However, development of the gas shielded arc welding processes and the many advantages these processes offer has caused a shift away from the use of covered electrodes for welding aluminum alloys. When shielded metal arc welding, an electrode is held in the standard electrode holder, and welding is usually performed using direct current, electrode positive (DCEP) polarity. Important factors to be considered when welding aluminum with covered electrodes are moisture content of the electrode covering and cleanliness of the electrode and base metal. Preheat is usually required to obtain good fusion and to improve soundness of the weld. Residual flux removal between passes is required to provide improved arc stability and weld fusion. Complete removal of the residual flux after welding is necessary to avoid corrosive attack in service.

A6.2 The presence of moisture in the electrode covering is a major cause of weld porosity. Dirt, grease, or other contamination of the electrode can also contribute to porosity. The absorption of moisture by the covering can be quite rapid, and the covering can deteriorate after only a few hours exposure to a humid atmosphere. For this reason, the electrodes should be stored in a dry, clean location. Electrodes taken from previously opened packages or those exposed to moisture should be "conditioned" by holding them at 350 °F to 400 °F [175 °C to 200 °C], for an hour before welding, or as recommended by the manufacturer. After conditioning, they should be stored in a dry, heated cabinet at 150 °F to 200 °F [65 °C to 95 °C] until used.

A6.3 The minimum base metal thickness recommended for shielded metal arc welding of aluminum is 1/8 in [3.2 mm]. For thicknesses less than 1/4 in [6.4 mm], no edge preparation other than a relatively smooth, square cut is required. Material over 1/4 in [6.4 mm] should be beveled to a single-V-groove with a 60° to 90° included angle. On very thick material, U-grooves may be used. Depending upon base metal gauge, root-face thicknesses may range between 1/16 in and 1/4 in [1.6 mm and 6.4 mm]. A root opening of 1/32 in to 1/16 in [0.8 mm to 1.6 mm] is desirable for all groove welds.

A6.4 Because of the high thermal conductivity of aluminum, preheating to 250 °F to 400 °F [120 °C to 200 °C] is nearly always necessary on thick material to maintain the weld pool and obtain proper fusion. Preheating will also help to avoid porosity due to too rapid cooling of the weld pool at the start of the weld. On complex assemblies, preheating is useful in avoiding distortion. Preheating may be done by torch using oxygen and acetylene or other suitable fuel gas, or by electrical resistance heating. Mechanical properties of 6XXX series aluminum-alloy weldments can be reduced significantly if the higher preheating temperatures, 350 °F [175 °C] or higher, are applied.

A6.5 Single-pass SMAW welds should be made whenever possible. However, where thicker plates require multiple passes, thorough cleaning between passes is essential for optimum results. After the completion of any welding, the weld and work should be thoroughly cleaned of residual flux. The major portion of the residual flux can be removed by mechanical means, such as a rotary wire brush, slag hammer, or peening hammer, and the rest by steaming or a hot-water rinse. The test for complete removal of residual flux is to swab a solution of 5% silver nitrate on the weld areas. Foaming will occur if residual flux is present.

A6.6 Interruption of the arc when shielded metal arc welding aluminum can cause the formation of a fused flux coating over the end of the electrode. Reestablishing a satisfactory arc is impossible unless this formation is removed.

A7.Description and Intended Use of Electrodes

A7.1 E1100 Classification. Electrodes of the E1100 classification produce weld metal of high ductility, good electrical conductivity, and a minimum tensile strength of 12 000 psi (80 MPa). E1100 electrodes are used to weld 1100, 1350(EC), and other commercially pure aluminum alloys.

A7.2 E3003 Classification. Electrodes of the E3003 classification produce weld metal of high ductility and a minimum tensile strength of 14 000 psi [95 MPa]. E3003 electrodes are used to weld aluminum alloys 1100 and 3003.

A7.3 E4043 Classification. The E4043 classification contains approximately 5% silicon, which provides superior fluidity at welding temperatures, and for this reason is preferred for general purpose welding. The E4043 classification produces weld metal with fair ductility and a minimum tensile strength of 14 000 psi [95 MPa]. E4043 electrodes can be used to weld the 6XXX series aluminum alloys, the 5XXX series aluminum alloys (up to 2.5% Mg content), and aluminum-silicon casting alloys, as well as aluminum base metals 1100, 1350(EC), and 3003.

A7.4 For many aluminum applications, corrosion resistance of the weld is of prime importance. In such cases, it is advantageous to choose an electrode with a composition as close as practical to that of the base metal. For this use, covered electrodes for base metals other than 1100 and 3003 usually are not stocked and must be specially ordered. For applications where corrosion resistance is important, it may be advantageous to use one of the gas shielded arc welding processes for which a wider range of filler metal compositions is available.

A8. Special Tests

It is recognized that supplementary tests may be required for certain applications. In such cases, tests to determine specific properties such as corrosion resistance, electrical conductivity, mechanical properties at elevated or cryogenic temperatures, and suitability for welding different combinations of aluminum base alloys may be required. AWS A5.01M/A5.01 contains provisions for ordering such tests. This clause is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed upon between the purchaser and supplier.

A9. Chemical Analysis

The accepted and most widely used method for chemical analysis is found in ASTM E227, *Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloy by the Point-to-Plane Technique (now withdrawn)*. This method analyzes a bulk sample and all elements simultaneously. Other established analytical methods are also acceptable. The ASTM E34, *Standard Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys*, prescribes individual test methods by which each element is tested. The ASTM E34 test methods are used as the referee method if a dispute arises concerning a specific elemental analysis.

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. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets and ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations. Safety and Health Fact Sheets may be downloaded and printed directly from the AWS website at http://www.aws.org.

Annex B (Informative)

Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard but is included for informational purposes only.

B1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

B2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. 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.

B3. General Procedure for all Requests

B3.1 Submission. All requests shall be sent to the Managing Director, AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

B3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

B3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

B3.4 Question(s). All requests shall be stated in the form of a question that can be answered "yes" or "no". The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

B3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

B3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

B4. AWS Policy on Interpretations

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 official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

B5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the *Welding Journal*, and post it on the AWS website.

B6. 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.

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, A5.35	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, A5.35	A5.9, A5.22	A5.22	A5.9, A5.22, A5.39	A5.9, A5.22, A5.39	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11, A5.35	A5.14, A5.34	A5.34	A5.14, A5.34, A5.39	A5.14, A5.34, A5.39		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	

AWS Filler Metal Specifications and Related Documents

Designation	Title
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*
A4.5M/A4.5 (ISO 15792-3 MOD)	*Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*
A5.01M/A5.01 (ISO 14344 MOD)	*Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes*
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 and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel 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 Electrodes for Shielded Metal Arc Welding*
A5.7/A5.7M	*Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*
A5.8M/A5.8	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M (ISO 14343 MOD)	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M (ISO 18273 MOD)	*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 (ISO 24034 MOD)	*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*
A5.31M/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 Flux Cored and Metal Cored Welding Electrodes*
A5.35/A5.35M-AMD1	*Specification for Covered Electrodes for Underwater Wet Shielded Metal Arc Welding*
A5.39/A5.39M	*Specification for Stainless Steel and Nickel-Alloy Electrodes and Fluxes for Submerged Arc and Electroslag Welding*

SPECIFICATION FOR STAINLESS STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.4/SFA-5.4M

(Identical with AWS Specification A5.4/A5.4M:2012 (R2022). In case of dispute, the original AWS text applies.)

Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of covered stainless steel electrodes for shielded metal arc welding.[1,2]

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

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

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 Annex Sections A5 and A11. Safety and health information is available from other sources, including, but not limited to ANSI Z49.1, *Safety in Welding, Cutting and Allied Processes*, and applicable state and federal regulations.

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 material properties. The specification with the designation A5.4 uses U.S. Customary Units. The specification A5.4M uses SI Units. The latter are shown in brackets [] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under A5.4 or A5.4M specifications.

2. Normative References

2.1 The following AWS standards[3] are referenced in the mandatory section of this document.

1. AWS A5.01M/A5.01 (ISO 14344 MOD). *Procurement Guidelines for Consumables – Welding and Allied Processes – Flux and Gas Shielded Electrical Welding Processes*
2. AWS A5.5, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*
3. AWS B4.0, *Standard Methods for Mechanical Testing of Welds*
4. AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

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

1. ANSI Z49.1[4], *Safety in Welding, Cutting and Allied Processes*

[1] Due to possible differences in composition, core wire from covered electrodes should not be used as bare filler wire.
[2] Classifications E502, E505, and E7Cr are no longer specified by this document. They are specified in AWS A5.5/A5.5M:2006, designated as follows: E502 as E801X-B6 and E801X-B6L, E505 as E801X-B8 and E801X-B8L, and E7Cr as E801X-B7 and E801X-B7L.
[3] AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.
[4] ANSI Z49.1 is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

2.3 The following ASTM standards[5] are referenced in the mandatory section of this document.

1. ASTM A36, *Specification for Structural Steel*

2. ASTM A240, *Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels*

3. ASTM A285, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

4. ASTM A515, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

5. ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

6. ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*

7. ASTM E353, *Standard Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys*

2.4 The following ISO standard[6] is referenced in the mandatory section of this document.

ISO 80 000-1 Quantities and Units Part 1: General

3. Classification

3.1 The welding electrodes covered by this A5.4/A5.4M specification are classified using the system that is independent of US customary units and the International System of Units (SI), and are classified according to:

1. Chemical composition requirements for undiluted weld metal (Table 1).

2. Type of welding current and position of welding (Table 2).

3.2 Materials classified under one classification may be classified under any other classification of this specification, provided they meet all the requirements for those classifications, except that a material may not be classified under more than one of the following EXXX-15, EXXX-16, EXXX-17, or EXXX-26 designations. Table 3 lists a number of examples of such dual classification.

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

4. Acceptance

Acceptance[7] of the material shall be in accordance with the provisions of AWS A5.01.

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.[8]

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[5] ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.
[6] ISO standards are published by the International Organization of Standardization, 1, chemin de la voie-creuse Case Postale 56 CH-1211 Genèva 20 Switzerland.
[7] See A3, Acceptance (in Annex A) for further information on acceptance, testing of material shipped and AWS A5.01M/A5.01 (ISO 14344 MOD).
[8] See A4, Certification (in Annex A) for further information concerning certification and the tests called for to meet this requirement.

Table 1
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]	UNS Number[d]	Weight Percent[a,b]											
		C	Cr	Ni	Mo	Nb (Cb) Plus Ta	Mn	Si	P	S	N	Cu	Other[e]
E209-XX	W32210	0.06	20.5–24.0	9.5–12.0	1.5–3.0	—	4.0–7.0	1.00	0.04	0.03	0.10–0.30	0.75	V = 0.10–0.30
E219-XX	W32310	0.06	19.0–21.5	5.5–7.0	0.75	—	8.0–10.0	1.00	0.04	0.03	0.10–0.30	0.75	
E240-XX	W32410	0.06	17.0–19.0	4.0–6.0	0.75	—	10.5–13.5	1.00	0.04	0.03	0.10–0.30	0.75	
E307-XX	W30710	0.04–0.14	18.0–21.5	9.0–10.7	0.5–1.5	—	3.30–4.75	1.00	0.04	0.03	—	0.75	
E308-XX	W30810	0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308H-XX	W30810	0.04–0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308L-XX	W30813	0.04	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308Mo-XX	W30820	0.08	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308LMo-XX[f]	W30823	0.04	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309-XX	W30910	0.15	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309H-XX	W30910	0.04–0.15	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309L-XX	W30913	0.04	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309Nb-XX[g]	W30917	0.12	22.0–25.0	12.0–14.0	0.75	0.70–1.00	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309Mo-XX	W30920	0.12	22.0–25.0	12.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309LMo-XX[f]	W30923	0.04	22.0–25.0	12.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E310-XX	W31010	0.08–0.20	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	0.75	0.03	0.03	—	0.75	
E310H-XX	W31015	0.35–0.45	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	0.75	0.03	0.03	—	0.75	
E310Nb-XX[g]	W31017	0.12	25.0–28.0	20.0–22.0	0.75	0.70–1.00	1.0–2.5	0.75	0.03	0.03	—	0.75	
E310Mo-XX	W31020	0.12	25.0–28.0	20.0–22.0	2.0–3.0	—	1.0–2.5	0.75	0.03	0.03	—	0.75	
E312-XX	W31310	0.15	28.0–32.0	8.0–10.5	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316-XX	W31610	0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316H-XX	W31610	0.04–0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316L-XX	W31613	0.04	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316LMn-XX	W31622	0.04	18.0–21.0	15.0–18.0	2.5–3.5	—	5.0–8.0	0.90	0.04	0.03	0.10–0.25	0.75	
E317-XX	W31710	0.08	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E317L-XX	W31713	0.04	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E318-XX	W31910	0.08	17.0–20.0	11.0–14.0	2.0–3.0	6 × C, min to 1.00 max	0.5–2.5	1.00	0.04	0.03	—	0.75	
E320-XX	W88021	0.07	19.0–21.0	32.0–36.0	2.0–3.0	8 × C, min to 1.00 max	0.5–2.5	0.60	0.04	0.03	—	3.0–4.0	
E320LR-XX	W88022	0.03	19.0–21.0	32.0–36.0	2.0–3.0	8 × C, min to 0.40 max	1.50–2.50	0.30	0.020	0.015	—	3.0–4.0	
E330-XX	W88331	0.18–0.25	14.0–17.0	33.0–37.0	0.75	—	1.0–2.5	1.00	0.04	0.03	—	0.75	
E330H-XX	W88335	0.35–0.45	14.0–17.0	33.0–37.0	0.75	—	1.0–2.5	1.00	0.04	0.03	—	0.75	

(Coninued)

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

AWS Classification[c]	UNS Number[d]	Weight Percent[a,b]											
		C	Cr	Ni	Mo	Nb (Cb) Plus Ta	Mn	Si	P	S	N	Cu	Other[e]
E347-XX	W34710	0.08	18.0–21.0	9.0–11.0	0.75	8 × C, min to 1.00 max	0.5–2.5	1.00	0.04	0.03	—	0.75	
E349-XX	W34910	0.13	18.0–21.0	8.0–10.0	0.35–0.65	0.75–1.20	0.5–25	1.00	0.04	0.03	—	0.75	V = 0.10–0.30 Ti = 0.15 max W = 1.25–1.75
E383-XX	W88028	0.03	26.5–29.0	30.0–33.0	3.2–4.2	—	0.5–2.5	0.90	0.02	0.02	—	0.6–1.5	
E385-XX	W88904	0.03	19.5–21.5	24.0–26.0	4.2–5.2	—	1.0–2.5	0.90	0.03	0.02	—	1.2–2.0	
E409Nb-XX	W40910	0.12	11.0–14.0	0.6	0.75	0.50–1.50	1.0	1.00	0.04	0.03	—	0.75	
E410-XX	W41010	0.12	11.0–13.5	0.7	0.75	—	1.0	0.90	0.04	0.03	—	0.75	
E410NiMo-XX	W41016	0.06	11.0–12.5	4.0–5.0	0.40–0.70	—	1.0	0.90	0.04	0.03	—	0.75	
E430-XX	W43010	0.10	15.0–18.0	0.6	0.75	—	1.0	0.90	0.04	0.03	—	0.75	
E430Nb-XX	W43011	0.10	15.0–18.0	0.6	0.75	0.50–1.50	1.0	1.00	0.04	0.03	—	0.75	
E630-XX	W37410	0.05	16.00–16.75	4.5–5.0	0.75	0.15–0.30	0.25–0.75	0.75	0.04	0.03	—	3.25–4.00	
E16-8-2-XX	W36810	0.10	14.5–16.5	7.5–9.5	1.0–2.0	—	0.5–2.5	0.60	0.03	0.03	—	0.75	
E2209-XX	W39209	0.04	21.5–23.5	8.5–10.5	2.5–3.5	—	0.5–2.0	1.00	0.04	0.03	0.08–0.20	0.75	
E2307-XX	*S82371*	*0.04*	*22.5–25.5*	*6.5–10.0*	*0.8*	—	*0.4–1.5*	*1.0*	*0.030*	*0.020*	*0.10–0.20*	*0.50*	
E2553-XX	W39553	0.06	24.0–27.0	6.5–8.5	2.9–3.9	—	0.5–1.5	1.00	0.04	0.03	0.10–0.25	1.5–2.5	
E2593-XX	W39593	0.04	24.0–27.0	8.5–10.5	2.9–3.9	—	0.5–1.5	1.00	0.04	0.03	0.08–0.25	1.5–3.0	
E2594-XX	W39594	0.04	24.0–27.0	8.0–10.5	3.5–4.5	—	0.5–2.0	1.00	0.04	0.03	0.20–0.30	0.75	
E2595-XX	W39595	0.04	24.0–27.0	8.0–10.5	2.5–4.5	—	2.5	1.2	0.03	0.025	0.20–0.30	0.4–1.5	W = 0.4–1.0
E3155-XX	W73155	0.10	20.0–22.5	19.0–21.0	2.5–3.5	0.75–1.25	1.0–2.5	1.00	0.04	0.03	—	0.75	Co = 18.5–21.0 W = 2.0–3.0
E33-31-XX	W33310	0.03	31.0–35.0	30.0–32.0	1.0–2.0	—	2.5–4.0	0.9	0.02	0.01	0.3–0.5	0.4–0.8	

[a] Analysis shall be made for the elements for which specific values are shown in the table. If, however, the presence of other elements is indicated in the course of analysis, further analysis shall be made to determine that the total of these other elements, except iron, is not present in excess of 0.50 percent.
[b] Single values are maximum percentages.
[c] Classification suffix -XX may be -15, -16, -17, or -26. See Clause A8 of Annex A for an explanation.
[d] ASTM DS-56H/SAE HS-1086, *Metal & Alloys in the Unified Numbering System*.
[e] Analysis for Bi is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.002%.
[f] E308LMo-XX and E309LMo-XX were formerly named E308MoL-XX and E309MoL-XX, respectively.
[g] E309Nb-XX and E310Nb-XX were formerly named E309Cb-XX and E310Cb-XX. The change was made to conform to the worldwide uniform designation of the element niobium.

Table 2
Type of Welding Current and Position of Welding

AWS Classification[a]	Welding Current[b]	Welding Position[c]
EXXX(X)-15	dcep	All[d]
EXXX(X)-16	dcep and ac	All[d]
EXXX(X)-17	dcep and ac	All[d]
EXXX(X)-26	dcep and ac	F, H-fillet

[a] See Clause A8, Classification as to Usability, for explanation of positions.
[b] dcep = direct current electrode positive (reverse polarity)
ac = alternating current
[c] The abbreviations F and H-fillet indicate welding positions as follows:
F = Flat
H-fillet = Horizontal fillet
[d] Electrodes 3/16 in [4.8 mm] and larger are not recommended for welding in all positions.

Table 3
Examples of Potentially Occurring Dual Classified Electrodes and Suggested Marking

Primary Classification	Alternate Classification	Suggested Electrode Marking[a]
E308L-XX	E308-XX	E308/E308L-XX
E308H-XX	E308-XX	E308/E308H-XX
E316L-XX	E316-XX	E316/E316L-XX

[a] This abbreviated, suggested marking is permitted only on the electrode (the E may be omitted). All packaging and packing labels and certifications must list the complete classification designation for all classifications intended.

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 E29 or ISO 80000-1, Annex B, Rule A (the results are the same). If the measured values are obtained by equipment calibrated in units other than those of the specified limit, the measured values shall be converted to the units of the specified limit before rounding off. If an average value is to be compared to the specified limit, rounding off shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1 000 psi (1 ksi) for tensile strength for A5.4, or to the nearest 10 MPa for tensile strength for A5.4M, 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

The tests required for each classification are specified in Table 4. The purpose of these tests is to determine the chemical composition, mechanical properties and soundness of the weld metal and the usability of the electrodes. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clause 9, Weld Test Assemblies; Clause 10, Chemical Analysis; Clause 11, Radiographic Test; Clause 12, Tension Test; and Clause 13, Fillet Weld Test.

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. For chemical analysis, retest material may be taken from the original test sample or from a new sample. Retest for chemical analysis need be only for those specific elements that failed to meet the test requirement.

