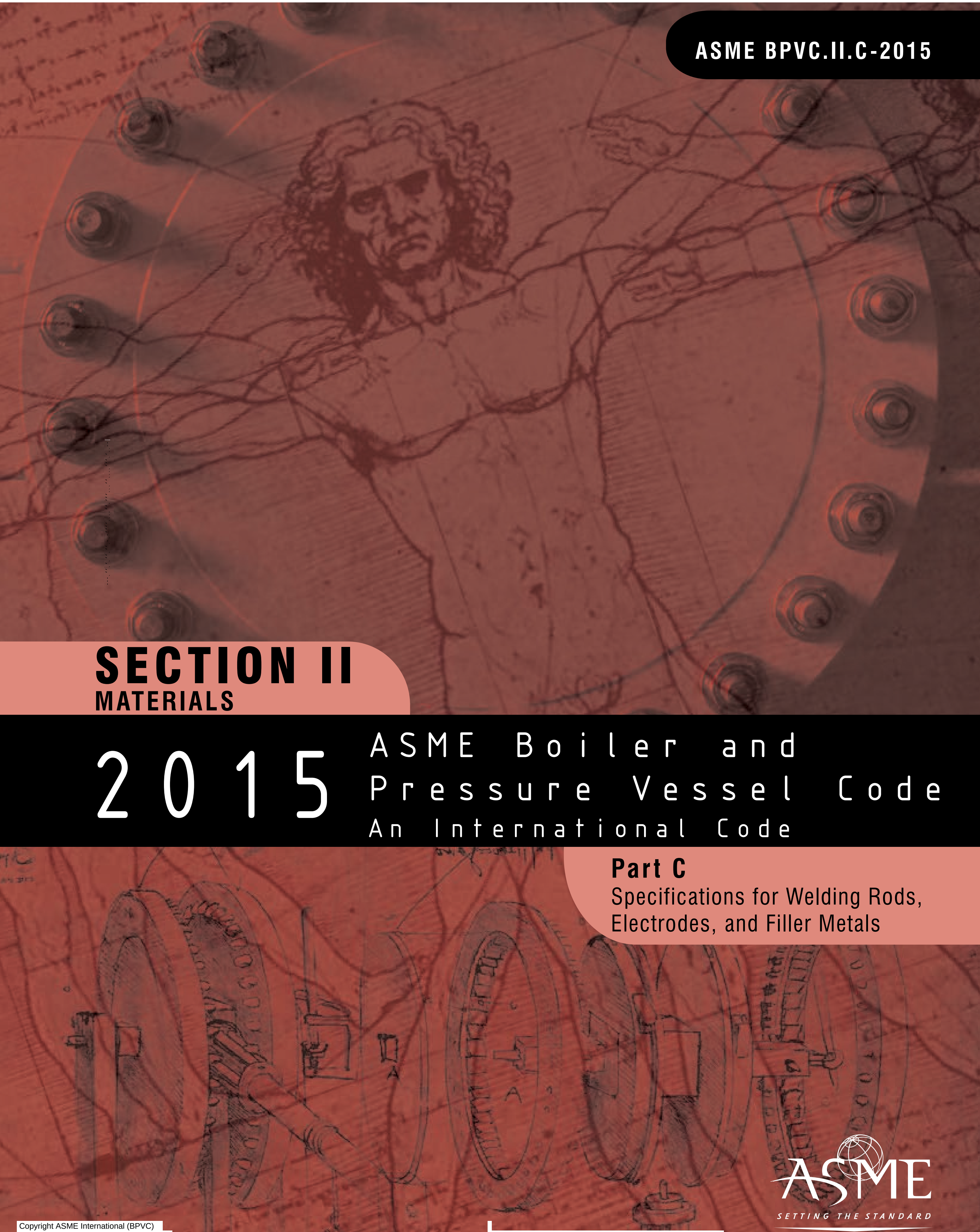

ASME BPVC.II.C-2015

SECTION II
MATERIALS

2015 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

2015 ASME Boiler & Pressure Vessel Code

2015 Edition July 1, 2015

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

Date of Issuance: July 1, 2015

This international code or standard was developed under procedures accredited as meeting the criteria for American National Standards and it is an American National Standard. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

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The above ASME symbol is registered in the U.S. Patent Office.

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Two Park Avenue, New York, NY 10016-5990

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[*] The 2015 Edition of Section III is the last edition in which Section III, Division 1, Subsection NH, *Class 1 Components in Elevated Temperature Service*, will be published. The requirements located within Subsection NH have been moved to Section III, Division 5, Subsection HB, Subpart B for the elevated temperature construction of Class A components.

INTERPRETATIONS

Interpretations of the Code have historically been posted in January and July at http://cstools.asme.org/interpretations.cfm. Interpretations issued during the previous two calendar years are included with the publication of the applicable Section of the Code in the 2015 Edition. Interpretations of Section III, Divisions 1 and 2 and Section III Appendices are included with Subsection NCA.

Following the 2015 Edition, interpretations will not be included in editions; they will be issued in real time in ASME's Interpretations Database at http://go.asme.org/Interpretations. Historical BPVC interpretations may also be found in the Database.

CODE CASES

The Boiler and Pressure Vessel Code committees meet regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases that have been adopted will appear in the appropriate 2015 Code Cases book: “Boilers and Pressure Vessels” or “Nuclear Components.” Supplements will be sent or made available automatically to the purchasers of the Code Cases books up to the publication of the 2017 Code.

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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) 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 only to pressure integrity, which govern the construction[**] of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. 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. This 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. 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 pressure vessels. 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.

This 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 judgement* 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 neither requires nor prohibits the use of computers for the design or analysis of components constructed to the

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[*] 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 pressure relief.

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 this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). 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 an ASME Certification Mark.

When required by context in this Section, the singular shall be interpreted as the plural, and vice versa, and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

STATEMENT OF POLICY ON THE USE OF THE 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 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 Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the 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 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 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 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 Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the Certification Mark. General usage is permitted only when all of a manufacturer’s items are constructed under the rules.

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 official Certification Mark described in the governing Section of the Code.

Markings such as “ASME,” “ASME Standard,” or any other marking including “ASME” or the 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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SUBMITTAL OF TECHNICAL INQUIRIES TO THE BOILER AND PRESSURE VESSEL STANDARDS COMMITTEES

1 INTRODUCTION

(a) The following information provides guidance to Code users for submitting technical inquiries to the committees. See Guideline on the Approval of New Materials Under the ASME Boiler and Pressure Vessel Code in Section II, Parts C and D for additional requirements for requests involving adding new materials to the Code. Technical inquiries include requests for revisions or additions to the Code rules, requests for Code Cases, and requests for Code Interpretations, as described below.

(1) Code Revisions. Code revisions are considered to accommodate technological developments, address administrative requirements, incorporate Code Cases, or to clarify Code intent.

(2) Code Cases. Code Cases represent alternatives or additions to existing Code rules. Code Cases are written as a question and reply, and are usually intended to be incorporated into the Code at a later date. When used, Code Cases prescribe mandatory requirements in the same sense as the text of the Code. However, users are cautioned that not all jurisdictions or owners automatically accept Code Cases. The most common applications for Code Cases are:

(-a) to permit early implementation of an approved Code revision based on an urgent need

(-b) to permit the use of a new material for Code construction

(-c) to gain experience with new materials or alternative rules prior to incorporation directly into the Code

(3) Code Interpretations. Code Interpretations provide clarification of the meaning of existing rules in the Code, and are also presented in question and reply format. Interpretations do not introduce new requirements. In cases where existing Code text does not fully convey the meaning that was intended, and revision of the rules is required to support an interpretation, an Intent Interpretation will be issued and the Code will be revised.

(b) The Code rules, Code Cases, and Code Interpretations established by the committees 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 rules.

(c) Inquiries that do not comply with these provisions or that do not provide sufficient information for a committee's full understanding may result in the request being returned to the inquirer with no action.

2 INQUIRY FORMAT

Submittals to a committee shall include:

(a) Purpose. Specify one of the following:

(1) revision of present Code rules

(2) new or additional Code rules

(3) Code Case

(4) Code Interpretation

(b) Background. Provide the information needed for the committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, Division, edition, addenda (if applicable), paragraphs, figures, and tables. Preferably, provide a copy of the specific referenced portions of the Code.

(c) Presentations. The inquirer may desire or be asked to attend a meeting of the committee to make a formal presentation or to answer questions from the committee members with regard to the inquiry. Attendance at a committee meeting shall be at the expense of the inquirer. The inquirer's attendance or lack of attendance at a meeting shall not be a basis for acceptance or rejection of the inquiry by the committee.

3 CODE REVISIONS OR ADDITIONS

Requests for Code revisions or additions shall provide the following:

(a) Proposed Revisions or Additions. For revisions, identify the rules of the Code that require revision and submit a copy of the appropriate rules as they appear in the Code, marked up with the proposed revision. For additions, provide the recommended wording referenced to the existing Code rules.

(b) Statement of Need. Provide a brief explanation of the need for the revision or addition.

(c) Background Information. Provide background information to support the revision or addition, including any data or changes in technology that form the basis for the request that will allow the committee to adequately evaluate the proposed revision or addition. Sketches, tables, figures, and graphs should be submitted as appropriate. When applicable, identify any pertinent paragraph in the Code that would be affected by the revision or addition and identify paragraphs in the Code that reference the paragraphs that are to be revised or added.

4 CODE CASES

Requests for Code Cases shall provide a Statement of Need and Background Information similar to that defined in 3(b) and 3(c), respectively, for Code revisions or additions. The urgency of the Code Case (e.g., project underway or imminent, new procedure, etc.) must be defined and it must be confirmed that the request is in connection with equipment that will bear the Certification Mark, with the exception of Section XI applications. The proposed Code Case should identify the Code Section and Division, and be written as a *Question* and a *Reply* in the same format as existing Code Cases. Requests for Code Cases should also indicate the applicable Code editions and addenda (if applicable) to which the proposed Code Case applies.

5 CODE INTERPRETATIONS

(a) Requests for Code Interpretations shall provide the following:

(1) Inquiry. Provide a condensed and precise question, omitting superfluous background information and, when possible, composed in such a way that a “yes” or a “no” *Reply,* with brief provisos if needed, is acceptable. The question should be technically and editorially correct.

(2) Reply. Provide a proposed *Reply* that will clearly and concisely answer the *Inquiry* question. Preferably, the *Reply* should be “yes” or “no,” with brief provisos if needed.

(3) Background Information. Provide any background information that will assist the committee in understanding the proposed *Inquiry* and *Reply.*

(b) Requests for Code Interpretations must be limited to an interpretation of a particular requirement in the Code or a Code Case. The committee cannot consider consulting type requests such as the following:

(1) a review of calculations, design drawings, welding qualifications, or descriptions of equipment or parts to determine compliance with Code requirements;

(2) a request for assistance in performing any Code-prescribed functions relating to, but not limited to, material selection, designs, calculations, fabrication, inspection, pressure testing, or installation;

(3) a request seeking the rationale for Code requirements.

6 SUBMITTALS

Submittals to and responses from the committees shall meet the following:

(a) Submittal. Inquiries from Code users shall be in English and preferably be submitted in typewritten form; however, legible handwritten inquiries will also be considered. They shall include the name, address, telephone number, fax number, and e-mail address, if available, of the inquirer and be mailed to the following address:

Secretary
ASME Boiler and Pressure Vessel Committee
Two Park Avenue
New York, NY 10016-5990

As an alternative, inquiries may be submitted via e-mail to: SecretaryBPV@asme.org or via our online tool at http://go.asme.org/InterpretationRequest.

(b) Response. The Secretary of the appropriate committee shall acknowledge receipt of each properly prepared inquiry and shall provide a written response to the inquirer upon completion of the requested action by the committee.

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January 1, 2015

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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 in three parts 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

After publication of the 2015 Edition, Errata to the BPV Code may be posted on the ASME Web site to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in the BPV Code. Such Errata shall be used on the date posted.

Information regarding Special Notices and Errata is published by ASME at http://go.asme.org/BPVCerrata.

Changes given below are identified on the pages by a margin note, **(15)**, placed next to the affected area.

The Record Numbers listed below are explained in more detail in "List of Changes in Record Number Order" following this Summary of Changes.

Page	*Location*	*Change (Record Number)*
v	List of Sections	Revised
vii	Foreword	*(1)* Revised *(2)* New footnote added by errata *(13-860)*
x	Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees	In last line of 6(a), URL revised
xii	Personnel	Updated
xxix	AWS Personnel	Updated
xxxi	Preface	Penultimate paragraph editorially revised
1	SFA-5.01M/SFA-5.01	Revised in its entirety *(13-1736)*
33	SFA-5.1/SFA-5.1M	Revised in its entirety *(13-348)*
101	SFA-5.4/SFA-5.4M	Revised in its entirety *(13-349)*
139	SFA-5.5/SFA-5.5M	Revised in its entirety *(14-1412)*
269	SFA-5.9/SFA-5.9M	Revised in its entirety *(13-350)*
327	SFA-5.11/SFA-5.11M	Revised in its entirety *(13-1047)*
441	SFA-5.16/SFA-5.16M	Revised in its entirety *(13-1046)*
565	SFA-5.22/SFA-5.22M	Revised in its entirety *(13-351)*
787	SFA-5.30/SFA-5.30M	In Table 2, for AWS Classification IN504, entry under V corrected by errata *(13-1065)*
839	SFA-5.34/SFA-5.34M	Revised in its entirety *(13-1655)*

LIST OF CHANGES IN RECORD NUMBER ORDER

Record Number	Change
13-348	Adopted AWS A5.1/A5.1M:2012, “Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding" as SFA-5.1/SFA-5.1M.
13-349	Adopted AWS A5.4/A5.4M:2012, "Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding" as SFA-5.4/SFA-5.4M.
13-350	Adopted AWS A5.9/A5.9M:2012, "Specification for Bare Stainless Steel Welding Electrodes and Rods" as SFA-5.9/SFA-5.9M.
13-351	Adopted AWS A5.22/A5.22M:2012, "Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods" as SFA-5.22/SFA-5.22M.
13-860	In the Foreword, the subtitle has been deleted and replaced with an ANSI disclaimer as footnote.
13-1046	Adopted AWS A5.16/A5.16M:2013 (ISO 24034:2010 MOD), "Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods" as SFA-5.16/SFA-5.16M.
13-1047	Adopted AWS A5.11/A5.11M:2010, "Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding" as SFA-5.11/SFA-5.11M.
13-1065	Errata correction. See Summary of Changes for details.
13-1655	Adopted AWS A5.34/A5.34M:2013, "Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding" as SFA-5.34/SFA-5.34M.
13-1736	Adopted AWS A5.01M/A5.01:2013 (ISO 14344:2010 MOD), "Welding Consumables — Procurement of Filler Materials and Fluxes" as SFA-5.01M/SFA-5.01.
14-1412	Adopted AWS A5.5/A5.5M:2014, “Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding” as SFA-5.5/SFA-5.5M.

CROSS-REFERENCING AND STYLISTIC CHANGES IN THE BOILER AND PRESSURE VESSEL CODE

There have been structural and stylistic changes to BPVC, starting with the 2011 Addenda, that should be noted to aid navigating the contents. The following is an overview of the changes:

Subparagraph Breakdowns/Nested Lists Hierarchy

- First-level breakdowns are designated as (a), (b), (c), etc., as in the past.
- Second-level breakdowns are designated as (1), (2), (3), etc., as in the past.
- Third-level breakdowns are now designated as (-a), (-b), (-c), etc.
- Fourth-level breakdowns are now designated as (-1), (-2), (-3), etc.
- Fifth-level breakdowns are now designated as (+a), (+b), (+c), etc.
- Sixth-level breakdowns are now designated as (+1), (+2), etc.

Footnotes

With the exception of those included in the front matter (roman-numbered pages), all footnotes are treated as endnotes. The endnotes are referenced in numeric order and appear at the end of each BPVC section/subsection.

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees has been moved to the front matter. This information now appears in all Boiler Code Sections (except for Code Case books).

Cross-References

It is our intention to establish cross-reference link functionality in the current edition and moving forward. To facilitate this, cross-reference style has changed. Cross-references within a subsection or subarticle will not include the designator/identifier of that subsection/subarticle. Examples follow:

- *(Sub-)Paragraph Cross-References.* The cross-references to subparagraph breakdowns will follow the hierarchy of the designators under which the breakdown appears.
  - If subparagraph (-a) appears in X.1(c)(1) and is referenced in X.1(c)(1), it will be referenced as (-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(c)(2), it will be referenced as (1)(-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).
- *Equation Cross-References.* The cross-references to equations will follow the same logic. For example, if eq. (1) appears in X.1(a)(1) but is referenced in X.1(b), it will be referenced as eq. (a)(1)(1). If eq. (1) appears in X.1(a)(1) but is referenced in a different subsection/subarticle/paragraph, it will be referenced as eq. X.1(a)(1)(1).

WELDING CONSUMABLES — PROCUREMENT OF FILLER MATERIALS AND FLUXES

(15)

SFA-5.01M/SFA-5.01

(Identical with AWS Specification A5.01M/A5.01:2013 (ISO 14344:2010 MOD). In case of dispute, the original AWS text applies.)

Welding 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 consumables. This standard, together with an AWS, ISO, or other recognized welding consumable standard, provides a method for preparing those specific details needed for welding consumable procurement which consist of the following:

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

b) the lot class (selected from Clause 4 of this standard);

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

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

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.

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

AWS A3.0 M/A3.0, *Standard Welding 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*

2.2 The following ASTM standard[2] is referenced in the mandatory section of this document:

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

2.3 The following ISO standard[3] is referenced in the mandatory section of this document.

ISO 544, *Welding Consumables — Technical Delivery Conditions for Welding Filler Materials — Type o Product, Dimensions, Tolerances and Markings*

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[1] AWS standards are published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

[2] ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[3] ISO standards are published by the International Organization for Standardization, 1 rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

3 Terms and Definitions

In production, the components of welding 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 consumable. This designation stays with the welding consumable and can be used to identify the material later, in those cases in which identification is necessary.

For the purposes of this standard, the following definitions describing discrete quantities of the components used in the manufacturing of welding consumables apply.

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 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 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 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 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 part 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 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 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 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 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.

- Chemical analysis only (per each heat or lot, for the size supplied)—Schedule 3 or H per AWS A5.01M/A5.01.
- Tests listed in Table 2 of AWS A5.01M (per each heat or lot, for the size supplied)—Schedule 4 or I per AWS A5.01M/A5.01.

- 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.
- 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)

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 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 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 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 consumable classification, size, form and temper produced in 24 h 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.

4.1.3 Lot Class S3

The quantity of one *fully metallic solid* welding 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 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 consumable 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 h 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.

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 h of consecutively scheduled production (i.e., consecutive normal work shifts).

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 as 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

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 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 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.

5.5 Schedule 5 or J

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

Table 1
Testing Schedules[a]

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

[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 designations may be used interchangeably.

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 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*.

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

Annex A (*Normative*)

Quality Assurance

This annex is part of AWS A5.01M/A5.01:2013 (ISO 14344:2010 MOD), *Welding Consumables—Procurement of Filler Materials and Fluxes*, 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:2007, *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 B.1 through B.7 (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 Consumables—Procurement of Filler Materials and Fluxes*

This annex is not part of AWS A5.01M/A5.01:2013 (ISO 14344:2010 MOD), *Welding Consumables—Procurement of Filler Materials and Fluxes*, 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/A5.01:2013 (ISO 14344:2010 MOD)*, Welding 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 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 material met the requirements of the specification. Representative material, in this case, is material from any production run of that classification using the same formulation. Certification is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of representative material cited above, and the Manufacturer's Quality Assurance Program in AWS A5.01M/A5.01 (ISO 14344 MOD).

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, *Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods*. 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	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

	Examples			
	1	2	3	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

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

SFA-5.02/SFA-5.02M

(Identical with AWS Specification A5.02/A5.02M:2007. In case of dispute, the original AWS text applies.)

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

SFA-5.02/SFA-5.02M

(Identical with AWS Specification A5.02/A5.02M:2007. In case of dispute, the original AWS text applies.)

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.

1.2 This specification applies to covered electrodes with both solid and tubular core wires; bare solid and tubular wires on spools, coils, and drums, or in straight lengths; and solid and sintered strip electrodes. It applies to all fusion welding processes, except brazing, braze welding, and thermal spraying, or granular metallic or mineral products, such as submerged arc fluxes, or other such products used in fusion welding processes.

1.3 Safety and health issues and concerns are beyond the scope of this standard and are, therefore, not fully addressed herein. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* and applicable federal and state regulations.

1.4 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.

2. Normative References

The following ANSI[1] standard is referenced in the normative sections of this document.

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

The following ISO[2] standard is referenced in the mandatory sections of this document.

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

3. Covered Electrodes

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

3.1.1 The diameter of the core wire shall not vary more than ±0.002 in. [±0.05 mm] from the diameter specified. The length shall not vary more than ±1/4 in. [±10 mm] from that specified.

3.2 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:

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

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

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

Concentricity may be measured by any suitable means.

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

[2] ISO standards are published by the International Organization for Standardization, 1 rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

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	450
5/16[c]	8.0[c]	18	450

NOTES:

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.

3.3 Exposed Core

3.3.1 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.

3.3.2 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.

3.4 Electrode Identification. All electrodes shall be identified as follows:

3.4.1 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.

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

3.4.3 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.

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

3.4.5 If allowed by the specific A5 specification, in lieu of imprinting, electrodes may be identified by:

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

(b) 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.

3.5 Packaging

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

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

3.5.3 Hermetically Sealed Containers. When specified for one or more classifications, such as low hydrogen types requiring protection against atmospheric moisture absorption during shipment and storage, electrodes shall be packaged in one of the following manners.

3.5.3.1 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 the leak test as follows:

Unit containers shall be immersed in water that is at a temperature of at least 50°F [10°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 air bubbles emanating from the container. A container with a stream that lasts for 30 seconds or more does not meet the requirements of this specification.

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

3.5.3.3 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 above.

3.6 Marking of Packages

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

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

(b) Supplier's name and trade designation

(c) Size and net weight

(d) Lot, control, or heat number

3.6.2 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 electrodes, including individual unit packages enclosed within a larger package.

4. Bare Solid and Tubular Electrodes and Rods

4.1 Standard Sizes and Shapes

4.2.1 Standard sizes of filler metal (except strip electrodes) and straight lengths of rods and their tolerances are shown in Table 2.

4.2.2 Standard sizes for strip electrodes in coils are shown in Table 3.

4.2 Finish and Uniformity

4.2.1 All filler metal shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams, laps (exclusive of the 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.

4.2.2 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.

4.2.3 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.

4.2.4 A suitable protective coating may be applied to any filler metal except as specifically restricted by the classification in the filler metal specification.

4.3 Packaging

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

4.3.2 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 Figs. 1A through 1D. Package forms and sizes other than these shall be as agreed upon between purchaser and supplier.

4.3.3 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.

4.3.4 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.

4.3.5 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 3.5.3.

4.4 Winding Requirements

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

4.4.2 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

4.5 Filler Metal Identification

4.5.1 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 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 designation is used, the ER may be omitted; for example, "308L" for classification "ER308L." Additional identification shall be as agreed upon between purchaser and supplier.

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

TABLE 2
STANDARD SIZES AND TOLERANCES OF SOLID AND TUBULAR BARE WIRES[a]

Nominal Diameter		Solid Wire Tolerance				Tubular Cored Wire Tolerance	
		GMAW/GTAW[c]		SAW/EGW/ESW			
in.[b]	mm	in.	mm	in.	mm	in.	mm
0.020	0.5	±0.001	+0.01/−0.03	—	—	—	—
. . .	0.6						
0.025	. . .						
0.030	. . .					±0.002	
. . .	0.8		+0.01/−0.04				
0.035	0.9						+0.02/−0.05
. . .	1.0				±0.04		
0.045	. . .						
$\frac{3}{64}$	1.2	±0.002					
0.052	. . .						
. . .	1.4						
$\frac{1}{16}$	1.6			±0.002			+0.02/−0.06
0.068	. . .					±0.003	
0.072	1.8						
$\frac{5}{64}$	2.0						
$\frac{3}{32}$	2.4, 2.5						
$\frac{7}{64}$	2.8	±0.003	+0.01/−0.07	±0.003			
. . .	3.0				±0.06		+0.02/−0.07
$\frac{1}{8}$	3.2						
$\frac{5}{32}$	4.0	—		±0.004		±0.004	
$\frac{3}{16}$	4.8[d]		—				
. . .	5.0						+0.02/−0.08
$\frac{7}{32}$	5.6[d]						
. . .	6.0						
$\frac{1}{4}$	6.4[d]						
$\frac{5}{16}$	8.0						

NOTES:

a. Dimensions, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.

b. To establish the nominal diameter for the tolerances, the fractions shall be converted to their decimal equivalents.

c. Bare straight lengths shall be 36 in. +0, −$\frac{1}{2}$ in. [900 mm +15, −0 mm].

d. These metric sizes are not shown in ISO 544.

4.5.2 The product information and the precautionary information required in 4.6 for marking each package shall also appear on each coil, spool, and drum.

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

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

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

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

TABLE 3
STANDARD SIZES OF STRIP ELECTRODES

Width		Thickness	
in.	mm	in.	mm
1.18	30	0.020	0.5
2.36	60	0.020	0.5
3.54	90	0.020	0.5
4.72	120	0.020	0.5

GENERAL NOTES:

(a) Other sizes shall be as agreed upon between purchaser and supplier.

(b) Strip electrodes shall not vary more than ±0.008 in. [±0.2 mm] in width and more than ±0.002 in. [±0.05 mm] in thickness.

4.6 Marking of Packages

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

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

(b) Supplier's name and trade designation,

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

(d) Lot, control, or heat number.

4.6.2 The appropriate precautionary information[4], 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.

TABLE 4
STANDARD PACKAGES[a]

	Width		Inside Diameter		Outside Diameter, Max.	
Type of Package	in.	mm[b]	in.	mm[b]	in.	mm[b]
Coils with support	3 max.	75 max.	6¾ ±⅛	170 ±3		
	2½ max.	*90, +0, −15*	12 ±⅛	*300, +15, −0*	17	*435*
	4⅝ max.	*100, +10, −5*	12 ±⅛	*300, +15, −5*	18	*450*
	5 max.	*120, +10, −5*	24	*600, +20, −0*	32	*800*
Coils without support	As agreed upon between purchaser and supplier					
Spools	See Figs. 1A, 1B, and 1C				4	100
					8	200
					12	300
					13.5	340
					14	350
					22	560
					24	610
					30	760
Drums	Not applicable				15½	400
					20	500
					23	600
Straight lengths[c]	Not applicable					

NOTES:

a. Dimensions, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.

b. Italicized values in the metric columns are as specified in ISO 544 for coils both with and without supports.

c. Standard lengths shall be 36, +0, −½ in. [900, +15, −0 mm].

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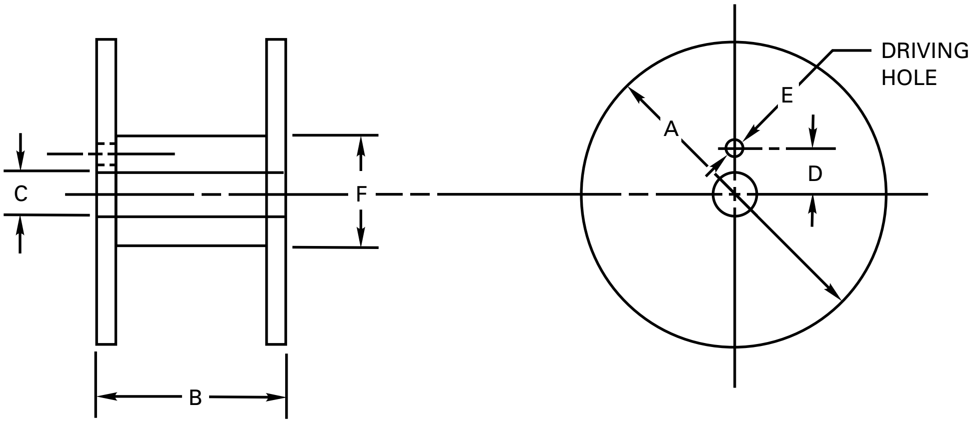
[4] Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

FIG. 1A DIMENSIONS OF 4 IN., 8 IN., 12 IN., AND 14 IN. [100 MM, 200 MM, 300 MM, AND 350 MM] SPOOLS



		DIMENSIONS							
		4 in. [100 mm] Spools		8 in. [200 mm] Spools		12 in. [300 mm] Spools		14 in. [350 mm] Spools	
	ISO 544 Denomination	S 100		S 200		S 300		S 350	
		in.	mm	in.	mm	in.	mm	in.	mm
A	Diameter, max. (Note 1)	4.0	102	8.0	203	12	305	14	355
B	Width	1.75	45	2.16	55	4.0	103	4.0	103
	Tolerance	±0.03	+0, −2	±0.03	+0, −3	±0.06	+0, −3	±0.06	+0, −3
C	Diameter	0.63	16.5	2.03	50.5	2.03	50.5	2.03	50.5
	Tolerance	+0.01, −0	+1, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0
D	Distance Between Axes	—	—	1.75	44.5	1.75	44.5	1.75	44.5
	Tolerance	—	—	±0.02	±0.5	±0.02	±0.5	±0.02	±0.5
E	Diameter (Note 2)	—	—	0.44	10	0.44	10	0.44	10
	Tolerance	—	—	+0, −0.06	+1, −0	+0, −0.06	+1, −0	+0, −0.06	+1, −0

GENERAL NOTES:

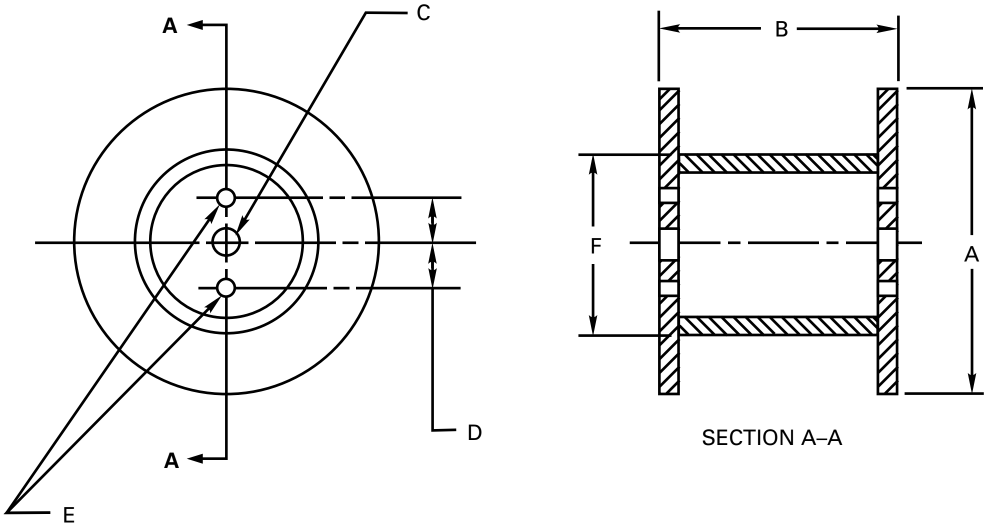
(a) Outside diameter of barrel, dimension F, shall be such as to permit proper feeding of the electrode.

(b) 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.

NOTES:

1. 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.
2. Holes are provided on each flange, but they need not be aligned. No driving holes required for 4 in. [100 mm] spools.

FIG. 1B DIMENSIONS OF 22 IN., 24 IN., AND 30 IN. [560 MM, 610 MM, AND 760 MM] SPOOLS (REELS)



		22 in. [560 mm] Spools		24 in. [610 mm] Spools		30 in. [760 mm] Spools	
	ISO 544 Denomination	S 560		S 610		S 760	
		in.	mm	in.	mm	in.	mm
A	Diameter, max. (Note 1)	22	560	24	610	30	760
B	Width, max.	12	305	13.5	345	13.5	345
C	Diameter	1.31	35.0	1.31	35.0	1.31	35.0
	Tolerance	+0.13, −0	±1.5	+0.13, −0	±1.5	+0.13, −0	±1.5
D	Distance, Center-to-Center	2.5	63.5	2.5	63.5	2.5	63.5
	Tolerance	±0.1	±1.5	±0.1	±1.5	±0.1	±1.5
E	Diameter (Note 2)	0.69	16.7	0.69	16.7	0.69	16.7
	Tolerance	+0, −0.06	±0.7	+0, −0.06	±0.7	+0, −0.06	±0.7

GENERAL NOTES:

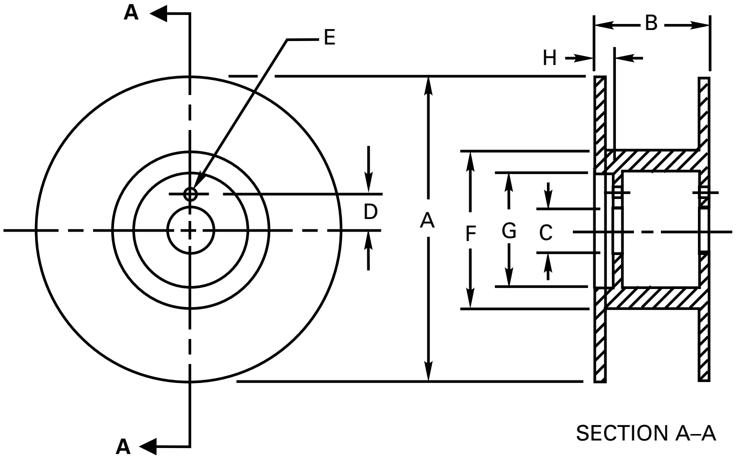
(a) Outside diameter of barrel, dimension F, shall be such as to permit proper feeding of the electrode.

(b) 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.

NOTES:

1. 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.
2. Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

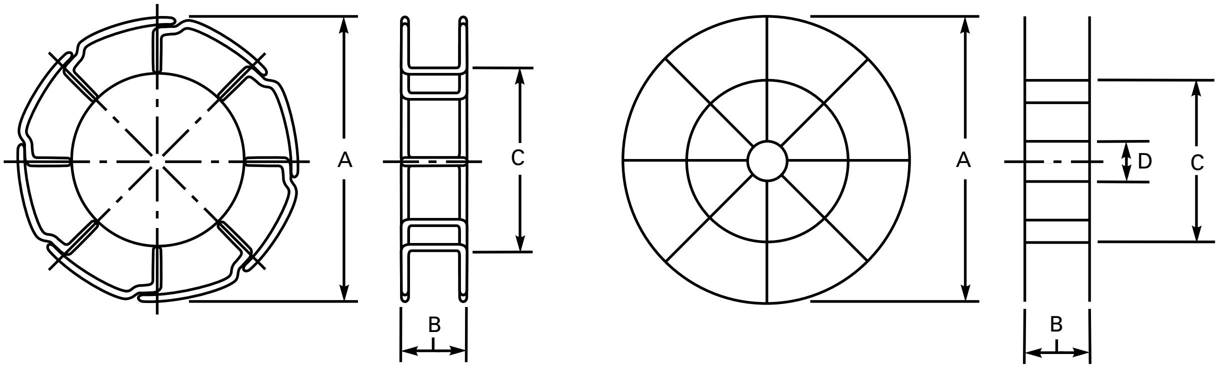
FIG. 1C DIMENSIONS OF STANDARD 13½ IN. [340 MM] STANDARD SPOOLS (FOR Al AND Mg ALLOYS ONLY)



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

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

FIG. 1D DIMENSIONS OF BASKET RIMS AND BASKET SPOOLS



BASKET RIM (B)

BASKET SPOOL (BS)

DIMENSIONS							
ISO 544 Denomination		Basket Rim B300		Basket Rim B 450		Basket Spool BS 300	
		in.	mm	in.	mm	in.	mm
A	Diameter	11.7	300	17.7 max.	450 max.	12.0	300
	Tolerance	±0.1	+0, −5			+0, −0.4	±5
B	Width	4.0	103	4	100	4.0	103
	Tolerance	±0.06	+0, −3	+0.06, −0.18	±3	±0.06	+0, −3
C	Diameter	7.0	180	12.0	300	7.44	189
	Tolerance	+0.2, −0	±2	+0, −0.4	±5	±0.02	±0.5
D	Bore Diameter	—	—	—	—	2.03 +0.06, −0	50.5 +2.5, −0

Annex A (Informative)
Guide to AWS Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes

(This annex is not part of AWS A5.02/A5.02M:2007, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*, but is included for informational purposes only.)

A1. Clause 3 of this standard may be applied to any of the following specifications for covered electrodes:

A5.1/A5.1M, *Specification for Carbon Steel Electrodes for Shielded Metal Arc 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, *Specification for Covered Copper and Copper Alloy Arc Welding Electrodes*

A5.11/A5.11M, *Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*

A5.13, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*

A2. Clause 4 of this standard may be applied to any of the following specifications for bare and tubular electrodes and rods:

A5.2/A5.2M, *Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding*

A5.7, *Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes*

A5.9/A5.9M, *Specification for Bare Stainless Steel Welding Electrodes and Rods*

A5.10/A5.10M, *Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods*

A5.14/A5.14M, *Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*

A5.16/A5.16M, *Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods*

A5.17/A5.17M, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*

A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

A5.19, *Specification for Magnesium Arc Welding Electrodes and Rods*

A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*

A5.22, *Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding*

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*

A3. Both Clauses 3 and 4 may be applied to the following specifications:

A5.15, *Specification for Welding Electrodes and Rods for Cast Iron*

A5.21, *Specification for Bare Electrodes and Rods for Surfacing*

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SPECIFICATION FOR CARBON STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

(**15**)

SFA-5.1/SFA-5.1M

(Identical with AWS Specification A5.1/A5.1M:2012. 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.

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 Informative Annex Clauses A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*,[1] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI).

The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification with the designation A5.1 uses U.S. Customary Units. The specification A5.1M 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 or both under A5.1 or A5.1M specifications.

Part A
General Requirements

2. Normative References

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

The following documents are referenced in the mandatory sections of this document:

(1) ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*[2]

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

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

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[1] ANSI Z49.1 is published by the American Welding Society, 8669 Doral Blvd., Doral, FL 33166.

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

(4) AWS A1.1, *Metric Practice Guide for the Welding Industry*[3]

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

(6) AWS A4.4M, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*

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

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

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

(10) ISO 544, *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances and markings*.[4]

3. Classification

3.1 The welding electrodes covered by the A5.1 specification utilize a system based on U.S. Customary Units to classify the welding electrodes covered according to:

(1) Type of current (see Table 1)

(2) Type of covering (see Table 1)

(3) Welding position (see Table 1)

(4) Mechanical properties of the weld metal in the as-welded or aged condition (see Tables 2 and 3).

3.1M The welding electrodes covered by the A5.1M specification utilize a system based on International System of Units to classify the welding electrodes covered according to:

(1) Type of current (see Table1)

(2) Type of covering (see Table 1)

(3) Welding position (see Table 1)

(4) Mechanical properties of the weld metal in the as-welded or aged condition (see Tables 2 and 3).

3.2 Material classified under one classification shall not be classified under any other classification in one specification, although it may be classified under both specifications, except that E7018M [E4918M] may also be classified as E7018 [E4918] provided the electrode meets all of the requirements of both classifications.

4. Acceptance

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

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[5]

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[3] AWS standards are published by the American Welding Society, 8669 Doral Blvd., Doral, FL 33166.

[4] ISO standards are published by the American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002.

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

Table 1
Electrode Classification

AWS Classification				
A5.1	A5.1M	Type of Covering	Welding Position[a]	Type of Current[b]
E6010	E4310	High cellulose sodium	F, V, OH, H	dcep
E6011	E4311	High cellulose potassium	F, V, OH, H	ac or dcep
E6012	E4312	High titania sodium	F, V, OH, H	ac or dcen
E6013	E4313	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E6018[c]	E4318[c]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E6019	E4319	Iron oxide titania potassium	F, V, OH, H	ac, dcep, or dcen
E6020	E4320	High iron oxide	H-fillet F	ac or dcen ac, dcep, or dcen
E6022[d]	E4322[d]	High iron oxide	F, H-fillet	ac or dcen
E6027	E4327	High iron oxide, iron powder	H-fillet F	ac or dcen ac, dcep, or dcen
E7014	E4914	Iron powder, titania	F, V, OH, H	ac, dcep, or dcen
E7015	E4915	Low-hydrogen sodium	F, V, OH, H	dcep
E7016[c]	E4916[c]	Low-hydrogen potassium	F, V, OH, H	ac or dcep
E7018[c]	E4918[c]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E7018M	E4918M	Low-hydrogen iron powder	F, V, OH, H	dcep
E7024[c]	E4924[c]	Iron power, titania	H-fillet, F	ac, dcep, or dcen
E7027	E4927	High iron oxide, iron powder	H-fillet F	ac or dcen ac, dcep, or dcen
E7028[c]	E4928[c]	Low-hydrogen potassium, iron powder	H-fillet, F	ac or dcep
E7048	E4948	Low-hydrogen potassium, iron powder	F, OH, H, V-down	ac or dcep

[a] 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 (for electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]). V-down = Vertical, progression downwards (for electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]), OH = Overhead (for electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]).

[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).

[c] Electrodes with supplemental elongation, notch toughness, absorbed moisture, and diffusible hydrogen requirements may be further identified as shown in Tables 2, 3, 10, and 11.

[d] Electrodes of the E6022 [E4322] classification are intended for single-pass welds only.

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 1000 psi (1 ksi) for tensile and yield strength for A5.1, or 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. The rounded-off results shall fulfill the requirements for the classification under test.

Table 2
Tension Test Requirements[a, b, c]

AWS Classification		Tensile Strength		Yield Strength at 0.2% Offset		Elongation Percentage in 4x Diameter Length
A5.1	A5.1M	A5.1 (ksi)	A5.1M (MPa)	A5.1 (ksi)	A5.1M (MPa)	
E6010	E4310	60	430	48	330	22
E6011	E4311	60	430	48	330	22
E6012	E4312	60	430	48	330	17
E6013	E4313	60	430	48	330	17
E6018	E4318	60	430	48	330	22
E6019	E4319	60	430	48	330	22
E6020	E4320	60	430	48	330	22
E6022[d]	E4322[d]	60	430	Not Specified		Not Specified
E6027	E4327	60	430	48	330	22
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
E7024	E4924	70	490	58	400	17[e]
E7027	E4927	70	490	58	400	22
E7028	E4928	70	490	58	400	22
E7048	E4948	70	490	58	400	22
E7018M	E4918M	Note f	Note f	53–72[g]	370–500[g]	24

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

Part B
Tests, Procedures, and Requirements

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, moisture content of the low-hydrogen electrode covering, and the usability of the electrode. 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 18. The supplemental tests for absorbed moisture, in Clause 17, and diffusible hydrogen, in Clause 18, are not required for classification of the low-hydrogen electrodes, except for E7018M [E4918M], where these are required (see notes i and m of Table 4).

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

Table 3
Charpy V-Notch Impact Requirements

AWS Classification		Limits for 3 out of 5 Specimens[a]	
A5.1	A5.1M	Average, Min.	Single Value, Min.
E6010, E6011, E6018 E6027, E7015, E7016[b], E7018[b], E7027, E7048	E4310, E4311, E4318 E4327, E4915, E4916[b], E4918[b], E4927, E4948	20 ft·lbf at –20°F [27 J at –30°C]	15 ft·lbf at –20°F [20 J at –30°C]
E6019 E7028	E4319 E4928	20 ft·lbf at 0°F [27 J at –20°C]	15 ft·lbf at 0°F [20 J at –20°C]
E6012, E6013, E6020, E6022, E7014, E7024[b]	E4312, E4313 E4320, E4322 E4914, E4924[b]	Not Specified	Not Specified
AWS Classification		Limits for 5 out of 5 Specimens[c]	
A5.1	A5.1M	Average, Min.	Single Value, Min.
E7018M	E4918M	50 ft·lbf at –20°F [67 J at –30°C]	40 ft·lbf at –20°F [54 J at –30°C]

[a] Both the highest and lowest test values obtained shall be disregarded in computing the average. Two of these remaining three values shall equal or exceed 20 ft·lbf [27 J].

[b] Electrodes with the following optional supplemental designations shall meet the lower temperature impact requirements specified below:

AWS Classification		Electrode Designation		Charpy V-Notch Impact Requirements, Limits for 3 out of 5 specimens (Refer to Note a above)	
A5.1	A5.1M	A5.1	A5.1M	Average, Min.	Single Value, Min.
E7016 E7018	E4916 E4918	E7016-1 E7018-1	E4916-1 E4918-1	20 ft·lbf at –50°F [27 J at –45°C]	15 ft·lbf at –50°F [20 J at –45°C]
E7024	E4924	E7024-1	E4924-1	20 ft·lbf at 0°F [27 J at –20°C]	15 ft·lbf at 0°F [20 J at –20°C]

[c] 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].

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 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 five weld test assemblies are required:

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

(2) The groove weld in Figure 2 for mechanical properties and soundness of weld metal made with all electrode classifications except E6022 [E4322] and E7018M [E4918M]

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

Table 4
Required Tests[a]

AWS Classification			Electrode Size		Welding Position for Test Assembly[b]				
A5.1	A5.1M	Current and Polarity[a]	A5.1 (in)	A5.1M (mm)	Chemical[c] Analysis	Radiographic Test[d] All-Weld-Metal Tension Test[e]	Impact Test[f]	Fillet Weld Test[g]	Moisture Test[i]
E6010	E4310	dcep	3/32, 1/8	2.4, 2.5, 3.2	NR	NR	NR	NR	NR
			5/32, 3/16	4.0, 4.8, 5.0	F	F	F	V & OH	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F	F	H-fillet	NR
			5/16	8.0	NR	F	NR	NR	NR
E6011	E4311	ac and dcep	3/32, 1/8	2.4, 2.5, 3.2	NR	NR	NR	NR	NR
			5/32, 3/16	4.0, 4.8, 5.0	F	F	F	V & OH	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F	F	H-fillet	NR
			5/16	8.0	NR	F	NR	NR	NR
E6012	E4312	ac and dcen	1/16 to 1/8 inc.	1.6 to 3.2 inc.	NR	NR	NR	NR	NR
			5/32, 3/16	4.0, 4.8, 5.0	F	F[h]	NR	V & OH	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4, 5/16	6.0, 6.4, 8.0	F	F[h]	NR	H-fillet	NR
E6013	E4313	ac, dcep, and dcen	1/16 to 1/8 inc.	1.6 to 3.2 inc.	NR	NR	NR	NR	NR
			5/32, 3/16	4.0, 4.8, 5.0	F	F[k]	NR	V & OH	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4, 5/16	6.0, 6.4, 8.0	F	F[k]	NR	H-fillet	NR
E6018	E4318	ac and dcep	3/32,1/8	2.4, 2.5, 3.2	NR	NR	NR	NR	NR
			5/32	4.0	F	F	F	V & OH	Reqd.
			3/16	4.8, 5.0	NR	F	F	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F	F	H-fillet	Reqd.
			5/16	8.0	NR	F	NR	NR	NR
E6019	E4319	ac, dcep, and dcen	5/64 to 1/8 inc.	2.0 to 3.2 inc.	NR	NR	NR	NR	NR
			5/32, 3/16	4.0, 4.8, 5.0	F	F[k]	F[l]	V & OH	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4, 5/16	6.0, 6.4, 8.0	F	F[k]	F[l]	H-fillet	NR
E6020	E4320	For H-fillet, ac and dcen; For flat position, ac, dcep, and dcen	1/8	3.2	NR	NR	NR	NR	NR
			5/32, 3/16	4.0, 4.8, 5.0	F	F[k]	NR	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F[k]	NR	H-fillet	NR
			5/16	8.0	NR	F[k]	NR	NR	NR
E6022	E4322	ac and dcen	1/8	3.2	NR	F[h,j]	NR	NR	NR
			5/32 to 7/32 inc.	4.0 to 5.6 inc.	NR	F[h,j]	NR	NR	NR
E6027	E4327	For H-fillet, ac and dcen; For flat position, ac, dcep, and dcen	1/8	3.2	NR	NR	NR	NR	NR
			5/32, 3/16	4.0, 4.8, 5.0	F	F[k,l]	F[k]	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F[k,l]	F[k]	H-fillet	NR
			5/16	8.0	NR	F[k,l]	NR	NR	NR
E7014	E4914	ac, dcep, and dcen	3/32, 1/8	2.4, 2.5, 3.2	NR	NR	NR	NR	NR
			5/32	4.0	F[k]	F[k]	NR	V & OH	NR
			3/16	4.8, 5.0	NR	F[k]	NR	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F[k]	F[k]	NR	H-fillet	NR
			5/16	8.0	NR	F[k]	NR	H-fillet	NR

(Continued)

Table 4 (Continued)
Required Tests[a]

AWS Classification			Electrode Size		Welding Position for Test Assembly[b]				
A5.1	A5.1M	Current and Polarity[a]	A5.1 (in)	A5.1M (mm)	Chemical[c] Analysis	Radiographic Test[d] All-Weld-Metal Tension Test[e]	Impact Test[f]	Fillet Weld Test[g]	Moisture Test[i]
E7015	E4915	dcep	3/32, 1/8	2.4, 2.5, 3.2	NR	NR	NR	NR	NR
			5/32	4.0	F	F	F	V & OH	Reqd.
			3/16	4.8, 5.0	NR	F	F	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F	F	H-fillet	Reqd.
			5/16	8.0	NR	F	NR	NR	NR
E7016	E4916	ac and dcep	3/32, 1/8	2.4, 2.5, 3.2	NR	NR	NR	NR	NR
			5/32	4.0	F	F	F	V & OH	Reqd.
			3/16	4.8, 5.0	NR	F	F	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F	F	H-fillet	Reqd.
			5/16	8.0	NR	F	NR	NR	NR
E7018	E4918	ac and dcep	3/32, 1/8	2.4, 2.5, 3.2	NR	NR	NR	NR	NR
			5/32	4.0	F	F	F	V & OH	Reqd.
			3/16	4.8, 5.0	NR	F	F	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F	F	H-fillet	Reqd.
			5/16	8.0	NR	F	NR	NR	NR
E7018M[m]	E4918M[m]	dcep	3/32 to 5/32 inc.	2.4 to 4.0 inc.	F	V	V	NR	Reqd.
			3/16 to 5/16 inc.	4.8 to 8.0 inc.	F	F	F	NR	Reqd.
E7024	E4924	ac, dcep, and dcen	3/32, 1/8	2.4, 2.5, 3.2	NR	NR	NR[n]	NR	NR
			5/32	4.0	F[l]	F[k,l]	F[n]	H-fillet	NR
			3/16	4.8, 5.0	NR	F[k,l]	F[n]	H-fillet	NR
			7/32	5.6	NR	NR	NR[n]	NR	NR
			1 / 4	6.0, 6.4	F[l]	F[k,l]	F[n]	H-fillet	NR
			5/16	8.0	NR	F[k,l]	NR[n]	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
			5/32	4.0	F[l]	F[k,l]	F[l]	H-fillet	NR
			3/16	4.8, 5.0	NR	F[k,l]	F[l]	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F[l]	F[k,l]	F[l]	H-fillet	NR
			5/16	8.0	NR	F[k,l]	NR	NR	NR
E7028	E4928	ac and dcep	1/8	3.2	NR	NR	NR	NR	NR
			5/32	4.0	F	F[l]	F	H-fillet	Reqd.
			3/16	4.8, 5.0	NR	F[l]	F	H-fillet	NR
			7/32	5.6	NR	NR	NR	NR	NR
			1/4	6.0, 6.4	F	F[l]	F	H-fillet	Reqd.
			5/16	8.0	NR	F[l]	NR	NR	NR
E7048	E4948	ac and dcep	1/8	3.2	NR	NR	NR	NR	NR
			5/32	4.0	F	F	F	V-down & OH	Reqd.
			3/16	4.8, 5.0	NR	F	F	V-down & H-fillet	NR

(Continued)

Table 4 (Continued)
Required Tests[a]

[a] NR means "not required." The abbreviations, F, H-fillet, V-down, V, and OH are defined in Note a of Table 1. The terms "dcep" and "dcen," are defined in Note b of Table 1.

[b] Standard electrode sizes not requiring this specific test can be classified provided at least two other sizes of that classification have passed the tests required for them, or the size to be classified meets specification requirements by having been tested in accordance with Figures 1, 2, and 3 and Table 6.

[c] See Clause 10.

[d] See Clause 11.

[e] See Clause 12.

[f] See Clause 14.

[g] See Clause 15.

[h] A radiographic test is not required for this classification.

[i] The moisture test given in Clause 16 is the required test for moisture content of the covering. In Clauses 17 and 18 are supplemental tests required only when their corresponding optional supplemental designators are to be used with the classification designators.

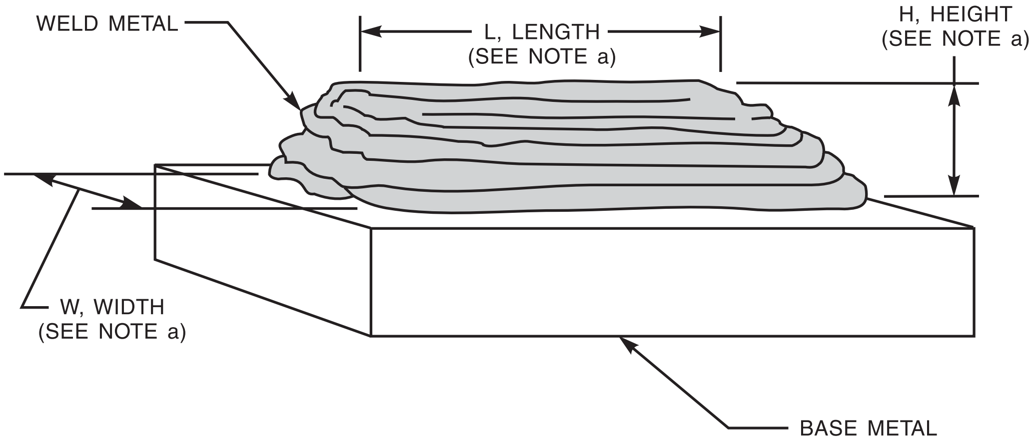
[j] An all-weld-metal tension test is not required for E6022 [E4322] electrodes. Instead, a transverse tension test (see 12.5) and a longitudinal guided bend test (see Clause 13) are required for classification of 5/32 in, 3/16 in, and 7/32 in [4.0 mm, 5.0 mm, and 6.0 mm] E6022 [E4322] electrodes.

[k] When dcep and dcen are shown, only dcen need be tested.

[l] Electrodes longer than 18 in [450 mm] will require a double length test assembly in accordance with Note 1 of Figure 2, to ensure uniformity of the entire electrode.

[m] Tests in Clause 17, and in Clause 18, are required for all sizes of E7018M [E4918M].

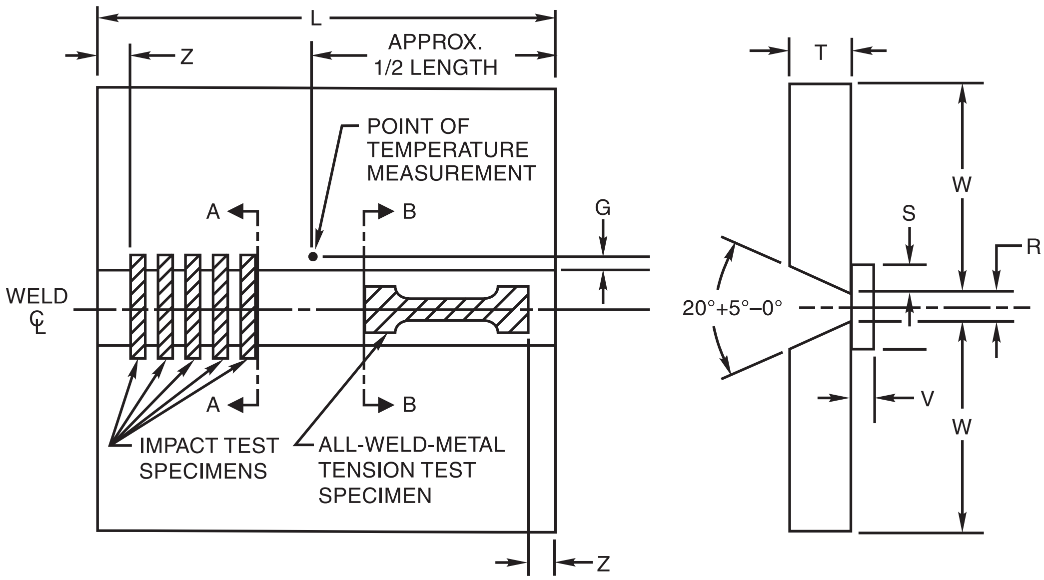
[n] Electrodes identified as E7024-1 [E4924-1] shall be impact tested (see Note b of Table 3).



[a] 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 at least 1/4 in [6.0 mm] above the original base metal surface.

Notes:
1. Base metal of any convenient size, of any type specified in Table 5, 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 4 except for those classifications identified by note k in Table 4.
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.

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS

(B) ORIENTATION AND LOCATION OF IMPACT TEST SPECIMEN

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

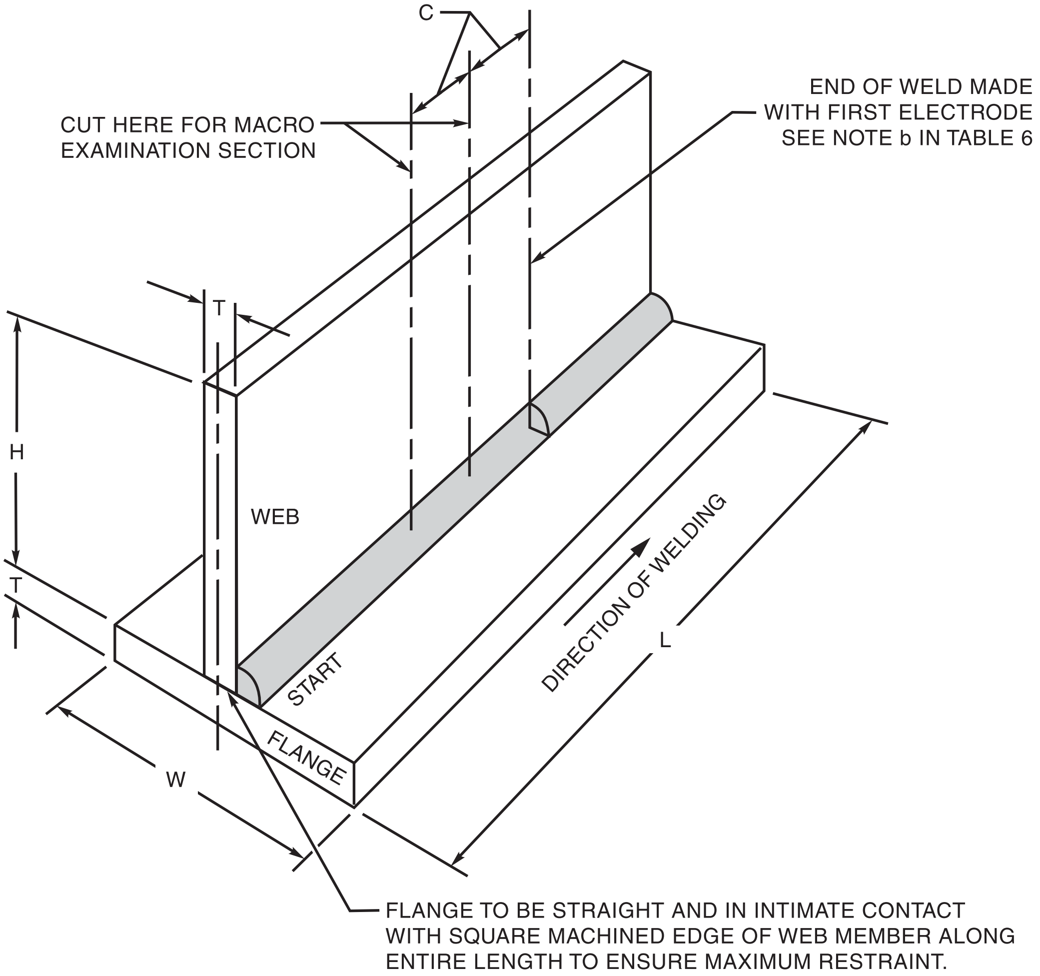
Dimension	Description	A5.1 (in)	A5.1M (mm)
G	Offset from Groove Edge	1/4–1/2	6–15
L	Length, min. (See Note 1)	10	250
S	Strip Overlap, min.	1/4	6
V	Strip Thickness, min.	1/4	6
W	Width, min.	5	125
Z	Discard, min.	1	25

Electrode Size		Plate Thickness (T)		Root Opening (R)		Passes per Layer	Total Layers
A5.1 (in)	A5.1M (mm)	A5.1 (in)	A5.1M (mm)	A5.1 (in)	A5.1M (mm)		
3/32	2.5	1/2	12	3/8	10	2	Not Specified
1/8	3.2	1/2	12	1/2	13	2	5–7
5/32	4.0	3/4	20	5/8	16	2	7–9
3/16	5.0	3/4	20	3/4	19	2	6–8
7/32	6.0	3/4	20	7/8	22	2	6–8
1/4	6.0	1	25	1	25	2	9–11
5/16	8.0	1-1/4	30	1-1/8	28	2	10-–12

Notes:

1. For electrodes longer than 18 in [450 mm], a 20 in [500 mm] long test assembly shall be welded.
2. Base metal shall be as specified in Table 5.
3. The surfaces to be welded shall be clean.
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° of plane. A welded test assembly that is more than 5° 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 4 except for classifications identified by Note k in Table 4.
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. The joint root may be seal welded with 3/32 in or 1/8 in [2.5 mm 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 2—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



DIMENSIONS	in	mm
C, approx.	1	25
H, min.	3	75
W, min.	3	75
T	See Table 6	
L	See Table 6	

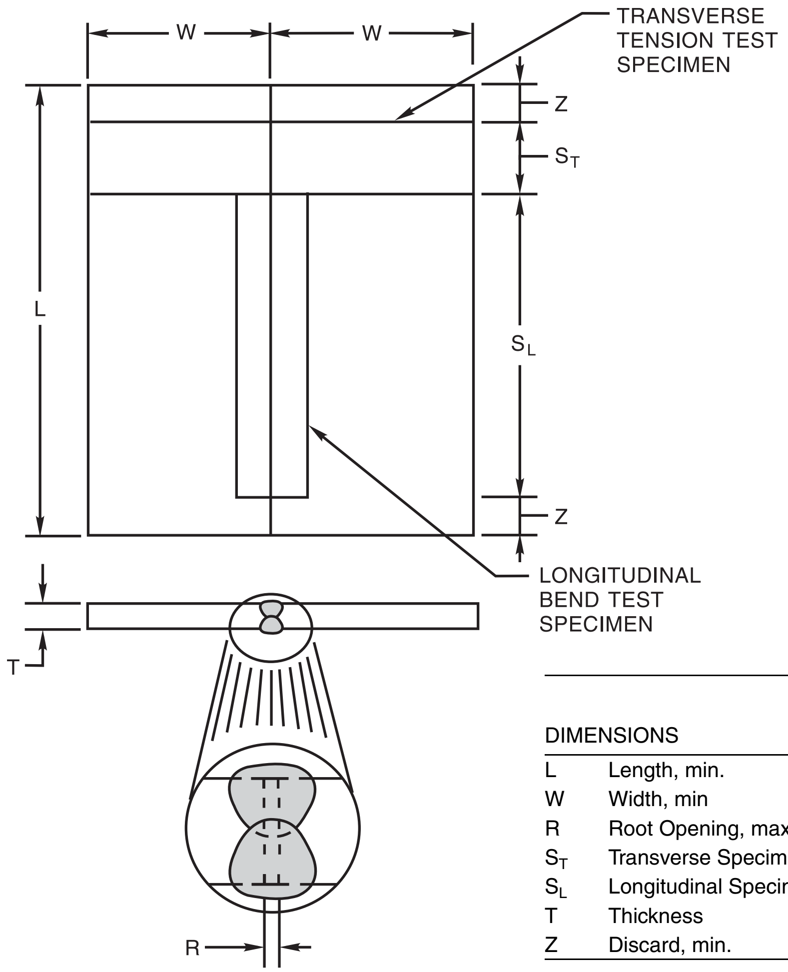
Notes:
1. Base metal shall be as specified in Table 5.
2. The surfaces to be welded shall be clean.
3. An assembly shall be welded in each position specified in Table 6 and shown in Figure 6 using each type of current specified in Table 4.
4. The preheat shall be 60°F [15°C] minimum.
5. A single pass fillet weld shall be made on one side of the joint. The first electrode shall be consumed to a stub length no greater than 2 in [50 mm].
6. Welding in the vertical position shall be upward progression, except the E7048 [E4948] classification where progression shall be downward.
7. Weld cleaning shall be limited to slag chipping, brushing, and needle scaling. Grinding or filing of the weld is prohibited.

Figure 3—Fillet Weld Test Assembly

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

(5) The groove weld in Figure 5 for mechanical properties and soundness of weld metal made with the E7018M [E4918M] electrode.

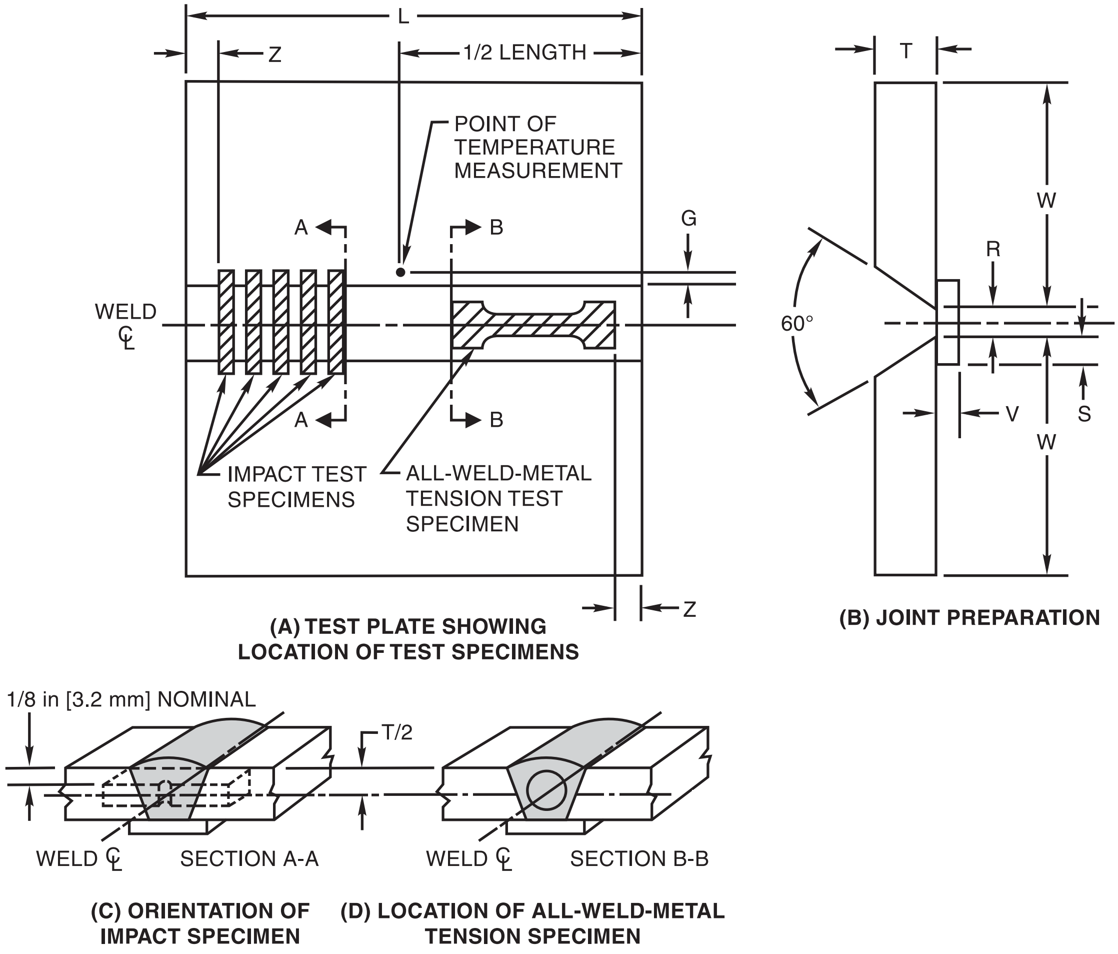
The sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figures 2 or 5, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.



		A5.1	A5.1M
DIMENSIONS		in	mm
L	Length, min.	10	250
W	Width, min	4	100
R	Root Opening, max.	1/16	1.6
S_T	Transverse Specimen	2	50
S_L	Longitudinal Specimen	6	150
T	Thickness	1/4	6
Z	Discard, min.	1	25

Notes:
1. Base metal shall be as specified in Table 5.
2. 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 4.
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 4—Test Assembly for Transverse Tension and Longitudinal Guided Bend Tests for Welds Made With E6022 [E4322] Electrodes



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS

(B) JOINT PREPARATION

(C) ORIENTATION OF IMPACT SPECIMEN

(D) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN

Dimension	Description	A5.1 (in)	A5.1M (mm)
G	Offset from Groove Edge	1/4–1/2	6–15
L	Length, min.	10	250
R	Root Opening, min.	1/4	6
S	Strip Overlap, min.	1/4	6
T	Plate Thickness	3/4	20
V	Strip Thickness, min.	1/4	6
W	Width, min.	5	125
Z	Discard, min.	1	25

Notes:
1. Base metal shall be as specified in Table 5.
2. 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 4 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

9.2 Preparation of each weld test assembly shall be as prescribed in 9.3 through 9.5. The base metal for each assembly shall be as required in Table 5 and shall meet the requirements of the ASTM specification shown there or an equivalent specification. Electrodes other than low-hydrogen electrodes shall be tested without conditioning.[6] Low-hydrogen electrodes, if they have not been 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 the assemblies shall be as prescribed in Clauses 10 through 15.

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 5) is selected. Base metal of any convenient size of the type specified in Table 5 shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal.

The preheat temperature shall be not 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. The dimensions of the completed pad shall be as shown in Figure 1. Testing of this assembly shall be as specified in Clause 10.

9.4 Groove Weld

9.4.1 Mechanical Properties and Soundness. A test assembly shall be prepared and welded as specified in Figure 2 or 5 using base metal of the appropriate type specified in Table 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 4 using base metal of the appropriate type specified in Table 5. Testing of this assembly shall be as specified in 12.5 through 12.7 and Clause13. The assembly shall be tested in the as-welded condition.

9.5 Fillet Weld. A test assembly shall be prepared and welded as specified in Table 4 and Figure 3 using base metal of the appropriate type specified in Table 5. The welding positions shall be as specified in Table 6 and Figures 3 and 6 according to the size and classification of electrode. Testing of the assembly shall be as specified in Clause 15.

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 all-weld-metal tension test specimen or from a corresponding location in the groove weld in Figure 2 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 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 and shall be taken at least 1/4 in [6 mm] from the nearest surface of the base metal.

The sample from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the groove weld in Figure 2 or 5 shall be prepared for analysis by any suitable mechanical means.

10.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron.*

10.3 The results of the analysis shall meet the requirements of Table 7 for the classification of the electrode under test.

11. Radiographic Test

11.1 When required in Table 4, the groove weld described in 9.4.1 and shown in Figure 2 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. The finished surface of the weld may be flush with the plate or have a reasonably uniform reinforcement not exceeding 3/32 in [2.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

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[6] Conditioning can be considered to be any preparation or procedure, such as baking the electrode, which the user would not normally practice.

Table 5
Base Metal for Test Assemblies

AWS Classification	Base Metal		
	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 6
Requirements for Preparation of Fillet Weld Test Assemblies

AWS Classification		Electrode Size		Thickness (T)[a]		Length (L), Min.[b]		Welding	Fillet Weld Size	
A5.1	A5.1M	in	mm	in	mm	in	mm	Position	in	mm
E6010 and E6011	E4310 and E4311	3/32	2.4, 2.5	1/8	3	10	250	V & OH	5/32 max.	4.0 max.
		1/8	3.2	3/16	5	12	300	V & OH	3/16 max.	5.0 max.
		5/32	4.0	3/8	10	12	300	V & OH	1/4 max.	6.0 max.
		3/16	4.8, 5.0	3/8	10	12	300	V & OH	5/16 max.	8.0 max.
		7/32	5.6	1/2	12	12 or 16[c]	300 or 400[c]	H-fillet	1/4 min.	6.0 min.
		1/4	6.0, 6.4	1/2	12	16	400	H-fillet	1/4 min.	6.0 min.
		5/16	8.0	1/2	12	16	400	H-fillet	1/4 min.	6.0 min.
E6012, E6013, and E6019	E4312, E4313, and E4319	1/16–5/64	1.6-2.0	1/8	3	6	150	V & OH	1/8 max.	3.0 max.
		3/32	2.4, 2.5	1/8	3	10	250	V & OH	1/8 max.	3.0 max.
		1/8	3.2	3/16	5	12	300	V & OH	3/16 max.	5.0 max.
		5/32	4.0	3/8	10	12	300	V & OH	1/4 max.	6.0 max.
		3/16	4.8, 5.0	1/2	12	12	300	V & OH	3/8 max.	10.0 max.
		7/32	5.6	1/2	12	12 or 16[c]	300 or 400[c]	H-fillet	1/4 min.	6.0 min.
		1/4	6.0, 6.4	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
		5/16	8.0	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
E7014	E4914	3/32	2.4, 2.5	1/8	3	12	300	V & OH	5/32 max.	4.0 max.
		1/8	3.2	3/16	5	12	300	V & OH	3/16 max.	5.0 max.
		5/32	4.0	3/8	10	12	300	V & OH	5/16 max.	8.0 max.
		3/16	4.8, 5.0	3/8	10	12	300	H-fillet	1/4 min.	6.0 min.
		7/32	5.6	3/8	10	12 or 16[c]	300 or 400[c]	H-fillet	1/4 min.	6.0 min.
		1/4	6.0, 6.4	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
		5/16	8.0	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
E7015 and E7016	E4915 and E4916	3/32	2.4, 2.5	1/8	3	10	250	V & OH	5/32 max.	4.0 max.
		1/8	3.2	1/4	6	12	300	V & OH	3/16 max.	5.0 max.
		5/32	4.0	3/8	10	12	300	V & OH	5/16 max.	8.0 max.
		3/16	4.8, 5.0	3/8	10	12	300	H-fillet	3/16 min.	5.0 min.
		7/32	5.6	1/2	12	12 or 16[c]	300 or 400[c]	H-fillet	1/4 min.	6.0 min.
		1/4	6.0, 6.4	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
		5/16	8.0	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.

(Continued)

Table 6 (Continued)
Requirements for Preparation of Fillet Weld Test Assemblies

AWS Classification		Electrode Size		Thickness (T)[a]		Length (L), Min.[b]		Welding	Fillet Weld Size	
A5.1	A5.1M	in	mm	in	mm	in	mm	Position	in	mm
E6018 and E7018	E4318 and E4918	3/32	2.4, 2.5	1/8	3	10 or 12[d]	250 or 300[d]	V & OH	3/16 max.	5.0 max.
		1/8	3.2	1/4	6	12	300	V & OH	1/4 max.	6.0 max.
		5/32	4.0	3/8	10	12	300	V & OH	5/16 max.	8.0 max.
		3/16	4.8, 5.0	3/8	10	12	300	H-fillet	1/4 min.	6.0 min.
		7/32	5.6	1/2	12	12 or 16[c]	300 or 400[c]	H-fillet	1/4 min.	6.0 min.
		1/4	6.0, 6.4	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
		5/16	8.0	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
E6020	E4320	1/8	3.2	1/4	6	12	300	H-fillet	1/8 min.	3.0 min.
		5/32	4.0	3/8	10	12	300	H-fillet	5/32 min.	4.0 min.
		3/16	4.8, 5.0	3/8	10	12 or 16[c]	300 or 400[c]	H-fillet	3/16 min.	5.0 min.
		7/32	5.6	1/2	12	16	400	H-fillet	1/4 min.	6.0 min.
		1/4	6.0, 6.4	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
		5/16	8.0	1/2	12	16	400	H-fillet	5/16 min.	8.0 min.
E6027, E7024, E7027, and E7028	E4327, E4924, E4927, and E4928	3/32[e]	2.4, 2.5[e]	1/4	6	10	250	H-fillet	5/32 min.	4.0 min.
		1/8	3.2	1/4	6	12	300	H-fillet	5/32 min.	4.0 min.
		5/32	4.0	3/8	10	12	300	H-fillet	3/16 min.	5.0 min.
		3/16	4.8, 5.0	3/8	10	12 or 16[c]	300 or 400[c]	H-fillet	1/4 min.	6.0 min.
		7/32	5.6	1/2	12	16 or 26[f]	400 or 650[f]	H-fillet	1/4 min.	6.0 min.
		1/4	6.0, 6.4	1/2	12	16 or 26[f]	400 or 650[f]	H-fillet	5/16 min.	8.0 min.
		5/16	8.0	1/2	12	16 or 26[f]	400 or 650[f]	H-fillet	5/16 min.	8.0 min.
E7048	E4948	1/8	3.2	1/4	6	12	300	V-down & OH	1/4 max.	6.0 max.
		5/32	4.0	3/8	10	12	300	V-down & OH	5/16 max.	8.0 max.
		3/16	4.8, 5.0	3/8	10	12 or 16	300 or 400	H-fillet & V-down	1/4 min.	6.0 max.

[a] See Figure 3. Any classification test can be conducted with either USC or SI thickness plate.

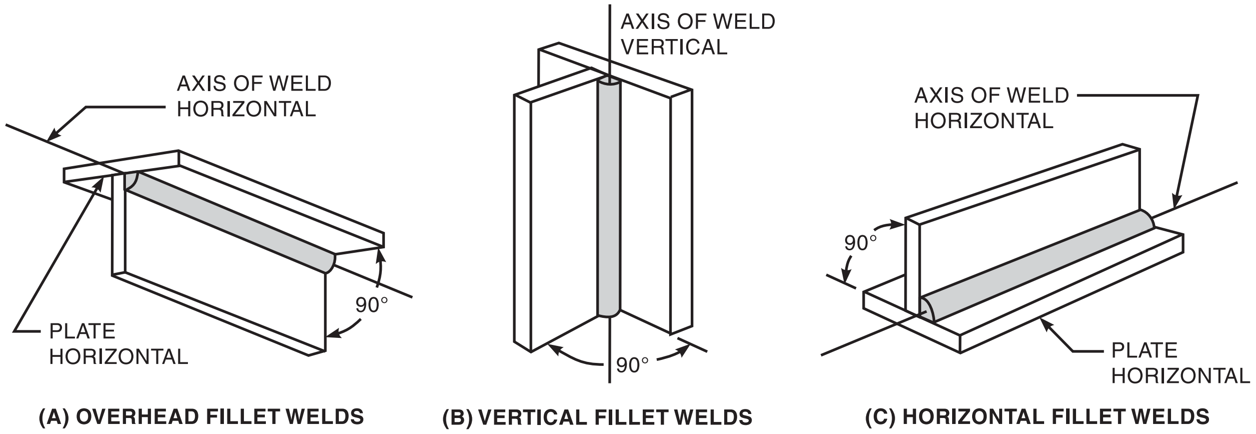
[b] When the end of the bead with the first electrode will be less than 4 in [100 mm] from the end of the test assembly, a starting tab or a longer test assembly shall be used.

[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 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].



(A) OVERHEAD FILLET WELDS (B) VERTICAL FILLET WELDS (C) HORIZONTAL FILLET WELDS

Figure 6—Welding Positions for Fillet Weld Test Assemblies

Table 7
Chemical Composition Requirements for Weld Metal

AWS Classification			Weight Percent[b]									
A5.1	A5.1M	UNS[a] Number	C	Mn	Si	P	S	Ni	Cr	Mo	V	Combined Limit for Mn + Ni + Cr + Mo + V
E6010	E4310	W06010	0.20	1.20	1.00	N.S.	N.S.	0.30	0.20	0.30	0.08	N.S.
E6011	E4311	W06011										
E6012	E4312	W06012										
E6013	E4313	W06013										
E6019	E4319	W06019										
E6020	E4320	W06020										
E6027	E4327	W06027										
E6018	E4318	W06018	0.03	0.60	0.40	0.025	0.015	0.30	0.20	0.30	0.08	N.S.
E7015	E4915	W07015	0.15	1.25	0.90	0.035	0.035	0.30	0.20	0.30	0.08	1.50
E7016	E4916	W07016	0.15	1.60	0.75	0.035	0.035	0.30	0.20	0.30	0.08	1.75
E7018	E4918	W07018	0.15	1.60	0.75	0.035	0.035	0.30	0.20	0.30	0.08	1.75
E7014	E4914	W07014	0.15	1.25	0.90	0.035	0.035	0.30	0.20	0.30	0.08	1.50
E7024	E4924	W07024	0.15	1.25	0.90	0.035	0.035	0.30	0.20	0.30	0.08	1.50
E7027	E4927	W07027	0.15	1.60	0.75	0.035	0.035	0.30	0.20	0.30	0.08	1.75
E7028	E4928	W07028	0.15	1.60	0.90	0.035	0.035	0.30	0.20	0.30	0.08	1.75
E7048	E4948	W07048										
E7018M	E4918M	W07018	0.12	0.40 to 1.60	0.80	0.030	0.020	0.25	0.15	0.35	0.05	N. S.

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

[b] Single values are maximum. N. S. means Not Specified.

[c] *Analysis for boron is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.0010%.*

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:

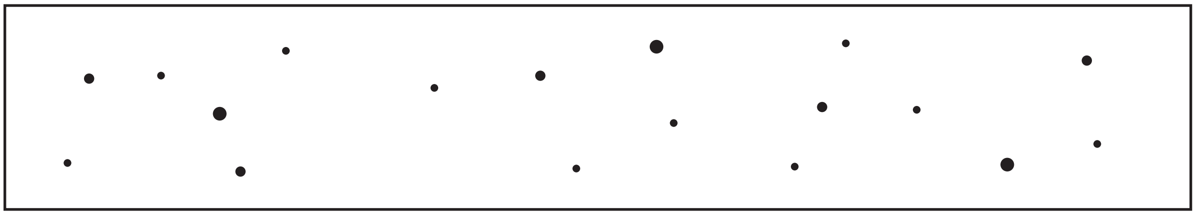
(1) No cracks, no incomplete fusion or incomplete joint penetration

(2) No slag inclusions longer than 1/4 in [6.0 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 6 times the length of the longest inclusions in the group

(3) No rounded indications in excess of those permitted by the radiographic standards in Figure 7 according to the grade specified in Table 8.

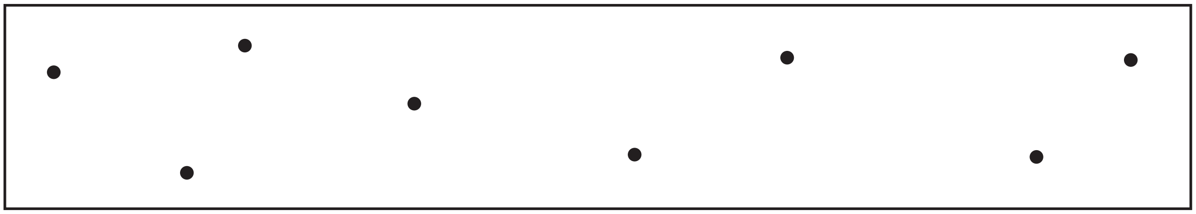
In evaluating the radiograph, 1 in [25 mm] of the weld measured from each end of the assembly shall be disregarded.

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, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be porosity or slag. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with porosity indications larger than the largest rounded indications permitted in the radiographic standards do not meet the requirements of this specification.



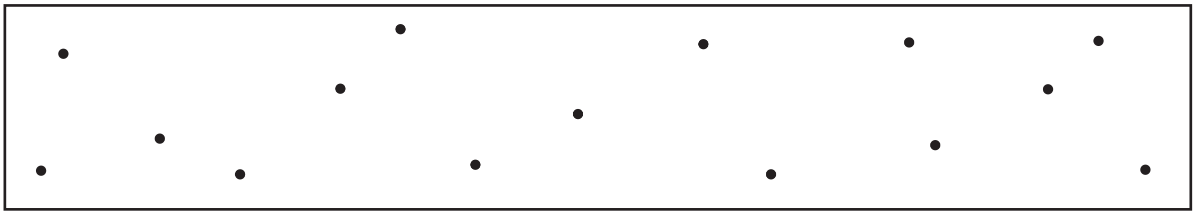
(A) ASSORTED ROUNDED INDICATIONS

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 [0.8mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 10.



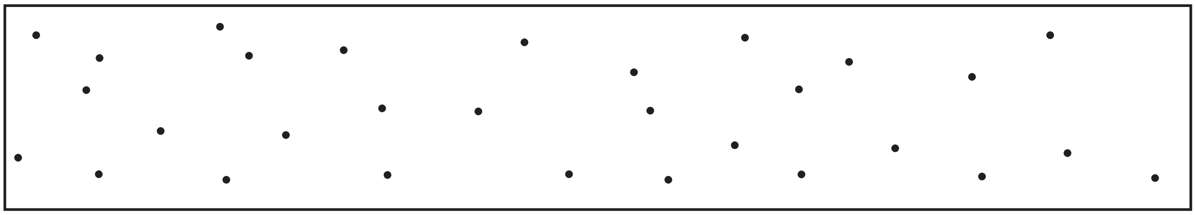
(B) LARGE ROUNDED INDICATIONS

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



(C) MEDIUM ROUNDED INDICATIONS

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



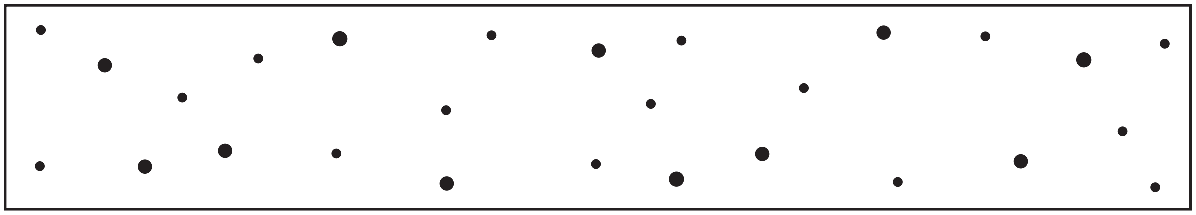
(D) SMALL ROUNDED INDICATIONS

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

Notes:

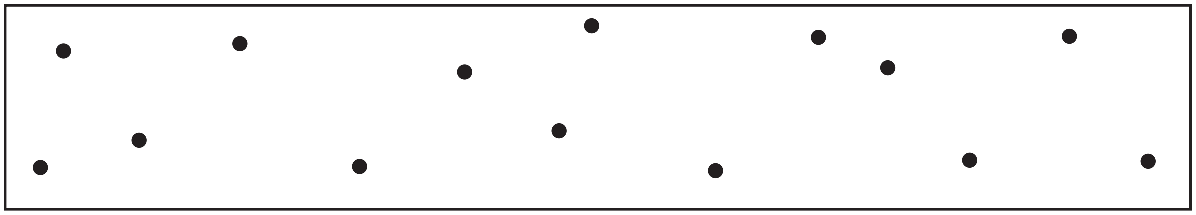
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification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

Figure 7—Radiographic Acceptance Standards for Rounded Indications (Grade 1)



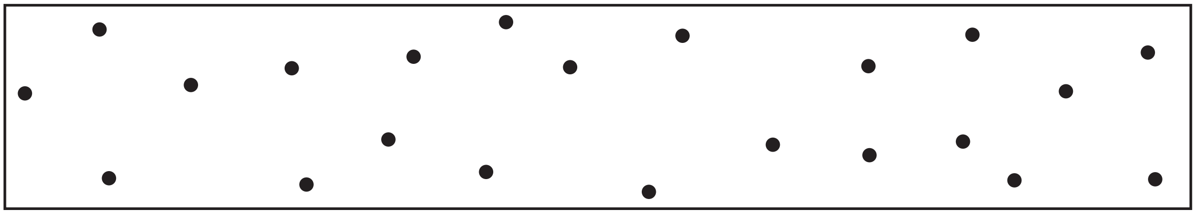
(E) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 5/64 in [0.4 mm TO 2.0 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 27, WITH THE FOLLOWING RESTRICTIONS:
MAXIMUM NUMBER OF LARGE 1/16 in TO 5/64 in [1.6 mm TO 2.0 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 8.
MAXIMUM NUMBER OF SMALL 1/64 in TO 3/64 in [0.4 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 16.



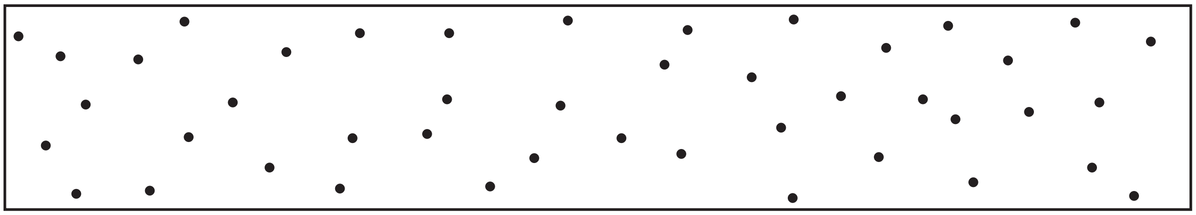
(F) LARGE ROUNDED INDICATIONS

SIZE 1/16 in TO 5/64 in [1.6 mm TO 2.0 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 14.



(G) MEDIUM 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 = 22.



(H) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 3/64 in [0.4 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 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 specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded.

Figure 7 (Continued)—Radiographic Acceptance Standards for Rounded Indications (Grade 2)

Table 8
Radiographic Soundness Requirements

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

[a] See Figure 7.

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

12. Tension Test

12.1 For all electrodes except E6022 [E4322], one all-weld-metal round tension test specimen as specified in the Tension Test section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in 9.4.1 and Figure 2 or 5. 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 [6.5 mm]. For a test plate thickness of 3/4 in [20 mm] or more, the all-weld-metal tension test specimen shall have a nominal diameter of 0.500 in [12.5 mm]. For all plate thicknesses, the gauge length-to-diameter ratio shall be 4:1.

12.2 After machining, but before testing, the specimen for all electrodes except the low hydrogen classifications may be aged at 200°F to 220°F [90°C to 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.

12.3 The aged and unaged specimens shall be tested in the manner described in the Tension Test section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*.

12.4 The results of the tension test shall meet the requirements specified in Table 2.

12.5 For E6022 [E4322], one transverse rectangular tension test specimen as specified in the Tension Test section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in 9.4.2 and shown in Figure 4. 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 4, shall be machined from the groove weld test assembly described in 9.4.2 and shown in Figure 4. 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 [6 mm]. Other dimensions shall be as specified in the Bend Test section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*.

13.2 After machining, but before testing, the specimen may be aged at 200°F to 220°F [90°C to 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 section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*, by bending it uniformly through 180° over a 3/4 in [19 mm] radius in any suitable jig, as specified in AWS B4.0 [AWS B4.0M]. 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 springback, 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, as specified in the Fracture Toughness Test section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*, shall be machined from the test assembly shown in Figure 2 or 5, for those classifications for which impact testing is required in Table 4. The Charpy V-notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in [0.05 mm]. The other two surfaces shall be square with the notched or struck surfaces within ±10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge within 1°.

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 50X magnification on either a shadowgraph or a metallograph. 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 section of AWS B4.0 [AWS B4.0M]. The test temperature shall be at or below that specified in Table 3 for the classification under test. The actual temperature used shall be listed on the certification documentation when issued.

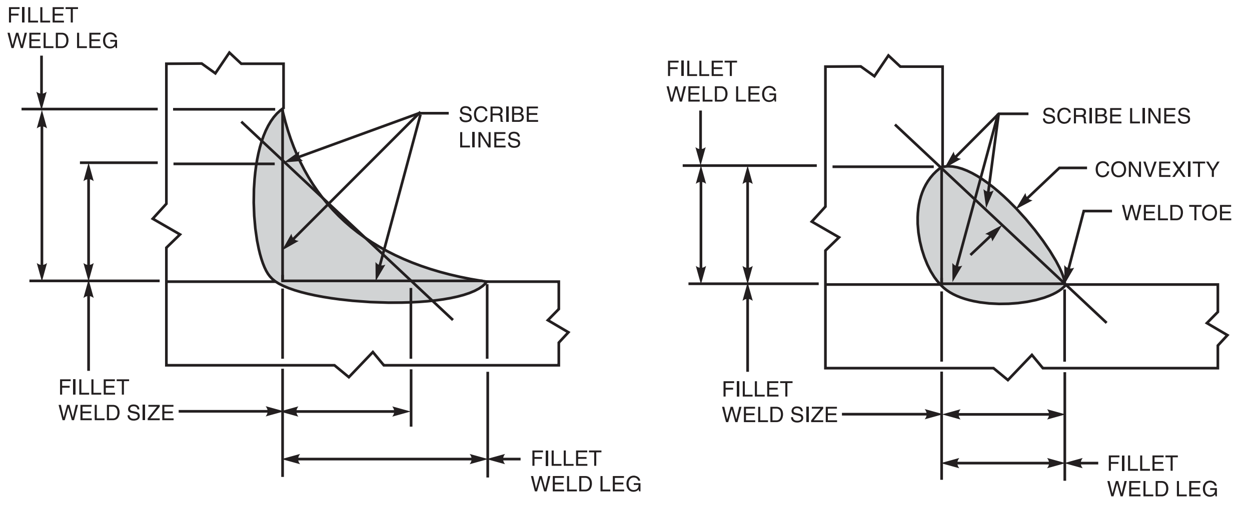
14.3 In evaluating the test results for all the classifications that require impact testing, except E7018M [E4918M], the lowest and highest values obtained shall be disregarded. Two of the three remaining values shall equal, or exceed, the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft·lbf [20 J], and the average of the three shall be not less than the required 20 ft·lbf [27 J] energy level.

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 5 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, 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. It shall be free of cracks, overlap, slag, and porosity, and shall be substantially free of undercut. An infrequent short undercut up to 1/32 in [0.8 mm] in depth shall be allowed. After the visual examination, a macro examination specimen, approximately 1 in [25 mm] in length, shall be removed as shown in Figure 3. One cross-sectional surface of the specimen shall be polished, etched, and then examined as required in 15.2.

15.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 8, and the fillet weld size, fillet weld leg, and convexity shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement—see Figure 8. These measurements shall meet the requirements of Table 6 with respect to minimum or maximum fillet weld size and the requirements of Table 9 with respect to maximum convexity and maximum difference between fillet weld legs according to the fillet weld size measured.



(A) CONCAVE FILLET WELD **(B) CONVEX FILLET WELD**

Notes:
1. Fillet weld size is the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section.
2. Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes.
3. Fillet weld leg is the distance from the joint root to the toe of the fillet weld.

Figure 8—Dimensions of Fillet Welds

Table 9
Dimensional Requirements for Fillet Weld Usability Test Specimens[a]

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in	mm	in	mm	in	mm
1/8	3.0	5/64	2.0	1/32	1.0
9/64	—	5/64	—	3/64	—
5/32	4.0	5/64	2.0	3/64	1.0
11/64	4.5	5/64	2.0	1/16	1.5
3/16	—	5/64	—	1/16	—
13/64	5.0	5/64	2.0	5/64	2.0
7/32	5.5	5/64	2.0	5/64	2.0
15/64	6.0	5/64	2.0	3/32	2.5
1/4	6.5	5/64	2.0	3/32	2.5
17/64	—	3/32	—	7/64	—
9/32	7.0	3/32	2.5	7/64	3.0
19/64	7.5	3/32	2.5	1/8	3.0
5/16	8.0	3/32	2.5	1/8	3.0
21/64	8.5	3/32	2.5	9/64	3.5
11/32	9.0	3/32	2.5	9/64	4.0
23/64	—	3/32	—	5/32	—
3/8 or more	9.5 or more	3/32	2.5	5/32	4.0

[a] All measurements shall be rounded to the nearest 1/64 in [0.5 mm].

15.3 The remaining two sections of the test assembly shall be broken through the fillet weld by a force exerted as shown in Figure 9. When necessary to facilitate fracture through the fillet, one or more of the following procedures may be used:

(1) A reinforcing bead, as shown in Figure 9A, may be added to each leg of the weld.

(2) The position of the web on the flange may be changed, as shown in Figure 9B.

(3) The face of the fillet may be notched, as shown in Figure 9C.

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

15.4 The fractured surfaces shall be visually examined without magnification. The fracture surface shall be free of cracks. Incomplete fusion at the weld root shall not be greater than 20% of the total length of the weld. There shall be no continuous length of incomplete fusion greater than 1 in [25 mm] as measured along the weld axis except for electrodes of the E6012 [E4312], E6013 [E4313], and E7014 [E4914] classifications. Fillet welds made with electrodes of these classifications may exhibit incomplete penetration through the entire length. They may also exhibit incomplete fusion which shall at no point exceed 25% of the smaller leg length of the fillet weld.

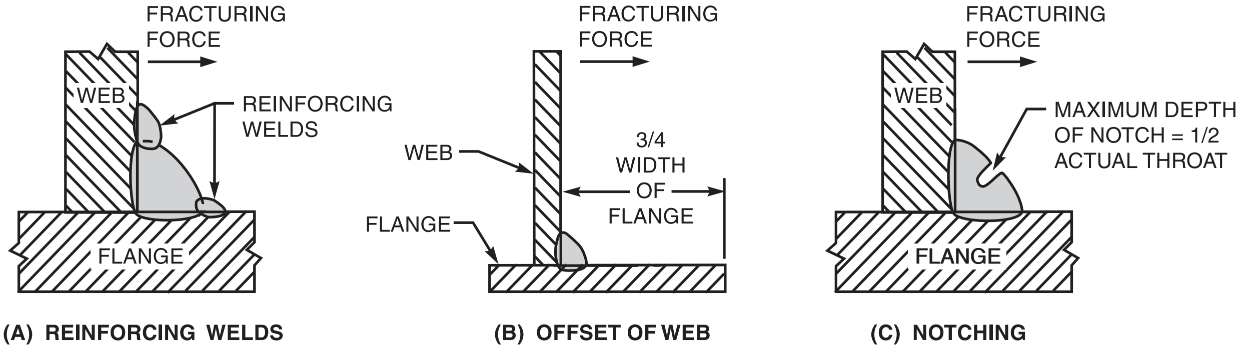
16. Moisture Test

16.1 The moisture content of the covering of the electrode, when required by Table 4, shall be determined by any suitable method. In case of dispute, the method described in AWS A4.4M, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*, shall be the referee method.

16.2 The electrodes shall be tested without conditioning, unless the manufacturer recommends otherwise. 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 test record. 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]/80% 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



(A) REINFORCING WELDS (B) OFFSET OF WEB (C) NOTCHING

Figure 9—Alternative Methods for Facilitating Fracture of the Fillet Weld

Table 10
Moisture Content Limits for Electrode Coverings

AWS Classification		Electrode Designation		Limit of Moisture Content, % by Wt, Max.	
A5.1	A5.1M	A5.1	A5.1M	As-Received or Conditioned[a]	As-Exposed[b]
E6018	E4318	E6018	E4318	0.6	Not Specified
E7015	E4915	E7015	E4915		
E7016	E4916	E7016	E4916		
		E7016-1	E4916-1		
E7018	E4918	E7018	E4918		
		E7018-1	E4918-1		
E7028	E4928	E7028	E4928		
E7048	E4948	E7048	E4948		
E6018	E4318	E6018R	E4318R	0.3	0.4
E7015	E4915	E7015R	E4915R		
E7016	E4916	E7016R	E4916R		
		E7016-1R	E4916-1R		
E7018	E4918	E7018R	E4918R		
		E7018-1R	E4918-1R		
E7028	E4928	E7028R	E4928R		
E7048	E4948	E7048R	E4948R		
E7018M	E4918M	E7018M	E4918M	0.1	0.4

[a] As-received or conditioned electrode coverings shall be tested as specified in Clause 16, Moisture Test.

[b] As-exposed electrode coverings shall have been exposed to a moist environment as specified in Clause 17 before being tested as specified in Clause 16.

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, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*, 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 test record. 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 nine hours minimum 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 within the envelope of air surrounding the covered electrode of 100 fpm to 325 fpm [0.5 m/s to 1.7 m/s].

(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 taken from previously unopened packages, or from a reconditioned lot, shall be heated to a temperature –0°, +10°F [6°C] above the dew point.

(2) The electrode sample shall be loaded into the chamber without delay after the packages are opened.

(3) The electrodes shall be placed in the chamber in a vertical or horizontal position on at least 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.

17.6 All of the critical variables which could affect test results have not been identified here. Consequently, the manufacturer shall control such other variables deemed relevant to ensure greater consistency of results.

18. Diffusible Hydrogen Test

18.1 The smallest and largest size of the electrode of each classification 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, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding.* Based upon the average value of test results which satisfy the requirements of Table 11, the appropriate diffusible hydrogen designator may be added at the end of the classification.

Table 11
Diffusible Hydrogen Limits for Weld Metal[a]

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

[a] Diffusible hydrogen testing in Clause 18, Diffusible Hydrogen Test, is required for E7018M [E4918M]. Diffusible hydrogen testing of other low hydrogen electrodes is only required when the optional diffusible hydrogen designator is added.

[b] Some low hydrogen classifications may not meet the H4 and H8 requirements.

18.2 Testing shall be done without conditioning of the electrode, unless the manufacturer recommends otherwise. 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 test record.

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 [1.43g/kg] of dry air at the time of welding.[7] 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 assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the actual test results for 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.

Part C
Manufacture, Identification, and Packaging

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

20.1 Standard sizes (diameter of the core wire) and lengths of electrodes are shown in Table 12.

20.2 The diameter of the core wire shall not vary more than ±0.002 in [0.05 mm] from the diameter specified. The length shall not vary more than ±1/4 in [10 mm] from that specified.

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[7] See A8.2 in Annex A.

Table 12
Standard Sizes and Lengths

Core Wire Diameter[a]		Lengths[a, b]	
A5.1 (in)	A5.1M[c] (mm)	A5.1 (in)	A5.1M (mm)
1/16	1.6	9	225
5/64	2.0	9 or 12	225 or 300
3/32	—	12 or 14	—
—	2.5	—	300 or 350
1/8	3.2	14	350
5/32	4.0	14 or 18	350 or 450
3/16	—	14 or 18	—
—	5.0	—	350 or 450
7/32	—	14 or 18 or 28	—
—	6.0	—	350 or 450 or 700
1/4	—	18 or 28	—
5/16	8.0	18 or 28	450 or 700

[a] Lengths and sizes other than these shall be as agreed between purchaser and supplier.
[b] In all cases, end-gripped electrodes are standard.
[c] ISO 544 *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances and markings*. See 20.2 for tolerances on diameter and length.

21. Core Wire and Covering

21.1 The core wire and covering shall be free of defects that would interfere with uniform deposition of the electrode.

21.2 The core wire and the 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 3/32 in [2.5 mm] and smaller;

(2) 5% of the mean dimension in sizes 1/8 in [3.2 mm] and 5/32 in [4.0 mm];

(3) 4% of the mean dimension in sizes 3/16 in [5.0 mm] and larger.

Concentricity may be measured by any suitable means.

22. Exposed Core

22.1 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 5/32 in [4.0 mm] and smaller sizes, and not less than 3/4 in [20 mm] nor more than 1-1/2 in [40 mm] for 3/16 in [5.0 mm] and larger sizes, to provide for electrical contact with the electrode holder.

22.2 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 [3.2 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 [6.0 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.

23. Electrode Identification

All electrodes shall be identified as follows:

23.1 At least one imprint of the electrode designation (classification plus any optional designators) shall be applied to the electrode covering in the order specified in Figure 10, 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.

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

23.3 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.

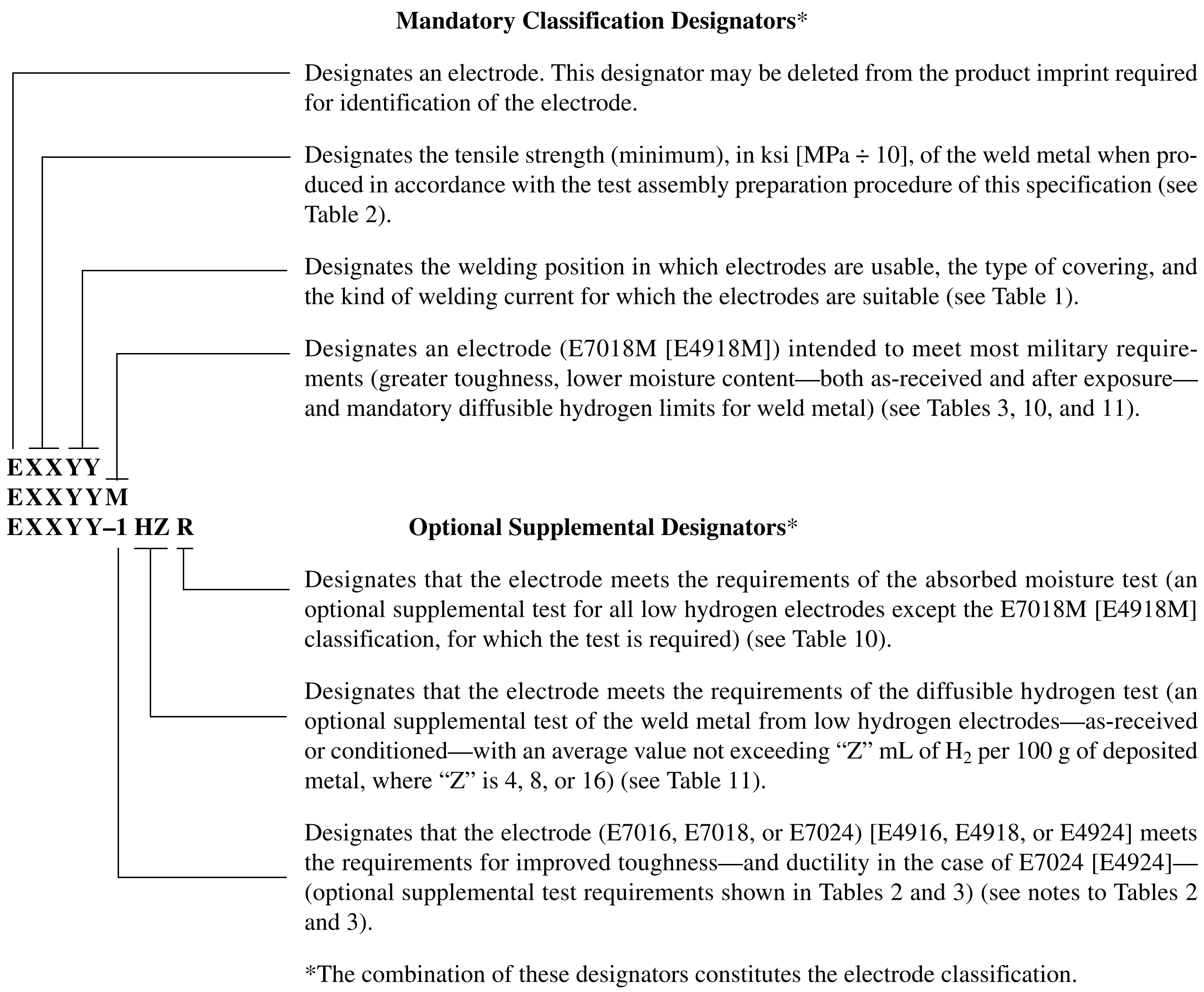
23.4 When an electrode is classified as meeting the requirements of A5.1 and A5.1M, both electrode designations shall be applied.

24. Packaging

24.1 Electrodes shall be suitably packaged to protect them from damage during shipment and storage under normal conditions. In addition, E7018M [E4918M] electrodes shall be packaged in hermetically sealed containers. These hermetically sealed containers shall be capable of passing the test specified in 24.3.

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

24.3 Hermetically sealed containers may be tested by selecting a representative sample container and immersing in water that is at a temperature of at least 50°F [30°C] above that of the packaged material (room temperature). The container shall be immersed so that the surface under observation is one inch [25 mm] below the water level 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 air bubbles emanating from the container. A container with a stream that lasts for 30 seconds or more does not meet the requirements of this specification.



Mandatory Classification Designators*

Designates an electrode. This designator may be deleted from the product imprint required for identification of the electrode.

Designates the tensile strength (minimum), in ksi [MPa ÷ 10], of the weld metal when produced in accordance with the test assembly preparation procedure of this specification (see Table 2).

Designates the welding position in which electrodes are usable, the type of covering, and the kind of welding current for which the electrodes are suitable (see Table 1).

Designates an electrode (E7018M [E4918M]) intended to meet most military requirements (greater toughness, lower moisture content—both as-received and after exposure—and mandatory diffusible hydrogen limits for weld metal) (see Tables 3, 10, and 11).

EXXYY
EXXYYM
EXXYY–1 HZ R

Optional Supplemental Designators*

Designates that the electrode meets the requirements of the absorbed moisture test (an optional supplemental test for all low hydrogen electrodes except the E7018M [E4918M] classification, for which the test is required) (see Table 10).

Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low hydrogen electrodes—as-received or conditioned—with an average value not exceeding “Z” mL of H_2 per 100 g of deposited metal, where “Z” is 4, 8, or 16) (see Table 11).

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 shown in Tables 2 and 3) (see notes to Tables 2 and 3).

*The combination of these designators constitutes the electrode classification.

Figure 10—Order of Mandatory and Optional Supplemental Designators

25. Marking of Packages

25.1 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.

25.2 The appropriate precautionary information[8] 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.

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[8] Typical examples of “warning labels” 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 Steel Electrodes for Shielded Metal Arc Welding

This annex is not part of AWS A5.1/A5.1M:2012, *Specification for Carbon 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 the specification can be used effectively. Appropriate base metal specifications are referred to whenever that can be done and when it would be most helpful. Such references are intended only as examples rather than complete listings of the base metals for which each electrode classification 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 first two digits, 60 [43], for example, designate tensile strength of at least 60 ksi [430 MPa] of the weld metal, produced in accordance with the test assembly preparation section of the specification. In this document, the classification in U.S. Customary Units is followed by the SI Unit classification in brackets. The third digit designates position usability that will allow satisfactory welds to be produced with the electrode.

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 Note b to Table 3). 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 e to Table 2).

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, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. 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, Absorbed Moisture Test, and Table 10).

A2.3 Table A.1 shows the classification for similar electrodes from Canadian Standards Association standard W48-01, *Filler Metals and Allied Materials for Metal Arc Welding*.

A2.4 Request for Filler Metal Classification

A2.4.1 When a welding electrode cannot be classified according to some classification given in this specification, the manufacturer may request that a classification be established for that welding electrode. The manufacturer may do this by following the procedure given in A2.4.3, below.

A2.4.2 A request to establish a new electrode 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, to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need.

A2.4.3 In particular, the request needs to include:

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

Table A.1
Canadian Electrode Classifications Similar to AWS Classifications

Canadian Electrode Classification[a]	A5.1	A5.1M
E4310	E6010	E4310
E4311	E6011	E4311
E4312	E6012	E4312
E4313	E6013	E4313
E4322	E6022	E4322
E4327	E6027	E4327
E4910	—	—
E4911	—	—
E4912	—	—
E4913	—	—
E4914	E7014	E4914
E4915	E7015	E4915
E4916	E7016	E4916
E4918[b]	E7018	E4918
E4922	—	—
E4924[c]	E7024	E4924
E4927	E7027	E4927
E4928	E7028	E4928
E4948	E7048	E4948

[a] From CSA Standard W48-01, *Filler Metals and Allied Materials for Metal Arc Welding*, published by Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3.

[b] Also includes E4918-1 designated electrode.

[c] Also includes E4924-1 designated electrodes.

(2) 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 the welding conditions are the same as for the other classifications.)

(3) Information on Descriptions and Intended Use, which parallels that for existing classifications, for that section of the annex.

(4) Proposed ASME "F" number, if appropriate.

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.

A2.4.4 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:

(1) Assign an identifying number to the request. The number shall include the date the request was received.

(2) Confirm receipt of the request, and give the identification number to the person making the request.

(3) Send a copy of the request to the Chair of the Committee on Filler Metals and Allied Materials, and the Chair of the particular Subcommittee involved.

(4) File the original request.

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

A2.4.5 All necessary action on each request shall be completed as soon as possible. If more than 12 months elapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and 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.

A2.4.6 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.

A2.5 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table A.2 shows those used in ISO 2560 for comparison with the classifications in this specification. To understand the proposed international designation system, one is referred to Table 1 and the annex of AWS document IFS:2002, entitled *International Index of Welding Filler Metal Classifications*. National specifications from many industrial countries having comparable filler metals are also found in Table 1 of IFS:2002.

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 A5.01. 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 the AWS A5.01. Testing in accordance with any other schedule in that table must be properly required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

A4. Certification

The act of placing the AWS Specification and Classification designations and optional supplemental designators, if applicable, on the packaging enclosing the product or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

Table A.2
Comparison of Equivalent Classifications[a]

ISO 2560[b]		USA AWS	
A	B	A5.1	A5.1M
E35xC21	E4310	E6010	E4310
E35xC11	E4311	E6011	E4311
E35xR12	E4312	E6012	E4312
E35xR12	E4313	E6013	E4313
—	E4318	E6018	E4318
E35xRA12	E4319	E6019	E4319
E35xA13	E4320	E6020	E4320
E35xA33	—	E6022	E4322
E35xRA54	E4327	E6027	E4327
E38xR32	E4914	E7014	E4914
E38xB22	E4915	E7015	E4915
E38xB12	E4916	E7016	E4916
—	E4916-1	E7016-1	E4916-1
E38xB32	E4918	E7018	E4918
—	E4918-1	E7018-1	E4918-1
—	—	E7018M	E4918M
E38xRR4	E4924	E7024	E4924
E38xRR4	E4924-1	E7024-1	E4924-1
E38xRA54	E4927	E7027	E4927
E38xB53	E4928	E7028	E4928
E38xB35	E4948	E7048	E4948

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

[b] ISO 2560, *Welding consumables — Covered electrodes for manual metal arc welding of nonalloy fine grain steels — Classification*.

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

A5. Ventilation During Welding

A5.1 The following 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 and welding operators to the fumes as they issue from the welding zone, and to the gases and dust 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 of that document entitled, "Health Protection and Ventilation."

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 which 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 (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 strengths remain relatively unchanged.

This specification permits aging of the test specimens at 200°F to 220°F [90°C to 105°C] for up to 48 hours before subjecting them to the all-weld-metal tension or transverse bend test. This is done to minimize discrepancies in testing (see also A8.2, Diffusible Hydrogen Test).

A6.4 When weldments are given a postweld heat treatment, the temperature and time at temperature are very important. The tensile and yield strengths generally are decreased as postweld heat treatment temperature 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 2, 3, and 7. 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 Table 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. This 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).

A6.10.3 Toughness. Charpy V-notch impact requirements are included in the specification. All classes 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 electrodes may have absorbed excessive moisture, they may be restored by rebaking. Some electrodes require rebaking at a temperature as high as 800°F [425°C] for approximately 1 hour 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 A.3.

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 them too much and adversely affect their operation (see Table A.3).

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

A6.13 Coverings

A6.13.1 Electrodes of some classifications have substantial quantities of iron powder added to their coverings. The iron powder fuses with the core wire and the other metals in the covering, as the electrode melts, and is deposited as part of the weld metal, just as is the core wire. 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 diameter 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 or 1/8 in [2.5 mm or 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 acknowledge the higher strength levels obtained with many of the iron powder and low-hydrogen electrodes, as well as to recognize the industry demand for

Table A.3
Typical Storage and Drying Conditions for Covered Arc Welding Electrodes

AWS Classification		Storage Conditions[a, b]		
A5.1	A5.1M	Ambient Air	Holding Ovens	Drying Conditions[c]
E6010, E6011	E4310, E4311	Ambient Temperature	Not recommended	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

[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.

electrodes with 70 ksi [490 MPa] minimum tensile strength. Unlike the E70XX-X [E49XX-X] classification in AWS A5.5, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*, these electrodes do not contain deliberate alloy additions, nor are they required to meet minimum 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.

A6.14 Amperage Ranges. Table A.4 gives amperage ranges which are satisfactory for most classifications. When welding vertically upward, currents near the lower limit of the range are generally used.

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.

Table A.4
Typical Amperage Ranges

Electrode Diameter		A5.1	E6010, E6011	E6012	E6013	E6019	E6020	E6022	E6027, E7027	E7014	E7015, E7016	E6018, E7018M, E7018	E7024, E7028	E7048
A5.1 (in)	A5.1M (mm)	A5.1M	E4310, E4311	E4312	E4313	E4319	E4320	E4322	E4327, E4927	E4914	E4915, E4916	E4318, E4918M, E4918	E4924, E4928	E4948
1/16	1.6		—	20 to 40	20 to 40	—	—	—	—	—	—	—	—	—
5/64	2.0		—	25 to 60	25 to 60	35 to 55	—	—	—	—	—	—	—	—
3/32[a]	2.4[a], 2.5[a]		40 to 80	35 to 85	45 to 90	50 to 90	—	—	—	80 to 125	65 to 110	70 to 110	100 to 145	—
1/8	3.2		75 to 125	80 to 140	80 to 130	80 to 140	100 to 150	110 to 160	125 to 185	110 to 160	100 to 150	105 to 155	140 to 190	80 to 140
5/32	4.0		110 to 170	110 to 190	105 to 180	130 to 190	130 to 190	140 to 190	160 to 240	150 to 210	140 to 200	130 to 200	180 to 250	150 to 220
3/16	5.0		140 to 215	140 to 240	150 to 230	190 to 250	175 to 250	170 to 400	210 to 300	200 to 275	180 to 255	200 to 275	230 to 305	210 to 270
7/32	5.6		170 to 250	200 to 320	210 to 300	240 to 310	225 to 310	370 to 520	250 to 350	260 to 340	240 to 320	260 to 340	275 to 365	—
1/4	6.0		210 to 320	250 to 400	250 to 350	310 to 360	275 to 375	—	300 to 420	330 to 415	300 to 390	315 to 400	335 to 430	—
5/16	8.0		275 to 425	300 to 500	320 to 430	360 to 410	340 to 450	—	375 to 475	390 to 500	375 to 475	375 to 470	400 to 525	—

[a] This diameter is not manufactured in the E7028 [E4828] classification.

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, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*, 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 (see also A8.2 in this annex).

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.3).

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 (see also A8.3 in this annex).

A7.6.5 E7015 [E4915] Classification

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 (see A6.13.4). 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 [4.0 mm], 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 of E7028 [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 has an average impact strength 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 position. 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.

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.

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 7). In other respects, all previous discussions for E6027 [E4327] electrodes also apply to E7027 [E4927] electrodes.

A8. Special Tests

A8.1 It is recognized that supplementary tests may be necessary to determine the suitability of these welding electrodes for applications involving properties not considered in this specification. In such cases, additional tests to determine specific properties, such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, wear resistance, and suitability for welding combinations of different carbon and low alloy steels, may need to be conducted.

A8.2 Diffusible Hydrogen Test

A8.2.1 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, nor 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.

A8.2.2 The coating moisture test has proven to be a satisfactory test over many years as a means of assessing the degree of care needed to avoid hydrogen-induced cracking. This is, however, an indirect test. Moisture itself does not cause cracking, but the diffusible hydrogen that forms from the moisture in the arc can cause cracking. Nor is moisture the only source of hydrogen.

A8.2.3 Since entry of diffusible hydrogen into the weld pool can be affected by the form of the moisture in the coating (for example, chemically bonded versus surface adsorbed), there is a fundamental utility for considering diffusible hydrogen for low-hydrogen electrodes. Accordingly, the use of optional designators for diffusible hydrogen is introduced to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.

A8.2.4 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

A8.2.5 The use of a reference atmospheric condition during welding is necessitated because the arc is imperfectly shielded. Moisture from the air, distinct from that in the covering, 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 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.

A8.2.6 The reference atmospheric condition during welding of the test assembly is 10 grains of water vapor per pound of dry air [1.43 g of water vapor per kg of dry air]. This corresponds to 70°F [21°C] and 10% RH on a standard psychrometric chart at 29.92 in [760 mm] Hg barometric pressure. Actual conditions, measured using a sling psychrometer, that equal or exceed this reference condition provide assurance that the conditions during welding will not diminish the final results of the test.

A8.3 Absorbed Moisture Test. The development of low-hydrogen electrode coverings that resist moisture absorption during exposure to humid air is a 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 this time.

A9. Discontinued Classifications

A number of electrode classifications have been discontinued during the numerous revisions of this specification, reflecting either changes in commercial practice, or changes in the scope of filler metals classified in the specification. These discontinued electrode classifications are listed in Table A.5, along with the year they were last published in this specification.

A10. General Safety Considerations

NOTE: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clause A5. Safety and health information is available from other sources, including, but not limited to, Safety and Health Fact Sheets listed in A10.2, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*,[9] and applicable federal and state regulations.

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[9] ANSI Z49.1 is published by the American Welding Society, 8669 Doral Blvd., Doral, FL 33166.

Table A.5
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.

A10.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.2 AWS Safety and Health Fact Sheets Index (SHF)[10]

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding & Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Arc Viewing Distance*
27	*Thoriated Tungsten Electrodes*
28	*Oxyfuel Safety: Check Valves and Flashback Arrestors*
29	*Grounding of Portable and Vehicle Mounted Welding Generators*
30	*Cylinders: Safe Storage, Handling, and Use*
31	*Eye and Face Protection for Welding and Cutting Operations*
33	*Personal Protective Equipment (PPE) for Welding & Cutting*
34	*Coated Steels: Welding and Cutting Safety Concerns*
36	*Ventilation for Welding & Cutting*
37	*Selecting Gloves for Welding & Cutting*

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[10] AWS standards are published by the American Welding Society, 8669 Doral Blvd., Doral, FL 33166.

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:2007. In case of dispute, the original AWS text applies.)

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:2007. In case of dispute, the original AWS text applies.)

1. Scope

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

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

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other withoutcombining 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.

2. Normative References

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

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

(1) AWS A5.01, *Filler Metal Procurement Guidelines*

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

2.3 The following ANSI standard[2] 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[3] are referenced in the normative clauses of this document:

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

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

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

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

(5) ASTM E 350, *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[4] is referenced in the normative clauses of this document:

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

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

[3] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[4] ISO standards are published by the International Organization for Standardization, 1 rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

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	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

NOTES:

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 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, classifications RMXX-G should be based on minimum tensile strength of all-weld tension test of the test assembly, expressed in multiples of 10 MPa. These designators shall be limited to 30, 40, 45, and 69.

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

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 for any other process for which they are found suitable.

4. Acceptance

Acceptance[5] of the welding rods 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.[6]

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

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi for tensile strength for A5.2, or 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 in accordance with the rounding-off method given in ASTM E 29.

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.

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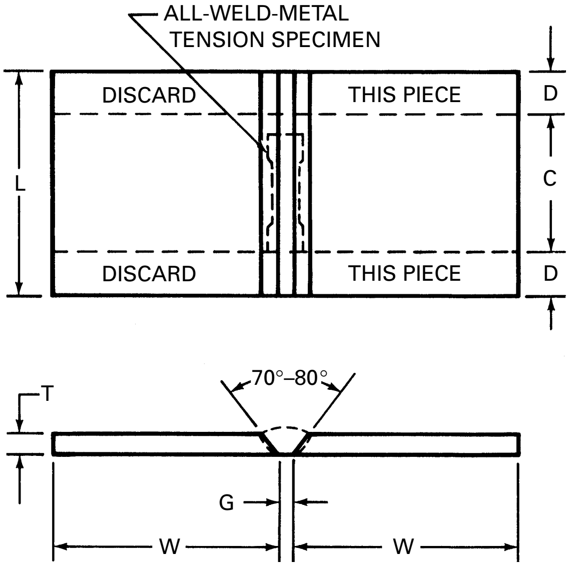
[5] See Annex Clause A3 for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

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

FIG. 1 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES



Dimension	in.	mm
L, min.	5	125
W, min.	5	125
T, nominal	$\frac{3}{8}$	10
D, min.	1	25
C, min.	$2\frac{1}{2}$	65
G	$\frac{1}{8}$ to $\frac{5}{32}$	3 to 4

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 Fig. 1.

9.2 Preparation of the weld test assembly shall be as specified in Fig. 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.

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 $\frac{3}{32}$ in. or $\frac{1}{8}$ in. [2.5 mm or 3.2 mm] diameter welding rod, and using a maximum of five layers. No layer shall exceed $\frac{1}{8}$ 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 $\frac{1}{8}$ in. [3 mm]. After the last pass has been completed, the assembly shall be allowed

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	A 36, A 285, grade C, or equivalent	K02600
R65	RM45	Carbon steel	A 36, A 285, grade C, or equivalent	K02600
R100	RM69	Low-alloy steel	Any grade of A 514, or equivalent	K11630
R(X)XX-G	RMXX-G	Material shall have a tensile and chemical composition similar to that of the rod being classified.		

NOTE:

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

TABLE 4
CHEMICAL COMPOSITION REQUIREMENTS FOR WELDING RODS AND ROD STOCK

AWS Classification		UNS Number[a]	Amount, Percent by Weight[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										

NOTES:

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).

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 (copper flashing, for example), 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 E 350.

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 Fig. 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.

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

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	±0.002	±0.05
	— (0.098)	2.5	±0.002	±0.05
	1/8 (0.125)	3.2	±0.002	±0.05
	5/32 (0.156)	4.0	±0.002	±0.05
	3/16 (0.188)	4.8[c]	±0.002	±0.05
	— (0.197)	5.0	±0.002	±0.05
	— (0.236)	6.0	±0.002	±0.05
	1/4 (0.250)	6.4[c]	±0.002	±0.05

NOTES:

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.

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.

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[7] 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.

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[7] Typical examples of "warning labels" 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 AWS A5.2/A5.2M:2007, *Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding*, 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 (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal — one that otherwise would have to await a revision of the specification — to be classified immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some certain respect (chemical composition, again, for example).

A2.3.2 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 A5.01, *Filler Metal Procurement Guidelines*) in the purchase order.

A2.4 Request for Filler Metal Classification

(1) When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this

by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

(2) A request to establish a new filler metal classification must be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

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

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

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

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

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

(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 the Chair of the particular Subcommittee involved.

(d) file the original request.

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

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

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, needs to 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 the supplier normally conducts 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 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 A5.01, *Filler Metal Procurement Guidelines.*

A5. Ventilation During Welding

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

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

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

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

(4) the proximity of 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 clause on Ventilation in that document.

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 $\frac{1}{8}$ to $\frac{1}{4}$ 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 A5.01, *Filler Metal Procurement Guidelines*, 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 A1, 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

TABLE A1
DISCONTINUED CLASSIFICATIONS

AWS Classifications	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

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, *Safety in Welding, Cutting, and Allied Processes*; and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[8]

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

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[8] AWS standards are published by the American Welding Society, 550 NW LeJeune Road, Miami, FL 33126.

SPECIFICATION FOR ALUMINUM AND ALUMINUM-ALLOY ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.3/SFA-5.3M

(Identical with AWS Specification A5.3/A5.3M:1999 (R2007). In case of dispute, the original AWS text applies.)

SPECIFICATION FOR ALUMINUM AND ALUMINUM-ALLOY ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.3/SFA-5.3M

[Identical with AWS Specification A5.3/A5.3M:1999 (R2007). In case of dispute, the original AWS text applies.]

1. Scope

This specification prescribes requirements for the classification of aluminum and aluminum-alloy electrodes for shielded metal arc welding.

PART A — GENERAL REQUIREMENTS

2. Normative References

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

(a) ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

(b) ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

2.2 The following ASTM standards[2] are referenced in the mandatory sections of this document:

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

(b) ASTM E 34, *Standard Methods for Chemical Analysis of Aluminum and Aluminum Alloys*.

(c) ASTM B 209, *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate*.

2.3 The following ISO standard[3] is referenced in the mandatory sections of this document:

(a) ISO 544, *Filler Materials for Manual Welding — Size Requirements*.

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

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.[5]

6. Units of Measure and Rounding-Off Procedure

6.1 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

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[1] AWS Standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[2] ASTM Standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[3] ISO Standards can be obtained from the American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.

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

[5] See Section A4, Certification (in Annex) for further information concerning certification and the testing called for to meet this requirement.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR CORE WIRE

AWS Classification[f]	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	—	0.0008	0.05	0.15	99.00 min[e]
E3003	A93003	0.6	0.7	0.05–0.20	1.0–1.5	—	0.10	—	0.0008	0.05	0.15	Remainder
E4043	A94043	4.5–6.0	0.8	0.30	0.05	0.05	0.10	0.20	0.0008	0.05	0.15	Remainder

NOTES:

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/ASTM Unified Numbering System for Metals and Alloys.

d. Silicon plus iron shall not exceed 0.95 percent.

e. The aluminum content for unalloyed aluminum is the difference between 100.00 percent and the sum of all other metallic elements present in amounts of 0.010 percent or more each, expressed to the second decimal before determining the sum.

f. Refer to Table A1 for Proposed ISO Designations.

TABLE 2
REQUIRED TESTS

AWS Classification	Electrode Size		Chemical Analysis[a]	Tension Test[b]	Bend Test[c]
	in.	mm			
E1100, E3003, and E4043	$\frac{3}{32}$	2.4	Required	Not Required[d]	Not Required[d]
	. . .	2.5	Required	Not Required[d]	Not Required[d]
	$\frac{1}{8}$	3.2	Required	Not Required[d]	Not Required[d]
	$\frac{5}{32}$	4.0	Required	Required[e]	Required[e]
	$\frac{3}{16}$	4.8	Required	Not Required[d]	Not Required[d]
		5.0	Required	Not Required[d]	Not Required[d]
	. . .	6.0	Required	Required[f]	Required[f]
	$\frac{1}{4}$	6.4	Required	Required[f]	Required[f]
	$\frac{5}{16}$	8.0	Required	Not Required[d]	Not Required[d]
	$\frac{3}{8}$	9.5	Required	Not Required[d]	Not Required[d]

NOTES:

a. Chemical analysis of the core wire or the stock from which it is made.

b. See Section 11.

c. See Section 12.

d. 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.

e. Electrodes $\frac{5}{32}$ in. (4.0 mm) and smaller shall be classified on the basis of the results obtained with the $\frac{5}{32}$ in. (4.0 mm) size of the same classification.

f. Electrodes $\frac{3}{16}$ in. (4.8 mm) and larger shall be classified on the basis of the results obtained with the $\frac{1}{4}$ in. (6.4 mm) size of the same classification.

combining in any way. The specification with the designation A5.3 uses U.S. Customary Units. The specification A5.3M uses SI Units. The latter are shown in appropriate columns in tables or within brackets [ ] when used in the text.

6.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] for tensile strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E 29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

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 Sections 9 through 12.

8. Retest

8.1 If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both tests 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, retest need be only for those specific elements that failed to meet the test requirement.

8.2 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.

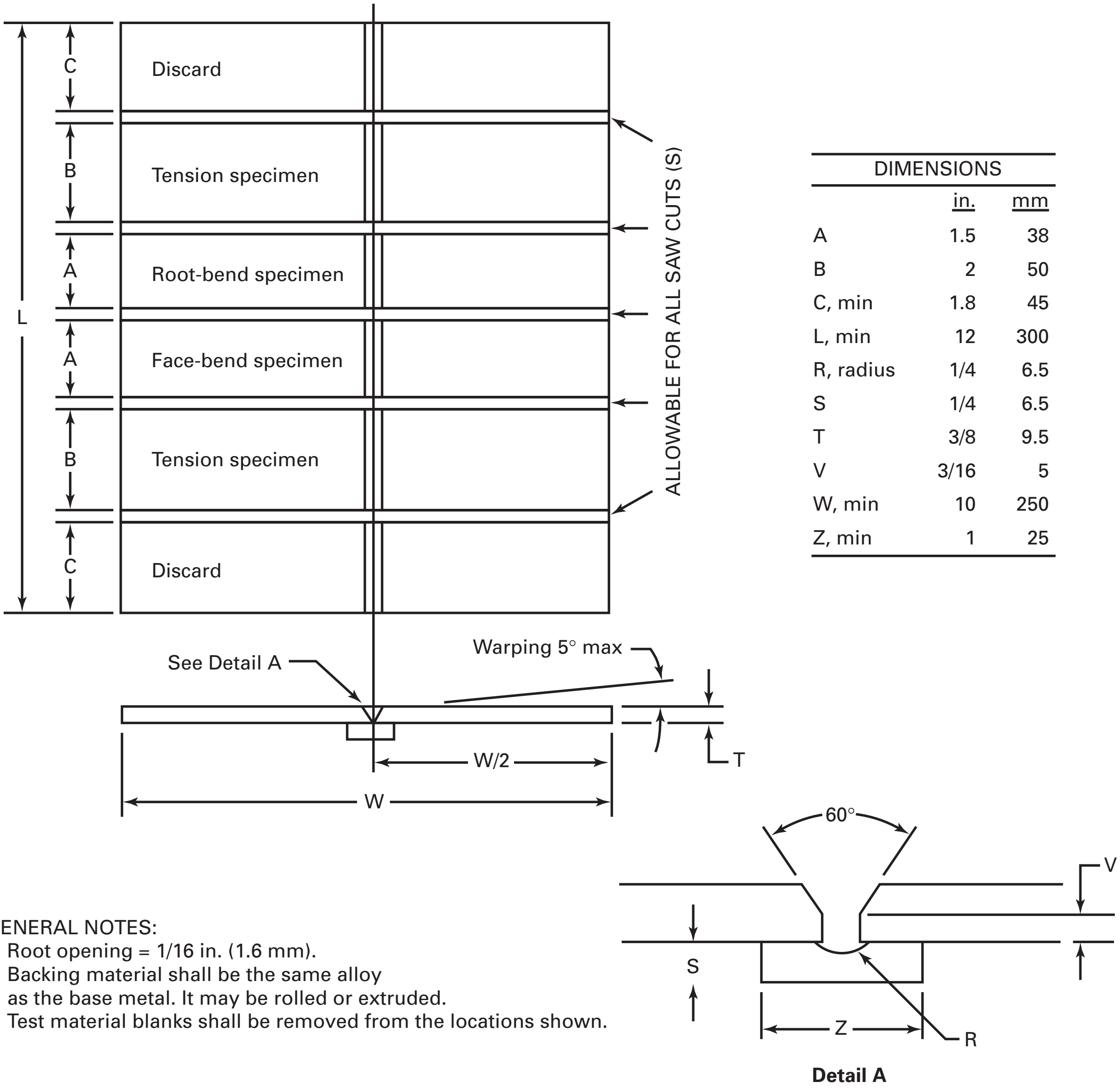
8.3 In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the weld test assembly or test specimens or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed, or whether the test results met, or failed to meet, the requirement. That test shall be repeated, following the proper prescribed 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 Fig. 1 for mechanical properties.

9.2 Preparation of the weld test assembly shall be as prescribed in 9.3, Fig. 1, and Table 2 [Notes (5) and (6)] using base metal of the appropriate type specified in Table 3. Testing of the assembly shall be as specified in

FIG. 1 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES



DIMENSIONS	in.	mm
A	1.5	38
B	2	50
C, min	1.8	45
L, min	12	300
R, radius	1/4	6.5
S	1/4	6.5
T	3/8	9.5
V	3/16	5
W, min	10	250
Z, min	1	25

GENERAL NOTES:
1. Root opening = 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.

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

NOTES:

a. Aluminum Association, Inc. registration numbers.

b. When welding 3003 with E4043 electrodes, 3003-0 (annealed temper) plate is preferred.

TABLE 4
TENSION TEST REQUIREMENTS

AWS Classification	Tensile Strength, Min.[a]	
	psi	MPa
E1100	12 000	80
E3003	14 000	95
E4043	14 000	95

NOTE:
a. Fracture may occur in either the base metal or the weld metal.

Sections 11, Tension Test, and 12, Bend Test. The assembly shall be tested in the as-welded condition.

9.3 The test assembly shall be preheated to a temperature between 350°F and 400°F [175°C and 200°C], and shielded metal arc (SMA) welded from one side, in the flat position. The test assembly should be precambered or restrained so that warping due to welding will not cause the finished test assembly to be out-of-plane by more than 5 degrees. If the completed test assembly is more than 5 degrees out-of-plane it shall be straightened at room temperature.

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. The referee method shall be ASTM E 34, *Standard Methods for Chemical Analysis of Aluminum and Aluminum Alloys*.

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 Section 9, Weld Test Assembly, and shown in Fig. 1. The dimensions of the specimens shall be as specified in the tension test section of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. 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 section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

11.3 The results of the tension test shall meet the requirements specified in Table 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 Section 9 and shown in Fig. 1. 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).

12.2 The specimens shall be tested in the manner described in the guided bend test section of ANSI/AWS B4.0 by bending them uniformly through 180 degrees over a 1-$^1/_4$ in. [32 mm] radius in any suitable jig. Typical bend test jigs as shown in bend test section of AWS B4.0 shall be used. 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.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

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 are shown in Table 5. Other sizes and lengths meet the requirements of this specification when agreed by the purchaser and supplier.

14.2 The diameter of the core wire shall not vary more than ±0.002 in. [±0.05 mm] from the diameter specified. The length shall not vary more than ±$^1/_4$ in. [±6 mm] from that specified.

15. Core Wire and Covering

15.1 The core wire and covering shall be free of defects that would interfere with uniform deposition of the electrode.

TABLE 5
STANDARD SIZES

AWS Classification	Diameter of Core Wire		Standard Lengths	
	in.	mm	in.	mm
E1100, E3003, and E4043	3/32 (0.094)	2.4[a]	14	350
	(0.098)	2.5		
	1/8 (0.125)	3.2		
	5/32 (0.156)	4.0		
	3/16 (0.188)	4.8[a]		
	(0.197)	5.0		
	(0.236)	6.0		
	1/4 (0.250)	6.4[a]		
	5/16 (0.312)	8.0	18	450
	3/8 (0.375)	9.5[a]		

NOTE:
a. These sizes are not included in ISO 544.

15.2 The core wire and the 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 the following:

(a) Seven percent of the mean dimension in sizes 3/32 in. [2.4 and 2.5 mm]

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

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

Concentricity may be measured by any suitable means.

15.3 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 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.

16.2 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% of the circumference of the core.

17. Electrode Identification

All electrodes shall be identified as follows:

17.1 At least one imprint of the electrode classification shall be applied to the electrode covering within 2-1/2 in. [65 mm] of the grip end of the electrode.

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

17.3 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.

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

17.5 In lieu of imprinting, electrodes may be identified by the following:

(a) Attaching to the bare grip end of each electrode a pressure sensitive tape bearing the classification number

(b) 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.

18. Packaging

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

18.2 Standard package net weights shall be 1 lb [0.5 kg], 5 lb [2.5 kg], and 10 lb [5 kg]. Other package weights meet the requirements of this specification when agreed by the purchaser and supplier.

19. Marking of Packages

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

(a) AWS specification and classification designations (year of issue may be excluded)

(b) Supplier's name and trade designation

(c) Size and net weight

(d) Lot, control, or heat number

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

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be hazardous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can KILL.

- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and *OSHA Safety and Health Standards*, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Phone: (202) 512-1800.

DO NOT REMOVE THIS INFORMATION

Annex
Guide to AWS Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding

[This Annex is not a part of AWS A5.3/A5.3M:1999 (R2007), *Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*, but is included for information 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. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable.

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 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 An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for aluminum filler metals. In that system the initial "E" designates a covered electrode, the letter "A" the alloy system, followed by a four-digit number. For wrought aluminum alloys, the four-digit number is the same as that commonly recognized worldwide.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this Specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing normally is performed on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. Testing in accordance with any other Schedule in that Table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall 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 ANSI/AWS 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:

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

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

TABLE A1
DESIGNATION REFERENCE GUIDE

AWS Composition Designation[a]	UNS Number	Proposed ISO Designation[b]	AWS Classification Number[c]
1100	A91100	EA1100	E1100
3003	A93003	EA3003	E3003
4043	A94043	EA4043	E4043

NOTES:

a. AWS chemical composition designation is that of the core wire and is the same as the Aluminum Association designation number.

b. The proposed ISO designation number (IIW doc. XII-1232-91) contains the last four digits of the UNS number for wrought alloys, preceded by "EA," "E" to signify a covered electrode and "A" to signify an aluminum base alloy.

c. The AWS classification number is the AWS chemical composition designation preceded by an "E" to signify an electrode which carries the electrical current.

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

(d) The proximity of the welders or welding operators 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

(e) 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 of that document on Health Protection and Ventilation.

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. When shielded metal arc welding, a flux-covered electrode is held in the standard electrode holder, and welding is done with direct current, electrode positive (DCEP). 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° to 400°F [175° to 200°C] for an hour before welding. After conditioning, they should be stored in a heated cabinet at 150° to 200°F [65° 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-degree included angle. On very thick material, U-grooves may be used. Depending upon base metal gauge, root-face thicknesses range between $^1/_{16}$ and $^1/_4$ in. [1.6 and 6.4 mm]. A root opening of $^1/_{32}$ to $^1/_{16}$ in. [0.8 to 1.6 mm] is desirable for all groove welds.

A6.4 Because of the high thermal conductivity of aluminum, preheating to 250° to 400°F [120° 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 SMA 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 five-percent 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

7.1 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 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 The E4043 classification contains approximately five-percent 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-percent 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.

A9. Chemical Analysis

The accepted and most widely used method for chemical analysis is found in ASTM E 227, *Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloy by the Point-to-Plane Technique*. This method analyzes a bulk sample and all elements simultaneously. The ASTM E 34, *Test Method for Chemical Analysis of Aluminum and Aluminum Alloy*, prescribes individual test methods for which each element is tested. The ASTM E 34 test methods are used as a referee method if a dispute arises concerning a specific element analysis.

A10. General Safety Considerations

A10.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn. Goggles or equivalent should also be worn to protect eyes. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used.

Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot work pieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load. Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. *(Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.)*

The following sources are for more detailed information on personal protection:

(a) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(b) *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Part 1910, OSHA General Industry Standards available from the U.S. Government Printing Office, Washington, DC 20402.

(c) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002.

(d) ANSI Z41, *American National Standard for Personal Protection — Protective Footwear*, American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002.

A10.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating-current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

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

A10.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management, personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal and base metal, welding process, flux, current level, arc length, and other factors. Fluxes, used for oxyfuel gas welding of aluminum alloys, are composed primarily of chlorides plus small fluoride additions. The coatings used in covered electrodes of the types shown in this specification A5.3/A5.3M contain both chlorides and fluorides.

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

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

All aluminum electrodes possess a compositional control of 0.0008 percent maximum beryllium content. This provides a check by the manufacturer that the filler metal is essentially free of this element and thus avoids the presence of concentrations of this highly toxic metallic particulate during the filler metal transfer across the arc. Since the electrode core wire is fabricated as drawn, wrought aluminum wire, the same beryllium control has been applied to all filler metals covered by this ANSI/AWS A5.3/A5.3M specification. Thus all electrodes possess a 0.0008 percent beryllium maximum limit.

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

(a) The permissible exposure limits required by OSHA can be found in CFR Title 29, Chapter XVII Part 1910. The OSHA *General Industry Standards* are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

(b) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1643.

(c) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*, available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

A10.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

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

A10.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A10.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser beam welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(a) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Education Eye and Face Protection*, published by American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(b) Exposed skin should be protected with adequate gloves and clothing as specified in ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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

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

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

A10.4.3 Ionizing radiation information sources include:

(a) AWS F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(b) Manufacturer's product information literature.

A10.4.4 Nonionizing radiation information sources include:

(a) Hinrichs, J.F., Project Committee on Radiation-Summary Report. *Welding Journal*, January 1978.

(b) Nonionizing Radiation Protection Special Study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*, available from the National Technical Information Service, Springfield, VA 22161, ADA-033768.

(c) Nonionizing Radiation Protection Special Study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electric Welding and Cutting Arcs*, available from the National Technical Information Service, Springfield, VA 22161, ADA-043023.

(d) Moss, C. E., and Murray, W. E. "Optical Radiation Levels Produced in Gas Welding, Torch Brazing, and Oxygen Cutting." *Welding Journal*, September 1979.

(e) "Optical Radiation Levels Produced by Air-Carbon Arc Cutting Processes." *Welding Journal*, March 1980.

(f) ANSI/ASC Z136.1, *Safe Use of Lasers*, published by American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002.

(g) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(h) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002.

(i) Moss, C. E. "Optical Radiation Transmission Levels through Transparent Welding Curtains." *Welding Journal*, March 1979.

SPECIFICATION FOR STAINLESS STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

(**15**)

SFA-5.4/SFA-5.4M

(Identical with AWS Specification A5.4/A5.4M:2012. 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*

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[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., Suite130, Doral, FL 33166.

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*

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.

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[4] ANSI Z49.1 is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

[5] ASTM standards are published by the American Society for Testing and Materials, 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).

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	

(Continued)

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.

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]

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.

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[8] See A4, Certification (in Annex A) for further information concerning certification and the tests called for to meet this requirement.

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.

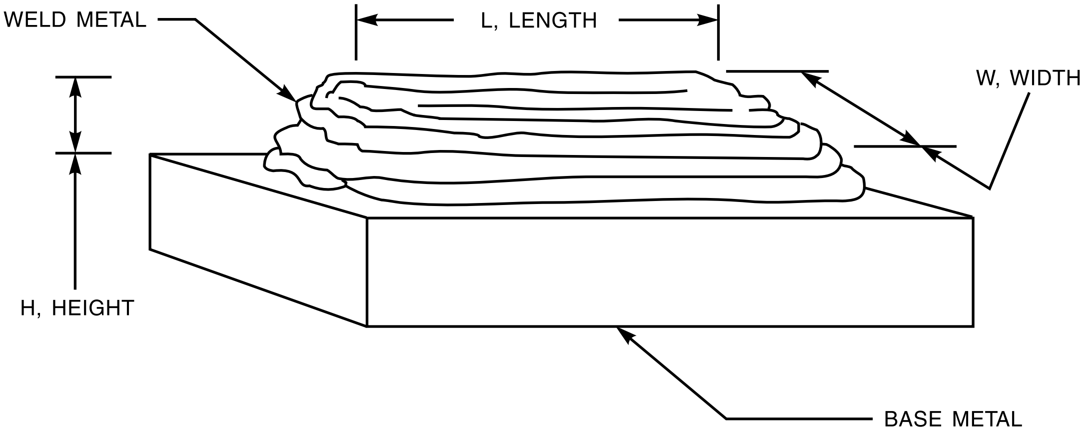
Table 4
Tests Required For Classification

	Electrode Diameter			Position of Welding[a]			
Classification	in	mm	Type of Current[b, c]	Chemical Analysis	Radiographic Test	All Weld Metal Tension Test	Fillet Weld Test
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.



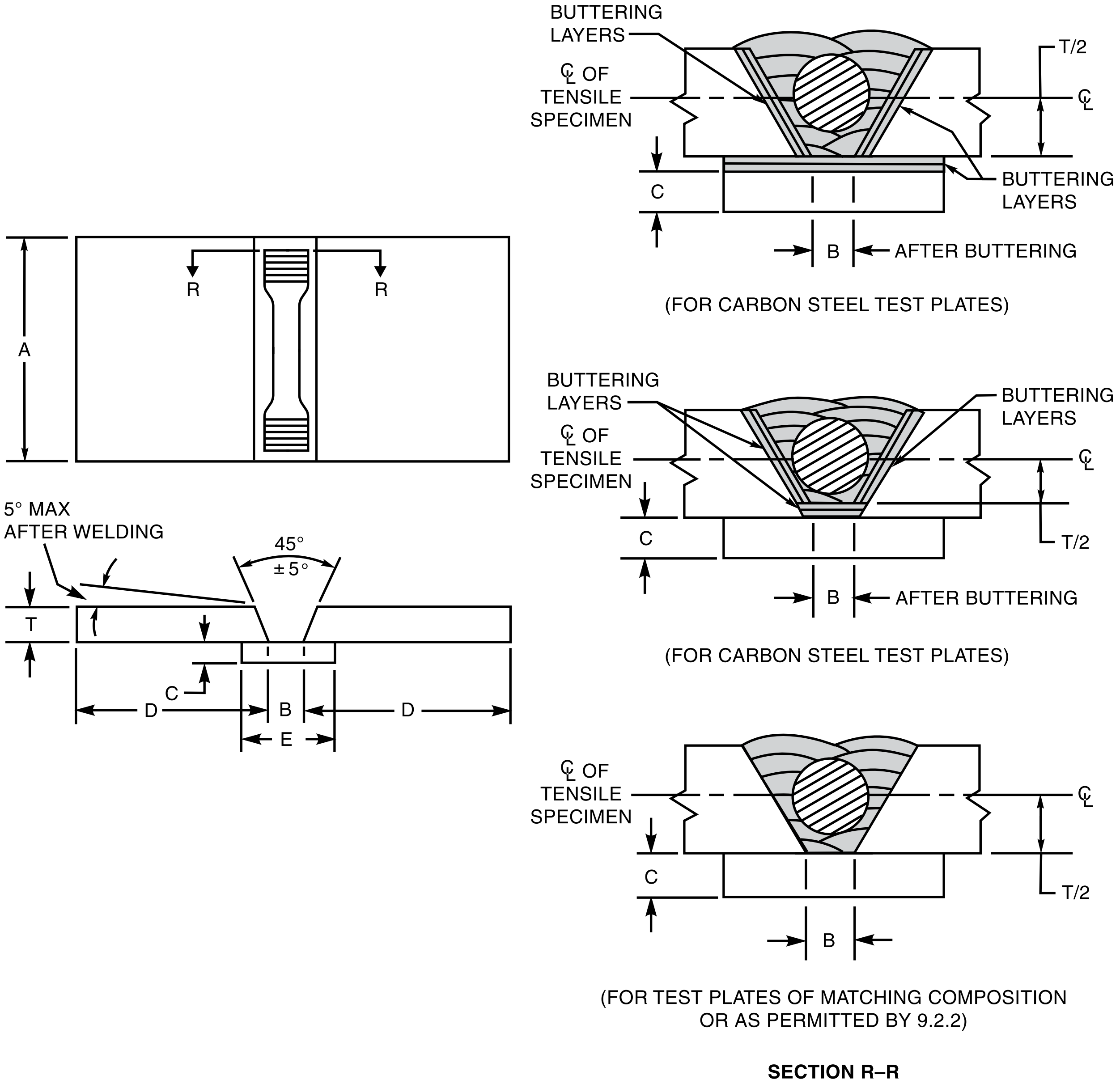
Electrode Size		Weld Pad Size, minimum						Minimum Distance of Sample from Surface of Base Plate	
		L		W		H			
in	mm	in	mm	in	mm	in	mm	in	mm
1/16 5/64 3/32 —	1.6 2.0 2.4 2.5	1-1/2	38	1/2	13	1/2	13	3/8	10
1/8 5/32 3/16 —	3.2 4.0 4.8 5.0	2	50	1/2	13	5/8	16	1/2	13
7/32 — 1/4	5.6 6.0 6.4	2-1/2	64	1/2	13	3/4	19	5/8	16

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal

9.2.3 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°F [15°C] 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.



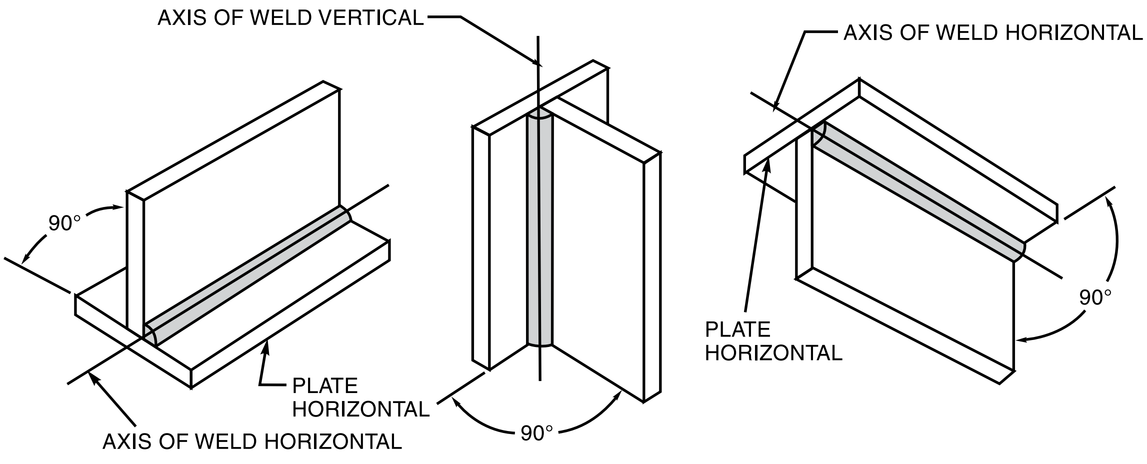
Electrode Diameter		Dimensions of Test Assembly					
		T[a]	A, min.[b]	B[c]	C, min.	D, min.	E, min.
in	1/8	1/2	3-1/2	1/4	3/16	3-1/2	1
mm	3.2	12	90	6.5	5	90	25
in	5/32 to 1/4 incl.	3/4	5-1/2	1/2	1/4	3-1/2	1
mm	4.0 to 6.4 incl.	20	140	12	6.5	90	25

[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.

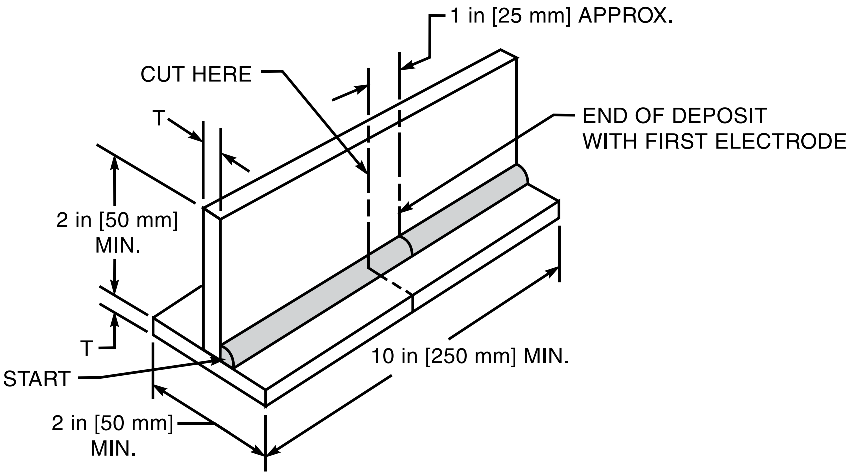
[c] Tolerance shall be +1/8 in [3 mm], –0.

Figure 2—Groove Weld Assembly for Tension and Radiographic Tests for Electrodes 1/8 in [3.2 mm] Diameter and Larger



(a) HORIZONTAL FILLET WELDS (b) VERTICAL FILLET WELDS (c) OVERHEAD FILLET WELDS

(A) POSITIONS OF TEST PLATES FOR WELDING FILLET-WELD TEST SPECIMENS



(B) PREPARATION OF FILLET-WELD TEST ASSEMBLY

Electrode Diameter		Plate Thickness, T			Maximum Fillet Size	
in	mm	in	mm	Position of Welding	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

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.

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.

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.

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

Table 6
All-Weld-Metal Mechanical Property Requirements

AWS Classification	Tensile Strength, min ksi	 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

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[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.

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 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.

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[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.

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.

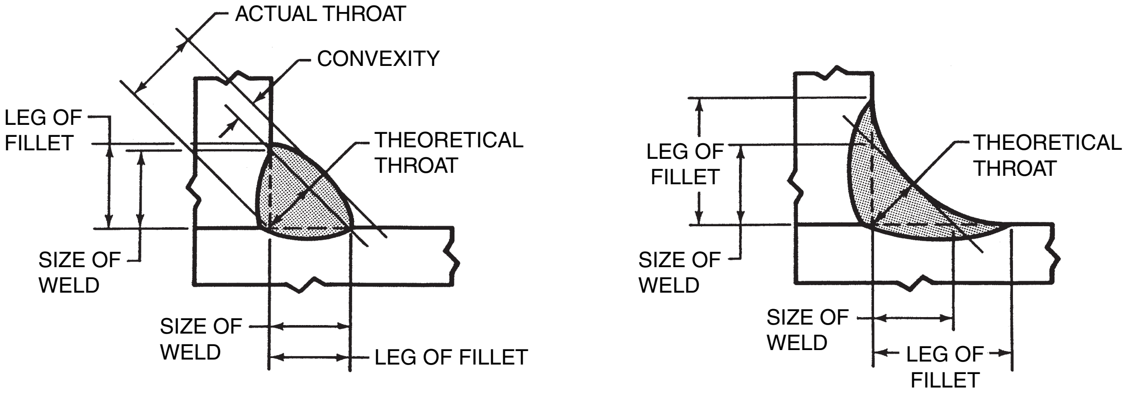
16. Core Wire and Covering

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.



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.

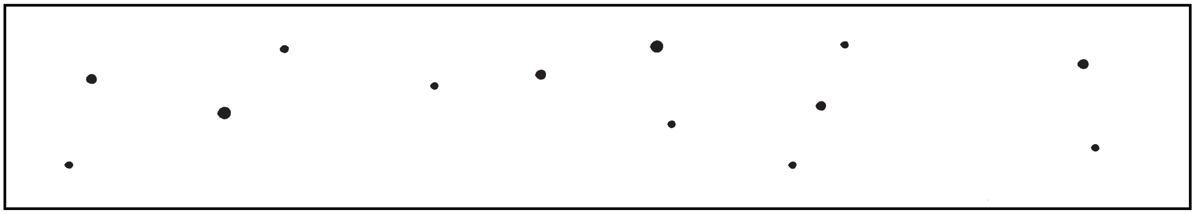
[b] Fillet weld size, convexity, and leg lengths of fillet welds shall be determined by actual measurement (nearest 1/64 in [0.5 mm]) on a section laid out with scribed lines shown.

Figure 4—Fillet Weld Test Specimen

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.

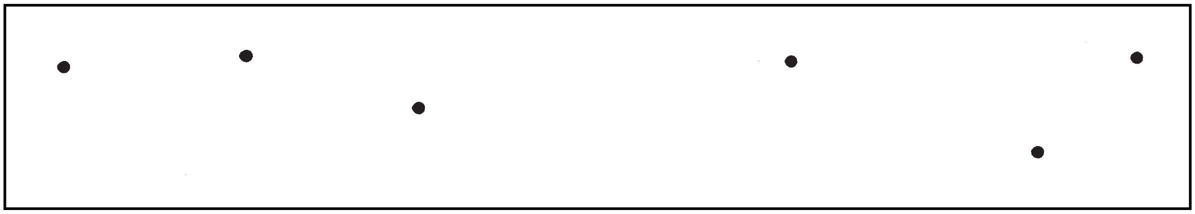
17.2 The arc end of each electrode shall be sufficiently bare and the covering sufficiently tapered to permit easy striking of the arc. The length of the bare portion (measured from the end of the core wire to the location where the full cross section of the covering is obtained) shall not exceed 1/8 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.