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

In the event that, during preparation or after completion of any test, it is clearly determined that specified 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 specified procedures. In this case, the requirement for doubling of the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 One, two, or three weld test assemblies are required depending on electrode diameter as shown in Table 4.

1. The weld pad in Figure 1 for chemical analysis of the undiluted weld metal
2. The groove weld in Figure 2 for Tension and Radiographic tests
3. The fillet weld in Figure 3 for usability of the electrode.

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

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

9.2.1 For the chemical analysis pad, the base metal to be used shall be carbon steel, alloy steel, or stainless steel of 0.25 percent carbon maximum for all electrode classifications except E308L, E308LMo, E309L, E309LMo, E316L, E316LMn, E317L, E320LR, E383, E385, E630, E2209, *E2307*, E2593, E2594, E2595, and E33-31. For chemical analysis of these low-carbon classifications, the base metal shall be steel of 0.03 percent maximum carbon. Other steels having a carbon content of 0.25 percent maximum may be used with the further restrictions specified in 10.6.

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

1. For E4XX and E630 classifications—Types 410, 430A, or 430B
2. For all other classifications—Types 304 or 304L.

Optionally, the steel may conform to one of the following specifications or their equivalents, providing two buttering layers of filler metal as shown in Figure 2A, are deposited in stringer beads using electrodes of the same classification as that being classified: ASTM A285, ASTM A36, or ASTM A515.

9.2.3 For the fillet weld test, the steel to be used shall be of a matching type or shall conform to the following specifications:

1. For E4XX and E630 classifications—ASTM A240, Type 410 or Type 430 A or B
2. For all other classifications—ASTM A240, Type 304 or Type 304L.

9.3 Weld Pad. A weld pad shall be prepared as specified in Figure 1 except when one of the alternatives in 9.1 (taking the sample from the broken tension test specimen or from a corresponding location or any location above it in the weld metal in the groove weld in Figure 2 or from the weld pad used for ferrite determination in Figure A.1) is selected. Base metal shall be of any convenient size, of the type specified in 9.2.1. 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, using as short an arc length as practical and at a current as agreed upon between consumer and manufacturer. Multiple layers shall be used to obtain undiluted weld metal. The preheat temperature shall not be less than 60 ºF [15 ºC] After depositing each layer, the weld pad shall be immersed in water (temperature unimportant) for approximately 30 seconds. The slag shall be removed after each pass. The completed pad shall be as shown in Figure 1 for each size of the electrode. Testing of the assembly shall be as specified in Clause 10, Chemical Analysis.

Table 4
Tests Required For Classification

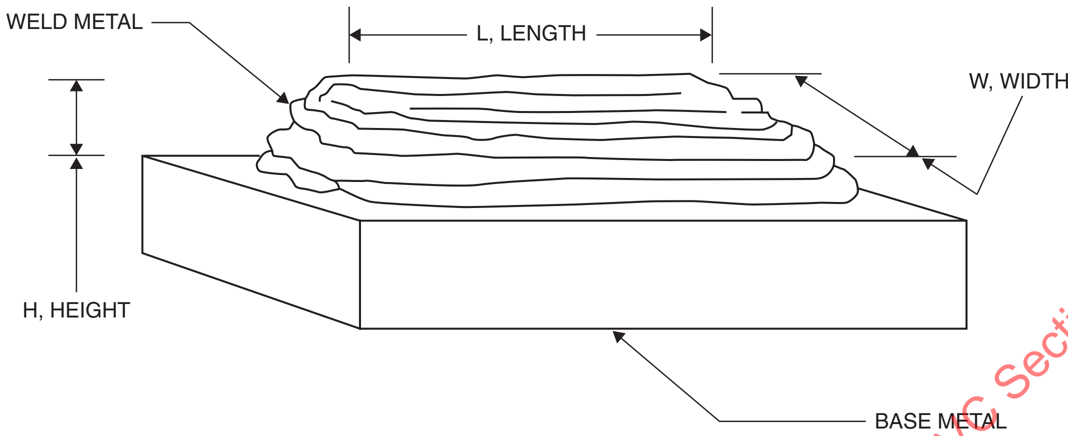
Classification	Electrode Diameter in	Electrode Diameter mm	Type of Current[b,c]	Chemical Analysis	Radiographic Test	All Weld Metal Tension Test	Fillet Weld Test
				Position of Welding[a]			
EXXX(X)-15	1/16	1.6	dcep	F	NR	NR	NR
EXXX(X)-15	5/64	2.0	dcep	F	NR	NR	NR
EXXX(X)-15	3/32	2.4	dcep	F	NR	NR	NR
EXXX(X)-15		2.5	dcep	F	NR	NR	NR
EXXX(X)-15	1/8	3.2	dcep	F	F	F	H, V, OH
EXXX(X)-15	5/32	4.0	dcep	F	F	F	H, V, OH
EXXX(X)-15	3/16	4.8	dcep	F	F	F	H
EXXX(X)-15		5.0	dcep	F	F	F	H
EXXX(X)-15	7/32	5.6	dcep	F	F	F	H
EXXX(X)-15		6.0	dcep	F	F	F	H
EXXX(X)-15	1/4	6.4	dcep	F	F	F	H
EXXX(X)-16, -17	1/16	1.6	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17	5/64	2.0	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17	3/32	2.4	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17		2.5	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17	1/8	3.2	ac and dcep	F	F	F	H, V, OH
EXXX(X)-16, -17	5/32	4.0	ac and dcep	F	F	F	H, V, OH
EXXX(X)-16, -17	3/16	4.8	ac and dcep	F	F	F	H
EXXX(X)-16, -17		5.0	ac and dcep	F	F	F	H
EXXX(X)-16, -17	7/32	5.6	ac and dcep	F	F	F	H
EXXX(X)-16, -17		6.0	ac and dcep	F	F	F	H
EXXX(X)-16, -17	1/4	6.4	ac and dcep	F	F	F	H
EXXX(X)-26	1/16	1.6	ac and dcep	F	NR	NR	NR
EXXX(X)-26	5/64	2.0	ac and dcep	F	NR	NR	NR
EXXX(X)-26	3/32	2.4	ac and dcep	F	NR	NR	NR
EXXX(X)-26		2.5	ac and dcep	F	NR	NR	NR
EXXX(X)-26	1/8	3.2	ac and dcep	F	F	F	H
EXXX(X)-26	5/32	4.0	ac and dcep	F	F	F	H
EXXX(X)-26	3/16	4.8	ac and dcep	F	F	F	H
EXXX(X)-26		5.0	ac and dcep	F	F	F	H
EXXX(X)-26	7/32	5.6	ac and dcep	F	F	F	H
EXXX(X)-26		6.0	ac and dcep	F	F	F	H
EXXX(X)-26	1/4	6.4	ac and dcep	F	F	F	H

[a] The abbreviations F, H, OH, and V indicate welding positions as follows:
F = Flat
H = Horizontal
V = Vertical
OH = Overhead
The abbreviation NR indicates that the test is not required.
[b] ac = alternating current; dcep = direct current, electrode positive (reverse polarity).
[c] Where both alternating and direct current are specified, only ac is required for classification testing.

9.4 Groove Weld for Mechanical Properties and Soundness

9.4.1 A test assembly shall be prepared and welded as specified in 9.4.1.1, 9.4.1.2, Figure 2, and the All Weld Metal Tension Test and/or Radiographic Test columns of Table 4 using base material of the appropriate type as specified in 9.2.2. Preheat and interpass temperatures shall be as specified in Table 5. Testing of this assembly shall be as specified in Clause 11, Radiographic Test and Clause 12, Tension Test.

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



Electrode Size		Weld Pad Size, minimum						Minimum Distance of Sample from Surface of Base Plate	
		L		W		H			
in	mm	in	mm	in	mm	in	mm	in	mm
1/16 5/64 3/32 —	1.6 2.0 2.4 2.5	1-1/2	38	1/2	13	1/2	13	3/8	10
1/8 5/32 3/16 —	3.2 4.0 4.8 5.0	2	50	1/2	13	5/8	16	1/2	13
7/32 — 1/4	5.6 6.0 6.4	2-1/2	64	1/2	13	3/4	19	5/8	16

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal

9.4.1.2 The test assembly shall be within the temperature ranges specified in Table 5 before starting each pass, including depositing of any buttering layer, as measured on the assembly at a distance of 1 in [25 mm] from the weld at the midlength of the test plate.

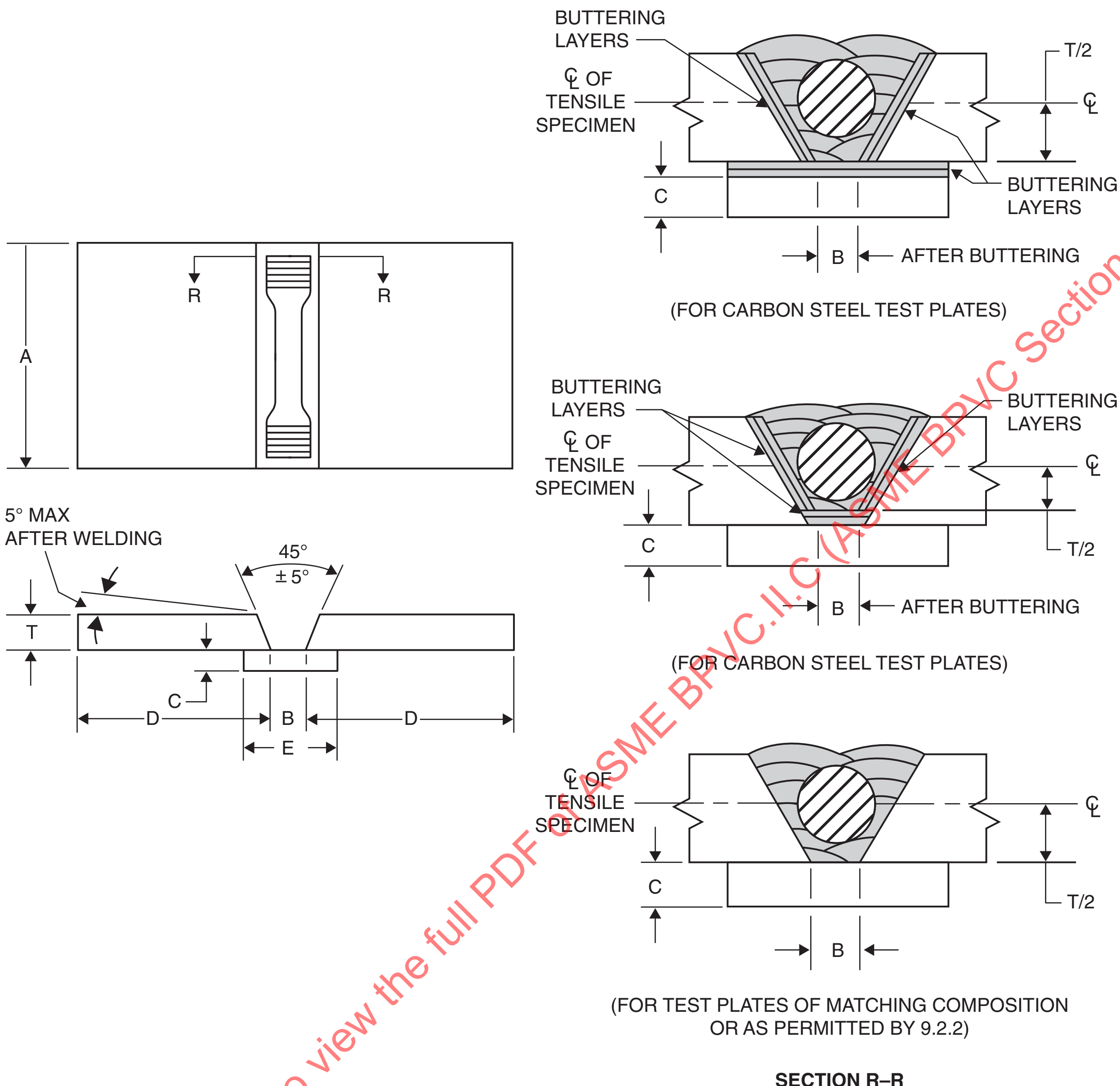
If, after any pass, the maximum temperature specified is exceeded, plates shall be allowed to cool in air (do not cool in water) to a temperature within the range shown.

The assembly shall be tested in the as-welded or postweld heat-treated condition as specified in Table 6.

9.5 Fillet Weld

9.5.1 A test assembly shall be prepared and welded as shown in Figure 3, using base metal of the appropriate type specified in 9.2.3. The welding position and conditions shall be as specified in the fillet weld column of Table 4 for the different electrode sizes and classifications. Testing of the assembly shall be as specified in Clause 13, Fillet Weld Test.

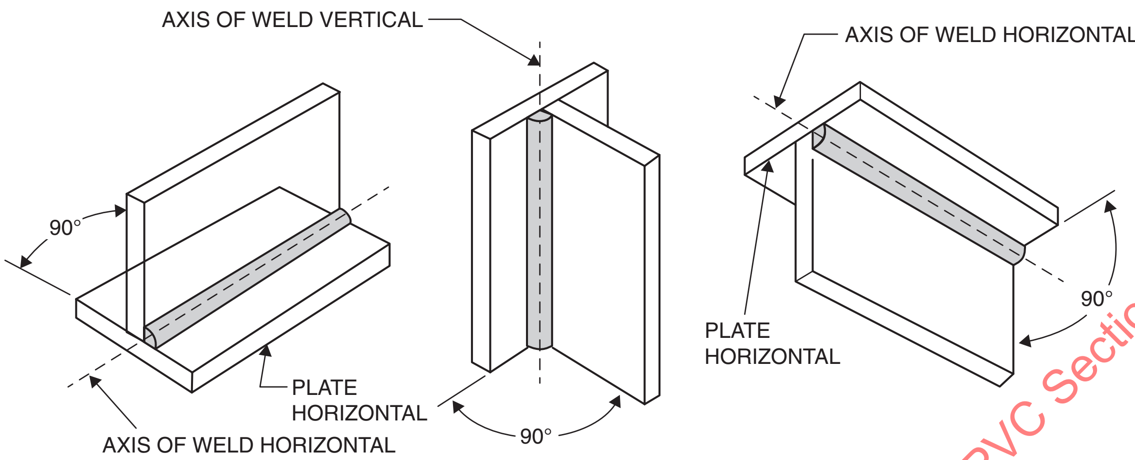
9.5.2 In preparing the two plates forming the test assembly, the standing member (web) shall have one edge prepared throughout its entire length so that when the web is set upon the base plate (flange), which shall be straight and flat, there will be intimate contact along the entire length of the joint.



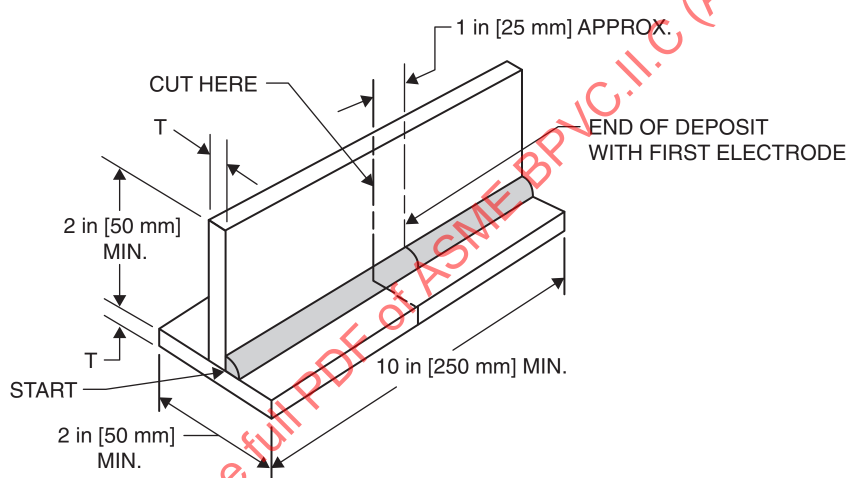
Electrode	Diameter	Dimensions of Test Assembly					
		T[a]	A, min.[b]	B[c]	C, min.	D, min.	E, min.
in	1/8	1/2	3-1/2	1/4	3/16	3-1/2	1
mm	3.2	12	90	6.5	5	90	25
in	5/32 to 1/4 incl.	3/4	5-1/2	1/2	1/4	3-1/2	1
mm	4.0 to 6.4 incl.	20	140	12	6.5	90	25

[a] For the radiographic test either 1/2 in [12 mm] or 3/4 in [20 mm] plate thickness may be used.
[b] Minimum length must be 8 in [200 mm], if being used for radiographic test.
[c] Tolerance shall be +1/8 in [3 mm], –0.

Figure 2—Groove Weld Assembly for Tension and Radiographic Tests for Electrodes 1/8 in [3.2 mm] Diameter and Larger



(A) POSITIONS OF TEST PLATES FOR WELDING FILLET-WELD TEST SPECIMENS



(B) PREPARATION OF FILLET-WELD TEST ASSEMBLY

Electrode Diameter		Plate Thickness, T		Position of Welding	Maximum Fillet Size	
in	mm	in	mm		in	mm
1/8	3.2	1/4	6	V	1/4	6.5
				H and OH	3/16	5
1/8[a]	3.2[a]	3/8	10	V	3/8	10
				H and OH	1/4	6.5
5/32	4.0	3/8	10	V	5/16	8
				H and OH	1/4	6.5
5/32[a]	4.0[a]	1/2	12	V	1/2	13
				H and OH	5/16	8
3/16	4.8 or 5.0	3/8	10	H	5/16	8
7/32	5.6	3/8	10	H	3/8	10
1/4	6.0 or 6.4	3/8	10	H	3/8	10

[a] For EXXX-17 electrodes only.

Figure 3—Fillet Weld Test Assembly

Table 5
Welding Conditions for Preparation of the Groove Weld

	Preheat and Interpass Temperature			
	Minimum		Maximum	
AWS Classification	°F	°C	°F	°C
E409Nb E410NiMo E430 E430Nb E630	300	150	500	260
E410	400	200	600	315
All Others	60	15	300	150

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

9.5.4 When welding in the vertical position, the welding shall progress upward.

10. Chemical Analysis

10.1 The top surface of the weld pad described in 9.3 and shown in Figure 1 shall be removed and discarded and a sample for analysis shall be obtained from the underlying metal by any appropriate mechanical means. The sample shall be free of slag.

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

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

10.4 The sample shall be analyzed by accepted analytical methods. In case of dispute, the referee method shall be ASTM E353.

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

10.6 If steel base metal other than those that have 0.03 percent maximum carbon are used for the low-carbon electrodes,[9] the sample shall come from material above the eighth layer.

11. Radiographic Test

11.1 When required in Table 4, the groove weld described in 9.4 and shown in Figure 2 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces (except as noted) 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

[9] Low-carbon electrodes are as follows: E308L, E308LMo, E309L, E309LMo, E316L, E316LMn, E317L, E320LR, E383, E385, E630, E2209, *E2307*, E2593, E2594, E2595, and E33-31.

Table 6
All-Weld-Metal Mechanical Property Requirements

AWS Classification	Tensile Strength, min ksi	Tensile Strength, min MPa	Elongation min. Percent	Heat Treatment
E209-XX	100	690	15	None
E219-XX	90	620	15	None
E240-XX	100	690	15	None
E307-XX	85	590	30	None
E308-XX	80	550	*30*	None
E308H-XX	80	550	*30*	None
E308L-XX	75	520	*30*	None
E308Mo-XX	80	550	*30*	None
E308LMo-XX[a]	75	520	*30*	None
E309-XX	80	550	30	None
E309H-XX	80	550	30	None
E309L-XX	75	520	30	None
E309Nb-XX[a]	80	550	30	None
E309Mo-XX	80	550	30	None
E309LMo-XX[a]	75	520	30	None
E310-XX	80	550	30	None
E310H-XX	90	620	10	None
E310Nb-XX[a]	80	550	25	None
E310Mo-XX	80	550	30	None
E312-XX	95	660	22	None
E316-XX	75	520	30	None
E316H-XX	75	520	30	None
E316L-XX	70	490	30	None
E316LMn-XX	80	550	20	None
E317-XX	80	550	30	None
E317L-XX	75	520	30	None
E318-XX	80	550	25	None
E320-XX	80	550	30	None
E320LR-XX	75	520	30	None
E330-XX	75	520	25	None
E330H-XX	90	620	10	None
E347-XX	75	520	30	None
E349-XX	100	690	25	None
E383-XX	75	520	30	None
E385-XX	75	520	30	None
E409Nb-XX	65	450	20	d
E410-XX	75	520	20	b
E410NiMo-XX	110	760	15	c
E430-XX	65	450	20	d
E430Nb-XX	65	450	20	d
E630-XX	135	930	7	e
E16-8-2-XX	80	550	35	None
E2209-XX	100	690	20	None
E2307-XX	*100*	*690*	*20*	*None*
E2553-XX	110	760	15	None
E2593-XX	110	760	15	None
E2594-XX	110	760	15	None
E2595-XX	110	760	15	None
E3155-XX	100	690	20	None
E33-31-XX	105	720	25	None

[a] E308LMo-XX, E309LMo-XX, E309Nb-XX, and E310Nb-XX were formerly named E308MoL-XX, E309MoL-XX, E309Cb-XX, and E310Cb-XX, respectively. The change was made to conform to the worldwide uniform designation of the element niobium.

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

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

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

[e] Heat to 1875 °F to 1925 °F [1025 °C to 1050 °C], hold for one hour (–0, +15 minutes), and air cool to ambient, and then precipitation harden at 1135 °F to 1165 °F [610 °C to 630 °C], hold for four hours (–0, +15 minutes), and air cool to ambient.

metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the normal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E1032. 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 in excess of the following:

a. in any 6 in [150 mm] length of the 1/2 in [12 mm] thick test assembly: no individual slag inclusion longer than 7/32 in [5.6 mm] and a maximum total length of 7/16 in [11 mm] for all slag inclusions

b. in any 6 in [150 mm] length of the 3/4 in [20 mm] thick test assembly: no individual slag inclusion in excess of 9/32 in [7.1 mm] and a maximum total length of 15/32 in [12 mm] for all slag inclusions.

3. no rounded indications in excess of those permitted by the radiographic standards in Figure 5A, or 5B as applicable.

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

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

11.3.2 Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications in excess of the sizes permitted in the radiographic standards do not meet the requirements of this specification.

12. Tension Test

12.1 One all-weld metal round tension specimen as specified in the Tension Test section of AWS B4.0 or AWS B4.0M shall be machined from the groove weld described in 9.4 and shown in Figure 2. For a test plate thickness of 1/2 in [12 mm], the all-weld-metal tension test specimen shall have a nominal diameter of 0.250 in [6.25 mm]. For a test plate thickness of 3/4 in [20 mm], the all-weld-metal tension test specimen shall have a nominal diameter of 0.500 [12.5 mm]. For all plate thicknesses, the gage length-to-diameter ratio shall be 4:1.

12.2 The specimen shall be tested in the manner described in the tension test section of AWS B4.0 or AWS B4.0M.

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

13. Fillet Weld Test

13.1 The fillet weld test, when required in Table 4, shall be made in accordance with 9.5 and Figure 3. The entire face of the completed fillet weld shall be examined visually. The weld shall be free from cracks or other open defects that would affect the strength of the weld. After the visual examination, a cross section shall be taken from the portion of the weld made with the first electrode at approximately 1 in [25 mm] from the end of that weld bead, as shown in Figure 3. The cross-sectional surface shall be polished and etched, and then examined as required in 13.2.

13.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 4, and the leg length and the convexity shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement.

13.2.1 The fillet weld shall have complete fusion to the joint root.

13.2.2 Both legs of the fillet weld shall be equal in length within 1/16 in [1.5 mm].

13.2.3 Convexity of the fillet weld shall be within the limits shown in Figure 4.

13.2.4 The fillet weld shall show no evidence of cracks.

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

14. Method of Manufacture

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

15. Standard Sizes and Lengths

Standard sizes (diameter of the core wire), standard lengths, and tolerances of electrodes shall be as shown in Table 7.

16. Core Wire and Covering

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

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

1. Seven percent of the mean dimension in sizes 3/32 in [2.5 mm] and smaller
2. Five percent of the mean dimension in sizes 1/8 in [3.2 mm] and 5/32 in [4.0 mm]
3. Four percent of the mean dimension in sizes 3/16 in [4.8 mm] and larger

The concentricity may be measured by any suitable means.

17. Exposed Core

17.1 The grip end of each electrode shall be bare (free of covering) for a distance of not less than 1/2 in [12 mm], nor more than 1-1/4 in [30 mm] for electrodes 5/32 in [4.0 mm] and smaller, and not less than 3/4 in [19 mm], nor more than 1-1/2 in [38 mm] for electrodes 3/16 in [4.8 mm] and larger, to provide for electrical contact with the electrode holder.

17.2 The arc end of each electrode shall be sufficiently bare and the covering sufficiently tapered to permit easy striking of the arc. The length of the bare portion (measured from the end of the core wire to the location where the full cross section of the covering is obtained) shall not exceed 1/8 in [3 mm] or the diameter of the core wire, whichever is less. Electrodes with chipped coverings near the arc end, baring the core wire no more than the lesser of 1/4 in [6 mm] or twice the diameter of the core wire, meet the requirements of this specification, provided no chip uncovers more than 50 percent of the circumference of the core.

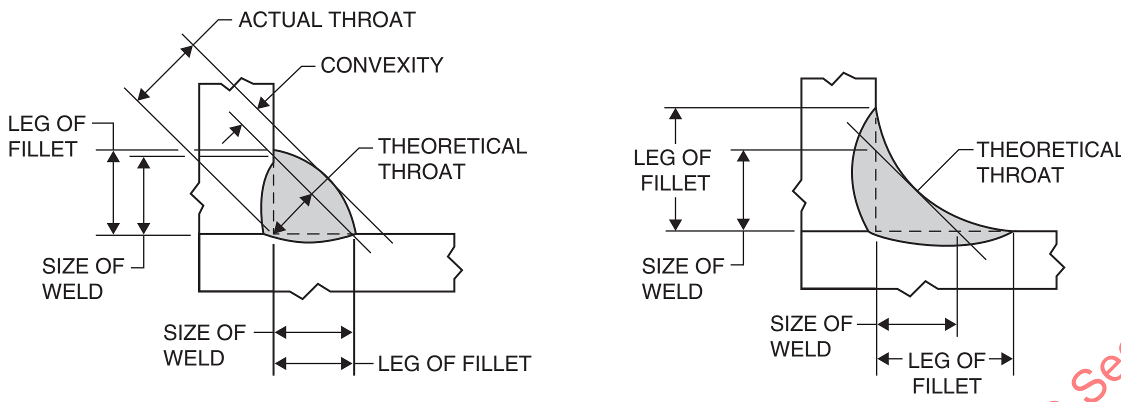
18. Electrode Identification

All electrodes shall be identified as follows:

18.1 At least one imprint of the electrode classification shall be applied to the electrode covering starting within 2-1/2 in [65 mm] of the grip end of the electrode. The prefix letter “E” in the electrode classification may be omitted from the imprint.

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

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



Measured Fillet Weld Size[a]		Maximum Convexity[b]	
in	mm	in	mm
1/8	3.0	3/64	1.0
9/64	3.5	3/64	1.0
5/32	4.0	3/64	1.0
11/64	4.5	3/64	1.0
3/16	5.0	1/16	1.5
13/64	5.0	1/16	1.5
7/32	5.5	1/16	1.5
15/64	6.0	1/16	1.5
1/4	6.5	1/16	1.5
17/64	6.5	1/16	1.5
9/32	7.0	1/16	1.5
19/64	7.5	1/16	1.5
5/16	8.0	5/64	2.0
21/64	8.5	5/64	2.0
11/32	8.5	5/64	2.0
23/64	9.0	5/64	2.0
3/8	9.5	5/64	2.0

[a] Size of fillet weld = leg length of largest inscribed isosceles right triangle.
[b] Fillet weld size, convexity, and leg lengths of fillet welds shall be determined by actual measurement (nearest 1/64 in [0.5 mm]) on a section laid out with scribed lines shown.

Figure 4—Fillet Weld Test Specimen

19. Packaging

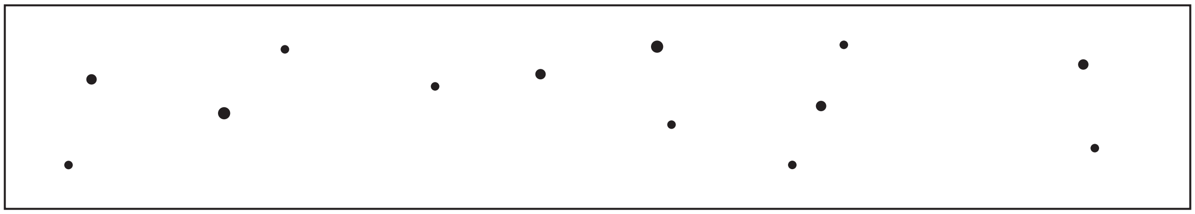
19.1 Electrodes shall be suitably packaged to protect them from damage during shipment and storage under normal conditions.

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

20. Marking of Packages

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

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



(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 13 WITH THE FOLLOWING RESTRICTIONS:

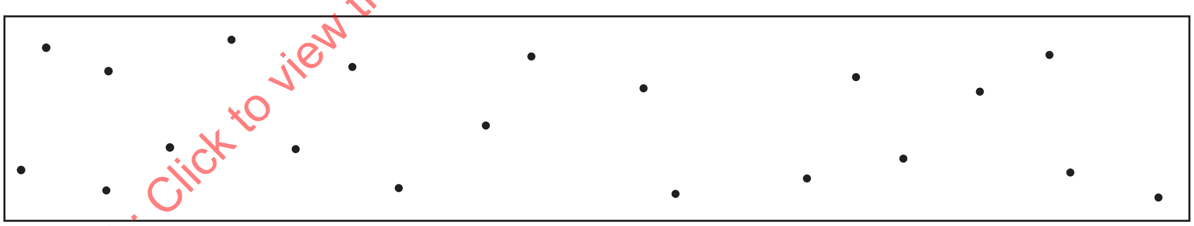
MAXIMUM NUMBER OF LARGE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 2.
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 4.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 7.

(B) LARGE ROUNDED INDICATIONS

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

(C) MEDIUM ROUNDED INDICATIONS

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

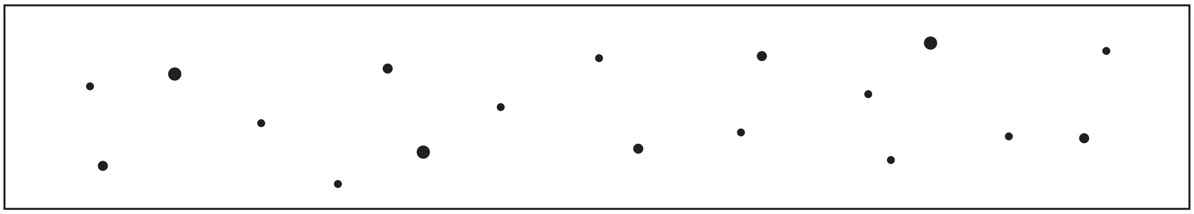


(D) SMALL ROUNDED INDICATIONS

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

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

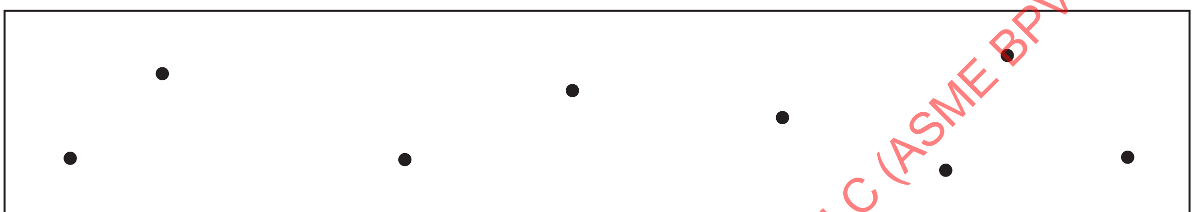
Figure 5A—Rounded Indication Standards for Radiograph Test—1/2 in [12 mm] Plate



(A) ASSORTED ROUNDED INDICATIONS

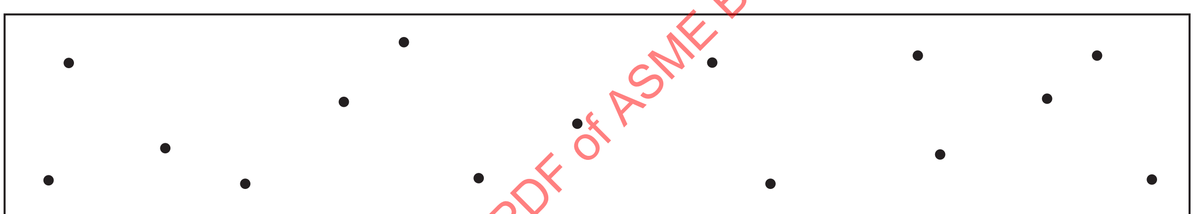
SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 18 WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 10.



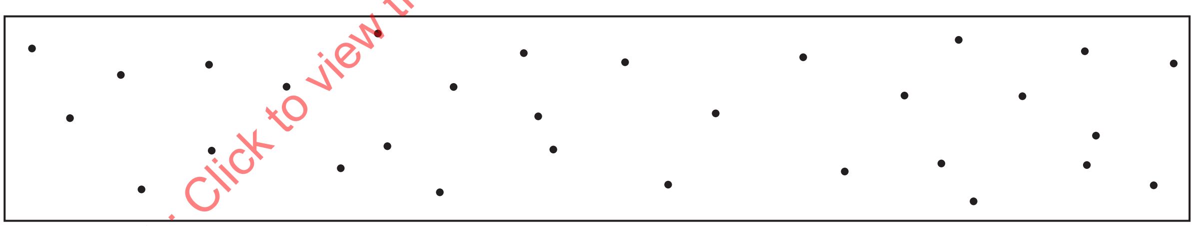
(B) LARGE ROUNDED INDICATIONS

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



(C) MEDIUM ROUNDED INDICATIONS

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



(D) SMALL ROUNDED INDICATIONS

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

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

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

Table 7
Standard Sizes and Lengths

Electrode Size (Diameter of Core Wire)[a]		Standard Lengths[b,c]	
in	mm	in	mm
1/16	1.6	9,10	225, 250
5/64	2.0	9,10	225, 250
3/32	2.4[e]	9, 10, 12, 14[d]	225, 250, 300, 350[d]
	2.5	9, 10, 12, 14[d]	225, 250, 300, 350[d]
1/8	3.2	14, 18[d]	350, 450[d]
5/32	4.0	14, 18[d]	350, 450[d]
3/16	4.8[e]	14, 18[d]	350, 450[d]
	5.0	14, 18[d]	350, 450[d]
7/32	5.6[e]	14, 18[d]	350, 450[d]
	6.0	14, 18[d]	350, 450[d]
1/4	6.4[e]	14, 18[d]	350, 450[d]

[a] Tolerance on the diameter shall be ±0.002 in [±0.05 mm].
[b] Tolerance on length shall be ±1/4 in [±6 mm].
[c] Other sizes and lengths shall be as agreed upon between purchaser and supplier.
[d] These lengths are intended only for the EXXX-26 type.
[e] These sizes are not standard in ISO 544.

20.2 The appropriate precautionary information[10] 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 electrodes, including individual unit packages enclosed within a larger package.

[10] Typical examples of "warning labels" and precautionary information are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

Annex A (Informative)
Guide to AWS Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

This annex is not part of AWS A5.4/A5.4M:2012, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, but is included for informational purposes only.

A1. Introduction

The purpose of this guide is to correlate the electrode classifications with their intended applications so that the specification can be used effectively. Appropriate base metal specifications or welding processes 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 or welding processes for which each welding material is suitable.

A2. Classification System

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

A2.1.1 The mechanical tests measure strength and ductility. In corrosive and high-temperature applications where there may be no load-carrying or pressure-retaining requirement, mechanical properties are often of lesser importance than the corrosion and heat-resisting properties. These mechanical test requirements, however, provide an assurance of freedom from weld metal flaws, such as check cracks and serious dendritic segregation which, if present, may cause failure in service.

A2.1.2 It is recognized that for certain applications, supplementary tests may be required. In such cases, additional tests to determine specific properties, such as corrosion resistance, scale resistance, or strength at elevated temperatures, may be required as agreed upon between supplier and purchaser (see A9).

A2.2 Request for New Classification

1. When a new classification that is different from those in this specification achieves commercial significance, the manufacturer, or the user, of this new classification may request that a classification be established for it and that it be included in this specification.

2. A request to establish a new classification must be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee on Stainless Steel Filler Metals 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, mechanical property requirements, and usability test requirements.

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

c. Information on Description and Intended Use, which parallels that for existing classifications, for that section of the annex.

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

3. The request should be sent to the Secretary of the 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 Committee on Filler Metals and Allied Materials, and to the Chair of the Subcommittee on Stainless Steel Filler Metals.

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 the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a timely manner and the Secretary shall report these to the Chair of the Committee on Filler Metals 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 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 International Classification System. Table A.1 shows the classifications of welding filler metals in ISO 3581:2003 corresponding to those in this specification. In accordance with the generic system being adopted in many ISO specifications, the initial letter "E" designates a covered electrode, and the letter "S" the alloy system. The subsequent designators follow the AWS system. This system applies to classifications in ISO 3581B. The designations used in Europe for the closely corresponding classifications in ISO 3581A appear in Table A.1.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, must be clearly stated in the purchase order, according to the provisions of AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing is normally conducted on material of that classification, as specified in Schedule F, Table 1, of AWS A5.01. Testing in accordance with any other Schedule in that Table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification. The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted.

The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in AWS A5.01M/A5.01(ISO 14344 MOD).

A5. Ventilation

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

A5.2 American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section on Ventilation in that document.

A6. Ferrite in Weld Deposits

A6.1 Ferrite is known to be very beneficial in reducing the tendency for cracking or fissuring in weld metals; however, it is not essential. Millions of pounds of fully austenitic weld metal have been used for years and provided satisfactory service performance. Generally, ferrite is helpful when the welds are restrained, the joints are large, and when cracks or fissures adversely affect service performance. Ferrite increases the weld strength level. Ferrite may have a detrimental effect on corrosion resistance in some environments. It also is generally regarded as detrimental to toughness in cryogenic service, and in high-temperature service where it can transform into the brittle sigma phase.

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

In order to substantially reduce this problem, the WRC Subcommittee published on July 1, 1972, *Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*.[11] In 1974, the American Welding Society extended this procedure and prepared AWS A4.2, *Standard Procedure for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Steel Weld Metal*. All instruments used to measure the ferrite content of AWS classified stainless electrode products are to be traceable to this AWS standard.

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

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

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

Table A.1
Comparison of Classification in ISO 3581:2003

AWS A5.4/A5.4M	ISO 3581A	ISO 3581B
E209	—	ES209
E219	—	ES219
E240	—	ES240
E307	E18 9 Mn Mo	ES307
E308	E19 9	ES308
E308H	E19 9 H	ES308H
E308L	E19 9 L	ES308L
E308Mo	E20 10 3	ES308Mo
E308LMo	—	ES308LMo
E309	E22 12	ES309
E309H	—	ES309H
E309L	E22 12 L	ES309L
E309Nb	E23 12 Nb	ES309Nb
E309Mo	—	ES309Mo
E309LMo	E23 12 2 L	ES309LMo
E310	E25 20	ES310
E310H	E25 20H	ES310H
E310Nb	—	ES310Nb
E310Mo	—	ES310Mo
E312	E29 9	ES312
E316	E19 12 2	ES316
E316H	—	ES316H
E316L	E19 12 3 L	ES316L
E316LMn	E20 16 3 Mn N L	ES316LMn
E317	—	ES317
E317L	—	ES317L
E318	E 19 2 3 Nb	ES318
E320	—	ES320
E320LR	—	ES320LR
E330	E18 36	ES330
E330H	—	ES330H
E347	E19 9 Nb	ES347
E349	—	ES349
E409Nb	—	ES409Nb
E410	E13	ES410
E410NiMo	E13 4	ES410NiMo
E430	E17	ES430
E430Nb	—	ES430Nb
E630	—	ES630
E16-8-2	E16 8 2	ES16-8-2
E2209	E22 9 3 N L	ES2209
E2307	*E23 7 NL*	—
E2553	—	ES2553
E2593	E25 9 3 Cu N L	—
E2594	E25 9 4 N L	—
E2595	—	—
E3155	—	—
E33-31	—	—

A6.5 Even on undiluted pads, ferrite variations from pad to pad must be expected due to slight changes in welding and measuring variables. On a large group of pads from one heat or lot and using a standard pad welding and preparation procedure, two sigma values indicate that 95 percent of the tests are expected to be within a range of approximately ±2.2 FN at about 8 FN. If different pad welding and preparation procedures are used, these variations will increase.