(A) ASSORTED ROUNDED INDICATIONS

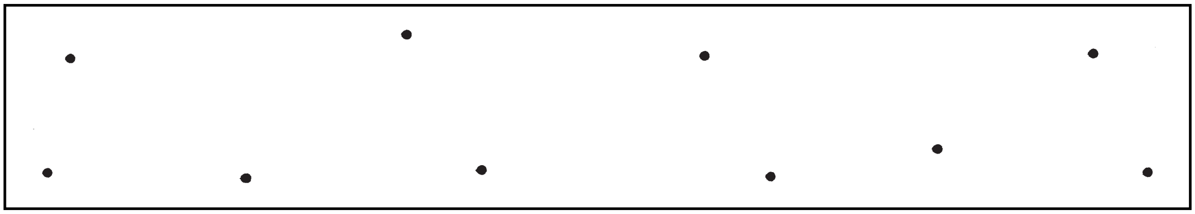
SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 13 WITH THE FOLLOWING RESTRICTIONS:

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.



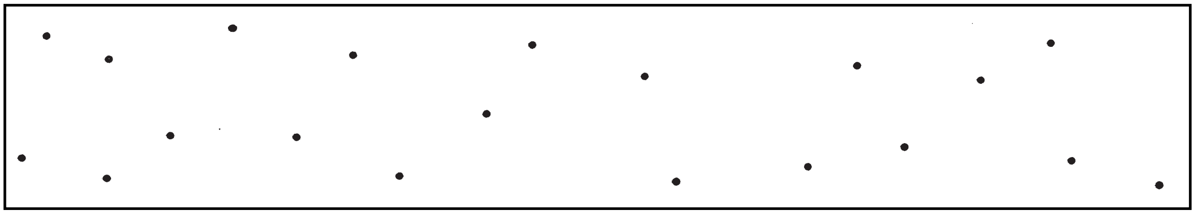
(B) LARGE ROUNDED INDICATIONS

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.



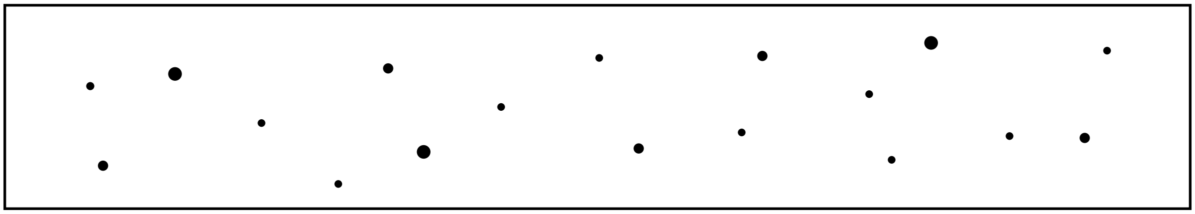
(D) SMALL ROUNDED INDICATIONS

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.

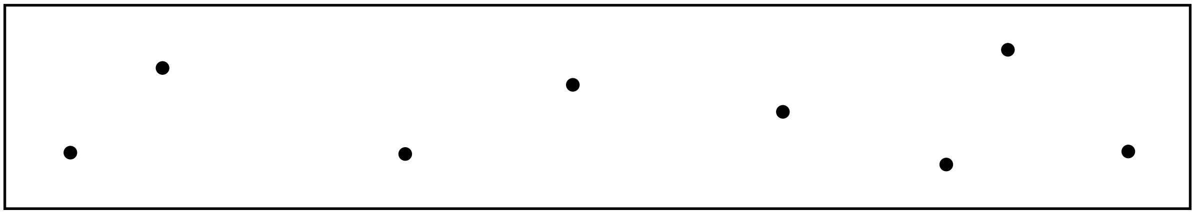
Figure 5A—Rounded Indication Standards for Radiograph Test—1/2 in [12 mm] Plate



(A) ASSORTED ROUNDED INDICATIONS

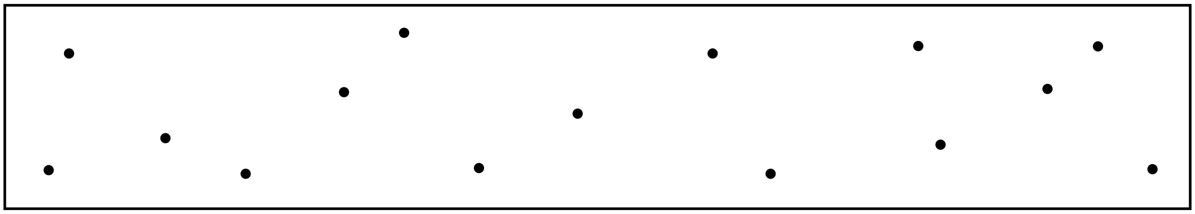
SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 18 WITH THE FOLLOWING RESTRICTIONS:

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



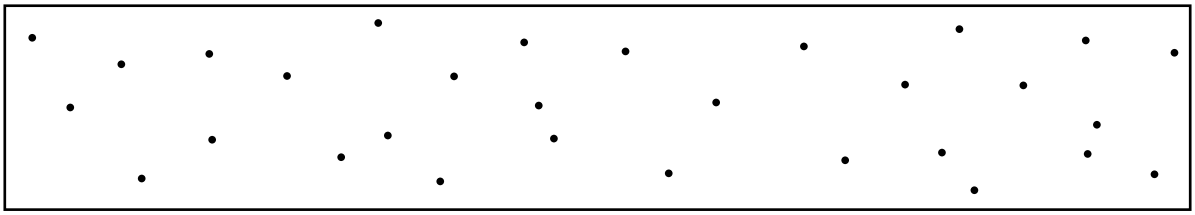
(B) LARGE ROUNDED INDICATIONS

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.

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.

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.

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.

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[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.

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[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.

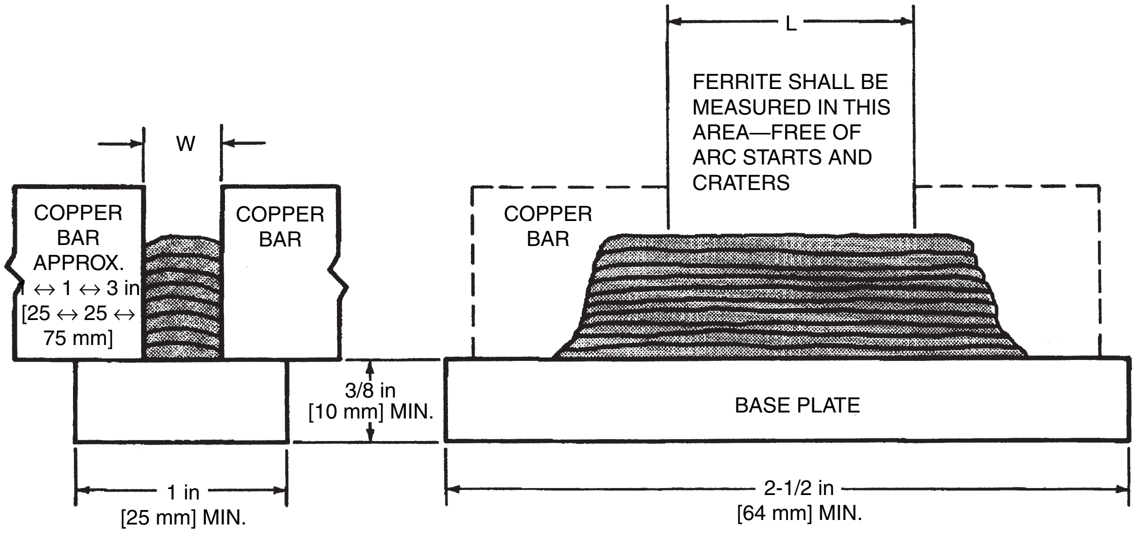
A6.9 When it is desired to measure ferrite content, the following procedure is recommended to minimize variation in measured ferrite content and avoid false low or false high values.

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°F [95°C]. Between passes, the weld pad may be cooled by quenching in water not sooner than 20 seconds after the completion of each pass. The last pass should be air cooled to below 800°F [430°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].



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

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 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.

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[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.

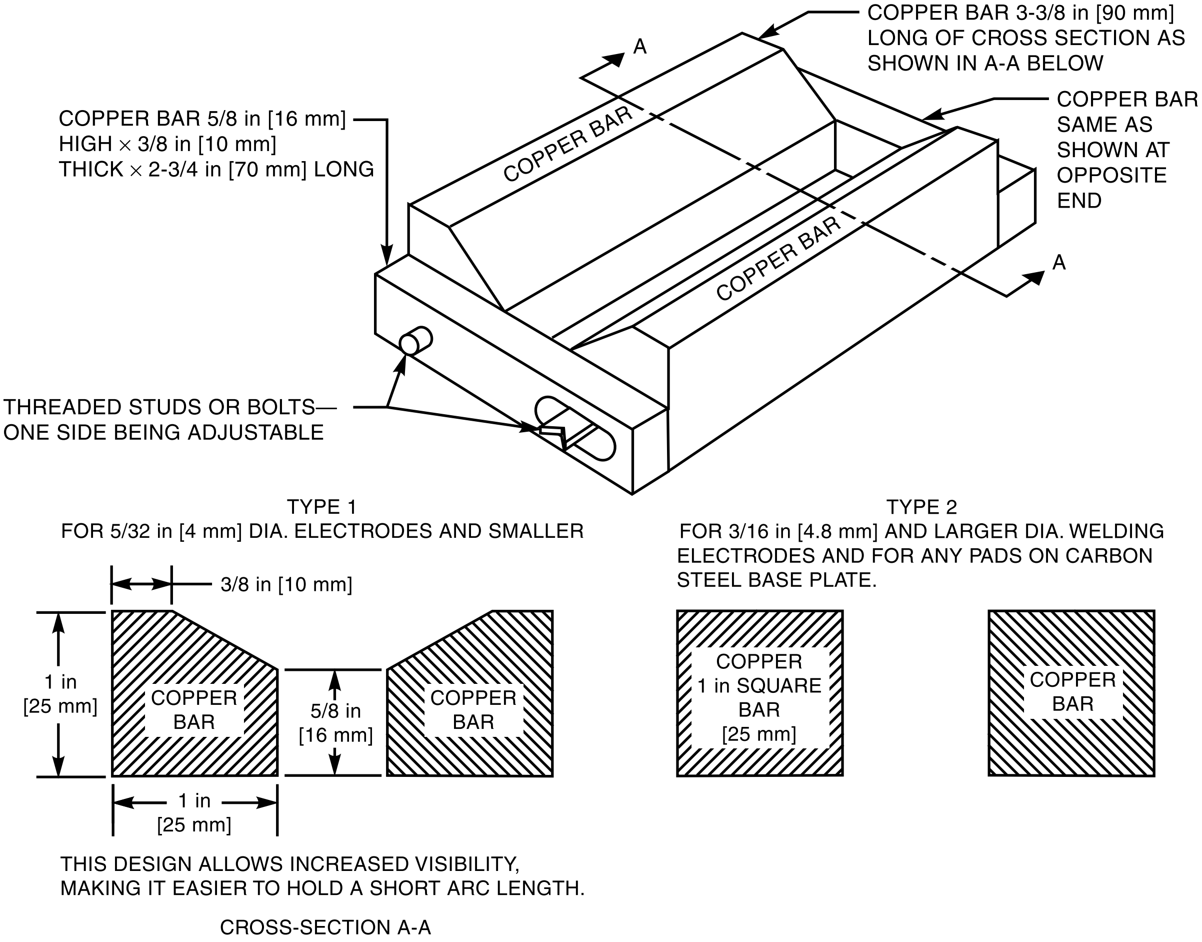

Figure A.2—Optional Welding Fixture for Welding Ferrite Test Pads

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

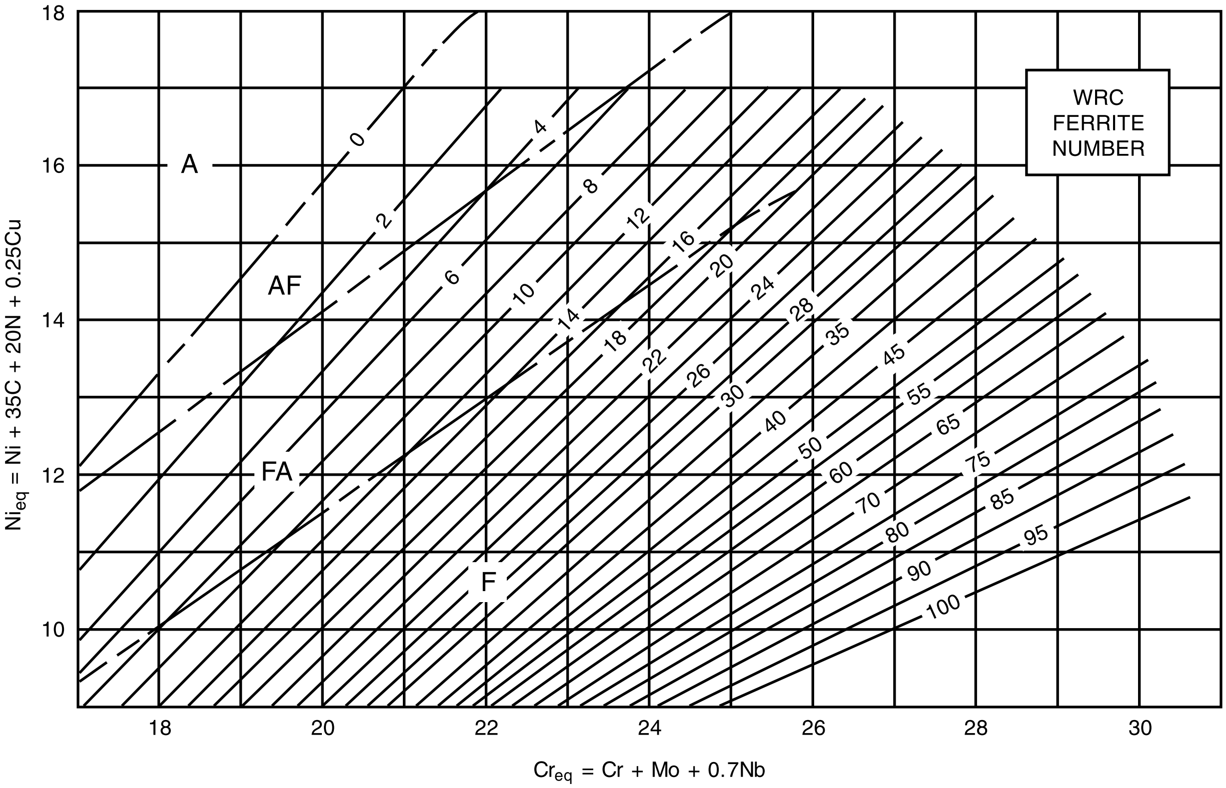

Figure A.3—WRC-1992 (FN) Diagram for Stainless Steel Weld Metal

alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion, and thereby increases resistance to intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. The E219 electrodes have sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications.

A7.3 E240. The nominal composition (wt %) of this weld metal is 18 Cr, 5 Ni, 12 Mn, and 0.20 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 °F [370 °C]. 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 °F [370 °C]. 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°F [930°C]. It is not recommended for high-sulfur atmospheres or where severe thermal shock is present. Long time exposure to temperatures in the approximate range of 1400°F to 1600°F [760°C to 870°C] 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°F [420°C] 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°F [–269°C].

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°F [–269°C]. 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°F [980°C] 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°F [1150°C] in oxidizing atmospheres and at 2000°F [1090°C] in reducing atmospheres. However, high-sulfur environments may adversely affect performance at elevated temperature.

A7.32 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°F [620°C]. 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 (PRE_N), is at least 40, thereby allowing the weld metal to be called a "superduplex stainless steel." This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride-containing environments. It is designed for the welding of superduplex stainless steels UNS 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°F [–196°C]. 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°F [–100°C].

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 °F [–196 °C].

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

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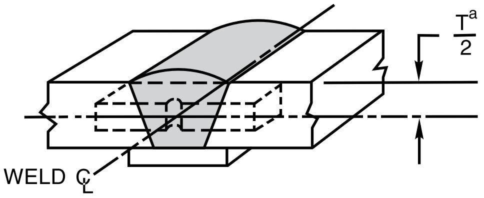
[14] ANSI Z49.1 is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.



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 Classificationsa

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*

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[15] AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

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SPECIFICATION FOR LOW-ALLOY STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

(**15**)

SFA-5.5/SFA-5.5M

(Identical with AWS Specification A5.5/A5.5M:2014. 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. These electrodes include steel alloys in which no single alloying element exceeds 10.5%.

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 nonmandatory annex Clauses A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification designated A5.5 uses U.S. Customary Units; and 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.

2. Normative References

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

2.2 AWS standards[1]:

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

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

(3) AWS A4.4M, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*

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

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[1] AWS standards are published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.

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

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

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

2.3 ANSI Standard[2]:

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

2.4 ASTM standards[3]:

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

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

(3) ASTM A203/A203M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

(4) ASTM A204/A204M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum*

(5) ASTM A242/A242M, *Standard Specification for High-Strength Low-Alloy Structural Steel*

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

(7) ASTM A302/A302M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum, and Manganese-Molybdenum-Nickel*

(8) ASTM A352/A352M, *Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service*

(9) ASTM A387/A387M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

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

(11) ASTM A516/A516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

(12) ASTM A517/A517M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered*

(13) ASTM A533/A533M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum, and Manganese-Molybdenum-Nickel*

(14) ASTM A537/A537M, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

(15) ASTM A543/A543M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum*

(16) 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*

(17) ASTM A709/A709M, *Standard Specification for Carbon Structural Steel for Bridges*

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

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

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

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[2] This ANSI standard is published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.

[3] ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959.

2.5 ISO standards[4]:

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

(2) ISO 2560, *Welding consumables — Covered electrodes for manual metal arc welding of nonalloy and fine grain steels — Classification*

(3) ISO 3580, *Welding consumables — Covered electrodes for manual metal arc welding of creep-resisting steels — Classification*

(4) ISO 18275, *Welding consumables — Covered electrodes for manual metal arc welding of high-strength steels — Classification*

(5) ISO 80000–1*:2009, Quantities and units — Part 1: General*

2.6 DoD publications[5]

(1) 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*

(2) *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*

(3) *MIL-E–22200/10, Military Specification: Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium, High Tensile and Higher-Strength Low Alloy Steels*

2.7 API standard[6]

(1) Spec 5L, *Specification for 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 Material classified under one classification shall not be classified under any other classification in the same specification. However, material may be classified under both A5.5 and A5.5M specifications.

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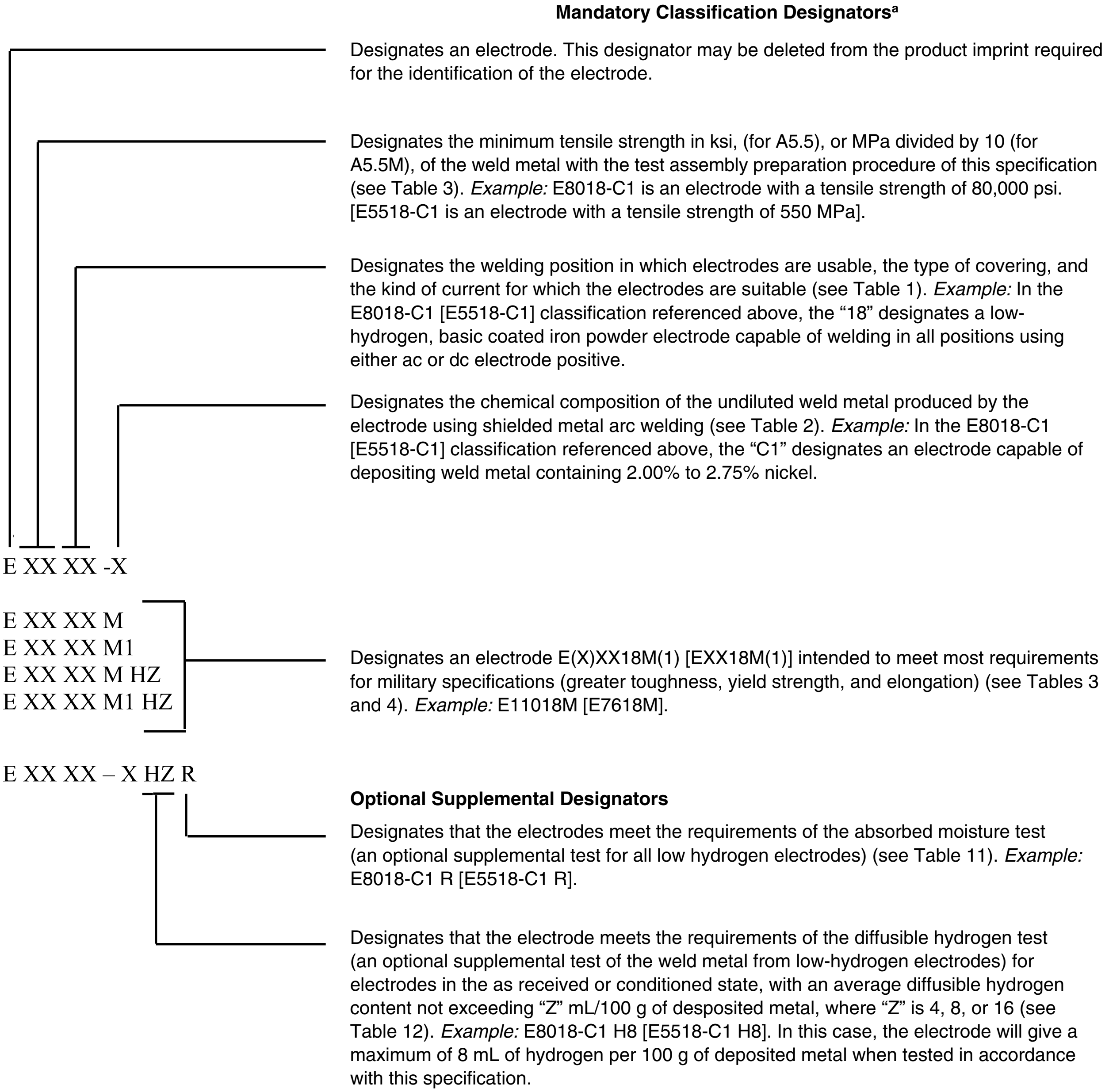
[4] ISO standards are published by the International Organization of Standardization, 1, chemin de la voie-creuse Case postale 56, CH–1211 Genéva, Geneva 20, Switzerland.

[5] DoD standards are published by the Department of Defense (DODSSP), Standardization Documents Order Desk, 700 Robbins Ave, Philadelphia, PA 19111.

[6] API specifications are published by the American Petroleum Institute, 1220 L Street NW, Washington, DC 20005.



Mandatory Classification Designators[a]

Designates an electrode. This designator may be deleted from the product imprint required for the identification of the electrode.

Designates the minimum tensile strength in ksi, (for A5.5), or MPa divided by 10 (for A5.5M), of the weld metal 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].

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 either ac or dc electrode positive.

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.

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].

Optional Supplemental Designators

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].

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 desposited 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.

Source: AWS A5.5/A5.5M:2006, Figure 9

Figure 1—Order of Electrode Mandatory and Optional Supplemental Designators

Table 1
Electrode Classification

AWS Classification[a]				
A5.5	A5.5M	Type of Covering	Welding Positions for Classification[b]	Type of Current[c]
E7010-X	E4910-X	High cellulose sodium	F, V, OH, H	dcep
E7011-X	E4911-X	High cellulose potassium	F, V, OH, H	ac or 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 or dcep
E7018-X[d,e]	E4918-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E7020-X	E4920-X	High iron oxide	H-fillets F	ac or dcen ac, dcep, or dcen
E7027-X	E4927-X	High iron oxide, iron powder[f]	H-fillets F	ac or dcen ac, dcep, or 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 or dcep
E8013-G	E5513-G	High titania potassium	F, V, OH, H	ac, dcep, or 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 or dcep
E8018-X[d,e]	E5518-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E8045-P2[d,e]	E5545-P2[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep
E9010-G	E6210-G	High cellulose sodium	F, V, OH, H	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 or dcep
E9013-G	E6213-G	High titania potassium	F, V, OH, H	ac, dcep, or 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 or dcep
E9018-X[d,e]	E6218-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E9018M[d,e]	E6218M[d,e]	Iron powder, low hydrogen [f]	F, V, OH, H	dcep
E9045-P2[d,e]	E6245-P2[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 or dcep
E10013-G	E6913-G	High titania potassium	F, V, OH, H	ac, dcep, or 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 or dcep
E10018-X[d,e]	E6918-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E10018M[d,e]	E6918M[d,e]	Iron powder, low hydrogen [f]	F, V, OH, H	dcep
E10045-P2[d,e]	E6945-P2[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep
E11010-G	E7610-G	High cellulose sodium	F, V, OH, H	dcep
E11011-G	E7611-G	High cellulose potassium	F, V, OH, H	ac or dcep
E11013-G	E7613-G	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E11015-G[d,e]	E7615-G[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E11016-G[d,e]	E7616-G[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E11018-G[d,e]	E7618-G[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or 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 or dcep
E12013-G	E8313-G	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E12015-G[d,e]	E8315-G[d,e]	Low hydrogen sodium	F, V, OH, H	dcep

Table 1 (Continued)
Electrode Classification

AWS Classification[a]				
A5.5	A5.5M	Type of Covering	Welding Positions for Classification[b]	Type of Current[c]
E12016-G[d,e]	E8316-G[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E12018-G[e,e]	E8318-G[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or 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" as used in this table, and elsewhere in this specification, stands for any allowable value of the designator it replaces in the classification. See Figure 1.

[b] The abbreviations, F, V, V-down, OH, H, and H-fillets 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, and E(X)XX18M(1).
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), and E(X)XX18M(1).

[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-P2 which meet 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-P2 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).

4. Acceptance

Acceptance[7] of the welding electrode shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[8]

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 80000–1:2009 (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 and yield strength for A5.5; and to the nearest 10 MPa for tensile and

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

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

Table 2
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]		UNS	Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M	Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
						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	–	–
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*	–	–

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]		UNS Number[d]	Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
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	W50316	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	–	–
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	W50406	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	–	–
E9015-B23 *E9016-B23* *E9018-B23*	*E6215-B23* *E6216-B23* *E6218-B23*	K20857	*0.04–0.12*	*1.00*	*0.60*	*0.015*	*0.015*	*0.50*	*1.9–2.9*	*0.30*	*W* *V* *Nb* *B* *Al* *Cu* *N*	*1.50–2.00* *0.15–0.30* *0.02–0.10* *0.006* *0.04* *0.25* *0.05*
E9015-B24 *E9016-B24* *E9018-B24*	*E6215-B24* *E6216-B24* *E6218-B24*	*K20885*	*0.04–0.12*	*1.00*	*0.60*	*0.020*	*0.015*	*0.50*	*1.9–2.9*	*0.80–1.20*	*V* *Nb* *Ti* *B* *Al* *Cu* *N*	*0.15–0.30* *0.02–0.10* *0.10* *0.006* *0.04* *0.25* *0.07*

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]			Weight Percent[a,b]								
										Additional Elements[e,f]	
A5.5	A5.5M	UNS Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
			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
E9015-B91[g,h]	*E6215-B91*[g,h]	W50425									Cu	0.25
E9016-B91[g,h]	*E6216-B91*[g,h]	W50426									Al	0.04
E9018-B91[g,h]	*E6218-B91*[g,h]	W50428									Nb	0.02–0.10
											N	0.02–0.07
		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*
E9015-B92[g]	*E6215-B92*[g]										*Nb*	*0.02–0.08*
E9016-B92[g]	*E6216-B92*[g]										*B*	*0.006*
E9018-B92[g]	*E6218-B92*[g]										*Al*	*0.04*
											Cu	*0.25*
											N	*0.03–0.08*
Nickel Steel Electrodes												
E8016-C1	E5516-C1	W22016	0.12	1.25	0.60	0.03	0.03	2.00–2.75	–	–	–	–
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	–	–	–	–

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]			Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M	UNS Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
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	*E6218-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*
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	–	–
E8016-D3	E5516-D3	W18016	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	–	–
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]

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]		UNS Number[d]	Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
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]
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

[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:2006.*

[i] The letters "(X)XX" ["XX"] used in the classification designations for all electrodes in this table stand for the various tensile 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	
A5.5	**A5.5M**	**ksi**	**MPa**	**ksi**	**MPa**	**Percent**	**Postweld Condition[d]**
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-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
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
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
E9018-NM2	*E6218-NM2*	*90*	*620*	*77*	*530*	*17*	*PWHT*
E9018-P2	E6218-P2	90	620	77	530	17	AW

Table 3 (Continued)
Tension Test Requirements[a,b]

AWS Classification[c]		Tensile Strength		Yield Strength, At 0.2% Offset		Elongation	
A5.5	A5.5M	ksi	MPa	ksi	MPa	Percent	Postweld Condition[d]
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
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
E10018M	E6918M	100	690	88 to 100[e]	610 to 690[e]	20	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
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

[a] See Table 5 for sizes to be tested.

[b] Single values are minima, except as otherwise specified.

[c] The letter suffix "X" as used in this table represents the suffixes (A1, B1, B2, etc.) which are tested in the PWHT condition only.

[d] "AW" signifies as-welded, which may or may not be 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.

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, and 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 the low-hydrogen electrodes (see Note i of Table 5).

Table 4
Charpy V-Notch Impact Requirements

AWS Classification		Limits for 3 out of 5 Specimens[a,b,c]	
A5.5	A5.5M	Average, min.[d]	Single Value, min.[d]
E7018-W1 E8018-W2	E4918-W1 E5518-W2	20 ft•lbf at 0°F [27 J at –20°C]	15 ft•lbf at 0°F [20 J at –20°C]
E12018M1	E8318M1	50 ft•lbf at 0°F [67 J at –20°C]	40 ft•lbf at 0°F [54 J at –20°C]
E7010-P1 E8010-P1 E8018-P2 E8045-P2 E9010-P1 E9018-P2 *E9018-NM2* [e] E9045-P2 E10045-P2	E4910-P1 E5510-P1 E5518-P2 E5545-P2 E6210-P1 E6218-P2 *E6218-NM2* [e] E6245-P2 E6945-P2	20 ft•lbf at –20°F [27 J at –30°C]	15 ft•lbf at –20°F [20 J at –30°C]
E8018-NM1 E8016-C3 E8018-C3	E5518-NM1 E5516-C3 E5518-C3	20 ft•lbf at –40°F [27 J at –40°C]	15 ft•lbf at –40°F [20 J at –40°C]
E8016-D3, E8018-D1 E8018-D3, E9015-D1 E9018-D1, E9018-D3 E10015-D2, E10016-D2 E10018-D2	E5516-D3, E5518-D1 E5518-D3, E6215-D1 E6218-D1, E6218-D3 E6915-D2, E6916-D2 E6918-D2	20 ft•lbf at –60°F [e] [27 J at –50°C]	15 ft•lbf at –60°F [e] [20 J at –50°C]
E7018-C3L E8016-C4, E8018-C4 E9018M, E10018M E11018M, E12018M	E4918-C3L E5516-C4, E5518-C4 E6218M, E6918M E7618M, E8318M	20 ft•lbf at –60°F [27 J at –50°C]	15 ft•lbf at –60°F [20 J at –50°C]
E8016-C1 E8018-C1	E5516-C1 E5518-C1	20 ft•lbf at –75°F [e] [27 J at –60°C]	15 ft•lbf at –75°F [e] [20 J at –60°C]
E7015-C1L E7016-C1L E7018-C1L E8016-C2 E8018-C2	E4915-C1L E4916-C1L E4918-C1L E5516-C2 E5518-C2	20 ft•lbf at –100°F [e] [27 J at –75°C]	15 ft•lbf at –100°F [e] [20 J at –75°C]
E7015-C2L E7016-C2L E7018-C2L	E4915-C2L E4916-C2L E4918-C2L	20 ft•lbf at –150°F [e] [27 J at –100°C]	15 ft•lbf at –150°F [e] [20 J at –100°C]
E9015-C5L	E6215-C5L	20 ft•lbf at –175°F [e] [27 J at –115°C]	15 ft•lbf at –175°F [e] [20 J at –115°C]
EXXXX-A1 EXXXX-BX EXXXX-BXL E(X)XXXX-G		Not specified	

[a] *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.*

[b] 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.

[c] *Impact test specimens are tested without thermal treatment, except as noted.*

[d] Impact test values shall be recorded to "nearest whole unit" of energy absorbed in accordance with the rounding method specified in Clause 6.

[e] *These classifications are tested in the postweld heat treated condition, as specified in 9.4.1.1 and in Table 7.*

Table 5
Required Tests[a]

AWS Classification[b]			Electrode Size[c]		Welding Position for Test Assembly				
A5.5	A5.5M	Type of Current[d]	in	mm	Chemical Analysis[e]	Soundness Test & All Weld Metal Tension Test[f, g]	Impact Test[h]	Fillet Weld Test[i, j]	Moisture Test[k]
E7010-X	E4910-X	dcep							
E8010-X	E5510-X		3/32, 1/8	2.5, 3.2	NR^m	NR^m	NR	NR^m	NR
E9010-X	E6210-X		5/32	4.0	F	F	NR	V, OH	NR
E10010-G	E6910-G		3/16	5.0	NR^m	F	NR	V, OH	NR
E11010-G	E7610-G		7/32	–	NR^m	NR^m	NR	NR^m	NR
E12010-G	E8310-G		1/4	6.0	F	F	NR	H	NR
E7011-X	E4911-X	ac and dcep	3/32, 1/8	2.5, 3.2	NR^m	NR^m	NR	NR^m	NR
E8011-G	E5511-G		5/32	4.0	F	F	NR	V, OH	NR
E9011-G	E6211-G		3/16	5.0	NR^m	F	NR	V, OH	NR
E10011-G	E6911-G		7/32	–	NR^m	NR^m	NR	NR^m	NR
E11011-G	E7611-G		1/4	6.0	F	F	NR	H	NR
E12011-G	E8311-G								
E8013-G	E5513-G	ac, dcen, and dcep							
E9013-G	E6213-G		3/32, 1/8	2.5, 3.2	NR^m	NR^m	NR	NR^m	NR
E10013-G	E6913-G		5/32	4.0	F^l	F^l	NR	V, OH	NR
E11013-G	E7613-G		3/16	5.0	NR^m	F^l	NR	V, OH	NR
E12013-G	E8313-G								
E7015-X	E4915-X	dcep							
E8015-X	E5515-X		3/32, 1/8	2.5, 3.2	NR^m	NR^m	NR^m	NR^m	NR^m
E9015-X	E6215-X		5/32	4.0	F	F	F	V, OH	Req'd
E10015-X	E6915-X		3/16	5.0	NR^m	F	F	H	NR^m
E11015-G	E7615-G		7/32	–	NR^m	NR^m	NR^m	NR^m	NR^m
E12015-G	E8315-G		1/4	6.0	F	F	F	H	Req'd
E7016-X	E4916-X	ac and dcep							
E8016-X	E5516-X		3/32, 1/8	2.5, 3.2	NR^m	NR^m	NR^m	NR^m	NR^m
E9016-X	E6216-X		5/32	4.0	F	F	F	V, OH	Req'd
E10016-X	E6916-X		3/16	5.0	NR^m	F	F	H	NR^m
E11016-G	E7616-G		7/32	–	NR^m	NR^m	NR^m	NR^m	NR^m
E12016-G	E8316-G		1/4	6.0	F	F	F	H	Req'd

Table 5 (Continued)
Required Tests[a]

AWS Classification[b]			Electrode Size[c]		Welding Position for Test Assembly				
A5.5	A5.5M	Type of Current[d]	in	mm	Chemical Analysis[e]	Soundness Test & All Weld Metal Tension Test[f, g]	Impact Test[h]	Fillet Weld Test[i, j]	Moisture Test[k]
E8045-P2	E5545-P2	dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E9045-P2	E6245-P2		5/32	4.0	F	F	F	V-down, OH	Req'd
E10045-P2	E6945-P2		–	4.5	F	F	F	V-down, OH	Req'd
E7018-X	E4918-X	ac and dcep							
E8018-X	E5518-X		3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E9018-X	E6218-X		5/32	4.0	F	F	F	V, OH	Req'd
E10018-X	E6918-X		3/16	5.0	NR[m]	F	F	H	NR[m]
E11018-G	E7618-G		7/32	–	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E12018-G	E8318-G		1/4	6.0	F	F	F	H	Req'd
		For H-fillets:	1/8	3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR
		ac and dcen.	5/32	4.0	F[l]	F[l]	NR	H	NR
E7020-X	E4920-X	For flat	3/16	5.0	NR[m]	F[l]	NR	H	NR
E7027-X	E4927-X	position:	7/32	–	NR[m]	NR[m,n]	NR	NR[m]	NR
		ac, dcen,	1/4	6.0	F[l]	F[l,n]	NR	H	NR
		and dcep	5/16	8.0	NR[m]	F[l,n]	NR	NR	NR
E9018M	E6218M	dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E10018M	E6918M		5/32	4.0	F	F	F	V, OH	Req'd
E11018M	E7618M		3/16	5.0	NR[m]	F	F	H	NR[m]
E12018M	E8318M		7/32	–	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E12018M1	E8318M1		1/4	6.0	F	F	F	H	Req'd

[a] NR means "not required."

[b] The letter suffix "X" as used in this table is defined in Note a of Table 1.

[c] Electrodes manufactured in sizes not shown shall be tested to the requirement of the nearest standard size.

[d] The abbreviations, F, H, H-fillets, V, V-down, and OH, are defined in Note b of Table 1. The terms "dcep" and "dcen" are defined in Note c of Table 1.

[e] See Clause 10.

[f] See Clause 11.

[g] See Clause 12.

[h] See Clause 13. Impact tests are required for classifications listed in Table 4.

[i] Progression for tests performed in the vertical position shall be upward, except for E(X)XX10-X electrodes which may be tested in either upward or downward progression and the E(X)XX45-P2, which is tested vertically down only.

[j] See Clause 14.

[k] The moisture test given in Clause 15 is the required test for measurement of moisture content of the covering. The absorbed moisture test, in Clause 16, and the diffusible hydrogen test, in Clause 17, are supplemental tests required only when their corresponding optional supplemental designators are to be used with the classification designators.

[l] When dcep and dcen are specified, only dcen need be tested.

[m] Standard electrode sizes not requiring this specific test can be classified provided at least two other sizes of that classification have passed the tests required for them, or the size to be classified meets specification requirements by having been tested in accordance with Clauses 8 through either 13, 14, 15, or 16, depending on the electrode being classified.

[n] 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.

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

In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the weld test assembly or 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 four 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 E(X)XX18M(1)

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

(4) The groove weld in Figure 5, an alternate to (2) above, for mechanical properties and soundness of the weld metal for E(X)XX18M(1) 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) in the weld metal in the groove weld in Figure 3 or 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 prescribed in 9.3 through 9.5. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the ASTM specification shown there or an equivalent specification. Electrodes other than low-hydrogen electrodes shall be tested without conditioning.[9] 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 14.

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, in the weld metal in the groove weld in Figure 3 or 5) is selected. Base metal of any convenient size, of the type specified in Table 6, shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple 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. The dimensions of the completed pad shall be as shown in Figure 2. Testing of this assembly shall be as specified in Clause 10.

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 5 using matching base material (see Table 6) with no buttering, or non-matching base material (see Table 6) buttered as shown in Figure 3(B), of thickness specified in Figure 3 or 5. Preheat and interpass temperatures shall be as specified in Table 7. Testing of this assembly shall be as specified in Clauses 11, 12, and 13. The assembly shall be tested in the as-welded condition or the postweld heat treated condition as specified in Table 3, except for the E(X)XXXX-G

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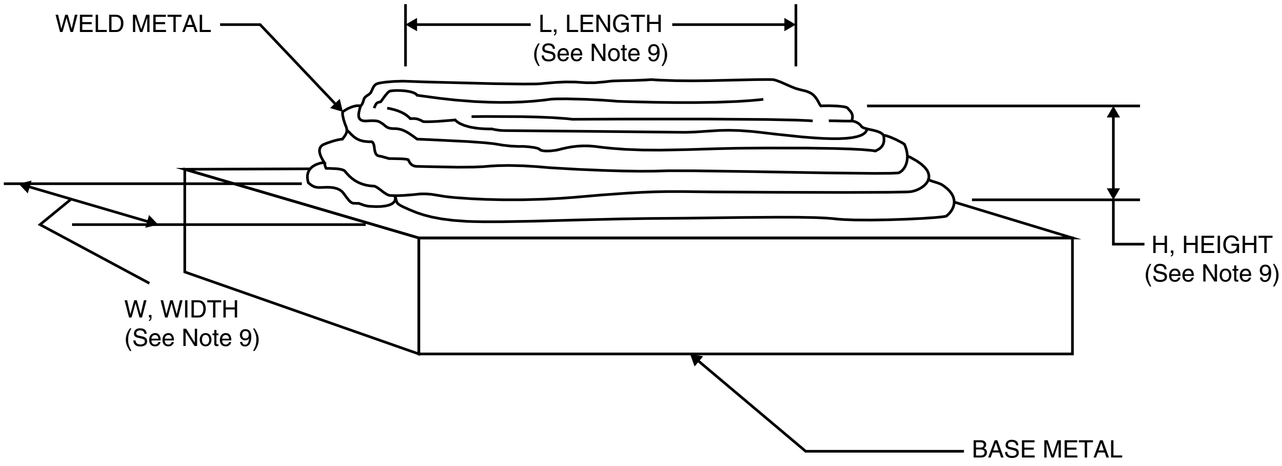
[9] Conditioning can be considered to be any special preparation or procedure, such as baking the electrode, which the user would not normally practice.



Notes:

1. Base metal of any convenient size, of the type specified in Table 6, 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 5 except for those classifications identified by note l in Table 5.
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.
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 the following distance above the original base metal surface:

Electrode Size		Minimum Distance From Surface of Base Plate	
in	mm	in	mm
3/32	2.5	1/4	6
1/8 5/32 3/16	3.2 4.0 4.5, 5.0	5/16	8
7/32 1/4 5/16	— 6.0 8.0	3/8	10

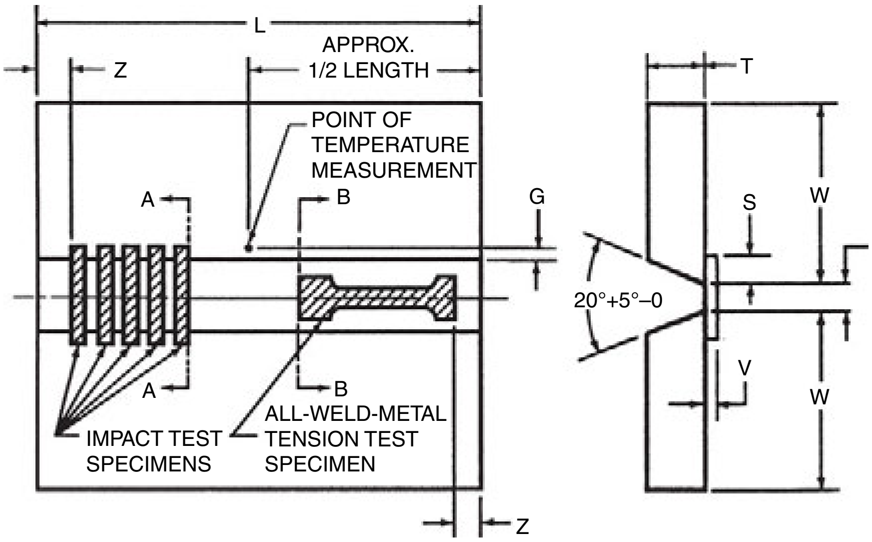
Figure 2—Pad for Chemical Analysis of Undiluted Weld Metal

classifications, which, when Postweld Heat Treatment (PWHT) is required, shall be tested in the postweld heat treated condition agreed upon between the purchaser and supplier (see Note b of Table 7).

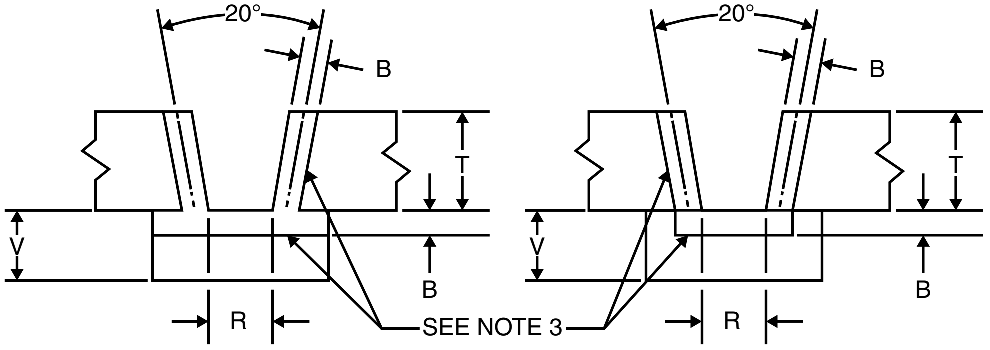
9.4.1.1 When PWHT is required, the heat treatment shall be applied to the assembly before specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination.

9.4.1.2 The temperature of the test assembly shall be raised in a suitable furnace, at the rate of 150°F to 500°F [85°C to 280°C] per hour until the postweld heat treatment temperature specified in Table 7, for the electrode classification, is attained. This temperature shall be maintained for the time specified in Table 7 (–0, +15 minutes).

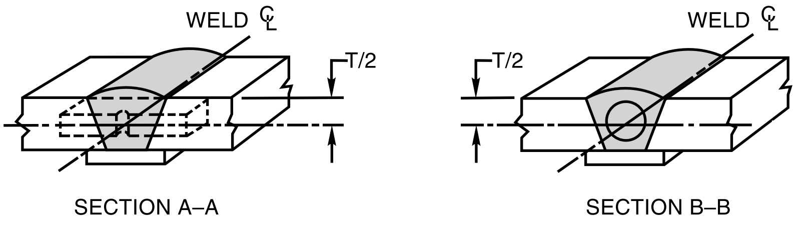
9.4.1.3 The test assembly shall then be allowed to cool in the furnace, at a rate not greater than 350°F [200°C] per hour, and may be removed from the furnace when the temperature of the furnace has reached 600°F [300°C] and allowed to cool in still air.



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) GROOVE PREPARATION OF TEST PLATE FOR NON-MATCHING BASE MATERIALS



(C) ORIENTATION AND LOCATION OF IMPACT TEST SPECIMEN

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

Figure 3—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using All Electrode Classifications Except E(X)XX18M(1)

Dimension	Description	A5.5, in	A5.5M, mm
B	Butter Layer Thickness, min.	1/8	3
G	Offset from groove edge	1/4 to 1/2	6 to 13
L	Length, min. (See Note 1)	10	250
S	Backing overlap, min.	1/4	6
V	Backing thickness, min.	1/4	6
W	Width, min.	5	125
Z	Discard, min.	1	25

Electrode Size		T, Nominal (Plate Thickness)		R (see Note 11) (Root Opening)		Passes per Layer	Total Layers
in	mm	in	mm	in	mm		
3/32	2.5	1/2	12	3/8	10	2	Not specified
1/8	3.2	1/2	12	1/2	13	2	5 to 7
5/32	4.0	3/4	20	5/8	16	2	7 to 9
3/16	4.5, 5.0	3/4	20	3/4	19	2	6 to 8
7/32	–	3/4	20	7/8	22	2	6 to 8
1/4	6.0	1	25	1	25	2	9 to 11
5/16	8.0	1–1/4	30	1–1/8	28	2	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. Base metal shall be as specified in Table 6. For other base metal which does not closely match the composition of the deposit of the electrode under test, the edges of the groove and the contacting face of the backing shall be surfaced as shown, using any size of an electrode having the same composition or classification as the electrode being tested, before welding the joint.
3. The surfaces to be welded shall be clean.
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 5 except for classifications identified by Note I in Table 5.
6. The preheat and interpass temperature shall be as specified in Table 7 for the classification being tested.
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.
10. The test assemblies shall be postweld heat treated as specified in Table 7 for the classification being tested.
11. Tolerance for root opening is –0, + 1/16 in [–0, + 1 mm].

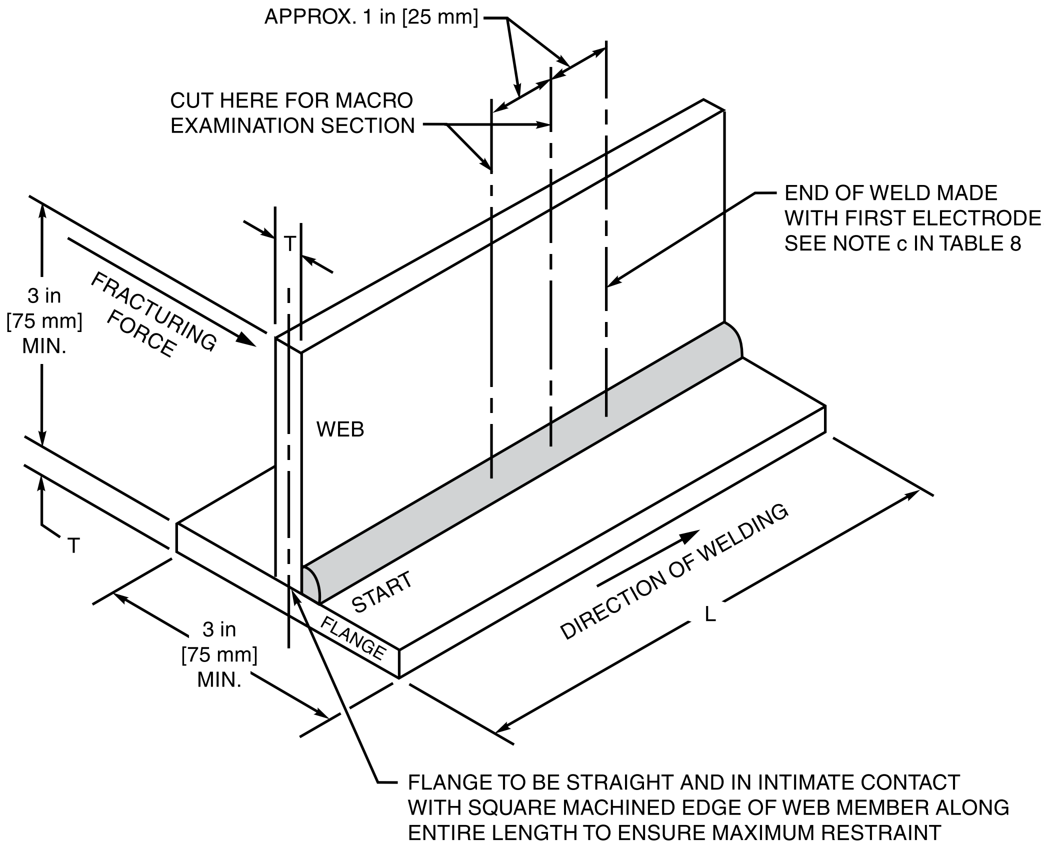
Source of Details A, C and D: AWS A5.1/A5.1M:2004 ERRATA, Figure 2.

Figure 3 (Continued)—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using All Electrode Classifications Except E(X)XX18M(1)

9.5 Fillet Weld. One or more test assemblies shall be prepared and welded as specified in Table 5 and shown in Figure 4 using base metal of the appropriate type specified in Table 6. The welding positions shall be as specified in Table 8 and Figure 6 according to the size and classification of the electrode. Testing of the assembly shall be as specified in Clause 14.

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, or from a corresponding location (or any location above it) in the groove weld in Figure 3 or 5. Areas where arc starts or craters exist shall be avoided.



Notes:
1. See Table 8 for values of T and L.
2. Base metal shall be as specified in Table 6.
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 6 using each type of current and polarity specified in Table 5.
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 for E(X)XX10-X electrodes, which may be tested in either upwards or downwards progression, and the E(X)XX45-P2, which is tested vertically down only.
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.

Source: AWS A5.5/A5.5M:2006, Figure 3.

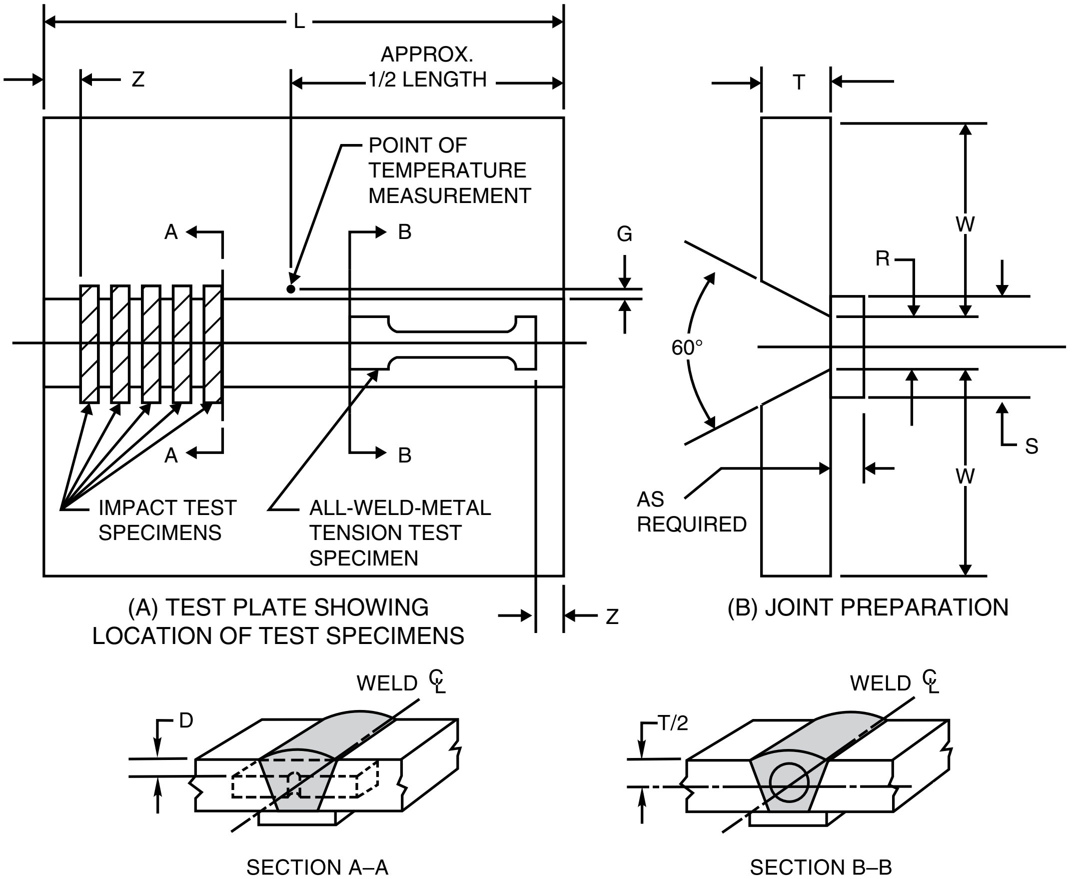
Figure 4—Fillet Weld Test Assembly

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 by any appropriate mechanical means. The sample shall be free of slag and shall be taken from metal that is at least the minimum distance 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 above it) in the groove weld in Figure 3 or 5, shall be prepared for analysis by any suitable mechanical means.

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 2 for the classification of the electrode under test.



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS

(B) JOINT PREPARATION

(C) ORIENTATION OF IMPACT SPECIMEN

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

Dimension	Description	A5.5, in	A5.5M, mm
G	Offset from groove edge	1/4 to 1/2	6 to 13
L	Length, min.	10	250
S	Backing width, min.	1	25
D	Specimen location, nominal	1/16	1.6
W	Width, min.	5	125
Z	Discard, min.	1	25

Electrode Size		T (Min. Plate Thickness)		R (Max. Root Opening)		Number of Layers	
in	mm	in	mm	in	mm	Min.	Max.
3/32	2.5	1/2	12	1/4	6	See note 1	
1/8	3.2	1/2	12	1/4	6	See note 1	
5/32	4.0	3/4	20	1/2	13	7	9
3/16	5.0	3/4	20	1/2	13	7	9
7/32	–	3/4	20	1/2	13	7	8
1/4	6.0	1	25	1/2	13	9	11

Figure 5—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using E(X)XX18M(1)

Notes:

1. Pass and layer sequence shall be reported.
2. Base metal shall be as specified in Table 6.
3. The surfaces to be welded shall be clean.
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 weld 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 performed in the flat position using the type of current specified in Table 5 for the classification.
6. The preheat and interpass temperature shall be that specified in Table 7 for the classification being tested.
7. Layers should be approximately 1/8 in [3 mm] thick with each layer being started at the finishing end of the preceding layer.
8. The weld shall be made with stringer beads or with maximum weave no wider than 2–1/2 times the diameter of the core wire.
9. The completed weld shall have a reinforcement of standard proportions, 1/32 in [0.8 mm] minimum; 1/8 in [3.2 mm] maximum. For electrodes larger than 1/8 in [3.2 mm], the root beads may be made with 3/32 in or 1/8 in [2.5 mm or 3.2 mm] electrodes.
10. The number of layers pertains specifically to minimum plate thicknesses. Use of thicker plates may increase the number of layers.

Figure 5 (Continued)—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using E(X)XX18M(1)

11. Radiographic Test

11.1 When required in Table 5, 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] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM 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, and

(2) no slag inclusions longer than 1/4 in [6.5 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 7A or Figure 7B according to the grade specified in Table 9.

In evaluating the radiograph, 1 in [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 they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present.

The indication may be 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 One all-weld-metal tension test 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 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 shall have a nominal diameter of 0.500 in

Table 6
Base Metal for Weld Test Assemblies

	Base Metal	
AWS Classification	**ASTM Specification Number[a]**	**UNS Number[b]**
EXXXX-A1	A204 Grade A	K11820
EXXXX-B1	A387 Grade 2	K12143
EXXXX-B2, EXXXX-B2L, EXXXX-B5	A387 Grade 11	K11789
EXXXX-B3, EXXXX-B3L, EXXXX-B4L	A387 Grade 22 or 22L	K21590
EXXXX-B6, EXXXX-B6L, EXXXX-B7, EXXXX-B7L	A387 Grade 5	S50200
EXXXX-B8, EXXXX-B8L	A387 Grade 9	K90941
EXXXX-B23, EXXXX-B24	A29 Grade 1015 or 1020; A283 Grade A, B, C, or D; A36; A131 Grade B (Buttering required)[d]	G10150, G10200, K01400, K01702, K02401, K02801, K02702, K02600 K02102
EXXXX-*B91*	A387 Grade 91	K90901, S50460
EXXXX-B92	*A387 Grade 92*	*K90901, K92460*
EXXXX-C1, EXXXX-C1L	A537 Class 1 or 2; A203 Grade A or B	K12437 K21703, K22103
EXXXX-C2, EXXXX-C2L	A203, Grade D or E	K31718, K32018
EXXXX-C3, EXXXX-C3L	A516 Grade 60, 65, or 70; A537 Class 1 or 2	K02100, K02403, K02700, K12437
EXXXX-NM1	A302 Grade C or D; A533 Type B or C	K12039, K12054, K12539, K12554
EXXXX-D1, E(X)XXXX-D2, EXXXX-D3	A302 Grade A or B	K12021, K12022
EXXXX-NM2, E(X)XX18M	A514, A517, A543 Type B or C; NAVSEA Technical Publication T9074-BD-GIB–010/0300 HY80 or HY100	K11630, K42339 K31820, K32045
E12018M1 [E8318M1]	NAVSEA Technical Publication T9074-BD-GIB–010/0300 HY100	K32045
EXX10-P1, EXX18-P2, E(X)XX45-P2 EXX10-G electrodes intended for pipe welding	API 5L X pipe steel [c]`	–
EXX18-W1, EXX18-W2	A588 Grade A, B, or C; A709 Grade 50W	K11947, K12043, K11538
All except E(X)XX18M(1)	A29 Grade 1015 or 1020; A283 Grade A, B, C, or D (Buttering required)[d]	G10150, G10200, K01400, K01702, K02401, K02702
All	A36; A131 Grade B (Buttering required)[d]	K02600, K02102

[a] Steel specifications providing compositions that are equivalent to those shown in other national and international specifications are acceptable.

[b] SAE HS–1086/ASTM DS–56, *Metals & Alloys in the Unified Numbering System*.

[c] Grade shall be appropriate for electrode classification strength level.

[d] Carbon steel base metal does not require buttering when used for fillet weld test assemblies.

Table 7
Preheat, Interpass, and Postweld Heat Treatment Temperatures

AWS Classification		Preheat and Interpass		Postweld Heat Treatment		
		Temperature		Temperature		Time[a]
A5.5	A5.5M	°F	°C	°F	°C	Hour(s)
E7010-A1	E4910-A1	200 to 225	95 to 110	1150 ± 25	620 ± 15	1
E7011-A1	E4911-A1					
E7015-A1	E4915-A1					
E7016-A1	E4916-A1					
E7018-A1	E4918-A1					
E7020-A1	E4920-A1					
E7027-A1	E4927-A1					
E8018-D1	E5518-D1					
E9015-D1	E6215-D1					
E9018-D1	E6218-D1					
E10015-D2	E6915-D2					
E10016-D2	E6916-D2					
E10018-D2	E6918-D2					
E8016-D3	E5516-D3					
E8018-D3	E5518-D3					
E9018-D3	E6218-D3					
E8016-B1	E5516-B1	325 to 375	160 to 190	1275 ± 25	690 ± 15	1
E8018-B1	E5518-B1					
E8015-B2	E5515-B2					
E8016-B2	E5516-B2					
E8018-B2	E5518-B2					
E7015-B2L	E4915-B2L					
E7016-B2L	E4916-B2L					
E7018-B2L	E4918-B2L					
E9015-B3	E6215-B3					
E9016-B3	E6216-B3					
E9018-B3	E6218-B3					
E8015-B3L	E5515-B3L					
E8018-B3L	E5518-B3L					
E8015-B4L	E5515-B4L					
E8016-B5	E5516-B5					
E8015-B6	E5515-B6	350 to 450	180 to 230	1375 ± 25	740 ± 15	1
E8016-B6	E5516-B6					
E8018-B6	E5518-B6					
E9018-B6	*E6218-B6*					
E8015-B6L	E5515-B6L					
E8016-B6L	E5516-B6L					
E8018-B6L	E5518-B6L					
E8015-B7	E5515-B7					
E8016-B7	E5516-B7					
E8018-B7	E5518-B7					
E8015-B7L	E5515-B7L					
E8016-B7L	E5516-B7L					
E8018-B7L	E5518-B7L					
E8015-B8	E5515-B8	400 to 500	200 to 250	1375 ± 25	740 ± 15	1
E8016-B8	E5516-B8					
E8018-B8	E5518-B8					
E8015-B8L	E5515-B8L					
E8016-B8L	E5516-B8L					
E8018-B8L	E5518-B8L					

Table 7 (Continued)
Preheat, Interpass, and Postweld Heat Treatment Temperatures

		Preheat and Interpass		Postweld Heat Treatment		
AWS Classification		**Temperature**		**Temperature**		**Time[a]**
A5.5	**A5.5M**	**°F**	**°C**	**°F**	**°C**	**Hour(s)**
E9015-B23	*E6215-B23*	*350 to 475*	*180 to 250*	*1365 ± 25*	*740 ± 15*	*2*
E9016-B23	*E6216-B23*					
E9018-B23	*E6218-B23*					
E9015-B24	*E6215-B24*					
E9016-B24	*E6216-B24*					
E9018-B24	*E6218-B24*					
E9015-*B91*	E6215-*B91*	400 to 600	200 to 315	1400 ± 25	760 ± 15	2
E9016-*B91*	E6216-*B91*					
E9018-*B91*	E6218-*B91*					
E9015-B92	*E6215-B92*					
E9016-B92	*E6216-B92*					
E9018-B92	*E6218-B92*					
E8016-C1	E5516-C1	200 to 225	95 to 110	1125 ± 25	605 ± 15	1
E8018-C1	E5518-C1					
E7015-C1L	E4915-C1L					
E7016-C1L	E4916-C1L					
E7018-C1L	E4918-C1L					
E8016-C2	E5516-C2					
E8018-C2	E5518-C2					
E7015-C2L	E4915-C2L					
E7016-C2L	E4916-C2L					
E7018-C2L	E4918-C2L					
E9015-C5L	E6215-C5L	200 to 250	95 to 120	1075 ± 25	580 ± 15	1
E9018-NM2	*E6218-NM2*	*200 to 225*	*95 to 110*	*1125 ± 25*	*605 ± 15*	*8*
E8010-G	E5510-G	*See Note c*		See Note c		
E8011-G	E5511-G					
E8013-G	E5513-G					
E9010-G	E6210-G					
E9011-G	E6211-G					
E9013-G	E6213-G					
E10010-G	E6910-G					
E10011-G	E6911-G					
E10013-G	E6913-G					
E11010-G	E7610-G					
E11011-G	E7611-G					
E11013-G	E7613-G					
E12010-G	E8310-G					
E12011-G	E8311-G					
E12013-G	E8313-G					

Table 7 (Continued)
Preheat, Interpass, and Postweld Heat Treatment Temperatures

AWS Classification		Preheat and Interpass Temperature		Postweld Heat Treatment Temperature		Postweld Heat Treatment Time[a]
A5.5	A5.5M	°F	°C	°F	°C	Hour(s)
E7010-G	E4910-G	See Note b		See Note b		
E7011-G	E4911-G					
E7015-G	E4915-G					
E7016-G	E4916-G					
E7018-G	E4918-G					
E7020-G	E4920-G					
E7027-G	E4927-G					
E8015-G	E5515-G					
E8016-G	E5516-G					
E8018-G	E5518-G					
E9015-G	E6215-G					
E9016-G	E6216-G					
E9018-G	E6218-G					
E10015-G	E6915-G					
E10016-G	E6916-G					
E10018-G	E6918-G					
E11015-G	E7615-G					
E11016-G	E7616-G					
E11018-G	E7618-G					
E12015-G	E8315-G					
E12016-G	E8316-G					
E12018-G	E8318-G					
E7010-P1	E4910-P1	200 to 250	95 to 120	Not Specified[c]		
E7018-C3L	E4918-C3L					
E7018-W1	E4918-W1					
E8016-C3	E5516-C3					
E8018-C3	E5518-C3					
E8016-C4	E5516-C4					
E8018-C4	E5518-C4					
E8018-NM1	E5518-NM1					
E8018-W2	E5518-W2					
E8018-P2	E5518-P2					
E8045-P2	E5545-P2					
E9018-P2	E6218-P2					
E9045-P2	E6245-P2					
E9018M	E6218M					
E10018M	E6918M					
E10045-P2	E6945-P2					
E11018M	E7618M					
E12018M	E8318M					
E12018M1	E8318M1					
E8010-P1	E5510-P1	325 to 375	160 to 190	Not Specified[c]		
E9010-P1	E6210-P1					

[a] Postweld heat treat at specified time, –0, +15 minutes.

[b] *The need for, and specific values for preheat and interpass temperatures, and postweld heat treatment conditions of weld test assemblies made with "G" electrodes shall be as agreed upon between the purchaser and supplier.*

[c] Postweld heat treatment is not required for those classifications listed as "as-welded" in Table 3.

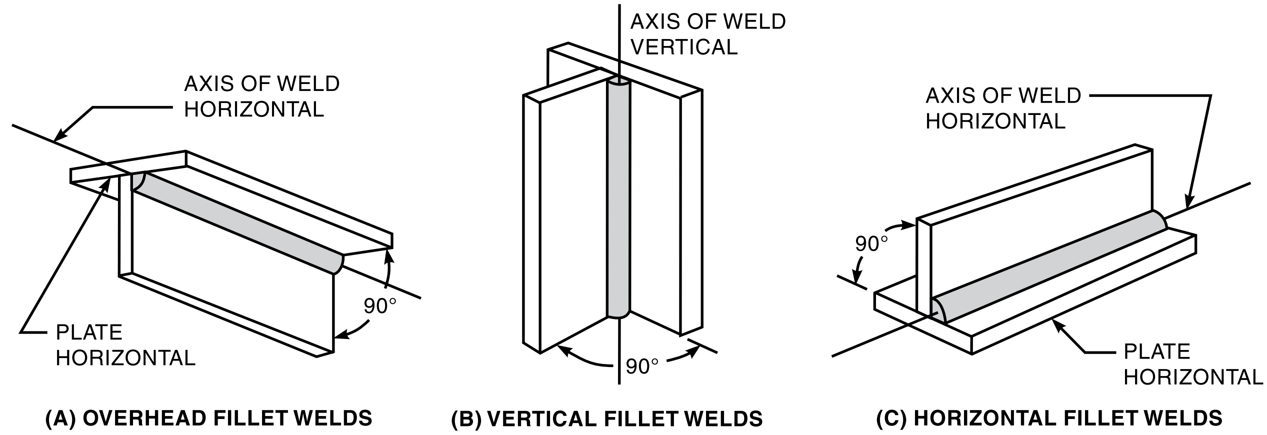
Table 8
Requirements for Preparation of Fillet Weld Test Assemblies

AWS Classification[a]		Electrode				Plate Size[b]				Position of Welding	Size of Fillet Weld	
		Size		Length		Thickness (T)		Length (L) min.[c]				
A5.5	A5.5M	in	mm	in	mm	in	mm	in	mm		in	mm
E(X)XX10-X E(X)XX11-X	EXX10-X EXX11-X	3/32	2.5	12	300	1/8	3	10	250	V, OH	5/32 max.	4.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V, OH	3/16 max.	5.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V, OH	1/4 max.	6.0 max.
		3/16	5.0	14	350	3/8	10	12	300	V, OH	5/16 max.	8.0 max.
		7/32	–	14 or 18	350 or 450	1/2	12	12 or 16	300 or 400	H	1/4 min.	6.0 min.
		1/4	6.0	18	450	1/2	12	16	400	H	1/4 min	6.0 min.
E(X)XX13-X	EXX13-X	3/32	2.5	12	300	1/8	3	10	250	V, OH	5/32 max.	4.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V, OH	3/16 max.	5.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V, OH	1/4 max.	6.0 max.
		3/16	5.0	14	350	3/8	10	12	300	V, OH	3/8 max.	10.0 max.
		7/32	–	14 or 18	350 or 450	1/2	12	12 or 16	300 or 400	H	1/4 min	6.0 min.
E(X)XX15-X E(X)XX16-X E(X)XX18M(1) E(X)XX18-X	EXX15-X EXX16-X EXX18M(1) EXX18-X	3/32	2.5	12 or 14	300 or 350	1/8	3	10 or 12	250 or 300	V, OH	3/16 max.	5.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V, OH	1/4 max.	6.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V, OH	5/16 max.	8.0 max.
		3/16	5.0	14	350	3/8	10	12	300	H	3/16 min.	5.0 min..
		7/32	–	14 or 18	350 or 450	1/2	12	12 or 16	300 or 400	H	1/4 min.	6.0 min.
		1/4	6.0	18	450	1/2	12	16	400	H	5/16 min.	8.0 min.
E7020-X E7027-X	E4920-X E4927-X	1/8	3.2	14	350	1/4	6	12	300	H	1/8 min.	3.0 min.
		5/32	4.0	14	350	3/8	10	12	300	H	3/16 min.	5.0 min.
		3/16	5.0	14 or 18	350 or 450	3/8	10	12 or 16	300 or 400	H	1/4 min.	6.0 min.
		7/32	–	18 or 28	450 or 700	1/2	12	16 or 26	400 or 650	H	1/4 min.	6.0 min.
		1/4	6.0	18 or 28	450 or 700	1/2	12	16 or 26	400 or 650	H	5/16 min.	8.0 min.
		5/16	8.0	18 or 28	450 or 700	1/2	12	16 or 26	400 or 650	H	5/16 min.	8.0 min.
E(X)XX45-P2	EXX45-P2	3/32	2.5	14	350	1/8	3	10 or 12	250 or 300	V-down, OH	3/16 max.	5.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V-down, OH	1/4 max.	6.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V-down, OH	5/16 max.	8.0 max.
		—	4.5	14	350	3/8	10	12	300	V-down, OH	1/4 min.	6.0 min.

[a] The letters "(X)XX" ["XX"] used in the classification designations in this table represent the various strength levels, 70, 80, 90, 100, 110, and 120 [49, 55, 62, 69, 76, and 83], of the weld metal. The letter suffix "X" as used in this table is defined in Note a of Table 1.

[b] See Figure 4.

[c] A starting tab, or a longer test assembly shall be used to ensure that the end of the first bead is more than 4 in [100 mm] from the end of the test assembly.



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

Figure 6—Welding Positions for Fillet Weld Test Assemblies

Table 9
Radiographic Soundness Requirements

AWS Classification[a]		
A5.5	**A5.5M**	**Radiographic Standard[b,c]**
E(X)XX15-X	EXX15-X	Grade 1
E(X)XX16-X	EXX16-X	
E(X)XX18-X	EXX18-X	
E7020-X	E4920-X	
E(X)XX18M(1)	EXX18M(1)	
E(X)XX45-P2	EXX45-P2	
E(X)XX10-X	EXX10-X	Grade 2
E(X)XX11-X	EXX11-X	
E(X)XX13-G	EXX13-G	
E7027-X	E4927-X	

[a] The letters "(X)XX" ["XX"] used in the classification designations in this table stand for the various strength levels 70, 80, 90, 100, 110, and 120 [49, 55, 62, 69, 76, and 83] of electrodes. The letter suffix "X" as used in this table stands for the suffixes A1, B1, B2, etc. (see Table 2).

[b] See Figure 7.

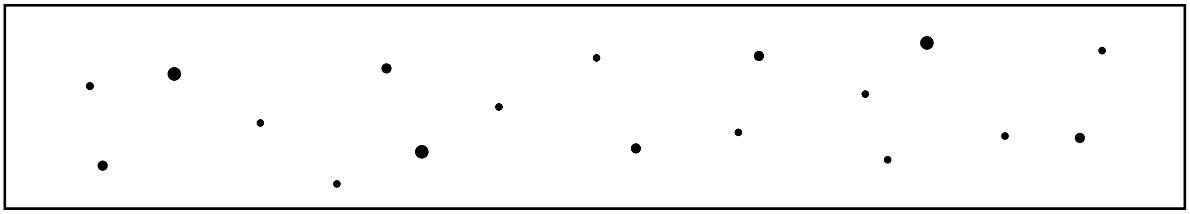
[c] The radiographic soundness obtainable under actual industrial conditions employed for various electrode classifications is discussed in A6.11.1 in Annex A.

[12.5 mm]. For specimens machined from 1/2 in [12 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, tension test specimens to be tested in the as-welded condition may be aged at 200°F to 220°F [90°C to 105°C] for up to 48 hours, then allowed to cool to room temperature. If the specimen is aged, that fact, together with the manner of aging, shall be recorded on the test certificate. Refer to A6.3 for a discussion on the purpose of aging. 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 (ISO 14344 MOD).

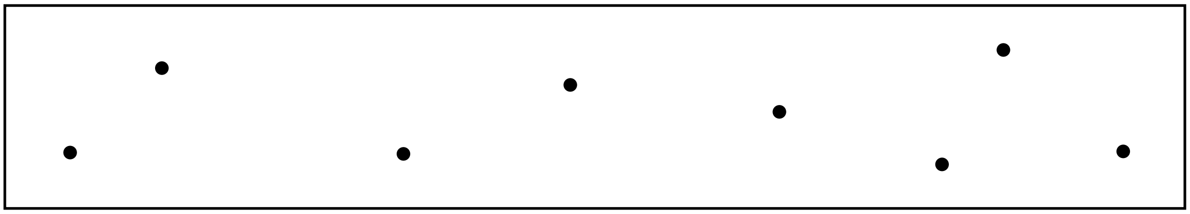
12.3 The aged and unaged specimens shall be tested in the manner described in the Tension Test section of AWS B4.0 or AWS B4.0M.

12.4 Results of the tension test shall meet the requirements specified in Table 3.



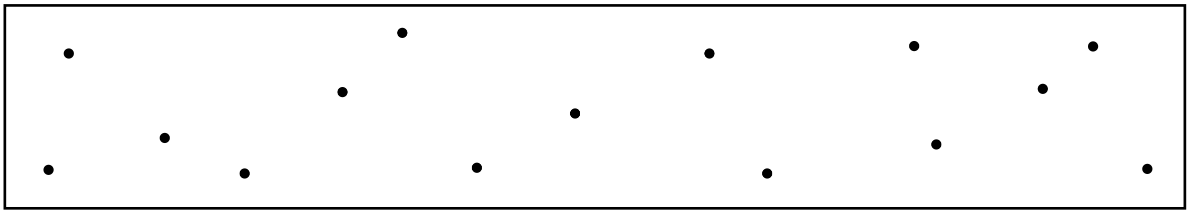
(A) ASSORTED ROUNDED INDICATIONS

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



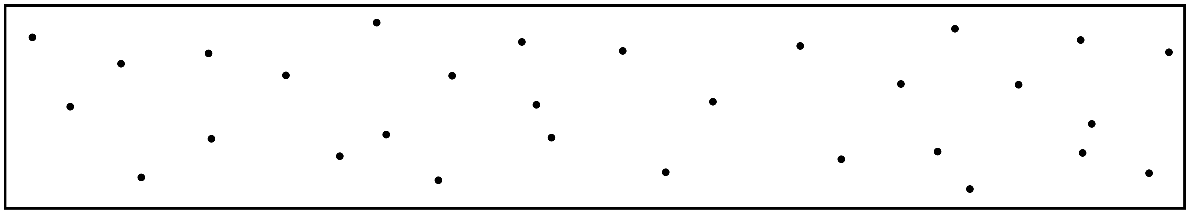
(B) LARGE ROUNDED INDICATIONS

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



(C) MEDIUM ROUNDED INDICATIONS

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



(D) SMALL ROUNDED INDICATIONS

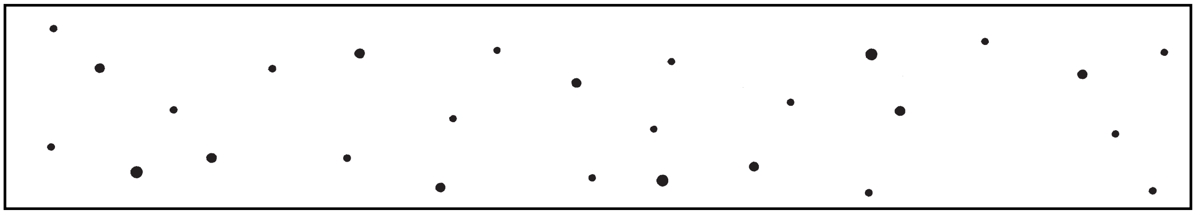
SIZE: 1/64 in [0.4 mm] TO 1/32 in [0.8 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 30.

Notes:

1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph, shall be used for determining conformance to these radiographic standards.
2. Since these are test welds 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.

Source: AWS A5.1/A5.1M:2004, ERRATA, Figure 7 on page 16.

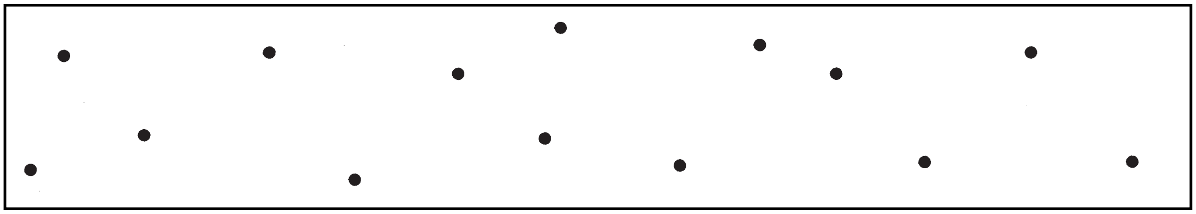
Figure 7A—Radiographic Acceptance Standards for Rounded Indications (Grade 1)



(A) ASSORTED ROUNDED INDICATIONS

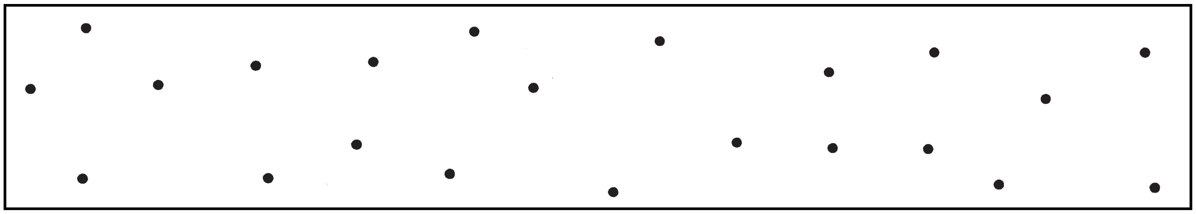
SIZE: 1/64 in [0.4 mm] TO 5/64 in [2.0 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 27, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE (1/16 in [1.6 mm] TO 5/64 in [2.0 mm] IN DIAMETER OR IN LENGTH) INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM (3/64 in [1.2 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH) INDICATIONS = 8.
MAXIMUM NUMBER OF SMALL (1/64 in [0.4 mm] TO 3/64 in [1.2 mm] IN DIAMETER OR IN LENGTH) INDICATIONS = 16.