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

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

A6.8 In the E3XX classifications, many types such as E310, E310Mo, E310Nb, E316LMn, E320, E320LR, E330, E383, E385, and E3155, and E31-33 are fully austenitic. The E316 group can be made with little or no ferrite and generally is used in that form because it has better corrosion resistance in certain media. It also can be obtained in a higher ferrite form, usually over 4 FN, if desired. Many of the other E3XX classifications can be made in low-ferrite versions, but commercial practice usually involves ferrite control above 4 FN. Because of composition limits covering these grades and various manufacturing limits, most lots will be under 10 FN and they are unlikely to go over 15 FN. E308LMo and E309L can have ferrite levels in excess of 15 FN. E16-8-2 generally is controlled at a low-ferrite level, under 5 FN; E309LMo, E312, E2209, *E2307*, E2553, E2593, and E2594, and E2595 generally are quite high in ferrite, usually over 20 FN.

A6.9 When it is desired to measure ferrite content, the following procedure is recommended to minimize variation in measured ferrite content and avoid false low or false high values.

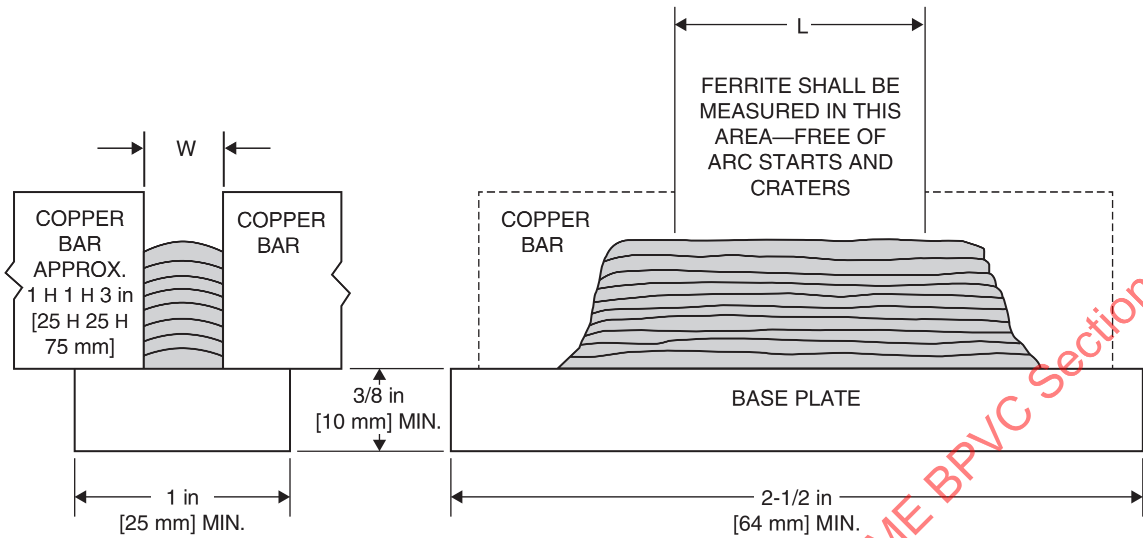
A6.9.1 Weld pads as detailed in Figure A.1 are prepared as described in A6.9.2 through A6.9.4. The base plate should be Type 301, 302, or 304 conforming to ASTM Specification A167 or A240. Carbon steel may be used provided that the weld pad is built up to the minimum height specified in A6.9.2.

A6.9.2 The weld pad should be built up between two copper bars laid parallel on the base plate by depositing single weld bead layers, one on top of the other to a minimum height of 1/2 in [13 mm]. The spacing between the copper bars for the size of the electrode being tested should be as specified in Figure A.1. An optional welding fixture is shown in Figure A.2. If carbon steel is used as the base plate, the weld pad should be built up to a minimum height of 5/8 in [16 mm].

A6.9.3 Typical welding currents used for the size of the electrode being tested are shown in Figure A.1. The arc length should be as short as practicable. The weld bead layers may be deposited with a weave, if necessary, to fill the space between the copper bars. The arc should not be allowed to impinge on the copper bars. The welding direction should be alternated from pass to pass. The weld stops and starts should be located at the ends of the weld buildup. Each pass should be cleaned prior to depositing the next weld bead. The maximum interpass temperatures should be 200 ºF [95 º C]. Between passes, the weld pad may be cooled by quenching in water not sooner than 20 seconds after the completion of each pass. The last pass should be air cooled to below 800 ºF [430 º C] prior to quenching in water.

A6.9.4 The completed weld pad when the anticipated ferrite is 30 FN or less should be draw filed to provide sufficient finished surface to make the required ferrite readings. Draw filing should be performed with a 14 in [360 mm] mill bastard file held on both sides of the weld with the long axis of the file perpendicular to the long axis of the weld. (Other methods of surface preparation have been shown to result in work hardening and/or overheating, causing false measurements.) Files should either be new or should have been used only on austenitic stainless steel. Filing should be accomplished by smooth draw filing strokes (one direction only) along the length of the weld while applying a firm downward pressure. Cross filing, that is, filing in two different directions, should not be permitted. The finished surface should be smooth with all traces of weld ripple removed and should be continuous in length where measurements are to be taken. The width of the prepared surface should not be less than 1/8 in [3 mm]. For anticipated ferrite levels greater than 30 FN, the surface should be ground with successfully finer abrasives to 600 grit or finer. Care should be taken during grinding to prevent overheating or burning. The completed weld pad should have the surface prepared so that it is smooth with all traces of weld ripple removed and should be continuous in length where measurements are to be taken. This can be accomplished by any suitable means providing the surface is not heated in excess during the machining operation (excessive heating may affect the final ferrite reading). The width of the prepared surface should not be less than 1/8 in [3 mm].

A6.9.5 A total of at least six ferrite readings should be taken on the finished surface along the longitudinal axis of the weld pad with an instrument calibrated in accordance with the procedures specified in AWS A4.2M, *Standard Procedures*



Electrode Size		Welding Current Amperes[a]	Approximate Dimensions of Deposit			
			Width, W		Length, L	
in	mm	–15,–16,–17, –26	in	mm	in	mm
1/16	1.6	35–50	0.25	6.5	1-1/4	32
5/64	2.0	45–60	0.25	6.5	1-1/4	32
3/32	2.4, 2.5	65–90	0.3	7.5	1-1/2	38
1/8	3.2	90–120	0.4	10	1-1/2	38
5/32	4.0	120–150	0.5	13	1-1/2	38
3/16	4.8, 5.0	160–200	0.6	15	1-1/2	38
7/32	5.6	200–240	0.7	18	1-1/2	38
	6.0	220–260	0.7	18	1-1/2	38
1/4	6.4	240–280	0.7	18	1-1/2	38

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

Figure A.1—Weld Pad for Ferrite Test

for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal (latest edition). The readings obtained should be averaged to a single value.

A6.10 The ferrite content of welds may be calculated from the chemical composition of the weld deposit. This can be done from the WRC-1992 Diagram (Figure A.3).

A6.10.1 The WRC-1992 Diagram[12] (Figure A.3) predicts the ferrite content in Ferrite Number (FN). It is a slight modification of the WRC-1988 Diagram[13] to take into account the effect of copper as originally proposed by Lake. Studies within the WRC Subcommittee on Welding of Stainless Steel and within Commission II of the International Institute of Welding show a closer agreement between measured and predicted ferrite contents using the WRC-1988 Diagram than when using the previously used DeLong Diagram. The WRC-1992 Diagram may not be applicable to compositions having greater than 0.3 percent nitrogen, one percent silicon, or greater than ten percent manganese. For stainless steel compositions not alloyed with Cu, the predictions of the 1988 and 1992 diagrams are identical.

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

[13] McCowan, C. N., Siewert, T. A., and Olson, D. L. 1989. WRC Bulletin 342, *Stainless Steel Weld Metal: Prediction of Ferrite Content*, New York, NY: Welding Research Council.

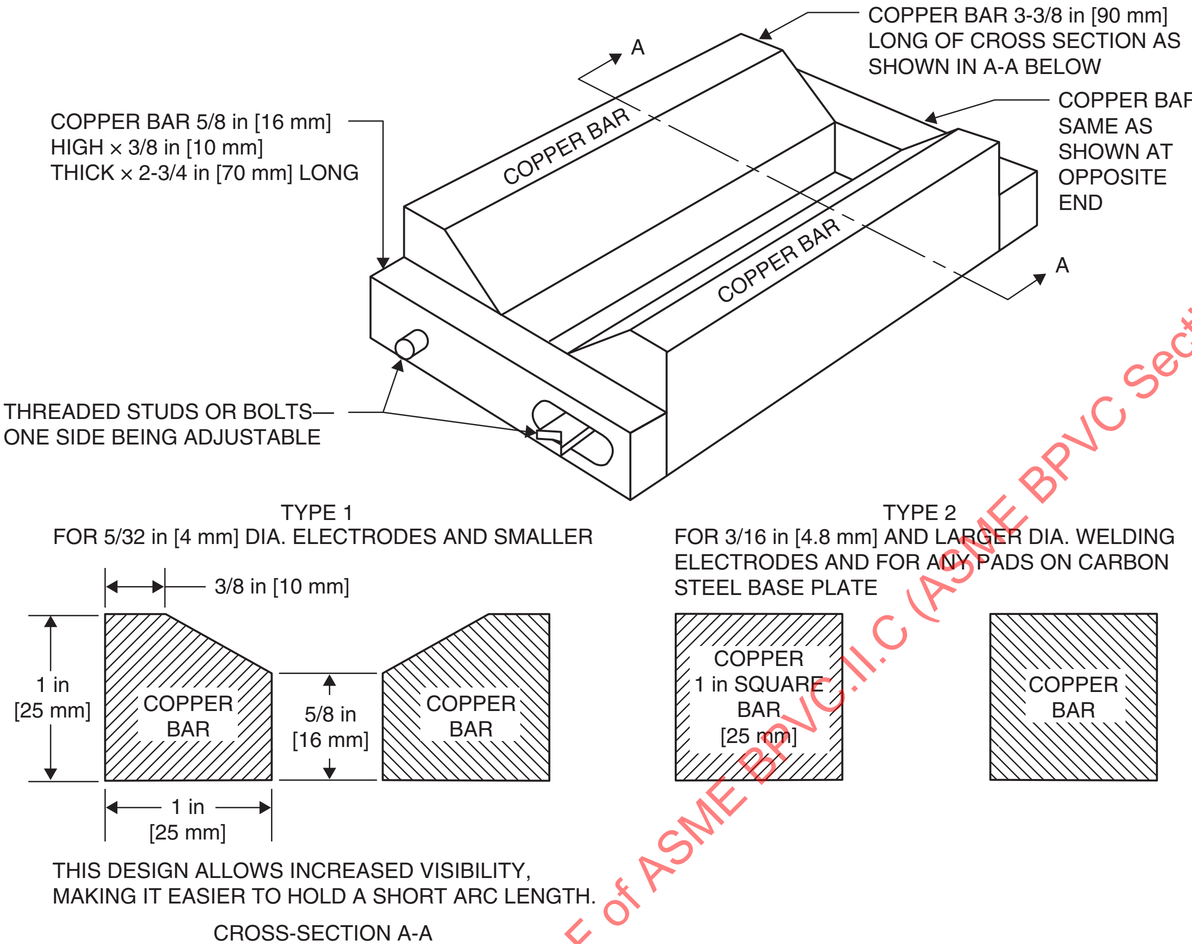


Figure A.2—Optional Welding Fixture for Welding Ferrite Test Pads

A6.10.2 The differences between measured and calculated ferrite are somewhat dependent on the ferrite level of the deposit, increasing as the ferrite level increases. The agreement between the calculated and measured ferrite values is also strongly dependent on the quality of the chemical analysis. Variations in the results of the chemical analyses encountered from laboratory to laboratory can have significant effects on the calculated ferrite value, changing it as much as 4 to 8 FN.

A7. Description and Intended Use of Filler Metals

A7.1 E209. The nominal composition (wt %) of this weld metal is 22 Cr, 11 Ni, 5.5 Mn, 2 Mo, and 0.20 N. Electrodes of this composition are most often used to weld AISI Type 209 (UNS S20910) base metals. The alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength with good toughness over a wide range of temperatures. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increasing resistance to intergranular corrosion. Nitrogen alloying coupled with the molybdenum content provides superior resistance to pitting and crevice corrosion in aqueous chloride-containing media. Type E209 electrodes have sufficient total alloy content for use in joining dissimilar alloys, like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications.

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

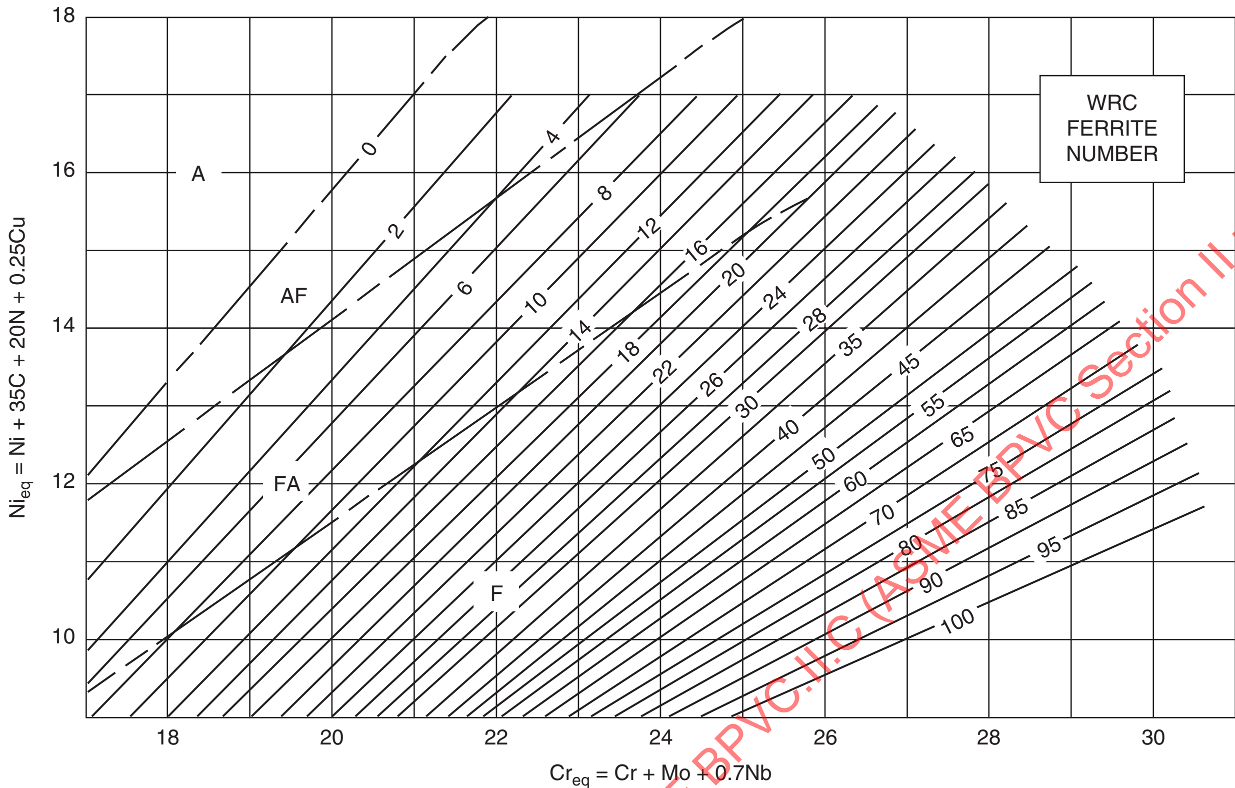


Figure A.3—WRC-1992 (FN) Diagram for Stainless Steel Weld Metal

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

A7.3 E240. The nominal composition (wt %) of this weld metal is 18 Cr, 5 Ni, 12 Mn, and 0.20 N. Electrodes of this composition are most often used to weld AISI Type 240 and 241 base metals. These alloys are nitrogen-strengthened austenitic stainless steels exhibiting high strength with good toughness over a wide range of temperatures. Significant improvement in resistance to wear in particle-to-metal and metal-to-metal (galling) applications is a desirable characteristic when compared to the more conventional austenitic stainless steels like Type 304. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increasing resistance to intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. In addition, weldments in Alloys AISI 240 and AISI 241 when compared to Type 304, exhibit improved resistance to transgranular stress corrosion cracking in hot aqueous chloride-containing media. The E240 electrodes have sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion and wear applications.

A7.4 E307. The nominal composition (wt %) of this weld metal is 19.8 Cr, 9.8 Ni, 4 Mn and 1 Mo. Electrodes of this composition are used primarily for moderate strength welds with good crack resistance between dissimilar steels such as austenitic manganese steel and carbon steel forgings or castings.

A7.5 E308. The nominal composition (wt %) of this weld metal is 19.5 Cr, and 10 Ni. Electrodes of this composition are most often used to weld base metal of similar composition such as AISI Types 301, 302, 304, and 305.

A7.6 E308H. These electrodes are the same as E308 except that the allowable weld metal carbon content has been restricted to eliminate the lowest carbon levels. Carbon content in the range of 0.04 to 0.08 percent provides higher tensile and creep strengths at elevated temperatures. These electrodes are used for welding Type 304H base metal. Weld metal ferrite content is normally targeted for 5 FN to minimize the effect of sigma embrittlement in high-temperature service.

A7.7 E308L. The composition of the weld metal is the same as E308, except for the carbon content. The 0.04 percent maximum carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. A carbon content of 0.04 percent maximum has been shown to be adequate in weld metal, even though it is recognized that similar base metal specifications require a 0.03 percent limitation. This low-carbon alloy, however, is not as strong at elevated temperature as E308H or E347.

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

A7.9 E308LMo. These electrodes are recommended for welding ASTM CF3M stainless steel castings, as they match the base metal with regard to chromium, nickel, and molybdenum. E308LMo electrodes may also be used for welding wrought materials such as Type 316L stainless when increased ferrite is desired beyond that attainable with E316L electrodes.

A7.10 E309. The nominal composition (wt %) of this weld metal is 23.5 Cr, 13 Ni with carbon levels allowed up to 0.15 percent and typical ferrite levels from 3 to 20 FN. Electrodes of this composition are used for welding similar compositions in wrought or cast form. They are also used for welding dissimilar steels, such as joining Type 304 to carbon or low-alloy steel, welding the clad side of Type 304-clad steels, making the first layer of a 308 weld cladding and applying stainless steel sheet linings to carbon steel shells. Embrittlement or cracking can occur if these dissimilar steel welds are subjected to a postweld heat treatment or to service above 700 ºF [370 ºC]. Occasionally, they are used to weld Type 304 and similar base metals where severe corrosion conditions exist requiring higher alloy weld metal. Essentially, there are two electrodes contained within this specification, E309H and E309L, and for critical applications their use is encouraged. See below for their specific applications.

A7.11 E309H. These electrodes are the same as E309, except that the allowable weld metal carbon content has been restricted to eliminate the lowest carbon levels. The carbon restriction will provide higher tensile and creep strengths at elevated temperatures. This together with a typical ferrite content of about 6 FN make these electrodes suitable for the welding of 24 Cr 12 Ni wrought and cast steels designed for corrosion and oxidation resistance. High-carbon castings to ACI's HH grade should be welded with an electrode that is similar to the casting composition.

A7.12 E309L. The composition of this weld metal is the same as that deposited by E309 electrodes, except for the lower carbon content. The 0.04 percent maximum carbon content of these weld deposits ensures a higher ferrite content than the E309H, usually greater than 8 FN and reduces the possibility of intergranular carbide precipitation. This thereby increases the resistance to intergranular corrosion without the use of niobium (columbium). E309L deposits are not as strong at elevated temperature as the niobium-stabilized alloy or E309H deposits. E309L electrodes are commonly used for welding dissimilar steels, such as joining Type 304 to mild or low-alloy steel, welding the clad side of Type 304-clad steels, welding the first layer of E308L weld cladding and applying stainless steel sheet linings to carbon steel. Embrittlement or cracking can occur if these dissimilar steel welds are subjected to a postweld heat treatment or to service above 700 ºF [370 ºC]. If postweld heat treatment of the carbon steel is essential, the total procedure, welding and heat treatment, should be proven prior to implementation.

A7.13 E309Nb. The composition of this weld metal is the same as Type 309, except for the addition of niobium and a reduction in the carbon limit. The niobium provides resistance to carbide precipitation and thus increases intergranular corrosion resistance, and also provides higher strength in elevated-temperature service. E309Nb electrodes are used also for welding Type 347 clad steels or for the overlay of carbon steel.

A7.14 E309Mo. The composition of this weld metal is the same as that deposited by E309 electrodes, except for the addition of molybdenum and a small reduction in the carbon limit. These electrodes are used for welding Type 316 clad steels or for the overlay of carbon steels.

A7.15 E309LMo. The composition of this weld metal is the same as that deposited by E309Mo electrodes, except for the restricted carbon content. The lower carbon content of the weld metal reduces the possibility of intergranular corrosion and increases the ferrite content. This in turn reduces the potential for solidification cracking when deposited onto carbon or low-alloy steels.

A7.16 E310. The nominal composition (wt %) of this weld metal is 26.5 Cr, 21 Ni. Electrodes of this composition are most often used to weld base metals of similar composition.

A7.17 E310H. The composition of this weld metal is the same as that deposited by E310 electrodes, except that carbon ranges from 0.35 to 0.45 percent. These electrodes are used primarily for welding or repairing high-alloy heat and corrosion-resistant castings of the same general composition which are designated as Type HK by the Alloy Castings Institute. The alloy has high strength at temperatures over 1700 ºF [930 ºC]. It is not recommended for high-sulfur atmospheres or where severe thermal shock is present. Long time exposure to temperatures in the approximate range of 1400 ºF to 1600 ºF [760 ºC to 870 ºC] may induce formation of sigma and secondary carbides which may result in reduced corrosion resistance, reduced ductility, or both. The composition of this electrode should not be confused with the stainless steel wrought alloy 310H which has a lower carbon content of 0.04–0.10 percent.

A7.18 E310Nb. The composition of this weld metal is the same as that deposited by E310 electrodes, except for the addition of niobium and a reduction in carbon limit. These electrodes are used for the welding of heat-resisting castings, Type 347 clad steels, or the overlay of carbon steels.

A7.19 E310Mo. The composition of this weld metal is the same as that deposited by E310 electrodes, except for the addition of molybdenum and a reduction in carbon limit. These electrodes are used for the welding of heat-resisting castings, Type 316 clad steels, or for the overlay of carbon steels.

A7.20 E312. The nominal composition (wt %) of this weld metal is 30 Cr, 9 Ni. These electrodes were originally designed to weld cast alloys of similar composition. They have been found to be valuable in welding dissimilar metals, especially if one of them is a stainless steel, high in nickel. This alloy gives a two-phase weld deposit with substantial amounts of ferrite in an austenitic matrix. Even with considerable dilution by austenite-forming elements, such as nickel, the microstructure remains two-phase and thus highly resistant to weld metal cracks and fissures. Applications should be limited to service temperature below 800 ºF [420 ºC] to avoid formation of secondary brittle phases.

A7.21 E316. The nominal composition (wt %) of this weld metal is 18.5 Cr, 12.5 Ni, 2.5 Mo. These electrodes are used for welding Type 316 and similar alloys. They have been used successfully in certain applications involving special base metals for high-temperature service. For these high-temperature applications in the past, the carbon level would have been about 0.06%. For similar current or future applications, the use of E316H would ensure similar carbon levels. The presence of molybdenum provides creep resistance and increased ductility at elevated temperatures. Rapid corrosion of Type 316 weld metal may occur when the following three factors coexist:

1. The presence of a continuous or semi-continuous network of ferrite in the weld metal microstructure
2. A composition balance of the weld metal giving a chromium-to-molybdenum ratio of less than 8.2 to 1
3. Immersion of the weld metal in a corrosive medium.

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

A7.22 E316H. These electrodes are the same as E316, except that the allowable weld metal carbon content has been restricted to eliminate the lowest carbon levels. Carbon content in the range of 0.04 to 0.08 percent provides higher tensile and creep strengths at elevated temperatures. These electrodes are used for welding 316H base metal.

A7.23 E316L. This composition is the same as E316, except for the carbon content. The 0.04 percent maximum carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. These electrodes are used principally for welding low-carbon, molybdenum-bearing austenitic alloys. Tests have shown that 0.04 percent carbon limit in the weld metal gives adequate protection against intergranular corrosion in most cases. This low-carbon alloy, however, is not as strong at elevated temperatures as Type E316H. This classification with maximum ferrite content of 2 FN has traditionally been the choice for welding Types 304 and 316 stainless steels for cryogenic service at temperatures down to –452 ºF [–269 ºC].

A7.24 E316LMn. The nominal composition (wt %) of this weld metal is 19.5 Cr, 16.5 Ni, 6.5 Mn, 3 Mo, 0.2 N. This is normally a fully austenitic alloy with a maximum ferrite content of 0.5 FN. In critical applications for cryogenic and corrosion-resistant service, the purchaser should specify the maximum ferrite allowable. One of the primary uses of this electrode is for the joining of similar and dissimilar cryogenic steels for applications down to –452 ºF [–269 ºC]. Similar steels include stainless steels such as UNS S30453 and S31653. This electrode also exhibits good corrosion resistance in acids and seawater, and is particularly suited to the corrosion conditions found in urea synthesis plants. It is also nonmagnetic. The high Mn-content of the alloy helps to stabilize the austenitic microstructure and aids in hot cracking resistance.

A7.25 E317. The alloy content of weld metal deposited by these electrodes is somewhat higher than that of Type E316 electrodes, particularly in molybdenum. These electrodes are usually used for welding alloys of similar composition and are utilized in severely corrosive environments (such as those containing halogens) where crevice and pitting corrosion are of concern.

A7.26 E317L. The composition of this weld metal is the same as that deposited by E317 electrodes, except for the carbon content. The 0.04 percent maximum carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, is not as strong at elevated temperatures as the niobium-stabilized alloys or the standard Type 317 weld metal with higher carbon content.

A7.27 E318. The composition of this weld metal is the same as that deposited by E316 electrodes, except for the addition of niobium. Niobium provides resistance to intergranular carbide precipitation and thus increased resistance to intergranular corrosion. These electrodes are used primarily for welding base metals of similar composition.

A7.28 E320. The nominal composition (wt %) of this weld metal is 20 Cr, 34 Ni, 2.5 Mo, 3.5 Cu, with Nb added to improve resistance to intergranular corrosion. These electrodes are primarily used to weld base metals of similar composition for applications where resistance to severe corrosion is required for a wide range of chemicals including sulfuric and sulfurous acids and their salts. These electrodes can be used to weld both castings and wrought alloys of similar compositions without postweld heat treatment.

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

A7.29 E320LR (Low Residuals). Weld metal deposited by E320LR electrodes has the same basic composition as that deposited by E320 electrodes; however, the elements C, Si, P, and S are specified at lower maximum levels, and Nb and Mn are controlled within narrower ranges. These changes reduce the weld metal fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals. Consequently, welding practices typically used to deposit ferrite-containing austenitic stainless steel weld metals can be used. Type 320LR weld metal has a lower minimum tensile strength than Type 320 weld metal.

A7.30 E330. The nominal composition (wt %) of this weld metal is 35 Ni, 15.5 Cr. These electrodes are commonly used where heat- and scale-resisting properties above 1800 ºF [980 ºC] are required. However, high-sulfur environments may adversely affect performance at elevated temperature. Repairs of defects in alloy castings and the welding of castings and wrought alloys of similar compositions are the most common applications.

A7.31 E330H. The composition of this weld metal is the same as that deposited by E330 electrodes, except that carbon ranges from 0.35 to 0.45 percent. These electrodes are used primarily for the welding and repairing of high-alloy heat and corrosion-resistant castings of the same general composition which are designated HT by the Alloy Castings Institute. This composition can be used to 2100 ºF [1150 ºC] in oxidizing atmospheres and at 2000 ºF [1090 ºC] in reducing atmospheres. However, high-sulfur environments may adversely affect performance at elevated temperature.

A7.32 E347. The nominal composition (wt %) of this weld metal is 19.5 Cr, 10 Ni with Nb or Nb plus Ta added as a stabilizer. Either of these additions reduces the possibility of intergranular chromium carbide precipitation and thus increases resistance to intergranular corrosion.

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

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

A7.33 E349. The normal composition (wt %) of this weld metal is 19.5 Cr, 9 Ni, 1 Nb, 0.5 Mo, 1.4 W. These electrodes are used for welding steels of similar composition such as AISI Type 651 or 652. The combination of niobium, molybdenum, and tungsten with chromium and nickel gives good high-temperature rupture strength. The chemical composition of the weld metal results in an appreciable content of ferrite which increases the crack resistance of the weld metal.

A7.34 E383. The nominal composition (wt %) of this weld metal is 28 Cr, 31.5 Ni, 3.7 Mo, 1 Cu. These electrodes are used to weld base metal of a similar composition to itself and to other grades of stainless steel. Type E383 weld metal is recommended for sulfuric and phosphoric acid environments. The elements C, Si, P, and S are specified at low maximum levels to minimize weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals.

A7.35 E385. The nominal composition (wt %) of this weld metal is 20.5 Cr, 25 Ni, 5 Mo, 1.5 Cu. These electrodes are used primarily for welding of Type 904L materials for the handling of sulfuric acid and many chloride-containing media. Type E385 electrodes also may be used to join Type 317L material where improved corrosion resistance in specific media is needed. E385 electrodes also can be used for joining Type 904L base metal to other grades of stainless. The elements C, Si, P, and S are specified at lower maximum levels to minimize weld metal hot cracking and fissuring (while maintaining corrosion resistance) frequently encountered in fully austenitic weld metals.

A7.36 E409Nb. The composition of this weld metal is very similar to that deposited by E410 electrodes, except that niobium has been added which produces a ferritic microstructure with fine grains. These electrodes are used for the welding of ferritic stainless steels such as Types 405 and 409. They are also used for the second and/or additional layers in the welding of Type 410 clad stainless steel and for the overlay of carbon and low-alloy steels. Preheat and postweld heat treatments are required to achieve welds of adequate ductility for many engineering purposes. This weld deposit cannot be expected to develop the strength and hardness of a fully hardened martensitic stainless steel alloy such as Type 410.

A7.37 E410. This 12 Cr alloy is an air-hardening steel. Preheat and postheat treatments are required to achieve welds of adequate ductility for many engineering purposes. The most common application of these electrodes is for welding alloys of similar compositions. They are also used for surfacing of carbon steels to resist corrosion, erosion, or abrasion.

A7.38 E410NiMo. These electrodes are used for welding ASTM CA6NM (CA-6NM) castings or similar materials, as well as light-gauge Type 410, 410S, and 405 base metals. Weld metal deposited by these electrodes is modified to contain less chromium and more nickel than weld metal deposited by E410 electrodes. The objective is to eliminate ferrite in the microstructure, as ferrite has a deleterious effect on mechanical properties of this alloy. Final postweld heat treatment should not exceed 1150 ºF [620 ºC]. Higher temperatures may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A7.39 E430. The weld metal deposited by these electrodes contains between 15 and 18 Cr (wt %). The composition is balanced by providing sufficient chromium to give adequate corrosion resistance for the usual applications and yet retain sufficient ductility in the heat-treated condition to meet the mechanical requirements of the specification. (Excessive chromium will result in lowered ductility.) Welding with E430 electrodes usually requires preheat and postheat. Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A7.40 E430Nb. The composition of this weld metal is the same as that deposited by E430 electrodes, except for the addition of niobium. The weld deposit is a ferritic microstructure with fine grains. Preheat and postweld heat treatments are required to achieve welds of adequate ductility for many engineering purposes. These electrodes are used for the welding of Type 430 stainless steel. They are also used for the first layer in the welding of Type 405 and 410 clad steels.

A7.41 E630. The nominal composition (wt %) of these electrodes is 16.4 Cr, 4.7 Ni, 3.6 Cu. These electrodes are primarily designed for welding ASTM A 564, Type 630, and some other precipitation-hardening stainless steels. The weld metal is modified to prevent the formation of ferrite networks in the martensite microstructure which could have a deleterious effect on mechanical properties. Dependent on the application and weld size, the weld metal may be used either as-welded; welded and precipitation hardened; or welded, solution treated, and precipitation hardened.

A7.42 E16-8-2. The nominal composition (wt %) of this weld metal is 15.5 Cr, 8.5 Ni, 1.5 Mo. These electrodes are used primarily for welding stainless steel, such as Types 16-8-2, 316, and 347, for high-pressure, high-temperature piping systems. The weld deposit usually has a Ferrite Number no higher than 5 FN. The deposit also has good, hot ductility properties which offer relative freedom from weld or crater cracking even under high-restraint conditions. The weld metal is usable in either the as-welded or solution-treated condition. These electrodes depend on a very carefully balanced chemical composition to develop their fullest properties. Corrosion tests indicate that Type 16-8-2 weld metal may have less corrosion resistance than Type 316 base metal depending on the corrosive media. Where the weldment is exposed to severely corrosive agents, the surface layers should be deposited with a more corrosion-resistant weld metal.

A7.43 E2209. The nominal composition (wt %) of this weld metal is 22.5 Cr, 9.5 Ni, 3 Mo, 0.15 N. Electrodes of this composition are used primarily to weld duplex stainless *steel such as UNS S31803 and S32205. They are also used for lean duplex stainless steel such as UNS S32101 and S32304*. Weld metal deposited by these electrodes has "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2209 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking. If postweld annealing is required this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A7.44 E2307. *The nominal composition (wt %) of this weld metal is 24 Cr, 8 Ni, 0.15 N. Electrodes of this classification are used primarily for the welding of lean, low-molybdenum duplex stainless steels which include UNS S32101 and UNS S32304. Weld metal deposited by these electrodes has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited with E2307 electrodes combines increased strength and improved resistance to stress corrosion cracking as compared to these properties in E308L and similar austenitic stainless steel weld metals.*

A7.45 E2553. The nominal composition (wt %) of this weld metal is 25.5 Cr, 7.5 Ni, 3.4 Mo, 2 Cu, and 0.17 N. These electrodes are used primarily to weld duplex stainless steels which contain approximately 25 percent of chromium. Weld metal deposited by these electrodes has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2553 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking.

A7.46 E2593. The nominal composition (wt %) of this weld metal is 25 Cr, 9.5 Ni, 3.4 Mo, 2.5 Cu, and 0.2 N. These electrodes are used primarily to weld duplex stainless steels which contain approximately 25 percent chromium. Weld metal deposited by these electrodes has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2593 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking. If postweld annealing is required this weld metal will require a higher annealing temperature than that required by the E2553 classification or the duplex base metal.

A7.47 E2594. The nominal composition (wt %) of this weld metal is 25.5 Cr, 10 Ni, 4 Mo, and 0.25 N. The sum of the Cr + 3.3 (Mo + 0.5 W) + 16 N, known as the Pitting Resistance Equivalent Number (PRE_N), is at least 40, thereby allowing the weld metal to be called a "super-duplex stainless steel." This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride-containing environments. It is designed for the welding of Type 2507 super-duplex stainless steels UNS S32750 (wrought) and UNS J93404 (cast), and similar compositions. It can also be used for the welding of carbon and low-alloy steels to duplex stainless steels as well as to weld "standard" duplex stainless steels such as Type 2205 although the weld metal impact toughness may be inferior to that from E2209 electrodes. If postweld annealing is required, this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A7.48 E2595. The nominal composition (wt %) of this weld metal is 25.5 Cr, 9 Ni, 3.8 Mo, 0.7 Cu, 0.7 W, and 0.25 N. The sum of the Cr + 3.3 (Mo + 0.5 W) + 16 N, known as the Pitting Resistance Equivalent Number (PREN), is at least 40, thereby allowing the weld metal to be called a "superduplex stainless steel." This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride-containing environments. It is designed for the welding of superduplex stainless steels UNS S32550, S32750, and S32760 (wrought), and UNS J93370, J93380, J93404, CD4MCuN (cast), and similar compositions. It can also be used for the welding of carbon and low-alloy steels to duplex stainless steels as well as to weld "standard duplex stainless steel" such as UNS S31803 and UNS S32205.

A7.49 E3155. The nominal chemical composition of this weld metal is 21.25 Cr, 19.75 Co, 20 Ni, 3.0 Mo, 2.5 W. These electrodes are used primarily for welding parts fabricated from material of similar or dissimilar composition, particularly when the weld zone is required to have corrosion and heat resistance comparable to that of the parent metal. It is used in aerospace applications including tailpipes and tail cones, afterburner parts, exhaust manifolds, combustion chambers, turbine blades, buckets, and nozzles. Its high-temperature properties are inherent and are not dependent upon age hardening.

A7.50 E33-31. The nominal chemical composition (wt %) of weld metal produced by electrodes of this classification is 31 Ni, 32 Fe, 33 Cr, 1.6 Mo, and low carbon. The filler materials are used for welding nickel-chromium-iron alloy (UNS R20033) to itself, and to weld to carbon steel. The ASTM specifications for this alloy are B625, B649, B366, B472, B564, B619, B622, and B626. The electrodes are generally used in the flat position.

A8. Classification as to Usability

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

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

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

A8.4 Usability Designation -16. The covering for these electrodes generally contains readily ionizing elements, such as potassium, in order to stabilize the arc for welding with alternating current. Electrode sizes 5/32 in [4.0 mm] and smaller may be used in all positions of welding.

A8.5 Usability Designation -17. The covering of these electrodes is a modification of the -16 covering, in that considerable silica replaces some of the titania of the -16 covering. Since both the -16 and the -17 electrode coverings permit ac operation, both covering types were classified as -16 in the past because there was no classification alternative until the 1992 revision of AWS A5.4. However, the operational differences between the two types have become significant enough to warrant a separate classification.

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

A8.6 Usability Designation -26. This designation is for those electrodes that are designed for flat and horizontal fillet welding and that have limited out of position characteristics. In practice, most of these electrodes give higher deposition rates than their all-positional counter-parts owing to their thicker coatings that contain higher levels of metal powders. The thicker coating gives larger fillet welds that are typically flat to concave. It also reduces the effects of core wire overheating, making 18 inch long electrodes possible for the larger electrodes, even with stainless steel core wire. Higher currents are usually required to achieve the necessary penetration compared to the all-positional types.

The slag system of these electrodes is similar to those of the -16 and -17 designations. The resulting slag may be more fluid and even slower freezing than that from electrodes with a -17 designation. Core wire compositions are typically either Type 304L stainless steel or low-carbon mild steel. Electrodes with the latter tend to have thicker coatings to accommodate the necessary alloys in order to attain the required weld metal composition. Such electrodes require even higher currents to compensate for the additional coating to be melted and the lower resistance of the core wire.

Electrodes with the -26 designation are recommended for welding only in the flat and horizontal fillet positions. The manufacturer's suggested operating currents should be consulted. Out of position welding may be possible with electrode sizes up to 1/8 in [3.2 mm] diameter.

A9. Special Tests

A9.1 Corrosion or Scaling Resistance Tests

A9.1.1 Although welds made with electrodes covered by this specification are commonly used in corrosion-resisting or heat-resisting applications, it is not practical to require tests for corrosion or scale resistance on welds or weld metal specimens. Such special tests which are pertinent to the intended application may be conducted as agreed upon between supplier and purchaser. This section is included for the guidance of those who desire to specify such special tests.