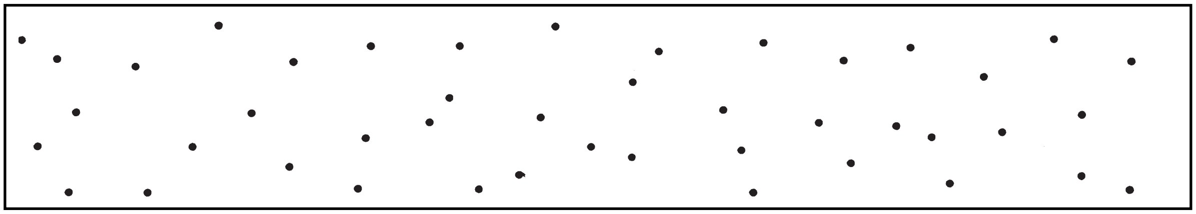
(B) LARGE ROUNDED INDICATIONS

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 = 14.



(C) 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 = 22.



(D) 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 = 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.

Source: AWS A5.1/A5.1M:2004, ERRATA, Figure 7 on page 17.

Figure 7B—Radiographic Acceptance Standards for Rounded Indications (Grade 2)

13. Impact Test

13.1 Five full-size Charpy V-notch impact test specimens, as specified in the Fracture Toughness Test section of AWS B4.0 or AWS B4.0M, shall be machined from the test assembly shown in Figure 3 or 5, for those classifications for which impact testing is required in Table 5. The Charpy V-notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50X magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the Fracture Toughness Test section of AWS B4.0 or AWS B4.0M. *The test temperature shall be at or below the temperature specified in Table 4 for the classification under test. The actual temperature used shall be listed on the certification documentation when issued.*

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than the single value indicated in Table 4, and the average of the three shall not be less than the required average energy level.

14. Fillet Weld Test

14.1 The fillet weld test, when required in Table 5, shall be made in accordance with the requirements of 9.5 and Figure 4. The entire face of the completed fillet shall be examined visually. It shall be free of cracks, overlap, slag, and porosity, and shall be substantially free of undercut. An infrequent short undercut up to 1/32 in [0.8 mm] in depth shall be allowed. After the visual examination, a specimen containing approximately 1 in [25 mm] of the weld (in the lengthwise direction) shall be prepared as shown in Figure 4. One cross-sectional surface of the specimen shall be polished, etched, and then examined as required in 14.2.

14.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 8, and the leg lengths and convexity of the fillet shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement (see Figure 8). These dimensions shall meet the requirements in Table 8 for fillet size, and Table 10 for convexity and permissible difference in the length of the legs.

14.3 The remaining two sections of the test assembly shall be broken longitudinally through the fillet weld by a force exerted as shown in Figure 9. When necessary, to facilitate fracture through the fillet, one or more of the following procedures may be used:

(1) A reinforcing bead, as shown in Figure 9A, may be added to each leg of the weld.

(2) The position of the web on the flange may be changed, as shown in Figure 9B.

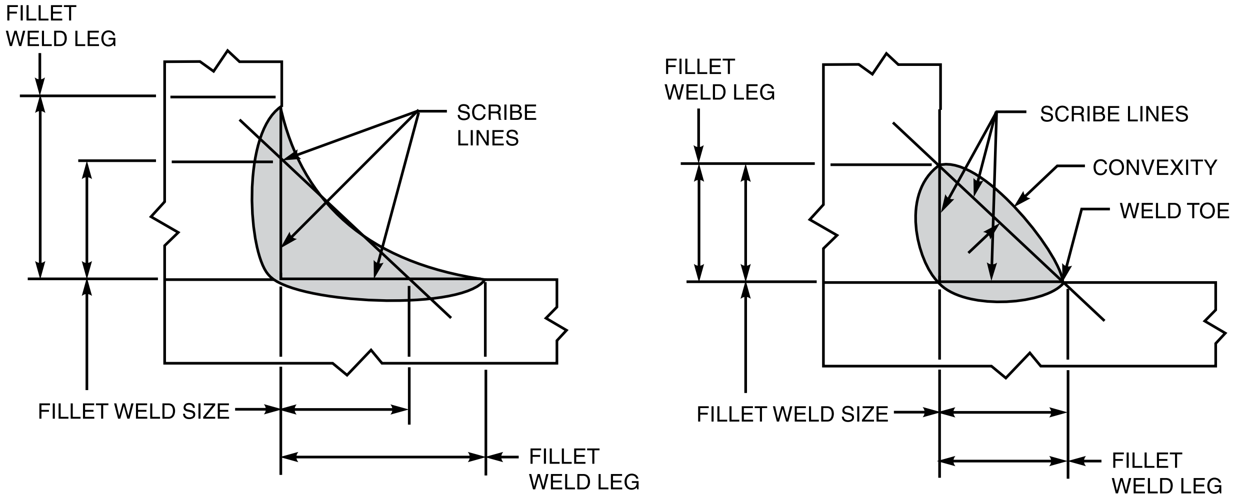
(3) The face of the fillet may be notched, as shown in Figure 9C.

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 specimens required for retest in Clause 8, does not apply.

14.4 The fractured surfaces shall be visually examined without magnification. The fracture surface shall be free of cracks. Incomplete fusion at the weld root shall not be greater than 20% of the total length of the weld. There shall be no continuous length of incomplete fusion greater than 1 in [25 mm] as measured along the weld axis, except for electrodes of E(X)XX13-G classifications. Fillet welds made with electrodes of these classifications may exhibit incomplete penetration through the entire weld length. They may also exhibit incomplete fusion, which shall at no point exceed 25% of the smaller leg of the fillet weld.

15. Moisture Test

15.1 The moisture content of the covering of the electrode, when required in Table 5, shall be determined by any suitable method. In case of dispute, the method described in AWS A4.4M shall be the referee method.



(A) CONCAVE FILLET WELD **(B) CONVEX FILLET WELD**

Notes:

1. Fillet weld size is the leg lengths of the largest isosceles right triangle that can be inscribed within the fillet weld cross section.
2. Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes.
3. Fillet weld leg is the distance from the joint root to the toe of the fillet weld.

Source: AWS A5.5/A5.5M:2006, Figure 7.

Figure 8—Dimensions of Fillet Welds

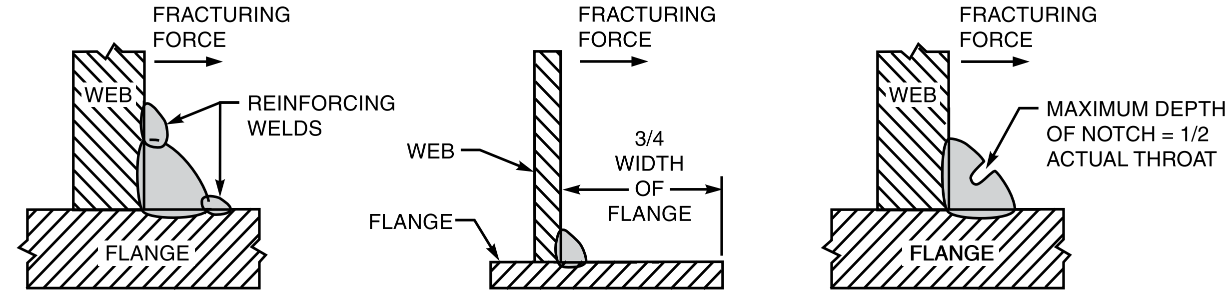
Table 10
Dimensional Requirements for Fillet Weld Usability Test Specimens

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in	**mm**	**in**	**mm**	**in**	**mm**
1/8, or less	3.0, or less	3/64	1.0	1/32	1.0
9/64	3.5	3/64	1.0	3/64	1.0
5/32	4.0	3/64	1.0	3/64	1.0
11/64	4.5	1/16	1.5	1/16	1.5
3/16	5.0	1/16	1.5	1/16	1.5
13/64	5.0	1/16	1.5	5/64	2.0
7/32	5.5	1/16	1.5	5/64	2.0
15/64	6.0	1/16	1.5	3/32	2.5
1/4	6.5	1/16	1.5	3/32	2.5
17/64	6.5	1/16	1.5	7/64	3.0
9/32	7.0	1/16	1.5	7/64	3.0
19/64	7.5	5/64	2.0	1/8	3.0
5/16	8.0	5/64	2.0	1/8	3.0
21/64	8.5	5/64	2.0	9/64	3.5
11/32	8.5	5/64	2.0	9/64	3.5
23/64	9.0	5/64	2.0	5/32	4.0
3/8, or more	9.5, or more	5/64	2.0	5/32	4.0

15.2 The electrodes shall be tested without conditioning, unless the manufacturer recommends otherwise. 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 test record. The moisture content shall not exceed the limit specified in Table 11, for the classification under test.

16. Absorbed Moisture Test

16.1 In order for a low-hydrogen electrode to be designated as low-moisture-absorbing, with the “R” suffix designator, sufficient electrodes shall be exposed to an environment of 80° F [27 °C] and 80% relative humidity (RH) for a period of not less than 9 hours by any suitable method. In case of dispute, the exposure method described in 16.2 through 16.6 shall



(A) REINFORCING WELDS **(B) OFFSET OF WEB** **(C) NOTCHING**

Source: AWS A5.5/A5.5M:2006, Figure 8.

Figure 9—Alternate Methods for Facilitating Fracture of the Fillet Weld

Table 11
Moisture Content Limits for Low-Hydrogen Electrode Coverings

AWS Electrode Designation[a]		Limit of Moisture Content, % by weight max.	
A5.5	**A5.5M**	**As-Received or Reconditioned[b]**	**As-Exposed[c]**
E70XX-X, E70XX-X HZ	E49XX-X, E49XX-X HZ	0.4	Not specified
E70XX-X R, E70XX-X HZ R	E49XX-X R, E49XX-X HZ R	0.3	0.4
E80XX-X, E80XX-X HZ	E55XX-X, E55XX-X HZ	0.2	Not specified
E80XX-X R, E80XX-X HZ R	E55XX-X R, E55XX-X HZ R	0.2	0.4
E90XX-X, E90XX-X HZ E9018M, E9018M HZ	E62XX-X, E62XX-X HZ E6218M, E6218M HZ	0.15	Not specified
E90XX-X R, E90XX-X HZ R E9018M R, E9018M HZ R	E62XX-X R, E62XX-X HZ R E6218M R, E6218M HZ R	0.15	0.4
E100XX-X, E100XX-X HZ E10018M, E10018M HZ	E69XX-X, E69XX-X HZ E6918M, E6918M HZ	0.15	Not specified
E100XX-X R, E100XX-X HZ R E10018M R, E10018M HZ R	E69XX-X R, E69XX-X HZ R E6918M R, E6918M HZ R	0.15	0.4
E110XX-G, E110XX-G HZ E11018M, E11018M HZ	E76XX-G, E76XX-G HZ E7618M, E7618M HZ	0.15	Not specified
E110XX-G R, E110XX-G HZ R E11018M R, E11018M HZ R	E76XX-G R, E76XX-G HZ R E7618M R, E7618M HZ R	0.15	0.4
E120XX-G, E120XX-G HZ E12018M, E12018M HZ	E83XX-G, E83XX-G HZ E8318M, E8318M HZ	0.15	Not specified
E120XX-G R, E120XX-G HZ R E12018M R, E12018M HZ R	E83XX-G R, E83XX-G HZ R E8318M R, E8318M HZ R	0.15	0.4
E12018M1, E12018M1 HZ	E8318M1, E8318M1 HZ	0.10	Not specified
E12018M1 R, E12018M1 HZ R	E8318M1 R, E8318M1 HZ R	0.10	0.4

[a] See Clause 16, Figure 1, and Table 12.

[b] As-received or reconditioned electrode coverings shall be tested as specified in Clause 15.

[c] As-exposed electrode coverings shall be treated with a moist environment as specified in 16.2 through 16.6 before being tested as specified in 16.1.

be the referee method. The moisture content of the electrode covering on the low-moisture-absorbing, low-hydrogen electrode {E(X)XX15-X R; E(X)XX16-X R; E(X)XX18-X R; E(X)XX45-P2 R; and E(X)XX18M(1) R} shall be determined by any suitable method. In case of dispute, the method described in AWS A4.4M shall be the referee method for the determination of moisture content. The moisture content of the exposed covering shall not exceed the maximum specified moisture content for the designated electrode and classification in Table 11.

16.2 An electrode sample of the smallest and largest sizes of "R" designated electrodes 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 test record. Conditioning of electrodes after exposure is not permitted.

16.3 The electrode sample shall be exposed in a suitably calibrated and controlled environmental chamber for 9 hours minimum at 80 °F, +5 °F, –0 °F, [27 °C, +3 °C, –0 °C,] and 80%, +5%, –0% relative humidity (RH).

16.4 The environmental chamber shall meet the following design requirements:

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

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

(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 airspeed 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.

16.5 The exposure procedure shall be as follows:

(1) The electrode sample taken from previously unopened packages, or from a reconditioned lot, shall be heated 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.

(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 15.

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

17. Diffusible Hydrogen Test

17.1 The smallest and largest sizes of an electrode to be identified by an optional supplemental diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results that satisfy the requirements of Table 12, the appropriate diffusible hydrogen designator may be added at the end of the classification.

Table 12
Diffusible Hydrogen Requirements for Weld Metal and Optional Supplemental Designators

AWS Classification	Diffusible Hydrogen Designator[a]	Diffusible Hydrogen Content Average, Maximum[b] mL(H_2)/100 g Deposited Metal
E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, E(X)XX18M(1), or E(X)XX45-P2	H16	*16*
	H8	*8*
	H4	*4*

[a] Diffusible hydrogen testing of low-hydrogen electrode classifications is only required when the diffusible hydrogen designator is added to the classification as specified in Figure 1. See Clause 17.

[b] The lower average diffusible hydrogen levels (H8 and H4) may not be available in all low-hydrogen classifications.

17.2 Testing shall be done without conditioning of the electrode, unless the manufacturer recommends otherwise. 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 test record.

17.3 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.[10]

17.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the actual test results for an electrode meet the requirements for the lower or lowest hydrogen designator, as specified in Table 12, the electrode also meets the requirements for all higher hydrogen designators in Table 12 without need to retest.

18. 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.

19. Standard Sizes and Lengths

Standard sizes (diameter of the core wire) and lengths of electrodes and their respective tolerances are specified in 3.1 of AWS A5.02/A5.02M:2007, and shown in Table 13.

20. Core Wire and Covering

Requirements for the core wire and covering, including concentricity requirements, are specified in 3.2 of AWS A5.02/A5.02M:2007.

21. Exposed Core

21.1 *Requirements for the grip end of each electrode are specified in 3.3.1 of AWS A5.02/A5.02M:2007.*

21.2 *Requirements for the arc end of each electrode are specified in 3.3.2 of AWS A5.02/A5.02M:2007.*

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[10] See A8.1.4 in Annex A.

Table 13
Standard Sizes and Lengths

Standard Size, (Core Wire Diameter[d])			Standard Length[a,b,c]			
			All Classifications except E7020-Al [E4920-A1], E7020-G [E4920-G], E7027-Al [E4927-A1], and E7027-G [E4927-G]		E7020-Al [E4920-A1], E7020-G [E4920-G], E7027-Al [E4927-A1], and E7027-G [E4927-G]	
in	**in**	**mm**	**in**	**mm**	**in**	**mm**
3/32[e]	*(0.093)*	—	12 or 14	300 or 350	12	300
—	*(0.098)*	*2.5*[e]	12 or 14	300 or 350	12	300
1/8	*(0.125)*	*3.2*	14	350	14	350
5/32	*(0.156)*	*4.0*	14	350	14	350
—	*(0.177)*	*4.5*[e]	14	350	—	—
3/16	*(0.187)*	—	14	350	14 or 18	350 or 450
—	*(0.197)*	*5.0*	14	350	14 or 18	350 or 450
7/32[e]	*(0.218)*	—	14 or 18	350 or 450	18 or 28	450 or 700
—	*(0.236)*	*6.0*	14 or 18	350 or 450	18 or 28	450 or 700
1/4[e]	*(0.250)*	—	18	450	18 or 28	450 or 700
5/16[e]	*(0.312)*	*8.0*[e]	—	—	18 or 28	450 or 700

[a] Tolerance on the length shall be ± 1/4 in [±10 mm].

[b] In all cases, end gripping is standard.

[c] Other lengths are acceptable and shall be as agreed upon between the purchaser and supplier.

[d] Tolerance on the core wire diameter shall be ± 0.002 in [±0.05 mm]. Electrodes produced in sizes other than those shown may be classified. Please see Note c of Table 5.

[e] These diameters are not manufactured in all electrode classifications (See Table 5).

22. Electrode Identification

22.1 *All electrodes shall be identified (imprinted) as specified in 3.4.1 to 3.4.4 of AWS A5.02/A5.02M:2007.*

22.2 *In lieu of imprinting, electrodes may be identified by the alternate method specified as option 2 in 3.4.5 of AWS A5.02/A5.02M:2007.*

23. Packaging

Electrodes shall be packaged as specified in 3.5.1 and 3.5.2 of AWS A5.02/A5.02M:2007. In addition, E(X)XX18M(1) electrodes shall be packaged in hermetically sealed containers. These hermetically sealed containers shall be capable of passing the test specified in 3.5.3.1 of AWS A5.02/A5.02M:2007.

24. Marking of Packages

24.1 *The product information specified in 3.6 of AWS A5.02/A5.02M:2007 (as a minimum) shall be legibly marked on the outside of each unit package.*

24.2 *The appropriate precautionary information*[11] *as given in ANSI Z49.1 (as a minimum), or its equivalent, shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package.*

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[11] Typical example "warning labels" *and precautionary information* are shown in figures in ANSI Z49.1 for some common or specific consumables using certain processes.

Annex A (*Informative*)

Guide to AWS Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

This annex is not part of AWS A5.5/A5.5M: 2014, *Specification for Low-Alloy 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 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 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 (or three) digits, 70 (or 110) [49 (or 76)], for example, designate tensile strength of at least 70 (or 110) ksi [490 (or 760) MPa] of the weld metal, welded and postweld heat treated (if required) in accordance with the test assembly preparation section of this specification. The third (or fourth) digit designates position usability that will allow satisfactory welds to be produced with the electrode.

Thus, the "1," as in E7018-C2L (or E11018M) [E4918-C2L (or E7618M)], means that the electrode is usable in all positions (flat, horizontal, vertical, and overhead). The "2," as in E7020-A1 [E4920-A1], 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 E8045-P2 [E5545-P2] designates that the electrode is usable in the flat, horizontal, and overhead positions, and is especially suitable for vertical welding with downward progression. 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.

With the exception of the military-similar electrodes (i.e., E(X)XX18M(1)), the classifications in this specification also include a suffix designator, separated by a hyphen from the tensile strength and usability designators. This composition designator, such as A1, B3, or W1, immediately identifies the classification as different from those in AWS A5.1/A5.1M, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.* The composition designator identifies the chemical composition of the weld metal as specified in Table 2. For example, an "A1" composition designator identifies the electrode as one that produces carbon-molybdenum steel weld metal, when the electrode is deposited using shielded metal arc welding.

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 upon between the purchaser and supplier. Certain low-hydrogen electrodes may have optional designators. An optional supplemental designator "HZ" following the composition designator indicates an average diffusible hydrogen content of not more than "Z" mL/100 g 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 12, 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 17, Figure 1, and Table 12.

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 hydrogen electrodes. See Clause 16, and Note d to Table 1, as well as Figure 1 and Table 11.

A2.3 "G" Classification

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

A2.3.2 The point of difference (although not necessarily the amount of 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 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 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 have to establish with that supplier just what the testing procedure and the acceptance requirements are to be, for that test. The purchaser may want to incorporate that information (via AWS A5.01M/A5.01 (ISO 14344 MOD)) in the purchase order.

A2.3.3 ***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 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 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.

(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. The requester shall also provide written assurance to AWS that:*

i. No patent rights will be enforced against anyone using the patent to comply with the standard;

or

ii. The owner will make licenses available to anyone wishing to use the patent to comply with the standard, without compensation or for reasonable rates, with reasonable terms and conditions demonstrably free of any unfair competition.

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 Committee on Filler Metals and Allied Materials, nor the relevant Subcommittee is required to consider the validity of any patent or patent application.

(4) 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 the Chair of the particular Subcommittee involved.

(d) File the original request.

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

(5) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requester of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to be 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.

(6) 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.

A2.4 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 identical, or close to, the AWS designation. Annex Table A1 shows the classifications and designations, appearing in ISO specifications, equivalent to filler metal classifications included in this specification.

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

Table A1
Comparison of Classifications

ISO						AWS	
2560A[a]	**2560B[a]**	**3580A[b]**	**3580B[b]**	**18275A[c]**	**18275B[c]**	**A5.5**	**A5.5M**
Carbon-Molybdenum Steel Electrodes							
E38xMo	E49xx–1M3	EMo x	E49xx-MM3			E70xx-A1	E49xx-A1
Manganese-Molybdenum Steel Electrodes							
	E55xx–3M2					E80xx-D1	E55xx-D1
					E69xx–4M2	E100xx-D2	E69xx-D2
				E550xMnMo	E62xx–3M3	E90xx-D3	E62xx-D3
Chromium-Molybdenum Steel Electrodes							
		ECrMo0.5	E55xx-CM			E80xx-B1	E55xx-B1
		ECrMo1	E55xx–1CM			E80xx-B2	E55xx-B2
		ECrMo1L	E55xx–1CML			E70xx-B2L	E49xx-B2L
		ECrMo2	E62xx–2C1M			E90xx-B3	E62xx-B3
		ECrMo2L	E55xx–2C1ML			E80xx-B3L	E55xx-B3L
			E55xx–2CM1L			E80xx-B4L	E55xx-B4L
			E55xx-C1M			E80xx-B5	E55xx-B5
		ECrMo5	E55xx–5CM			E80xx-B6	E55xx-B6
		ECrMo5	*E62xx–5CM*			*E90xx-B6*	*E62xx-B6*
			E55xx–5CML			E80xx-B6L	E55xx-B6L
			E55xx–7CM			E80xx-B7	E55xx-B7
			E55xx–7CML			E80xx-B7L	E55xx-B7L
		ECrMo9	E55xx–9C1M			E80xx-B8	E55xx-B8
			E55xx–9C1ML			E80xx-B8L	E55xx-B8L
		—	—			*E90xx-B23*	*E62xx-B23*
		—	—			*E90xx-B24*	*E62xx-B24*
		ECrMo91	E62xx–9C1MV			E90xx-*B91*	E62xx-*B91*
		—	—			*E90xx-B92*	*E62xx-B92*
Nickel Steel Electrodes							
	E55xx-N5					E80xx-C1	E55xx-C1
	E49xx-N5					E70xx-C1L	E49xx-C1L
	E55xx-N7					E80xx-C2	E55xx-C2
	E49xx-N7					E70xx-C2L	E49xx-C2L
E38x1Ni	E55xx-N2					E80xx-C3	E55xx-C3
	E49xx-N2					E70xx-C3L	E49xx-C3L
	E55xx-N3					E80xx-C4	E55xx-C4
	E6215-N13L					E90xx-C5L	E62xx-C5L
Nickel-Molybdenum Steel Electrodes							
E38x1NiMo	E55xx-N2M3					E80xx-NM1	E55xx-NM1
—	—					*E90xx-NM2*	*E62xx-NM2*
Military-Similar Electrodes							
E550x1,5NiMo	E6218-N3M1					E9018M	E6218M
	E6918-N3M2					E10018M	E6918M
				E69xMn2NiCrMo	E7618-N4CM2	E11018M	E7618M
				E69xMn2Ni1CrMo	E8318-N4C2M2	E12018M	E8318M
						E12018M1	E8318M1
Weathering Alloy Steel Electrodes							
	E49xx-NCC2					E7018-W1	E4918-W1
	E55xx-NCC1					E8018-W2	E5518-W2

[a] ISO 2560, *Welding consumables — Covered electrodes for manual metal arc welding of nonalloy and fine grain steels — Classification.*

[b] ISO 3580, *Welding consumables — Covered electrodes for manual metal arc welding of creep-resisting steels — Classification.*

[c] ISO 18275, *Welding consumables — Covered electrodes for manual metal arc welding of high-strength steels — Classification.*

F, Table 1, of AWS A5.01M/A5.01 (ISO 14344 MOD). Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations, and optional designators, if applicable, on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all the requirements of the specification. The only testing requirement implicit in this *certification* is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that 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 (ISO 14344 MOD).

A5. Ventilation During Welding

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

(1) Dimensions of the space in which 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

(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 {E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, E(X)XX18M(1), and E(X)XX45-P2} 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 in 24 hours to 48 hours at 200°F to 220°F [95°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 strengths remain relatively unchanged.

This specification permits aging of the test specimens of cellulosic electrodes at 200°F to 220°F [95°C to 105°C] for 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. Even weld metal produced from the same classification and the same welding procedure but with different postweld heat-treatment holding temperatures or times at holding temperatures will have different strength levels. With low-alloy steel weld metals produced by the classifications in this specification, postweld heat treatment can produce tempering (softening) or secondary hardening of the weld metal. It is recommended that users conduct their own evaluation of the welding procedure to be used in production in order to verify that the weld metal properties obtained in actual production are those desired.

A6.6 Preheat and interpass minimum temperatures also have a significant effect on the strength levels attained with certain low-alloy steel weld metals. These weld metals are affected by rapid cooling rates which tend to produce more martensitic or bainitic microstructures. These microstructures will often exhibit higher yield and tensile strengths with a decrease in ductility. The cooling rate can be retarded by utilizing a higher preheat and interpass temperature. The preheat and interpass temperature ranges given in Table 7 of this specification are adequate for the preparation of the test assemblies. However, in actual production, users are encouraged to test their own procedures to verify that they have selected preheat and interpass temperatures which will produce desirable results in production.

A6.7 Heat input usually is measured as Joules per linear inch, J/in [kJ/mm]. However, in this specification the heat input is governed in the preparation of the test assembly by the bead sequence and the total weld layer count upon completion of the groove weld test assembly. Heat input will have a significant effect on the strength levels attained in many of the higher strength weld metals produced from the electrode classifications in this specification. For instance, weld metal produced with E11018M [E7618M] electrode at a 35 000 J/in [1.38 kJ/mm] heat input may exceed 110 ksi [760 MPa] yield strength in the as-welded condition and 95 ksi [655 MPa] yield strength after postweld heat treatment. On the other hand, if the heat input is raised to 55 000 J/in [2.17 kJ/mm], this same electrode will produce weld metal that does not exceed 110 ksi [760 MPa] as-welded yield strength and after postweld heat treatment may be below 95 ksi [655 MPa] yield strength. It is, therefore, recommended that, if the user is going to use either lower or higher heat inputs than normally used for classification testing of electrodes, the user should test the welding procedure to be used to determine that the strength levels expected will be attained in production. This is especially true if out-of-position welding is to be performed.

A6.8 Electrodes that meet all the requirements of any given classification may be expected to have similar characteristics (the "G" classifications notwithstanding). Certain minor differences continue to exist from one brand to another due to differences in preferences that exist regarding specific operating characteristics.

A6.9 Since electrodes within a given classification have similar operating characteristics and mechanical properties, the user can usually limit study of available electrodes to those within a single classification after determining which classification best suits the user's particular requirements.

A6.10 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 would best fulfill a particular need. The information included in Annex 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 the performance requirements for the intended applications under the specific fabrication conditions in use.

A6.11 Some important tests for measuring major electrode characteristics are as follows:

A6.11.1 Radiographic Test. Nearly all the low-alloy 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 Table 9 are not necessarily indicative of the average radiographic soundness to be expected in production use. Electrodes of the E(X)XX10-X, E(X)XX11-X, and E7020-X 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 E(X)XX15-X, E(X)XX16-X, E(X)XX18M(1), E(X)XX18-X, and E(X)XX45-P2 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. E(X)XX13-X electrodes usually produce the best radiographic soundness in welding small, thin parts.

E7027-X [E4927-X] electrodes produce welds which may be either quite good or rather inferior in radiographic soundness. The tendency seems to be in the latter direction.

A6.11.2 Fillet Weld Test. This test is included as a means of demonstrating the usability of an electrode. This 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.

A6.11.3 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.

A6.12 Electrode Covering Moisture Content and Conditioning

A6.12.1 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.

A6.12.2 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 that has been designed to provide the degree of moisture protection considered necessary for the type of covering involved.

A6.12.3 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 hour 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 A2.

A6.12.4 Cellulosic coverings for E(X)XX10-X and E(X)XX11-X classifications 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 A2).

A6.13 Core Wire. The core wire for all the electrodes in this specification is usually (but not always) a mild steel having a typical composition which may differ significantly from that of the weld metal produced by the covered electrode.

Table A2
Typical Storage and Drying Conditions for Covered Arc Welding Electrodes

AWS Classifications		Storage Conditions[a]		
A5.5	**A5.5M**	**Ambient Air**	**Holding Ovens**	**Drying Conditions[b]**
E(X)XX10-X E(X)XX11-X	EXX10-X EXX11-X	Ambient temperature	Not recommended	Not recommended
E(X)XX13-G E7020-X E7027-X	EXX13-G E4920-X E4927-X	60°F–100°F [15°C–40°C] 50% max. relative humidity	100°F–120°F [40°C–50°C]	250°F–300°F [125°C–150°C] 1 hour at temperature
E(X)XX15-X E(X)XX16-X E(X)XX18M(1) E(X)XX18-X E(X)XX45-P2	EXX15-X EXX16-X EXX18M(1) EXX18-X EXX45-P2	Not recommended[c]	250°F–300°F [125°C–150°C]	500°F–800°F [250°C–425°C] 1 hour at temperature

[a] After removal from manufacturer's packaging.

[b] Because of inherent differences in covering compositions the manufacturer should be consulted for the exact drying conditions.

[c] 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.

A6.14 Coverings

A6.14.1 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. For example, quite large quantities of chromium and ferro-chromium powders can be added in such alloy designations as B7, B8, and *B91*.) 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.

A6.14.2 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.

A6.14.3 The E70XX-X [E49XX-X] electrodes were included in this specification to recognize the lowest strength levels obtained with low-alloy steel electrodes, as well as to recognize the industry demand for low-alloy electrodes with 70 ksi [490 MPa] minimum tensile strength. Unlike the E70XX [E49XX] classifications in AWS A5.1/A5.1M, these electrodes do contain deliberate alloy additions, and some are required to meet minimum tensile properties after postweld heat treatment.

A6.14.4 Low-hydrogen electrodes have mineral coverings, which are high in calcium carbonate and other ingredients that are low in moisture and organic materials and hence "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 cracks also may occur. These cracks are caused by the hydrogen absorbed from the arc atmosphere. Although these cracks do not generally occur in carbon steels which have low carbon content, they may occur when welding higher carbon or low-alloy steels with other than low-hydrogen electrodes and without precautions, such as increased preheat temperatures and postweld heating. For more information on special tests for low-hydrogen electrodes, see Clauses 16 and 17 in the specification and A8.2 and A8.3 in this Annex.

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.

A6.15 Amperage Ranges. Table A3 gives amperage ranges that are satisfactory for most electrode classifications. When welding in the vertical position with upward progression, currents near the lower limit of the range are generally used.

A7. Description and Intended Use of Electrodes

A7.1 Chemical Composition. The chemical composition of the weld metal produced is often the primary consideration for electrode selection. Together with appropriate heat treatments, each composition can achieve a wide range of corrosion resistance and mechanical properties at various service temperatures. It is usually desirable for weld metal to match the chemical composition and the mechanical properties of the base metal as closely as possible. In fact, many of the electrodes classified to this specification have been developed for specific base metal grades or classes. If an optimum match is not possible, engineering judgment together with weld testing may be required to select the most suitable electrodes.

Table 2 provides detailed weld metal chemical composition requirements for each electrode classification. Tables 3 and 4 list the mechanical properties of the weld metal when the electrode is used in the flat downhand position, and the weldment is subjected to the Postweld Heat-Treatment (PWHT) requirements in Tables 3 and 7. It should be noted that changes in welding position, welding variables, or heat treatment can be expected to affect the mechanical properties. However, except for the effects of dilution, the chemical composition can be expected to remain reasonably unchanged.

The suffixes, which are part of each alloy electrode classification, identify the chemical composition of the weld metal produced by the electrode. The following paragraphs highlight the differences between these electrodes and electrode groups and indicate typical applications.

A7.1.1 E70XX-A1 [E49XX-A1] (C-Mo Steel) Electrodes. These electrodes are similar to the E70XX [E49XX] carbon steel electrodes classified in AWS A5.1/A5.1M, except that 0.5% molybdenum has been added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance; however, it may reduce the notch toughness of the weld metal. Typical applications include the welding of C-Mo steel base metals such as ASTM A204 plate and A335-P1 pipe.

A7.1.2 EXXXX-BX and EXXXX-BXL (Cr-Mo Steel) Electrodes. These low-hydrogen electrodes produce weld metal that *nominally* contains between 0.5% and *10%* chromium and *up to 1.25%* molybdenum. They are designed to produce weld metal for high-temperature service and for matching the properties of the typical Cr-Mo base metals, some of which are shown in Table 6.

For many of these Cr-Mo electrode classifications, low carbon EXXXX-BXL classifications have been established. While regular Cr-Mo electrodes produce weld metal with about 0.08% carbon, the "L-Grades" are limited to a maximum of 0.05% carbon. While the lower percent carbon in the weld metal will improve ductility and lower hardness, it will also reduce the high-temperature strength and creep resistance of the weld metal.

Since all Cr-Mo electrodes produce weld metal which will harden in still air, both preheat and PWHT are required for most applications.

No minimum notch toughness requirements have been established for any of the Cr-Mo electrode classifications. While it is possible to obtain Cr-Mo electrodes with minimum toughness values at ambient temperatures down to 32°F [0°C], specific values and testing must be agreed upon between the purchaser and supplier.

A7.1.2.1 E70XX-B2L [E49XX-B2L] and E80XX-B3L [E55XX-B3L] Electrodes. In AWS A5.5–81, and previous revisions, electrodes classified as E70XX-B2L [E49XX-B2L] were classified as E80XX-B2L [E55XX-B2L]. Likewise, electrodes herein classified as E80XX-B3L [E55XX-B3L] were classified as E90XX-B3L [E62XX-B3L]. The composition ranges in AWS A5.5–96, or the present edition, have not been changed from A5.5–81 for the corresponding classifications. The strength designations and room-temperature strength requirements after postweld heat treatment have been reduced to reflect the fact that commercial products have been producing marginal tensile strength results in classification tests over many years. The base metals with which these classifications are generally used have lower strength requirements than were reflected by the former electrode classifications. Therefore, unless the higher strength

Table A3
Typical Amperage Ranges for Covered Arc Welding Electrodes

Electrode Diameter		E(X)XX10-X, E(X)XX11-X	E(X)XX13-G	E7020-X [E4920-X]	E7027-X [E4927-X]	E(X)XX15-X, E(X)XX16-X	E(X)XX18M(1), E(X)XX18-X	E(X)XX45-P2
in	mm							
3/32	2.5	40 to 80	45 to 90	—	—	65 to 110	70 to 100	80 to 110
1/8	3.2	75 to 125	80 to 130	100 to 150	125 to 185	100 to 150	115 to 155	125 to 160
5/32	4.0	110 to 170	105 to 180	130 to 190	160 to 240	140 to 200	135 to 185	170 to 215
—	4.5	—	—	—	—	—	—	180 to 240
3/16	5.0	140 to 215	150 to 230	175 to 250	210 to 300	180 to 255	200 to 275	—
7/32	—	170 to 250	—	225 to 310	250 to 350	240 to 320	260 to 340	—
1/4	6.0	210 to 320	—	275 to 375	300 to 420	300 to 390	315 to 400	—
5/16	8.0	—	—	—	375 to 475	—	—	—

indicated by the former classifications of these electrodes is specifically necessary for a particular welding procedure, the E70XX-B2L [E49XX-B2L] classifications in this standard should be considered as identical to the corresponding E80XX-B2L [E55XX-B2L] classifications of A5.5–81. Likewise, the E80XX-B3L [E55XX-B3L] classifications in this standard should be considered as identical to the E90XX-B3L [E62XX-B3L] classifications of A5.5–81.

A7.1.2.2 E8015-B6 [E5515-B6] and E8015-B6L [E5515-B6L] Electrodes. The E8015-B6 [E5515-B6] and E8015-B6L [E5515-B6L] electrodes were formerly classified as E502–15 in AWS A5.4–92, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*. The E8016-B6 [E5516-B6] and E8016-B6L [E5516-B6L] were formerly classified as E502–16 in A5.4–92. The E8018-B6 [E5518-B6] and E8018-B6L [E5518-B6L] were not formerly classified, but were produced to the E502 composition ranges in A5.4–92 but with the EXX18 covering of this specification. Similarly, the E80XX-B7(L) [E55XX-B7(L)] classifications were formerly classified as E7Cr-XX in A5.4–92; and the E80XX-B8(L) [E55XX-B8(L)] classifications were formerly classified as E505-XX in A5.4–92.

A7.1.2.3 ***E90XX-B23 [E62XX-B23] Electrodes.*** *E90XX-B23 [E62XX-B23] is a 2.5% Cr–1.5% W–0.2% Mo–0.20% V–0.04% Nb, low-hydrogen electrode designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. In addition to the classification requirements in this specification, impact toughness or high temperature creep strength properties may be determined. Additional testing requirements must be agreed upon between the purchaser and supplier depending upon the application.*

A7.1.2.4 ***E90XX-B24 [E62XX-B24] Electrodes.*** *E90XX-B24 [E62XX-B24] is a 2.5% Cr–1.0% Mo–0.20% V–0.10% Ti–0.04% Nb, low-hydrogen electrode designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. In addition to the classification requirements in this specification, impact toughness or high temperature creep strength properties may be determined. Additional testing requirements must be agreed upon between the purchaser and supplier depending upon the application.*

A7.1.2.5 E90XX-*B91* [E62XX-*B91*] ***(formerly E90XX-B9 [E62XX-B9])*** **Electrodes.** This electrode, *formerly classified as E90XX-B9 [E62XX-B9],* is a 9% Cr–1% Mo, low-hydrogen electrode modified with niobium (columbium) and vanadium, designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.

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

Thermal treatment of this alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation to martensite (M_f) is relatively low. For applications requiring optimal ductility and creep resistance, consideration should be given to allowing the weldment to cool sufficiently to maximize transformation to martensite.

The maximum allowable temperature for postweld heat treatment is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To aid in allowing for an adequate postweld heat treatment, the restriction on Mn +Ni has been imposed (see Table 2, note g). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

A7.1.2.6 E90XX-B92 [E62XX-B92] Electrodes. *E90XX-B92 [E62XX-B92] is a 9% Cr–2% W–0.5% Mo–0.20% V–0.05% Nb, low-hydrogen electrode designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.*

In addition to the classification requirements in this specification, impact toughness or high-temperature creep strength properties may be determined. Due to the influence of various levels of carbon and niobium, testing must be agreed upon between the purchaser and supplier.

Thermal treatment of this alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation to martensite (M_f) is relatively low. For applications requiring optimum ductility and creep resistance, consideration should be given to allowing the weldment to cool to at least 200°F [93°C] before PWHT to maximize transformation to martensite.

The maximum allowable temperature for PWHT is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To ensure proper PWHT results, a restriction on Mn + Ni has been imposed (see Table 2, Note g). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

A7.1.2.7 X-Factor*. A major application of the Cr-Mo steels is in the fabrication of pressure vessels for the petrochemical and power generation industries. Where these materials are subjected to elevated temperatures for extended periods of time, temper embrittlement usually occurs. Temper embrittlement is the migration of certain elements within the material matrix to the grain boundaries over time, resulting in a loss of impact toughness. In 1970, Bruscato*[12] *developed a formula using only the critical elements affecting temper embrittlement, as follows:*

$$X\text{-Factor} = (10\,P + 5\,Sb + 4\,Sn + As)/100$$

with analytical results for the elements in ppm. The industry X-Factor requirement is less than 15. An X-Factor less than 15, combined with low Mn and Si levels, is recommended in industry to minimize temper embrittlement effects.[12]

A7.1.3 EXXXX-CX and EXXXX-CXL (Ni Steel) Electrodes. These low-hydrogen electrodes have been designed to produce weld metal with increased strength without being air-hardenable or with increased notch toughness at temperatures as low as –175 °F [–115 °C]. They have been specified with nickel contents which fall into five nominal levels of 1% Ni, 1.5% Ni, 2.5% Ni, 3.5% Ni, and 6.5% Ni in steel.

With carbon levels of up to 0.12%, strength increases and permits these Ni steel electrodes to be classified as E80XX-CX [E55XX-CX]. However, with lower levels of carbon, low-temperature toughness improves to match the base-metal properties of nickel steels, such as ASTM A203 Grade E, and ASTM A352 LC3 and LC4 classifications. Thus, the intended application and the needed mechanical properties determine whether or not "L-Grades" should be selected.

Many low-alloy steels require postweld heat treatment to stress relieve the weld or temper the weld metal and heat affected zone to achieve increased ductility. It is often acceptable to exceed the PWHT holding temperatures shown in Table 7. However, for many applications, nickel steel weld metal can be used without postweld heat treatment. If PWHT is to be specified for a nickel steel weldment, the holding temperature should not exceed the maximum temperature given in Table 7 for the classification considered since nickel steels can be embrittled at higher temperatures.

A7.1.4 EXXXX-NMX (Ni-Mo Steel) Electrodes

A7.1.4.1 E8018-NM1 [E5518-NM1] Electrodes. This low-hydrogen electrode, which contains about 1% nickel and 0.5% molybdenum, is similar to the Mn-Mo steel electrodes discussed in A7.1.5. However, this electrode can often be welded without PWHT, but the resulting strength and notch toughness are lower than the values obtained with Mn-Mo electrodes. Some typical applications include the welding of high-strength low-alloy or microalloyed structural steels.

A7.1.4.2 E9018-NM2 [E6218-NM2] Electrodes. *This electrode is intended to meet strength requirements after extended postweld heat treatment as required in the construction of nuclear power plants and in the fabrication of components (*e.g.*, steam generators and pressurizers) used in nuclear power plants. In production environments, the length of postweld heat treatments can be as long as 48 hours. Increased carbon aids in achieving desired response to heat treatment. In addition to the requirements listed in this specification, these applications also often require drop weight testing to determine nil ductility temperature as well as measurement of mils of lateral expansion on broken Charpy V-notch specimens.*

A7.1.5 E(X)XX1X-DX [EXX1X-DX] (Mn-Mo Steel) Electrodes. These low-hydrogen electrodes produce weld metal that contains about 1.5% manganese and between 0.33% and 0.67% molybdenum. This weld metal provides higher strength and better notch toughness than the C–0.5% Mo and 1% Ni–0.5% Mo steel weld metal discussed in A7.1.1 and A7.1.4, respectively. However, the weld metal from these Mn-Mo steel electrodes is quite air-hardenable and usually requires preheat and PWHT. The individual electrodes classified under this electrode group have been designed to match the mechanical properties and corrosion resistance of the high-strength, low-alloy pressure vessel steels, such as ASTM A302 Grade B.

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[12] *Bruscato, R,. Welding Journal Research Supplement, Vol 49, pp. 148-s–156-s, 1970.*

A7.1.6 E(X)XXXX-G (General Low-Alloy Steel) Electrodes. These electrodes are described in A2.3. These electrode classifications may be either modifications of other discrete classifications or totally new classifications. Purchaser and user should determine from the supplier what the description and intended use of the electrode is.

A7.1.7 E(X)XX18M(1) (Military-Similar) Electrodes. These low-hydrogen electrodes were originally designed for military applications such as welding HY80 and HY100 type steels. To achieve desired weld metal properties and soundness, these electrodes have small alloy additions (especially some Ni) and require careful control of moisture in the electrode covering. It is important that moisture levels in the coating be maintained during electrode manufacture, packaging, transport, and site storage.

These electrodes are usually employed without subsequent postweld heat treatment. However, hydrogen-release treatments at lower temperatures, typically less than 500°F [260°C], are often applied. In the as-welded condition, the weld-metal mechanical properties include ultimate tensile strength minima ranging from 90 ksi to 120 ksi [620 MPa to 830 MPa] and good notch toughness at temperatures ranging from 0°F to –60°F [–20°C to –50°C]. With these properties, the E(X)XX18M(1) type electrodes are suitable for joining many high-strength, low-alloy or microalloyed steels to themselves or to lower strength steels, including carbon steels.

A7.1.8 EXX10-P1 (Pipeline) Electrodes. These electrodes have been designed primarily for welding typical high-strength pipe butt joints in the vertical welding position with downward or upward progression. With their cellulosic coverings, they produce deep penetrating, spray-type welding arcs and thin, easily removable slag. This combination is best suited for achieving full penetration and radiographic quality for the downhill welding of butt joints when the axis of the pipe is in the horizontal position.

While weld metals produced from these electrodes do not have any minimum chemical composition requirements, the supplier must provide sufficient alloying elements to meet the increased mechanical property requirements. Special emphasis must be placed upon the minimum yield strength values, since most transmission pipeline materials and systems are designed to yield strength limits. Typical application for E7010-P1 [E4910-P1], E8010-P1 [E5510-P1], and E9010-P1 [E6210-P1] electrodes is the welding of API–5L-X52, API–5L-X65, and API–5L-X70 piping assemblies, respectively.

A7.1.9 EXX18-P2 Pipe Welding Electrodes: These electrodes have been designed primarily for the welding of the hot, fill, and cap passes in high strength pipe butt joints in the vertical position, in upward progression. Some electrodes of these classifications may also be used on fillet welds with downward progression. The low-hydrogen nature of the coating of these electrodes makes them especially suited for joining crack-sensitive high strength pipe. Typical application for electrodes of these classifications is the welding of API 5L pipe steels up to and including Grade X80, along with many other high strength, medium and high carbon, and low-alloy steels. Electrodes of these classifications are normally not recommended for the root pass (stringer bead) on open gaps.

A7.1.10 E(X)XX45-P2 Pipe Welding Electrodes. These electrodes have specifically been designed for the welding of hot, fill, and cap passes in high strength pipe butt joints using vertical downward progression. This classification is not recommended for welding with vertical upward progression. While specifically designed for butt welds, electrodes of these classifications can often be used on fillet welds with downward progression, such as repair welding when attaching pipe sleeves. The low-hydrogen nature of the coating of these electrodes makes them especially suited for downhill welding of butt joints on crack sensitive high strength pipe when the axis of the pipe is horizontal. Typical application for electrodes of these classifications is the welding of API 5L pipe steels using the appropriate strength level electrode, along with many other high strength, medium and high carbon, and low-alloy steels. Electrodes of these classifications are normally not recommended for root pass (stringer bead) on open gaps.

A7.1.11 EXX18-WX (Weathering Steel) Electrodes. These low-hydrogen electrodes have been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels. These special properties are achieved by the addition of about 0.5% copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, some chromium and nickel additions are also made. These electrodes are used to weld the typical weathering steels, such as ASTM A242 and ASTM A588.

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 (ISO

14344 MOD) 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 2 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 and Bend 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 towards its inherent value, while yield, tensile, and impact strength remain relatively unchanged. This specification permits the aging of tension and bend test specimens at elevated temperatures up to 220°F [105°C] for up to 48 h before subjecting them to tension or bend testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrode deposits, especially when testing high-strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds.

A8.3 Absorbed Moisture Test. The development of low-hydrogen electrode coverings that resist moisture absorption during exposure to humid air is a 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 16 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 this 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 A4, along with the year in which they were last included in the specification.

Table A4
Discontinued Electrode Classifications[a]

AWS Classification	Last A5.5 (ASTM A316[b]) Publication Date	AWS Classification	Last A5.5 (ASTM A316[b]) Publication Date
E7010[c]	1954	E10026	1948
E7011[c]	1954	E10030	1948
E7013	1948	E12015[c]	1954
E7015[d]	1954	E12016[c]	1954
E7016[d]	1954	E7015-C1	1954
E7020[c]	1954	E7016-C1	1954
E7025	1948	E7015-C2	1954
E7026	1948	E7016-C2	1954
E7030	1948	E9010-B3	1954
E8010[c]	1954	E9011-B3	1954
E8011[c]	1954	E9013-B3	1954
E8013[c]	1954	E8010-B1	1958
E8015[c]	1954	E8011-B1	1958
E8016[c]	1954	E8013-B1	1958
E8020	1948	E8015-B1	1958
E8025	1948	E8010-B2	1958
E8026	1948	E8011-B2	1958
E8030	1948	E8013-B2	1958
E9010[c]	1954	E8015-B4	1958
E9011[c]	1954	E8016-B4	1958
E9013[c]	1954	E8018-B4	1958
E9015[c]	1954	E8015-C1	1958
E9016[c]	1954	E8015-C2	1958
E9020	1948	E8015-C3	1958
E9025	1948	E9016-D1	1958
E9026	1948	E7018-W[e]	1981
E9030	1948	E8015-B2L[f]	1981
E10010[c]	1954	E8018-B2L[f]	1981
E10011[c]	1954	E8018-NM[g]	1981
E10013[c]	1954	E8018-W[e]	1981
E10015[c]	1954	E9015-B3L[f]	1981
E10016[c]	1954	E9018-B3L[f]	1981
E10020	1948	*E90XX-B9 [E62XX-B9]*[h]	*2006*
E10025	1948		

[a] See Clause A10, Discontinued Classifications (in Annex A), for information on discontinued classifications and how they may be used.

[b] ASTM A316 *was withdrawn without replacement in 1969.*

[c] The higher tensile strength electrode classifications without chemistry requirements for classifications were discontinued in 1958 and replaced with the "G" classifications in order to permit a single classification system with chemistry requirements.

[d] Both E7015 and E7016 classifications were transferred to AWS A5.1–58T and continue to be included in the current revision of that specification.

[e] Both E7018-W and E8018-W classification designations have been changed to E7018-W1 and E8018-W2 in order to permit the suffix designator to differentiate between the two chemical compositions of undiluted weld metal.

[f] These Cr-Mo electrode classifications were modified by using a lower strength designator. This reflects a more realistic minimum tensile strength for low-carbon chromium molybdenum steel weld metal. This change may or may not show a corresponding reduction in creep strength of the weld metal depending on how the chemical composition of the weld metal is controlled.

[g] The E8018-NM classification has been changed to E8018-NM1 to allow for other possible Ni-Mo steel electrode classifications in future revisions.

[h] *The E90XX-B9 [E62XX-B9] classification has been changed to E90XX-B91[E62XX-B91] to better conform to industry standards and practices.*

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,[13] and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[14]

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 and 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*

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[13] ANSI Z49.1 is published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.

[14] AWS standards are published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.

SPECIFICATION FOR COPPER AND COPPER-ALLOY ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.6/SFA-5.6M

(Identical with AWS Specification A5.6/A5.6M:2008. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR COPPER AND COPPER-ALLOY ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.6/SFA-5.6M

(Identical with AWS Specification A5.6/A5.6M:2008. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of covered copper and copper-alloy electrodes for shielded metal arc welding. It includes compositions in which the copper content exceeds that of any other element.[1]

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

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to filler metal properties. The specification with the designation A5.6 uses U.S. Customary Units. The specification A5.6M 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 electrodes or packaging or both under A5.6 or A5.6M specifications.

2. Normative References

2.1 The following AWS standards[2] are referenced in the mandatory section of this document.

(a) AWS A5.01, *Filler Metal Procurement Guidelines*

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

2.2 The following ANSI standard[3] is referenced in the mandatory section of this document:

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

2.3 The following ASTM standards[4] are referenced in the mandatory section of this document.

(a) ASTM B 96/B 96M, *Standard Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels*

(b) ASTM B 103/B 103M, *Standard Specification for Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar*

(c) ASTM B 122/B 122M, *Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar*

(d) ASTM B 148, *Standard Specification for Aluminum-Bronze Sand Castings*

(e) ASTM B 152/B 152M, *Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar*

(f) ASTM B 169/B 169M, *Standard Specification for Aluminum Bronze Sheet, Strip, and Rolled Bar*

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

(h) ASTM E 75, *Standard Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys*

(i) ASTM E 478, *Standard Test Methods for Chemical Analysis of Copper Alloys*

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

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[1] No attempt has been made to provide for the classification of all grades of copper and copper-alloy welding electrodes. Only the more commonly used grades have been included.

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

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

[4] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

2.4 The following ISO standard[5] is referenced in the mandatory sections of this document.

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

3. Classification

3.1 The welding materials covered by the A5.6/A5.6M specification are classified using the system that is independent of U.S. Customary Units and the International System of Units (SI). Classifications are according to the chemical composition of the undiluted weld metal as specified in Table 1.

3.2 Materials classified under one classification shall be classified under any other classification in this specification. However, material may be classified under both A5.6 and A5.6M.

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

4. Acceptance

Acceptance[6] 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.[7]

6. Rounding-Off Procedure

For the purposes of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] for tensile strength, and to the “nearest unit” in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E 29.

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, and soundness of the weld metal. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 13.

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 Two test assemblies are required for all classifications except ECuNi, which may require three test assemblies (see Fig. 3). The three test assemblies are as follows:

(a) the weld pad in Fig. 1 for chemical analysis of the undiluted weld metal

(b) the groove weld in Fig. 2 for mechanical properties and soundness of the weld metal

(c) the groove weld in Fig. 3 for the usability of ECuNi electrodes

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

9.2 Preparation of each weld test assembly shall be as prescribed in 9.3 and 9.4. The base metal for each assembly shall be as required in Table 3 according to the tests to be conducted and shall meet the requirements of the appropriate ASTM specification shown there, or an equivalent

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[5] ISO standards are published by the International Organization for Standardization, 1 rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

[6] See A3 in Annex A for further information concerning acceptance, testing of the material shipped, and AWS A5.01, *Filler Metal Procurement Guidelines*.

[7] See A4 in Annex A for further information concerning certification and the testing called for to meet this requirement.

Table 1
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification	UNS Number[c]	Common Name	Composition, weight-percent[a, b]											
			Cu Including Ag	Zn	Sn	Mn	Fe	Si	Ni[d]	P	Al	Pb	Ti	Total Other Elements
ECu	W60189	Copper	Remainder	f	f	0.10	0.20	0.10	f	f	0.10	*0.01*	—	0.50
ECuSi	W60656	Silicon bronze (copper-silicon)	Remainder	f	1.5	1.5	0.50	2.4–4.0	f	f	0.01	0.02	—	0.50
ECuSn-A	W60518	Phosphor bronze (copper-tin)	Remainder	f	4.0–6.0	f	0.25	f	f	0.05–0.35	0.01	0.02	—	0.50
ECuSn-C	W60521		Remainder	f	7.0–9.0	f	0.25	f	f	0.05–0.35	0.01	0.02	—	0.50
ECuNi[e]	W60715	Copper nickel (70/30)	Remainder	f	f	1.00–2.50	0.40–0.75	0.50	29.0–33.0	0.020	—	0.02	0.50	0.50
ECuAl-A2	W60614	Aluminum bronze	Remainder	f	f	f	0.50–5.0	1.5	f	—	*6.5–9.5*	0.02	—	0.50
ECuAl-B	W60619	Aluminum bronze	Remainder	f	f	f	2.5–5.0	1.5	f	—	*9.5–11.5*	0.02	—	0.50
ECuNiAl	W60632	Nickel aluminum bronze	Remainder	f	f	0.50–3.5	3.0–6.0	1.5	4.0–6.0	—	*8.0–9.5*	0.02	—	0.50
ECuMnNiAl	W60633	Manganese-nickel aluminum bronze	Remainder	f	f	*11.0–14.0*	*2.0–4.0*	1.5	*1.5–3.0*	—	*6.0–8.5*	0.02	—	0.50

[a] Analysis shall be made for the elements for which specific values or an “f” are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of other elements is not present in excess of the limits specified for “total other elements” in the last column in the table.

[b] Single values shown are maximum.

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

[d] Includes cobalt.

[e] Sulfur shall be restricted to 0.015% maximum for the ECuNi classification.

[f] This element must be included in total other elements.

TABLE 2
REQUIRED TESTS FOR CLASSIFICATION[a]

AWS Classification	Chemical Analysis	Tension Test	Transverse Side-Bend Test	Radiographic Test
ECu	Required	Required	Required	Not Required
ECuSi	Required	Required	Required	Not Required
ECuSn-A	Required	Required	Required	Not Required
ECuSn-C	Required	Required	Required	Not Required
ECuNi	Required	Required	Required	Required
ECuAl-A2	Required	Required	Required	Not Required
ECuAl-B	Required	Required	Not Required	Not Required
ECuNiAl	Required	Required	Not Required	Not Required
ECuMnNiAl	Required	Required	Not Required	Not Required

NOTE:
a. All welding for chemical analysis, all-weld-metal tension tests, and transverse side-bend tests shall be done with the test plates in the flat position.

specification. Testing of the assemblies shall be as prescribed in Clause 10, Chemical Analysis, Clause 11, Radiographic Test, Clause 12, Tension Test, and Clause 13, Bend Test.

9.3 Weld Pad. A weld pad shall be prepared as specified in Fig. 1 except when one of the alternatives in 10.1 (taking the sample from the broken tension test specimen or from a corresponding location in the groove weld) is selected. Base metal of any convenient size, of the type specified in Table 3 (including notes a and b to that table) shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple beads 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 of a temperature above 60°F [15°C] between passes. The dimensions of the completed pad shall be as shown in Fig. 1 for each size of electrode. 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 Fig. 2 using base material of the appropriate type as specified in Table 3. Testing of the assembly shall be as specified in Clause 12, Tension Test, and Clause 13, Bend Test. The test specimens shall be tested in the as welded condition.

9.4.2 Usability Test. A test assembly shall be for electrodes of the ECuNi classification and welded as shown in Fig. 3, using base metal of the appropriate type specified in Table 3. The welding position shall be vertical for the $^3/_{32}$ in. [2.4 mm or 2.5 mm] and $^1/_8$ in. [3.2 mm] diameter electrodes or flat for the $^5/_{32}$ in. [4.0 mm] and $^3/_{16}$ in. [4.8 mm, 5.0 mm, or 6.0 mm] diameter electrodes. Testing of the assembly shall be as specified in Clause 11, Radiography Test.

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 (see Fig. 1), from the reduced section of the fractured all-weld-metal tension specimen (see Fig. 2), or from a corresponding location in the groove weld (see Fig. 2 or Fig. 3). The top surface of the weld pad described in 9.3 and shown in Fig. 1 shall be removed and discarded, and a sample for analysis shall be obtained by any appropriate mechanical means. The sample shall be free of slag.

10.2 The sample taken from the reduced section of the fractured tension specimen, or from the corresponding location in the groove weld in Fig. 2 or Fig. 3 shall be prepared for analysis by any suitable mechanical means.

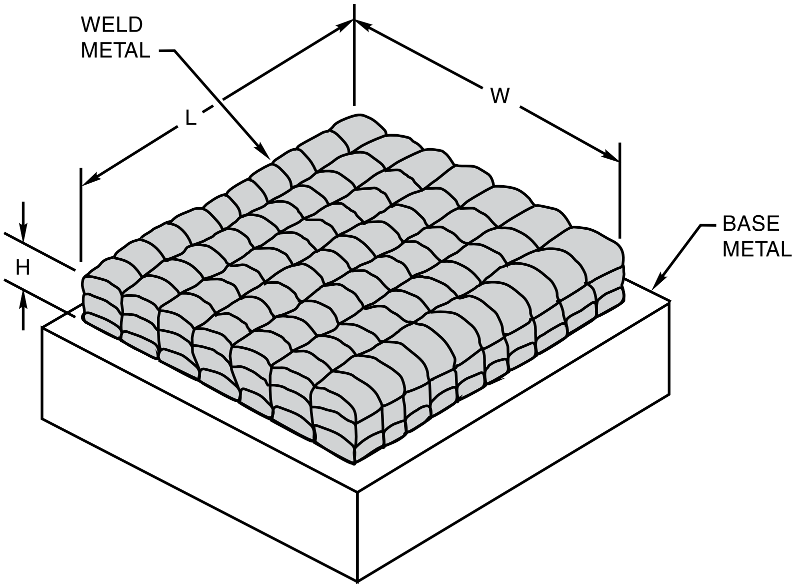
10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 478. For classification ECuNi, where titanium may be intentionally added up to 0.50%, the element titanium should be analyzed by using ASTM E 75.

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

11. Radiographic Test

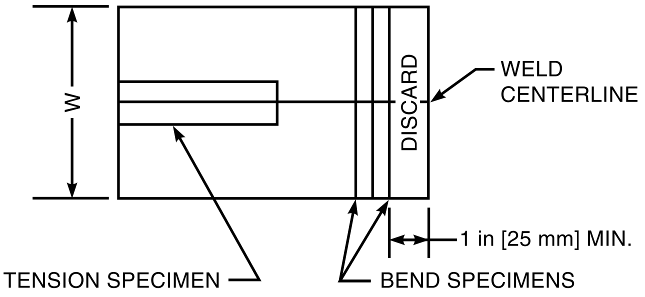
11.1 When required in Table 2, the groove weld described in 9.4.2 and shown in Fig. 3 shall be radiographed to evaluate the soundness of the weld metal and the usability of the electrode. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the

FIG. 1 PAD FOR CHEMICAL ANALYSIS OF UNDILUTED WELD METAL

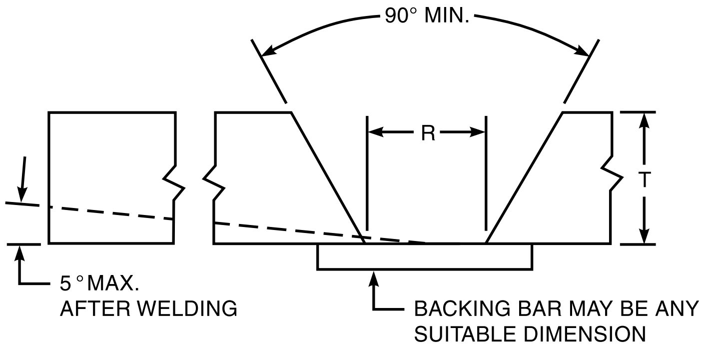


Electrode Size			Weld Pad Size, Minimum		Minimum Distance of Sample From Surface of Base Plate	
in.	mm		in.	mm	in.	mm
3/32	2.4	L	1½	38	⅜	10
		W	½	13		
		H	½	13		
3/32	2.5	L	1½	38	⅜	10
		W	½	13		
		H	½	13		
⅛	3.2	L	2	50	½	13
		W	½	13		
		H	⅝	16		
5/32	4.0	L	2	50	½	13
		W	½	13		
		H	⅝	16		
3/16	4.8	L	2	50	½	13
		W	½	13		
		H	⅝	16		
3/16	5.0	L	2	50	½	13
		W	½	13		
		H	⅝	16		
3/16	6.0	L	2	50	½	13
		W	½	13		
		H	⅝	16		

FIG. 2 TEST ASSEMBLY FOR TENSION AND BEND TEST



LAYOUT OF TEST ASSEMBLY



GROOVE PREPARATION

	Root Opening, R[a]		Test Plate Thickness T, min.			Width of Test Plate, W, min.	
Elecrode Size, in. [mm]	in.	mm	in.	mm	Number of Layers[b]	in.	mm
1⁄8 [3.2] and less	1⁄4	6.4	1⁄2	12	. . .	6	150
5⁄32 [4.0] and larger	1⁄2	13	3⁄4	20	6 to 9	6	150

GENERAL NOTES:

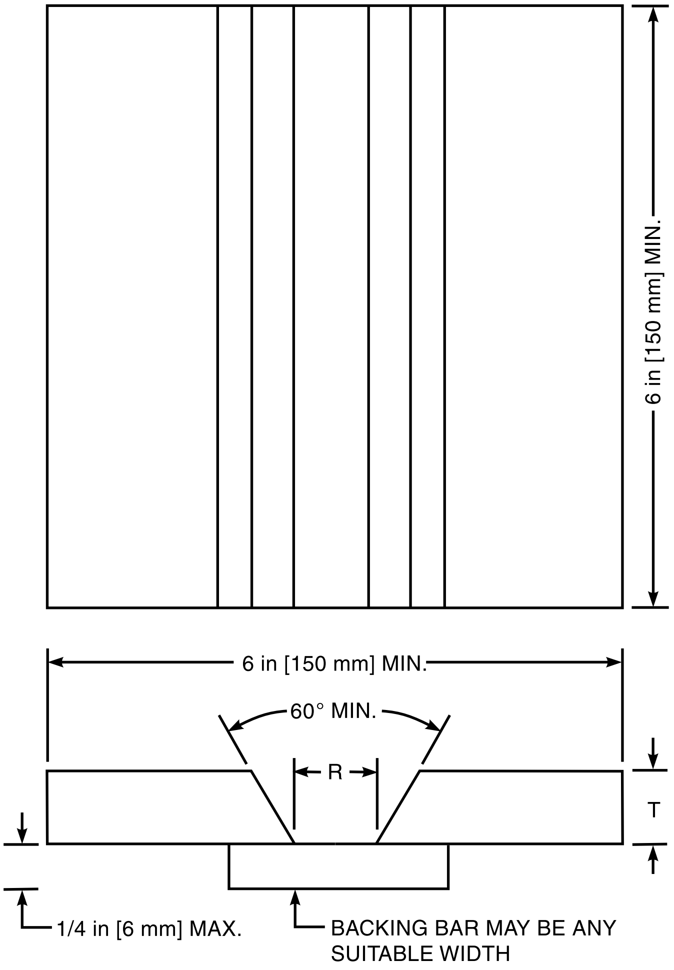
1. Weld test plates for all-weld-metal tension and bend specimens shall be prepared using the plate base metal shown in Table 3.
2. The surfaces to be welded shall be clean.
3. Welding shall be performed with the plates in the flat position, using the current values and welding techniques recommended by the electrode manufacturer.
4. Preheat temperature shall be 60°F [15°C] minimum. The interpass temperature shall not exceed 300°F [150°C]. For ECuSi classification, the interpass temperature shall not exceed 150°F [65°C].
5. The weld metal shall have a maximum bead width equal to six (6) times the core wire diameter. The completed weld shall be at least flush with the surface of the test plate.
6. Tests shall be conducted in the as welded condition.

NOTES:

a. Root opening tolerance is ±1⁄16 in. [±1.5 mm].

b. For the ECuNi classification, the minimum groove angle shall be 60 deg. For all classifications, the number of layers for the 1⁄8 in. [3.2 mm] and smaller electrodes shall be recorded and reported. The 5⁄32 in. [4.0 mm] and larger electrodes shall have a minimum of six layers and a maximum of nine layers.

FIG. 3 GROOVE WELD FOR RADIOGRAPHIC TEST (ECuNi ONLY)



Electrode Size		Root Opening[a]		Test Plate Thickness T, min.	
in.	mm	in.	mm	in.	mm
3/32	2.4, 2.5	1/4	6.4	1/4	6
1/8	3.2	5/16	8	3/8	10
5/32	4.0	3/8	9.5	1/2	12
3/64	4.8, 5.0, 6.0	1/2	12	1/2	12

GENERAL NOTES:

1. Welding shall be conducted in the vertical position or flat position as prescribed in 9.4.2.
2. Base metal shall be in accordance with Table 3.
3. The surfaces to be welded shall be clean.
4. Each weld bead shall contain a start in the area to be evaluated. The weld metal shall have a maximum bead width equal to six (6) times the core wire diameter. The root layer for a test of 5/32 in. [4.0 mm] electrode or larger may be deposited with a 3/32 in. [2.4 mm or 2.5 mm] or 1/8 in. [3.2 mm] electrode.

5 The completed weld shall be at least flush with the surface of the test plate.

6. Preheat temperature shall be 60°F [15°C] minimum. The interpass temperature shall not exceed 300°F [150°C].
7. After completion of the weld, the weld reinforcement and backing strip shall be removed flush with the base plate surfaces and the assembly shall be radiographed.

NOTE:

[a] Root opening tolerance is ±1/16 in. [±1.5 mm].

TABLE 3
BASE METALS FOR TEST ASSEMBLIES

AWS Classification	Base Metal (ASTM Specification and UNS Numbers)			
	UNS Number[a]	Chemical Analysis	All-Weld-Metal Tension Test	Transverse Side-Bend Test
ECu	C12200	B152	B152	B152
ECuSi	C65500	B96	B97	B96
ECuSn-A	C51100	B103	B103	B103
ECuSn-C	C52100	B103	B103	B103
ECuNi[b]	C71500	B122	B122	B122
ECuAl-A2	C61400	B169	B169	B169
ECuAl-B	C95400	B148	B148	. . .
ECuNiAl	C95800	B148	B148	. . .
ECuMnNiAl	C95700	B148	B148	. . .

NOTES:

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

b. Groove weld usability tests shall be conducted for the ECuNi classification as per Fig. 3 using B122 base metal (UNS C71500).

original surfaces of the base metal or with a uniform reinforcement not exceeding $\frac{3}{32}$ in. [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of $\frac{1}{16}$ in. [1.5 mm] nominal 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 $\frac{1}{16}$ in. [1.5 mm] so that the machined thickness of the radiographic test specimen equals at least the thickness of the base metal minus $\frac{1}{16}$ in. [1.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 1032.

11.3 The soundness of the weld metal and the usability of the electrode meet the requirements of this specification if the radiograph shows

(a) no cracks, no incomplete fusion and no incomplete penetration

(b) no slag inclusions in excess of those permissible in Note 4 in the radiographic standards in Figs. 4A, 4B, 4C, and 4D

(c) no rounded indications in excess of those permitted by the radiographic standards in Figs. 4A, 4B, 4C, and 4D

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.

11.3.2 The indications may be of porosity or slag. Indications whose largest dimension does not exceed $\frac{1}{64}$ 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 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 9.4.1 and shown in Fig. 2. The tensile specimen shall have a nominal diameter of 0.500 in. [12.5 mm] for test assemblies $\frac{3}{4}$ in. [20 mm] thick, or 0.250 in. [6 mm] for test assemblies $\frac{1}{2}$ in. [12 mm] thick. All tensile specimens shall have a nominal gage-length-to-diameter ratio of 4:1. Other dimensions of the tension test specimen shall be as specified in AWS B4.0 or B4.0M.

12.2 The specimen shall be tested in the as-welded condition in the manner described in the tension test section of AWS B4.0 or AWS B4.0M.

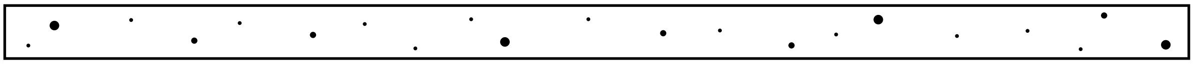
12.3 The results of the tension test shall meet the requirements specified in Table 4.

13. Bend Test

13.1 Two transverse side bend specimens as required in Table 2 shall be machined from the groove weld described in 9.4.1 and shown in Fig. 2.

13.2 The specimens (in the as-welded condition) shall be tested in the manner described in the bend test section of AWS B4.0 or AWS B4.0M. A $\frac{3}{8}$ in. [10 mm] thick specimen shall be uniformly bent 180 deg over a $\frac{3}{4}$ in. [19 mm] radius. Any suitable fixture, as specified in the Bend Test section of AWS B4.0 or AWS B4.0M, may be used. Positioning of the specimen shall be such that the

FIG. 4A RADIOGRAPHIC ACCEPTANCE STANDARD FOR ¼ IN. [6 MM] TEST PLATE



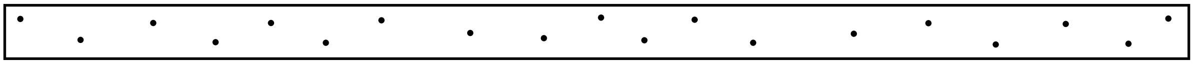
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 0.050 in [0.4 mm TO 1.3 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 21, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 0.031 in TO 0.050 in [0.8 mm TO 1.3 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 4
MAXIMUM NUMBER OF MEDIUM 0.020 in TO 0.031 in [0.5 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5
MAXIMUM NUMBER OF SMALL 1/64 in TO 0.020 in [0.4 mm TO 0.5 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 12

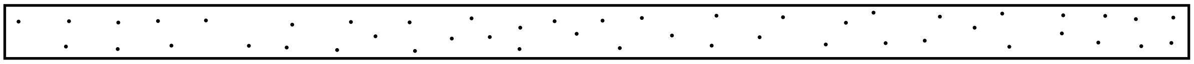
(B) LARGE ROUNDED INDICATIONS

SIZE 0.031 in TO 0.050 in [0.8 mm TO 1.3 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 8



(C) MEDIUM ROUNDED INDICATIONS

SIZE 0.020 in TO 0.031 in [0.5 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 19



(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 0.020 in [0.4 mm TO 0.5 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 48

GENERAL NOTES:

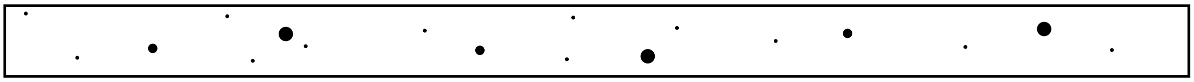
(1) The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications $^1/_{64}$ in. [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.

(2) These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.

(3) When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.015 in.^{2} [10 mm^2] in any 6 in. [150 mm] of weld.

(4) The acceptance standard for slag inclusions in this assembly is the following:
  - *(a)* Length of each individual slag indication: $^5/_{32}$ in. [4.0 mm] maximum
  - *(b)* Total length of all slag indications: $^1/_4$ in. [6.4 mm] maximum

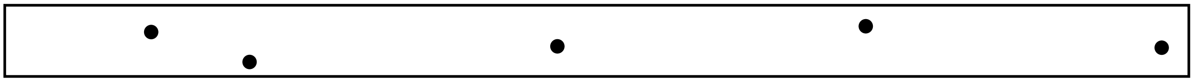
FIG. 4B RADIOGRAPHIC ACCEPTANCE STANDARD FOR $\frac{3}{8}$ IN. [10 MM] TEST PLATE



(A) ASSORTED ROUNDED INDICATIONS

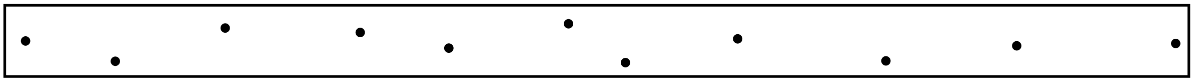
SIZE 1/64 in TO 0.075 in [0.4 mm TO 1.9 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 17, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 0.049 in TO 0.075 in [1.3 mm TO 1.9 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3
MAXIMUM NUMBER OF MEDIUM 0.020 in TO 0.049 in [0.5 mm TO 1.3 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3
MAXIMUM NUMBER OF SMALL 1/64 in TO 0.020 in [0.4 mm TO 0.5 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 11



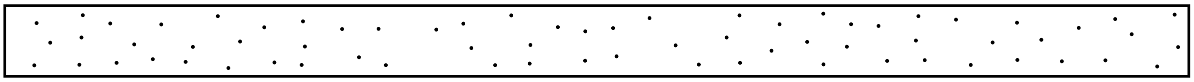
(B) LARGE ROUNDED INDICATIONS

SIZE 0.049 in TO 0.075 in [1.3 mm TO 1.9 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 5



(C) MEDIUM ROUNDED INDICATIONS

SIZE 0.020 in TO 0.049 in [0.5 mm TO 01.3 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 11



(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 0.020 in [0.4 mm TO 0.5 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 72

GENERAL NOTES:

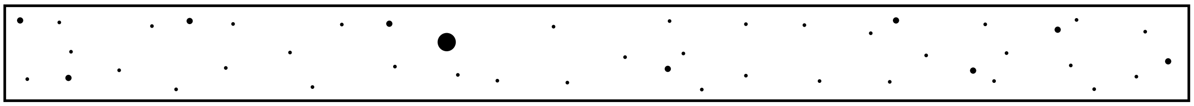
(1) The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications $\frac{1}{64}$ in. [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.

(2) These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.

(3) When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.023 in.^{2} [15 mm^2] in any 6 in. [150 mm] of weld.

(4) The acceptance standard for slag inclusions in this assembly is the following:
  (a) Length of each individual slag indication: $\frac{7}{32}$ in. [5.6 mm] maximum
  (b) Total length of all slag indications: $\frac{3}{8}$ in. [10 mm] maximum

FIG. 4C RADIOGRAPHIC ACCEPTANCE STANDARD FOR ½ IN. [12 MM] TEST PLATE



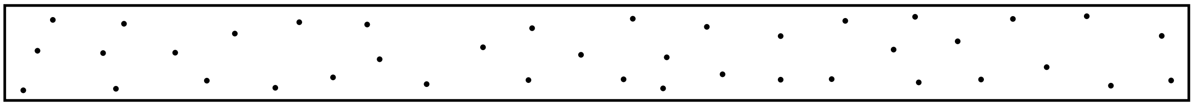
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 0.10 in [0.4 mm TO 2.5 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 45, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 0.031 in TO 0.10 in [0.8 mm TO 2.5 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 1
MAXIMUM NUMBER OF MEDIUM 0.020 in TO 0.031 in [0.5 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 9
MAXIMUM NUMBER OF SMALL 1/64 in TO 0.020 in [0.4 mm TO 0.5 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 35

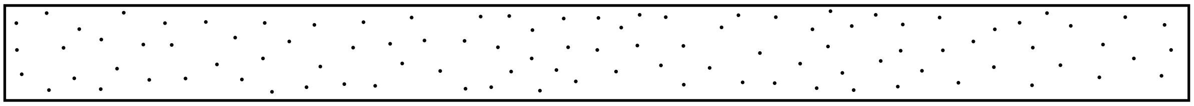
(B) LARGE ROUNDED INDICATIONS

SIZE 0.031 in TO 0.10 in [0.8 mm TO 2.5 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 4



(C) MEDIUM ROUNDED INDICATIONS

SIZE 0.020 in TO 0.031 in [0.5 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 40



(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 0.020 in [0.4 mm TO 0.5 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 101

GENERAL NOTES:

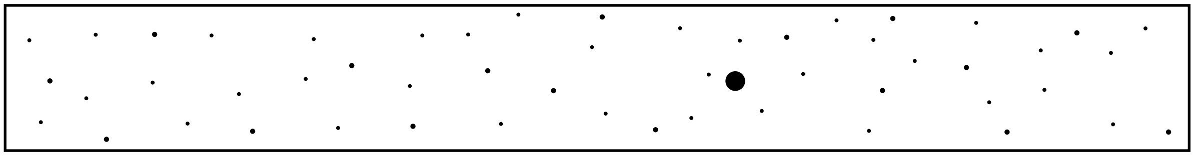
(1) The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications $^{1}/_{64}$ in. [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.

(2) These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.

(3) When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.030 in.^{2} [20 mm^2] in any 6 in. [150 mm] of weld.