A9.1.2 Corrosion or scaling tests of joint specimens have the advantage that the joint design and welding procedure can be made identical to those being used in fabrication. They have the disadvantage of being a test of the combined properties of the weld metal, the heat-affected zone of the base metal, and the unaffected base metal. Furthermore, it is difficult to obtain reproducible data if a difference exists between the corrosion or oxidation rates of the various metal structures (weld metal, heat-affected zone, and unaffected base metal). Test samples cannot be readily standardized if welding procedure and joint design are to be considered variables. Joint specimens for corrosion tests should not be used for qualifying the electrode but may be used for qualifying welding procedures using approved materials.

A9.1.3 All-weld-metal specimens for testing corrosion or scale resistance are prepared by following the procedure outlined for the preparation of pads for chemical analysis (see Clause 10). The pad size should be at least 3/4 in [19 mm] in height by 2-1/2 in [65 mm] wide by 1 + 5/8n in [25 + 16n mm] long, where "n" represents the number of specimens required from the pad. Specimens measuring 1/2 × 2 × 1/4 in [13 × 50 × 6.4 mm] are machined from the top surface of the pad in such a way that the 2 in [50 mm] dimension of the specimen is parallel to the 2-1/2 in [65 mm] width dimension of the pad and the 1/2 in [13 mm] dimension is parallel to the length of the pad.

A9.1.4 The heat treatments, surface finish, and marking of the specimens prior to testing should be in accordance with standard practices for tests of similar alloys in the wrought or cast forms. The testing procedure should correspond to the ASTM G4, *Standard Method for Conducting Corrosion Tests in Plant Equipment*, or ASTM A262, *Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels*, or ASTM G48, *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*.

A9.2 Mechanical Properties Tests for Dissimilar Metal Welds

A9.2.1 Tests for mechanical properties of joint specimens may be desired when the intended application involves the welding of dissimilar metals. Procedures for the mechanical testing of such joints should be in accordance with the latest edition of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*.

A9.2.2 Tests of joint specimens may be influenced by the properties of the base metal and welding procedures and may not provide adequate tests of the weld metal. Such tests should be considered as tests for qualifying welding procedures using approved materials rather than tests for qualifying the electrodes.

A9.2.3 Where fabrication codes require tests of welds in heat-treated conditions other than those specified in Table 6, all-weld-metal tests of heat-treated specimens may be desired. For the preparation of such specimens, the procedures outlined in Clause 12, Tension Test, and Clause 13, Fillet Weld Test, should be followed.

A9.3 Impact Property Tests for Welds Intended for Cryogenic Service

A9.3.1 Fully austenitic stainless steel weld metals are known to possess excellent toughness at cryogenic temperatures such as –320 ºF [–196 ºC]. To ensure freedom from brittle failure, Section VIII of the ASME *Boiler and Pressure Vessel Code* requires weldments intended for cryogenic service be qualified by Charpy V-notch testing. The criterion for acceptability is the attainment of a lateral expansion opposite the notch of not less than 15 mils (0.015 in) [0.38 mm] for each of three specimens.

A9.3.2 Austenitic stainless steel weld metals usually are not fully austenitic but contain some delta ferrite. Delta ferrite is harmful to cryogenic toughness. However, fully austenitic weld metal has a greater susceptibility to hot cracking (see A6). It has been found that such weld metals require judicious compositional balances to meet the 15 mils [0.38 mm] lateral expansion criterion even at moderately low temperatures such as –150 ºF [–100 ºC].

A9.3.3 Electrode classifications which can be used if special attention is given to the weld deposit composition content to maximize toughness are E308L-XX, E316L-XX, and E316LMn-XX. Published studies of the effect of composition changes on weldment toughness properties for these types have shown the following:

A9.3.3.1 Both carbon and nitrogen contents have strong adverse effects on weld metal toughness so that their contents should be minimized. Low-carbon weld metals with nitrogen content below 0.06 percent are preferred.

A9.3.3.2 Nickel appears to be the only element whose increased content in weld metal improves weld metal toughness.

A9.3.3.3 Delta ferrite is harmful; therefore, minimizing ferrite in weld metal (3 FN maximum) is recommended. Weld metal free of ferrite (fully austenitic) is preferred; the more austenitic, the better.

A9.3.3.4 Fully austenitic E316L weld metal appears to be the preferred composition because of the ease in achieving ferrite-free weld metal, while compositionally conforming to AWS A5.4 and retaining crack resistance.

A9.3.3.5 Lime-covered, typically the -15 classification type, electrodes tend to produce weldments having slightly superior lateral expansion values for Charpy V-notch impact specimens than titania-covered, typically -16, -17, and -26 classification type, electrodes when weld metal composition factors are essentially the same. This appears to be due to two factors:

A9.3.3.5.1 Lime-covered SMAW electrodes usually provide better protection from nitrogen incursion into the weld metal than that provided by titania-covered electrodes. Nitrogen, as noted above, has significantly adverse effects on weld toughness.

A9.3.3.5.2 Lime-covered SMAW electrodes appear to produce weld metals of lower oxygen levels and inclusion population, i.e., cleaner weld metal, or both. The above suggestions are particularly important when the intended application involves very-low temperatures such as –320 ºF [–196 ºC].

A9.3.4 Limited SMAW electrode weld metal data have indicated that welding in the vertical position, as compared to flat position welding, does not reduce toughness properties, providing good operator's technique is employed.

A9.3.5 Where cryogenic service below –150 ºF [–100 ºC] is intended, it is recommended that each lot of electrodes be qualified with Charpy V-notch impact tests. When such tests are required, the test specimens must be taken from a test plate prepared in accordance with Figure 2. The impact specimens must be located in the test plate as shown in Figure A.4. The specimens must be prepared and tested in accordance with the impact test sections of the latest edition of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*. The test temperature must be selected on the basis of intended service.

A10. Discontinued Classifications

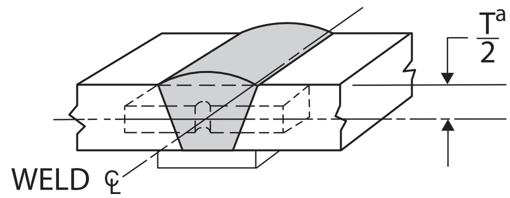
Some classifications have been discontinued from one revision of this specification to another. This results either from changes in commercial practice or changes in the classification system used in the specification. The Classifications that have been discontinued are listed in Table A.2 along with the year in which they were last included in this specification.

A11. General Safety Considerations

A11.1 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clause A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A11.3, ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*,[14] and applicable federal and state regulations.

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

[14] ANSI Z49.1 is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.



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

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

Figure A.4—Orientation and Location of Optional Impact Specimen

Table A.2
Discontinued Classifications[a]

AWS Classification	Last A5.4 Publication Date
EXXX-25	1948, 1992[b]
EXXX-26	1948[c]
E308ELC-XX	1955[d]
E316ELC-XX	1955[d]
E502-XX	1992[e]
E505-XX	1992[f]
E7Cr-XX	1992[g]
E308MoL-XX	1992[h]
E309MoL-XX	1992[h]
E309Cb-XX	1992[i]
E310Cb-XX	1992[i]

[a] See A10, Discontinued Classifications (in Annex A).
[b] The -25 classifications were discontinued with the publication of the 1955 edition of A5.4, included again in the 1992 edition, and then discontinued again in the 2006 edition.
[c] The -26 classifications were discontinued with the publication of the 1955 edition of A5.4 and then were included again in the 1992 edition.
[d] Starting with the 1962 edition of A5.4, the designator suffix for the low-carbon classifications was changed from "ELC" to "L." Thus the E308ELC-XX and E316ELC-XX classifications were not really discontinued; they became E308L-XX and E316L-XX, respectively.
[e] This classification was transferred to ANSI/AWS A5.5 in 1996 with the new designation E801X-B6 and E801X-B6L.
[f] This classification was transferred to ANSI/AWS A5.5 in 1996 with the new designation E801X-B8 and E801X-B8L.
[g] This classification was transferred to ANSI/AWS A5.5 in 1996 with the new designation E801X-B7and E801X-B7L.
[h] These two classifications were not really discontinued but were changed to E308LMo-XX and E309LMo-XX to reflect that the "L" for low carbon is the principal modifying suffix.
[i] These two classifications were not really discontinued but were changed to E309Nb-XX and E310Nb-XX to reflect the adoption of Nb for niobium instead of Cb for columbium.

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

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electric Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Space*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding & Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Arc Viewing Distance*
27	*Thoriated Tungsten Electrodes*
28	*Oxyfuel Safety: Check Valves and Flashback Arrestors*
29	*Grounding of Portable and Vehicle Mounted Welding Generators*
30	*Cylinders: Safe Storage, Handling, and Use*
31	*Eye and Face Protection for Welding and Cutting Operations*
33	*Personal Protective Equipment (PPE) for Welding & Cutting*
34	*Coated Steels: Welding and Cutting Safety Concerns*
36	*Ventilation for Welding & Cutting*
37	*Selecting Gloves for Welding & Cutting*

[15] AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

Annex B (Informative)
Requesting an Official Interpretation on an AWS Standard

This annex is not part of AWS A5.4/A5.4M:2012, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, but is included for informational purposes only.

B1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

B2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. 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.

B3. General Procedure for all Requests

B3.1 Submission. All requests shall be sent to the Managing Director, AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

B3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

B3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

B3.4 Question(s). All requests shall be stated in the form of a question that can be answered "yes" or "no". The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

B3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

B3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

B4. AWS Policy on Interpretations

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 official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

B5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the Welding Journal, and post it on the AWS website.

B6. AWS Technical Committees

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.

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SPECIFICATION FOR LOW-ALLOY STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.5/SFA-5.5M

(Identical with AWS Specification A5.5/A5.5M:2022. In case of dispute, the original AWS text applies.)

Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

1. Scope

1.1. This specification prescribes requirements for the classification of low-alloy steel electrodes for shielded metal arc welding of carbon and low-alloy steels. The weld metal deposited by these electrodes are steel alloys in which no single alloying element exceeds 10.5 percent.

In addition to the low-alloy steel electrodes above, this specification also prescribes the requirements for the classification of austenitic, high manganese steel electrodes having weld metal with nominally 20% Mn.

1.2. 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 material properties. The specification designated A5.5 uses U.S. Customary Units. The specification designated A5.5M uses SI Units. The latter units are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under A5.5 or A5.5M specification.

1.3. Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Some safety and health information can be found in Annex A, Clauses A5 and A10.

Safety and health information is available from the following sources:

American Welding Society:

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

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies.

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to or revisions of any of these publications do not apply.

American Welding Society (AWS) documents:

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

AWS A4.3 ADD1, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

AWS A4.4M, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coatings*

AWS A4.5M/A4.5, *Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*

AWS A5.01M/A5.01, *Welding and Brazing Consumables — Procurement of Filler Metals and Fluxes*

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

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

American National Standards Institute (ANSI) documents:

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

ASTM International (ASTM) documents:

ASTM A29/A29M, *Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought*

ASTM A36/A36M, *Standard Specification for Carbon Structural Steel*

ASTM A203/A203M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

ASTM A204/A204M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum*

ASTM A242/A242M, *Standard Specification for High-Strength Low-Alloy Structural Steel*

ASTM A283/A283M, *Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates*

ASTM A302/A302M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum, and Manganese-Molybdenum-Nickel*

ASTM A352/A352M, *Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service*

ASTM A387/A387M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

ASTM A514/A514M, *Standard Specification for High-Yield-Strength, Quenched and Tempered, Alloy Steel Plate, Suitable for Welding*

ASTM A516/A516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

ASTM A517/A517M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered*

ASTM A533/A533M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum, and Manganese-Molybdenum-Nickel*

ASTM A537/A537M, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

ASTM A543/A543M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum*

ASTM A588/A588M, *Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4-in. [100-mm] Thick*

ASTM A709/A709M, *Standard Specification for Carbon Structural Steel for Bridges*

ASTM A1106, *Standard Specification for Pressure Vessel Plate, Alloy Steel, Austenitic High Manganese for Cryogenic Application*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

ASTM E350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*

ASTM E353, *Standard Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys*

ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*

ASTM E2033, *Standard Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)*

ASTM E2698, *Standard Practice for Radiographic Examination Using Digital Detector Arrays*

International Organization for Standardization (ISO) documents:

ISO 80000-1, *Quantities and units—Part 1*: *General.*

United States Department of Defense (DODSSP) publications:

NAVSEA Technical Publication T9074-BD-GIB-010/0300, *Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY-80/100/130 and HSLA-80/100*

MIL-E-22200/1, *Military Specification: Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium and High Tensile Steel, As Welded or Stress-Relieved Weld Application*

MIL-E-22200/10, *Military Specification: Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium, High Tensile and Higher-Strength Low Alloy Steels*

American Petroleum Institute (API) standard:

Specification 5L, *Line Pipe*

3. Classification

3.1 The welding electrodes covered by the A5.5 and A5.5M specifications utilize a classification system (shown in Figure 1) based upon U.S. Customary Units and the International System of Units (SI), respectively, and are classified according to:

(1) Type of current (Table 1)

(2) Type of covering (Table 1)

(3) Welding position (Table 1)

(4) Chemical composition of the weld metal (Table 2)

(5) Mechanical properties of the weld metal in the as-welded or postweld heat treated condition (Tables 3 and 4)

3.2 Electrodes classified under one classification shall not be classified under any other classification in this specification, *except that an electrode may be classified with both a defined chemical composition designator and a "-G" composition designator*. Also, an electrode may be classified under both A5.5 and A5.5M specifications.

3.3 Electrodes may be classified under A5.5 using U.S. Customary Units or under A5.5M using the International System of Units (SI), or they may be classified under both systems. Electrodes classified under either classification system must meet all requirements for classification under that system. The classification system is shown in Figure 1.

Mandatory Classification Designators[a]

E XX XX -X

- E — Designates an electrode. This designator may be deleted from the product imprint required for the identification of the electrode.
- XX — Two (or three) digits are used for AWS A5.5 to designate in ksi, or for A5.5M to designate in MPa divided by 10, the minimum tensile strength of the weld metal produced in accordance with the test assembly preparation procedure of this specification (see Table 3). *Example:* E8018-C1 is an electrode with a tensile strength of 80,000 psi. [E5518-C1 is an electrode with a tensile strength of 550 MPa].
- XX — Designates the welding position in which electrodes are usable, the type of covering and the kind of current for which the electrodes are suitable (see Table 1). *Example:* In the E8018-C1 [E5518-C1] classification referenced above, the "18" designates a low-hydrogen, basic coated iron powder electrode capable of welding in all positions using ac and dc electrode positive.
- -X — Designates the chemical composition of the undiluted weld metal produced by the electrode using shielded metal arc welding (see Table 2). *Example:* In the E8018-C1 [E5518-C1] classification referenced above, the "C1" designates an electrode capable of depositing weld metal containing 2.00 to 2.75% nickel.

E XX XX M
E XX XX M1
E XX XX M HZ
E XX XX M1 HZ

- Designates an electrode E(X)XX18M(1) [EXX18M(1)] intended to meet most requirements for military specifications (greater toughness, yield strength, and elongation) (see Tables 3 and 4). *Example:* E11018M [E7618M].

E XX XX – X HZ R

Optional Supplemental Designators[b]

- R — Designates that the electrodes meet the requirements of the absorbed moisture test (an optional supplemental test for all low hydrogen electrodes) (see Table 11). *Example:* E8018-C1 R [E5518-C1 R].
- HZ — Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low-hydrogen electrodes) for electrodes in the as received or conditioned state, with an average diffusible hydrogen content not exceeding "Z" mL/100 g of deposited metal, where "Z" is 4, 8, or 16 (see Table 12). *Example:* E8018-C1 H8 [E5518-C1 H8]. In this case, the electrode will give a maximum of 8 mL of hydrogen per 100 g of deposited metal when tested in accordance with this specification.

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

Figure 1—Order of Electrode Mandatory and Optional Supplemental Designators

Table 1
Electrode Classification

AWS Classification[a]		Type of Covering	Welding Positions for Classification[b]	Type of Current[c]
A5.5	A5.5M			
E7010-X	E4910-X	High cellulose sodium	F, V, OH, H	dcep
E7011-X	E4911-X	High cellulose potassium	F, V, OH, H	ac, dcep
E7015-X[d,e]	E4915-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E7016-X[d,e]	E4916-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac, dcep
E7018-X[d,e]	E4918-X[d,e]	Low hydrogen potassium, iron powder[f]	F, V, OH, H	ac, dcep
E7020-X	E4920-X	High iron oxide	H-fillets	ac, dcen
			F	ac, dcep, dcen
E7027-X	E4927-X	High iron oxide, iron powder[f]	H-fillet	ac, dcen
			F	ac, dcep, dcen
E8010-X	E5510-X	High cellulose sodium	F, V, OH, H	dcep
E8011-G	E5511-G	High cellulose potassium	F, V, OH, H	ac, dcep
E8013-G	E5513-G	High titania potassium	F, V, OH, H	ac, dcep, dcen
E8015-X[d,e]	E5515-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E8016-X[d,e]	E5516-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac, dcep
E8018-X[d,e]	E5518-X[d,e]	Low hydrogen potassium, iron powder[f]	F, V, OH, H	ac, dcep
E8045-X[d,e]	E5545-X[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep
E9010-X	E6210-X	High cellulose sodium	F, V, OH, H	dcep
E9011-G	E6211-G	High cellulose potassium	F, V, OH, H	ac, dcep
E9013-G	E6213-G	High titania potassium	F, V, OH, H	ac, dcep, dcen
E9015-X[d,e]	E6215-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E9016-X[d,e]	E6216-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac, dcep
E9018-X[d,e]	E6218-X[d,e]	Low hydrogen potassium, iron powder[f]	F, V, OH, H	ac, dcep
E9018M[d,e]	E6218M[d,e]	Iron powder, low hydrogen[f]	F, V, OH, H	dcep
E9045-X[d,e]	E6245-X[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep
E10010-G	E6910-G	High cellulose sodium	F, V, OH, H	dcep
E10011-G	E6911-G	High cellulose potassium	F, V, OH, H	ac, dcep
E10013-G	E6913-G	High titania potassium	F, V, OH, H	ac, dcep, dcen
E10015-X[d,e]	E6915-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E10016-X[d,e]	E6916-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac, dcep
E10018-X[d,e]	E6918-X[d,e]	Low hydrogen potassium, iron powder[f]	F, V, OH, H	ac, dcep
E10018M[d,e]	E6918M[d,e]	Iron powder, low hydrogen[f]	F, V, OH, H	dcep
E10045-X[d,e]	E6945-X[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep

(Continued)

Table 1 (Continued) Electrode Classification

AWS Classification[a]		Type of Covering	Welding Positions for Classification[b]	Type of Current[c]
A5.5	A5.5M			
E11010-G	E7610-G	High cellulose sodium	F, V, OH, H	dcep
E11011-G	E7611-G	High cellulose potassium	F, V, OH, H	ac, dcep
E11013-G	E7613-G	High titania potassium	F, V, OH, H	ac, dcep, dcen
E11015-G[d,e]	E7615-G[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E11016-*X*[d,e]	E7616-*X*[d,e]	Low hydrogen potassium	F, V, OH, H	ac, dcep
E11018-*X*[d,e]	E7618-*X*[d,e]	Low hydrogen potassium, iron powder[f]	F, V, OH, H	ac, dcep
E11018M[d,e]	E7618M[d,e]	Iron powder, low hydrogen[f]	F, V, OH, H	dcep
E12010-G	E8310-G	High cellulose sodium	F, V, OH, H	dcep
E12011-G	E8311-G	High cellulose potassium	F, V, OH, H	ac, dcep
E12013-G	E8313-G	High titania potassium	F, V, OH, H	ac, dcep, dcen
E12015-G[d,e]	E8315-G[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E12016-G[d,e]	E8316-G[d,e]	Low hydrogen potassium	F, V, OH, H	ac, dcep
E12018-G[e,e]	E8318-G[d,e]	Low hydrogen potassium, iron powder[f]	F, V, OH, H	ac, dcep
E12018M[d,e]	E8318M[d,e]	Iron powder, low hydrogen[f]	F, V, OH, H	dcep
E12018M1[d,e]	E8318M1[d,e]	Iron powder, low hydrogen[f]	F, V, OH, H	dcep

a. The letter "X" *in the composition designator position (see Figure 1)* as used in this table and elsewhere in this specification stands for any allowable value of the designator *not otherwise individually listed*.

b. The abbreviations F, H, H-fillets, V, V-down, and OH indicate the welding position, as follows:
- F = Flat
- H = Horizontal
- H-fillets = Horizontal fillets
- V = Vertical (For electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classification E(X)XX15-X, E(X)XX16-X, E(X)XX18-X)
- V-down = vertical, with downward progression
- OH = overhead (For electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E(X)XX15-X, E(X)XX16-X, E(X)XX18-X)

c. The term "dcep" refers to direct current, electrode positive (dc, reverse polarity). The term "dcen" refers to direct current, electrode negative (dc, straight polarity).

d. Electrodes classified as E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, E(X)XX18M(1) or E(X)XX45-X which meet the supplemental absorbed moisture requirements in Table 11 may be further identified as shown in Table 11 and Figure 1.

e. Electrodes classified as E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, E(X)XX18M(1) or E(X)XX45-X which produce weld metal that meets the maximum average level of diffusible hydrogen in Table 12 may be further identified as specified in Table 12 and Figure 1.

f. Use of the term "iron powder" is intended to include other metal powders added to the covering for alloying of the weld metal (See A6.14).

Table 2
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Weight Percent[a,b]								Other Required Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
Carbon-Molybdenum Steel Electrodes												
E7010-A1	E4910-A1	W17010	0.12	0.60	0.40	0.03	0.03	—	—	0.40–0.65	—	—
E7011-A1	E4911-A1	W17011	0.12	0.60	0.40	0.03	0.03	—	—	0.40–0.65	—	—
E7015-A1	E4915-A1	W17015	0.12	0.90	0.60	0.03	0.03	—	—	0.40–0.65	—	—
E7016-A1	E4916-A1	W17016	0.12	0.90	0.60	0.03	0.03	—	—	0.40–0.65	—	—
E7018-A1	E4918-A1	W17018	0.12	0.90	0.80	0.03	0.03	—	—	0.40–0.65	—	—
E7020-A1	E4920-A1	W17020	0.12	0.60	0.40	0.03	0.03	—	—	0.40–0.65	—	—
E7027-A1	E4927-A1	W17027	0.12	1.00	0.40	0.03	0.03	—	—	0.40–0.65	—	—
Chromium-Molybdenum Steel Electrodes												
E8016-B1	E5516-B1	W51016	0.05–0.12	0.90	0.60	0.03	0.03	—	0.40–0.65	0.40–0.65	—	—
E8018-B1	E5518-B1	W51018	0.05–0.12	0.90	0.80	0.03	0.03	—	0.40–0.65	0.40–0.65	—	—
E8015-B2	E5515-B2	W52015	0.05-0.12	0.90	1.00	0.03	0.03	—	1.00–1.50	0.40-0.65	—	—
E8016-B2	E5516-B2	W52016	0.05–0.12	0.90	0.60	0.03	0.03	—	1.00–1.50	0.40–0.65	—	—
E8018-B2	E5518-B2	W52018	0.05–0.12	0.90	0.80	0.03	0.03	—	1.00–1.50	0.40–0.65	—	—
E7015-B2L	E4915-B2L	W52115	0.05	0.90	1.00	0.03	0.03	—	1.00–1.50	0.40–0.65	—	—
E7016-B2L	E4916-B2L	W52116	0.05	0.90	0.60	0.03	0.03	—	1.00–1.50	0.40–0.65	—	—
E7018-B2L	E4918-B2L	W52118	0.05	0.90	0.80	0.03	0.03	—	1.00–1.50	0.40–0.65	—	—
E9015-B3	E6215-B3	W53015	0.05–0.12	0.90	1.00	0.03	0.03	—	2.00–2.50	0.90–1.20	—	—
E9016-B3	E6216-B3	W53016	0.05–0.12	0.90	0.60	0.03	0.03	—	2.00–2.50	0.90–1.20	—	—
E9018-B3	E6218-B3	W53018	0.05–0.12	0.90	0.80	0.03	0.03	—	2.00–2.50	0.90–1.20	—	—
E8015-B3L	E5515-B3L	W53115	0.05	0.90	1.00	0.03	0.03	—	2.00–2.50	0.90–1.20	—	—
E8018-B3L	E5518-B3L	W53118	0.05	0.90	0.80	0.03	0.03	—	2.00–2.50	0.90–1.20	—	—

(Continued)

Table 2 (Continued) Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Weight Percent[a,b]								Other Required Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
E8015-B4L	E5515-B4L	W53415	0.05	0.90	1.00	0.03	0.03	—	1.75–2.25	0.40–0.65	—	—
E8016-B5	E5516-B5	W51316	0.07–0.15	0.40–0.70	0.30-0.60	0.03	0.03	—	0.40–0.60	1.00–1.25	V	0.05
E8015-B6	E5515-B6	W50215	0.05–0.10	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	—	—
E8016-B6	E5516-B6	W50216	0.05–0.10	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	—	—
E8018-B6	E5518-B6	W50218	0.05–0.10	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	—	—
E9018-B6	E6218-B6	W50219	0.05-0.10	1.0	0.90	0.03	0.03	0.40	4.0-6.0	0.45-0.65	—	—
E8015-B6L	E5515-B6L	W50205	0.05	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	—	—
E8016-B6L	E5516-B6L	W50206	0.05	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	—	—
E8018-B6L	E5518-B6L	W50208	0.05	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	—	—
E8015-B7	E5515-B7	W50315	0.05–0.10	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	—	—
E8016-B7	E5516-B7	W50416	0.05–0.10	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	—	—
E8018-B7	E5518-B7	W50318	0.05–0.10	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	—	—
E8015-B7L	E5515-B7L	W50305	0.05	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	—	—
E8016-B7L	E5516-B7L	W50306	0.05	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	—	—
E8018-B7L	E5518-B7L	W50308	0.05	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	—	—
E8015-B8	E5515-B8	W50415	0.05–0.10	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	—	—
E8016-B8	E5516-B8	W50416	0.05–0.10	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	—	—
E8018-B8	E5518-B8	W50418	0.05–0.10	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	—	—

(Continued)

Table 2 (Continued) Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Weight Percent[a,b]								Other Required Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
E8015-B8L	E5515-B8L	W50405	0.05	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	—	—
E8016-B8L	E5516-B8L	W50506	0.05	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	—	—
E8018-B8L	E5518-B8L	W50408	0.05	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	—	—
											V	*0.15–0.50*
E9016-B9A	*E6216-B9A*	—	*0.04–0.12*	*1.00–2.00*	*0.60*	*0.025*	*0.025*	*0.50–1.00*	*8.0–10.5*	*0.85–1.20*	*Nb*	*0.02–0.15*
											W	1.50–2.00
											V	0.15–0.30
E9015-B23	E6215-B23										Nb	0.02–0.10
E9016-B23	E6216-B23	K20857	0.04–0.12	1.00	0.60	0.015	0.015	0.50	1.9–2.9	0.30	B	0.006
E9018-B23	E6218-B23										Al	0.04
											Cu	0.25
											N	0.05
											W	*1.30–2.00*
											V	*0.15–0.30*
											Nb	*0.01–0.10*
E8016-B23A	*E5516-B23A*	—	*0.03–0.12*	*1.00*	*0.60*	*0.015*	*0.015*	*0.50*	*1.9–2.9*	*0.30*	*B*	*0.006*
											Al	*0.04*
											Cu	*0.25*
											N	*0.05*
E9015-B24	E6215-B24										V	0.15–0.30
E9016-B24	E6216-B24	K20885	0.04–0.12	1.00	0.60	0.020	0.015	0.50	1.9–2.9	0.80–1.20	Nb	0.02–0.10
E9018-B24	E6218-B24										Ti	0.10
											B	0.006
											Al	0.04
											Cu	0.25
											N	0.07

(Continued)

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c] A5.5	AWS Classifications[c] A5.5M	UNS Number[d]	Weight Percent[a,b] C	Mn	Si	P	S	Ni	Cr	Mo	Other Required Elements[e,f] Element	Amount
E9015-B91[g,h] E9016-B91[g,h] E9018-B91[g,h]	E6215-B91[g,h] E6216-B91[g,h] E6218-B91[g,h]	W50425 W50426 W50428	0.08–0.13	1.20	0.30	0.01	0.01	0.80	8.0–10.5	0.85–1.20	V	0.15–0.30
											Cu	0.25
											Al	0.04
											Nb	0.02–0.10
											N	0.02–0.07
E9015-B92[g] E9016-B92[g] E9018-B92[g]	E6215-B92[g] E6216-B92[g] E6218-B92[g]	W59016	0.08–0.15	1.20	0.60	0.020	0.015	1.00	8.0–10.0	0.30–0.70	W	1.50–2.00
											V	0.15–0.30
											Nb	0.02–0.08
											B	0.006
											Al	0.04
											Cu	0.25
											N	0.03–0.08
E9016-B92A	*E6216-B92A*	—	*0.06–0.15*	*1.20*	*0.60*	*0.020*	*0.015*	*1.00*	*8.0–10.5*	*0.10–0.70*	*W*	*1.50–2.00*
											V	*0.10–0.40*
											Co	*1.00–2.00*
											Nb	*0.01–0.08*
											B	*0.006*
											Al	*0.04*
											Cu	*0.25*
											N	*0.03–0.08*
E9015-B115	*E6215-B115*	—	*0.08–0.13*	*0.80*	*0.50*	*0.01*	*0.01*	*0.50*	*9.5–12.0*	*0.40–0.65*	*V*	*0.10–0.30*
											Nb	*0.02–0.10*
											Al	*0.04*
											Cu	*0.20*
											N	*0.02–0.07*

(Continued)

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Weight Percent[a,b]								Other Required Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
Nickel Steel Electrodes												
E8016-C1	E5516-C1	W22016	0.12	1.25	0.60	0.03	0.03	2.00–2.75	—	—	—	—
E9016-C1	*E6216-C1*	—	*0.12*	*0.60–1.20*	*0.80*	*0.03*	*0.03*	*2.00–2.75*	—	*0.30*	—	—
E8018-C1	E5518-C1	W22018	0.12	1.25	0.80	0.03	0.03	2.00–2.75	—	—	—	—
E7015-C1L	E4915-C1L	W22115	0.05	1.25	0.50	0.03	0.03	2.00–2.75	—	—	—	—
E7016-C1L	E4916-C1L	W22116	0.05	1.25	0.50	0.03	0.03	2.00–2.75	—	—	—	—
E7018-C1L	E4918-C1L	W22118	0.05	1.25	0.50	0.03	0.03	2.00–2.75	—	—	—	—
E8016-C2	E5516-C2	W23016	0.12	1.25	0.60	0.03	0.03	3.00–3.75	—	—	—	—
E8018-C2	E5518-C2	W23018	0.12	1.25	0.80	0.03	0.03	3.00–3.75	—	—	—	—
E7015-C2L	E4915-C2L	W23115	0.05	1.25	0.50	0.03	0.03	3.00–3.75	—	—	—	—
E7016-C2L	E4916-C2L	W23116	0.05	1.25	0.50	0.03	0.03	3.00–3.75	—	—	—	—
E7018-C2L	E4918-C2L	W23118	0.05	1.25	0.50	0.03	0.03	3.00–3.75	—	—	—	—
E8016-C3	E5516-C3	W21016	0.12	0.40–1.25	0.80	0.03	0.03	0.80–1.10	0.15	0.35	V	0.05
E8018-C3	E5518-C3	W21018	0.12	0.40–1.25	0.80	0.03	0.03	0.80–1.10	0.15	0.35	V	0.05
E7018-C3L	E4918-C3L	W20918	0.08	0.40–1.40	0.50	0.03	0.03	0.80–1.10	0.15	0.35	V	0.05
E8016-C4	E5516-C4	W21916	0.10	1.25	0.60	0.03	0.03	1.10–2.00	—	—	—	—
E8018-C4	E5518-C4	W21918	0.10	1.25	0.80	0.03	0.03	1.10–2.00	—	—	—	—
E9015-C5L	E6215-C5L	W25018	0.05	0.40–1.00	0.50	0.03	0.03	6.00–7.25	—	—	—	—

(Continued)

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Weight Percent[a,b]								Other Required Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
E7016-C6	*E4916-C6*	—	*0.12*	*0.60–1.60*	*0.25–0.90*	*0.03*	*0.03*	*0.30–1.00*	—	*0.35*	*V* *Ti* *B*	*0.05* *0.005–0.035* *0.0005–0.0045*
E8016-C7	*E5516-C7*	—	*0.10*	*1.00–1.60*	*0.60*	*0.03*	*0.03*	*1.10–2.00*	—	—	*Ti* *B*	*0.005–0.035* *0.0005–0.0045*
Nickel-Molybdenum Steel Electrodes												
E8018-NM1	E5518-NM1	W21118	0.10	0.80–1.25	0.60	0.02	0.02	0.80–1.10	0.10	0.40–0.65	V Cu Al	0.02 0.10 0.05
E9018-NM2	E5518-NM2	W21119	0.04–0.15	0.50–1.60	0.70	0.02	0.02	1.40–2.10	0.20	0.20–0.50	V Cu Al	0.05 0.10 0.05
E10016-NM3	*E6916-NM3*	—	*0.12*	*1.20–1.70*	*0.80*	*0.03*	*0.03*	*1.20–1.70*	*0.10–0.30*	*0.10–0.30*	—	—
E9016-NM4	*E6216-NM4*	—	*0.12*	*0.70–1.50*	*0.80*	*0.03*	*0.03*	*0.30–1.00*	—	*0.10–0.40*	—	—
E10016-NM5	*E6916-NM5*	—	*0.12*	*0.80–1.40*	*0.80*	*0.03*	*0.03*	*3.00–3.80*	*0.10–0.40*	*0.30–0.60*	—	—
E11016-NM6	*E7616-NM6*	—	*0.12*	*1.20–1.80*	*0.80*	*0.03*	*0.03*	*1.50–2.10*	*0.10–0.40*	*0.25–0.55*	—	—
E11016-NM7	*E7616-NM7*	—	*0.12*	*1.40–2.00*	*0.80*	*0.03*	*0.03*	*2.10–2.80*	—	*0.50–0.80*	—	—
E11018-NM8	*E7618-NM8*	—	*0.12*	*1.20–1.90*	*0.20–0.75*	*0.03*	*0.03*	*2.50–3.30*	—	*0.40–1.00*	—	—
Manganese-Molybdenum Steel Electrodes												
E8018-D1	E5518-D1	W18118	0.12	1.00–1.75	0.80	0.03	0.03	0.90	—	0.25–0.45	—	—
E9015-D1	E6215-D1	W19015	0.12	1.00–1.75	0.60	0.03	0.03	0.90	—	0.25–0.45	—	—
E9018-D1	E6218-D1	W19018	0.12	1.00–1.75	0.80	0.03	0.03	0.90	—	0.25–0.45	—	—
E10015-D2	E6915-D2	W10015	0.15	1.65–2.00	0.60	0.03	0.03	0.90	—	0.25–0.45	—	—
E10016-D2	E6916-D2	W10016	0.15	1.65–2.00	0.60	0.03	0.03	0.90	—	0.25–0.45	—	—
E10018-D2	E6918-D2	W10018	0.15	1.65–2.00	0.80	0.03	0.03	0.90	—	0.25–0.45	—	—

(Continued)

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Weight Percent[a,b]								Other Required Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
E8016-D3	E5516-D3	W18016	0.12	1.00–1.80	0.60	0.03	0.03	0.90	—	0.40–0.65	—	—
E9016-D3	*E6216-D3*	—	*0.12*	*1.00–1.80*	*0.60*	*0.03*	*0.03*	*0.90*	—	*0.40–0.65*	—	—
E8018-D3	E5518-D3	W18018	0.12	1.00–1.80	0.80	0.03	0.03	0.90	—	0.40–0.65	—	—
E9018-D3	E6218-D3	W19118	0.12	1.00–1.80	0.80	0.03	0.03	0.90	—	0.40–0.65	—	—
High Manganese Electrodes												
E10016-Mn2	*E6916-Mn2*	—	*0.25–0.50*	*16.0–24.0*	*1.0*	*0.020*	*0.015*	*3.0*	*1.5–3.5*	*1.5*	*Cu*	*0.5*
E10018-Mn2	*E6918-Mn2*	—	*0.25–0.50*	*16.0–24.0*	*1.0*	*0.020*	*0.015*	*3.0*	*1.5–3.5*	*1.5*	*Cu*	*0.5*
General Low-Alloy Steel Electrodes												
E(X)XX10-G[i]	EXX10-G[i]	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX11-G[i]	EXX11-G[i]	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX13-G[i]	EXX13-G[i]	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX15-G[i]	EXX15-G[i]	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX16-G[i]	EXX16-G[i]	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX18-G[i]	EXX18-G[i]	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX45-G[i]	EXX45-G[i]	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E7020-G	E4920-G	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]

(Continued)

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Weight Percent[a,b]								Other Required Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
E7027-G	E4927-G	—	—	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
Military-Similar Electrodes												
E9018M[k]	E6218M[k]	W21218	0.10	0.60–1.25	0.80	0.030	0.030	1.40–1.80	0.15	0.35	V	0.05
E10018M[k]	E6918M[k]	W21318	0.10	0.75–1.70	0.60	0.030	0.030	1.40–2.10	0.35	0.25–0.50	V	0.05
E11018M[k]	E7618M[k]	W21418	0.10	1.30–1.80	0.60	0.030	0.030	1.25–2.50	0.40	0.25–0.50	V	0.05
E12018M[k]	E8318M[k]	W22218	0.10	1.30–2.25	0.60	0.030	0.030	1.75–2.50	0.30–1.50	0.30–0.55	V	0.05
E12018M1[k]	E8318M1[k]	W23218	0.10	0.80–1.60	0.65	0.015	0.012	3.00–3.80	0.65	0.20–0.30	V	0.05
Pipeline Steel Electrodes												
E7010-P1	E4910-P1	W17110	0.20	1.20	0.60	0.03	0.03	1.00	0.30	0.50	V	0.10
E8010-P1	E5510-P1	W18110	0.20	1.20	0.60	0.03	0.03	1.00	0.30	0.50	V	0.10
E9010-P1	E6210-P1	W19110	0.20	1.20	0.60	0.03	0.03	1.00	0.30	0.50	V	0.10
E8018-P2	E5518-P2	W18218	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E9018-P2	E6218-P2	W19218	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E8045-P2	E5545-P2	W18245	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E9045-P2	E6245-P2	W19245	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E10045-P2	E6945-P2	W10245	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
Weathering Steel Electrodes												
E7018-W1	E4918-W1	W20018	0.12	0.40–0.70	0.40–0.70	0.025	0.025	0.20–0.40	0.15–0.30	—	V Cu	0.08 0.30–0.60
E8018-W2	E5518-W2	W20118	0.12	0.50–1.30	0.35–0.80	0.03	0.03	0.40–0.80	0.45–0.70	—	Cu	0.30–0.75

NOTES:

[a] Single values are maxima, except where specified otherwise.

[b] Weld metal shall be analyzed for those elements for which specific values are shown. Other elements listed without specified values shall be reported, if intentionally added. The total of these latter unspecified elements and all other elements not intentionally added shall not exceed 0.50%.

[c] The suffixes A1, B3, C3, etc. designate the chemical composition of the electrode classification.

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

[e] Analysis for boron is required to be reported for any weld metal if it has been intentionally added or is known to be present at levels greater than 0.0010%.

[f] Analysis for cobalt is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.20%.

[g] Mn + Ni shall be 1.40% max.

[h] The E90XX-B91 [E62XX-B91] classifications were formerly classified as E90XX-B9 [E62XX-B9] in AWS A5.5/A5.5M.

[i] The letters "(X)XX" ["XX"] *following the "E" in a classification designation* in this table stand for the various strength levels (70, 80, 90, 100, 110, and 120 ksi) [49, 55, 62, 69, 76, and 83 MPa x 10] of weld metals.

[j] In order to meet the alloy requirements of the "G" group, the undiluted weld metal shall have the minimum of at least one of the elements listed in this table. Additional chemical requirements may be agreed upon between the purchaser and supplier.