(4) The acceptance standard for slag inclusions in this assembly is the following:
  (a) Length of each individual slag indication: $^{7}/_{32}$ in. [5.6 mm] maximum
  (b) Total length of all slag indications: $^{7}/_{16}$ in. [11 mm] maximum

FIG. 4D RADIOGRAPHIC ACCEPTANCE STANDARD FOR $\frac{3}{4}$ IN. [20 MM] TEST PLATE



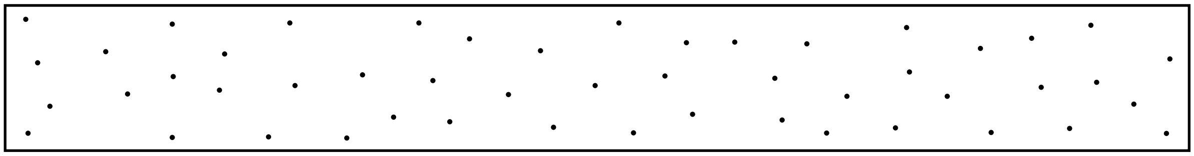
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 0.125 in [0.4 mm TO 3.2 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 53, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 0.034 in TO 0.125 in [0.9 mm TO 3.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 1
MAXIMUM NUMBER OF MEDIUM 0.024 in TO 0.034 in [0.6 mm TO 0.9 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 17
MAXIMUM NUMBER OF SMALL 1/64 in TO 0.024 in [0.4 mm TO 0.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 35

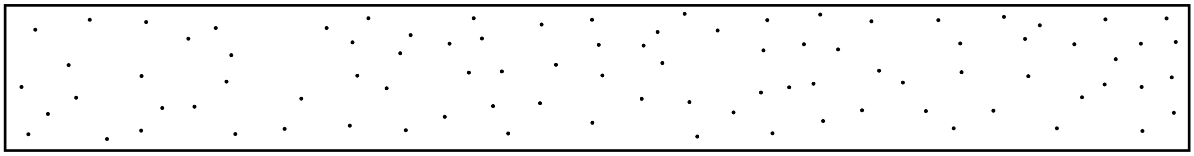
(B) LARGE ROUNDED INDICATIONS

SIZE 0.034 in TO 0.1 in [0.9 mm TO 2.5 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 4



(C) MEDIUM ROUNDED INDICATIONS

SIZE 0.024 in TO 0.034 in [0.6 mm TO 0.9 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 50



(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 0.024 in [0.4 mm TO 0.6 mm] IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER INDICATIONS IN ANY 6 in [150 mm] OF WELD = 90

GENERAL NOTES:

(1) The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications $\frac{1}{64}$ in. [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.

(2) These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.

(3) When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.045 in.^{2} [30 mm^2] in any 6 in. [150 mm] of weld.

(4) The acceptance standard for slag inclusions in this assembly is the following:
  - *(a)* Length of each individual slag indication: $\frac{5}{16}$ in. [7.9 mm] maximum
  - *(b)* Total length of all slag indications: $\frac{15}{32}$ in. [11.9 mm] maximum

TABLE 4
MECHANICAL PROPERTY REQUIREMENTS

AWS Classification	Tensile Strength, min. ksi	Tensile Strength, min. MPa	Elongation Percent, min.
ECu	25	170	20
ECuSi	50	350	20
ECuSn-A	35	240	20
ECuSn-C	40	280	20
ECuNi	50	350	20
ECuAl-A2	60	410	20
ECuAl-B	65	450	20
ECuNiAl	72	500	10
ECuMnNiAl	75	520	15

side of the specimen with the greater discontinuities, if any, is in tension.

13.3 Each specimen, after bending, shall conform to the specified radius, with appropriate allowance for spring back, and the weld metal shall show no cracks or open discontinuities exceeding $\frac{1}{8}$ in. [3.2 mm] measured in any direction. Small checks or cracks at the edges of the test specimen shall be disregarded.

14. Method of Manufacture

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

15. Standard Sizes and Lengths

15.1 Standard sizes and lengths of electrodes are shown in Table 5. Other sizes shall be as agreed upon between the purchaser and manufacturer.

15.2 Diameter of the core wire shall not vary more than ±0.003 in. [±0.1 mm] from the diameter specified. Length shall not vary more than $\pm\frac{1}{4}$ in. [±2% of the nominal mm length].

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 electrode.

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:

(a) 7% of the mean dimension for $\frac{3}{32}$ in. [2.4 mm and 2.5 mm]

(b) 5% of the mean dimension for sizes $\frac{1}{8}$ in. and $\frac{5}{32}$ in. [3.2 mm and 4.0 mm]

(c) 4% of the mean dimension for $\frac{3}{16}$ in. [4.8 mm, 5.0 mm, and 6.0 mm]

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 $\frac{1}{2}$ in. [12 mm], nor more than $1\frac{1}{4}$ in. [30 mm] for electrodes $\frac{5}{32}$ in. [4.0 mm] and smaller, and not less than $\frac{3}{4}$ in. [19 mm], nor more than $1\frac{1}{2}$ in. [38 mm] for electrodes $\frac{3}{16}$ 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 $\frac{1}{8}$ 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 $\frac{1}{4}$ in. [6 mm] or twice the diameter of the core wire, meet the requirement of this specification provided no chip uncovers more than 50% 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 beginning within $2\frac{1}{2}$ in. [65 mm] of the grip end of the electrode. The prefix letter "E" in the classification may be omitted from the imprint.

18.2 The numbers and letters of the imprint shall be of bold block type 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.

19. Packaging

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

19.2 Standard package weights shall be as agreed upon by the supplier and purchaser.

20. Marking of Packages

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

TABLE 5
STANDARD SIZES AND LENGTHS

Standard Size (Core Wire Diameter)		Standard Length[a, b]			
		Classification			
		ECuAl-B, ECuNiAl		All Others	
in.	mm	in.	mm	in.	mm
3/32	2.4[c]	...	...	9 or 12	250 or 300
...	2.5	...	...	9 or 12	250 or 300
1/8	3.2	14	350	14	350
5/32	4.0	14 or 18	350 or 450	14 or 18	350 or 450
3/16	4.8[c]	14 or 18	350 or 450	14 or 18	350 or 450
...	5.0	14 or 18	350 or 450	14 or 18	350 or 450
...	6.0	14 or 18	350 or 450	14 or 18	350 or 450

NOTES:

a. Lengths other than these shall be as agreed upon between purchaser and supplier.

b. In all cases, end-gripped electrodes are standard.

c. Not included in ISO 544.

(a) AWS specification and classification designations (year of issue may be excluded)

(b) Supplier's name and trade designation

(c) Size and net weight

(d) Lot, control, or heat number

20.2 The appropriate precautionary information[8] given in ANSI Z49.1, latest edition (as a minimum), or its equivalent, shall be prominently displayed in legible print on all packages, including individual unit packages within a larger package.

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[8] Typical examples of "warning labels" 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 Copper and Copper-Alloy Electrodes for Shielded Metal Arc Welding

(This annex is not part of AWS A5.6/A5.6M:2008, *Specification for Copper and Copper-Alloy 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 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 electrode 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, namely:

(a) The letter E at the beginning of each classification designation indicates a covered electrode.

(b) The chemical symbol Cu is used to identify the electrodes as copper-base alloys, and the additional chemical symbol, such as Si in ECuSi, Sn in ECuSn, etc., indicates the principal alloying element of each classification or group of similar classifications. Where more than one classification is included in a basic group, the individual classifications in the group are identified by the letters A, B, C, etc., as in ECuSn-A. Further subdividing is done by using a 1, 2, etc., after the last letter, as the 2 in ECuAl-A2.

A2.2 Request for Filler Metal Classification

A2.2.1 A request to establish a new electrode classification must be written, and it needs to provide sufficient detail to permit the A5 Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether a new classification or a 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 the other classifications.)

(c) Information on Descriptions and Intended Use, which parallels existing classifications for that section in 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.

A2.2.2 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 the Chair of the particular Subcommittee involved.

(d) file the original request.

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

A2.2.3 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 A5 Committee on Filler Metals and Allied Materials for action.

A2.2.4 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 A5 Committee on Filler Metals and Allied Materials meeting. Any other

TABLE A1
COMPARISON OF SPECIFICATIONS

Covered Electrodes A5.6/A5.6M	Bare Rods and Electrodes A5.7/A5.7M[a]	Proposed ISO Designations[b]
ECu	ERCu	EC1898
ECuSi	ERCuSi-A	EC6560
ECuSn-A	ERCuSn-A	EC5180
ECuSn-C	ERCuSn-C	EC5210
ECuNi	ERCuNi	EC7158
. . .	ERCuAl-A1	EC6100
ECuAl-A2	ERCuAl-A2	EC6180
. . .	ERCuAl-A3	EC6240
ECuAl-B	. . .	EC6220
ECuNiAl	ERCuNiAl	EC6328
ECuMnNiAl	ERCuMnNiAl	EC6338

NOTES:

a. AWS A5.7/A5.7M, *Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes.*

b. AWS Publication IFS:2002, *International Index of Filler Metal Classifications,* Table 12A. Also, Table 12B of that document covers bare welding materials which carry the initial letter, "SC," in place of "EC" for the comparable guide.

publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A2.3 Compositions of bare welding filler metal in AWS A5.7 similar to those in this specification are shown in Table A1.

A2.4 An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for copper-alloy filler metals. To understand the proposed international designation system, refer to Table 12A and the Annex of AWS publication IFS 2002, *International Index of Welding Filler Metal Classifications.*

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, needs to 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 the supplier normally conducts 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 the tested material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the "certification" required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01.

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. These are:

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

(b) number of welders working in that space

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

(d) the proximity of the welders 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

(e) the ventilation provided to the space in which the welding is performed

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. Further information concerning ventilation in welding can be found in AWS F3.2, *Ventilation Guide for Weld Fume.*

A6. Welding Considerations

A6.1 Before welding or heating any copper-base alloy, the base metal should be clean. Oil, grease, paint, lubricants, marking pencils, temperature indicating materials, threading compounds, and other such materials frequently contain sulfur, lead, or silver, that may cause cracking (embrittlement) of the base metal or the weld metal if present during welding or heating.

A6.2 Electrodes of some of the classifications are used for dissimilar metal welds. When making such welds, it is important to obtain as little dilution as possible from the dissimilar metal member (steels, for example). This can be done by traveling slowly to deposit a thicker bead and to dissipate the energy of the arc against the molten weld metal or the copper base metal, rather than the dissimilar metal member.

A6.3 Most of the electrodes in this specification are intended to be used with direct current, electrode positive (dcep) polarity. Some electrodes may be designated to operate also on alternating current, which makes them desirable for minimizing arc blow. The electrode manufacturer should be consulted to determine if the particular product is designed to be used with alternating current.

A7. Description and Intended Use of Electrodes

A7.1 Copper and copper-alloy electrodes generally operate with DCEP and the coverings often are hygroscopic.

A7.1.1 The supplier should be consulted regarding the following:

(a) specific operating parameters and positions

(b) recommended storage conditions and reconditioning temperatures

A7.1.2 The weld area should be free from moisture and other contaminants.

A7.2 ECu Classification (Copper Electrodes). ECu electrodes are generally manufactured from deoxidized copper wire (essentially pure copper with small amounts of deoxidizers added) and may be used for shielded metal arc welding (SMAW) of deoxidized coppers, oxygen-free coppers, and tough pitch (electrolytic) coppers.

The electrodes are also used to repair or surface these base metals as well as to surface steel and cast iron. Mechanically and metallurgically sound joints can best be made in deoxidized coppers.

Reactions with hydrogen in oxygen-free copper, and the segregation of copper oxide in tough pitch copper may detract from joint efficiency. However, when highest quality is not required, ECu electrodes may be successfully used on these base metals.

The high thermal conductivity of unalloyed coppers in thick sections may require preheat and interpass temperatures up to 1000°F [540°C].

A7.3 ECuSi Classification (Silicon Bronze). ECuSi electrodes contain approximately 3% silicon plus small percentages of manganese and tin. They are used primarily for welding copper-silicon alloys. ECuSi electrodes are occasionally used for the joining of copper, dissimilar metals, and some iron base metals. Silicon bronze weld metal seldom is used to surface bearing surfaces, but often is used to surface areas subject to corrosion.

A7.4 ECuSn Classification (Phosphor Bronze). ECuSn electrodes are used to join phosphor bronzes of similar compositions. They are also useful for joining brasses and, in some cases, for welding them to cast iron and carbon steel. ECuSn weld metals tend to flow sluggishly, requiring preheat and interpass temperatures of at least 400°F [200°C] on heavy sections. Postweld heat treatment may not be necessary, but it is desirable for maximum ductility, particularly if the weld metal is to be cold worked.

A7.4.1 ECuSn-A electrodes are used primarily to join base metals of similar composition. They also may be used to weld copper if the resultant weld metal has adequate electrical conductivity and corrosion resistance for the specific application.

A7.4.2 ECuSn-C electrodes have higher tin content resulting in weld metals of higher hardness, tensile strength, and yield strength compared to ECuSn-A weld metal.

A7.5 ECuNi Classification (Copper-Nickel). Electrodes of the ECuNi classification are used for shielded metal arc welding (SMAW) of wrought or cast $^{70}/_{30}$, $^{80}/_{20}$, and $^{90}/_{10}$ copper-nickel alloys to themselves or to each other. They also are used for welding the clad side of copper-nickel clad steel. Preheating generally is not necessary.

A7.6 ECuAl Classification (Aluminum Bronze)

A7.6.1 The copper-aluminum electrodes are used only in the flat position. For butt joints, a 90 deg single V-groove is recommended for plate thicknesses up to and including $^{7}/_{16}$ in. [10 mm]. A modified U- or double V-groove is recommended for heavier plate thicknesses. Preheat and interpass temperature should be as follows:

(a) For iron-base materials, 200°F to 300°F [100°C to 150°C]

(b) For bronzes, 300°F to 400°F [150°C to 200°C]

(c) For brasses, 500°F to 600°F [250°C to 300°C]

A7.6.2 ECuAl-A2 electrodes are used in joining aluminum bronzes of similar composition, high strength copper-zinc alloys, silicon bronzes, manganese bronzes, some nickel alloys, many ferrous metals and alloys, and combinations of dissimilar metals. The weld metal is also suitable for surfacing wear- and corrosion-resistant bearing surfaces.

TABLE A2
HARDNESS OF COPPER AND COPPER-ALLOY WELD METAL

	Hardness[a]			
	Brinell		Vickers	
AWS Classification	HBS	Load, kgf	HV	Load, kgf
ECu	25[b]	. . .	38	1
ECuSi	80–100	500	94–110	1
ECuSn-A	70–85	500	76–98	1
ECuSn-C	85–100	500	98–110	1
ECuNi	60–80	20	64–94	1
ECuAl-A2	130–150	3000	130–150	10
ECuAl-B	130–180	3000	140–184	10
ECuNiAl	160–200	3000	163–205	10
ECuMnNiAl	160–200	3000	163–205	10

NOTES:

a. These values are average values for an as-welded deposit made with the filler metal specified. This table is for information only.

b. Rockwell F-scale (HRF).

A7.6.3 ECuAl-B electrodes deposit weld metal having a higher tensile strength, yield strength, and hardness (with a correspondingly lower ductility) than ECuAl-A2 weld metal. ECuAl-B electrodes are used for repairing aluminum bronze and other copper-alloy castings. ECuAl-B weld metal also is used for wear- and corrosion-resistant bearing surfaces.

A7.6.4 ECuNiAl electrodes are used to join or repair cast or wrought nickel-aluminum bronze materials. These weld metals also may be used for applications requiring high resistance to corrosion, erosion, or cavitation in salt and brackish water.

A7.6.5 ECuMnNiAl electrodes are used to join or repair cast or wrought manganese-nickel-aluminum bronze materials. These weld metals exhibit excellent resistance to corrosion, erosion, and cavitation.

A8. Special Testing

A8.1 It is recognized that supplementary tests may be necessary to determine the suitability of these electrodes for applications involving properties not considered in this specification. In such cases, additional tests to determine such specific properties as corrosion resistance, mechanical properties at low and high temperatures, and suitability for welding combinations of dissimilar metals may be required upon agreement between the purchaser and supplier.

A8.2 Tests for hardness are not included in this specification. For reference, however, a chart of typical hardness values is included as Table A2.

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 A3, along with the year in which they were last included in the specification.

TABLE A3
DISCONTINUED CLASSIFICATIONS

Discontinued Classifications	Last Year Published
ECuAl-A[a]	1948
ECuAl-C[b]	1948
ECuAl-D[c]	1948
ECuAl-E[d]	1948
ECuAl-A1[a]	1969

NOTES:

a. This electrode classification was reclassified as ECuAl-A1 with a wider aluminum content by dropping the minimum allowable. That classification was later discontinued in 1977.

b. This older electrode classification, together with the old version of ECuAl-B, was reclassified into a new single electrode classifiction ECuAl-A2 with a combined wider range of aluminum, and is currently listed in this current revision. This older classification continues in the A5.13 specification, but with a higher aluminum content than was specified in A5.6-48T.

c. This older electrode classification became the newer version of ECuAl-B and still continues in the current specification. This older classification continues in the A5.13 specfication, but with a higher aluminum content than was specified in A5.6-48T.

d. This older electrode classification was reclassified as ECuAl-C in the A5.13-56T specification. This older classification continues in the A5.13 specfication, but with a higher aluminum content than was specified in A5.6-48T.

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, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[9]

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 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

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

SPECIFICATION FOR COPPER AND COPPER-ALLOY BARE WELDING RODS AND ELECTRODES

SFA-5.7/SFA-5.7M

(Identical with AWS Specification A5.7/A5.7M:2007. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR COPPER AND COPPER-ALLOY BARE WELDING RODS AND ELECTRODES

SFA-5.7/SFA-5.7M

(Identical with AWS Specification A5.7/A5.7M:2007. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of copper and copper-alloy bare welding rods and electrodes for plasma arc, gas metal arc, and gas tungsten arc welding. It includes compositions in which the copper content exceeds that of any other element.[1]

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

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification with the designation A5.7 uses U.S. Customary Units. The specification A5.7M 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 or both under A5.7 or A5.7M specification.

2. Normative References

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

2.2 The following AWS standard[2] is referenced in the normative clauses of this document:

(1) AWS A5.01, *Filler Metal Procurement Guidelines*.

2.3 The following ANSI standard[3] 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 International standards[4] are referenced in the normative clauses of this document:

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

(2) ASTM E 75, *Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys*.

(3) ASTM E 478, *Standard Test Methods for Chemical Analysis of Copper Alloys*.

2.5 The following ISO standard[5] is referenced in the normative clauses of this document:

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

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[1] No attempt has been made to provide for classification of all grades of copper and copper-alloy filler metals; only the more commonly used have been included.

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

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

[4] ASTM International standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[5] ISO standards are published by the International Organization for Standardization, 1 rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

3. Classification

3.1 The welding materials covered by the AWS A5.7/A5.7M 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 filler metal or rod stock from which it was made, as specified in Table 1.

3.2 Material classified under one classification shall not be classified under any other classification of this specification.

3.3 The materials classified under this specification are intended for plasma arc, gas metal arc, and gas tungsten arc welding, but that does not prohibit their use with other welding processes for which they are found suitable.

4. Acceptance

Acceptance[6] 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 AWS classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[7]

6. Rounding-Off Procedure

For purposes of determining conformance with this specification, 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 value in accordance with the rounding-off method given in ASTM E 29.

7. Summary of Tests

Chemical analysis of the filler metal, or the stock from which it was made, is the only test required for classification of a product under this specification.

8. Retest

If the results of any test fail to meet its requirement, that test shall be repeated twice. The results of both tests shall meet the requirements. Specimens for retest may be taken from the original test sample or from a new test sample. For chemical analysis, retest need be only for those specific elements that failed to meet their 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 test specimens 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 prescribed procedures. In this case the requirement for doubling of the number of test specimens does not apply.

9. Chemical Analysis

9.1 A sample of the filler metal or the stock from which it is made shall be prepared for chemical analysis.

9.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 478, and ASTM E 75 for copper-nickel alloys, as appropriate.

9.3 The results of the analysis shall meet the requirements of Table 1 for the classification of filler metal under test.

10. Method of Manufacture

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

11. Standard Sizes and Shapes

Standard sizes for filler metal in the different package forms (straight lengths, coils with support, coils without support, and spools) are shown in Table 2.

12. Finish and Uniformity

12.1 All filler metal 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, the operation of the welding equipment, or the properties of the weld metal.

12.2 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 or semiautomatic equipment.

13. Standard Package Forms

13.1 Standard package forms are straight lengths, coils with support, coils without support, and spools. Standard

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[6] See Clause A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

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

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, PERCENT

			Composition, Weight Percent[a,b]											
AWS Classification	UNS Number[c]	Common Name	Cu Including Ag[e]	Zn	Sn	Mn	Fe	Si	Ni Including Co[f]	P	Al	Pb	Ti	Total Other Elements
ERCu	C18980	Copper	98.0 min	—	1.0	0.50	—	0.50	—	0.15	0.01	0.02	—	0.50
ERCuSi-A	C65600	Silicon bronze (copper-silicon)	Remainder	1.0	1.0	1.5	0.50	2.8–4.0	—	—	0.01	0.02	—	0.50
ERCuSn-A	C51800	Phosphor bronze (copper-tin)	Remainder	—	4.0–6.0	—	—	—	—	0.10–0.35	0.01	0.02	—	0.50
ERCuSn-C	C52100	Phosphor bronze (copper-tin)	Remainder	0.20	7.0—9.0	—	0.10	—	—	0.10–0.35	0.01	0.02	—	0.50
ERCuNi[d]	C71581	Copper-nickel	Remainder	—	—	1.0	0.40–0.75	0.25	29.0–32.0	0.02	—	0.02	0.20 to 0.50	0.50
ERCuAl-A1	C61000	Aluminum bronze	Remainder	0.20	—	0.50	—	0.10	—	—	6.0–8.5	0.02	—	0.50
ERCuAl-A2	C61800	Aluminum bronze	Remainder	0.02	—	—	1.5	0.10	—	—	8.5–11.0	0.02	—	0.50
ERCuAl-A3	C62400	Aluminum bronze	Remainder	0.10	—	—	2.0–4.5	0.10	—	—	10.0–11.5	0.02	—	0.50
ERCuNiAl	C63280	Nickel-aluminum bronze	Remainder	0.10	—	0.60–3.50	3.0–5.0	0.10	4.0–5.5	—	8.50–9.50	0.02	—	0.50
ERCuMnNiAl	C63380	Manganese-nickel aluminum bronze	Remainder	0.15	—	11.0–14.0	2.0–4.0	0.10	1.5–3.0	—	7.0–8.5	0.02	—	0.50

NOTES:

a. Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for ‘Total other elements’ in the last column in this table.

b. Single values shown are maximum, unless otherwise noted.

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

d. Sulfur shall be 0.01% maximum for the ERCuNi classification.

e. Ag may or may not be present.

f. Co may or may not be present.

TABLE 2
STANDARD SIZES

	Diameter			Tolerance[b]	
Standard Package Form	in.	in.	mm	in.	mm
Straight lengths[c]	1/16	(0.062)	1.6	±0.002	±0.1
	5/64	(0.078)	2.0	±0.002	±0.1
	3/32	(0.094)	2.4	±0.002	±0.1
	. . .	(0.097)	2.5	±0.002	±0.1
	1/8	(0.125)	3.2	±0.002	±0.1
	5/32	(0.156)	4.0	±0.002	±0.1
	3/16	(0.187)	4.8[d]	±0.002	±0.1
	. . .	(0.197)	5.0	±0.002	±0.1
	1/4	(0.250)	6.4[d]	±0.002	±0.1
Coils, with or without support	1/8	(0.125)	3.2	±0.002	+0.01 −0.07
	5/32	(0.156)	4.0	±0.002	+0.01 −0.07
	3/16	(0.187)	4.8[d]	±0.002	+0.01 −0.07
	. . .	(0.197)	5.0	±0.002	+0.01 −0.07
	. . .	(0.237)	6.0	±0.002	+0.01 −0.07
	1/4	(0.250)	6.4[d]	±0.002	+0.01 −0.07
Spools	0.020		0.5	±0.002	+0.01 −0.04
	0.030		0.8	±0.002	+0.01 −0.04
	0.035		0.9	±0.002	+0.01 −0.04
	. . .		1.0	±0.002	+0.01 −0.04
	0.045		—	±0.002	+0.01 −0.04
	. . .	(0.047)	1.2	±0.002	+0.01 −0.04
	1/16	(0.062)	1.6	±0.002	+0.01 −0.04
	5/64	(0.078)	2.0	±0.002	+0.01 −0.04
	3/32	(0.094)	2.4	±0.002	+0.01 −0.04
	. . .	(0.097)	2.5	±0.002	+0.01 −0.04

NOTES:

a. Dimensions, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.

b. Out of roundness (the difference between the major and minor diameters) shall not exceed one-half of the tolerance.

c. Length shall be 36 in. +0, −1/2 in. [900 mm ±2%].

d. Not included in ISO 544.

TABLE 3
STANDARD PACKAGE DIMENSIONS AND WEIGHT[a]

					Diameter			
	Net Weight[b]		Width, max.		Inside		Outside	
Package Form	lb	kg	in.	mm	in.	mm	in.	mm
Coils without support	As agreed by the purchaser and supplier							
Coils with support	25	12	2½	65	12 ± ⅛	305 + 10, −0	17½	445
	50	25	4⅝	120	12 ± ⅛	305 + 10, −0	17	430
	60	30	4⅝	120	12 ± ⅛	305 + 10, −0	17	430
Spools[c]	2[d]	1[d]	. . .	. . .	. . .	. . .	4	100
	10[d]	5[d]	. . .	. . .	. . .	. . .	8	200
	25[e]	12[e]	. . .	. . .	. . .	. . .	12	300
Straight lengths	5	2.5	. . .	. . .	. . .	. . .	. . .	. . .
	10	5	. . .	. . .	. . .	. . .	. . .	. . .
	25	12	. . .	. . .	. . .	. . .	. . .	. . .
	50	25	. . .	. . .	. . .	. . .	. . .	. . .

NOTES:

a. Weights, dimensions, and package forms other than these shall be as agreed upon between purchaser and supplier.

b. Net weight may vary ±10% from the nominal weight, except as provided in Notes d and e.

c. Dimensions of the standard spools are specified in Figure 1.

d. ±20%.

e. ±20%, except that 20% of any lot may contain spools that vary in weight from 12-½ lb to 20 lb [5 kg to 10 kg].

package dimensions and weights for each form are given in Table 3. Dimensions for standard spools are given in Fig. 1. Package forms, sizes, and weights other than these shall be as agreed upon between purchaser and supplier.

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

13.3 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. Spools shall electrically insulate the filler metal from the spindle.

14. Winding Requirements

14.1 The electrode on spools and in coils shall be closely wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be identified so that it can be located readily and shall be fastened to avoid unwinding. The outermost layer of electrode or rod on spools shall be at least ⅛ in. [3 mm] from the rim (the O.D.) of the flanges of the spool.

14.2 The cast and helix of the filler metal in coils and spools shall be such that the filler metal will feed in an uninterrupted manner in automatic and semi-automatic equipment.

14.3 The cast and helix of filler metal on 4 in. [100 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will:

(1) form a circle not less than 4 in. [100 mm], nor more than 15 in. [380 mm] in diameter; and

(2) rise above the flat surface no more than ½ in. [13 mm] at any location.

14.4 The cast and helix of filler metal on 8 in. [200 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will:

(1) form a circle not less than 10 in. [250 mm] nor more than 30 in. [760 mm] in diameter, and

(2) rise above the flat surface no more than ¾ in. [19 mm] at any location.

14.5 The cast and helix of filler metal on 12 in. [300 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will:

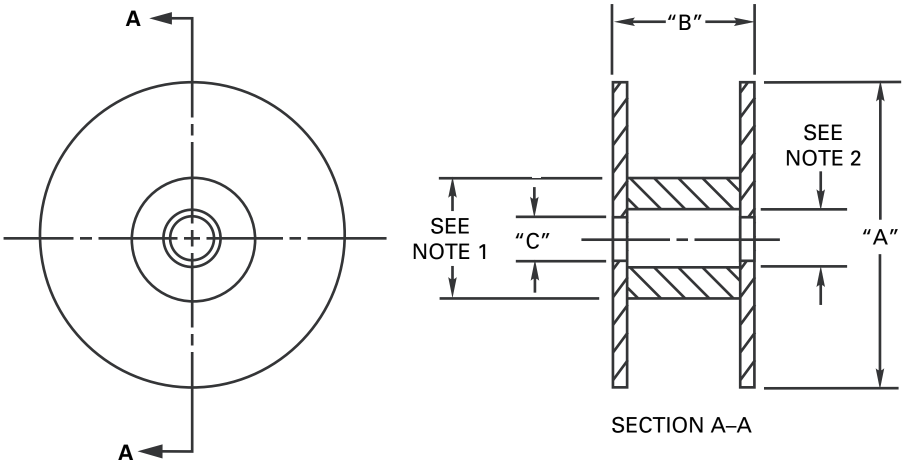
(1) form a circle not less than 15 in. [380 mm] nor more than 50 in. [1 250 mm] in diameter, and

(2) rise above the flat surface no more than 1 in. [25 mm] at any location.

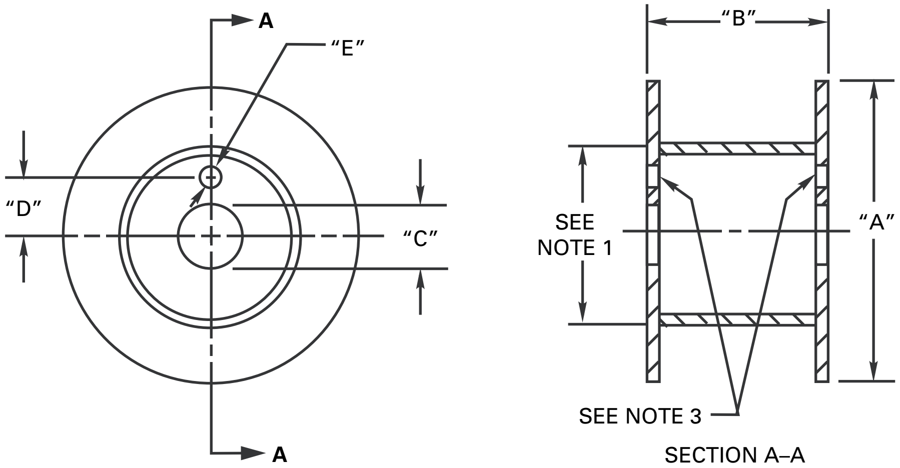
15. Filler Metal Identification

15.1 The product information and precautionary information required in 17.1 and 17.2 for marking each package shall also appear on each coil and spool.

FIG. 1 DIMENSIONS OF 4 IN., 8 IN., AND 12 IN. [100 MM, 200 MM, AND 300 MM] SPOOLS



DIMENSIONS OF STANDARD 4 in. [100 mm] SPOOL



DIMENSIONS OF STANDARD 8 in. AND 12 in. [200 mm AND 300 mm] SPOOLS

		DIMENSIONS					
		4 in. [100 mm] Spools		8 in. [200 mm] Spools		12 in. [300 mm] Spools	
		in.	mm	in.	mm	in.	mm
A	Diameter, max. (Note 4)	4.0	102	8.0	203	12	305
B	Width	1.75	46	2.16	56	4.0	103
	Tolerance	±0.03	+0, −2	±0.03	+0, −3	±0.06	+0, −3
C	Diameter	0.63	16 +1,	2.03	50.5	2.03	50.5
	Tolerance	+0.01, −0	−0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0
D	Distance between axes	—	—	1.75	44.5	1.75	44.5
	Tolerance	—	—	±0.02	±0.5	±0.02	±0.5
E	Diameter (Note 3)	—	—	0.44	10	0.44	10
	Tolerance	—	—	+0, −0.06	+1, −0	+0, −0.06	+1, −0

NOTES:

1. Outside diameter of barrel shall be such as to permit proper feeding of the filler metals.
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.

15.2 Coils without support shall have a tag containing this information securely attached to the inside end of the coil.

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

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

15.5 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 supplier and purchaser and the color shall be identified on the packaging.) When the AWS classification designation is used, the "ER" may be omitted; for example, "CuAl-A2" for classification ERCuAl-A2. Additional identification shall be as agreed upon between supplier and purchaser.

16. Packaging

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

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[8] 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.

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[8] Typical example of "warning labels" 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 Copper and Copper-Alloy Bare Welding Rods and Electrodes

(This annex is not part of AWS A5.7/A5.7M:2007, *Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*, but is included for informational purposes only.)

A1. Introduction

The purpose of this guide is to correlate the filler metal 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 filler metal classification in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix letters ER at the beginning of each classification designation stand for electrode and rod, indicating that the filler metal may be used either way. The chemical symbol Cu is used to identify the electrodes as copper-base alloys. The additional chemical symbol, such as Si for silicon in ERCuSi, Sn for tin in ERCuSn, etc., indicates the principal alloying element of each classification or group of classifications. Where more than one classification is included in a basic group, the individual classifications in the group are identified by using letters (A, B, C, etc.), as in ERCuSn-A and ERCuSn-C. Further subdividing is done by using digits (1, 2, etc.) following the letter, as in ERCuAl-A1, ERCuAl-A2, and ERCuAl-A3.

A2.2 An international system for designating welding filler metals, developed by the International Institute of Welding (IIW), is being adopted in many ISO specifications. Table A1 shows the designations for bare copper-alloy filler metals in ISO 24373 corresponding to those in this specification.

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, needs to 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 normally is 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 the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the "certification" required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes to which welders and welding operators can be exposed during welding. These are:

TABLE A1
COMPARISON OF SPECIFICATIONS

Bare Rods and Electrodes A5.7/A5.7M	Covered Electrodes A5.6/A5.6M[a]	ISO 24373 Designations[b]
ERCu	ECu	SCu 1898
ERCuSi-A	ECuSi	SCu 6560
ERCuSn-A	ECuSn-A	SCu 5180
ERCuSn-C	ECuSn-C	SCu 5210
ERCuNi	ECuNi	SCu 7158
ERCuAl-A1	. . .	SCu 6100
ERCuAl-A2	ECuAl-A2	SCu 6180
ERCuAl-A3	. . .	SCu 6240
ERCuNiAl	ECuNiAl	SCu 6328
ERCuMnNiAl	ECuMnNiAl	SCu 6338

NOTES:

a. AWS A5.6/A5.6M, *Specification for Copper and Copper-Alloy Electrodes for Shielded Metal Arc Welding.*

b. ISO 24373, *Welding consumables — Solid wires and rods for fusion welding of copper and copper alloys — Classification.*

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

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

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

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

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

A5.2 ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the clause on Health Protection and Ventilation in that document. Further details about ventilation can be found in AWS F3.2, *Ventilation Guide for Welding Fume*.

A6. Welding Considerations

A6.1 The filler metals in this specification can be used with any of a variety of welding processes. Most notable of them are the gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW) processes.

A6.2 Before welding or heating any copper-base alloy, the base metal must be clean. Oil, grease, paint, lubricants, marking pencils, temperature indicating materials, threading compounds and other such materials frequently contain sulfur or lead that may cause cracking (embrittlement) of the base metal or the weld metal if present during welding or heating.

A6.3 For GTAW, direct current-electrode negative (dcen) is used. High purity grades of either argon or helium (or a combination of the two) are used as a shielding gas.

A6.4 For GMAW, direct current-electrode positive (dcep) is employed. Argon shielding gas is most often used, but mixtures of argon and helium are also commonly used when welding high conductivity copper.

A7. Description and Intended Use of Electrodes and Rods

A7.1 General Characteristics

A7.1.1 Gas tungsten arc welding normally employs dcen current.

A7.1.2 Gas metal arc welding normally employs dcep current.

A7.1.3 Shielding gas for use with either process normally is argon, helium, or a mixture of the two, with or without hydrogen. Oxygen-bearing gases normally are not recommended.

A7.1.4 Base metal should be free from moisture and all other contaminants, including surface oxides.

A7.2 ERCu (Copper) Filler Metal Classification

A7.2.1 ERCu filler metals are made of deoxidized copper, but also may contain one or more of the following elements: phosphorus, silicon, tin, manganese, and silver. Phosphorus and silicon are added primarily as deoxidizers. The other elements add either to the ease of welding or to the properties of the final weldment. ERCu filler metals generally are used for the welding of deoxidized and electrolytic tough pitch (ETP) copper. Reactions with hydrogen in oxygen-free copper, and the segregation of copper oxide in tough pitch copper may detract from joint efficiency. ERCu welding electrodes and rods may be used to weld these base metals when the highest quality is not required.

A7.2.2 Preheating is desirable on most work; on thick base metal it is essential. Preheat temperatures of 400°F to 1000°F [200°C to 500°C] are suitable.

A7.2.3 For thick base metals, gas metal arc welding is preferred. Conventional joint designs consistent with good welding practice are generally satisfactory. An external source of preheating generally is not needed when welding base metal ¼ in. [6 mm] and less in thickness. Preheating in the range of 400°F to 1000°F [200°C to 500°C] is desirable when welding base metal thicker than ¼ in. [6 mm] if high-quality welds are to be obtained.

A7.3 ERCuSi (Silicon Bronze) Filler Metal Classification

A7.3.1 ERCuSi filler metals are copper-base alloys containing approximately three percent silicon; they may also contain small percentages of manganese, tin, or zinc. They are used for gas tungsten and gas metal arc welding of copper-silicon and copper-zinc base metals, to themselves and also to steel.

A7.3.2 When gas metal arc welding with ERCuSi filler metals, it generally is best to keep the weld pool small and the interpass temperature below 150°F [65°C] to minimize hot cracking. The use of narrow weld passes reduces contraction stresses and also permits faster cooling through the hot-short temperature range.

A7.3.3 When gas tungsten arc welding with ERCuSi filler metals, best results are obtained by keeping the weld pool small. Preheating is not required. Welding can be done in all positions, but the flat position is preferred.

A7.4 ERCuSn-x (Phosphor Bronze) Filler Metal Classification

A7.4.1 ERCuSn-A filler metals contain about five percent tin and up to 0.35% phosphorus added as a deoxidizer. Tin increases wear resistance of the weld metal and slows the rate of solidification by broadening the temperature differential between the liquidus and solidus. This slower solidification increases the tendency to hot shortness. To minimize this effect, the weld pool should be kept small and welding time as short as possible. ERCuSn-A filler metals can be used to weld bronze and brass. They also can be used to weld copper if the presence of tin in the weld metal is not objectionable.

A7.4.2 ERCuSn-C filler metal contains about 8% tin and up to 0.35% phosphorus. The higher tin increases strength and wear resistance and increases the solidification temperature range during deposition of the weld metal.

A7.4.3 When gas tungsten arc welding with ERCuSn filler metals, preheating is desirable. Welding is done in the flat position only.

A7.5 ERCuNi (Copper-Nickel) Filler Metal Classification

A7.5.1 ERCuNi electrodes and rods are used for the welding of wrought or cast 70/30, 80/20, and 90/10 copper-nickel alloys to themselves or to each other. These filler metals also are used for welding the clad side of copper-nickel clad steel. Preheating generally is not necessary.

A7.5.2 When gas tungsten or gas metal arc welding with ERCuNi filler metals, preheating is not required. Welding is done in all positions. The arc should be kept as short as possible to assure adequate shielding gas coverage and thus minimize porosity. This filler metal may also be used for surfacing applications where high resistance to corrosion, erosion, or cavitation is required.

A7.6 ERCuAl (Aluminum Bronze) Filler Metal Classification

A7.6.1 ERCuAl-A1 filler metal is an iron-free aluminum bronze. It is recommended for use as a surfacing metal for wear-resistant surfaces having relatively light loads, for resistance to corrosive media such as salt or brackish water, and for resistance to many commonly used acids in varying concentrations and temperatures. This alloy is not recommended for joining.

A7.6.2 ERCuAl-A2 filler metal is iron-bearing aluminum bronze and is generally used for joining aluminum bronzes of similar composition, manganese bronze, silicon bronze, and some copper-nickel alloys, ferrous metals and dissimilar metals. The most common dissimilar metal combinations are aluminum bronze to steel and copper to steel. This alloy is also used to provide wear-and corrosion-resistant surfaces.

A7.6.3 ERCuAl-A3 is a higher strength aluminum bronze filler metal used for joining and repair welding of aluminum bronze castings of similar composition, and for depositing bearing surfaces and wear- and corrosion-resistant surfaces.

A7.6.4 ERCuNiAl is a nickel-aluminum bronze filler metal used for joining and repairing of cast and wrought nickel-aluminum bronze base metals.

A7.6.5 ERCuMnNiAl is a manganese-nickel-aluminum bronze filler metal used for joining or repairing of cast or wrought base metals of similar composition. This filler metal may also be used for surfacing applications where high resistance to corrosion, erosion, or cavitation is required.

A7.6.6 Because of the formation of aluminum oxide in the molten weld pool, aluminum bronze filler metals are not recommended for use with the oxyfuel gas welding process.

A7.6.7 Copper-aluminum weld metals are characterized by relatively high tensile strength, yield strength, and hardness. Depending upon the thickness or composition of the base metal, preheat may or may not be necessary.

TABLE A2
HARDNESS AND TENSILE STRENGTH OF COPPER AND COPPER-ALLOY WELD METAL

	Hardness				Minimum Tensile Strength	
	Brinell		Vickers			
AWS Classification	HBW	Load, kgf	HV	Load, Kgf	psi	MPA
ERCu	25[b]	. . .	38	. . .	25 000	170
ERCuSi-A	80–100	500	94–110	1	50 000	345
ERCuSn-A	70–85	500	76–98	1	35 000	240
ERCuSn-C	85–100	500	98–110	1	55 000	380
ERCuNi	60–80	500	64–94	1	50 000	345
ERCuAl-A1	80–110	500	94–115	10	55 000	380
ERCuAl-A2[a]	130–150	3000	130–150	10	60 000	415
ERCuAl-A3[a]	140–180	3000	140–184	10	65 000	450
ERCuNiAl[a]	160–200	3000	163–205	10	72 000	480
ERCuMnNiAl[a]	160–200	3000	163–205	10	75 000	515

GENERAL NOTE: Hardness values as listed above are average values for an as-welded deposit made with the filler metal specified. This table is included for information only.

NOTES:

a. Gas tungsten arc process only.

b. Rockwell F.

A7.6.8 Welding in the flat position is preferred. Welding in other positions can be done successfully with pulsed arc welding equipment and welder technique.

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, scaling resistance, or strength at elevated or cryogenic temperatures) may be required. AWS A5.01, *Filler Metal Procurement Guidelines*, 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 purchaser and supplier.

Tests for tensile strength and hardness are not included in this specification. A chart of strength and hardness is included in Table A2. When tests for mechanical properties are specified, the procedures should be in accordance with AWS B4.0 or AWS B 4.0M, *Standard Methods for Mechanical Testing of Welds*.

It should be noted that the variables in the procedure (current, voltage, and welding speed), variables in shielding medium (the specific gas mixture or the flux), variables in the composition of the base metal and the filler metal influence the results which may be obtained. When these variables are properly controlled, however, the filler metal should give sound welds whose strengths (determined by all-weld-metal tension tests) should meet or exceed the minimums shown in Table A2.

A9. Discontinued

A9.1 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 A3, 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 and below. 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, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

TABLE A3
DISCONTINUED CLASSIFICATIONS

Discontinued Classifications	Last Year Published
RCuAl-A1	1952
RCuSn[a]	1952
RCuSi-B	1957
RCu[b]	1969
RCuSi-A[b]	1969
RCuSn-A[b]	1969
RCuNi[b]	1969
RCuAl-A2[b]	1969
RBCuZn-A[c]	1969
RCuZn-B[c]	1969
RCuZn-C[c]	1969
RBCuZn-D[c]	1969
RCuAl-B	1969

NOTES:

[a] This rod classification was reclassified as RCuSn-A with a wider range listed for phosphorus.

[b] These classifications were redesignated as ERxx-x in A5.7-77 to indicate both electrode and rod materials and continue in the current specification.

[c] These classifications were transferred to A5.27 where they became RBxx-x rod for braze welding. The A5.27 specification was later withdrawn, and these classifications moved to the current A5.8 specification.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[9]

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

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

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SPECIFICATION FOR FILLER METALS FOR BRAZING AND BRAZE WELDING

SFA-5.8/SFA-5.8M

(Identical with AWS Specification A5.8/A5.8M:2011. In case of dispute, the original AWS text applies.)

Specification for Filler Metals for Brazing and Braze Welding

1. General Requirements

1.1 Scope. This specification prescribes requirements for the classification of brazing filler metals for brazing and braze welding. It includes brazing filler metals for brazing with or without a flux and in all protective atmospheres for various applications, including those for vacuum service.[1] The prefix "RB" indicates that the brazing filler metal is suitable for use both as brazing rod for braze welding and as a brazing filler metal.

1.2 Units of Measurement. This specification makes use of both the International System of Units (SI) and U.S. Customary Units. 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 A5.8M uses the International System of Units. The specification A5.8 uses U.S. Customary Units. The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing or packaging of brazing filler metal, or both, under A5.8M or A5.8 specifications.

1.3 Safety. Safety issues and concerns are addressed in this standard, although health issues and concerns are beyond the scope of this standard. Some safety and health information can be found in nonmandatory Annex Clauses B5 and B10.

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 (see Annex Clause B10)

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

Material or Equipment Manufacturers:

(1) Material Safety Data Sheets supplied by the 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.

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[1] Filler metals for vacuum service are for devices operating in vacuum service, regardless of the atmosphere used in making the joint.

2. Normative References

The standards listed below contain provisions that, through reference in this text, constitute mandatory provisions of this AWS standard. 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) standards:[2]

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

AWS A5.01M/A5.01 (ISO 14344:2002 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

2.2 American National Standards Institute (ANSI) standard:[3]

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

2.3 ASTM International standards:[4]

ASTM B214, *Standard Method for Sieve Analysis of Metal Powders*

ASTM E11-01, *Standard Specification for Wire Cloth and Sieves for Testing Purposes*

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

ASTM E1371-05, *Standard Test Method for Gravimetric Determination of Phosphorus in Phosphorus–Copper Alloys or Phosphorus–Copper–Silver Alloys*

Annual Book of ASTM Standards, Section 03—Metals Test Methods and Analytical Procedures, Volume 5—Analytical Chemistry for Metals, Ores, and Related Materials

2.4 International Organization for Standardization (ISO) standard:[5]

ISO 80000–1 *Quantities and units—Part 0: General Principles*

2.5 SAE International standard:[6]

SAE HS-1086, *Metals & Alloys in the Unified Numbering System*

3. Classification[7]

3.1 The brazing filler metals covered by the A5.8M/A5.8 specification are classified using a system that is independent of the International System of Units (SI) and U.S. Customary Units. Their classification is according to the chemical composition as specified in Tables 1 through 7.

3.2 Brazing filler metal classified under one classification shall not be classified under any other classification in this specification. However, material may be classified under both A5.8M and A5.8 specifications.

4. Acceptance

Acceptance[8] of the brazing filler metal shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

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[2] AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

[3] This ANSI standard is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

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

[5] ISO standards are published by the International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56 CH-1211 Geneva 20, Switzerland.

[6] SAE International standards are published by SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

[7] An explanation of the method of classification of the filler metals is included in B2 (in Annex B).

[8] See B3 (in Annex B) for further information concerning acceptance, testing of the material shipped, and AWS A5.01M/A5.01 (ISO 14344 MOD).

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[9]

6. Rounding-Off Procedure

For purposes of determining compliance with the requirements of this standard, the actual test values shall be subjected to the rounding-off 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 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 10 MPa [1000 psi] for tensile and yield strength and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded-off results shall fulfill the requirements for the classification under test.

7. Summary of Tests

7.1 The tests required for each classification or product form are as follows:

7.1.1 Chemical analysis of the brazing filler metal is required for all classifications.

7.1.2 Brazing filler metals for vacuum service require a melt cleanliness test and a spatter test in addition to chemical analysis.

7.1.3 Sieve analysis is required for all powdered brazing filler metals.

7.1.4 A binder content test for transfer tape used in conjunction with powdered brazing filler metals is required.

7.2 The material for the preparation of test samples, the brazing and testing procedures to be employed, and the results required are specified in Clauses 9 through 13.

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. Samples for retest may be taken from the original sample or from one or two new samples. For chemical analysis, retest need be only for the specific elements that failed to meet the 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 the preparation or after the completion of any test it is clearly determined that prescribed or proper procedures were not followed in preparing the 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.

9. Chemical Analysis

9.1 Brazing filler metals shall conform to the chemical composition requirements of Tables 1 through 7 for the specific brazing filler metal being tested.

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[9] See B4 (in Annex B) for further information concerning certification and the testing called for to meet this requirement.

Table 1[a, b]
Chemical Composition Requirements for Silver Brazing Filler Metals

AWS Classification	UNS Number[c]	Chemical Composition, Weight Percent								
		Ag	Cu	Zn	Cd	Ni	Sn	Li	Mn	Other Elements, Total[d]
BAg-1	P07450	44.0–46.0	14.0–16.0	14.0–18.0	23.0–25.0	—	—	—	—	0.15
BAg-1a	P07500	49.0–51.0	14.5–16.5	14.5–18.5	17.0–19.0	—	—	—	—	0.15
BAg-2	P07350	34.0–36.0	25.0–27.0	19.0–23.0	17.0–19.0	—	—	—	—	0.15
BAg-2a	P07300	29.0–31.0	26.0–28.0	21.0–25.0	19.0–21.0	—	—	—	—	0.15
BAg-3	P07501	49.0–51.0	14.5–16.5	13.5–17.5	15.0–17.0	2.5–3.5	—	—	—	0.15
BAg-4	P07400	39.0–41.0	29.0–31.0	26.0–30.0	—	1.5–2.5	—	—	—	0.15
BAg-5	P07453	44.0–46.0	29.0–31.0	23.0–27.0	—	—	—	—	—	0.15
BAg-6	P07503	49.0–51.0	33.0–35.0	14.0–18.0	—	—	—	—	—	0.15
BAg-7	P07563	55.0–57.0	21.0–23.0	15.0–19.0	—	—	4.5–5.5	—	—	0.15
BAg-8	P07720	71.0–73.0	Remainder	—	—	—	—	—	—	0.15
BAg-8a	P07723	71.0–73.0	Remainder	—	—	—	—	0.25–0.50	—	0.15
BAg-9	P07650	64.0–66.0	19.0–21.0	13.0–17.0	—	—	—	—	—	0.15
BAg-10	P07700	69.0–71.0	19.0–21.0	8.0–12.0	—	—	—	—	—	0.15
BAg-13	P07540	53.0–55.0	Remainder	4.0–6.0	—	0.5–1.5	—	—	—	0.15
BAg-13a	P07560	55.0–57.0	Remainder	—	—	1.5–2.5	—	—	—	0.15
BAg-18	P07600	59.0–61.0	Remainder	—	—	—	9.5–10.5	—	—	0.15
BAg-19	P07925	92.0–93.0	Remainder	—	—	—	—	0.15–0.30	—	0.15
BAg-20	P07301	29.0–31.0	37.0–39.0	30.0–34.0	—	—	—	—	—	0.15
BAg-21	P07630	62.0–64.0	27.5–29.5	—	—	2.0–3.0	5.0–7.0	—	—	0.15
BAg-22	P07490	48.0–50.0	15.0–17.0	21.0–25.0	—	4.0–5.0	—	—	7.0–8.0	0.15
BAg-23	P07850	84.0–86.0	—	—	—	—	—	—	Remainder	0.15
BAg-24	P07505	49.0–51.0	19.0–21.0	26.0–30.0	—	1.5–2.5	—	—	—	0.15
BAg-26	P07250	24.0–26.0	37.0–39.0	31.0–35.0	—	1.5–2.5	—	—	1.5–2.5	0.15
BAg-27	P07251	24.0–26.0	34.0–36.0	24.5–28.5	12.5–14.5	—	—	—	—	0.15
BAg-28	P07401	39.0–41.0	29.0–31.0	26.0–30.0	—	—	1.5–2.5	—	—	0.15
BAg-33	P07252	24.0–26.0	29.0–31.0	*26.5–28.5*	16.5–18.5	—	—	—	—	0.15
BAg-34	P07380	37.0–39.0	31.0–33.0	26.0–30.0	—	—	1.5–2.5	—	—	0.15
BAg-35	P07351	34.0–36.0	31.0–33.0	31.0–35.0	—	—	—	—	—	0.15
BAg-36	P07454	44.0–46.0	26.0–28.0	23.0–27.0	—	—	2.5–3.5	—	—	0.15
BAg-37	P07253	24.0–26.0	39.0–41.0	31.0–35.0	—	—	1.5–2.5	—	—	0.15

[a] See Table B.3 for discontinued brazing filler metal classifications.

[b] See Table 7 for the following Ag classifications intended for vacuum service not included here: BVAg-0, BVAg-6b, BVAg-8b, and BVAg-29 to BVAg-32.

[c] SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*

[d] The brazing filler metal shall be analyzed for those specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified.

9.2 The sample shall be analyzed by accepted analytical methods.

9.3 In case of dispute, the referee methods for all elements except phosphorus shall be the appropriate analytical method in the latest edition of the *Annual Book of ASTM Standards, Section 03—Metals Test Methods and Analytical Procedures, Volume 5—Analytical Chemistry for Metals, Ores, and Related Materials*. For phosphorus, the referee method shall be that of ASTM E1371-05.

10. Sieve Analysis

10.1 Sieve analyses for standard sizes of powdered brazing filler metals shall be made in accordance with ASTM B214.

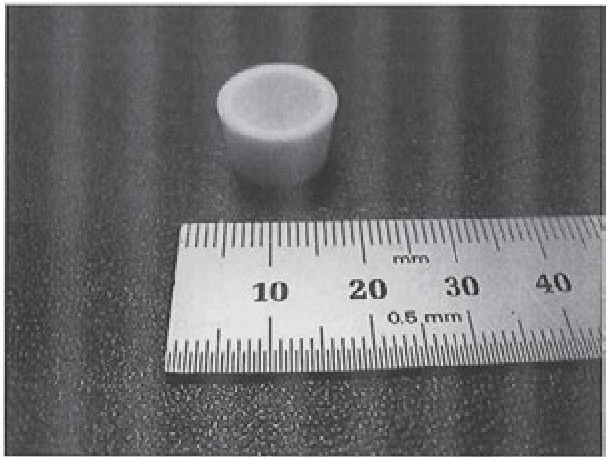
10.2 The results of the sieve analysis shall conform to the particle size distribution shown in Table 8. Sizes other than the standard sizes shall be as agreed upon between the purchaser and the supplier.

11. Melt Cleanliness Test

11.1 The melt cleanliness test shall be required for all BV class brazing filler metals produced for use in vacuum service applications only. The melt cleanliness test shall be performed on a sample of approximately 0.5 grams (g) [0.015 troy ounce (0.001 pound (lb))] of brazing filler metal. Clean, dry tools shall be used to extract the sample from the stock, and the sample shall be placed in a clean, dense polycrystalline (greater than 94%) high purity alumina crucible. As an alternative, a fused silica crucible or boat that has been precleaned by air firing at a temperature of at least 1100 °C [2000 °F] and stored in a dust-free container may be used. Figure 1 illustrates a representative test crucible.

11.2 The container with the sample shall be placed in a combustion tube muffle made of dense polycrystalline alumina, fused silica, or an equivalent. The muffle shall be purged with a minimum of 30% dry hydrogen to keep the nitrogen level balanced (–40 °C [–40 °F] dew point or lower), and the sample shall be heated to a minimum of 20 °C [36 °F] above the liquidus temperature established for the material (see Table B.2). It shall be held at that temperature for ten minutes and then allowed to cool in the muffle to a temperature no higher than 65 °C [150 °F]. At that time, the flow of hydrogen shall be stopped, and the sample shall be removed for examination.

11.3 The fused sample shall be examined at a magnification of 5×. If it has melted completely and does not exhibit excessive black specks on the surface, it meets the requirements of the cleanliness test. The acceptance standard for black specks shall be established by the supplier or as agreed upon between the supplier and purchaser. Evidence of proper melting of the specimen is shown by the alloy forming into a spherical shape in the alumina crucible.



Photograph courtesy of WESGO Ceramics

Figure 1—Illustration of an Acceptable Crucible

Table 2[a,b]
Chemical Composition Requirements for Gold Brazing Filler Metals

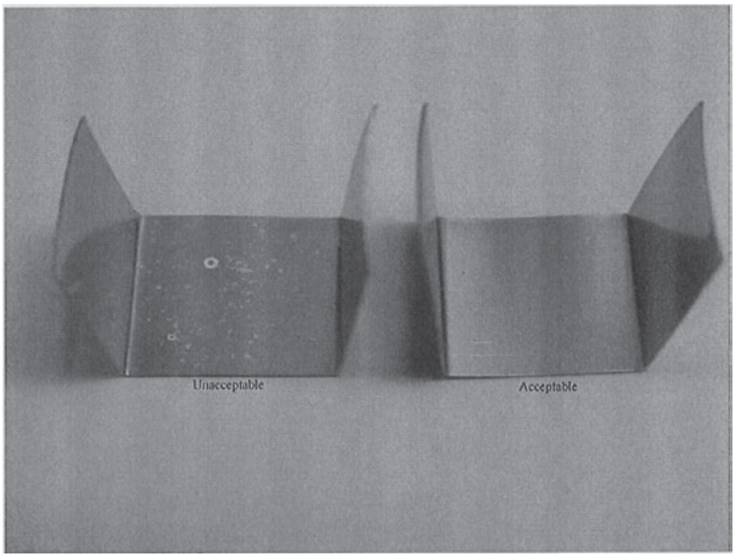
	Chemical Composition, Weight Percent					
AWS Classification	UNS Number[c]	Au	Cu	Pd	Ni	Other Elements, Total[d]
BAu-1	P00375	37.0–38.0	Remainder	—	—	0.15
BAu-2	P00800	79.5–80.5	Remainder	—	—	0.15
BAu-3	P00350	34.5–35.5	Remainder	—	2.5–3.5	0.15
BAu-4	P00820	81.5–82.5	—	—	Remainder	0.15
BAu-5	P00300	29.5–30.5	—	33.5–34.5	35.5–36.5	0.15
BAu-6	P00700	69.5–70.5	—	7.5–8.5	21.5–22.5	0.15

[a] See Table B.3 for discontinued brazing filler metal classifications.

[b] See Table 7 for the following Au classifications intended for vacuum service not included here: BVAu-2, BVAu-3, BVAu-4, BVAu-7, BVAu-8, BVAu-9, and BVAu-10.

[c] SAE HS-1086, *Metals & Alloys in the Unified Numbering System*.

[d] The brazing filler metal shall be analyzed for those specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified.



Photograph courtesy of Lucas-Milhaupt, Incorporated

Figure 2—Nickel Channel with Acceptable Test Results (right) and Unacceptable Spatter (left)

12. Spatter Test

12.1 The spatter test shall be required for all BV class brazing filler metals produced for use in vacuum service applications only. Brazing filler metal in the form of powder is exempt from the spatter test due to its high ratio of surface area to volume and the oxides usually present on these surfaces.

12.2 The spatter test shall be performed at the same time as the melt cleanliness test by bridging the crucible or boat with a nickel channel, the legs of which are designed to allow a small clearance, 1.5 mm [0.06 in] maximum, above the crucible. The bridge shall be no more than 10 mm [0.39 in] above the brazing filler metal. Figure 2 shows a suitable nickel channel and illustrates acceptable and unacceptable test results.

12.3 Upon completion of the test, the bottom side of the nickel channel shall be examined at a 5× magnification for evidence of any spatter. If there is no evidence of spatter, the sample meets the requirements.

Table 3[a]
Chemical Composition Requirements for Aluminum and Magnesium Brazing Filler Metals

		Chemical Composition, Weight Percent[b]													
AWS	UNS													Other Elements[d]	
Classification	Number[c]	Si	Cu	Mg	Bi	Fe	Zn	Mn	Cr	N	Ti	Be	Al	Each	Total
BAlSi-2	A94343	6.8–8.2	0.25	—	—	0.8	0.20	0.10	—	—	—	—	Remainder	0.05	0.15
BAlSi-3	A94145	9.3–10.7	3.3–4.7	0.15	—	0.8	0.20	0.15	0.15	—	—	—	Remainder	0.05	0.15
BAlSi-4	A94047	11.0–13.0	0.30	0.10	—	0.8	0.20	0.15	—	—	—	—	Remainder	0.05	0.15
BAlSi-5	A94045	9.0–11.0	0.30	0.05	—	0.8	0.10	0.05	—	—	0.20	—	Remainder	0.05	0.15
BAlSi-7	A94004	9.0–10.5	0.25	1.0–2.0	—	0.8	0.20	0.10	—	—	—	—	Remainder	0.05	0.15
BAlSi-9	A94147	11.0–13.0	0.25	0.10–0.50	—	0.8	0.20	0.10	—	—	—	—	Remainder	0.05	0.15
BAlSi-11	A94104	9.0–10.5	0.25	1.0–2.0	0.02–0.20	0.8	0.20	0.10	—	—	—	—	Remainder	0.05	0.15
BMg-1	M19001	0.05	0.05	Remainder	—	0.005	1.7–2.3	0.15–1.50	—	0.005	—	0.0002–0.0008	8.3–9.7	—	0.30

[a] See Table B.3 for discontinued brazing filler metal classifications.

[b] Single values are maximum unless noted.

[c] SAE HS-1086, *Metals & Alloys in the Unified Numbering System*.

[d] The brazing filler metal shall be analyzed for those specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified.

Table 4
Chemical Composition Requirements for Copper, Copper–Zinc, and Copper–Phosphorus Brazing Filler Metals[a, b]

AWS Classification	UNS Number[d]	Chemical Composition, Weight Percent[c] Cu	Ag	Zn	Sn	Fe	Mn	Ni	P	Pb	Al	Si	Other Elements, Total[e]
BCu-1	C14180	99.90 min.	—	—	—	—	—	—	0.075	0.02	0.01	—	0.10
BCu-1a	TBD	99.00[f] min.	—	—	—	—	—	—	—	—		—	0.30
BCu-1b	C11000	99.90 min.	—	—	—	—	—	—	—	—		—	0.10
BCu-2[g]	TBD	86.50[f] min.	—	—	—	—	—	—	—	—		—	0.50
BCu-3[h]	C10200	99.95 min.	—	—	—	—	—	—	—	—		—	0.05
RBCuZn-A	C47000	57.0–61.0	—	Remainder	0.25–1.00	*	*	—	—	0.05*	0.01*	*	0.50
RBCuZn-B	C68000	56.0–60.0[j]	—	Remainder	0.80–1.10	0.25–1.20	0.01–0.50	0.20–0.80[i]	—	0.05*	0.01*	0.04–0.20	0.50
RBCuZn-C	C68100	56.0–60.0[j]	—	Remainder	0.80–1.10	0.25–1.20	0.01–0.50	—	—	0.05*	0.01*	0.04–0.15	0.50
RBCuZn-D	C77300	46.0–50.0[j]	—	Remainder	—	—	—	9.0–11.0[i]	0.25	0.05*	0.01*	0.04–0.25	0.50
BCuP-2	C55181	Remainder	—	—	—	—	—	—	7.0–7.5	—	—	—	0.15
BCuP-3	C55281	Remainder	4.8–5.2	—	—	—	—	—	5.8–6.2	—	—	—	0.15
BCuP-4	C55283	Remainder	5.8–6.2	—	—	—	—	—	7.0–7.5	—	—	—	0.15
BCuP-5	C55284	Remainder	14.5–15.5	—	—	—	—	—	4.8–5.2	—	—	—	0.15
BCuP-6	C55280	Remainder	1.8–2.2	—	—	—	—	—	6.8–7.2	—	—	—	0.15
BCuP-7	C55282	Remainder	4.8–5.2	—	—	—	—	—	6.5–7.0	—	—	—	0.15
BCuP-8	C55285	Remainder	17.2–18.0	—	—	—	—	—	6.0–6.7	—	—	—	0.15
BCuP-9	C55385	Remainder	—	—	6.0–7.0	—	—	—	6.0–7.0	—	—	0.01–0.40	0.15
BCuP-10	*C55386*	*Remainder*	—	—	*5.5–6.5*	—	—	*3.0–5.0*	*6.8–7.2*	—	—	—	*0.15*

[a] See Table B.3 for discontinued brazing filler metal classifications.

[b] See Table 7 for the following Cu classifications intended for vacuum service not included here: BVCu-1x.

[c] Single values are maximum unless noted.

[d] SAE HS-1086, *Metals & Alloys in the Unified Numbering System*. Classifications BCu-1a and BCu-2 have had UNS Numbers applied for.

[e] The brazing filler metal shall be analyzed for those specific elements for which values or asterisks (*) are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified in "Other Elements, Total."

[f] The balance is oxygen, which is present as cuprous oxide. Oxygen is not to be included in "Other Elements."

[g] These chemical composition requirements pertain only to the cuprous oxide powder and do not include requirements for the organic vehicle in which the cuprous oxide is suspended, when supplied in paste form.

[h] The maximum allowable percentage of oxygen for this alloy is 0.001%.

[i] Includes residual cobalt.

[j] Includes residual silver.

Table 5[a]
Chemical Composition Requirements for Nickel and Cobalt Brazing Filler Metals

		Chemical Composition, Weight Percent[b]																	
AWS Classification	UNS Number[c]	Ni	Cr	B	Si	Fe	C	P	S	Al	Ti	Mn	Cu	Zr	W	Co	Mo	Nb	Se	Other Elements, Total[d]
BNi-1	N99600	Rem.	13.0–15.0	2.75–3.50	4.0–5.0	4.0–5.0	0.60–0.90	0.02	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-1a	N99610	Rem.	13.0–15.0	2.75–3.50	4.0–5.0	4.0–5.0	0.06	0.02	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-2	N99620	Rem.	6.0–8.0	2.75–3.50	4.0–5.0	2.5–3.5	0.06	0.02	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-3	N99630	Rem.	—	2.75–3.50	4.0–5.0	0.5	0.06	0.02	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-4	N99640	Rem.	—	1.50–2.20	3.0–4.0	1.5	0.06	0.02	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-5	N99650	Rem.	18.5–19.5	0.03	9.75–10.50	—	0.06	0.02	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-5a	N99651	Rem.	18.5–19.5	1.0–1.5	7.0–7.5	0.5	0.10	0.02	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-5b	N99652	Rem.	14.5–15.5	1.1–1.6	7.0–7.5	1.0	0.06	0.02	0.02	0.05	0.05	—	—	0.05	—	1.0	—	—	0.005	0.50
BNi-6	N99700	Rem.	—	—	—	—	0.06	10.0–12.0	0.02	0.05	0.05	—	—	0.05	—	0.10	—	—	0.005	0.50
BNi-7	N99710	Rem.	13.0–15.0	0.02	0.10	0.2	0.06	9.7–10.5	0.02	0.05	0.05	0.04	—	0.05	—	0.10	—	—	0.005	0.50
BNi-8	N99800	Rem.	—	—	6.0–8.0	—	0.06	0.02	0.02	0.05	0.05	21.5–24.5	4.0–5.0	0.05	—	0.10	—	—	0.005	0.50
BNi-9	N99612	Rem.	13.5–16.5	3.25–4.00	—	1.5	0.06	0.02	0.02	0.05	0.05		—	0.05	—	0.10	—	—	0.005	0.50
BNi-10	N99622	Rem.	10.0–13.0	2.0–3.0	3.0–4.0	2.5–4.5	0.40–0.55	0.02	0.02	0.05	0.05		—	0.05	15.0–17.0	0.10	—	—	0.005	0.50
BNi-11	N99624	Rem.	9.00–11.75	2.2–3.1	3.35–4.25	2.5–4.0	0.30–0.50	0.02	0.02	0.05	0.05		—	0.05	11.00–12.75	0.10	—	—	0.005	0.50
BNi-12	N99720	Rem.	24.0–26.0	0.02	0.1	0.2	0.06	9.0–11.0	0.02	0.05	0.05		—	0.05		0.10	—	—	0.005	0.50
BNi-13	N99810	Rem.	7.0–9.0	2.75–3.50	3.8–4.8	0.4	0.06	0.02	0.02	0.05	0.05		2.0–3.0	0.05		0.10	1.5–2.5	1.5–2.5	0.005	0.50
BNi-14	*N99660*	*Rem.*	*21.0–23.0*	*0.1*	*6.0–7.0*	*0.5*	*0.16*	*3.5–4.5*	*0.02*	*0.05*	*0.05*	—	—	*0.05*	—	*0.10*	—	—	*0.005*	*0.50*
BCo-1	R39001	16.0–18.0	18.0–20.0	0.70–0.90	7.5–8.5	1.0	0.35–0.45	0.02	0.02	0.05	0.05	—	—	0.05	3.5–4.5	Rem.	—	—	0.005	0.50

[a] See Table B.3 for discontinued brazing filler metal classifications.

[b] Single values are maximum.

[c] SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*

[d] The brazing filler metal shall be analyzed for those specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified.

Table 6
Chemical Composition Requirements for Titanium and Titanium–Zirconium Brazing Filler Metals

		Chemical Composition, Weight Percent[a]												
AWS Classification	UNS Number[b]	Ti	Zr	Cu	Ni	Mo	Hf	Fe	Al	Si	O	N	C	Other Elements, Total[c]
BTi-1	TBD	Remainder	—	14.0–16.0	14.0–16.0	—	—	0.1	0.05	0.02	0.15	0.02	0.04	0.30
BTi-2	TBD	Remainder	—	14.0–16.0	24.0–26.0	—	—	0.1	0.05	0.02	0.15	0.02	0.04	0.30
BTi-3	TBD	Remainder	37.0–38.0	14.0–16.0	9.5–10.5	0.1	0.1	0.08	0.05	0.02	0.20	0.03	0.04	0.50
BTi-4	TBD	Remainder	23.5–24.5	15.0–17.0	15.0–17.0	1.5	0.1	0.08	0.05	0.02	0.20	0.03	0.04	0.50
BTi-5	TBD	Remainder	19.0–21.0	19.0–21.0	19.0–21.0	0.1	0.1	0.08	0.05	0.02	0.20	0.03	0.04	0.50

[a] Single values are maximum.

[b] UNS number has been applied for.

[c] The brazing filler metal shall be analyzed for those specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified.

Table 7
Chemical Composition Requirements for Brazing Filler Metals for Vacuum Service

AWS	UNS	Chemical Composition, Weight Percent[a,b]												
Classification	Number[c]	Ag	Au	Cu	Ni	Co	Sn	Pd	In	Zn	Cd	Pb	P	C
Grade 1														
BVAg-0	P07017	99.95 min.		0.05	—	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAg-6b	P07507	49.0–51.0	—	Remainder	—	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAg-8	P07727	71.0–73.0	—	Remainder	—	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAg-8b	P07728	70.5–72.5	—	Remainder	0.3–0.7	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAg-18	P07607	59.0–61.0	—	Remainder	—	—	9.5–10.5	—	—	0.001	0.001	0.002	0.002	0.005
BVAg-29	P07627	60.5–62.5	—	Remainder	—	—	—	—	14.0–15.0	0.001	0.001	0.002	0.002	0.005
BVAg-30	P07687	67.0–69.0	—	Remainder	—	—	—	4.5–5.5	—	0.001	0.001	0.002	0.002	0.005
BVAg-31	P07587	57.0–59.0	—	31.0–33.0	—	—	—	Remainder	—	0.001	0.001	0.002	0.002	0.005
BVAg-32	P07547	53.0–55.0	—	20.0–22.0	—	—	—	Remainder	—	0.001	0.001	0.002	0.002	0.005
BVAu-2	P00807	—	79.5–80.5	Remainder	—	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAu-3	P00351	—	34.5–35.5	Remainder	2.5–3.5	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAu-4	P00827	—	81.5–82.5	—	Remainder	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAu-7	P00507	—	49.5–50.5	—	24.5–25.5	0.06	—	Remainder	—	0.001	0.001	0.002	0.002	0.005
BVAu-8	P00927	—	91.0–93.0	—	—	—	—	Remainder	—	0.001	0.001	0.002	0.002	0.005
BVAu-9	P00354	—	34.5–35.5	Remainder	—	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVAu-10	P00503	—	49.5–50.5	Remainder	—	—	—	—	—	0.001	0.001	0.002	0.002	0.005
BVPd-1	P03657	—	—	—	0.06	Remainder	—	64.0–66.0	—	0.001	0.001	0.002	0.002	0.005
Grade 2														
BVAg-0	P07017	99.95 min.		0.05	—	—	—	—	—	0.002	0.002	0.002	0.002	0.005
BVAg-6b	P07507	49.0–51.0	—	Remainder	—	—	—	—	—	0.002	0.002	0.002	0.020	0.005
BVAg-8	P07727	71.0–73.0	—	Remainder	—	—	—	—	—	0.002	0.002	0.002	0.020	0.005
BVAg-8b	P07728	70.5–72.5	—	Remainder	0.3–0.7	—	—	—	—	0.002	0.002	0.002	0.020	0.005
BVAg-18	P07607	59.0–61.0	—	Remainder	—	—	9.5–10.5	—	—	0.002	0.002	0.002	0.020	0.005
BVAg-29	P07627	60.5–62.5	—	Remainder	—	—	—	—	14.0–15.0	0.002	0.002	0.002	0.020	0.005
BVAg-30	P07687	67.0–69.0	—	Remainder	—	—	—	4.5–5.5	—	0.002	0.002	0.002	0.020	0.005
BVAg-31	P07587	57.0–59.0	—	31.0–33.0	—	—	—	Remainder	—	0.002	0.002	0.002	0.002	0.005
BVAg-32	P07547	53.0–55.0	—	20.0–22.0	—	—	—	Remainder	—	0.002	0.002	0.002	0.002	0.005
BVAu-2	P00807	—	79.5–80.5	Remainder	—	—	—	—	—	0.002	0.002	0.002	0.002	0.005
BVAu-3	P00351	—	34.5–35.5	Remainder	2.5–3.5	—	—	—	—	0.002	0.002	0.002	0.002	0.005
BVAu-4	P00827	—	81.5–82.5	—	Remainder	—	—	—	—	0.002	0.002	0.002	0.002	0.005
BVAu-7	P99507	—	49.5–50.5	—	24.5–25.5	0.06	—	Remainder	—	0.002	0.002	0.002	0.002	0.005
BVAu-8	P00927	—	91.0–93.0	—	—	—	—	Remainder	—	0.002	0.002	0.002	0.002	0.005
BVAu-9	P00354	—	34.5–35.5	Remainder	—	—	—	—	—	0.002	0.002	0.002	0.002	0.005
BVAu-10	P00503	—	49.5–50.5	Remainder	—	—	—	—	—	0.002	0.002	0.002	0.002	0.005
BVPd-1	P03657	—	—	—	0.06	Remainder	—	64.0–66.0	—	0.002	0.002	0.002	0.002	0.005
BVCu-1x	C14181	—	—	99.99 min.	—	—	—	—	—	0.002	0.002	0.002	0.002	—

[a] The brazing filler metal shall be analyzed for those specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined. Elements detected that have a vapor pressure higher than 1.3×10^{-5} Pa [10^{-7} torr] at 500°C [932°F] are limited to 0.001% each for Grade 1 brazing filler metals and 0.002% each for Grade 2 brazing filler metals. The total of all high vapor pressure elements (including zinc, cadmium, and lead) is limited to 0.010%. The total of all other impurity elements is 0.01% maximum for Grade 1 and 0.05% maximum for Grade 2.

[b] Single values are maximum unless noted.

[c] SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*

Table 8
Powder Mesh Designations and Particle Size Distribution[a]

Powder Mesh[b] Designation		Particle Size Distribution		
		Sieve Size		Distribution
µm	U.S. Number	µm	U.S. Number	%
150	100 mesh	Through 250	Through 60	100
		Through 150	Through 100	95 min.
106 (C)	140 C[c] mesh	On 150	On 100	0.5 max.
		On 106	On 140	10 max.
		Through 45	Through 325	20 max.
106 (F)	140 F[d] mesh	On 150	On 100	0.5 max.
		On 106	On 140	10 max.
		Through 45	Through 325	55 max.
45	325 mesh	On 75	On 200	0.5 max.
		On 45	On 325	10 max.
		Through 45	Through 325	90 min.

[a] All of the above sieve sizes are standard ASTM sizes selected from Table 1 of ASTM E11-01, *Standard Specification for Wire Cloth and Sieves for Testing Purposes*.

[b] 106 µm F [140 F mesh] shall be supplied unless otherwise specified by the customer.

[c] C = Coarse

[d] F = Fine

13. Binder Content of Transfer Tape

13.1 The binder content of the transfer tape shall be determined by the following method:

13.1.1 A strip of Type 304 stainless steel approximately 0.8 mm × 13 mm × 50 mm [0.03 in × 0.5 in × 2 in] shall be weighed, and the weight shall be recorded as **Weight A**.

13.1.2 The transfer tape shall be shaped to the dimensions of the stainless steel strip, applied to the strip, the plastic carrier removed, and the composite weighed. This weight shall be recorded as **Weight B**.

13.1.3 The composite strip and transfer tape shall be heated in a vacuum or other protective atmosphere furnace to a temperature of 550°C to 650°C [1022°F to 1200°F], then cooled in the protective atmosphere, and reweighed. This weight shall be recorded as **Weight C**.

13.1.4 The percentage of binder shall be calculated as follows:

$$\text{Percentage of binder} = \frac{\text{Weight B} - \text{Weight C}}{\text{Weight B} - \text{Weight A}} \times 100$$

13.1.5 The binder content of the transfer tape may also be determined by the alternative method described in 13.1.6 through 13.1.9.

13.1.6 A ceramic crucible shall be used. The crucible should be a clean, dense polycrystalline alumina. As an alternative, a fused silica crucible or boat that has been precleaned by air firing at a temperature of at least 1100°C [2000°F] and stored in a dust-free container may be used. The crucible shall be weighed, and the weight shall be recorded as "Weight A."

13.1.7 A section of transfer tape approximately 0.8 mm × 13 mm × 50 mm [0.03 in × 0.5 in × 2 in], with the plastic carrier removed, shall be placed in the ceramic crucible. The crucible and transfer tape shall be weighed. This weight shall be recorded as "Weight B."

13.1.8 The crucible and transfer tape shall be heated in a protective atmosphere furnace (including vacuum) to a temperature of 550°C to 650°C [1022°F to 1200°F], then cooled in the protective atmosphere, and reweighed. This weight shall be recorded as "Weight C."

13.1.9 The percentage of binder shall be calculated as specified in 13.1.4.

13.2 To meet the requirements, the binder content of transfer tape shall be 6% maximum binder for transfer tape above 0.25 mm [0.010 in] and 10% maximum binder for transfer tape for 0.25 mm [0.010 in] and below; titanium transfer tape binder content shall not exceed 15% maximum.

14. Method of Manufacture

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

15. Standard Forms, Sizes, and Tolerances

15.1 Standard forms and sizes of brazing filler metals shall be as shown in Table 9.

15.2 Dimensional tolerances of wrought wire, rod, sheet, and strip shall be in accordance with Tables 10 and 11, as applicable.

15.3 Size and tolerances of cast rod, transfer tape, bonded sheet, and bonded rope shall be as agreed upon between the purchaser and supplier.

16. Brazing Filler Metal Identification

16.1 Brazing filler metal identification is to be accomplished by tags, labels, or appropriate marking on the unit package. Unit packages include coils, spools, bundles, mandrels, and containers. Specific marking requirements are listed in Clause 18.

16.2 When required by the purchase order or contract, special identification of individual pieces of brazing filler metals shall be provided in addition to the identification of the unit package. When so prescribed, the use of pressure-sensitive labels or imprint marking shall become a requirement for conformance to this specification.

17. Packaging

Brazing filler metals shall be suitably packaged to ensure against damage during shipment or storage under normal conditions.

18. Marking of Packages

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

(1) AWS specification and classification 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; and

(5) Date of manufacture for tape and paste.