[k] These classifications are intended to be similar to types of electrodes covered by military specifications MIL-E-22200/1 and MIL-E-22200/10.

Table 3
Tension Test Requirements[a,b]

AWS Classification[c]		Tensile Strength		Yield Strength, At 0.2% Offset		Elongation	Postweld Condition[d]
A5.5	A5.5M	ksi	MPa	ksi	MPa	Percent	
E7010-P1	E4910-P1	70	490	60	415	22	AW
E7010-A1	E4910-A1	70	490	57	390	22	PWHT
E7010-G	E4910-G	70	490	57	390	22	AW or PWHT
E7011-A1	E4911-A1	70	490	57	390	22	PWHT
E7011-G	E4911-G	70	490	57	390	22	AW or PWHT
E7015-X	E4915-X	70	490	57	390	22	PWHT
E7015-B2L	E4915-B2L	75	520	57	390	19	PWHT
E7015-G	E4915-G	70	490	57	390	22	AW or PWHT
E7016-X	E4916-X	70	490	57	390	22	PWHT
E7016-B2L	E4916-B2L	75	520	57	390	19	PWHT
E7016-C6	*E4916-C6*	*70*	*490*	*57*	*390*	*22*	*AW*
E7016-G	E4916-G	70	490	57	390	22	AW or PWHT
E7018-X	E4918-X	70	490	57	390	22	PWHT
E7018-B2L	E4918-B2L	75	520	57	390	19	PWHT
E7018-C3L	E4918-C3L	70	490	57	390	22	AW
E7018-W1	E4918-W1	70	490	60	415	22	AW
E7018-G	E4918-G	70	490	57	390	22	AW or PWHT
E7020-A1	E4920-A1	70	490	57	390	22	PWHT
E7020-G	E4920-G	70	490	57	390	22	AW or PWHT
E7027-A1	E4927-A1	70	490	57	390	22	PWHT
E7027-G	E4927-G	70	490	57	390	22	AW or PWHT
E8010-P1	E5510-P1	80	550	67	460	19	AW
E8010-G	E5510-G	80	550	67	460	19	AW or PWHT
E8011-G	E5511-G	80	550	67	460	19	AW or PWHT
E8013-G	E5513-G	80	550	67	460	16	AW or PWHT
E8015-X	E5515-X	80	550	67	460	19	PWHT
E8015-B3L	E5515-B3L	80	550	67	460	17	PWHT
E8015-G	E5515-G	80	550	67	460	19	AW or PWHT
E8016-X	E55516-X	80	550	67	460	19	PWHT
E8016-C3	E5516-C3	80	550	68 to 80[e]	470 to 550[e]	24	AW
E8016-C4	E5516-C4	80	550	67	460	19	AW
E8016-G	E5516-G	80	550	67	460	19	AW or PWHT
E8016-C7	*E5516-C7*	*80*	*550*	*67*	*460*	*19*	*AW*
E8018-X	E5518-X	80	550	67	460	19	PWHT
E8018-B3L	E5518-B3L	80	550	67	460	17	PWHT
E8018-C3	E5518-C3	80	550	68 to 80[e]	470 to 550[e]	24	AW
E8018-C4	E5518-C4	80	550	67	460	19	AW
E8018-NM1	E5518-NM1	80	550	67	460	19	AW
E8018-P2	E5518-P2	80	550	67	460	19	AW
E8018-W2	E5518-W2	80	550	67	460	19	AW
E8018-G	E5518-G	80	550	67	460	19	AW or PWHT
E8045-P2	E5545-P2	80	550	67	460	19	AW
E8045-G	*E5545-G*	*80*	*550*	*67*	*460*	*19*	*AW or PWHT*
E9010-P1	E6210-P1	90	620	77	530	17	AW
E9010-G	E6210-G	90	620	77	530	17	AW or PWHT
E9011-G	E6211-G	90	620	77	530	17	AW or PWHT
E9013-G	E6213-G	90	620	77	530	14	AW or PWHT
E9015-X	E6215-X	90	620	77	530	17	PWHT
E9015-G	E6215-G	90	620	77	530	17	AW or PWHT
E9016-X	E6216-X	90	620	77	530	17	PWHT
E9016-G	E6216-G	90	620	77	530	17	AW or PWHT
E9018M	E6218M	90	620	78 to 90[e]	540 to 620[e]	24	AW

(Continued)

Table 3 (Continued) Tension Test Requirements[a,b]

AWS Classification[c]		Tensile Strength		Yield Strength, At 0.2% Offset		Elongation	Postweld Condition[d]
A5.5	A5.5M	ksi	MPa	ksi	MPa	Percent	
E9018-NM2	*E6218-NM2*	*90*	*620*	*77*	*530*	*17*	*PWHT*
E9018-P2	E6218-P2	90	620	77	530	17	AW
E9018-X	E6218-X	90	620	77	530	17	PWHT
E9018-G	E6218-G	90	620	77	530	17	AW or PWHT
E9045-P2	E6245-P2	90	620	77	530	17	AW
E9045-G	*E6245-G*	*90*	*620*	*77*	*530*	*17*	*AW or PWHT*
E10010-G	E6910-G	100	690	87	600	16	AW or PWHT
E10011-G	E6911-G	100	690	87	600	16	AW or PWHT
E10013-G	E6913-G	100	690	87	600	13	AW or PWHT
E10015-X	E6915-X	100	690	87	600	16	PWHT
E10015-G	E6915-G	100	690	87	600	16	AW or PWHT
E10016-X	E6916-X	100	690	87	600	16	PWHT
E10016-G	E6916-G	100	690	87	600	16	AW or PWHT
E10016-Mn2	*E6916-Mn2*	*100*	*690*	*58*	*400*	*22*	*AW*
E10016-NM3	*E6916-NM3*	*100*	*690*	*87*	*600*	*16*	*AW*
E10016-NM5	*E6916-NM5*	*100*	*690*	*87*	*600*	*16*	*AW*
E10018M	E6918M	100	690	88 to 100[e]	610 to 690[e]	20	AW
E10018-Mn2	*E6918-Mn2*	*100*	*690*	*58*	*400*	*22*	*AW*
E10018-X	E6918-X	100	690	87	600	16	PWHT
E10018-G	E6918-G	100	690	87	600	16	AW or PWHT
E10045-P2	E6945-P2	100	690	87	600	16	AW
E10045-G	*E6945-G*	*100*	*690*	*87*	*600*	*16*	*AW or PWHT*
E11016-NM6	*E7616-NM6*	*110*	*760*	*97*	*670*	*15*	*AW*
E11016-NM7	*E7616-NM7*	*110*	*760*	*97*	*670*	*15*	*AW*
E11018-NM8	*E7618-NM8*	*110*	*760*	*97*	*670*	*15*	*AW*
E11010-G	E7610-G	110	760	97	670	15	AW or PWHT
E11011-G	E7611-G	110	760	97	670	15	AW or PWHT
E11013-G	E7613-G	110	760	97	670	13	AW or PWHT
E11015-G	E7615-G	110	760	97	670	15	AW or PWHT
E11016-G	E7616-G	110	760	97	670	15	AW or PWHT
E11018-G	E7618-G	110	760	97	670	15	AW or PWHT
E11018M	E7618M	110	760	98 to 110[e]	680 to 760[e]	20	AW
E12010-G	E8310-G	120	830	107	740	14	AW or PWHT
E12011-G	E8311-G	120	830	107	740	14	AW or PWHT
E12013-G	E8313-G	120	830	107	740	11	AW or PWHT
E12015-G	E8315-G	120	830	107	740	14	AW or PWHT
E12016-G	E8316-G	120	830	107	740	14	AW or PWHT
E12018-G	E8318-G	120	830	107	740	14	AW or PWHT
E12018M	E8318M	120	830	108 to 120[e]	745 to 830[e]	18	AW
E12018M1	E8318M1	120	830	108 to 120[e]	745 to 830[e]	18	AW

NOTES:

a. See Table 5 for sizes to be tested

b. Single values are minima

c. The letter "X" *in the composition designator position (See Figure 1),* as used in this table, represents the *designators not otherwise individually listed* which are tested in the PWHT condition only.

d. "AW" signifies as-welded, which may or may not have been aged, at the manufacturer's option(see 12.2). "PWHT" signifies postweld heat treated, as specified in 9.4.1.1 and in Table 7, except that the "G" designated classifications, marked as "AW" or "PWHT" in this table may have weld metal tested with or without PWHT, as agreed upon between the purchaser and supplier.

e. For 3/32 in [2.5 mm] electrodes, the upper value for the yield strength may be 5 ksi [35 MPa] higher than the indicated value.

Table 4
Charpy V-Notch Impact Test Requirements

A5.5 Classification			A5.5M Classification		
AWS Classification[a]	Limits for 3 out of 5 Specimens[b, c, d]		AWS Classification	Limits for 3 out of 5 Specimens[b, c, d]	
A5.5	A5.5 Average, minimum[e]	A5.5 Single Value, minimum[e]	A5.5M	A5.5M Average, minimum[e]	A5.5M Single Value, minimum[e]
E7018-W1	20 ft•lbf at 0 °F	15 ft•lbf at 0 °F	E4918-W1	27 J at -20 °C	20 J at -20 °C
E8018-W2	20 ft•lbf at 0 °F	15 ft•lbf at 0 °F	E5518-W2	27 J at -20 °C	20 J at -20 °C
E9016-NM4	*20 ft•lbf at 0 °F*	*15 ft•lbf at 0 °F*	*E6216-NM4*	*27 J at -20 °C*	*20 J at -20 °C*
E10016-NM3	*20 ft•lbf at 0 °F*	*15 ft•lbf at 0 °F*	*E6916-NM3*	*27 J at -20 °C*	*20 J at -20 °C*
E11016-NM6	*20 ft•lbf at 0 °F*	*15 ft•lbf at 0 °F*	*E7616-NM6*	*27 J at -20 °C*	*20 J at -20 °C*
E12018M1	50 ft•lbf at 0 °F	40 ft•lbf at 0 °F	E8318M1	67 J at –20 °C	54 J at –20 °C
E7010-P1	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E4910-P1	27 J at -30 °C	20 J at -30 °C
E8010-P1	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E5510-P1	27 J at -30 °C	20 J at -30 °C
E8018-P2	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E5518-P2	27 J at -30 °C	20 J at -30 °C
E8045-P2	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E5545-P2	27 J at -30 °C	20 J at -30 °C
E9010-P1	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E6210-P1	27 J at -30 °C	20 J at -30 °C
E9018-P2	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E6218-P2	27 J at -30 °C	20 J at -30 °C
E9018-NM2	20 ft•lbf at -20 °F[f]	15 ft•lbf at -20 °F[f]	E6218-NM2	27 J at -30 °C[f]	20 J at -30 °C[f]
E9045-P2	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E6245-P2	27 J at -30 °C	20 J at -30 °C
E10045-P2	20 ft•lbf at -20 °F	15 ft•lbf at -20 °F	E6945-P2	27 J at -30 °C	20 J at -30 °C
E8018-NM1	20 ft•lbf at -40 °F	15 ft•lbf at -40 °F	E5518-NM1	27 J at -40 °C	20 J at -40 °C
E8016-C3	20 ft•lbf at -40 °F	15 ft•lbf at -40 °F	E5516-C3	27 J at -40 °C	20 J at -40 °C
E8018-C3	20 ft•lbf at -40 °F	15 ft•lbf at -40 °F	E5518-C3	27 J at -40 °C	20 J at -40 °C
E10016-NM5	*20 ft•lbf at -40 °F*	*15 ft•lbf at -40 °F*	*E6916-NM5*	*27 J at -40 °C*	*20 J at -40 °C*
E8016-D3	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E5516-D3	27 J at -50 °C[f]	20 J at -50 °C[f]
E8018-D1	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E5518-D1	27 J at -50 °C[f]	20 J at -50 °C[f]
E8018-D3	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E5518-D3	27 J at -50 °C[f]	20 J at -50 °C[f]
E9015-D1	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E6215-D1	27 J at -50 °C[f]	20 J at -50 °C[f]
E9018-D1	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E6218-D1	27 J at -50 °C[f]	20 J at -50 °C[f]
E9016-D3	*20 ft•lbf at -60 °F[f]*	*15 ft•lbf at -60 °F[f]*	*E6216-D3*	*27 J at -50 °C[f]*	*20 J at -50 °C[f]*
E9018-D3	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E6218-D3	27 J at -50 °C[f]	20 J at -50 °C[f]
E10015-D2	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E6915-D2	27 J at -50 °C[f]	20 J at -50 °C[f]
E10016-D2	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E6916-D2	27 J at -50 °C[f]	20 J at -50 °C[f]
E10018-D2	20 ft•lbf at -60 °F[f]	15 ft•lbf at -60 °F[f]	E6918-D2	27 J at -50 °C[f]	20 J at -50 °C[f]
E7018-C3L	20 ft•lbf at -60 °F	15 ft•lbf at -60 °F	E4918-C3L	27 J at -50 °C	20 J at -50 °C
E8016-C4	20 ft•lbf at -60 °F	15 ft•lbf at -60 °F	E5516-C4	27 J at -50 °C	20 J at -50 °C
E8018-C4	20 ft•lbf at -60 °F	15 ft•lbf at -60 °F	E5518-C4	27 J at -50 °C	20 J at -50 °C
E9018M	20 ft•lbf at -60 °F	15 ft•lbf at -60 °F	E6218M	27 J at -50 °C	20 J at -50 °C
E10018M	20 ft•lbf at -60 °F	15 ft•lbf at -60 °F	E6918M	27 J at -50 °C	20 J at -50 °C
E11018M	20 ft•lbf at -60 °F	15 ft•lbf at -60 °F	E7618M	27 J at -50 °C	20 J at -50 °C
E12018M	20 ft•lbf at -60 °F	15 ft•lbf at -60 °F	E8318M	27 J at -50 °C	20 J at -50 °C
E7016-C6	*20 ft•lbf at -75 °F*	*15 ft•lbf at -75 °F*	*E4916-C6*	*27 J at -60 °C*	*20 J at -60 °C*
E8016-C7	*20 ft•lbf at -75 °F*	*15 ft•lbf at -75 °F*	*E5516-C7*	*27 J at -60 °C*	*20 J at -60 °C*

(Continued)

Table 4 (Continued)
Charpy V-Notch Impact Test Requirements

A5.5 Classification			A5.5M Classification		
AWS Classification[a]	Limits for 3 out of 5 Specimens[b, c, d]		AWS Classification	Limits for 3 out of 5 Specimens[b, c, d]	
A5.5	A5.5 Average, minimum[e]	A5.5 Single Value, minimum[e]	A5.5M	A5.5M Average, minimum[e]	A5.5M Single Value, minimum[e]
E9016-C1	*20 ft•lbf at -75 °F*[f]	*15 ft•lbf at -75 °F*[f]	*E6216-C1*	*27 J at -60 °C*[f]	*20 J at -60 °C*[f]
E11016-NM7	*20 ft•lbf at -75 °F*	*15 ft•lbf at -75 °F*	*E7616-NM7*	*27 J at -60 °C*	*20 J at -60 °C*
E11018-NM8	*20 ft•lbf at -75 °F*	*15 ft•lbf at -75 °F*	*E7618-NM8*	*27 J at -60 °C*	*20 J at -60 °C*
E8016-C1	20 ft•lbf at -75 °F[f]	15 ft•lbf at -75 °F[f]	E5516-C1	27 J at -60 °C[f]	20 J at -60 °C[f]
E8018-C1	20 ft•lbf at -75 °F[f]	15 ft•lbf at -75 °F[f]	E5518-C1	27 J at -60 °C[f]	20 J at -60 °C[f]
E7015-C1L	20 ft•lbf at -100 °F[f]	15 ft•lbf at -100 °F[f]	E4915-C1L	27 J at -75 °C[f]	20 J at -75 °C[f]
E7016-C1L	20 ft•lbf at -100 °F[f]	15 ft•lbf at -100 °F[f]	E4916-C1L	27 J at -75 °C[f]	20 J at -75 °C[f]
E7018-C1L	20 ft•lbf at -100 °F[f]	15 ft•lbf at -100 °F[f]	E4918-C1L	27 J at -75 °C[f]	20 J at -75 °C[f]
E8016-C2	20 ft•lbf at -100 °F[f]	15 ft•lbf at -100 °F[f]	E5516-C2	27 J at -75 °C[f]	20 J at -75 °C[f]
E8018-C2	20 ft•lbf at -100 °F[f]	15 ft•lbf at -100 °F[f]	E5518-C2	27 J at -75 °C[f]	20 J at -75 °C[f]
E7015-C2L	20 ft•lbf at -150 °F[f]	15 ft•lbf at -150 °F[f]	E4915-C2L	27 J at -100 °C[f]	20 J at -100 °C[f]
E7016-C2L	20 ft•lbf at -150 °F[f]	15 ft•lbf at -150 °F[f]	E4916-C2L	27 J at -100 °C[f]	20 J at -100 °C[f]
E7018-C2L	20 ft•lbf at -150 °F[f]	15 ft•lbf at -150 °F[f]	E4918-C2L	27 J at -100 °C[f]	20 J at -100 °C[f]
E9015-C5L	20 ft•lbf at -175 °F[f]	15 ft•lbf at -175 °F[f]	E6215-C5L	27 J at -115 °C[f]	20 J at -115 °C[f]
E10016-Mn2	*0.015 in at -320 °F*[g]	*0.015 in at -320 °F*[g]	*E6916-Mn2*	*0.38 mm at -196 °C*[g]	*0.38 mm at -196 °C*[g]
E10018-Mn2	*0.015 in at -320 °F*[g]	*0.015 in at -320 °F*[g]	*E6918-Mn2*	*0.38 mm at -196 °C*[g]	*0.38 mm at -196 °C*[g]
EXXXX-A1	Not specified	Not specified	EXXXX-A1	Not specified	Not specified
EXXXX-BXXX	Not specified	Not specified	EXXXX-BXXX	Not specified	Not specified
EXXXX-BXL	Not specified	Not specified	EXXXX-BXL	Not specified	Not specified
E(X)XXXX-G	Not specified	Not specified	EXXXX-G	Not specified	Not specified

NOTES:

a. *The letters "(X)XX" ["XX"] following the "E" in a classification designation in this table stand for the various strength levels (70, 80, 90, 100, 110, and 120 ksi) [49, 55, 62, 69, 76, and 83 MPa x 10] of weld metals. The "XXX" and "XL" following the "B" in the composition designator position represent any of the allowed Chromium-Molybdenum electrode composition designators in Table 2*

b. The test temperature for the five specimens shall be at or below the temperature listed. The actual temperature used shall be listed on the certification documentation when issued.

c. Both the highest and the lowest test values obtained shall be disregarded in computing the average value. Two of the three remaining values shall equal or exceed the minimum average value listed; one of these three remaining values may be lower than minimum average value, but shall not be less than the minimum single value listed. The average of the three remaining values shall not be less than the minimum average value listed.

d. Impact test specimens are tested without thermal treatment, except as noted.

e. Impact test values shall be recorded to "nearest whole unit" of energy absorbed in accordance with the rounding method specified in Clause 6.

f. These classifications are tested in the postweld heat treated condition, as specified in 9.4.1.1 and in Table 7.

g. *Requirements refer to minimum of lateral expansion, See 13.4.*

4. Acceptance

Acceptance of the welding electrodes shall be in accordance with the provisions of AWS A5.01M/A5.01. See A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01M/A5.01.

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. See A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

6. Rounding Procedure

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in Clause B.3 of ISO 80000-1 (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. If an average value is to be compared to the specified limit, rounding 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 and yield strength for A5.5, to the nearest 10 MPa for tensile and yield strength for A5.5M, and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded results shall fulfill the requirements for the classification under test.

7. Summary of Tests

The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the chemical composition, mechanical properties, soundness of the weld metal, the usability of the electrode, and the moisture content of the low-hydrogen electrode covering. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 15. The supplemental tests for absorbed moisture (see Clause 16) and for diffusible hydrogen (see Clause 17) are not required for classification of electrodes (see Note k of Table 5).

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or sample or from a new test assembly or sample. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

In the event that, during preparation or after completion of any test, it is clearly determined that specified or proper procedures were not followed in preparing the weld test assembly 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.