Table 9
Standard Forms and Sizes of Brazing Filler Metals[a, b, c]

AWS Classification	Standard Form	Standard Sizes			
		Dimensions Specified	Width, Length, or Powder Mesh Designation	Thickness or Diameter	
				mm	in
BAg All Classifications	Strip[d] (coiled or spooled)	Width and Thickness	6 mm to 150 mm in multiples of 1 mm	0.05	0.002
				0.08	0.003
				0.10	
				0.13	0.005
			or	0.15	
				0.20	
			0.25 in to 6.0 in in multiples of 2.25 in	0.25	0.010
				0.50	0.020
	Round Wire (coiled or spooled); Rod (straight lengths)	Diameter for Wire and Rod	—	0.8	1/32 (0.031)
				1.0	
				1.2	3/64 (0.047)
				1.5	
				1.6	1/16 (0.062)
		Length for Rod	450 mm and 900 mm or 18 in and 36 in	2.0	
				2.4	3/32 (0.094)
				2.5	
				3.0	
				3.2	1/8 (0.125)
	Powder and Paste	Mesh Size (see Table 8)	150 µm [100 mesh] 106 µm C [140 C mesh] 106 µm F [140 F mesh] 45 µm [325 mesh]		
BVAg All Classifications	Strip, Wire (coiled or spooled), and Powder	Dimension shall be agreed by the purchaser and supplier			
BAu, BVAu, BVPd, BCu All Classifications	Strip, Wire (coiled or spooled), and Powder	Dimension shall be agreed by the purchaser and supplier			
BAlSi, BMg-1 All Classifications	Sheet (coiled)[e]	Thickness		0.25	0.010
				0.38	0.015
				0.50	0.020
BAlSi-3 BAlSi-4 BMg-1	Wire (coiled) or Rod (straight lengths)	Length and Diameter for Rod	900 mm or 36 in	1.6	1/16 (0.062)
				2.4	3/32 (0.094)
				3.2	1/8 (0.125)
				4.0	5/32 (0.156)
				4.8	3/16 (0.188)
BAlSi-4	Powder and Paste	Mesh Size (see Table 8)	150 µm [100 mesh]		
BCuP-5	Strip (coiled or spooled)	Width and Thickness	6.35 mm to 152.4 mm in multiples of 6.35 mm [0.25 in to 6.0 in in multiples of 0.25 in]	0.08	0.003
				0.13	0.005
				0.25	0.010
				0.6	0.025

Table 9 (Continued)
Standard Forms and Sizes of Brazing Filler Metals

AWS Classification	Standard Form	Standard Sizes Dimensions Specified	Width, Length, or Powder Mesh Designation	Thickness or Diameter mm	in
BCuP: All Classifications	Round Wire (coiled or spooled)	Diameter	—		
	Round Rod (straight lengths)	Length and Diameter	450 mm and 900 mm or 18 in and 36 in		
	Rectangular Wire (coils or spools)	Width and Thicknesses	1.6 mm to 6.4 mm width in multiples of 0.8 mm or 1/16 in to 1/4 in width in multiples of 1/32 in	1.3 1.6 2.0 2.4	0.050 0.062 0.094
	Rectangular Rod (straight lengths)	Width, Length, and Thickness	1.6 mm, 2.4 mm, and 3.2 mm or 1/16 in, 3/32 in, and 18 in width 450 mm and 900 mm lengths or 18 in and 36 in length	2.8 3.2 4.0 6.4	0.109 0.125 0.250
	Powder and Paste	Mesh Size (see Table 8)	150 µm [100 mesh] 106 µm C [140 C mesh] 106 µm F [140 F mesh] 45 µm [325 mesh]		
BCu-1, BCu-1b, BCu-3 RBCuZn-A	Strip (coiled or spooled)	Dimensions shall be agreed upon between the purchaser and supplier			
BCu-1, BCu-1b, BCu-3 RBCuZn-A RBCuZn-B RBCuZn-C RBCuZn-D	Round Wire (coiled)	Diameter		0.8 1.6 2.4 3.2 4.0 4.8 6.4 8.0 9.5	1/32 (0.031) 1/16 (0.062) 3/32 (0.094) 1/8 (0.125) 5/32 (0.156) 3/16 (0.188) 1/4 (0.250) 5/16 (0.312) 3/8 (0.375)
	Rod (straight lengths)	Length and Diameter	450 mm and 900 mm or 18 in and 36 in		
BCu-1a BCu-2	Powder and Paste	Mesh Size (see Table 8)	106 µm C [140 C mesh] 106 µm F [140 F mesh] 45 µm [325 mesh]		
BVCu-1x	Strip, Round Wire (coils or spools)	Dimensions shall be agreed upon between the purchaser and supplier			

Table 9 (Continued)
Standard Forms and Sizes of Brazing Filler Metals

AWS Classification	Standard Form	Standard Sizes			
		Dimensions Specified	Width, Length, or Powder Mesh Designation	Thickness or Diameter	
				mm	in
BNi: All Classifications except BNi-5a and BNi-5b BCo-1	Cast Round (straight lengths)[f] Foil	Diameter	—	1.6	1/16 (0.062)
				3.2	1/8 (0.125)
	Cast and Wrought (borided) Foil	Width and Thickness	1/8 in to 4.0 in or 3.2 mm to 100 mm	0.025	0.001
				0.037[g]	0.0015
				0.05	0.002
				0.06	0.0025
	Bonded Powder Rope, Sheet, and Transfer Tape[h]	Dimensions shall be agreed upon between the purchaser and supplier			
	Powder and Paste	Mesh Size (see Table 8)	106 µm C [140 C mesh] 106 µm F [140 F mesh] 45 µm [325 mesh]		
BNi-5a	Foil		1/8 in to 4.0 in or 3.2 mm to 100 mm	0.025	0.001
				0.037	0.015
				0.05	0.002
				0.06	0.0025
BNi-5b	Foil		1/8 in to 8.0 in or 3.2 mm to 200 mm	0.025	0.001
				0.037	0.0015
				0.05	0.002
				0.06	0.0025
	Powder and Paste	*Mesh Size (see Table 8)*	*149 µm [100 mesh]* *106 µm C [140 C mesh]* *106 µm F [140 F mesh]* *74 µm [200 mesh]* *45 µm [325 mesh]*		
BTi: All Classifications	*Transfer Tape and Sheet*	*Thickness*	*As Specified*		
	Amorphous or Partly Amorphous Foil	*Thickness*	*As Specified*		
	Clad Tape	*Thickness*	*As Specified*		

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[a] Dimensions, sizes, and package forms other than those shown shall be as agreed upon between the purchaser and supplier.

[b] C = Coarse

[c] F = Fine

[d] BAg-2, BAg-3, BAg-4, BAg-22, BAg-24, and BAg-26 as filler metal clad or bonded to each side of a copper core is also a standard form. The standard thickness ratios of filler metal to copper core to filler metal cladding are 1:2:1 or 1:4:1.

[e] BAlSi-2, BAlSi-5, BAlSi-7, BAlSi-9, BAlSi-11 filler metal clad or bonded to one or both sides of an aluminum alloy is also a standard form. The standard thickness of the filler metal cladding is 5% to 10% of the thickness of the aluminum alloy core.

[f] Tolerances listed in Table 10 do not apply for cast rod forms.

[g] Available in widths up to 50 mm [2 in].

[h] Tolerances listed in Table 11 do not apply for these bonded powder forms.

18.2 Marking of any overpacking of unit packages only requires conformance with regulations of DOT or other shipping agencies. Items listed in 18.1 are not required in any overpacking.

18.3 The appropriate precautionary information[10] as given in ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, (as a minimum) or its equivalent shall be prominently displayed in legible print on all packages of brazing filler metal, including individual unit packages enclosed within a larger package.

18.4 In addition to the precautionary information required in 18.3, all packages (including individual unit packages enclosed within a larger package and special containers such as spools and mandrels) of brazing filler metals BAg-1, BAg-1a, BAg-2, BAg-2a, BAg-3, BAg-27, and BAg-33 shall have the appropriate precautionary information for cadmium (as given in ANSI Z49.1) permanently affixed and prominently displayed in legible print.

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[10] Typical examples of "warning labels" from ANSI Z49.1 for some common or specific consumables used with certain processes are shown in Figure B.1 and Figure B.2.

Table 10
Tolerances for Wrought Wire and Rod[a,b]

				Tolerances, ±					
				Round		Rectangular			
		Nominal Size[c]				Thickness		Width	
Form	Condition	mm	in	mm	in	mm	in	mm	in
Wire	Cold-Drawn or Cold-Rolled	Over 0.25–0.51	Over 0.010–0.020	0.008	0.0003	0.020	0.0008	0.13	0.005
		Over 0.51–0.80	Over 0.020–0.031	0.013	0.0005	0.040	0.0016	0.13	0.005
		Over 0.80–1.00	Over 0.031–0.040	0.018	0.0007	0.045	0.0018	0.13	0.005
		Over 1.00–1.30	Over 0.040–0.051	0.020	0.0008	0.050	0.0020	0.13	0.005
		Over 1.30–1.50	Over 0.051–0.060	0.025	0.0010	0.064	0.0025	0.13	0.005
		Over 1.50–2.00	Over 0.060–0.080	0.038	0.0015	0.080	0.0031	0.13	0.005
		Over 2.00–6.40	Over 0.080–0.252	0.051	0.0020	0.100	0.0040	0.13	0.005
Rod	Cold-Drawn or Cold-Rolled	4.00 and under	5/32 and under	0.08	0.0031	0.23	0.0090	0.25	0.010
		4.80 and over	3/16 and over	0.10	0.0040	0.25	0.0100	0.25	0.010
Rod and Wire	Hot-Rolled or Extruded	Over 1.20–1.60	Over 3/64–1/16	0.13	0.0051	0.20	0.0080	0.25	0.010
		Over 1.60–3.20	Over 1/16–1/8	0.15	0.0060	0.23	0.0090	0.25	0.010
		Over 3.20–4.80	Over 1/8–3/16	0.18	0.0070	0.23	0.0090	0.25	0.010
		Over 4.80–6.40	Over 3/16–1/4	0.20	0.0080	0.25	0.0100	0.25	0.010

[a] Tolerances for cast rod shall be as agreed upon between the purchaser and the supplier.

[b] Length tolerance shall be ± 12mm [± 1/2 in] for rod.

[c] Diameter for round; thickness or width for rectangular.

Table 11
Tolerances for Foil Strip and Sheet

Nominal Thickness		Thickness Tolerance, ±			
		Width 200 mm [8 in] and Under		Width over 200 mm [8 in]	
mm	in	mm	in	mm	in
0.15 and under	0.006 and under	0.015	0.0006	0.020	0.0008
Over 0.15–0.33 incl.	Over 0.006–0.013 incl.	0.025	0.0010	0.025	0.0010
Over 0.33–0.53 incl.	Over 0.013–0.021 incl.	0.038	0.0015	0.038	0.0015
Over 0.53–0.66 incl.	Over 0.021–0.026 incl.	0.050	0.0020	0.051	0.0020
Nominal Width		Width Tolerance, ±			
		Thickness of 1.59 mm [0.062 in] and Under		Thickness of 1.6 mm [0.063 in] to 3.18 mm [0.125 in] incl.	
mm	in	mm	in	mm	in
Over 1.6 to 25 incl.	Over 0.062–1.0.	0.13	0.005	0.007	0.18
Over 25–50 incl.	Over 1.0–2.0 incl.	0.13	0.005	0.009	0.23
Over 50–150 incl.	Over 2.0–6.0 incl.	0.13	0.005	0.012	0.30
Over 150–380 incl.	Over 6.0–15.0 incl.	0.18	0.007	0.43	0.017
Over 380–500 incl.	Over 15.0	0.18	0.007	0.43	0.017

Annex A (Informative)

Informative References

This annex is not part of AWS A5.8M/A5.8:2011, *Specification for Filler Metals for Brazing and Braze Welding*, but is included for informational purposes only.

AWS, 2007, *Brazing Handbook*, 5th ed., Miami: American Welding Society.

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

AWS A5.31M/A5.31, *Specification for Fluxes for Brazing and Braze Welding*, American Welding Society.

AWS B2.2/B2.2M, *Specification for Brazing Procedure and Performance Qualification*, American Welding Society.

AWS C3.2M/C3.2, *Standard Method for Evaluating the Strength of Brazed Joints,* American Welding Society.

AWS C3.3, *Recommended Practices for the Design, Manufacture, and Examination of Critical Brazed Components*, American Welding Society.

AWS C3.4M/C3.4, *Specification for Torch Brazing*, American Welding Society.

AWS C3.5M/C3.5, *Specification for Induction Brazing*, American Welding Society.

AWS C3.6M/C3.6, *Specification for Furnace Brazing*, American Welding Society.

AWS C3.7M/C3.7, *Specification for Aluminum Brazing*, American Welding Society.

AWS C3.8M/C3.8, *Specification for the Ultrasonic Pulse-Echo Examination of Brazed Joints*, American Welding Society.

AWS C3.9M/C3.9, *Specification for Resistance Brazing*, American Welding Society.

AWS D10.13, *Recommended Practice for the Brazing of Copper Pipe and Tubing for Medical Gas Systems,* American Welding Society.

Annex B (Informative)

Guide to AWS A5.8M/A5.8:2011, *Specification for Filler Metals for Brazing and Braze Welding*

This annex is not part of AWS A5.8M/A5.8:2011, *Specification for Filler Metals for Brazing and Braze Welding*, but is included for informational purposes only.

B1. Introduction

B1.1 Brazing is a group of joining processes that produces the coalescence of materials by heating them to the brazing temperature in the presence of a brazing filler metal having a liquidus above 450°C [840°F] and below the solidus of the base metal. The brazing filler metal is distributed into or held in the closely fitted faying surfaces of the joint by capillary action.

B1.2 The purpose of this guide is to correlate the brazing filler metal classifications with their intended applications so that the specification can be used effectively. The AWS *Brazing Handbook* should be consulted for detailed information. If the component has critical applications, AWS C3.3 should be followed.

B1.3 This specification is intended to provide both the supplier and the user of brazing filler metals with a guide for production control and a basis of acceptance through mutually acceptable standard requirements. This specification classifies only those brazing filler metals that were commercially significant at the time it was issued. As other brazing filler metals become commercially significant, they may be added to the specification. Those that lose their commercial significance may be discontinued.

B2. Method of Classification

B2.1 The classification of brazing filler metals is based on chemical composition rather than on mechanical property requirements. The mechanical properties of a brazed joint depend, among other things, on the base metal, the brazing filler metal, and the brazing conditions. Therefore, a classification method based on mechanical properties would be misleading as it would only apply if the brazing filler metal were used on a given base metal using specific brazing conditions. If the user of a brazing filler metal desires to determine the mechanical properties of a given base metal and brazing filler metal combination, tests should be conducted using the latest edition of AWS C3.2M/C3.2.

B2.2 Brazing filler metals are standardized into eight groups as follows: silver, gold, aluminum, copper, nickel, cobalt, magnesium, and titanium brazing filler metals. Many brazing filler metals in these classifications are used for joining assemblies for vacuum service applications, such as vacuum tubes and other electronic devices. For these critical applications, it is desirable to hold the high vapor pressure elements to a minimum, as they usually contaminate the vacuum with vaporized elements during the operation of the device. Filler metals for electronic devices have been incorporated as additional "vacuum grade" classifications within this specification.

B2.3 The basic classifications of brazing filler metal are identified by the principal element in their chemical composition, as shown in Tables 1 through 7 (see also Table B.2). For example, in the designation BCuP-2, the "B" denotes *brazing filler metal* (as the "E" denotes *electrodes* and the "R" denotes *welding rods* in other AWS specifications). The "RB" in RBCuZn-A, RBCuZn-B, RBCuZn-C, and RBCuZn-D indicates that the brazing filler metal is suitable as a braze welding rod and as a brazing filler metal. The term "CuP" denotes *copper–phosphorus*, the two principal elements in this particular brazing filler metal (similarly, in other brazing filler metals, "Si" denotes *silicon,* "Ag" denotes *silver,* and so forth, using standard chemical symbols). The designation following the chemical symbol indicates the chemical composition within a group.

The nomenclature for the vacuum grade brazing filler metals follows the examples above, with two exceptions. The first exception is the addition of the letter "V," yielding the generic letters "BV," denoting brazing filler metals for vacuum service. The second exception is the use of the grade suffix number; Grade 1 is used to indicate the more stringent requirements for high vapor pressure impurities, and Grade 2 is used to indicate less stringent requirements for high vapor pressure impurities. Vacuum grade brazing filler metals are considered to be spatter free. Therefore, this specification no longer lists spatter-free and nonspatter-free vacuum grades. An example of a brazing filler metal for vacuum service is BVAg-6b, Grade l. Table 7 lists brazing filler metals for vacuum service.

B2.4 Request for Brazing Filler Metal Classification. When a brazing filler metal cannot be classified according to a classification given in this specification, the manufacturer may request that a classification be established for that brazing filler metal. The manufacturer can do this using the following procedure:

(1) A request to establish a new brazing filler metal classification must be a written request, and it needs to provide sufficient detail to permit the AWS A5 Committee on Filler Metals and Allied Materials or the AWS A5H Subcommittee on Filler Metals and Fluxes for Brazing to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need.

In particular, the request needs to include:

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

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

(c) Information on Descriptions and Intended Use, paralleling that for existing classifications within that clause of the respective Annex; and

(d) For all A5 specifications, other than A5.10/A5.10M: actual test data for all tests required for classification according to the requirements of the specification for a minimum of two production heats/lots must be provided. In addition, if the filler metal specification is silent regarding mechanical properties, test data submitted shall include appropriate weld metal mechanical properties from a minimum of two production heats/lots.

(e) Patent policy: 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 the request. Prior to adoption of a standard that requires the use of any patented classification, the owner of the patent shall provide written assurance to AWS that:

i. No patent rights will be enforced against anyone using the patent to comply with the standard;

or

ii. The owner will make a license available to anyone wishing to use the patent to comply with the standard, without compensation or for reasonable rates, with reasonable terms and conditions demonstrably free of any unfair competition.

The Secretary will return the request to the requestor for further information.

(2) 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. 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 the Chair of the Subcommittee on Filler Metals and Fluxes for Brazing;

(d) File the original request; and

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

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

(4) 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.

Table B.1
Comparison of Classifications with ISO/CD 17672

Aluminum (& Mg) Alloys	
A5.8M/A5.8	ISO 17672
BAlSi-2	Al 107
BAlSi-3	Al 210
BAlSi-4	Al 112
BAlSi-5	Al 110
BAlSi-7	Al 310
BAlSi-9	Al 317
BAlSi-11	Al 311
BMg-1	Mg 001

Silver (& Pd) Alloys	
A5.8M/A5.8	ISO 17672
BAg-1	Ag 345
BAg-1a	Ag 350
BAg-2	Ag 335
BAg-2a	Ag 330
BAg-3	Ag 351
BAg-4	Ag 440*
BAg-5	Ag 245
BAg-6	Ag 250
BAg-7	Ag 156
BAg-8	Ag 272
BAg-8a	
BAg-9	Ag 265
BAg-10	Ag 270
BAg-13	Ag 454
BAg-13a	Ag 456
BAg-18	Ag 160
BAg-19	–
BAg-20	Ag 230
BAg-21	Ag 463
BAg-22	Ag 449
BAg-23	Ag 485
BAg-24	Ag 450
BAg-26	Ag 425
BAg-27	–
BAg-28	Ag 140
BVAg 29	–
BVAg 30	Pd 305
BVAg 31	Pd 309
BVAg 32	Pd 325
BAg-33 (Ag 326*)	–
BAg-34	Ag 138
BAg-35	Ag 235
BAg-36 (Ag 145*)	–
BAg-37	Ag 125
BVPd-1	Pd 365

* Nearest equivalent

Copper Alloys	
A5.8M/A5.8	ISO 17672
BCu-1	Cu 141
BCu-1a	Cu 099
BCu-1b	Cu 100
BCu-2	Cu 087
BCu-3	Cu 103
RBCuZn-A	Cu 470*
RBCuZn-B	Cu 680
RBCuZn-C	Cu 681
RBCuZn-D	Cu 773
BCuP-2	Cu 181
BCuP-3	CuP 281
BCuP-4	CuP 283
BCuP-5	CuP 284
BCuP-6	CuP 280
BCuP-7	Cu 282
BCuP-8	CuP 285
BCuP-9	CuP 385
BCuP-10	–

* Nearest equivalent

Nickel (& Co) Alloys	
A5.8M/A5.8	ISO 17672
BNi-1	Ni 600
BNi-1a	Ni 610
BNi-2	Ni 620
BNi-3	Ni 630
BNi-4	Ni 631
BNi-5	Ni 650
BNi-5a	Ni 660
BNi-5b	Ni 661
BNi-6	Ni 700
BNi-7	Ni 710
BNi-8	Ni 800
BNi-9	Ni 612
BNi-10	Ni 670
BNi-11	Ni 671
BNi-12	Ni 720
BNi-13	Ni 810
BNi-14	–
BCo-1	Co 1

Gold Alloys	
A5.8M/A5.8	ISO 17672
BAu1*	Au 375
BVAu-2	Au 800
BVAu-3	Au 351
BVAu-4	Au 827
BAu-5*	Au 300
BAu-6*	Au 700
BVAu-7	Au 507
BVAu-8	Au 927
BVAu-9	Au 354
BVAu-10	Au 503

* Per A5.8/A5.8M:2004

B2.5 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table B.1 shows those used in the ISO/CD 17672 specification for comparison with comparable classifications in this specification.

B3. Acceptance

Acceptance of all brazing filler metals classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344 MOD) as this specification states. Any sampling and testing a purchaser requires of the supplier for brazing filler metal shipped in accordance with this specification should 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 brazing filler metal with whatever testing the supplier normally conducts on brazing filler metal 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 Table 1 should be specifically required by the purchase order. In such cases, the acceptance of the brazing filler metal shipped should be in accordance with those requirements.

B4. 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 or the 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 has met the requirements of this specification. Representative material, in this case, is any production run of that classification from 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).

B5. Ventilation during Brazing

B5.1 Five major factors govern the quantity of fumes to which brazers and brazing operators can be exposed during brazing. They are:

(1) Dimensions of the space in which brazing is performed;

(2) Number of brazers and brazing 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 brazer or brazing operators to the fumes, as these fumes issue from the brazing 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 brazing is performed.

B5.2 American National Standard ANSI Z49.1 discusses the ventilation that is required during brazing and braze welding and should be referred to for details. Particular attention should be drawn to the clause on ventilation in that document. Further information concerning ventilation during brazing can be found in AWS F3.2, *Ventilation Guide for Weld Fume*.

B6. Brazing Terminology and Considerations

B6.1 To avoid confusion, solidus and liquidus are specified instead of melting and flow points. The terms *solidus* and *liquidus* are defined as follows:

solidus. The highest temperature at which a metal or alloy is completely solid.[11]

liquidus. The lowest temperature at which a metal or alloy is completely liquid.[12]

B6.2 Table B.2 lists the nominal solidus, liquidus, and the recommended brazing temperature range for the various brazing filler metals. When brazing with some brazing filler metals (particularly those with a wide temperature range between solidus and liquidus), the several constituents of the brazing filler metals tend to separate during the melting process. The lower melting constituent will flow, leaving behind an unmelted residue or skull of the high-melting constituent. This occurrence, termed *liquation*, is usually undesirable in that the unmelted skull does not readily flow into the joint. However, when wide joint clearance occurs, a brazing filler metal with a wide temperature range will usually fill the capillary joint more easily.

B6.3 Brazing requires an understanding of several elements of procedures that are beyond the scope of this annex. The *AWS Brazing Handbook* should be referred to for particulars on such items as cleaning, brazing fluxes, brazing atmospheres, brazing safety, joint clearances, etc. Also, AWS C3.3 should be consulted for information on procedures for critical components.

B7. Brazing Characteristics and Applications

B7.1 BAg-XX Group of Classifications (Silver). Brazing filler metals in the BAg-XX group of classifications are used to join most ferrous and nonferrous metals, except aluminum and magnesium. These brazing filler metals have good brazing properties and are suitable for preplacement in the joint or for manual feeding into the joint. Although lap joints are generally used, butt joints may be used if requirements are less stringent. Joint clearances of 0.025 mm to 0.13 mm [0.001 in to 0.005 in] are recommended for the proper capillary action. Flux is generally required on most metals.

When furnace brazing in a protective atmosphere, flux is generally not required. If brazing filler metals containing zinc or cadmium are used in a protective atmosphere furnace, the zinc or cadmium is vaporized, changing the chemical composition as well as the solidus and liquidus. Therefore, cadmium- and zinc-free brazing filler metals are recommended for furnace brazing in a protective atmosphere. Brazing filler metals containing cadmium and/or zinc should not be used in a vacuum furnace.

Brazing filler metals conforming to BAg-1, BAg-1a, BAg-2, BAg-2a, BAg-3, BAg-27, and BAg-33 contain cadmium. The special precautions in Figure B.2 shall be followed. The balance of the BAg classifications is cadmium free.[13]

B7.1.1 Brazing filler metal BAg-1 has the lowest brazing temperature range of the BAg brazing filler metals. It also flows most freely into narrow clearance capillary joints. Its narrow melting range is suitable for rapid or slow methods of heating. BAg-1 is more economical (less silver) than BAg-1a. **DANGER!** This brazing filler metal contains cadmium, and the fumes formed upon heating are toxic. Special precautions as shown in the required precautionary information, as specified in 18.4 of this specification, shall be followed.[14]

B7.1.2 Brazing filler metal BAg-1a has properties similar to those of BAg-1. BAg-1a has a narrower melting range than BAg-1, making it slightly more free flowing. It also has a higher silver-plus-copper to zinc-plus-cadmium ratio, resulting in a slight increase in its resistance to corrosion in chlorine, sulfur, and steam environments. Either composition may be used when low-temperature, free-flowing brazing filler metals are desired. **DANGER!** This brazing filler metal contains cadmium, and the fumes formed upon heating are toxic. Special precautions as shown in the required precautionary information, as specified in 18.4 of this specification, shall be followed.

B7.1.3 Brazing filler metal BAg-2, like BAg-1, is free flowing and suited for general-purpose work. Its broader melting range is helpful when clearances are wide or not uniform. Unless heating is rapid, care must be taken to prevent

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[11] AWS A3.0M/A3.0:2010, *Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, p. 39.

[12] AWS A3.0M/A3.0:2010, *Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, p. 26.

[13] Cadmium-free brazing filler metal contains no intentionally added cadmium and meets AWS specifications of 0.15% maximum for all other elements including cadmium.

[14] See Footnote 13.

Table B.2
Solidus, Liquidus, and Recommended Brazing Temperature Ranges

	Solidus[a]		Liquidus[a]		Recommended Brazing Temperature Range	
AWS Classification	°C	°F	°C	°F	°C	°F
			SILVER			
BAg-1	607	1125	618	1145	620–760	1145–1400
BAg-1a	627	1160	635	1175	635–760	1175–1400
BAg-2	607	1125	702	1295	700–840	1295–1550
BAg-2a	607	1125	710	1310	710–840	1310–1550
BAg-3	632	1170	688	1270	690–815	1270–1500
BAg-4	671	1240	779	1435	780–900	1435–1650
BAg-5	663	1225	743	1370	740–845	1370–1550
BAg-6	688	1270	774	1425	775–870	1425–1600
BAg-7	618	1145	652	1205	650–760	1205–1400
BAg-8	779	1435	779	1435	780–900	1435–1650
BAg-8a	766	1410	766	1410	765–870	1410–1600
BAg-9	671	1240	718	1325	720–840	1325–1550
BAg-10	691	1275	738	1360	740–845	1360–1550
BAg-13	718	1325	857	1575	860–970	1575–1775
BAg-13a	771	1420	893	1640	870–980	1600–1800
BAg-18	602	1115	718	1325	720–840	1325–1550
BAg-19	760	1400	891	1635	880–980	1610–1800
BAg-20	677	1250	766	1410	765–870	1410–1600
BAg-21	691	1275	802	1475	800–900	1475–1650
BAg-22	680	1260	699	1290	700–830	1290–1525
BAg-23	960	1760	970	1780	970–1040	1780–1900
BAg-24	660	1220	707	1305	705–845	1305–1550
BAg-26	707	1305	800	1475	800–870	1475–1600
BAg-27	605	1125	745	1375	745–860	1375–1575
BAg-28	649	1200	710	1310	710–840	1310–1550
BAg-33	607	1125	682	1260	680–760	1260–1400
BAg-34	649	1200	721	1330	720–845	1330–1550
BAg-35	685	1265	754	1390	755–840	1390–1545
BAg-36	646	1195	677	1251	680–815	1251–1495
BAg-37	688	1270	779	1435	780–885	1435–1625
BVAg-0	961	1761	961	1761	960–1035	1761–1900
BVAg-6b	779	1435	872	1602	870–980	1600–1800
BVAg-8	779	1435	779	1435	780–900	1435–1650
BVAg-8b	779	1435	795	1463	800–900	1470–1650
BVAg-18	602	1115	718	1325	715–840	1325–1550
BVAg-29	624	1155	707	1305	705–790	1305–1450
BVAg-30	806	1485	809	1490	810–900	1490–1650
BVAg-31	824	1515	852	1565	850–885	1565–1625
BVAg-32	900	1650	950	1740	950–980	1740–1800
			GOLD			
BAu-1	991	1815	1016	1860	1015–1090	1860–2000
BAu-2	891	1635	891	1635	890–1010	1635–1850
BAu-3	990	1814	1010	1850	1010–1070	1850–1950
BAu-4	949	1740	949	1740	950–1005	1740–1840
BAu-5	1135	2075	1166	2130	1165–1230	2130–2250
BAu-6	1007	1845	1046	1915	1045–1120	1915–2050
BVAu-2	891	1635	891	1935	890–1010	1635–1850
BVAu-3	990	1814	1010	1850	1010–1070	1850–1950

Table B.2 (Continued)
Solidus, Liquidus, and Recommended Brazing Temperature Ranges

	Solidus[a]		Liquidus[a]		Recommended Brazing Temperature Range	
AWS Classification	°C	°F	°C	°F	°C	°F
BVAu-4	949	1740	949	1740	950–1005	1740–1840
BVAu-7	1102	2015	1121	2050	1120–1155	2050–2110
BVAu-8	1200	2190	1240	2265	1240–1275	2265–2325
BVAu-9	990	1814	1010	1850	1010–1060	1850–1940
BVAu-10	955	1751	970	1778	970–1020	1778–1868
PALLADIUM						
BVPd-1	1230	2245	1235	2255	1235–1250	2255–2285
ALUMINUM						
BAlSi-2	577	1070	617	1142	600–620	1110–1150
BAlSi-3	521	970	585	1085	570–605	1060–1120
BAlSi-4	577	1070	582	1080	580–605	1080–1120
BAlSi-5	577	1070	599	1110	580–605	1090–1120
BAlSi-7	559	1038	596	1105	590–605	1090–1120
BAlSi-9	562	1044	582	1080	580–605	1080–1120
BAlSi-11	559	1038	596	1105	590–605	1090–1120
COPPER						
BCu-1	1083	1981	1083	1981	1095–1150	2000–2100
BCu-1a	1083	1981	1083	1981	1095–1150	2000–2100
BCu-1b	1083	1981	1083	1981	1095–1180	2000–2150
BVCu-1X	1083	1981	1083	1981	1095–1150	2000–2100
BCu-2	1083	1981	1083	1981	1095–1150	2000–2100
BCu-3	1083	1981	1083	1981	1095–1150	2000–2100
RBCuZn-A	888	1630	899	1650	910–955	1670–1750
RBCuZn-B	866	1590	882	1620	880–980	1620–1800
RBCuZn-C	866	1590	888	1630	910–955	1670–1750
RBCuZn-D	921	1690	935	1715	940–980	1720–1800
BCuP-2	710	1310	793	1460	730–845	1350–1550
BCuP-3	643	1190	813	1495	720–815	1325–1500
BCuP-4	643	1190	718	1325	690–790	1275–1450
BCuP-5	643	1190	802	1475	705–815	1300–1500
BCuP-6	643	1190	788	1450	730–815	1350–1500
BCuP-7	643	1190	771	1420	705–815	1300–1500
BCuP-8	643	1190	666	1230	665–685	1230–1270
BCuP-9	637	1178	675	1247	645–695	1190–1280
BCuP-10	*597*	*1107*	*683*	*1262*	*630–710*	*1170–1310*
NICKEL						
BNi-1	977	1790	1038	1900	1065–1205	1950–2200
BNi-1a	977	1790	1077	1970	1080–1205	1970–2200
BNi-2	971	1780	999	1830	1010–1180	1850–2150
BNi-3	982	1800	1038	1900	1010–1180	1850–2150
BNi-4	982	1800	1066	1950	1010–1180	1850–2150
BNi-5	1079	1975	1135	2075	1150–1205	2100–2200
BNi-5a	1065	1931	1150	2111	1150–1205	2100–2200
BNi-5b	1030	1886	1126	2053	1150–1205	2100–2200
BNi-6	877	1610	877	1610	930–1095	1700–2000
BNi-7	888	1630	888	1630	930–1095	1700–2000
BNi-8	982	1800	1010	1850	1010–1095	1850–2000
BNi-9	1055	1930	1055	1930	1065–1205	1950–2200

Table B.2 (Continued)
Solidus, Liquidus, and Recommended Brazing Temperature Ranges

	Solidus[a]		Liquidus[a]		Recommended Brazing Temperature Range	
AWS Classification	°C	°F	°C	°F	°C	°F
BNi-10	970	1780	1105	2020	1150–1205	2100–2200
BNi-11	970	1780	1095	2003	1150–1205	2100–2200
BNi-12	880	1620	950	1740	980–1095	1800–2000
BNi-13	970	1775	1080	1980	1095–1175	2000–2150
BNi-14	*960*	*1760*	*1015*	*1860*	*1065–1175*	*1950–2150*
COBALT						
BCo-1	1120	2050	1149	2100	1150–1230	2100–2250
MAGNESIUM						
BMg-1	443	830	599	1110	605–630	1120–1160
TITANIUM						
BTi-1[b]	*902*	*1655*	*950*	*1742*	*980–1050*	*1800–1920*
BTi-2[b]	*901*	*1653*	*915*	*1679*	*930–960*	*1705–1760*
BTi-3[b]	*825*	*1510*	*835*	*1535*	*850–880*	*1560–1620*
BTi-4[b]	*835*	*1535*	*850*	*1560*	*890–920*	*1630–1690*
BTi-5[b]	*848*	*1555*	*856*	*1572*	*870–900*	*1560–1620*

[a] The solidus and liquidus shown are for the nominal composition in each classification.

[b] The brazing temperature ranges presented in this table relate to the brazing of titanium and titanium alloys. Brazing temperatures can be increased over these ranges for the brazing of titanium aluminide alloys, graphite, and ceramics.

the lower melting constituents from separating out due to liquation. **DANGER!** This brazing filler metal contains cadmium, and the fumes formed upon heating are toxic. Special precautions as shown in the required precautionary information, as specified in 18.4 of this specification, shall be followed.

B7.1.4 Brazing filler metal BAg-2a is similar to BAg-2, but it is more economical than BAg-2 because it contains 5% less silver. **DANGER!** This brazing filler metal contains cadmium, and the fumes formed upon heating are toxic. Special precautions as shown in the required precautionary information, as specified in 18.4 of this specification, shall be followed.

B7.1.5 Brazing filler metal BAg-3 is a modification of BAg-1a in that nickel is added. It has good corrosion resistance in marine environment and caustic media. When used on stainless steel, it inhibits crevice (interface) corrosion. Because its nickel content improves wettability on tungsten carbide tool tips, the largest use is in the brazing of carbide tool assemblies. Its melting range and low fluidity make BAg-3 suitable for forming larger fillets or filling wide joint clearances. **DANGER!** This brazing filler metal contains cadmium, and the fumes formed upon heating are toxic. Special precautions as shown in the required precautionary information, as specified in 18.4 of this specification, shall be followed.

B7.1.6 Brazing filler metal BAg-4, like BAg-3, is used extensively for the brazing of carbide tips, but it flows less freely than BAg-3. This brazing filler metal is cadmium free.

B7.1.7 Brazing filler metals BAg-5 and BAg-6 are cadmium-free brazing filler metals used especially for brazing in the electrical industry. They are used, along with BAg-7 and BAg-24, in the dairy and food industries, in which the use of cadmium-containing brazing filler metals is prohibited. BAg-5 is an excellent brazing filler metal for the brazing of brass components (e.g., ship piping, band instruments, lamps, and so forth). Since BAg-6 has a broad melting range and is not as free flowing as BAg-1 and BAg-2, it is a better brazing filler metal for filling wide joint clearances or forming large fillets.

B7.1.8 Brazing filler metal BAg-7, a cadmium-free substitute for BAg-1, is low-melting with good flow and wetting properties. BAg-7 is typically used for food equipment when cadmium must be avoided, when the white color will improve the color match with the base metal, and to minimize the stress corrosion cracking of nickel or nickel-based alloys at low brazing temperatures.

B7.1.9 Brazing filler metal BAg-8 is suitable for furnace brazing in a protective atmosphere without the use of a flux, as well as for brazing procedures requiring a flux. It is usually used on copper or copper alloys. When molten, BAg-8 is very fluid and may flow out over the workpiece surfaces during some furnace brazing applications. It can also be used on stainless steel, nickel-based alloys, and carbon steel, although its wetting action on these metals is slow. Higher brazing temperatures improve flow and wetting. This brazing filler metal is cadmium free.

B7.1.10 Brazing filler metal BAg-8a is used for brazing in a protective atmosphere and is advantageous when brazing precipitation-hardening and other stainless steels in the 760°C to 870°C [l400°F to l600°F] range. The lithium content serves to promote wetting and to increase the flow of the brazing filler metal on difficult-to-braze metals and alloys. Lithium is particularly helpful on base metals containing minor amounts of titanium or aluminum. This brazing filler metal is cadmium free.

B7.1.11 Brazing filler metals BAg-9 and BAg-10 are used particularly for joining sterling silver. These brazing filler metals have different brazing temperatures. Therefore, they can be used for the step brazing of successive joints. After brazing, the color of the brazing filler metal approximates the color of sterling silver. These brazing filler metals are cadmium free.

B7.1.12 Brazing filler metal BAg-13 is used for service temperatures up to 370°C [700°F]. Its low zinc content makes it suitable for furnace brazing when used at the low end of the temperature range and with flux. Without flux in a gaseous protective atmosphere or vacuum, the zinc vaporizes. This brazing filler metal is cadmium free.

B7.1.13 Brazing filler metal BAg-13a is similar to BAg-13, except that it contains no zinc, which is advantageous when volatilization is objectionable in furnace brazing. This brazing filler metal is cadmium free.

B7.1.14 Brazing filler metal BAg-18 is similar to BAg-8 in its applications. Its tin content helps promote wetting on stainless steel, nickel-base alloys, and carbon steel. BAg-18 has a lower liquidus than BAg-8 and is used in step brazing applications in which fluxless brazing is important. This brazing filler metal is cadmium free.

B7.1.15 Brazing filler metal BAg-19 is used for the same applications as BAg-8a. BAg-19 is often used in higher brazing temperature applications in which precipitation-hardening heat treatment and brazing are combined. This brazing filler metal is cadmium free.

B7.1.16 Brazing filler metal BAg-20 possesses good wetting and flow characteristics and has a brazing temperature range higher than the popular Ag-Cu-Zn-Cd compositions. Due to its good brazing properties and economical silver content, new uses for this brazing filler metal are being developed. This brazing filler metal is cadmium free.

B7.1.17 Brazing filler metal BAg-21 is used in brazing AISI 300- and 400-series stainless steels, as well as the precipitation-hardening nickel and steel alloys. BAg-21 is particularly suited to furnace brazing in a protective atmosphere because of the absence of zinc and cadmium. It does not require a flux for proper brazing when the temperature is 1010°C [1850°F] or above. It requires a high brazing temperature, and it flows in a sluggish manner. The nickel-rich layer (halo) formed along the fillet edges during melting and flow of the brazing filler metal prevents crevice (interface) corrosion of stainless steels. This is particularly important for the 400-series steels that do not contain nickel and are, therefore, more susceptible to crevice (interface) corrosion. BAg-21 has been used for brazing stainless steel vanes of aircraft gas turbine engines. This brazing filler metal is cadmium free.

B7.1.18 Brazing filler metal BAg-22 is a low-temperature brazing filler metal with improved wetting characteristics, particularly in the brazing of tungsten carbide tools. This brazing filler metal is cadmium free.

B7.1.19 Brazing filler metal BAg-23 is a high-temperature, free-flowing brazing filler metal usable for both torch brazing and furnace brazing in a protective atmosphere. This brazing filler metal is mainly used in the brazing of stainless steel, nickel-based, and cobalt-based alloys for high-temperature applications. If this brazing filler metal is used in a high-vacuum atmosphere, a loss of manganese will occur due to its high vapor pressure. Thus, a partial pressure produced by inert gas backfilling and a flow to provide a pressure of 67 Pa to 267 Pa [0.5 torr to 2 torr] is desirable when brazing with this brazing filler metal. This brazing filler metal is cadmium free.

B7.1.20 Brazing filler metal BAg-24 is a low-melting, free-flowing brazing filler metal suitable for use in joining 300-series stainless steels (particularly food-handling equipment and hospital utensils) and small tungsten carbide inserts in cutting tools. This brazing filler metal is cadmium free.

B7.1.21 Brazing filler metal BAg-26 is a low-silver brazing filler metal suitable for carbide and stainless steel brazing. The brazing filler metal is characterized by its low brazing temperature, good wetting and flow, and moderate-strength joints when used with these base metals. This brazing filler metal is cadmium free.

B7.1.22 Brazing filler metal BAg-27 is similar to BAg-2 but has a lower silver content and is somewhat more subject to liquation due to a wider melting range. **DANGER!** This brazing filler metal contains cadmium, and the fumes formed upon heating are toxic. Special precautions as shown in the required precautionary information, as specified in 18.4 of this specification, shall be followed.

B7.1.23 Brazing filler metal BAg-28 has a lower brazing temperature with a narrower melting range than other cadmium-free classifications with similar silver content. BAg-28 also has free-flowing characteristics. This brazing filler metal is cadmium free.

B7.1.24 Brazing filler metal BAg-33 was developed to minimize brazing temperature for a brazing filler metal containing 25% silver. It has a lower liquidus and therefore a narrower melting range than BAg-27. Its higher total zinc-plus-cadmium content may require more care during brazing. **DANGER!** This brazing filler metal contains cadmium, and the fumes formed upon heating are toxic. Special precautions as shown in the required precautionary information, as specified in 18.4 of this specification, shall be followed.

B7.1.25 Brazing filler metal BAg-34 is a brazing filler metal with free-flowing characteristics. Its brazing temperature range is similar to that of BAg-2 and BAg-2a, making it an ideal substitute for these brazing filler metals. This brazing filler metal is cadmium free.

B7.1.26 Brazing filler metal BAg-35 is a brazing filler metal used for brazing ferrous and nonferrous base metals. It is a moderate-temperature brazing filler metal frequently used for production brazing applications. This brazing filler metal is cadmium free.

B7.1.27 Brazing filler metal BAg-36 is a low-temperature brazing filler metal suitable for the brazing of ferrous and nonferrous base metals. Its lower brazing temperature makes it a useful replacement for several of the cadmium-bearing classifications. This brazing filler metal is cadmium free.

B7.1.28 Brazing filler metal BAg-37 is frequently used for the brazing of steel, copper, and brass. The low silver content makes it an economical brazing filler metal suitable for applications in which lower ductility is acceptable. This brazing filler metal is cadmium free.

B7.2 BAu-X Group of Classifications (Gold). Brazing filler metals in the BAu-X group of classifications are used for the brazing of iron, nickel, and cobalt base metals when better ductility or a greater resistance to oxidation and corrosion is required. Because of their low rate of interaction with the base metal, they are commonly used on thin base metals. These brazing filler metals are usually used with induction, furnace, or resistance brazing in a protective atmosphere. In these cases, no flux is used. Additional information is provided in AWS A5.31M/A5.31 or the AWS *Brazing Handbook* chapter on “Fluxes and Atmospheres.”

B7.2.1 Brazing filler metals BAu-1, BAu-2, and BAu-3, when used for different joints in the same assembly, permit variation in brazing temperature so that step brazing can be used.

B7.2.2 Brazing filler metal BAu-4 is used to braze a wide range of high-temperature iron- and nickel-based alloys.

B7.2.3 Brazing filler metal BAu-5 is primarily used to join heat- and corrosion-resistant base metals when corrosion-resistant joints with good strength at high temperatures are required. This brazing filler metal is well suited for furnace brazing under protective atmospheres (including vacuum).

B7.2.4 Brazing filler metal BAu-6 is primarily used for the joining of iron and nickel-based superalloys for service at elevated temperature. This brazing filler metal is well suited for furnace brazing under protective atmospheres (including vacuum).

B7.3 BAlSi-X Group of Classifications (Aluminum–Silicon). Brazing filler metals in the BAlSi-X group of classifications are used for joining the following grades of aluminum and aluminum alloys: 1060, 1350, 1100, 3003, 3004, 3005, 3105, 5005, 5050, 6053, 6061, 6951, 7005, and cast alloys 710.0 and 711.0. Joint clearances of 0.05 mm to 0.20 mm [0.002 in to 0.008 in] are common for members that overlap less than 6.4 mm [0.25 in]. Joint clearances up to 0.20 mm to 0.25 mm [0.008 in to 0.010 in] are used for members that overlap more than 6.4 mm [0.25 in].

Fluxing is essential for all processes, except when brazing aluminum in a vacuum when clearances of 0.00 mm to 0.05 mm [0.000 in to 0.002 in] are recommended. After brazing with flux, the brazed parts should be cleaned thoroughly. Immersion in boiling water generally removes the residue. If this is not adequate, the parts are usually immersed in a concentrated commercial nitric acid or other suitable acid solution and then rinsed thoroughly.

B7.3.1 Brazing filler metal BAlSi-2 is available as sheet and as a cladding on one or both sides of a brazing sheet having a core of either 3003 or 6951 aluminum alloy. It is used for furnace and dip brazing only.

B7.3.2 Brazing filler metal BAlSi-3 is used with all brazing processes, some casting alloys, and when limited flow is desired; it is a general purpose brazing filler metal.

B7.3.3 Brazing filler metal BAlSi-4 is used with all brazing processes requiring a free-flowing brazing filler metal and good corrosion resistance; it is a general purpose brazing filler metal.

B7.3.4 Brazing filler metal BAlSi-5 is available as sheet and as a cladding on one side or both sides of a brazing sheet having a core of 6951 aluminum alloy. BAlSi-5 is used for furnace and dip brazing at a lower temperature than BAlSi-2 is. The core alloy employed in brazing sheet with this brazing filler metal cladding can be solution heat treated and aged.

B7.3.5 Brazing filler metal BAlSi-7 is suitable for brazing in a vacuum. It is available as a cladding on one or both sides of a brazing sheet having a core of 3003 or 6951 aluminum alloy. The 6951 alloy core can be solution heat treated and aged after brazing. This brazing filler metal contains additional magnesium, which is used as an oxygen getter to improve brazing.

B7.3.6 Brazing filler metal BAlSi-9 is suitable for brazing in a vacuum. It is available as a cladding on one side or both sides of a brazing sheet having a core of 3003 aluminum alloy and is typically used in heat-exchanger applications to join fins made from 5000- or 6000-series aluminum alloys. This brazing filler metal contains additional magnesium, which is used as an oxygen getter to improve brazing.

B7.3.7 Brazing filler metal BAlSi-11 is a brazing sheet clad on one or two sides of alloy 3105 to form a composite sheet suitable for brazing in a vacuum. It is designed for brazing in a multi-zone furnace in which the vacuum level is interrupted one or more times during the brazing cycle. The composite can be used in batch-type vacuum furnaces; however, vacuum sheet suitable for brazing with a 3003 core is more resistant to erosion. The maximum brazing temperature for the BAlSi-11/3105 composite is 595°C [1110°F]. BAlSi-11 contains additional magnesium, which is used as an oxygen getter to improve brazing.

B7.4 BCuP-XX Group of Classifications (Copper–Phosphorus). Brazing filler metals in the BCuP-XX group of classifications are used primarily for joining copper and copper alloys, although they have some limited use on silver, tungsten, and molybdenum. These brazing filler metals should not be used on ferrous or nickel-based alloys or on copper–nickel alloys containing a nickel content in excess of 10%, as brittle intermetallic compounds are formed at the brazing filler metal–base metal interface. They are suitable for all brazing processes. These brazing filler metals have self-fluxing properties when used on copper; however, a flux is recommended when used on all other base metals, including alloys of copper. Corrosion resistance is satisfactory except when the joint is in contact with sulfurous atmospheres. It should be noted that the brazing temperature ranges begin below the liquidus (see Table B.2).

B7.4.1 Brazing filler metals BCuP-2 and BCuP-4 are very fluid at brazing temperatures and penetrate joints with small clearances. Best results are obtained with clearances of 0.03 mm to 0.08 mm [0.001 in to 0.003 in].

B7.4.2 Brazing filler metals BCuP-3 and BCuP-5 can be used when narrow joint clearances cannot be held. Joint clearances of 0.05 mm to 0.13 mm [0.002 in to 0.005 in] are recommended.

B7.4.3 Brazing filler metal BCuP-6 combines some of the properties of BCuP-2 and BCuP-3. It has the ability to fill wide joint clearances at the lower end of its brazing range. At the high end of the brazing range, it is more fluid. Joint clearances of 0.05 mm to 0.13 mm [0.002 in to 0.005 in] are recommended.

B7.4.4 Brazing filler metal BCuP-7 is slightly more fluid than BCuP-3 or BCuP-5 and has a lower liquidus temperature. It is used extensively in the form of preplaced rings in heat exchanger and tubing joints. Joint clearances of 0.05 mm to 0.13 mm [0.002 in to 0.005 in] are recommended.

B7.4.5 Brazing filler metal BCuP-8 is the most fluid and has the lowest brazing temperature of the BCuP series filler metals. It is used primarily for tight clearances, 0.03 mm to 0.08 mm [0.001 in to 0.003 in].

B7.4.6 Brazing filler metal BCuP-9 is used for the brazing of copper, brass, and bronze. The addition of silicon lowers the melting temperature and produces a silver-colored braze that resists oxidation darkening during cooling. It also provides the ability to produce a large shoulder or cap around the assembly. The phosphorous inclusion gives the brazing filler metal a self-fluxing property on copper. A flux is required when brazing brass or bronze. Joint clearances of 0.051 mm to 0.127 mm [0.002 in to 0.005 in] are recommended.

B7.4.7 *Brazing filler metal BCuP-10 is used for the brazing of copper, brass, and bronze. The addition of nickel improves corrosion resistance and produces a silver-colored braze that resists oxidation during cooling. The phosphorous inclusion gives the brazing filler metal a "self-fluxing" property on copper. A flux is required when brazing brass or bronze. Joint clearances of 0.05 mm to 0.13 mm [0.002 in to 0.005 in] are recommended.*

B7.5 BCu-X and RBCuZn-X Group of Classifications (Copper and Copper–Zinc). Brazing filler metals in the BCu-X and RBCuZn-X group of classifications are used for joining various ferrous and nonferrous metals. They can also be used with various brazing processes. However, with the RBCuZn filler metals, overheating should be avoided. Voids may be formed in the joint by entrapped zinc vapors.

B7.5.1 Brazing filler metal BCu-1 is used for the joining of ferrous metals, nickel-based alloys, and copper–nickel alloys. It is very free flowing and is often used in furnace brazing, with a protective atmosphere of partially combusted natural gas, hydrogen, dissociated ammonia, or a nitrogen-based atmosphere, generally without flux. On metals that have constituents with difficult-to-reduce oxides (chromium, manganese, silicon, titanium, vanadium, and aluminum), a flux may be required. However, pure dry hydrogen, argon, dissociated ammonia, and vacuum atmospheres are suitable for base metals containing chromium, manganese, or silicon. Flux may also be used with zinc-containing base metals to retard vaporization. Vacuum atmospheres, electrolytic nickel plating, or both, are used for base metals containing titanium and aluminum. Mineral fluxes should not be used in vacuum atmospheres.

B7.5.2 Brazing filler metal BCu-1a is a powder form similar to BCu-1. Its application and use are similar to those of BCu-1.

B7.5.3 Brazing filler metal BCu-1b is very free flowing. It is used most often in furnace brazing with a protective atmosphere of partially combusted natural gas, hydrogen, dissociated ammonia, or nitrogen-based atmosphere, usually without flux.

B7.5.4 Brazing filler metal BCu-2 is supplied as a copper-oxide suspension in an organic vehicle. Its applications are similar to those of BCu-1 and BCu-1a.

B7.5.5 Brazing filler metal BCu-3 is similar to BCu-1 and may be used for the joining of ferrous metals, nickel-based alloys, and copper–nickel alloys. It is very free flowing and is often used in furnace brazing, with a protective atmosphere of partially combusted natural gas, hydrogen, dissociated ammonia, or nitrogen-base atmosphere, generally without flux.

On metals that have constituents with difficult-to-reduce oxides (chromium, manganese, silicon, titanium, vanadium, and aluminum), a flux may be required. However, pure dry hydrogen, argon, dissociated ammonia, and vacuum atmospheres are suitable for base metals containing chromium, manganese, or silicon. Flux may also be used with zinc-containing base metals to retard vaporization. Vacuum atmospheres, electrolytic nickel plating, or both, are used for base metals containing titanium and aluminum. Mineral fluxes should not be used in vacuum atmospheres.

B7.5.6 Brazing filler metal RBCuZn-A is used on steel, copper, copper alloys, nickel, nickel alloys, and stainless steel when corrosion resistance is not of importance. It is used with torch, furnace, and induction brazing processes. Fluxing is generally required, and a borax–boric acid type flux is commonly used.[15] Joint clearances from 0.05 mm to 0.13 mm [0.002 in to 0.005 in] are suitable.

B7.5.7 Brazing filler metal RBCuZn-B is used for the brazing and braze welding of steel, cast iron, copper, copper alloys, nickel, nickel alloys, and stainless steel. It is also used for the surfacing of steel, as well as with torch, induction, and furnace processes. RBCuZn-B (low-fuming brass–nickel) braze welding rods are similar to RBCuZn-A rods but contain additions of iron and manganese that serve to increase the hardness and strength. In addition, a small amount of silicon (0.04% to 0.20%) serves to control the vaporization of the zinc, yielding the "low-fuming" property. The nickel addition (0.2% to 0.8%) assures uniform distribution of the iron in the deposit. Flux and joint clearances are the same as those specified for RBCuZn-A.[16]

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[15] For additional information, see AWS A5.31M/A5.31, or the AWS *Brazing Handbook* chapter entitled "Fluxes and Atmospheres."

[16] See Footnote 15.

B7.5.8 Brazing filler metal RBCuZn-C is used on steel, copper, copper alloys, nickel, nickel alloys, and stainless steel. It is used with the torch, furnace, and induction brazing processes. Fluxing is required, and a borax–boric acid flux is commonly used.[17] Joint clearances from 0.05 mm to 0.13 mm [0.002 in to 0.005 in] are suitable.

B7.5.9 Brazing filler metal RBCuZn-D (referred to as *nickel silver*) is primarily used for brazing tungsten carbide. It is also used with steel, nickel, and nickel alloys. It can be used with all brazing processes. This brazing filler metal is unsuitable for furnace brazing in a protective atmosphere.[18]

B7.6 BNi-X Group of Classifications (Nickel). Brazing filler metals in the BNi-X group of classifications are generally used for their corrosion-resistant and heat-resistant properties. The BNi brazing filler metals have excellent properties at high service temperatures. They are also satisfactorily used for room-temperature applications and when the service temperatures are equal to the temperature of liquid oxygen, helium, or nitrogen. Best quality can be obtained by brazing in an atmosphere that is reducing to both the base metal and the brazing filler metal. Narrow joint clearances and postbraze thermal diffusion cycles are often employed to minimize the presence of intermetallic compounds, increase joint ductility, and raise the remelt temperature. With complete diffusion, the remelt temperature can be increased to above 1370°C [2500°F].

When BNi brazing filler metals are used with the torch, air-atmosphere furnace, and induction brazing processes, a suitable flux must be used. BNi brazing filler metals are particularly suited to vacuum systems and vacuum tube applications because of their low vapor pressure. Chromium is the limiting element in metals to be used in vacuum applications. It should be noted that when phosphorus is combined with some other elements, these compounds have very low vapor pressures and can be readily used in a vacuum brazing atmosphere of 0.13 Pa [1×10^{-3} torr] at 1066°C [1950°F] without removal of the phosphorus. Greater strength and ductility in this group of brazing filler metals is obtainable by diffusion brazing.

B7.6.1 Brazing filler metal BNi-1 was the first of the nickel brazing filler metals to be developed. The nickel, chromium, and iron contents render it suitable for the brazing of nickel, chromium, or iron base metals. Since high carbon content in 300-series stainless steels is usually metallurgically undesirable from a corrosion standpoint, the high carbon in BNi-1 would appear to make it undesirable for brazing stainless steels. However, Strauss test results have not shown any adverse affects when used on base metals such as AISI 347 stainless steel since the carbon is already tied up with the chromium in the brazing filler metal.

B7.6.2 Brazing filler metal BNi-1a is a low-carbon grade of BNi-1 with an identical chemical composition, except that while the specified carbon content is 0.06% maximum, the carbon content is usually 0.03% or lower. While the carbon content is lower, corrosion testing results with the Strauss and Huey tests are no better than for joints made with BNi-1. This brazing filler metal produces stronger joints but is less fluid than brazing filler metal BNi-1.

B7.6.3 Brazing filler metal BNi-2 has a lower and narrower melting range and better flow characteristics than BNi-1. These characteristics have made this brazing filler metal the most widely used of the nickel brazing filler metals.

B7.6.4 Brazing filler metal BNi-3 is used for applications similar to BNi-1 and BNi-2 and is less sensitive to marginally protective atmospheres (includes vacuum). BNi-3 is a Ni-Si-B brazing filler metal that does not contain chromium.

B7.6.5 Brazing filler metal BNi-4 is similar to but more ductile than BNi-3. It is used to form large fillets or joints when large joint clearances are present.

B7.6.6 Brazing filler metal BNi-5 is used for applications similar to those for BNi-1, except that it can be used in certain nuclear applications in which boron cannot be tolerated.

B7.6.7 Brazing filler metal BNi-5a is a modified BNi-5 composition with reduced silicon content plus a small addition of boron. The presence of boron excludes this alloy from nuclear applications. Otherwise, the applications are similar to those of BNi-5. High-strength joints can be produced. BNi-5a material can be used in place of BNi-1 when a reduced level of boron is desired. The brazing of thin-gauge honeycomb to sheet metal base parts is a typical application.

B7.6.8 Brazing filler metal BNi-5b is a modified BNi-5 composition with reduced chromium. The presence of boron excludes this alloy from nuclear applications. Otherwise, the applications are similar to those of BNi-5. High-strength joints can be produced. BNi-5b material can be used in place of BNi-1 when a reduced level of boron is desired.

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[17] See Footnote 15.

[18] See Footnote 15.

B7.6.9 Brazing filler metal BNi-6 is free flowing. It is used in marginally protective atmospheres and for the brazing of low-carbon steels in exothermic atmospheres.

B7.6.10 Brazing filler metal BNi-7 is used for the brazing of honeycomb structures, thin-walled tube assemblies, and other structures that are used at high temperatures. It is recommended for nuclear applications when boron cannot be used. The best results are obtained when it is used in the furnace brazing process. The microstructure and ductility of the joint are improved by increasing the time at the brazing temperature.

B7.6.11 Brazing filler metal BNi-8 is used in honeycomb brazements and on stainless steels and other corrosion-resistant base metals. Since this brazing filler metal contains a high percentage of manganese, special brazing procedures should be observed. As manganese oxidizes more readily than chromium, the hydrogen, argon, and helium brazing atmospheres must be pure and very dry, with a dew point of –57°C [–70°F] or below. The vacuum atmosphere must employ a partial pressure using dry argon or nitrogen, and the furnace must have a low leak rate to ensure a very low partial pressure of oxygen. It should be noted that the chemical composition and the melting characteristics of this brazing filler metal change when the manganese is oxidized or vaporized during brazing in gas or vacuum atmospheres. However, the effect of manganese is not a concern in an atmosphere of proper quality.

B7.6.12 Brazing filler metal BNi-9 is a eutectic nickel–chromium–boron brazing filler metal that is particularly well suited for diffusion brazing applications. As boron has a small molecular diameter, it diffuses rapidly out of the brazed joint, leaving the more ductile nickel–chromium alloy in the joint along with elements that diffuse from the base metal into the joint, such as aluminum, titanium, and so forth. Depending on the diffusion time and temperature, the joint remelt temperature can be above 1370°C [2500°F], and, depending on the base metal, the hardness can be as low as HRB70. With further diffusion time, the grains can grow across the joint, and it may appear as all base metal. The single solidus and liquidus temperature (eutectic) eliminates the possibility of liquation and thus helps in brazing thick sections that require slower heating.

B7.6.13 Brazing filler metal BNi-10 is a high-strength material for high-temperature applications. The tungsten is a matrix strengthener that makes it useful for brazing base metals containing cobalt, molybdenum, and tungsten. This brazing filler metal has a wide melting range. It has been used for brazing cracks in 0.5 mm [0.02 in] thick combustion chambers. It results in a layer of brazing filler metal across the joint that acts as a doubler, while the lower melting constituent is fluid enough to flow through the thin crack and produce a suitable brazement.

B7.6.14 Brazing filler metal BNi-11 is a strong material for high-temperature brazement applications. The tungsten matrix hardener makes it suitable for brazing base metals containing cobalt, molybdenum, and tungsten. With its wider melting range, it is suitable for slightly higher than normal brazing clearances.

B7.6.15 Brazing filler metal BNi-12 is formulated to improve the oxidation resistance and corrosion resistance of the brazed joint. It is recommended for nuclear applications in which boron-containing brazing filler metals cannot be used. This brazing filler metal is also used to coat base metals, such as copper to protect against oxidation at temperatures such as 816°C [1500°F]. Best results are obtained when using the furnace brazing process. The microstructure, strength, and ductility of the joint are improved by increasing the time and/or the temperature of brazing.

B7.6.16 Brazing filler metal BNi-13 is formulated to improve the corrosion resistance of the brazed joint. It is especially used for brazing 300-series stainless steels when interfacial corrosion has occurred under some conditions. For best results, the brazing cycle should be as short as possible with the brazing temperature as low as practical. Alternatively, the diffusion brazing process is used, and the brazement is held at the highest practical brazing temperature for up to two hours.

B7.6.17 *Brazing filler metal BNi-14 is formulated to provide a lower brazing temperature compared to BNi-5. It is recommended for applications where boron filler metals cannot be used. This filler metal is also used to braze assemblies made of thin sheet metal as the diffusion with the base metal is minimized. Microstructure, strength, and ductility of the brazed joint are improved by increasing the time and/or the temperature of brazing and reducing the joint clearance.*

B7.7 BCo Classification Group (Cobalt). Brazing filler metals in the BCo-1 classification group are generally used for their high-temperature properties and their compatibility with cobalt-alloy base metals.

B7.8 BMg Classification Group (Magnesium). Brazing filler metal BMg-1 is used for the joining of AZ10A, KlA, and M1A magnesium alloys.

B7.9 Brazing Filler Metals for Vacuum Service. The brazing filler metals listed in Table 7 are specially controlled to fabricate high-quality electronic devices when the service life and operating characteristics are of prime importance.

Brazing filler metals for vacuum service should be brazed in a high-purity protective atmosphere in order to maintain the purity of the brazing filler metal and to assure proper brazing and final brazement quality. In some applications, it is very important that the brazing filler metal not spatter onto areas near the joint area. For this reason, this specification includes the spatter test requirements described in Clause 12, "Spatter Test," for the vacuum grade classifications.

In addition to these brazing filler metals tested and classified for vacuum service, BCo-1 and all BNi-xx brazing filler metals except BNi-8 may also be suitable for vacuum service, although they are not required to be tested per Clause 12, "Spatter Test," and are not alternatively classified in this specification as BVxx-xx, Grade y.

B7.10 ***BTi-X Group of Classifications (Titanium)****. Brazing filler metals of the BTi classification group are used primarily for the joining of titanium, titanium alloys, and titanium aluminide alloys, although they are successfully used for the joining of titanium matrix composites, ceramics, ceramic composites, graphite, and carbon–carbon composite materials.*

The brazing filler metals of the BTi group are considered the best choice for joining titanium-based materials, especially for brazed structures that should operate at high temperatures up to 550°C [1020°F] and in highly corrosive atmospheres such as marine environments. The hot strength of brazed joints at 500°C to 550°C [932°F to 1020°F] is about 40% to 50% of the strength of the same joints at room temperature. However, the strength of titanium brazed joints produced with BTi brazing filler metals is significantly higher than that of joints produced with Ag-Cu-based or Al-based brazing filler metals both at hot and room temperatures.

All BTi brazing filler metals provide the best joint formation and strength with a maximum joint clearance of <0.1 mm [<0.004 in]. It is preferable to use a joint clearance of <0.08 mm [<0.003 in].

Brazing filler metals in the clad strip form can be placed both at the brazing clearance edge and into the joint between the titanium parts to be brazed. Brazing filler metals in the form of amorphous foil should be placed only into the joint. It is recommended that brazing filler metals in the form of powder or paste be applied at the edge of the brazing clearance. In order to braze large surfaces such as honeycombs or fin-plate heat exchangers, the powdered BTi brazing filler metal can be applied by painting with a paste or seeding dry powders on the surface first covered with a liquid adhesive binder.

When setting up brazing technology using the BTi group, attention should be paid to the microstructure to prevent uncontrolled growth of a continuous intermetallic layer at the joint–base metal interface, which may cause low impact and fatigue resistance of the brazed joints.

B7.10.1 *Although brazing filler metal BTi-1 has a brazing temperature above 900°C [1652°F], it provides sufficiently high-strength brazed joints, usually above 50% of the strength of the base metals. Moreover, the increase of brazing temperature up to 1050°C [1920°F] for BTi-1 may result in increasing the tensile and shear strength of joints with titanium alloys.*

B7.10.2 *Although brazing filler metal BTi-2 has a brazing temperature above 900°C [1652°F], it provides sufficiently high-strength brazed joints, usually above 50% of the strength of the base metals. Moreover, the increase of brazing temperature up to 960°C [1760°F] for BTi-2 may result in increasing the tensile and shear strength of joints with titanium alloys.*

B7.10.3 *Brazing filler metal BTi-3 has a brazing temperature below 900°C [1652°F] and can be especially recommended for the joining of thin-wall structures. BTi-3 is suitable for brazing beta-titanium alloys with the proviso of a relatively short holding time at the brazing temperature.*

The particle size of –105 microns [–140 mesh] is optimal for powdered brazing filler metal BTi-3 used for the brazing of titanium alloys and titanium matrix composites. Coarse powder of –177 microns [–80 mesh] or –149 microns [–100 mesh] is recommended for brazing titanium aluminide alloys, graphite, or carbon–carbon composites.

B7.10.4 *Brazing filler metal BTi-4 has a brazing temperature above 920°C [1688°F] and can be especially recommended for the joining of thin-wall structures. The particle size of –105 microns [–140 mesh] is optimal for powdered brazing filler metal BTi-4 when used for the brazing of titanium alloys and titanium matrix composites. Coarse powders of –177 microns [–80 mesh] or –149 microns [–100 mesh] are recommended for brazing titanium aluminide alloys, graphite, or carbon–carbon composites.*

B7.10.5 *Brazing filler metal BTi-5 has a brazing temperature below 900°C [1652°F] and can be especially recommended for the joining of thin-wall structures. BTi-5 is suitable for brazing beta-titanium alloys with the proviso of a relatively short holding time at the brazing temperature.*

The particle size of –105 microns [–140 mesh] is optimal for powdered brazing filler metal BTi-5 used for the brazing of titanium alloys and titanium matrix composites. Coarse powder of –177 microns [–80 mesh] or –129 microns [–100 mesh] is recommended for brazing titanium aluminide alloys, graphite, or carbon–carbon composites.

B8. 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 B.3, along with the year in which they were last included in the specification.

B9. Special Marking

Strip, wire, and rods may be identified by either indenting or imprinting on the surface of the brazing filler metal. Spooled wire that is too small to be marked with imprinting or indenting may be identified with fade-proof ink on the flange of the spools and on the interior and exterior of shipping containers. Preformed rings may be identified with fade-proof ink on metal surfaces or, when in individual envelopes, on the envelope itself. Powders may be identified on the interior container. Fade-proof ink shall be resistant to oils, solvents, all atmospheric conditions, and to the normal wear and tear encountered during shipping and handling. Marking by the use of a group of impressed, dots is not permitted.

Table B.3
Discontinued Brazing Filler Metal Classifications

AWS Classification	Last AWS A5.8 Publication Date
RBCuZn-1	1952
RBCuZn-2	1952
RBCuZn-3	1952
RBCuZn-4	1952
RBCuZn-5	1952
RBCuZn-6	1952
RBCuZn-7	1952
BAgMn	1956
BAlSi-1	1956
BNiCr	1956
BCuAu-1	1956
BCuAu-2	1956
BAg-11	1962
BMg-2	1962
BMg-2a	1976
BAlSi-6	1981
BAlSi-8	1981
BAlSi-10	1981
BAg-25	1981
RBCuZn-E	1981
RBCuZn-F	1981
RBCuZn-G	1981
RBCuZn-H	1981
BCuP-1	1992
BAg-12	The Committee has chosen not to use these numbers, as they were improperly placed in another publication.
BAg-14	
BAg-15	
BAg-16	
BAg-17	

B10. General Safety Considerations

B10.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org; revisions and additional sheets are periodically posted.

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 and Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Under Development*
27	*Thoriated Tungsten Electrodes*
28	*Under Development*
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*

B11. General Label Information

B11.1 An example of the minimum appropriate precautionary information as given in ANSI Z49.1:2005 is shown in Figure B.1.

B11.2 An example of the precautionary information used for brazing filler metals containing cadmium (e.g., BAg-1, BAg-1a, BAg-2, BAg-2a, BAg-3, BAg-27, and BAg-33) is shown in Figure B.2.

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be hazardous to your health.

HEAT RAYS (INFRARED RADIATION) from flame or hot metal can injure eyes.

- Before use, read and understand the manufacturer’s instructions, Material Safety Data Sheets (MSDSs), and your employer’s safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the flame, or both, to keep fumes and gases from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- See American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, Florida 33166. OSHA *Safety and Health Standards* are published by the U.S. Government Printing Office, 732 North Capitol Street NW, Washington DC 20401.

DO NOT REMOVE THIS INFORMATION

Source: Reproduced from ANSI Z49.1:2005, *Safety in Welding, Cutting, and Allied Processes,* American Welding Society, Figure 2.

Figure B.1—Precautionary Information for Brazing Processes and Equipment

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DANGER: CONTAINS CADMIUM

PROTECT yourself and others. Read and understand this information.

FUMES ARE POISONOUS AND CAN KILL.

- Before use, read and understand the manufacturer’s instructions, Material Safety Data Sheets (MSDSs), and your employer’s safety practices.
- Do not breathe fumes. Even brief exposure to high concentrations should be avoided.
- Use enough ventilation or exhaust, or both, to keep fumes and gases from your breathing zone and the general area. If this cannot be done, use air supplied respirators.
- Keep children away when using.
- See American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, Florida 33166. OSHA *Safety and Health Standards,* available from the U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

First Aid: If chest pain, shortness of breath, cough, or fever develops after use, obtain medical help immediately.

DO NOT REMOVE THIS INFORMATION

Source: Adapted from ANSI Z49.1:2005, *Safety in Welding, Cutting, and Allied Processes,* American Welding Society, Figure 3.

Figure B.2—Precautionary Information for Brazing Filler Metals Containing Cadmium

Annex C (Informative)

Analytical Methods

This annex is not part of AWS A5.8M/A5.8:2011, *Specification for Filler Metals for Brazing and Braze Welding*, but is included for informational purposes only.

In case of dispute, the referee methods for all elements shall be the appropriate analytical method in *Annual Book of ASTM Standards, Section 03 — Metals Test Methods and Analytical Procedures, Volume 5 — Analytical Chemistry for Metals, Ores, and Related Materials*, or as indicated in this annex.

The following methods are suggested for the analysis of various elements in silver brazing filler metals:

C1. Phosphorous in Silver or Copper Brazing Filler Metals

Phosphorous range: Less than 0.030%, the Vanadate Colorimetric method in accordance with ASTM E378-97, *Standard Test Method for Spectrographic Analysis of Silver by the Powder Technique*.

Phosphorous range: 4.0% to 8.0%, gravimetric as magnesium pyrophosphate in accordance with ASTM E1371-05.

C2. Lithium in Silver Brazing Filler Metals

Lithium range: Less than 5%, atomic absorption in accordance with ASTM E663-86(1991)E01, *Practice for Flame Atomic Absorption Analysis*.

C3. Manganese in Silver or Copper Brazing Filler Metals

Manganese range: Less than 0.1%, optical emission spectroscopy in accordance with ASTM E378-97, *Standard Test Method for Spectrographic Analysis of Silver by the Powder Technique*.

Manganese range: Greater than 0.1%, atomic absorption in accordance with ASTM E663-86(1991)E01, *Practice for Flame Atomic Absorption Analysis*.

C4. Tin in Silver or Copper Brazing Filler Metals

Tin range: 1% or less, optical emission spectroscopy in accordance with ASTM E378-97, *Standard Test Method for Spectrographic Analysis of Silver by the Powder Technique*.

Tin range: Greater than 0.1%, gravimetric method in accordance with *Standard Methods of Chemical Analysis*, 5th edition.[19]

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[19] Scott, W. W., and N. H. Furman, eds., 1939, *Standard Methods of Chemical Analysis*, 5th ed., New York: D. Van Nostrand.

C5. Nickel in Silver or Palladium Brazing Filler Metals

Nickel range: 0% to 3.0%, atomic absorption in accordance with ASTM E663-86(1991)E01.

Nickel range: 3% to 20%, gravimetric method as Ni-dimethylglyoxime, ASTM E1473-03, *Standard Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys*.

C6. Palladium in Silver, Gold, or Palladium Brazing Filler Metals

Palladium range: Less than 0.1%, optical emission spectroscopy, ASTM E378-97.

Palladium range: 1% to 5%, atomic absorption in accordance with ASTM E663-86(1991)E01.

Palladium range: 5% to 90%, gravimetric method in accordance with *Standard Methods of Chemical Analysis*, 5th edition.[20]

NOTE: Although several of the above-referenced specifications have been discontinued, the bases for analysis are still derived from these standards.

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[20] Scott, W. W., and N. H. Furman, eds., 1939, *Standard Methods of Chemical Analysis*, 5th ed., New York: D. Van Nostrand.

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SPECIFICATION FOR BARE STAINLESS STEEL WELDING ELECTRODES AND RODS

(**15**)

SFA-5.9/SFA-5.9M

(Identical with AWS Specification A5.9/A5.9M:2012. In case of dispute, the original AWS text applies.)

Specification for Bare Stainless Steel Welding Electrodes and Rods

1. Scope

1.1 This specification prescribes requirements for the classification of bare stainless steel wire, strip, composite metal cored, and stranded welding electrodes and rods for gas metal arc, gas tungsten arc, submerged arc, and other fusion welding processes. The chromium content of these filler metals 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.

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 Informative Annex Clauses A6 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*,[1] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way. The specification designated A5.9 uses U.S. Customary Units and the specification designated A5.9M 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 A5.9 or A5.9M specification.

2. Normative References

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

2.2 The following AWS standard[2] is referenced in the normative sections of this document.

1. AWS A5.01M/A5.01 (ISO 14344:2002 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*.

2.3 The following ANSI standard is referenced in the normative sections of this document.

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

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[1] ANSI Z49.1 is published by the American Welding Society, 550 NW LeJeune Road, Miami, FL 33126.

[2] AWS standards are published by the American Welding Society, 550 NW LeJeune Road, Miami, FL 33126.

2.4 The following ASTM standards[3] are referenced in the normative sections of this document:

1. ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*
2. ASTM E 353, *Standard Test Methods for Chemical Analysis of Stainless, Heat Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys*.

2.5 The following ISO standard[4] is referenced in the normative sections of this document:

ISO 80000-1, *Quantities and units*.

2.6 The following OSHA standard[5] is referenced in the mandatory sections of this document:

1. OSHA Safety and Health Standards, *29CFR 1910*.

3. Classification

3.1 The welding materials covered by this specification are classified according to chemical composition and product form. The first two designators are "ER" for solid wires that may be used as electrodes or rods; "EC" for composite cored or stranded wires; and "EQ" for strip electrodes (see Table 1).

3.2 Materials may be classified under more than one classification provided they meet all the requirements of those classifications as specified in Table 1.

4. Acceptance

Acceptance[6] of the material shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344:2002 MOD).

5. Certification

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

6. Rounding-Off Procedure

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E 29 or 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 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 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.

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[3] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohockon, PA 19428-2959.

[4] ISO standards *are published by International Organization of Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.*

[5] OSHA standards are published by the U.S. Government Printing Office, Washington, DC 20402, and can also be downloaded from www.osha-slc.gov

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

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

Table 1
Chemical Composition Requirements[a]

AWS Classification[d]	UNS Number[e]	Composition, Wt. %[b, c]										Other Elements	
		C	Cr	Ni	Mo	Mn	Si[f]	P	S	N	Cu	Element	Amount
ER209	S20980	0.05	20.5–24.0	9.5–12.0	1.5–3.0	4.0–7.0	0.90	0.03	0.03	0.10–0.30	0.75	V	0.10–0.30
ER218	S21880	0.10	16.0–18.0	8.0–9.0	0.75	7.0–9.0	3.5–4.5	0.03	0.03	0.08–0.18	0.75	—	—
ER219	S21980	0.05	19.0–21.5	5.5–7.0	0.75	8.0–10.0	1.00	0.03	0.03	0.10–0.30	0.75	—	—
ER240	S24080	0.05	17.0–19.0	4.0–6.0	0.75	10.5–13.5	1.00	0.03	0.03	0.10–0.30	0.75	—	—
ER307	S30780	0.04–0.14	19.5–22.0	8.0–10.7	0.5–1.5	3.30–4.75	0.30–0.65	0.03	0.03	—	0.75	—	—
ER308	S30880	0.08	19.5–22.0	9.0–11.0	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER308Si	S30881	0.08	19.5–22.0	9.0–11.0	0.75	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—	—
ER308H	S30880	0.04–0.08	19.5–22.0	9.0–11.0	0.50	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER308L	S30883	0.03	19.5–22.0	9.0–11.0	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER308LSi	S30888	0.03	19.5–22.0	9.0–11.0	0.75	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—	—
ER308Mo	S30882	0.08	18.0–21.0	9.0–12.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER308LMo	S30886	0.04	18.0–21.0	9.0–12.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER309	S30980	0.12	23.0–25.0	12.0–14.0	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER309Si	S30981	0.12	23.0–25.0	12.0–14.0	0.75	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—	—
ER309L	S30983	0.03	23.0–25.0	12.0–14.0	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER309LSi	S30988	0.03	23.0–25.0	12.0–14.0	0.75	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—	—
ER309Mo	S30982	0.12	23.0–25.0	12.0–14.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER309LMo	S30986	0.03	23.0–25.0	12.0–14.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER310	S31080	0.08–0.15	25.0–28.0	20.0–22.5	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER312	S31380	0.15	28.0–32.0	8.0–10.5	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER316	S31680	0.08	18.0–20.0	11.0–14.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER316Si	S31681	0.08	18.0–20.0	11.0–14.0	2.0–3.0	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—	—
ER316H	S31680	0.04–0.08	18.0–20.0	11.0–14.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER316L	S31683	0.03	18.0–20.0	11.0–14.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER316LSi	S31688	0.03	18.0–20.0	11.0–14.0	2.0–3.0	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	—	—
ER316LMn	S31682	0.03	19.0–22.0	15.0–18.0	2.5–3.5	5.0–9.0	0.30–0.65	0.03	0.03	0.10–0.20	0.75	—	—
ER317	S31780	0.08	18.5–20.5	13.0–15.0	3.0–4.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER317L	S31783	0.03	18.5–20.5	13.0–15.0	3.0–4.0	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER318	S31980	0.08	18.0–20.0	11.0–14.0	2.0–3.0	1.0–2.5	0.30–0.65	0.03	0.03	v	0.75	Nb[g]	8 × C min/1.0 max
ER320	N08021	0.07	19.0–21.0	32.0–36.0	2.0–3.0	2.5	0.60	0.03	0.03	—	3.0–4.0	Nb[g]	8 × C min/1.0 max
ER320LR	N08022	0.025	19.0–21.0	32.0–36.0	2.0–3.0	1.5–2.0	0.15	0.015	0.02	—	3.0–4.0	Nb[g]	8 × C min/0.40 max
ER321	S32180	0.08	18.5–20.5	9.0–10.5	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	Ti	9 × C min/1.0 max
ER330	N08331	0.18–0.25	15.0–17.0	34.0–37.0	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	—	—
ER347	S34780	0.08	19.0–21.5	9.0–11.0	0.75	1.0–2.5	0.30–0.65	0.03	0.03	—	0.75	Nb[g]	10 × C min/1.0 max
ER347Si	S34788	0.08	19.0–21.5	9.0–11.0	0.75	1.0–2.5	0.65–1.00	0.03	0.03	—	0.75	Nb[g]	10 × C min/1.0 max
ER383	N08028	0.025	26.5–28.5	30.0–33.0	3.2–4.2	1.0–2.5	0.50	0.02	0.03	—	0.70–1.50	—	—
ER385	N08904	0.025	19.5–21.5	24.0–26.0	4.2–5.2	1.0–2.5	0.50	0.02	0.03	—	1.2–2.0	—	—

(Continued)

Table 1 (Continued)
Chemical Composition Requirements[a]

AWS	UNS	Composition, Wt. %[b, c]										Other Elements	
Classification[d]	Number[e]	C	Cr	Ni	Mo	Mn	Si[f]	P	S	N	Cu	Element	Amount
ER409	S40900	0.08	10.5–13.5	0.6	0.50	0.8	0.8	0.03	0.03	—	0.75	Ti	10 × C min/1.5 max
ER409Nb	S40940	0.08	10.5–13.5	0.6	0.50	0.8	1.0	0.04	0.03	—	0.75	Nb[g]	10 × C min/0.75 max
ER410	S41080	0.12	11.5–13.5	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER410NiMo	S41086	0.06	11.0–12.5	4.0–5.0	0.4–0.7	0.6	0.5	0.03	0.03	—	0.75	—	—
ER420	S42080	0.25–0.40	12.0–14.0	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER430	S43080	0.10	15.5–17.0	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER439	S43035	0.04	17.0–19.0	0.6	0.5	0.8	0.8	0.03	0.03	—	0.75	Ti	10 × C min./1.1 max.
ER446LMo	S44687	0.015	25.0–27.5	[h]	0.75–1.50	0.4	0.4	0.02	0.02	0.015	[h]	—	—
ER630	S17480	0.05	16.00–16.75	4.5–5.0	0.75	0.25–0.75	0.75	0.03	0.03	—	3.25–4.00	Nb[g]	0.15–0.30
ER19–10H	S30480	0.04–0.08	18.5–20.0	9.0–11.0	0.25	1.0–2.0	0.30–0.65	0.03	0.03	—	0.75	Nb[g]	0.05
												Ti	0.05
ER16–8–2	S16880	0.10	14.5–16.5	7.5–9.5	1.0–2.0	1.0–2.0	0.30–0.65	0.03	0.03		0.75	—	—
ER2209	S39209	0.03	21.5–23.5	7.5–9.5	2.5–3.5	0.50–2.00	0.90	0.03	0.03	0.08–0.20	0.75	—	—
ER2307	*S82371*	*0.03*	*22.5–25.5*	*6.5–9.5*	*0.8*	*2.5*	*1.0*	*0.03*	*0.02*	*0.10–0.20*	*0.50*	—	—
ER2553	S39553	0.04	24.0–27.0	4.5–6.5	2.9–3.9	1.5	1.0	0.04	0.03	0.10–0.25	1.5–2.5	—	—
ER2594	S32750	0.03	24.0–27.0	8.0–10.5	2.5–4.5	2.5	1.0	0.03	0.02	0.20–0.30	1.5	W	1.0
ER33–31	R20033	0.015	31.0–35.0	30.0–33.0	0.5–2.0	2.00	0.50	0.02	0.01	0.35–0.60	0.3–1.2		
ER3556	R30556	0.05–0.15	21.0–23.0	19.0–22.5	2.5–4.0	0.50–2.00	0.20–0.80	0.04	0.015	0.10–0.30		Co	16.0–21.0
												W	2.0–3.5
												Nb	0.30
												Ta	0.30–1.25
												Al	0.10–0.50
												Zr	0.001–0.100
												La	0.005–0.100
												B	0.02

[a] Classifications ER502 and ER505 have been discontinued (see Table A.4). Classifications EB6 and ER80S-B6, which are similar to ER502, have been added to AWS A5.23 and A5.28, respectively. EB8 and ER80S-B8, which are similar to ER505, have been added to AWS A5.23 and AWS A5.28, respectively.

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

[c] Single values shown are maximum percentages.

[d] In the designator for composite, stranded, and strip electrodes, the R shall be deleted. A designator C shall be used for composite and stranded electrodes and a designator Q shall be used for strip electrodes. For example, ERXXX designates a solid wire and EQXXX designates a strip electrode of the same general analysis, and the same UNS number. However, ECXXX designates a composite metal cored or stranded electrode and may not have the same UNS number. Consult SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System* for the proper UNS number.

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

[f] For special applications, electrodes and rods may be purchased with less than the specified silicon content.

[g] Nb may be reported as Nb + Ta.

[h] Nickel + copper equals 0.5 percent maximum.

7. Summary of Tests

7.1 Chemical analysis of the solid electrode, rod, or strip is the only test required for classification of these product forms under this specification.

7.2 Chemical analysis of a fused sample of composite or stranded electrode, rod, or strip is the only test required for classification of these product forms under this specification. See Annex Clause A5, Preparation of Samples for Chemical Analysis.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material for retest may be taken from the original test sample or from a new sample. 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 samples 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 of the number of test samples does not apply.

9. Chemical Analysis

9.1 A sample of the filler metal, or the stock from which it is made in the case of solid electrodes or rods, or a fused sample shall be prepared for analysis. See Annex Clause A5, Preparation of Samples for Chemical Analysis, for several possible methods.

9.2 The sample shall be analyzed by acceptable analytical methods capable of determining whether the composition meets the requirements of this specification. In case of dispute, the referee method shall be ASTM E 353.

9.3 The results of the analysis shall meet the requirements of Table 1 for the classification of the filler metal under test.

10. Method of Manufacture

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

11. Standard Sizes and Shapes

11.1 Standard sizes for filler metal (except strip electrodes) in the different package forms (straight lengths, coils with support, coils without support, and spools) shall be as shown in Table 2.

11.2 Standard sizes for strip electrodes in coils shall be as shown in Table 3.

12. Finish and Uniformity

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

Table 2
Standard Wire Sizes of Electrodes and Rods[a]

				Tolerance[a]			
	Diameter[a]			Solid		Composite	
Form	in		mm	in	mm	in	mm
Welding rods in straight lengths[b]	0.045		1.1[c]	± 0.001	± 0.03	± 0.002	± 0.05
	—		1.2				
	1/16	(0.063)	1.6	± 0.002	± 0.05	± 0.003	± 0.08
	5/64	(0.078)	2.0				
	3/32	(0.094)	2.4				
	1/8	(0.125)	3.2				
	5/32	(0.156)	4.0				
	3/16	(0.187)	4.8				
Filler metals in coils with or without support	0.045		1.1[c]	± 0.001	± 0.03	± 0.002	± 0.05
	—		1.2				
	1/16	(0.063)	1.6	± 0.002	± 0.05	± 0.003	± 0.08
	5/64	(0.078)	2.0				
	3/32	(0.094)	2.4				
	7/64	(0.109)	2.8				
	1/8	(0.125)	3.2				
	5/32	(0.156)	4.0				
	3/16	(0.187)	4.8				
	1/4	(0.250)	6.4				
Filler metal wound on 8, 12, or 14 in (200, 300, or 350 mm) O.D. spools	0.030		0.8	± 0.001	± 0.03	± 0.002	± 0.05
	0.035		0.9				
	0.045		1.1[c]				
	—		1.2				
	1/16	(0.063)	1.6	± 0.002	± 0.05	± 0.003	± 0.08
	5/64	(0.078)	2.0				
	3/32	(0.094)	2.4				
	7/64	(0.109)	2.8				
Filler metal wound on 4 in (100 mm) O.D. spools	0.020		0.5	± 0.001	± 0.03	± 0.002	± 0.05
	0.025		0.6				
	0.030		0.8				
	0.035		0.9				
	0.045		1.1[c]				
	—		1.2				

[a] Dimensions, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.

[b] Length shall be 36 in +0, –1/2 in [900 mm + 15, –0 mm].

[c] Metric size not shown in ISO 544.

Table 3
Standard Sizes of Strip Electrodes[a,b]

Width		Thickness	
in	mm	in	mm
1.18	30	0.020	0.5
2.36	60	0.020	0.5
3.54	90	0.020	0.5
4.72	120	0.020	0.5

[a] Other sizes shall be as agreed upon between purchaser and supplier.

[b] Strip electrodes shall not vary more than ±0.008 in [±0.20 mm] in width and more than ±0.002 in [±0.05 mm] in thickness.

12.2 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.

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

12.4 The slit edges of strip electrodes shall be free from burrs exceeding five percent of the strip thickness.

13. Standard Package Forms

13.1 Standard package forms are straight lengths, coils with support, coils without support, and spools. Standard package dimensions and weights for each form are shown in Table 4.

13.2 Package forms, sizes, and weights other than those shown in Table 4 shall be as agreed upon between the purchaser and supplier.

13.3 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.

13.4 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal (see Figure 1).

13.5 Net weights shall be within ±10 percent of the nominal weight.

14. Winding Requirements

14.1 The filler metal shall be wound so that kinks, waves, sharp bends, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be identified so that it can be readily located and shall be fastened to avoid unwinding.

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

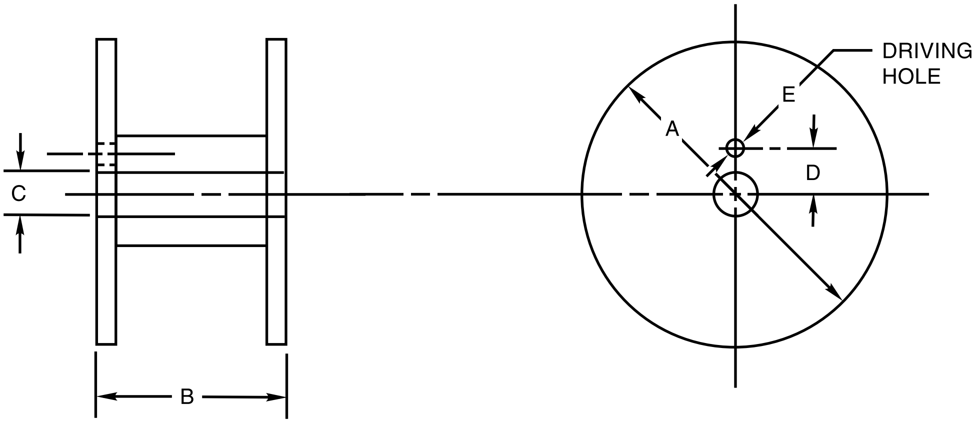
14.2.1 The cast and helix of drawn, solid filler metal on 4 in. [100 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

Table 4
Standard Package Dimensions and Weights[a]

	Spool or Coil Diameter		Strip Width		Nominal Weight	
Product Form	in	mm	in	mm	lbs	kg
Welding Rods in Straight Lengths	—	—	—	—	10, 50	4.5, 23
Spools	4	100	—	—	1-1/2, 2-1/2	0.7, 1.1
	8	200	—	—	10	4.5
	12	300	—	—	25, 33	11.4, 15
	14	350	—	—	50	22.8
Coil with Support[b]	12	300	—	—	25, 50, 60	11, 23, 27
Strip Electrode	12	300	1.18	30	60	27.5
	12	300	2.36	60	60	27.5
	12	300	3.54	90	120	55
	12	300	4.72	120	120	55

[a] Net weights shall be within ±10% of the nominal weight.

[b] Weight of coils without support shall be as specified by the purchaser.



DIMENSIONS

		4 in [100 mm]		8 in [200 mm]		12 in [300 mm]		14 in [350 mm]	
	Spools	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	46 +0, –2	2.16 ±0.03	56 +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 +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 shall be such as to permit feeding of the filler metals.
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.

Source: Figure A.1 of AWS A5.9/A5.9M:2006 ERRATA

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

1. Form a circle not less than 2.5 in. [65 mm] nor more than 15 in [380 mm] in diameter
2. Rise above the flat surface no more than 1/2 in. [13 mm] at any location.

14.2.2 The cast and helix of drawn solid filler metal on 8 in. [200 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

1. Form a circle not less than 8 in. [200 mm] nor more than 50 in. [1.3 m] in diameter
2. Rise above the flat surface no more than 1 in. [25 mm] at any location.

14.2.3 The cast and helix of drawn solid filler metal on 12 in. and 14 in. [300 mm and 350 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface will do the following:

1. Form a circle not less than 15 in. [380 mm] in diameter and not more than 50 in. [1.3 m] in diameter
2. Rise above the flat surface no more than 1 in. [25 mm] at any location.

14.3 The edge of the strip electrodes (camber) shall not deviate from a straight line by more than 0.5 in. [12.5 mm] in any 8 ft [2.5 m] length.

15. Filler Metal Identification

15.1 The product information and the precautionary information required in Clause 17, Marking of Packages, shall also appear on each coil and each spool.

15.2 Coils without support shall have a tag containing this information securely attached to the inside end of the coil.

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

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

15.5 Each bare straight 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 between supplier and purchaser and the color shall be identified on the packaging.) When the AWS classification designation is used, the “ER” may be omitted; for example “308L” for classification ER308L. Additional identification shall be as agreed upon between the purchaser and supplier.

16. Packaging

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

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

17.2 The appropriate precautionary information[8] given in ANSI Z49.1, latest edition (as a minimum) shall be prominently displayed in legible print on all packages including individual unit packages within a larger package.

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[8] 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 Bare Stainless Steel Welding Electrodes and Rods

This annex is not part of AWS A5.9/A5.9M:2012, *Specification for Bare Stainless Steel Welding Electrodes and Rods,* but is included for informational purposes only.

A1. Introduction

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

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

A1.3 For definitions of bare electrodes, composite metal cored electrodes, and composite stranded electrodes, see "electrode" in AWS A3.0, *Standard Welding Terms and Definitions*. For purposes of this specification, composite metal cored rods are defined by composite metal cored electrodes and composite stranded rods are defined by composite stranded electrodes, except for the basic differences between welding electrode and welding rod as defined by AWS A3.0.

A1.4 In some cases, the composition of bare filler metal classified in this specification may differ from that of core wire used for the corresponding classification of covered electrodes classified in AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*. Caution, therefore, should be exercised regarding the use of core wire from a covered electrode as bare filler metal.

A2. Classification System

A2.1 The chemical composition of the filler metal is identified by a series of numbers and, in some cases, chemical symbols, the letters L, H, and LR, or both. Chemical symbols are used to designate modifications of basic alloy types, for example, ER308Mo. The letter "H" denotes carbon content restricted to the upper part of the range that is specified for the standard grade of the specific filler metal. The letter "L" denotes carbon content in the lower part of the range that is specified for the corresponding standard grade of filler metal. The letters "LR" denote low residuals (see A8.31).

A2.1.1 The first two designators may be "ER" for solid wires that may be used as electrodes or rods; or they may be "EC" for composite cored or stranded wires; or they may be "EQ" for strip electrodes.

A2.1.2 The three- or four-digit number, such as 308 in ER308, designates the nominal chemical composition of the filler metal.

A2.2 An international system for designating welding filler metals has been published by the International Standards Organization (ISO) prepared by the International Institute of Welding (IIW), ISO 14343. Table A.1 shows the designations for stainless steel bare filler metals along with the corresponding grades in this specification.

Table A.1
Comparison of Classifications in ISO 14343[a]

AWS A5.9/A5.9M[b]	ISO 14343A	ISO 14343B[c]
ER209	—	—
ER218	—	—
ER219	—	—
ER240	—	—
ER307	—	SS307
ER308	—	SS308
ER308H	—	SS308H
ER308L	19 9 L	SS308L
ER308Mo	20 10 3	SS308Mo
ER308LMo	—	SS308LMo
ER308Si	—	SS308Si
ER308LSi	19 9 L Si	SS308LSi
ER309	22 12 H	SS309
ER309L	23 12 L	SS309L
ER309Mo	—	SS309Mo
ER309LMo	23 12 2 L	SS309LMo
ER309Si	—	SS309Si
ER309LSi	23 12 L Si	SS309LSi
ER310	25 20	SS310
ER312	29 9	SS312
ER316	—	SS316
ER316H	19 12 3 H	SS316H
ER316L	19 12 3 L	SS316L
ER316LMn	20 16 3 Mn N L	SS316LMn
ER316Si	—	SS316Si
ER316LSi	19 12 3 LSi	SS316LSi
ER317	—	SS317
ER317L	18 15 3 L	SS317L
ER318	19 12 3 Nb	SS318
ER320	—	SS320
ER320LR	—	SS320LR
ER321	—	SS321
ER330	18 36 H	SS330
ER347	19 9 Nb	SS347
ER347Si	19 9 Nb Si	SS347Si
ER383	27 31 4 Cu L	SS383
ER385	20 25 5 Cu L	SS385
ER409	—	SS409
ER409Nb	—	SS409Nb
ER410	13	SS410
ER410NiMo	13 4	SS410NiMo
ER420	—	SS420
ER430	17	SS430
ER439	—	SS439
ER446LMo	—	—
ER630	—	SS630
ER19-10H	19 9 H	SS19-10H
ER16-8-2	16 8 2	SS16-8-2
ER2209	22 9 3 N L	SS2209
ER2307	*23 7 N L*	—
ER2553	—	—
ER2594	25 9 4 N L	SS2594
ER33-31	—	—
ER3556	—	—

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

[b] The classification designator R shall be replaced by Q for strip, and by C for tubular composite metal cored electrodes.

[c] The first S in the classification designator shall be replaced by B for strip, and by T for tubular composite metal cored electrodes.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344:2002 MOD), as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01M/A5.01 (ISO 14344:2002 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 14344:2002 MOD). Testing in accordance with any other schedule in that table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been 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 14344:2002 MOD).

A5. Preparation of Samples for Chemical Analysis

A5.1 Solid Bare Electrodes and Rod. Preparation of a chemical analysis sample from solid, bare welding electrodes and rods presents no technical difficulties. Such filler metal may be subdivided for analysis by any convenient method with all samples or chips representative of the lot of filler metal.

A5.2 Composite Metal Cored or Stranded Electrodes

A5.2.1 Gas tungsten arc welding with argon gas shielding may be used to melt a button (or slug) of sufficient size for analytical use.

A5.2.2 Other processes that melt a sample under a vacuum or inert atmosphere that results in a cast button (slug) may be used to produce a specimen for analysis.

A5.2.3 Gas metal arc welding with argon gas shielding may also be used to produce a homogeneous deposit for analysis. In this case, the weld pad is similar to that used to prepare a sample of filler metal deposited by covered electrodes.

A5.2.4 These methods must be utilized in such a manner that no dilution of the base metal or mold occurs to contaminate the fused sample. Copper molds often are used to minimize the effects of dilution by the base metal or mold.

A5.2.5 Special care must be exercised to minimize such dilution effects when testing low carbon filler metals.

A5.3 Preparation of the fused sample by gas tungsten arc welding using argon shielding gas will transfer essentially all of the components. Some slight loss in carbon may occur, but such loss will never be greater than would be encountered in an actual welding operation, regardless of process (see A7.9.1). Nonmetallic ingredients, when present in the core, will form a slag on top of the deposit that must be removed and discarded.

A5.4 The sample of fused filler metal must be large enough to provide the amount of undiluted material required by the chemist for analysis. No size or shape of deposited pads has been specified because these are immaterial if the deposit is truly undiluted.

A5.5 A sample made using the composite-type filler metal that has been fused in a copper mold should be undiluted since there will be essentially no admixture with base metal.

A5.6 Assurance that an undiluted sample is being obtained from the chosen size of pad at the selected distance above the base metal can be obtained by analyzing chips removed from successively lower layers of the pad. Layers that are undiluted will all have the same chemical composition. Therefore, the determination of identical compositions for two successive layers of deposited filler metal will provide evidence that the last layer is undiluted. Layers diluted by mild steel base metal will be low in chromium and nickel. Particular attention should be given to carbon when analyzing Type 308L, 308LSi, 308LMo, 309L, 309LSi, 309LMo, 316L, 316LMn, 316LSi, 317L, 320LR, 383, 385, 439, 446LMo, 2209, 2307, 2553, 2594, or 33-31 weld metal deposited using either electrodes or rods. Because of carbon pick-up, the undiluted layers in a pad built on high-carbon base metal begin a considerable distance above the base.

A6. Ventilation During Welding

A6.1 Five major factors govern the quantity of fumes to which welders and welding operators can be 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 the space
3. Rate of evolution of fumes, gases, or dust, according to the materials and processes involved
4. The proximity of the welders or welding operators to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which they are working
5. The ventilation provided to the space in which the welding is done.

A6.2 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 particularly drawn to the section of that document related to Health Protection and Ventilation. Further information concerning ventilation in welding can be found in AWS F3.2, *Ventilation Guide for Welding Fume*.

A7. Ferrite in Weld Deposits

A7.1 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 is also generally regarded as detrimental to toughness in cryogenic service, and in high-temperature service where it can transform into the brittle sigma phase.

A7.2 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, *A Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*.[9] In 1974, the AWS extended this procedure and prepared AWS A4.2, *Standard Procedures 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 were to be traceable to this AWS standard.

A7.3 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

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

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.

A7.4 In the opinion of the WRC Subcommittee, it has been impossible, to date, to accurately determine the true absolute ferrite content of weld metals.

A7.5 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 plus or minus 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.

A7.6 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.

A7.7 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.

A7.8 The welding process used and the welding conditions and technique have a significant influence on the chemical composition and the ferrite content of the weld deposit in many instances. These influences must be considered by the user if the weld deposit must meet specific chemical or Ferrite Number limits. The purpose of A7.9.1 through A7.9.3 is to present some general information on the effect of common arc welding processes on the chemical composition and the ferrite content of weld deposits made with filler metal classified in this specification.

A7.9 The chemical composition of a given weld deposit has the capability of providing an approximately predictable Ferrite Number for the undiluted deposit, as described in A7.13 with the limitations discussed here. However, important changes in the chemical compositions can occur from wire to deposit as described in A7.9.1 through A7.9.3.

A7.9.1 Gas Tungsten Arc Welding. This welding process involves the least change in the chemical composition from wire to deposit, and hence produces the smallest difference between the ferrite content calculated from the wire analysis and that measured on the undiluted deposit. There is some loss of carbon in gas tungsten arc welding—about half of the carbon content above 0.02 percent. Thus, a wire of 0.06 percent carbon will typically produce a deposit of 0.04 percent carbon. There is also some nitrogen pickup—a gain of 0.02 percent. The change in other elements is not significant in the undiluted weld metal.

A7.9.2 Gas Metal Arc Welding. For this process, typical carbon losses are low, only about one quarter those of the gas tungsten arc welding process. However, the typical nitrogen pick up is much higher than in gas tungsten arc welding, and it should be estimated at about 0.04 percent (equivalent to about 3 or 4 FN loss) unless specific measurements on welds for a particular application establish other values. Nitrogen pickup in this process is very dependent upon the welding technique and may go as high as 0.15 percent or more. This may result in little or no ferrite in the weld deposits of filler metals such as ER308 and ER309. Some slight oxidation plus volatilization losses may occur in manganese, silicon, and chromium contents.

A7.9.3 Submerged Arc Welding. Submerged arc welds show variable gains or losses of alloying elements, or both depending on the flux used. All fluxes produce some changes in the chemical composition as the electrode is melted and deposited as weld metal. Some fluxes deliberately add alloying elements such as niobium (columbium) and molybdenum; others are very active in the sense that they deplete significant amounts of certain elements that are readily oxidized, such as chromium. Other fluxes are less active and may contain small amounts of alloys to offset any losses and thereby, produce a weld deposit with a chemical composition close to the composition of the electrode. If the flux is active or alloyed, changes in the welding conditions, particularly voltage, will result in significant changes in the chemical composition of the deposit. Higher voltages produce greater flux/metal interactions and, for example, in the case of an alloy flux, greater alloy pickup. When close control of ferrite content is required, the effects of a particular flux/electrode combination should be evaluated before any production welding is undertaken due to the effects as shown in Table A.2.

A7.10 Bare solid filler metal wire, unlike covered electrodes and bare composite cored wires, cannot be adjusted for ferrite content by means of further alloy additions by the electrode producer, except through the use of flux in the

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

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

submerged arc welding process. Thus, if specific FN ranges are desired, they must be obtained through wire chemical composition selection. This is further complicated by the changes in the ferrite content from wire to deposit caused by the welding process and techniques, as previously discussed.

A7.11 In the 300 series filler metals, the compositions of the bare filler metal wires in general tend to cluster around the midpoints of the available chemical ranges. Thus, the potential ferrite for the 308, 308L, and 347 wires is approximately 10 FN, for the 309 wire approximately 12 FN, and for the 316 and 316L wires approximately 5 FN. Around these midpoints, the ferrite contents may be ±7 FN or more, but the chemical compositions of these filler metals will still be within the chemical limits specified in this specification.

A7.12 In summary, the ferrite potential of a filler metal afforded by this chemical composition will, except for a few instances in submerged arc welding, be modified downward in the deposit due to changes in the chemical composition that are caused by the welding process and the technique used.

A7.13 The ferrite content of welds may be calculated from the chemical composition of the weld deposit. This can best be done using the WRC-1992 Diagram (Figure A.1). Many earlier diagrams have been proposed and found useful. These may be reviewed in handbooks and other references.

A7.13.1 WRC-1992 Diagram (Figure A.1) predicts ferrite in Ferrite Number (FN). This diagram is the newest of the diagrams mentioned. Studies within the WRC Subcommittee on Welding Stainless Steel and within Commission II of the International Institute of Welding show the closest agreement between measured and predicted ferrite using this diagram. It should be noted that predictions of the WRC-1992 Diagram are independent of silicon and manganese contents because these elements were not found to have statistically significant effects. The WRC 1992 Diagram is preferred for "300" series stainless steels and for duplex stainless steels. It may not be applicable to compositions having greater than 1% Si.

A7.13.2 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. Cooling rate has a significant effect on the actual ferrite content and is one reason for the variations between calculated and measured ferrite of weld metal.

A8. Description and Intended Use of Filler Metals[10]

A8.1 ER209. The nominal composition (wt. %) of this classification is 22 Cr, 11 Ni, 5.5 Mn, 2 Mo, and 0.20 N. Filler metals of this classification are most often used to weld UNS S20910 base metal. This alloy is a nitrogen-strengthened, austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperature. Weldments in the as-welded condition made using this filler metal are not subject to carbide precipitation. Nitrogen alloying reduces the tendency for carbon diffusion and thereby increases resistance to intergranular corrosion.

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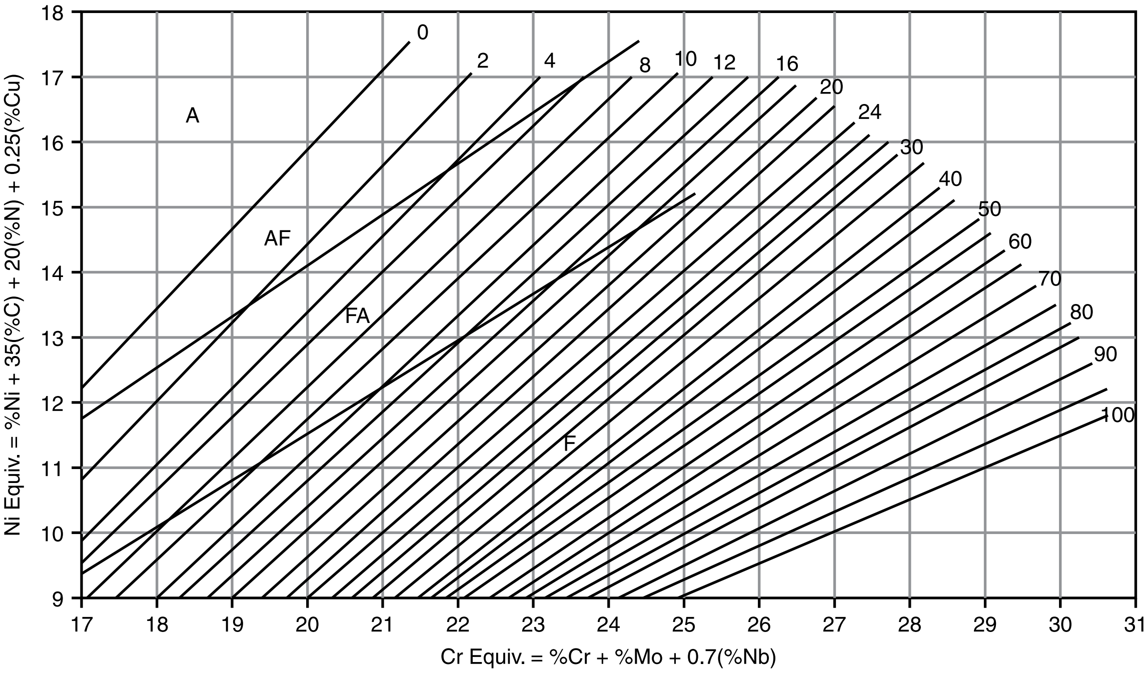
[10] ERXXX can be ECXXX or EQXXX. See Table 1 note d.



Source: Figure 1 of AWS A5.9/A5.9M:2006 ERRATA

Figure A.1—WRC-1992 Diagram for Stainless Steel Weld Metal

The ER209 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications when used with the gas metal arc welding process.

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

A8.2 ER218. The nominal composition (wt. %) of this classification is 17 Cr, 8.5 Ni, 8 Mn, 4 Si, and 0.13 N. Filler metals of this classification are most often used to weld UNS S21800 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperature. Nitrogen alloying in this base composition results in significant improvement in wear resistance in particle-to-metal and metal-to-metal (galling) applications when compared to the more conventional austenitic stainless steels such as Type 304. The ER218 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3 ER219. The nominal composition (wt. %) of this classification is 20 Cr, 6 Ni, 9 Mn, and 0.20 N. Filler metals of this classification are most often used to weld UNS S21900 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperatures.

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

The ER219 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosive applications when used with the gas metal arc welding process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.4 ER240. The nominal composition (wt. %) of this classification is 18 Cr, 5 Ni, 12 Mn, and 0.20 N. Filler metal of this classification is most often used to weld UNS S24000 and UNS S24100 base metals. These alloys are nitrogen-strengthened austenitic stainless steels exhibiting high strength and good toughness over a wide range of temperatures. Significant improvement of wear resistance in particle-to-metal and metal-to-metal (galling) applications is a valuable characteristic when compared to the more conventional austenitic stainless steels such as Type 304. Nitrogen alloying reduces the tendency toward intergranular carbide precipitation in the weld area by inhibiting carbon diffusion thereby reducing the possibility for intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. In addition, weldments in Type 240 exhibit improved resistance to transgranular stress corrosion cracking in hot aqueous chloride-containing media. The ER240 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.5 ER307. The nominal composition (wt. %) of this classification is 21 Cr, 9.5 Ni, 4 Mn, 1 Mo. Filler metals of this classification are used primarily for moderate-strength welds with good crack resistance between dissimilar steels such as austenitic manganese steel and carbon steel forgings or castings.

A8.6 ER308. The nominal composition (wt. %) of this classification is 21 Cr, 10 Ni. Commercial specifications for filler and base metals vary in the minimum alloy requirements; consequently, the names 18-8, 19-9, and 20-10 are often associated with filler metals of this classification. This classification is most often used to weld base metals of similar composition, in particular, Type 304.

A8.7 ER308Si. This classification is the same as ER308, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld metal, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.8 ER308H. This classification is the same as ER308, except that the allowable carbon content has been restricted to the higher portion of the 308 range. Carbon content in the range of 0.04%–0.08% provides higher strength at elevated temperatures. This filler metal is used for welding 304H base metal.

A8.9 ER308L. This classification is the same as ER308, except for the carbon content. Low carbon (0.03 percent maximum) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. Strength of this low-carbon alloy, however, is less than that of the niobium-stabilized alloys or Type 308H at elevated temperatures.

A8.10 ER308LSi. This classification is the same as ER308L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.11 ER308Mo. This classification is the same as ER308, except for the addition of molybdenum. It is used for welding ASTM CF8M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for welding wrought materials such as Type 316 (UNS31600) stainless when a ferrite content in excess of that attainable with the ER316 classification is desired.

A8.12 ER308LMo. This classification is used for welding ASTM CF3M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for welding wrought materials such as Type 316L stainless when a ferrite in excess of that attainable with ER316L is desired.

A8.13 ER309. The nominal composition (wt. %) of this classification is 24 Cr, 13 Ni. Filler metals of this classification are commonly used for welding similar alloys in wrought or cast form. Occasionally, they are used to weld Type 304 and similar base metals where severe corrosion conditions exist requiring higher alloy weld metal. They are also used in dissimilar metal welds, such as joining Type 304 to carbon steel, welding the clad side of Type 304 clad steels, and applying stainless steel sheet linings to carbon steel shells.

A8.14 ER309Si. This classification is the same as ER309, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.15 ER309L. This classification is the same as ER309, except for the carbon content. Low carbon (0.03 percent maximum) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. Strength of this low-carbon alloy, however, may not be as great at elevated temperatures as that of the niobium-stabilized alloys or ER309.

A8.16 ER309LSi. This classification is the same as ER309L, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.17 ER309Mo. This classification is the same as ER309, except for the addition of 2.0 percent to 3.0 percent molybdenum to increase its pitting corrosion resistance in halide-containing environments. The primary application for this filler metal is surfacing of base metals to improve their corrosion resistance. The ER309Mo is used to achieve a single-layer overlay with a chemical composition similar to that of a 316 stainless steel. It is also used for the first layer of multilayer overlays with filler metals such as ER316 or ER317 stainless steels. Without the first layer of 309Mo, elements such as chromium and molybdenum might be reduced to unacceptable levels in successive layers by dilution from the base metal. Other applications include the welding of molybdenum-containing stainless steel linings to carbon steel shells, the joining of carbon steel base metals that had been clad with a molybdenum-containing stainless steel, and the joining of dissimilar base metals such as carbon steel to Type 304 stainless steel.

A8.18 ER309LMo. This classification is the same as an ER309Mo, except for a lower maximum carbon content (0.03%). Low-carbon contents in stainless steels reduce the possibility of chromium carbide precipitation and thereby increase weld metal resistance to intergranular corrosion. The ER309LMo is used in the same type of applications as the ER309Mo, but where excessive pickup of carbon from dilution by the base metal, where intergranular corrosion from carbide precipitation, or both are factors to be considered in the selection of the filler metal. In multilayer overlays, the low carbon ER309LMo is usually needed for the first layer in order to achieve low carbon contents in successive layers with filler metals such as ER316L or ER317L.

A8.19 ER310. The nominal composition (wt. %) of this classification is 26.5 Cr, 21 Ni. Filler metal of this classification is most often used to weld base metals of similar composition.

A8.20 ER312. The nominal composition (wt. %) of this classification is 30 Cr, 9 Ni. Filler metal of this classification was originally designed to weld cast alloys of similar composition. It also has been found to be valuable in welding dissimilar metals such as carbon steel to stainless steel, particularly those grades high in nickel. This alloy gives a two-phase weld deposit with substantial percentages of ferrite in an austenite matrix. Even with considerable dilution by austenite-forming elements such as nickel, the microstructure remains two-phase and thus highly resistant to weld metal cracks and fissures.

A8.21 ER316. The nominal composition (wt. %) of this classification is 19 Cr, 12.5 Ni, and 2.5 Mo. This filler metal is used for welding Type 316 and similar alloys. It has been used successfully in certain applications involving special base metals for high-temperature service. The presence of molybdenum provides creep resistance at elevated temperatures and pitting resistance in a halide atmosphere.

Rapid corrosion of ER316 weld metal may occur when the following three factors co-exist:

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

A8.22 ER316Si. This classification is the same as ER316, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.23 ER316H. This filler metal is the same as ER316, except that the allowable carbon content has been restricted to the higher portion of the 316 range. Carbon content in the range of 0.04 wt. % to 0.08 wt. % provides higher strength at elevated temperatures. This filler metal is used for welding 316H base metal.

A8.24 ER316L. This classification is the same as ER316, except for the carbon content. Low carbon (0.03 percent maximum) in this filler metal reduces the possibility of intergranular chromium carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This filler metal is primarily used for welding low-carbon molybdenum-bearing austenitic alloys. This low-carbon alloy, however, is not as strong at elevated temperature as the niobium-stabilized alloys or Type ER316H.

A8.25 ER316LSi. This classification is the same as ER316L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity is somewhat higher than that of lower silicon content weld metal.

A8.26 ER316LMn. The nominal composition (wt. %) of this classification is 19 Cr, 15 Ni, 7 Mn, 3 Mo, and 0.2 N. This is a fully austenitic alloy with a typical ferrite content of 0.5 FN maximum. One of the primary uses of this filler metal is for the joining of similar and dissimilar cryogenic steels for applications down to –452 °F (–269 °C). This filler metal also exhibits good corrosion resistance in acids and seawater, and is particularly suited for corrosion conditions found in urea synthesis plants. It is also nonmagnetic. The high Mn-content of the alloy helps to stabilize the austenitic microstructure and aids in hot cracking resistance.

A8.27 ER317. The nominal composition (wt. %) of this classification is 19.5 Cr, 14 Ni, 3.5 Mo, somewhat higher than ER316. It is usually used for welding alloys of similar composition. ER317 filler metal is utilized in severely corrosive environments where crevice and pitting corrosion are of concern.

A8.28 ER317L. This classification is the same as ER317, except for the carbon content. Low carbon (0.03 percent maximum) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, may not be as strong at elevated temperature as the niobium-stabilized alloys or Type 317.

A8.29 ER318. This composition is identical to ER316, except for the addition of niobium. Niobium provides resistance to intergranular chromium carbide precipitation and thus increased resistance to intergranular corrosion. Filler metal of this classification is used primarily for welding base metals of similar composition.

A8.30 ER320. The nominal composition (wt. %) of this classification is 20 Cr, 34 Ni, 2.5 Mo, 3.5 Cu, with Nb added to provide resistance to intergranular corrosion. Filler metal of this classification is primarily used to weld base metals of similar composition for applications where resistance to severe corrosion involving a wide range of chemicals, including sulfuric and sulfurous acids and their salts, is required. This filler metal can be used to weld both castings and wrought alloys of similar composition without postweld heat treatment. A modification of this classification without niobium is available for repairing castings that do not contain niobium, but with this modified composition, solution annealing is required after welding.

A8.31 ER320LR (Low Residuals). This classification has the same basic composition as ER320; however, the elements C, Si, P, and S are specified at lower maximum levels and the Nb and Mn are controlled at narrower ranges. These changes reduce the weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals. Consequently, welding practices typically used for austenitic stainless steel weld metals containing ferrite can be used in bare filler metal welding processes such as gas tungsten arc and gas metal arc. ER320LR filler metal has been used successfully in submerged arc overlay welding, but it may be prone to cracking when used for joining base metal by the submerged arc process. ER320LR weld metal has a lower minimum tensile strength than ER320 weld metal.

A8.32 ER321. The nominal composition (wt. %) of this classification is 19.5 Cr, 9.5 Ni, with titanium added. The titanium acts in the same way as niobium in Type 347 in reducing intergranular chromium carbide precipitation and thus increasing resistance to intergranular corrosion. The filler metal of this classification is used for welding chromium nickel stainless steel base metals of similar composition, using an inert gas shielded process. It is not suitable for use with the submerged arc process because only a small portion of the titanium will be recovered in the weld metal.

A8.33 ER330. The nominal composition (wt. %) of this classification is 35.5 Ni, 16 Cr. Filler metal of this type is commonly used where heat and scale resisting properties above 1800 °F (980 °C) are required, except in high-sulfur environments, as these environments may adversely affect elevated temperature performance. Repairs of defects in alloy castings and the welding of castings and wrought alloys of similar composition are the most common applications.

A8.34 ER347. The nominal composition (wt. %) of this classification is 20 Cr, 10 Ni, with Nb added as a stabilizer. The addition of niobium reduces the possibility of intergranular chromium carbide precipitation and thus susceptibility to intergranular corrosion. The filler metal of this classification is usually used for welding chromium-nickel stainless steel base metals of similar composition stabilized with either Nb or Ti. Although Nb is the stabilizing element usually specified in Type 347 alloys, it should be recognized that tantalum (Ta) is also present. Ta and Nb are almost equally effective in stabilizing carbon and in providing high-temperature strength. If dilution by the base metal produces a low ferrite or fully austenitic weld metal, the crack sensitivity of the weld may increase substantially.

A8.35 ER347Si. This classification is the same as ER347, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.36 ER383. The nominal composition (wt. %) of this classification is 27.5 Cr, 31.5 Ni, 3.7 Mo, and 1 Cu. Filler metal of this classification is used to weld UNS N08028 base metal to itself, or to other grades of stainless steel. ER383 filler metal is recommended for sulfuric and phosphoric acid environments. The elements C, Si, P, and S are specified at low maximum levels to minimize weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals.

A8.37 ER385. The nominal composition (wt. %) of this classification is 20.5 Cr, 25 Ni, 4.7 Mo, and 1.5 Cu. ER385 filler metal is used primarily for welding of ASTM B625, B673, B674, and B677 (UNS N08904) materials for the handling of sulfuric acid and many chloride containing media. ER385 filler metal also may be used to join Type 317L material where improved corrosion resistance in specific media is needed. ER385 filler metal may be used for joining UNS N08904 base metals to other grades of stainless steel. The elements C, S, P, and Si are specified at lower maximum levels to minimize weld metal hot cracking and fissuring (while maintaining corrosion resistance) frequently encountered in fully austenitic weld metals.

A8.38 ER409. This 12 Cr alloy (wt. %) differs from Type 410 material because it has a ferritic microstructure. The titanium addition forms carbides to improve corrosion resistance, increase strength at high temperature, and promote the ferritic microstructure. ER409 filler metals may be used to join matching or dissimilar base metals. The greatest usage is for applications where thin stock is fabricated into exhaust system components.

A8.39 ER409Nb. This classification is the same as ER409, except that niobium is used instead of titanium to achieve similar results. Oxidation losses across the arc generally are lower. Applications are the same as those of ER409 filler metals.

A8.40 ER410. This 12 Cr alloy (wt. %) is an air-hardening steel. Preheat and postweld heat treatments are required to achieve welds of adequate ductility for many engineering purposes. The most common application of filler metal of this type is for welding alloys of similar composition. It is also used for deposition of overlays on carbon steels to resist corrosion, erosion, or abrasion.

A8.41 ER410NiMo. The nominal composition (wt. %) of this classification is 12 Cr, 4.5 Ni, 0.55 Mo. It is primarily designed for welding ASTM CA6NM castings or similar material, as well as light-gauge 410, 410S, and 405 base metals. Filler metal of this classification is modified to contain less chromium and more nickel to eliminate ferrite in the microstructure as it has a deleterious effect on mechanical properties. Final postweld heat treatment should not exceed 1150°F [620°C], as higher temperatures may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A8.42 ER420. This classification is similar to ER410, except for slightly higher chromium and carbon contents. ER420 is used for many surfacing operations requiring corrosion resistance provided by 12 percent chromium along with somewhat higher hardness than weld metal deposited by ER410 electrodes. This increases wear resistance.

A8.43 ER430. This is a 16 Cr (wt. %) alloy. The composition is balanced by providing sufficient chromium to give adequate corrosion resistance for the usual applications, and yet retain sufficient ductility in the heat-treated condition. (Excessive chromium will result in lower ductility.) Welding with filler metal of the ER430 classification usually requires preheating and postweld heat treatment.

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

A8.44 ER439. This is an 18 Cr (wt. %) alloy that is stabilized with titanium. ER439 provides improved oxidation and corrosion resistance over ER409 in similar applications. Applications are the same as those of ER409 filler metals where thin stock is fabricated into exhaust system components.

A8.45 ER446LMo. The nominal composition (wt. %) of this classification (formerly listed as ER26-1) is 26 Cr, 1 Mo. It is used for welding base metal of the same composition with inert gas shielded welding processes. Due to the high purity of both base metal and filler metal, cleaning of the parts before welding is most important. Complete coverage by shielding gas during welding is extremely important to prevent contamination by oxygen and nitrogen. Nonconventional gas shielding methods (leading, trailing, and back shielding) often are employed.

A8.46 ER630. The nominal composition (wt. %) of this classification is 16.4 Cr, 4.7 Ni, 3.6 Cu. The composition is designed primarily for welding ASTM A 564 Type 630 and some other precipitation-hardening stainless steels. The composition is modified to prevent the formation of ferrite networks in the martensitic microstructure which have a deleterious effect on mechanical properties. Dependent on the application and weld size, the weld metal may be used as-welded; welded and precipitation hardened; or welded, solution treated, and precipitation hardened.

A8.47 ER19-10H. The nominal composition (wt. %) of this classification is 19 Cr, 10 Ni and similar to ER308H, except that the chromium content is lower and there are additional limits on Mo, Nb, and Ti. This lower limit of Cr and additional limits on other Cr equivalent elements allows a lower ferrite range to be attained. A lower ferrite level in the weld metal decreases the chance of sigma embrittlement after long-term exposure at temperatures in excess of 1000 °F [540 °C]. This filler metal should be used in conjunction with welding processes and other welding consumables that do not deplete or otherwise significantly change the amount of chromium in the weld metal. If used with submerged arc welding, a flux that neither removes nor adds chromium to the weld metal is highly recommended.

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

A8.48 ER16-8-2. The nominal composition (wt. %) of this classification is 15.5 Cr, 8.5 Ni, 1.5 Mo. Filler metal of this classification is used primarily for welding stainless steel such as types 16-8-2, 316, and 347 for high-pressure, high-temperature piping systems. The weld deposit usually has a Ferrite Number no higher than 5 FN. The deposit also has good hot-ductility properties that offer greater freedom from weld or crater cracking even under restraint conditions. The weld metal is usable in either the as-welded condition or solution-treated condition. This filler metal depends on a very carefully balanced chemical composition to develop its fullest properties. Corrosion tests indicate that the 16-8-2 weld metal may have less corrosion resistance than 316 base metal, depending on the corrosive media. Where the weldment is exposed to severe corrodants, the surface layers should be deposited with a more corrosion-resistant filler metal.

A8.49 ER2209: The nominal composition (wt. %) of this classification is 22.5 Cr, 8.5 Ni, 3 Mo, 0.15 N. Filler metal of this classification is used primarily to weld duplex stainless steels which contain approximately 22 percent chromium such as UNS S31803 and S32205. *They are also used for lean duplex stainless steel such as UNS S32101 and S32304.* Deposits of this alloy have "duplex" microstructures consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting *as compared to these properties in austenitic stainless steels such as 304L.*

A8.50 ER2307. *The nominal composition (wt. %) of this classification is 24 Cr, 8.0 Ni, and 0.15 N. Filler metals of this classification are used primarily for welding lean duplex stainless steels such as UNS S32101 and S32304. Weld metal deposited with this electrode has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited with ER2307 filler metal combines increased tensile strength and improved resistance to stress corrosion cracking as compared to these properties in weld metal from ER308L.*

A8.51 ER2553. The nominal composition (wt. %) of this classification is 25.5 Cr, 5.5 Ni, 3.4 Mo, 2 Cu, 0.2 N. Filler metal of this classification is used primarily to weld duplex stainless steels UNS S32550 that contain approximately 25 percent chromium. Deposits of this alloy have a "duplex" microstructure consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting.

A8.52 ER2594. The nominal composition (wt. %) of this classification is 25.5 Cr, 9.2 Ni, 3.5 Mo, 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 "superduplex stainless steel." This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride-containing environments. It is designed for the welding of superduplex stainless steels UNS S32750 and 32760 (wrought), and UNS J93380, and J93404 (cast). It can also be used for the welding of UNS S32550, J93370, and J93372 when not subject to sulfurous or sulfuric acids in service. It can also be used for the welding of carbon and low alloy steels to duplex stainless steels as well as to weld "standard" duplex stainless steel such as UNS S32205 and J92205 especially for root runs in pipe.

A8.53 ER33-31. The nominal composition (wt. %) of this classification is 33 Cr, 31Ni, 1.6 Mo. The filler metal is used for welding nickel-chromium-iron alloy (UNS R20033) to itself and to carbon steel, and for weld overlay on boiler tubes. The weld metal is resistant to high-temperature corrosive environments of coal fired power plant boilers.

A8.54 ER3556. The nominal composition (wt. %) of this classification is 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W (UNS R30556). Filler metal of this classification is used for welding 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W (UNS R30556) base metal to itself, for joining steel to other nickel alloys, and for surfacing steel by the gas tungsten arc, gas metal arc, and plasma arc welding processes. The filler metal is resistant to high-temperature corrosive environments containing sulfur. Typical specifications for 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W base metal are ASTM B435, B572, B619, B622, and B626, UNS number R30556.

A9. Usability

A9.1 When welding stainless steels with the gas tungsten arc process, direct current electrode negative (dcen) is preferred. For base metal up to 1/16 in [1.6 mm] thick, argon is the preferred shielding gas because there is less tendency to melt through these lighter thicknesses. For greater thicknesses, or for automatic welding, mixtures of helium and argon are recommended because of the greater penetration and better surface appearance. Argon gas for shielding may also be used and will give satisfactory results in most cases, but a somewhat higher amperage will be required. For information on the effects of higher silicon, see A9.2 and the classification of interest.

A9.2 When using the gas metal arc welding process in which the filler metal is employed as an electrode, direct current electrode positive (dcep) is most commonly used. The shielding gas for spray transfer is usually argon, with or without minor additions of oxygen. For short circuiting transfer, shielding gases composed of helium plus additions of oxygen and carbon dioxide often are used. The minimum thickness that can be welded by spray transfer is approximately 1/8 to 3/16 in [3.2 to 4.8 mm]. Short circuiting transfer can be used to weld material as thin as 1/16 in [1.6 mm]. However, thinner sections can be joined if a backing is used. The higher silicon levels improve the washing and wetting behavior of the weld metal. For instance, for increases from 0.30 to 0.65 percent silicon, the improvement is pronounced; for increases from 0.65 to 1.0 percent silicon, further improvement is experienced but is less pronounced.

A9.3 For submerged arc welding, direct current electrode positive (dcep) or alternating current (ac) may be used. Basic or neutral fluxes are generally recommended in order to minimize silicon pickup and the oxidation of chromium and other elements. When welding with fluxes that are not basic or neutral, electrodes having a silicon content below the normal 0.30 percent minimum may be desired for submerged arc welding. Such active fluxes may contribute some silicon to the weld metal. In this case, the higher silicon does not significantly improve the washing and wetting action of the weld metal.

A9.4 The strip cladding process closely resembles conventional submerged arc welding, except that a thin, consumable strip electrode is substituted for the conventional wire. Thus, the equipment consists of conventional submerged arc units with modified contact tips and feed rolls. Normal power sources with a minimum output of 750 amperes are used. If submerged arc equipment is available, then the same feeding motor, gear box, flux-handling system, wire spool, and controls used to feed wire electrodes can be used for strip surfacing. The only difference in most cases is a strip welding head and "bolt-on" adaptor plate.

Strip surfacing is generally carried out using direct current supplied either from a generator or from a rectifier. Power sources with either constant voltage or drooping characteristics are used routinely.

A constant-voltage power source is preferable, however, generator or rectifier type can be connected in parallel to produce higher current for specific applications. The use of direct current electrode positive (dcep) yields somewhat better edge shape and a more regular deposit surface.

Strip cladding is conducted with either the submerged arc or electroslag welding process. Although electroslag welding does not involve an arc, except for initiation, it uses identical strip feeding equipment, controls, and power sources. Voltage and flux composition control are generally necessary whether the process is submerged arc or electroslag. The electroslag process is widely used because of its ability to deposit weld metal with low dilution.

A10. Special Tests

A10.1 Corrosion or Scaling Tests. Tests of joint specimens have the advantage that the joint design and welding procedure can be made identical to that being used in fabrication. They have the disadvantage of testing the combined properties of the weld metal, the heat-affected zone (HAZ) 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 filler metal, but may be used for qualifying welding procedures using approved materials. Special corrosion or scale resisting tests that are pertinent to the intended application may be conducted as agreed upon between the purchaser and supplier. This section is included for the guidance of those who desire to specify such special tests.

A10.1.1 The heat treatments, surface finish, and marking of the specimens prior to testing should be in accordance with standard practices for tests of similar alloys in the wrought or cast forms. The testing procedure should correspond to ASTM G 4, *Standard Method for Conducting Corrosion Tests in Plant Equipment* or ASTM A 262, *Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels*, or ASTM G 48, *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*.

A10.2 Tests for Mechanical Properties. The tensile properties, bend ductility, and soundness of welds produced using filler metal that conforms with this specification are frequently determined during welding procedure qualification. For cryogenic applications, impact properties of welds are required. It should be realized that the variables in the process, such as current, voltage, and welding speed; variables in the shielding medium, such as the gas mixture or flux; variables in the manual dexterity of the welder; and variables in the composition of the base metal influence the results that may be obtained. When properly controlled, however, these filler metals will give sound welds under widely varying conditions with tensile strength and ductility similar to that obtained by the covered arc welding electrodes.

Tensile and elongation requirements for weld metal deposited by shielded metal arc welding (covered) electrodes specified in AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, are shown in Table A.3. For a discussion of impact properties for cryogenic applications, see Annex Clause A8 of AWS A5.4/A5.4M. Note that the impact properties of welds made with bare filler metals in the GTAW or GMAW processes are usually superior to those produced with the SMAW or SAW processes. When supplementary tests for mechanical properties are specified, the procedures should be in accordance with the latest edition of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*.

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 A6. 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*,[11] and applicable federal and state regulations. ANSI Z49.1 can be downloaded and printed from the AWS website at http://www.aws.org.

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

A11.3 AWS Safety and Health Fact Sheets Index (SHF)[12]

No.	Title
1	*Fumes and Gases*
2	*Radiation*

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

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

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 Welding 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*

Table A.3
All-Weld-Metal Mechanical Property Requirements from AWS A5.4/A5.4M:2006

AWS Classification	Tensile Strength, min.		Elongation, min.	Heat Treatment
	ksi	MPa	percent	
E209-XX	100	690	15	none
E219-XX	90	620	15	none
E240-XX	100	690	15	none
E307-XX	85	590	30	none
E308-XX	80	550	35	none
E308H-XX	80	550	35	none
E308L-XX	75	520	35	none
E308Mo-XX	80	550	35	none
E308LMo-XX	75	520	35	none
E309-XX	80	550	30	none
E309H-xx	80	550	30	none
E309L-XX	75	520	30	none
E309Nb-XX	80	550	30	none
E309Mo-XX	80	550	30	none
E309LMo-XX	75	520	30	none
E310-XX	80	550	30	none
E310H-XX	90	620	10	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	a
E410-XX	75	520	20	b
E410NiMo-XX	110	760	15	c
E430-XX	65	450	20	a
E630-XX	135	930	7	d
E16-8-2-XX	80	550	35	none
E2209-XX	100	690	20	none
ER2307-XX[e]	*100*	*690*	*20*	*none*
E2553-XX	110	760	15	none
E2594-XX	110	760	15	none
E33-31-XX	105	720	25	none

[a] 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.

[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 exceed 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 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.

[e] Not found in AWS A5.4/A5.4M:2006, but expected to be added to the next revision of AWS A5.4/A5.4M.

Table A.4
Discontinued Classifications

Discontinued Classification	Last Published
ER26-1[a]	1981
ER349	1981
ER502[b]	1993
ER505[c]	1993
ER409Cb[d]	1993

[a] This classification was not really discontinued, but was changed to ER446LMo.

[b] This electrode classification was transferred to the AWS A5.28 specification where it is classified as ER80S-B6, and to the AWS A5.23 specification where it is classified as EB6.

[c] This electrode classification was transferred to the AWS A5.28 specification where it is classified as ER80S-B8, and to the AWS A5.23 specification where it is classified as EB8.

[d] This classification was not really discontinued, but was changed to ER409Nb to reflect the adoption of Nb for niobium instead of Cb for columbium.

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SPECIFICATION FOR BARE ALUMINUM AND ALUMINUM-ALLOY WELDING ELECTRODES AND RODS

SFA-5.10/SFA-5.10M

(Identical with AWS Specification A5.10/A5.10M:2012. In case of dispute, the original AWS text applies.)

Welding consumables — Wire electrodes, wires and rods for welding of aluminum and aluminum-alloys — Classification

1 Scope

1.1 This standard specifies requirements for classification of solid wires and rods for fusion welding of aluminum and aluminum alloys. The classification of the solid wires and rods is based on their chemical composition.

1.2 *Safety and health issues and concerns are beyond the scope of this standard and are therefore not fully addressed herein. Some safety and health information can be found in informative annex Clauses A6 and A12. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes, and applicable federal and state regulations.*

1.3 *This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification A5.10 uses U.S. Customary Units. The specification with the designation A5.10M uses SI Units. The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing of electrodes or packaging or both under specification A5.10 or A5.10M.*

2 Normative references

This standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

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

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

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

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

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

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

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

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[1] *AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.*

[2] *This ANSI standard is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.*

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

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

ASTM E34, Standard Methods for Chemical Analysis of Aluminum and Aluminum Alloys

ASTM B108, Standard Specification for Aluminum-Alloy Permanent Mold Castings

ASTM B209, Standard Specification for Aluminum and Aluminum Alloy Sheet and Plate

ASTM E1032, Standard Test Methods for Radiographic Examination of Weldments

2.4 *The following ISO standards[4] are referenced in the mandatory clause of this document:*

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

ISO 80000-1, Quantities and units.

3 Classifications

3.1 *AWS Classifications (Table 1)*

3.1.1 *Any filler metal tested and classified as an electrode shall also be considered classified as a welding rod. Filler metal tested and classified only as a welding rod shall not be classified as an electrode.*

3.1.2 *The electrodes and rods classified under this specification are intended for gas metal arc, gas tungsten arc, oxyfuel gas, and plasma arc welding, but that is not to prohibit their use with any other process for which they are found suitable.*

3.1.3 *Filler metal containing more than 0.0003% by weight of beryllium shall not be classified as electrode and should not be used as an electrode.*

4 *Acceptance*

Acceptance[5] of the material shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

5 *Certification*

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[6]

6 *Rounding-off procedure*

For purposes of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E29 or ISO 80000-1, Part 1: General (the results are the same). If the measured values are obtained by equipment calibrated in units other than

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[3] *ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.*

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

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

[6] *See A4, Certification (in Annex A) for further information concerning certification and the testing called for to meet this requirement.*

Table 1 — Symbol for the Chemical Composition of Solid Wires and Rods

Alloy Symbol			Chemical Composition in Weight Percent$^{a, b}$													
AWS Classification	ISO 18273 Numerical	ISO 18273 Chemical	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ga, V	Ti	Zr	$Al_{min.}$	Be	Other Each	Other Total
ALUMINIUM-LOW ALLOYED																
ER1070, R1070	Al 1070	Al99,7	0.20	0.25	0.04	0.03	0.03	—	0.04	V 0.05	0.03	—	99.70	0.0003	0.03	—
ER1080A, R1080A	Al 1080A	Al99,8(A)	0.15	0.15	0.03	0.02	0.02	—	0.06	Ga 0.03	0.02	—	99.80	0.0003	0.02	—
ER1100, R1100	Al 1100	Al99,0Cu	Si + Fe 0.95		0.05–0.20	0.05	—	—	0.10	—	—	—	99.00	0.0003	0.05	0.15
ER1188 R1188	Al 1188	Al 99,88	0.06	0.06	0.005	0.01	0.01	—	0.03	Ga 0.03 V 0.05	0.01	—	99.88	0.0003	0.01	—
ER1200, R1200	Al 1200	Al99,0	Si + Fe 1.00		0.05	0.05	—	—	0.10	—	0.05	—	99.00	0.0003	0.05	0.15
ER1450, R1450	Al 1450	Al99,5Ti	0.25	0.40	0.05	0.05	0.05	—	0.07	—	0.10–0.20	—	99.50	0.0003	0.03	—
ALUMINIUM-COPPER																
R-206.0^{c}	—	—	0.10	0.15	4.2–5.0	0.20–0.50	0.15–0.35	—	0.10	—	0.15–0.30	—	Rem	—	0.05	0.15
ER2319, R2319	Al 2319	AlCu6MnZrTi	0.20	0.30	5.8–6.8	0.20–0.40	0.02	–	0.10	V 0.05–0.15	0.10–0.20	0.10–0.25	Rem	0.0003	0.05	0.15
ALUMINIUM-MANGANESE																
ER3103, R3103	Al 3103	AlMn 1	0.50	0.7	0.10	0.9–1.5	0.30	0.10	0.20	—	Ti + Zr 0.10		Rem	0.0003	0.05	0.15
ALUMINIUM-SILICON																
R-C355.0	—	—	4.5–5.5	0.20	1.0–1.5	0.10	0.40–0.6	—	0.10	—	0.20	—	Rem	—	0.05	0.15
R-A356.0	—	—	6.5–7.5	0.20	0.20	0.10	0.25–0.45	—	0.10	—	0.20	—	Rem	—	0.05	0.15
R-357.0	—	—	6.5–7.5	0.15	0.05	0.03	0.45–0.6	—	0.05	—	0.20	—	Rem	—	0.05	0.15
R-A357.0	—	—	6.5–7.5	0.20	0.20	0.10	0.40–0.7	—	0.10	—	0.04–0.20	—	Rem	0.04–0.07	0.05	0.15
ER4009, R4009	Al 4009	AlSi5Cu1Mg	4.5–5.5	0.20	1.0–1.5	0.10	0.45–0.6	—	0.10	—	0.20	—	Rem	0.0003	0.05	0.15
ER4010, R4010	Al 4010	AlSi7Mg	6.5–7.5	0.20	0.20	0.10	0.30–0.45	—	0.10	—	0.20	—	Rem	0.0003	0.05	0.15
R4011	Al 4011	AlSi7Mg0,5Ti	6.5–7.5	0.20	0.20	0.10	0.45–0.7	—	0.10	—	0.04–0.20	—	Rem	0.04–0.07	0.05	0.15
ER4018, R4018	Al 4018	AlSi7Mg	6.5–7.5	0.20	0.05	0.10	0.50–0.8	—	0.10	—	0.20	—	Rem	0.0003	0.05	0.15
ER4043, R4043	Al 4043	AlSi5	4.5–6.0	0.8	0.30	0.05	0.05	—	0.10	—	0.20	—	Rem	0.0003	0.05	0.15
ER4043A, R4043A	Al 4043A	AlSi5(A)	4.5–6.0	0.6	0.30	0.15	0.20	—	0.10	—	0.15	—	Rem	0.0003	0.05	0.15
ER4046, R4046	Al 4046	AlSi10Mg	9.0–11.0	0.50	0.03	0.40	0.20–0.50	—	0.10	—	0.15	—	Rem	0.0003	0.05	0.15
ER4047, R4047	Al 4047	AlSi12	11.0–13.0	0.8	0.30	0.15	0.10	—	0.20	—	—	—	Rem	0.0003	0.05	0.15
ER4047A, R4047A	Al 4047A	AlSi12(A)	11.0–13.0	0.6	0.30	0.15	0.10	—	0.20	—	0.15	—	Rem	0.0003	0.05	0.15
ER4145, R4145	Al 4145	AlSi10Cu4	9.3–10.7	0.8	3.3–4.7	0.15	0.15	0.15	0.20	—	—	—	Rem	0.0003	0.05	0.15

(Continued)

Table 1 (Continued) — Symbol for the Chemical Composition of Solid Wires and Rods

Alloy Symbol			Chemical Composition in Weight Percent[a, b]													
AWS Classification	ISO 18273 Numerical	ISO 18273 Chemical	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ga, V	Ti	Zr	$Al_{min.}$	Be	Other Each	Other Total
ALUMINIUM-SILICON (Continued)																
ER4643, R4643	Al 4643	AlSi4Mg	3.6–4.6	0.8	0.10	0.05	0.10–0.30	—	0.10	—	0.15	—	Rem	0.0003	0.05	0.15
ER4943,[d] *R4943*[d]	—	—	*5.0–6.0*	*0.40*	*0.10*	*0.05*	*0.10–0.50*	—	*0.10*	—	*0.15*	—	*Rem*	*0.0003*	*0.05*	*0.15*
ALUMINIUM-MAGNESIUM																
ER5087, R5087	Al 5087	AlMg4,5MnZr	0.25	0.40	0.05	0.7–1.1	4.5–5.2	0.05–0.25	0.25	—	0.15	0.10–0.20	Rem	0.0003	0.05	0.15
ER5183, R5183	Al 5183	AlMg4,5Mn0,7(A)	0.40	0.40	0.10	0.50–1.0	4.3–5.2	0.05–0.25	0.25	—	0.15	—	Rem	0.0003	0.05	0.15
ER5183A, R5183A	Al 5183A	AlMg4,5Mn0,7(A)	0.40	0.40	0.10	0.50–1.0	4.3–5.2	0.05–0.25	0.25	—	0.15	—	Rem	0.0005	0.05	0.15
ER5187, R5187	Al 5187	AlMg4,5MnZr	0.25	0.40	0.05	0.7–1.1	4.5–5.2	0.05–0.25	0.25	—	0.15	0.10–0.20	Rem	0.0005	0.05	0.15
ER5249, R5249	Al 5249	AlMg2Mn0,8Zr	0.25	0.40	0.05	0.50–1.1	1.6–2.5	0.30	0.20	—	0.15	0.10–0.20	Rem	0.0003	0.05	0.15
ER5356, R5356	Al 5356	AlMg5Cr(A)	0.25	0.40	0.10	0.05–0.20	4.5–5.5	0.05–0.20	0.10	—	0.06–0.20	—	Rem	0.0003	0.05	0.15
ER5356A R5356A	Al 5356A	AlMg5Cr(A)	0.25	0.40	0.10	0.05–0.20	4.5–5.5	0.05–0.20	0.10	—	0.06–0.20	—	Rem	0.0005	0.05	0.15
ER5554, R5554	Al 5554	AlMg2,7Mn	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	0.25	—	0.05–0.20	—	Rem	0.0003	0.05	0.15
ER5556, R5556	Al 5556	AlMg5Mn1Ti	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	0.25	—	0.05–0.20	—	Rem	0.0003	0.05	0.15
ER5556A, R5556A	Al 5556A	AlMg5Mn	0.25	0.40	0.10	0.6–1.0	5.0–5.5	0.05–0.20	0.20	—	0.05–0.20	—	Rem	0.0003	0.05	0.15
ER5556B, R5556B	Al 5556B	AlMg5Mn	0.25	0.40	0.10	0.6–1.0	5.0–5.5	0.05–0.20	0.20	—	0.05–0.20	—	Rem	0.0005	0.05	0.15
ER5556C, R5556C	Al 5556C	AlMg5Mn1Ti	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	0.25	—	0.05–0.20	—	Rem	0.0005	0.05	0.15
ER5654, R5654	Al 5654	AlMg3,5Ti	Si + Fe 0.45		0.05	0.01	3.1–3.9	0.15–0.35	0.20	—	0.05–0.15	—	Rem	0.0003	0.05	0.15
ER5654A, R5654A	Al 5654A	AlMg3,5Ti	Si + Fe 0.45		0.05	0.01	3.1–3.9	0.15–0.35	0.20	—	0.05–0.15	—	Rem	0.0005	0.05	0.15
ER5754, R5754	Al 5754[e]	AlMg3	0.40	0.40	0.10	0.50	2.6–3.6	0.30	0.20	—	0.15	—	Rem	0.0003	0.05	0.15

[a] Single values shown in the table are maximum values, except for Al.

[b] The results shall be rounded to the same number of significant figures as in the specified value using the rules in accordance with *ISO 80000-1* or ASTM E29.

[c] For R-206.0, Ni = 0.05 max. and Sn = 0.05 max.

[d] These classifications have patent application pending.

[e] Alloy Al 5754 also limits the sum (Mn + Cr): 0.10 to 0.6.

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 unit in the last right-hand place of figures used in expressing the limiting values. 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 2. The purpose of these tests is to determine the chemical composition of the filler metal, soundness of the weld metal produced by gas metal arc welding electrodes, and the deposition characteristics of welding rods. 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.

8 Retest

If any test fails to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for the retest may be taken from the original test sample or from a new test sample. For chemical analysis, retest need be only for those specific elements that failed to meet their 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 sample or test specimen(s), or in conducting the tests, 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 prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9 *Weld test assemblies*

9.1 *One of two weld test assemblies is required:*

a) *The groove weld test assembly for the usability of electrodes and the soundness of the weld metal (see Figure 1).*

b) *The bead-on-plate weld test assembly for the usability of rods (see 9.4).*

9.2 *Usability tests shall be made using electrodes and welding rods of each diameter. A filler metal that satisfactorily meets the requirements of the radiographic soundness test, when tested as an electrode, shall also be classified as a welding rod without being subjected to the bead-on-plate test required for a welding rod. A filler metal that satisfactorily meets the bead-on-plate weld test requirements, when tested as a welding rod, shall also be tested as an electrode and meet the requirements of the radiographic soundness test in order to be classified as an electrode.*

9.3 *Groove weld for soundness and usability of electrodes*

9.3.1 *A test assembly shall be prepared and welded, as specified in Figure 1 and 9.3.2 through 9.3.4, using base metal of the appropriate type specified in Table 3. The welding position shall be as specified in Figure 1 for the different electrode diameter. Testing of the assembly shall be as specified in Clause 11, Radiographic test.*

9.3.2 *Welding of the test assembly shall be conducted using the gas metal arc welding process with techniques and procedures specified by the manufacturer for the factors not covered herein.*

Table 2 — Required Tests

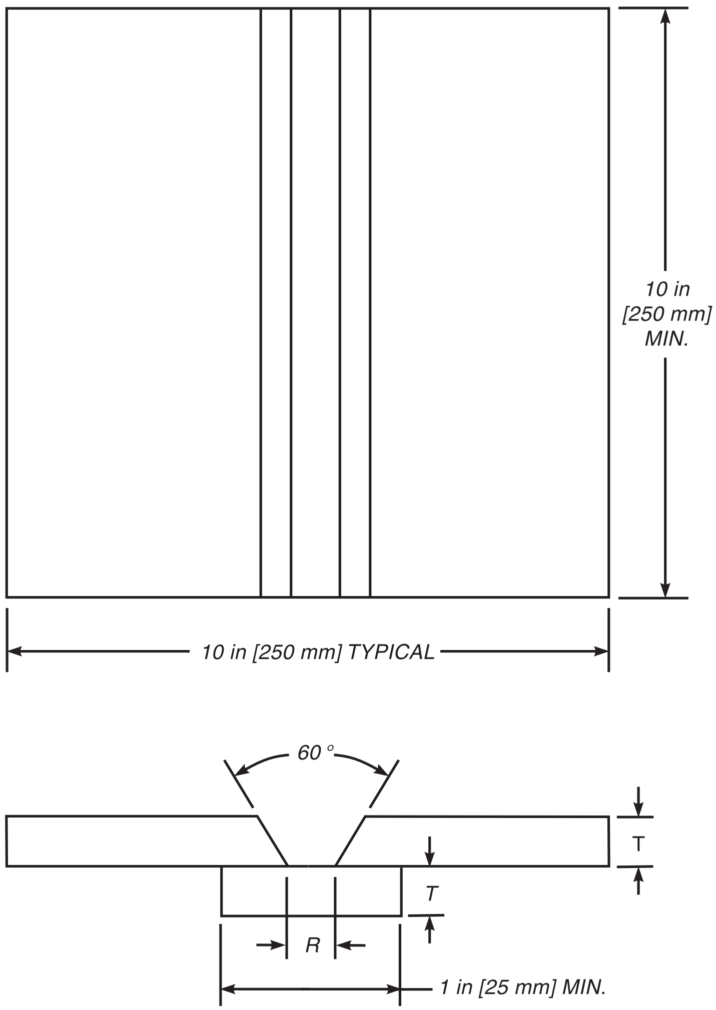
AWS Classification	Chemical Analysis	Radiographic Test[a] (Electrode)	Bead-on-Plate Test (Rod)
ER1070	X	X	—
R1070	X	—	X
ER1080A	X	X	—
R1080A	X	—	X
ER1100	X	X	—
R1100	X	—	X
ER1188	X	X	—
R1188	X	—	X
ER1200	X	X	—
R1200	X	—	X
ER1450	X	X	—
R1450	X	—	X
ER2319	X	X	—
R2319	X	—	X
ER3103	X	X	—
R3103	X	—	X
ER4009	X	X	—
R4009	X	—	X
ER4010	X	X	—
R4010	X	—	X
R4011	X	—	X
ER4018	X	X	—
R4018	X	—	X
ER4043	X	X	—
R4043	X	—	X
ER4043A	X	X	—
R4043A	X	—	X
ER4046	X	X	—
R4046	X	—	X
ER4047	X	X	—
R4047	X	—	X
ER4145	X	X	—
R4145	X	—	X
ER4643	X	X	—
ER4943	X	X	—
R4943	X	—	X
ER5087	X	X	—
R5087	X	—	X
ER5183	X	X	—
R5183	X	—	X

(Continued)

Table 2 (Continued) — Required Tests

AWS Classification	Chemical Analysis	Radiographic Test[a] (Electrode)	Bead-on-Plate Test (Rod)
ER5183A	X	X	—
R5183A	X	—	X
ER5187	X	X	—
R5187	X	—	X
ER5249	X	X	—
R5249	X	—	X
ER5356	X	X	—
R5356	X	—	X
ER5356A	X	X	—
R5356A	X	—	X
ER5554	X	X	—
R5554	X	—	X
ER5556	X	X	—
R5556	X	—	X
ER5556A	X	X	—
R5556A	X	—	X
ER5556B	X	X	—
R5556B	X	—	X
ER5556C	X	X	—
R5556C	X	—	X
ER5654	X	X	—
R5654	X	—	X
ER5654A	X	X	—
R5654A	X	—	X
ER5754	X	X	—
R5754	X	—	X
R-206.0	X	—	X
R-C355.0	X	—	X
R-A356.0	X	—	X
R-357.0	X	—	X
R-A357.0	X	—	X

[a] Filler metal meeting the radiographic requirement, when tested as an electrode, is not required to be tested as a rod, as specified in 9.2.



Electrode Diameter		Plate Thickness, T[a]		Nominal Root Opening, R		Welding Position
in	mm	in	mm	in	mm	
0.030 0.035	0.8 0.9	3/16 or 1/4	5 or 6.5	1/4	6.5	Overhead
	1.0	1/4	6.5	1/4	6.5	Overhead
3/64	1.2	1/4	6.5	1/4	6.5	
1/16	1.6	3/8	10	3/8	10	Overhead
	2.0	3/8	10	3/8	10	
3/32	2.4	3/8	10	3/8	10	Flat
	2.5	3/8	10	3/8	10	
1/8	3.2	3/8	10	1/2	13	Flat

[a] A variation of ±5% in the specified plate thickness is acceptable.

Notes:
1. Assembly shall be welded employing the gas metal arc welding process.
2. Assembly may be machined or extruded as a single piece if the minimum dimensions shown are maintained for the specific electrode diameter being tested.

Figure 1 — Groove Weld Test Assembly for Radiographic Test

Table 3 — Base Metal for Test Assemblies

Electrode and Rod (AWS Classification)	Base Metal [a] (Aluminum Association Designations)[b]
ER1070, R1070, ER1080A, R1080A ER1100, R1100, ER1188, R1188 ER1200, R1200, ER14t50, R1450	1060, 1100, 1350, 3003, 6005, or 6061
ER2319, R2319, ER4145, R4145	2014, 2219,3003, 6005, or 6061
ER4009, R4009, ER4010, R4010 R4011, ER4018, R4018, ER4043, R4043, ER4043A, R4043A ER4046, R4046, ER4047, R4047, ER4047A, R4047A, ER4643, R4643 ER4943, R4943 ER3103, R3103	3003, 6005, or 6061
ER5087, R5087, ER5183, R5183 ER5183A, R5183A, ER5187, R5187, ER5249, R5249, ER5356, R5356, ER5356A, R5356A ER5554, R5554, ER5556 R5556, ER5556A, R5556A ER5556B, R5556B, ER5556C, R5556C, ER5654, R5654, ER5654A, R5654A ER5754 R5754	3004, 5052, 5083, 5086, 5154, 5454, 5456, 6005, or 6061
R-206.0	206.0, 2014, 2219, 3003, 6005, or 6061
R-C355.0	355.0, C355.0, 3003, 6005, or 6061
R-A356.0, R357.0, R-A357.0	356.0, A356.0, 357.0, A357.0, 3003, 6005, or 6061

[a] All wrought base alloys 1060, 1100, 2014, 2219, 3003, 3004, 5052, 5083, 5086, 5154, 5454, 6005, and 6061 are included in ASTM B209. Cast base alloys 355.0, C355.0, 356.0, A356.0, 357.0, and A357.0 are included in ASTM B108.

[b] The Aluminum Association, Inc., 1525 Wilson Blvd., Suite 600, Arlington, VA 22209.

9.3.3 *Dimensions of the groove weld joint and the position of welding shall be as specified in Figure 1 for the electrode diameter being tested. The backing material shall be of the same type of base metal as the test plate base metal.*

9.3.4 *The test assembly shall be at a temperature of not less than 60°F [16°C] when commencing the initial or subsequent weld passes. The preheat and interpass temperatures shall not exceed 150°F [66°C].*

9.4 *Bead-on-plate weld test for usability of welding rods*

9.4.1 *The test assembly shall consist of sheet, plate, or extrusion approximately 12 in [300 mm] in length upon which a weld shall be made as specified in 9.4.2, using base metal of the appropriate type specified in Table 3. Examination of the assembly shall be as specified in Clause 12, Bead-on-plate test.*

9.4.2 *Welding of the assembly shall be done in the flat position with the gas tungsten arc welding process employing alternating current and argon gas shielding. The test plate thickness and the welding current shall be compatible with the rod being tested.*

9.4.3 *The completed bead-on-plate welds shall be examined with the unaided eye (corrected to normal vision) and shall meet the requirements specified in Clause 12, Bead-on-plate test.*

10 Chemical analysis

10.1 *A sample of the filler metal, 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.*[7] *The referee method shall be ASTM E34, Standard Methods for Chemical Analysis of Aluminum and Aluminum Alloys.*

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

11 *Radiographic test*

11.1 *The groove weld described in 9.3 and shown in Figure 1, shall be completed and then radiographed to evaluate the soundness of the weld metal and to determine the usability of the electrode. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing 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 ASTM E1032. The quality level of inspection shall be 2-2T.*

11.3 *The soundness of the weld metal and the usability of the electrode meet the requirements of this specification if the radiograph shows no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Figure 2 for test assemblies welded in the overhead position for electrode sizes up to and including 1/16 in [1.6 mm] and Figure 3 for test assemblies welded in the flat position for electrode sizes larger than 1/16 in [1.6 mm]. In evaluating the radiograph, the center 6 in [150 mm] of the test specimen shall be considered, and all extra weld shall be disregarded.*

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

11.4 *An electrode that produces a groove weld which satisfactorily meets these radiographic requirements may also be classified as a welding rod under this specification without conducting the test specified in 9.4.*

12 *Bead-on-plate test*

12.1 *Welding rod tested in accordance with 9.4 shall produce weld metal that flows freely and uniformly without sputtering or other irregularities. The resultant weld metal shall be smooth and uniform with no visible evidence of cracks or porosity.*

12.2 *If a filler metal satisfactorily meets the weld bead-on-plate test requirements when tested as a welding rod, it also shall be tested as an electrode if it is to be classified as an electrode.*

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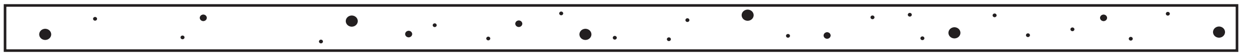
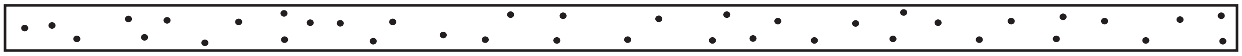
[7] *See Clause A10 (in Annex A) for further information concerning accepted analysis methods.*



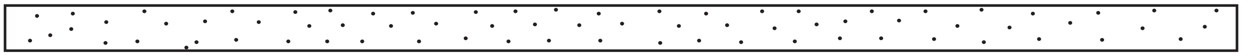
ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.050 in [1.3 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 29 WITH THE FOLLOWING RESTRICTIONS:
LARGE: UP TO 0.050 in [1.3 mm]—6 PERMITTED
MEDIUM: UP TO 0.031 in [0.8 mm]—5 PERMITTED
SMALL: UP TO 0.020 in [0.5 mm]—18 PERMITTED



MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.030 in [0.8 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 39



SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.020 in [0.5 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 72

Notes:

1. *In using these standards, the chart that 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. *Indications which do not exceed 1/64 in [0.4 mm] diameter or length, or both, shall be disregarded.*
3. *Total area of porosity in a 6 in [150 mm] length of weld is 0.0225 sq in [14.52 sq mm] based on 1.5% T per in [25 mm] where T is the base metal thickness.*

Figure 2A — Radiographic Acceptance Standards for 3/16 in [5 mm] and 1/4 in [6.4 mm] Thick Test Assemblies — Overhead Welding Position

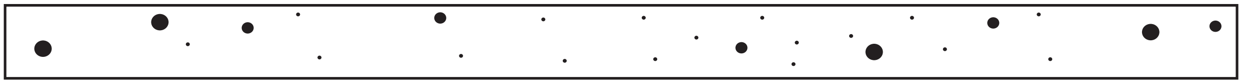
13 *Method of manufacture*

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

14 *Standard sizes*

14.1 *Standard sizes for round filler metal in the different package forms of straight lengths, coils without support, and spools are as shown in Table 4. Diameters of cast rods in straight lengths are approximate with no specified tolerance.*

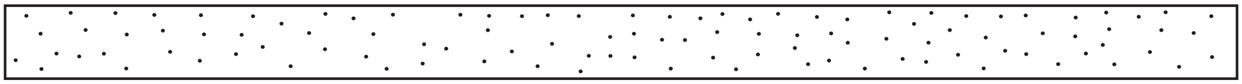
14.2 *Typical sizes for flattened shapes of straight length welding rod are shown in Table 5. The cross-sectional area of such shapes shall be equivalent to that of corresponding round rods of the same nominal diameter as listed in Table 5.*



ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.075 in [1.9 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 26 WITH THE FOLLOWING RESTRICTIONS:

LARGE:	UP TO 0.075 in [1.9 mm]—4 PERMITTED
MEDIUM:	UP TO 0.049 in [1.3 mm]—5 PERMITTED
SMALL:	UP TO 0.020 in [0.5 mm]—17 PERMITTED



SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.020 in [0.5 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 108

Notes:

1. In using these standards, the chart that 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. Indications which do not exceed 1/64 in [0.4 mm] diameter or length, or both, shall be disregarded.
3. Total area of porosity in a 6 in [150 mm] length of weld is 0.0337 sq in [21.7 sq mm] based on 1.5% T per in [25 mm] where T s the base metal thickness.
4. These radiographic acceptance standards are identical to those previously incorporated in MIL-E-16053L (Amendment 2, 20 October 1980) and as Class 3 NAVSEA 0900-LP-003-9000 (see Annex A5).

Figure 2B — Radiographic Acceptance Standards for 3/8 in [10 mm] Thick Test Assemblies — Overhead Welding Position

15 *Finish and uniformity*

Finish and uniformity shall be as specified in 4.2.1 and 4.2.2 of AWS A5.02/A5.02M.

16 *Standard package forms*

Standard package dimensions and weights and other requirements for each form shall be as specified in 4.3 of AWS A5.02/A5.02M.

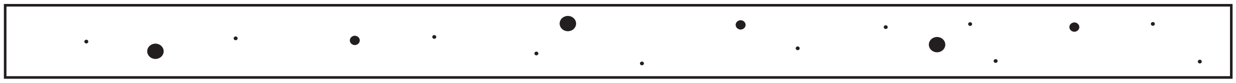
17 *Winding requirements*

17.1 *Winding requirement shall be as specified in 4.4.1 of AWS A5.02/A5.02M.*

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

18 *Filler metal identification*

Filler metal identification, product information, and the precautionary information shall be as specified in 4.5.1 through 4.5.6 of AWS A5.02/A5.02M.

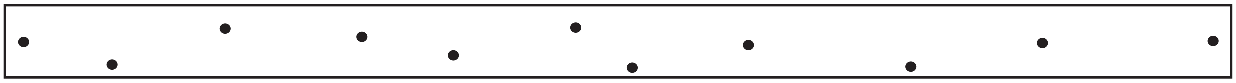


ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.075 in [1.9 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 17 WITH THE FOLLOWING RESTRICTIONS:
LARGE: UP TO 0.075 in [1.9 mm]—3 PERMITTED
MEDIUM: UP TO 0.049 in [1.3 mm]—3 PERMITTED
SMALL: UP TO 0.020 in [0.5 mm]—11 PERMITTED

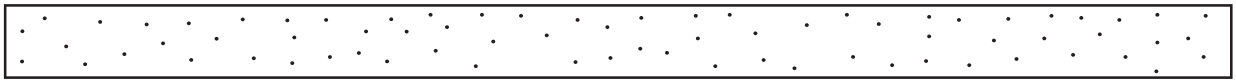
LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 0.075 in [1.9 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 5



MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.049 in [1.3 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 11



SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.020 in [0.5 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 72

Notes:
1. *In using these standards, the chart that 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. *Indications which do not exceed 1/64 in [0.4 mm] diameter or length, or both, shall be disregarded.*
3. *Total area of porosity in a 6 in [150 mm] length of weld is 0.0225 sq in [14.52 sq mm] based upon 1.0% T per in [25 mm] where T is the base metal thickness.*
4. *This radiographic acceptance standard is identical to that previously incorporated in MIL-E-16053L (Amendment 2, 20 October 1980) and as Class 1 NAVSEA 0900-LP-003-9000 (see Annex A5).*

Figure 3 — Radiographic Acceptance Standard for Test Assemblies — Flat Position Welding

Table 4 — Standard Sizes[a]

Standard Package Forms	*Diameter*			*Tolerances*	
	in[b]		*mm*	*in*	*mm*
Straight lengths and coils without support (Notes c, d)	1/16	(0.062)	1.6	+0.001, –0.002	+0.03, –0.05
		(0.079)	2.0		
	3/32	(0.094)	2.4[e]		
		(0.098)	2.5		
	1/8	(0.125)	3.2		
	5/32	(0.156)	4.0		
	3/16	(0.188)	4.8[e]		
		(0.197)	5.0		
	1/4	(0.250)	6.4[e]		
4 in [100 mm] and 8 in [200 mm] Spools	0.030		0.8	+0.001, –0.002	+0.03, –0.05
	0.035		0.9		
		(0.039)	1.0		
	3/64	(0.047)	1.2		
	1/16	(0.062)	1.6		
12 in [300 mm] Spools	0.030		0.8	+0.001, –0.002	+0.03, –0.05
	0.035		0.9		
		(0.039)	1.0		
	3/64	(0.047)	1.2		
	1/16	(0.062)	1.6		
		(0.079)	2.0		
	3/32	(0.094)	2.4[e]		
		(0.098)	2.5		
	1/8	(0.125)	3.2		
13-1/2 in [340 mm] Spools	1/16	(0.062)	1.6	+0.001, –0.002	+0.03, –0.05
		(0.079)	2.0		
	3/32	(0.094)	2.4[e]		
		(0.098)	2.5		
	1/8	(0.125)	3.2		

[a] *Dimensions, tolerances, and package forms (for round filler metal) other than those shown shall be as agreed by purchaser and supplier.*

[b] *Decimal inches are exact conversions with appropriate rounding.*

[c] *There is no specified tolerance for cast rod in straight lengths.*

[d] *Length of wrought rods shall be 36 in, +0, –1/2 in [900 mm ± 2%]. Length of cast rods shall be 18 in ± 1/2 in [450 mm ± 2%].*

[e] *Metric sizes not shown in ISO 544.*

Table 5 — Typical Sizes of Flattened Rods

Equivalent Round Diameter		*Thickness*		*Width*	
in	*mm*	*in*	*mm*	*in*	*mm*
1/16	1.6	0.047	1.2	0.072	1.8
	2.0		1.5		2.1
3/32	2.4	0.070	1.8	0.105	2.7
	2.5		1.9		2.6
1/8	3.2	0.095	2.4	0.142	3.6
5/32	4.0	0.115	2.9	0.175	4.4
3/16	4.8	0.140	3.6	0.210	5.0
	5.0		3.8		5.2
1/4	6.4	0.187	4.8	0.280	7.1

Note: Standard length shall be 36 in, +0, –1/2 in [900 mm ± 2%].

19 *Packaging*

19.1 *Filler metal in all product forms, excepting welding rods in straight lengths, shall be packaged in accordance with 4.3 of AWS A5.02/A5.02M and Table 6 of this standard.*

19.2 *Packaging of straight lengths of bare welding rods shall be as agreed upon between the purchaser and supplier.*

20 *Marking of packages*

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

21 Symbols and requirements

21.1 Symbols for the product form

The symbol for the solid wire and rod shall be *ER or R for AWS classifications*.

NOTE One product form may be used for more than one welding process.

21.2 Symbol for the chemical composition

The numerical symbol in Table 1 indicates the chemical composition of a solid wire and rod, determined under conditions given in Clause 10.

22 Mechanical properties of the weld metal

Mechanical properties of the weld metal are not part of the classification.

Table 6 — Standard Packages, Dimensions, and Weights[a]

Package Form[b]			***Nominal Net Weight***	
			lb	***kg***
Straight lengths			*5* *10* *25* *50*	*2.5* *5* *10* *25*
Coils without support[c]			*25* *50*	*10* *25*
	in	*mm*		
Spools	*4*	*100*	*1*	*0.5*
	8	*200*	*5*	*2.5*
	12	*300*	*10–26*	*5–12*
	13-1/2	*340*	*30*	*15*

[a] *Filler metal diameters for all forms and lengths are given in Table 4.*

[b] *No more than one classification or size shall be included in each package.*

[c] *Dimensions of coils shall be as agreed between purchaser and supplier.*

National Annexes

Annex A (Informative)

Guide to Welding Consumables—Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum-Alloys—Classifcation

This annex is not part of AWS A5.10/A5.10M:2012 (ISO 18273:2004 MOD), Welding Consumables—Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum-Alloys—Classifications, *but is included for informational purposes only.*

A1. *Introduction*

This guide is designed to correlate the filler metal classifications with their intended applications so the specification can be used more effectively. Reference to appropriate base metal alloys is made whenever that can be done and when it would be helpful. Such references are intended as examples rather than complete listings of the materials for which each filler metal is suitable.

A2. *Classification System*

A2.1 *Both welding electrodes and rods are classified upon the basis of the chemical composition of the aluminum filler metal and a usability test. The AWS classifications used in this specification are based as follows:*

A2.2 *The Aluminum Association alloy designation nomenclature is used for the numerical portion to identify the alloy and thus its registered chemical composition.*

A2.3 *A letter prefix designates usability of the filler metal. The letter system for identifying the filler metal classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix "E" indicates the filler metal is suitable for use as an electrode and the prefix "R" indicates suitability as welding rod. Since some of these filler metals are used as electrodes in gas metal arc welding, and as welding rods in oxyfuel gas, gas tungsten arc, and plasma arc welding, both letters, "ER," are used to indicate suitability as an electrode or a rod. In all cases, a product which meets the test requirements for an electrode in this specification, also meets the requirements for a welding rod. A product that meets the test requirements for a welding rod, must also pass the test for an electrode before being classified as an electrode.*

A2.4 Description of ISO Alloy Symbols (Table 1)

A2.4.1 *The ISO alloy symbols in Table 1 are divided into two parts:*

(1) the first part indicates the product form being solid wires or rods, see A2.4.2;

(2) the second part gives a numerical symbol indicating the chemical composition of the solid wire or rod, see Table 1.

A2.4.2 ISO Symbols for the Product Form

The ISO symbol for the solid wire and rod shall be S.

NOTE: One product form may be used for more than one welding process.

A2.4.3 ISO Designation

The ISO designation of solid wires and rods shall follow the principle given in the example below.

EXAMPLE 1 A solid wire (S) for gas shielded metal arc welding has a chemical composition within the limits for the alloy symbol Al 4043 (AlSi5) of Table 1, is designated:

Solid wire ISO 18273 – S Al 4043

or alternatively

Solid wire ISO 18273 – S Al 4043 (AlSi5)

EXAMPLE 2 A solid rod (S) for tungsten arc welding is designated

Solid rod ISO 18273 – S Al 4043

or alternatively

Solid rod ISO 18273 – S Al 4043 (AlSi5)

where:

ISO 18273 is the standard number;

S is the product form (see A2.4.2);

Al 4043 is the chemical composition of welding consumable (see Table 1);

AlSi5 is the optional chemical composition symbol of welding consumable (see Table 1).

A2.5 *Minor changes in procedures used in the manufacture of aluminum filler metals can affect their surface quality and significantly affect the resultant weld soundness. Usability testing of the electrode is desirable on a periodic basis to assure that the product classified in this specification continues to meet the soundness requirement. The supplier should perform the usability tests of this specification on an annual basis, as a minimum, to assure that the specified soundness and operating characteristics criteria are maintained. AWS A5.01M/A5.01 (ISO 14344 MOD) should be used by a purchaser for definition of lot and frequency of testing references when purchasing aluminum filler metals.*

A2.6 ***Request for Filler Metal Classification***

(1) *When an existing electrode or rod cannot be classified as given in this specification, the manufacturer may request that a classification be established for that welding electrode. The manufacturer may do this by following the procedure given here.*

(2) *A request to establish a new electrode or rod classification must be a written request, and must provide sufficient detail to permit the AWS A5 Committee on Filler Metals and Allied Materials or the subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request needs to state the variables and their limits, for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed. In particular, the request needs to include:*

(a) *All classification requirements as given for existing classifications, such as, chemical composition ranges 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 Descriptions and Intended Use, which parallels that for existing classifications, for that clause of the annex.*

(d) *Actual test data for all tests required for classification according to the requirements of the specification for a minimum of two production heats/lots must be provided.*

(e) *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 AWS A5 Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will:*

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

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

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

(d) *File the original request.*

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

(4) *All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chair of the AWS A5 Committee on Filler Metals and Allied Materials, for action.*

(5) *The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each AWS A5 Committee on Filler Metals and Allied Materials meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.*

A3. *Acceptance*

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

A5. *Application of Military and Federal Specifications*

At the time of cancellation (June 7, 1982) of Military Specification MIL-E-16053L, Amendment 2 (October 20, 1980), Electrodes, Welding, Bare, Aluminum Alloys, the technical requirements were identical to those of AWS A5.10-80. They both covered the same aluminum alloys, compositions, welding tests, and radiographic standards. The MIL-E-16053L cancellation notice canceled the Qualified Products List QPL-16053 as well as the specification and stated, "Future acquisition of replacement electrodes should be made under AWS A5.10-80, Aluminum and Aluminum Alloy Bare Welding Rods and Electrodes."

Federal Specification QQ-R-566B, Rods and Electrodes, Welding, Aluminum, and Aluminum Alloys, was technically the same as AWS A5.10 when it was issued July 5, 1973, and was in the process of being updated at the time of the

MIL-E-16053L cancellation. On November 29, 1982, Federal Specification QQ-R-566B was also cancelled with the recommendation, "The ANSI/AWS Standard A5.10, latest issue in effect, concerning Aluminum Alloy Bare Welding Rods and Electrodes should be used." Straight length, coiled, and spooled rod for Oxyfuel gas and gas tungsten arc welding were included in QQ-R-566B, as well as the spooled electrode for gas metal arc welding. Thus the total coverage was the same as ANSI/AWS A5.10.

AWS A5.10/A5.10M (ISO 18273 MOD) is a classification document, which defines tests and acceptance criteria to determine that the product meets the requirements for classification. These tests need to be repeated only if a significant change is made in the manufacturing process. These tests become a part of the specific procurement only when used in combination with AWS A5.01M/A5.01 (ISO 14344 MOD) which identifies lot classifications, level of testing and the frequency of tests. To order the specific tests previously required by MIL-E-16053L and QQ-R-566B specifications, the following Lot Classification and Level of Testing defined in AWS A5.01M/A5.01 (ISO 14344 MOD) document apply:

Lot Definition	***AWS A5.01M/A5.01 (ISO 14344 MOD) Lot Classification***
A lot consists of bare solid electrodes or rods, not exceeding 100 000 lb [45 000 kg] of one classification, size, form, and temper identified by controlled chemical composition	*Class S2*
Tests	***Level of Testing Schedule***
a. Conformance to chemical composition limits	*Sch. H, I, or J*
b. Welding tests upon the lot shipped	*Sch. I or J*
c. Visual Examination, diameters and finish	*A5.10 Requirement*
d. Filler wire tension test	*Identify as part of Sch. K*

The minimum tensile requirement for the test shall be as agreed upon between the supplier and purchaser.

Purchase Order Information

In addition to stating the AWS classification, AWS Specification A5.10/A5.10M (ISO 18273 MOD), diameter, form, and quantity, the purchase order should state that the material is to conform to AWS A5.01M/A5.01 (ISO 14344 MOD), Lot Class S2, Schedule K. Schedule K must be stated to be, "Schedule J plus tension tests of the filler wire for each lot of 2000 lb [900 kg] supplied." When referencing level of testing Schedules I or J, certification of performance to the chemical composition limits and acceptable welding test results will be supplied. Quantitative results of the tension test can be requested on the purchase order.

A6. *Ventilation During Welding*

A6.1 *Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding:*

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

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

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

(4) *The proximity of the welder or welding operator to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which the welder or welding operator is working*

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

A6.2 *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 sections of that document covering Ventilation and Confined Spaces. See also AWS F3.2, Ventilation Guide for Weld Fume, for more detailed description of ventilation options.*

A7. *Welding Considerations*

The electrodes and rods described in this specification are primarily for use with the inert gas arc welding processes. However, they may be used with other welding processes such as electron beam or oxyfuel gas welding.

A7.1 *The gas metal arc process permits the successful welding of aluminum alloys that are crack-sensitive when welded by oxyfuel gas or other manual welding processes. The reasons for this might be described briefly as follows:*

Distortion is reduced to a minimum because the increase in temperature of the parts being welded is confined to a narrow zone. Because the aluminum alloys have high thermal conductivity, the reduction of distortion is greater than would be the case with ferrous base metals. Cracking of welds in the aluminum alloys is reduced if the cooling rate is high. The gas metal arc process permits the welding of alloys that have a wide melting range, which heretofore have been difficult to weld without cracking.

A7.2 *The high melting and solidification rate of the weld metal from the gas metal arc process can result in entrapped hydrogen gas in the welds. Control of this factor should be understood to obtain good results. Hydrogen gas in the welds can be caused by contaminating influences, such as grease, hydrocarbon cleaning agents, or moisture on the electrode or on the base metal. Moist air leaking into the inert gas lines may also cause this condition. The introduction of hydrogen gas in the weld metal from any of these causes can result in porosity, because the solidification rate is high and the gas may not have time to escape before the molten metal solidifies.*

A7.3 *Welds can be made in all positions with the gas metal arc process. Edge preparation similar to that used for gas tungsten arc welding is satisfactory. Either pure argon or argon/helium mixtures may be used as shielding. Semiautomatic welding, in which the welding gun is moved by a welder, may be difficult to control on metal thicknesses below 0.08 in [2 mm]. The use of a pulsed power supply permits the welding of base metal as thin as 0.03 in [0.8 mm]. No upper limit on metal thickness has been established for the gas metal arc welding process. Welds in plate up to 8 in [200 mm] in thickness have been made. Automatic gas metal arc welding is suitable for all thicknesses welded, and particularly for 1/8 in [3.2 mm] or less in thickness.*

A7.4 *Gas metal arc welding is typically performed with direct current (electrode positive). An electrode feeding mechanism, in which electrode speed can be adjusted is needed. U-groove radiused top and bottom electrode feed rolls are preferred in both manual and mechanized equipment. Stabilization of the arc with high-frequency current is not required.*

A7.5 *Gas tungsten arc welds can be made in all positions. Welding travel speed is reduced compared to GMA welding, however, this is beneficial in several aspects. The process is more maneuverable for manually welding small tubes or piping than GMAW; entrapment of gases is minimized to permit production of sound welds; short repair welds can be made more easily; and the reduced concentration of heat allows welding aluminum base metal thicknesses as thin as 0.02 in [0.5 mm] or less. Corner and edge joints in sheet gauges can be made more satisfactorily than with GMAW due to the better control of the filler metal additions.*

A7.6 *Gas tungsten arc welds are most commonly made with alternating-current power and pure argon (AWS A5.32 (ISO 14175) – I1) gas shielding. Helium (AWS A5.32 (ISO 14175) – I2) additions to the extent of 25% of the mixture with argon are used to increase the rate of initial melting and the amount of melting in thick base metal. Pure tungsten (AWS A5.12M/A5. 12 Class EWP or zirconia-tungsten (AWS A5.12M/A5.12 Class EWZr-1) electrodes are preferred for AC-GTAW. The positive electrode polarity of the AC power provides an arc cleaning action to remove the surface oxide; however, thick aluminum oxides caused by weathering, thermal treatments, or anodic treatments need to be reduced by chemical or mechanical means prior to welding to obtain uniform results and proper fusion. As stated in A7.2, sources of hydrogen, such as moisture on the base or filler metals or in the gas shielding and residual hydrocarbons on the base or filler metals, must be removed to avoid porosity in the welds.*

A7.7 *Direct current power can also be used to GTA weld aluminum. DCEP power can be used to weld sheet gauges; however, a 1/4 in [6.40 mm] diameter tungsten electrode is required to carry the 125 amperes needed to weld 1/8 in [3.2 mm] thickness, so this polarity is seldom used. DCEN power is used with helium (AWS A5.32 (ISO 14175) – I2) gas shielding and a thoriated tungsten electrode for welding aluminum-base alloys. This negative electrode polarity provides a deep, narrow melting pattern, which is advantageous for repair of thick weldments or castings and for increased welding speeds in all thicknesses. Higher as-welded strength is obtained with DCEN-GTA welds in the heat treatable aluminum alloys due to the reduced heat input compared to ACGTAW. Since no arc cleaning action occurs in the DCEN arc, special attention must be given to minimizing the oxide thickness immediately before welding, such as mechanical scraping or arc cleaning all base metal surfaces within the fusion zone.*

A8. *Description and Intended Use*

A8.1 *The selection of the proper classification of filler metal depends primarily on the aluminum base alloy used in the parts to be welded; and secondly on the welding process, the geometry of the joints, the resistance to corrosion required in service, and on the finish or appearance desired on the welded part. For example, welded vessels for holding hydrogen peroxide require special aluminum alloys, quite frequently a high-purity alloy, in order to have good resistance to corrosion or to prevent contamination of the product contained. In this case, the proper choice of filler metal is an alloy that has at least as high a purity as the base metal. Another example is the foundry welding of castings, where an alloy meeting the composition limits of the castings is, in most cases, the best choice; for example, as in the repair and fabrication of cast alloys including 206.0, C355.0, A356.0, 357.0, and A357.0.*

A8.2 *Experience has shown that certain classifications of filler metal are suitable for welding specific base metals and combinations of base metals. These are listed in Table A.1. If it is desired to weld other combinations than those listed, they should be evaluated as to suitability for the purpose intended. The alloy combinations listed will be suitable for most environments; some are preferable from one or more standpoints. In the absence of specific information, consultation with the material supplier is recommended. Additional information may be found in the aluminum chapter of Welding Handbook, Volume 3, Eighth Edition.*

A8.3 *Filler metal in the form of straight lengths and coils without support is used as welding rod with a number of welding processes. These include oxyfuel gas welding, plasma arc welding, and gas tungsten arc welding. The filler metal is usually fed by hand, although mechanized welding in these processes may involve either manual feeding of the welding rod or use of a feeding mechanism.*

A8.4 *Spooled filler metal is used most commonly as electrode for the gas metal arc welding process. It also is used as filler rod when mechanized feeding systems are employed for gas tungsten arc, plasma-arc welding and other processes. Finite lengths of filler metal can be removed from the spools for use as a high-quality, handfed filler rod with manual gas tungsten arc, plasma-arc or oxyfuel gas welding processes.*

A8.5 *The cleanliness and minimal surface oxidation of the filler metal are important with all welding processes. Oil, or other organic materials, as well as a heavy oxide film on the rod, will interfere with coalescence of the weld and also are sources of porosity. Because of this, it is necessary to clean the welding rod and electrode before packaging.*

A8.6 *Proper storage of welding rods and electrodes is essential to avoid contamination which may affect their performance. Packages of filler metal should not be left outdoors or in unheated buildings because the greater variations in temperature and humidity increase the possibility of condensation creating hydrated surface oxides. Experience has demonstrated that undesirable storage conditions may adversely affect filler metal performance. Investigation of the effect of storage time on electrode performance indicates that packaged electrodes, stored under good conditions (dry places in heated buildings), are satisfactory after extended storage.*

A8.7 *Contamination of filler metal from handling or storage may occur. In most cases, the contaminating influences will dictate the cleaning method. The practice of giving the welding rod, if it has been exposed to the shop atmosphere for long periods of time, a rub with stainless steel wool just before welding is quite widely followed.*

A9. *Special Tests*

This specification classifies those aluminum and aluminum alloy filler metals used most extensively at the time of issuance of the specification. It is recognized that supplementary tests may be necessary to determine the suitability of these welding electrodes and rods for applications involving properties not considered in this specification. In such cases, additional tests to determine such specific properties as corrosion resistance, mechanical properties at high and low temperature, wear resistance, and suitability for welding combinations of dissimilar metals may need to be conducted.

Table A.1
Guide to the Choice of Filler Metal for General Purpose Welding

Base Metal	201.0 206.0 224.0	319.0, 333.0, 354.0, 355.0, C355.0	356.0, A356.0 357.0, A357.0 413.0, 443.0, A444.0	511.0, 512.0, 513.0, 514.0, 535.0	7004, 7005, 7039, 710.0, 712.0	6009 6010 6070	6005, 6061, 6063, 6101, 6151, 6201, 6351, 6951	5456	5454
1060, 1070, 1080, 1350	ER4145	ER4145	ER4043[a, b]	ER5356[c, d]	ER5356[c, d]	ER4043[a, b]	ER4043[b]	ER5356[d]	ER4043[b, d]
1100, 3003, Al[c] 3003	ER4145	ER4145	ER4043[a, b]	ER5356[c, d]	ER5356[c, d]	ER4043[a, b]	ER4043[b]	ER5356[d]	ER4043[b, d]
2014, 2036	ER4145[e]	ER4145[e]	ER4145	—	—	ER4145	ER4145	—	—
2219	ER2319[a]	ER4145[e]	ER4145[b, c]	ER4043	ER4043	ER4043[a, b]	ER4043[a, b]	—	ER4043[b]
3004, Al[c] 3004	—	ER4043[b]	ER4043[b]	ER5356[f]	ER5356[f]	ER4043[b]	ER4043[b, f]	ER5356[d]	ER5356[f]
5005, 5050	—	ER4043[b]	ER4043[b]	ER5356[f]	ER5356[f]	ER4043[b]	ER4043[b, f]	ER5356[d]	ER5356[f]
5052, 5652[i]	—	ER4043[b]	ER4043[f]	ER5356[f]	ER5356[f]	ER4043[b]	ER5356[c, f]	ER5356[f]	ER5356[f]
5083	—	—	ER5356[c, d]	ER5356[d]	ER5183[d]	—	ER5356[d]	ER5183[d]	ER5356[d]
5086	—	—	ER5356[c, d]	ER5356[d]	ER5356[d]	—	ER5356[d]	ER5356[d]	ER5356[d]
5154, 5254[i]	—	—	ER4043[f]	ER5356[f]	ER5356[f]	—	ER5356[f]	ER5356[f]	ER5356[f]
5454	—	ER4043[b]	ER4043[f]	ER5356[f]	ER5356[f]	ER4043[b]	ER5356[c, f]	ER5356[f]	ER5554[c, f]
5456	—	—	ER5356[c, d]	ER5356[d]	ER5556[d]	—	ER5356[d]	ER5556[d]	
6005, 6061, 6063 6101, 6151, 6201 6351, 6951	ER4145	ER4145[b, c]	ER4043[b, f, g]	ER5356[f]	ER5356[c, f]	ER4043[a, b, g]	ER4043[b, f, g]		
6009, 6010, 6070	ER4145	ER4145[b, c]	ER4043[a, b, g]	ER4043	ER4043	ER4043[a, b, g]			
7004, 7005, 7039 710.0, 712.0	—	ER4043[b]	ER4043[b, f]	ER5356[f]	ER5356[d]				
511.0, 512.0, 513.0 514.0, 535.0	—	—	ER4043[f]	ER5356[f]					
356.0, A356.0, 357.0 A357.0, 413.0 443.0, A444.0	ER4145	ER4145[b, c]	ER4043[b, h]						
319.0, 333.0 354.0, 355.0 C355.0	ER4145[c]	ER4145[b, c, h]							
201.0, 206.0, 224.0	ER2319[a, h]								

(Continued on next page)

Table A.1 (Continued)
Guide to the Choice of Filler Metal for General Purpose Welding

Base Metal	5154 5254[i]	5086	5083	5052 5652[i]	5005 5050	3004 Alc. 3004	2219	2014 2036	1100 3003 Alc. 3003	1060 1070 1080 1350
1060, 1070, 1080, 1350	ER5356[c, d]	ER5356[d]	ER5356[d]	ER4043[b, d]	ER1100[b, c]	ER4043[b, d]	ER4145[b, c]	ER4145	ER1100[b, c]	ER1188[b, c, h, j]
1100, 3003, Al[c] 3003	ER5356[c, d]	ER5356[d]	ER5356[d]	ER4043[b, d]	ER1100[b, c]	ER4043[b, d]	ER4145[b, c]	ER4145	ER1100[b, c]	
2014, 2036	—	—	—	—	ER4145	ER4145	ER4145[e]	ER4145[e]		
2219	ER4043	—	—	ER4043[b]	ER4043[a, b]	ER4043[a, b]	ER2319[a]			
3004, Al[c] 3004	ER5356[f]	ER5356[d]	ER5356[d]	ER5356[c, f]	ER5356[c, f]	ER5356[c, f]				
5005, 5050	ER5356[f]	ER5356[d]	ER5356[d]	ER5356[c, d]	ER5356[c, f]					
5052, 5652[i]	ER5356[f]	ER5356[d]	ER5356[d]	ER5654[c, f, i]						
5083	ER5356[d]	ER5356[d]	ER5183[d]							
5086	ER5356[d]	ER5356[d]								
5154, 5254[i]	ER5356[f, i]									

Note: ISO Classifications different from AWS Classifications have not been added to this table.

[a] ER4145 may be used for some applications.

[b] ER4047 may be used for some applications.

[c] ER4043 may be used for some applications.

[d] ER5183, ER5356, or ER5556 may be used.

[e] ER2319 may be used for some applications. It can supply high strength when the weldment is postweld solution heat-treated and aged.

[f] ER5183, ER5356, ER5554, ER5556, and ER5654 may be used. In some cases, they provide: (1) improved color match after anodizing treatment, (2) highest weld ductility, and (3) higher weld strength. ER5554 is suitable for sustained elevated temperature service.

[g] ER4643 and ER4943 will provide higher strength than ER4043 in 1/2 in [12 mm] and thicker groove welds in 6XXX base alloys when postweld solution heat-treated and aged. They will also provide higher strength fillet welds than ER4043 in the as welded, postweld aged, or postweld heat-treated and aged conditions.

[h] Filler metal with the same analysis as the base metal is sometimes used. The following wrought filler metals possess the same chemical composition limits as cast filler alloys: ER4009 and R4009 as R-C355.0; ER4010 and R4010 as R-A356.0; and R4011 as R-A357.0.

[i] Base metal alloys 5254 and 5652 are used for hydrogen peroxide service. ER5654 filler metal is used for welding both alloys for service temperatures below 150°F [66°C].

[j] ER1100 may be used for some applications.

Notes:

1. ER4047, ER4643, or ER4943 may be used in some applications when alloy ER4043 is specified.
2. Service conditions such as immersion in fresh or salt water, exposure to specific chemicals, or a sustained high temperature (over 150°F [66°C]) may limit the choice of filler metals. Filler metals ER5183, ER5356, and ER5556 are not recommended for sustained elevated temperature service.
3. Recommendations in this table apply to gas shielded arc welding processes. For oxyfuel gas welding, only ER1188, ER1100, ER4043, ER4047, and ER4145 filler metals are ordinarily used.
4. Where no filler metal is listed, the base metal combination is not recommended for welding.

A10. *Chemical Analysis*

The most widely used method for chemical analysis is ASTM E227, Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloy by the Point-to-Plane Technique*, but other established analytical methods are acceptable. The ASTM E227 method analyzes a bulk sample and all elements simultaneously. The ASTM E34 standard method prescribes individual test methods for which each element is tested. The ASTM E34 tests methods are used as a referee method if a dispute arises concerning a specific element analysis.*

A11. *Discontinued and Replaced Alloys*

Compositions of aluminum alloy welding electrodes and rods have been discontinued and/or replaced as new editions of A5. 10/A5.10M have been issued (see Table A.2).

Table A.2
Discontinued Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods

Discontinued		*Replacement*	
AWS A5.10		*AWS A5.10*	
Classification	*Issue*	*Classification*	*Issue*
ER1060	1961	—	—
ER1260	1980	ER1188	1988
ER2014	1961	—	—
ER3004	1961	—	—
ER5039	1980	—	—
ER5052	1967	—	—
ER5154	1969	ER5654	1969
ER5254	1969	ER5654	1969
ER5652	1969	ER5654	1969
R242.0	1988	—	—
R295.0	1988	—	—
R355.0	1988	R-C355.0	1988
		ER4009 & R4009	1992
R356.0	1988	R-A356.0	1988
		ER4010 & R4010	1992
R-990A	1957	ER1100	1992
E-990A	1957	ER1100	1992
R-996A	1957	ER1060	1957
E-996A	1957	ER1060	1957
R-C4A	1980	R295.0	1980
R-CN42A	1980	R242.0	1980
R-C541A	1957	ER2014	1957
E-C541A	1957	ER2014	1957
R-G1A	1961	—	—
E-G1A	1961	—	—
R-GM50A	1957	ER5356	1957
E-GM50A	1957	ER5356	1957
R-GR20A	1957	ER5052	1957
E-GR20A	1957	ER5052	1957
R-GR40A	1957	ER5154	1957
E-GR40A	1957	ER5154	1957
R-MG11A	1957	ER3004	1957
E-MG11A	1957	ER3004	1957
R-SG70A	1980	R356.0	1980

A12. *General Safety Considerations*

A12.1 *Safety issues and concerns are addressed in this standards, although health issues and concerns are beyond the scope of this standard. Some safety and health information can be found in Annex Clause A6. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A12.3, ANSI Z49.1, and applicable federal and state regulations.*

A12.2 ***Safety and Health Fact Sheets.*** *The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.*

A12.3 AWS Safety and Health Fact Sheets Index (SHF)[8]

No.	**Title**
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding & Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Arc Viewing Distance*
27	*Thoriated Tungsten Electrodes*
28	*Oxyfuel Safety: Check Valves and Flashback Arrestors*
29	*Grounding of Portable and Vehicle Mounted Welding Generators*
30	*Cylinders: Safe Storage, Handling, and Use*
31	*Eye and Face Protection for Welding and Cutting Operations*
33	*Personal Protective Equipment (PPE) for Welding & Cutting*
34	*Coated Steels: Welding and Cutting Safety Concerns*
36	*Ventilation for Welding & Cutting*
37	*Selecting Gloves for Welding & Cutting*

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[8] *AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.*

Annex B (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS A5.10/A5.10M: 2012 (ISO 18273:2004 MOD), Welding Consumables—Wire Electrodes, Wire and Rods for Welding of Aluminum and Aluminum-Alloys—Classification, but is included for informational purposes only.

B1. Introduction

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

B2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
8669 Doral Blvd., Suite 130
Doral, FL 33166

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

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

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

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

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

B3. Interpretation of Provisions of the Standard

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

B4. Publication of Interpretations

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

B5. Telephone Inquiries

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

B6. AWS Technical Committees

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

Annex C (Informative)

List of Deviations from ISO 18273:2004

This annex is not part of AWS A5.10/A5.10M: 2012 (ISO 18273:2004 MOD), Welding Consumables—Wire Electrodes, Wire and Rods for Welding of Aluminum and Aluminum-Alloys—Classification, but is included for informational purposes only.

Deleted "European" globally

Added names and addresses of the publishers whose documents are referred in this specification

ISO uses comma (,) for decimal, but AWS uses period (.) for decimal. Decimal commas have been changed to decimal periods.

Numbered all clauses

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

Added "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 A510M uses SI Units. The specification A5.10 uses U.S. Customary Units. The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing of electrodes or packaging or both under specification A5.10M or A5.10" in Clause 1.

Added subclauses 2.1, 2.2, and 2.3

***2.4** The following ISO standards is referenced in the mandatory clause of this document:"*

Changed "ISO 31-0:1992, principles" to "ISO 80000-1, Quantities and units*"*

Replaced "ISO 14344, Welding and allied processes — Flux and gas shielded electrical welding processes — Procurement guidelines for consumables*" with "AWS A5.01M/A5.01 (ISO 14344 MOD)" globally.*

Added "in Table 1" in 3b

Added Clauses 3.1, 3.2, 3.3, and 3.4

*Replaced "**8 Technical delivery conditions***

Technical delivery conditions shall meet the requirements in EN ISO 544 and ISO 14344" with clause titled as "Acceptance."

Added Clauses 4, 5, 6, 7, and 9

*Replaced "**10. Chemical Analysis***

Chemical analysis shall be performed on samples of the product or the stock from which it is made. Any analytical technique may be used, but in case of dispute reference shall be made to established published methods" with the text shown now.

Added Clauses 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20

Renumbered other clauses as needed

Deleted Note 1 “Consumables not listed in the Table can be symbolized by Al Z. Chemical symbol established by the manufacturer may be added in brackets” from Table 1.

SPECIFICATION FOR NICKEL AND NICKEL-ALLOY WELDING ELECTRODES FOR SHIELDED METAL ARC WELDING

(**15**)

SFA-5.11/SFA-5.11M

(Identical with AWS Specification A5.11/A5.11M:2010. In case of dispute, the original AWS text applies.)

Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of nickel and nickel-alloy covered electrodes for shielded metal arc welding. It includes those compositions in which the nickel content generally exceeds that of any other element.[1]

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

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification with the designation A5.11 uses U.S. Customary Units. The specification A5.11M 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 or both under A5.11 or A5.11M specifications.

2. Normative References

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

2.2 The following AWS standards[2] are referenced in the mandatory Clauses of this document:

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

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

(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[3] is referenced in the mandatory Clauses of this document:

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[1] Nickel-base covered electrodes for welding cast iron are treated separately in AWS A5.15, *Specification for Welding Electrodes and Rods for Cast Iron*.

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

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

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

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

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

(2) ASTM A 240/A 240M, *Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels*

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

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

(5) ASTM A 560/A 560M, *Standard Specification for Castings, Chromium-Nickel Alloy*

(6) ASTM B 127, *Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip*

(7) ASTM B 160, *Standard Specification for Nickel Rod and Bar*

(8) ASTM B 162, *Standard Specification for Nickel Plate, Sheet, and Strip*

(9) ASTM B 164, *Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire*

(10) ASTM B 166, *Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire*

(11) ASTM B 167, *Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Seamless Pipe and Tube*

(12) ASTM B 168, *Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip*

(13) ASTM B 333, *Standard Specification for Nickel-Molybdenum Alloy Plate, Sheet, and Strip*

(14) ASTM B 435, *Standard Specification for UNS N06002, UNS N06230, UNS N12160, and UNS R30556 and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip*

(15) ASTM B 443, *Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625), and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip*

(16) ASTM B 446, *Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar*

(17) ASTM B 575, *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip*

(18) ASTM B 582, *Standard Specification for Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet, and Strip*

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

(20) ASTM E 76, *Standard Methods for Chemical Analysis of Nickel-Copper Alloys*

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

(21) ASTM E 354, *Test Methods for Chemical Analysis of High-temperature, Electrical, Magnetic and Other Similar Iron, Nickel, and Cobalt Alloys*

(22) ASTM E 1019, *Methods for Determination of Carbon, Sulfur, Nitrogen, Oxygen, and Hydrogen in Steel and in Iron, Nickel and Cobalt Alloys*

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

(24) ASTM E 1473, *Test Methods for Chemical Analysis of Nickel, Cobalt and High Temperature Alloys*

2.4 The following ISO standards[5] are referenced in the mandatory Clauses of this document:

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

(2) ISO 14172, *Welding consumables — Covered electrodes for manual metal arc welding of nickel and nickel alloys — Classification*

3. Classification

3.1 The welding electrodes covered by the A5.11/A5.11M 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 their undiluted weld metal, as specified in Table 1.

3.2 Electrodes classified under one classification shall not be classified under any other classification in this specification. However, material may be classified under both A5.11 and A5.11M specifications. However, material may be classified under both A5.11 and A5.11M specifications.

4. Acceptance

Acceptance[6] of the electrodes shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344).

5. Certification

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

6. Rounding-Off Procedure

For purposes of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E 29 or 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 off. If an average value is to be compared to the specified limit, rounding off shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi (1 ksi) for tensile and yield strength for A5.11 or to the nearest 10 MPa for tensile and yield strength for A5.11M; 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 fulfil the requirements for the classification under test.

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

[6] See Clause A3, Acceptance (in Annex A), for further information concerning acceptance and testing of the material shipped, as well as AWS A5.01M/A5.01 (ISO 14344).

[7] See Clause A4, Certification (in Annex A), for further information concerning certification and the testing called for to meet this requirement.

Table 1
Chemical Composition Requirements for Undiluted Weld Metal

		Weight-Percent[a,b]															
AWS Classification	UNS Number[c]	C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) plus Ta	Mo	V	W	Other Elements Total
ENi-1	W82141	0.10	0.75	0.75	0.03	0.02	1.25	0.25	92.0 min.	—	1.0	1.0 to 4.0	—	—	—	—	—	0.50
ENiCr-4	W86172	0.10	1.5	1.0	0.02	0.02	1.0	0.25	Rem	—	—	—	48.0 to 52.0	1.0 to 2.5	—	—	—	0.50
ENiCu-7	W84190	0.15	4.0	2.5	0.02	0.015	1.5	Rem	62.0 to 69.0	—	0.75	1.0	—	—	—	—	—	0.50
ENiCrFe-1	W86132	0.08	3.5	11.0	0.03	0.015	0.75	0.50	62.0 min.	—	—	—	13.0 to 17.0	1.5 to 4.0[f]	—	—	—	0.50
ENiCrFe-2	W86133	0.10	1.0 to 3.5	12.0	0.03	0.02	0.75	0.50	62.0 min.	(e)	—	—	13.0 to 17.0	0.5 to 3.0[f]	0.5 to 2.5	—	—	0.50
ENiCrFe-3	W86182	0.10	5.0 to 9.5	10.00	0.03	0.015	1.0	0.50	59.0 min.	(e)	—	1.0	13.0 to 17.0	1.0 to 2.5[f]	—	—	—	0.50
ENiCrFe-4	W86134	0.20	1.0 to 3.5	12.00	0.03	0.02	1.0	0.50	60.0 min.	—	—	—	13.0 to 17.0	1.0 to 3.5	1.0 to 3.5	—	—	0.50
ENiCrFe-7[g]	W86152	0.05	5.0	7.0 to 12.0	0.03	0.015	0.75	0.50	Rem	(e)	0.50	0.50	28.0 to 31.5	1.0 to 2.5	0.5	—	—	0.50
ENiCrFe-9	W86094	0.15	1.0 to 4.5	12.00	0.02	0.015	0.75	0.50	55.0 min.	—	—	—	12.0 to 17.0	0.5 to 3.0	2.5 to 5.5	—	1.5	0.50
ENiCrFe-10	W86095	0.20	1.0 to 3.5	12.00	0.02	0.015	0.75	0.50	55.0 min.	—	—	—	13.0 to 17.0	1.0 to 3.5	1.0 to 3.5	—	1.5 to 3.5	0.50
ENiCrFe-12	W86025	0.10 to 0.25	1.0	8.0 to 11.0	0.04	0.02	1.0	0.20	Rem	1.0	1.5 to 2.2	0.10 to 0.40	24.0 to 26.0	—	—	—	—	0.50

(Continued)

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

AWS Classification	UNS Number[c]	Weight-Percent[a,b]																
		C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) plus Ta	Mo	V	W	Other Elements Total
ENiCrFe-13[h]	*W86155*	*0.05*	*1.0*	*Rem*	*0.020*	*0.015*	*0.75*	*0.30*	*52.0 to 62.0*	*0.10*	*0.50*	*0.50*	*28.5 to 31.0*	*2.1 to 4.0*	*3.0 to 5.0*	—	—	*0.50*
ENiCrFeSi-1	W86045	0.05 to 0.20	2.5	21.0 to 25.0	0.04	0.03	2.5 to 3.0	0.30	Rem	1.0	0.30	—	26.0 to 29.0	—	—	—	—	0.50
ENiMo-1	W80001	0.07	1.0	4.0 to 7.0	0.04	0.03	1.0	0.50	Rem	2.5	—	—	1.0	—	26.0 to 30.0	0.60	1.0	0.50
ENiMo-3	W80004	0.12	1.0	4.0 to 7.0	0.04	0.03	1.0	0.50	Rem	2.5	—	—	2.5 to 5.5	—	23.0 to 27.0	0.60	1.0	0.50
ENiMo-7	W80665	0.02	1.75	2.25	0.04	0.03	0.2	0.50	Rem	1.0	—	—	1.0	—	26.0 to 30.0	—	1.0	0.50
ENiMo-8	W80008	0.10	1.5	10.0	0.02	0.015	0.75	0.50	60.0 min.	—	—	—	0.5 to 3.5	—	17.0 to 20.0	—	2.0 to 4.0	0.50
ENiMo-9	W80009	0.10	1.5	7.0	0.02	0.015	0.75	0.3 to 1.3	62.0 min.	—	—	—	—	—	18.0 to 22.0	—	2.0 to 4.0	0.50
ENiMo-10	W80675	0.02	2.0	1.0 to 3.0	0.04	0.03	0.2	0.50	Rem	3.0	—	—	1.0 to 3.0	—	27.0 to 32.0	—	3.0	0.50
ENiMo-11	W80629	0.02	2.5	2.0 to 5.0	0.04	0.03	0.2	0.5	Rem	1.0	0.1 to 0.5	0.3	0.5 to 1.5	0.5	26.0 to 30.0	—	—	0.50
ENiCrMo-1	W86007	0.05	1.0 to 2.0	18.0 to 21.0	0.04	0.03	1.0	1.5 to 2.5	Rem	2.5	—	—	21.0 to 23.5	1.75 to 2.50	5.5 to 7.5	—	1.0	0.50
ENiCrMo-2	W86002	0.05 to 0.15	1.0	17.0 to 20.0	0.04	0.03	1.0	0.50	Rem	0.50 to 2.50	—	—	20.5 to 23.0	—	8.0 to 10.0	—	0.2 to 1.0	0.50

(Continued)

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

AWS Classification	UNS Number[c]	Weight-Percent[a,b] C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) plus Ta	Mo	V	W	Other Elements Total
ENiCrMo-3	W86112	0.10	1.0	7.0	0.03	0.02	0.75	0.50	55.0 min.	(e)	—	—	20.0 to 23.0	3.15 to 4.15	8.0 to 10.0	—	—	0.50
ENiCrMo-4	W80276	0.02	1.0	4.0 to 7.0	0.04	0.03	0.2	0.50	Rem	2.5	—	—	14.5 to 16.5	—	15.0 to 17.0	0.35	3.0 to 4.5	0.50
ENiCrMo-5	W80002	0.10	1.0	4.0 to 7.0	0.04	0.03	1.0	0.50	Rem	2.5	—	—	14.5 to 16.5	—	15.0 to 17.0	0.35	3.0 to 4.5	0.50
ENiCrMo-6	W86620	0.10	2.0 to 4.0	10.0	0.03	0.02	1.0	0.50	55.0 min.	—	—	—	12.0 to 17.0	0.5 to 2.0	5.0 to 9.0	—	1.0 to 2.0	0.50
ENiCrMo-7	W86455	0.015	1.5	3.0	0.04	0.03	0.2	0.50	Rem	2.0	—	0.70	14.0 to 18.0	—	14.0 to 17.0	—	0.5	0.50
ENiCrMo-9	W86985	0.02	1.0	18.0 to 21.0	0.04	0.03	1.0	1.5 to 2.5	Rem	5.0	—	—	21.0 to 23.5	0.5	6.0 to 8.0	—	1.5	0.50
ENiCrMo-10	W86022	0.02	1.0	2.0 to 6.0	0.03	0.015	0.2	0.50	Rem	2.5	—	—	20.0 to 22.5	—	12.5 to 14.5	0.35	2.5 to 3.5	0.50
ENiCrMo-11	W86030	0.03	1.5	13.0 to 17.0	0.04	0.02	1.0	1.0 to 2.4	Rem	5.0	—	—	28.0 to 31.5	0.3 to 1.5	4.0 to 6.0	—	1.5 to 4.0	0.50
ENiCrMo-12	W86032[h]	0.03	2.2	5.0	0.03	0.02	0.7	0.50	Rem	—	—	—	20.5 to 22.5	1.0 to 2.8	8.8 to 10.0	—	—	0.50
ENiCrMo-13	W86059	0.02	1.0	1.5	0.015	0.01	0.2	0.50	Rem	—	—	—	22.0 to 24.0	—	15.0 to 16.5	—	—	0.50
ENiCrMo-14	W86686	0.02	1.0	5.0	0.02	0.02	0.25	0.50	Rem	—	—	0.25	19.0 to 23.0	—	15.0 to 17.0	—	3.0 to 4.4	0.50

(Continued)

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

		Weight-Percent[a,b]															
AWS Classification	UNS Number[c]	C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) plus Ta	Mo	V	W	Other Elements Total
ENiCrMo-17	W86200	0.020	0.5	3.0	0.030	0.015	0.2	1.3 to 1.9	Rem	2.0	—	—	22.0 to 24.0	—	15.0 to 17.0	—	—	0.50
ENiCrMo-18	W86650	0.03	0.7	12.0 to 15.0	0.03	0.02	0.6	0.3	Rem	1.0	0.5	—	19.0 to 22.0	0.3	10.0 to 13.0	0.15	1.0 to 2.0	0.50
ENiCrMo-19[i]	W86058	0.02	1.5	1.5	0.03	0.02	0.2	0.5	Rem	0.3	0.4	—	20.0 to 23.0	—	19.0 to 21.0	—	0.3	0.50
ENiCrMo-22	*W86035*	*0.05*	*0.50*	*2.00*	*0.030*	*0.015*	*0.60*	*0.30*	*Rem*	*1.00*	*0.40*	*0.20*	*32.25 to 34.25*	*0.50*	*7.6 to 9.0*	*0.20*	*0.60*	*0.50*
ENiCrCoMo-1	W86117	0.05 to 0.15	0.3 to 2.5	5.0	0.03	0.015	0.75	0.50	Rem	9.0 to 15.0	—	—	21.0 to 26.0	1.0	8.0 to 10.0	—	—	0.50
ENiCrWMo-1	W86231	0.05 to 0.10	0.3 to 1.0	3.0	0.02	0.015	0.25 to 0.75	0.50	Rem	5.0	0.50	0.10	20.0 to 24.0	—	1.0 to 3.0	—	13.0 to 15.0	0.50

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[a] The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of the work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for “Other Elements, Total” in the last column of the table.

[b] Single values are maximum, except where otherwise specified. Rem = remainder.

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

[d] Includes incidental cobalt. Rem = remainder.

[e] Cobalt—0.12 maximum, when specified by the purchaser.

[f] Tantalum—0.30 maximum, when specified by the purchaser.

[g] Boron is 0.005% maximum and Zr is 0.020% maximum when specified by purchaser.

[h] B is 0.003% max. and Zr is 0.020% max.

[i] UNS number formerly was W86040.

[j] N = 0.02 to 0.15.

7. Summary of Tests

The tests required for classification are specified in Table 2. The purpose of these tests is to determine the chemical composition, the mechanical properties and soundness of the weld metal, and the usability of the electrode. 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, through Clause 13, Bend Test.

8. Retest

8.1 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 from one or two new test assemblies. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement.

8.2 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.

8.3 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 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 of the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 To perform all required tests as specified in Table 2, a minimum of one weld test assembly is required. Two, or even three, may be necessary (according to the classification, size, and manner in which the testing is conducted, i.e., with respect to alternative options).

The weld test assemblies are identified as follows:

(1) The weld pad in Figure 1 for chemical analysis of the undiluted weld metal

(2) The groove weld in Figure 2 for mechanical properties and soundness

(3) The groove weld in Figure 3 for radiographic soundness

The sample for chemical analysis may be taken from a low dilution area in the groove weld in Figure 2, or from the reduced section of the fractured tension test specimen, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

9.2 Preparation of each weld test assembly shall be as prescribed in 9.3, 9.4.1, and 9.4.2. The base metal for each assembly shall meet the requirements of the appropriate ASTM specification shown in Table 3 or an equivalent specification. Testing of assemblies shall be as prescribed in Clauses 10 through 13.

9.3 Weld Pad. A weld pad shall be prepared as specified in Table 2 and shown in Figure 1, except when one of the alternatives in 9.1 (taking the sample from the weld metal in the groove or from the tension test specimen) is selected. Base metal of any convenient size, of the type specified in Table 3, shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple beads and layers to obtain undiluted weld metal. The type of current and range of amperage used for welding shall be as recommended by the manufacturer. The preheat temperature shall be not less than 60°F [16°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 (temperature above 60°F [16°C]) between passes. The dimensions of the completed pad shall be as shown in Figure 1 for each size of electrode. Testing of this assembly shall be as specified in Clause 10, Chemical Analysis.

Table 2
Required Tests and Positions[a]

	Electrode Diameter		Required Tests				
AWS Classification	in	mm	Chemical Analysis	Tension Test	Bend Test[b]	Radiographic Test[c]	Position Radiographic Test[d]
ENi-1 ENiCr-4[g] ENiCu-7 ENiCrFe-1 ENiCrFe-2 ENiCrFe-3 ENiCrFe-4 ENiCrFe-7 ENiCrFe-9 ENiCrFe-10 *ENiCrFe-13* ENiMo-11 ENiCrMo-3 ENiCrMo-6 ENiCrMo-10 ENiCrMo-12 ENiCrMo-14 ENiCrMo-17 ENiCrCoMo-1	5/64 3/32 — 1/8	2.0 2.4[e] 2.5 3.2	Required	Required	Required	Required	V
	5/32 3/16 — 1/4[f]	4.0 4.8[e] 5.0 6.4[e, f]	Required	Required	Required	Required	F
ENiCrFe-12 ENiCrFeSi-1 ENiMo-1 ENiMo-3 ENiMo-7 ENiMo-8 ENiMo-9 ENiMo-10 ENiCrMo-1 ENiCrMo-2 ENiCrMo-4 ENiCrMo-5 ENiCrMo-7 ENiCrMo-9 ENiCrMo-11 ENiCrMo-13 ENiCrMo-18 ENiCrMo-19 *ENiCrMo-22* ENiCrWMo-1	5/64 3/32 — 1/8 5/32 3/16 —	2.0 2.4[e] 2.5 3.2 4.0 4.8[e] 5.0	Required	Required	Required	Required	F

[a] See Table 3 for base metals to be used in these tests.

[b] Three transverse side-bend test specimens are required except for 5/64 in [2.0 mm] electrodes. For that size, two transverse face-bend specimens are required.

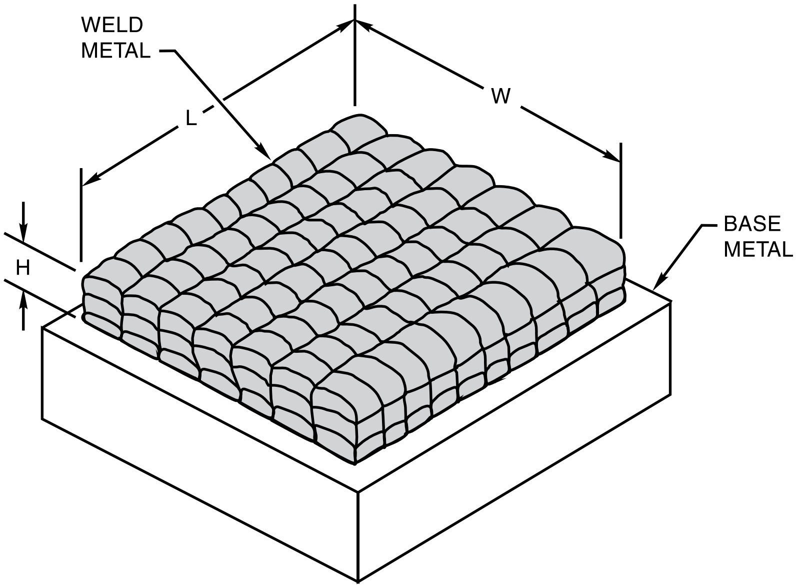
[c] The groove weld for mechanical properties (Figure 2) may also be used for the radiographic soundness test conducted in the flat position. In that case, the test assembly is radiographed before the coupons for the tensile and bend test specimens are removed.

[d] The position of welding shown in this column is only for the radiographic soundness test (V = vertical with uphill progression, F = flat). All other test assemblies are welded in the flat position.

[e] Metric sizes not shown in ISO 544.

[f] Applies only to ENiCu-7 classification.

[g] No bend test required for this classification.



Electrode Size		Weld Pad Size		
in	mm		in, min.	mm, min.
5/64 3/32 — 1/8	2.0 2.4[a] 2.5 3.2	L = W = H =	1-1/2 1-1/2 1/2	38 38 13
5/32 3/16 — 1/4	4.0 4.8[a] 5.0 6.4[a]	L = W = H =	2 2 7/8	50 50 22

[a] Metric sizes not shown in ISO 544.

Notes:

1. 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.
2. If carbon steel base metal is used for the chemical analysis pad, the height of the pad (dimension H) shall be increased as required in note "a" of Table 3.

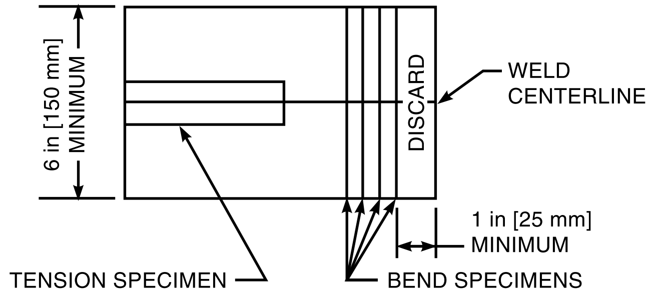
Source: Figure 1 of AWS A5.11/A5.11M:2005.

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal

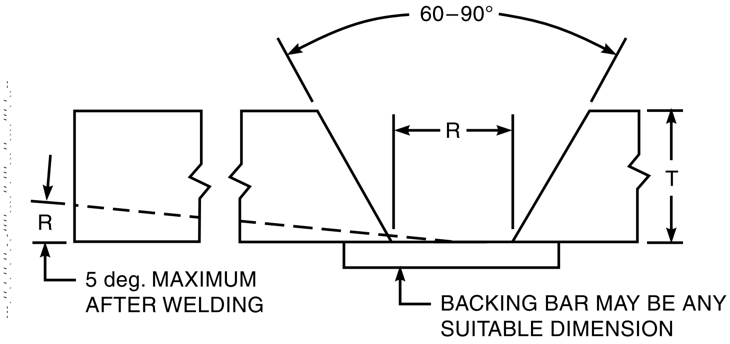
9.4 Groove Weld

9.4.1 Mechanical Properties and Soundness. A test assembly shall be prepared and welded as specified in Figure 2 and Table 2 using base metal of an appropriate type in Table 3. Testing of this assembly shall be as specified in Clause 12, Tension Test, and Clause 13, Bend Test. Additionally, this assembly may be used to satisfy the requirements of the flat position radiographic test (note c to Table 2). In that case, the assembly shall be radiographed as required in Clause 11, Radiographic Test. The assembly shall be tested in the as-welded condition.

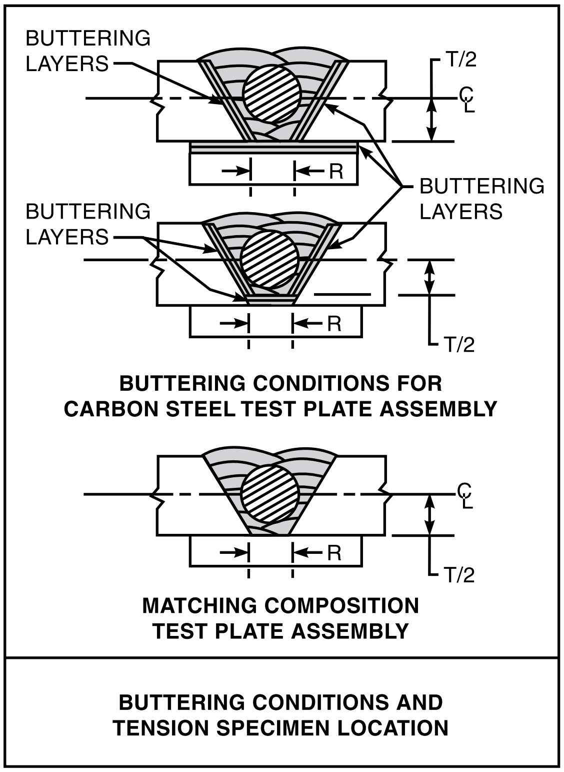
9.4.2 Radiographic Soundness. A test assembly shall be prepared for electrodes of all classifications and welded as shown in Figure 3, using base metal of the appropriate type specified in Table 3. The welding position shall be as specified in Table 2 for the different electrode sizes and classifications. Testing of the assembly shall be as specified in Clause 11, Radiographic Test. The groove weld in Figure 2 may be radiographed (for those classifications for which the radiographic test is welded in the flat position), thus eliminating the need to make the groove weld in Figure 3, in those cases.



LAYOUT OF TEST ASSEMBLY



GROOVE PREPARATION



BUTTERING CONDITIONS FOR CARBON STEEL TEST PLATE ASSEMBLY

MATCHING COMPOSITION TEST PLATE ASSEMBLY

BUTTERING CONDITIONS AND TENSION SPECIMEN LOCATION

Electrode Size		T (Thickness), min.		R (Root Opening)[a]		Number of Layers
in	mm	in	mm	in	mm	min.
5/64	2.0	3/8	10	3/16	5	(b)
3/32	2.4[c]	1/2	13	1/4	7	(b)
—	2.5	1/2	13	1/4	7	(b)
1/8	3.2	1/2	13	1/4	7	(b)
5/32	4.0	3/4	19	1/2	13	6
3/16	4.8[c]	3/4	19	1/2	13	6
—	5.0	3/4	19	1/2	13	6
1/4	6.4[c]	3/4	19	1/2	13	6

[a] Tolerance: ±1/16 in [2 mm].

[b] Number of layers not specified, but pass and layer sequence shall be recorded and reported.

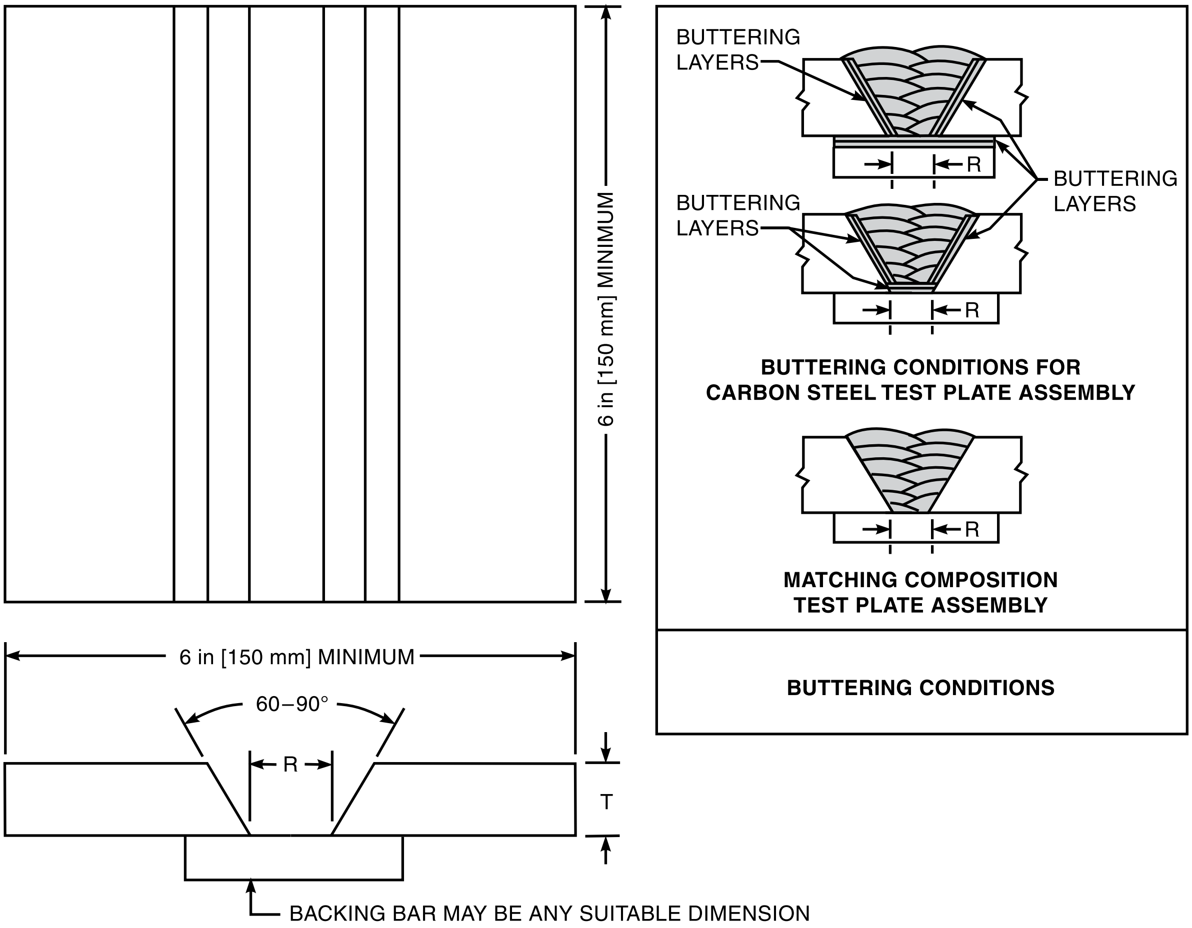
[c] Metric sizes not shown in ISO 544.

Notes:

1. Base metal shall be as specified in Table 3.
2. The surfaces to be welded shall be clean.
3. The minimum length of the test assembly is 6 in [150 mm] but the assembly shall be as long as necessary to provide the specimens for the number and type of tests required. Minimum width is 6 in [150 mm].
4. Prior to welding, the assembly may be preset so that the welded joint will be within 5 degrees of plane after welding. As an alternate, restraint or a combination of restraint and presetting may be used. A 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 performed in the flat position, using the type and range of current and welding technique recommended by the electrode manufacturer.
6. The preheat temperature shall be 60°F [16°C]. The interpass temperature shall not exceed 300°F [150°C].
7. The welds shall be made with stringer beads or weave beads no wider than four times the diameter of the core wire. The completed weld shall be at least flush with the surface of the test plate. For electrodes larger than 1/8 in [3.2 mm], the root beads may be deposited with 3/32 or 1/8 in [2.4, 2.5, or 3.2 mm] electrodes.
8. The tests shall be conducted without a postweld heat treatment.

Source: Figure 2 of AWS A5.11/A5.11M:2005.

Figure 2—Groove Weld Test Assembly for Mechanical Properties and Soundness



Electrode Size		T (Thickness), min.		R (Root opening)[a]	
in	mm	in	mm	in	mm
5/64	2.0	1/8	3	1/8	3
3/32	2.4[b]	1/4	7	1/4	7
—	2.5	1/4	7	1/4	7
1/8	3.2	3/8	10	5/16	8
5/32	4.0	3/8	10	3/8	10
3/16	4.8[b]	1/2	13	1/2	13
—	5.0	1/2	13	1/2	13
1/4	6.4[b]	1/2	13	1/2	13

[a] Tolerance: ±1/16 in [2 mm].

[b] Metric sizes not shown in ISO 544.

Notes:
1. Base metal shall be as specified in Table 3.
2. The surfaces to be welded shall be clean.
3. Welding shall be conducted in the vertical-up or flat position, as required in Table 2 (also see note c in Table 2) using the type and range of current, and technique recommended by the electrode manufacturer.
4. The preheat temperature shall be 60°F [16°C]. The interpass temperature shall not exceed 300°F [150°C].
5. The welds shall be made with a stringer bead technique or a weave to produce a bead no wider than four times the diameter of the core wire. The root layer in tests of electrodes larger than 1/8 in [3.2 mm] diameter may be deposited with 3/32 or 1/8 in [2.4, 2.5, or 3.2 mm] electrodes of that same classification. In addition to the start and stop at the ends of the weld, each bead shall also contain a start and a stop somewhere in between.
6. A small amount of grinding between beads is permissible for welds in the vertical position, but an inordinate amount should not be required to produce a satisfactory weld.
7. The completed weld shall be at least flush with the surface of the test plate.
8. The backing strip shall be removed, and the weld on both sides of the assembly shall be machined or ground smooth and flush with the original surfaces of the base plate (see 11.1).
9. The assembly shall be radiographed as specified in Clause 11, Radiographic Test.

Source: Figure 3 of AWS A5.11/A5.11M:2005.

Figure 3—Groove Weld Test Assembly for Radiographic Soundness Test

Table 3
Base Metals for Test Assemblies

AWS Classification	Materials[a,b]	ASTM Specifications[c]	UNS Number
ENi-1	Nickel	B 160, B 162	N02200, N02201
ENiCr-4	Nickel-Chromium	A 560	R20500
ENiCu-7	Nickel-Copper Alloy	B 127, B 164	N04400
ENiCrFe-1, 2, 3, 4, 9, 10	Nickel-Chromium-Iron Alloy	B 166, B 168	N06600
ENiCrFe-7, *13*	Nickel-Chromium-Iron Alloy	B 166, B 167, B 168	N06690
ENiCrFe-12	Nickel-Chromium-Iron Alloy	B 168	N06025
ENiCrFeSi-1	Nickel-Chromium-Iron-Silicon Alloy	B 168	N06045
ENiMo-1, 3, 7, 8, 9, 10	Nickel-Molybdenum Alloy	B 333	N10001, N10665, N10675
ENiMo-11	Nickel-Molybdenum Alloy	B 333	N10629
ENiCrMo-1, 9, 11	Nickel-Chromium-Molybdenum Alloy	B 582	N06007, N06985, N06030
ENiCrMo-2	Nickel-Chromium-Molybdenum Alloy	B 435	N06002
ENiCrMo-3	Nickel-Chromium-Molybdenum Alloy	B 443, B 446	N06625
ENiCrMo-4, 5, 7, 10, 13, 14, 19, *22*	Low Carbon Nickel-Chromium-Molybdenum Alloy	B 575	N10276, N06455, N06022, N06059, N06686, N06058, *N06035*
ENiCrMo-6	Nickel-Chromium-Molybdenum Alloy	B 166, B 168	N06600
ENiCrMo-12	Chromium-Nickel-Molybdenum Alloy (Austenitic Stainless Steel)	A 240	S31254
ENiCrMo-17	Low Carbon Nickel-Chromium-Molybdenum Alloy	B 575	N06200
ENiCrMo-18	Nickel-Chromium-Iron-Molybdenum-Tungsten Alloy	B 446	N06650
ENiCrCoMo-1	Nickel-Chromium-Cobalt-Molybdenum Alloy	B 166, B 168	N06617
ENiCrWMo-1	Nickel-Chromium-Tungsten-Molybdenum Alloy	B 435	N06230

[a] Either the base metals specified or carbon steel (A 131, A 285, A 515) may be used. If carbon steel is used, two layers of buttering shall be applied to the surface and the backing strip if appropriate. For chemical analysis, base metals other than those specified may be used as the base for the undiluted weld pad provided that, for electrodes of the 1/8 in [3.2 mm] size and smaller, the minimum height shown in Figure 1 is 3/4 in [19 mm] and the sample for analysis is taken at least 5/8 in [16 mm] from the nearest surface of the base metal. For electrode sizes 5/32 in [4 mm] through 1/4 in [6.4 mm], the dimensions are 1 in [25 mm] and 7/8 in [22 mm], respectively.

[b] All specified base metals shall be in the annealed condition prior to welding.

[c] Equivalent material specifications may be used.

10. Chemical Analysis

10.1 The sample for analysis shall be taken from weld metal obtained from the weld pad, the reduced section of the fractured tension test specimen, or a low-dilution area of the groove weld in Figure 2. The top surface of the pad described in 9.3 and shown in Figure 1 (when the pad is used), shall be removed and discarded. A sample for analysis shall be obtained from the underlying metal by any appropriate mechanical means. The sample shall be free of slag.

For electrodes smaller than 5/32 in [4.0 mm], the sample shall be taken at least 3/8 in [9.5 mm] from the nearest surface of the base metal. For electrodes 5/32 in [4.0 mm] and larger, the sample shall be taken at least 3/4 in [19 mm] from that surface. If carbon-steel base metal is used in the chemical analysis test pad, see Note "a" in Table 3. The sample from the reduced section of the fractured tension test specimen and the sample from a low-dilution area of the groove weld shall be prepared for analysis by any suitable mechanical means.

10.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 1473, supplemented by ASTM E 1019 and ASTM E 354 for nickel base alloys, and ASTM E 76 for nickel copper alloys, as appropriate.

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

11. Radiographic Test

11.1 The radiographic soundness test weld described in 9.4.2 and shown in Figure 3 (or the groove weld described in 9.4.1 and shown in Figure 2, when that is desired and is permitted by note c of Table 2), shall be radiographed to evaluate the usability of the electrode. 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 metal to a depth of 1/1 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

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

11.3 The electrode meets the requirements of this specification if the radiograph shows the following:

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

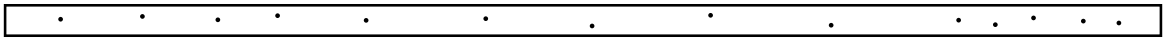
(2) No slag inclusions in excess of those permitted by Note 4 to the radiographic standards in Figures 4 through 8, according to the size of the electrode

(3) No rounded indications in excess of those permitted by the radiographic standards in Figures 4 through 8, according to the thickness of the test assembly, or the alternative method of evaluation in 11.3.1

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

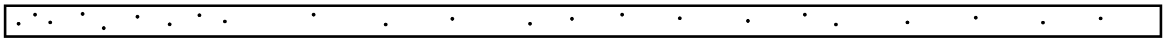
11.3.1 The alternative method of evaluation involves calculation of the total area of the rounded indications as they appear on the radiograph. This total area shall not exceed 1 percent of the thickness of the test assembly multiplied by the length of the weld used in the evaluation (length of the weld in the test assembly minus 1 in [25 mm] on each end). The value given in Note 3 to each of the Figures (4 through 8) has been calculated for 6 in [150 mm] of weld (an 8 in [200 mm] long test assembly). The value for weld lengths other than this will differ on a linearly proportional basis.

11.3.2 A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication including any tail that may be present. The indications may be of porosity or slag. The total area of the rounded indications for the alternative method shall not exceed the values given in Note 3 to the radiographic standards (Figures 4 through 8). Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with rounded indications larger than the largest indications permitted in the radiographic standards do not meet the requirements of this specification.



(A) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.025 in [0.6 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 14.



(B) SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.020 in [0.5 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 23.

Notes:

1. The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications 1/64 in [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.008 in^2 [5.2 mm^2] in any 6 in [150 mm] of weld.
4. The acceptance standard for slag inclusions in this assembly is the following:
   (a) Length of each individual slag indication: 1/16 in [1.6 mm] maximum
   (b) Total length of all slag indications: 1/8 in [3.2 mm] maximum

Source: Figure 4 of AWS A5.11/A5.11M:2005.

Figure 4—Radiographic Standards for 1/8 in [3 mm] Test Assembly

12. Tension Test

12.1 One all-weld-metal tension test specimen, as specified in the Tension Test section of AWS B4.0 or AWS B4.0M shall be machined as described and shown in Figure 2. The tensile specimen shall have a nominal diameter of 0.500 in [12.5 mm] for test assemblies 3/4 in [19 mm] thickness, a nominal diameter of 0.250 in [6.4 mm] for test assemblies 1/2 in [13 mm] thickness, and a nominal diameter of 0.160 in [4.0 mm] for test assemblies of 3/8 in [10 mm] thickness.

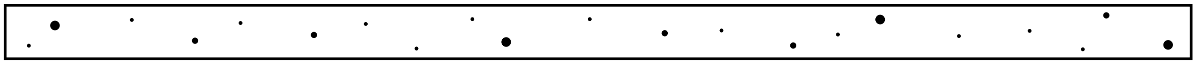
12.2 The specimen shall be tested in the manner described in the tension test section of the latest edition of AWS B4.0 or AWS B4.0M.

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

13. Bend Test

13.1 Three transverse side bend specimens (for electrodes larger than 5/64 in [2.0 mm]) or two transverse face bend specimens (for 5/64 in [2.0 mm] electrodes), as required in Table 2, shall be taken from the assembly described in 9.4.1 and shown in Figure 2. The dimensions of the specimens shall be as shown in Table 5.

13.2 The specimens shall be tested in the manner described in the Bend Test section of AWS B4.0 or B4.0M, by bending them uniformly through 180 degrees over a 3/4 in [19 mm] radius. Any suitable jig, as specified in the Bend Test section of AWS B4.0 or B4.0M may be used. Positioning of the side bend specimens shall be such that the side of the specimen with the greater discontinuities, if any, is in tension. Positioning of the face bend specimens shall be such that face of the weld is in tension. For both types of transverse bend specimen, the weld shall be at the center of the bend.



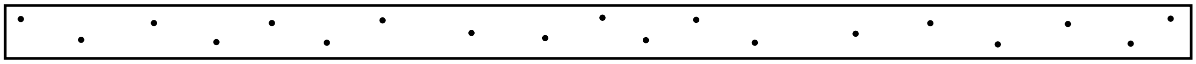
(A) ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.050 in [1.3 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 21, WITH THE FOLLOWING RESTRICTIONS:

LARGE: UP TO 0.050 in [1.3 mm] – 4 PERMITTED
MEDIUM: UP TO 0.031 in [0.8 mm] – 5 PERMITTED
SMALL: UP TO 0.020 in [0.5 mm] – 12 PERMITTED

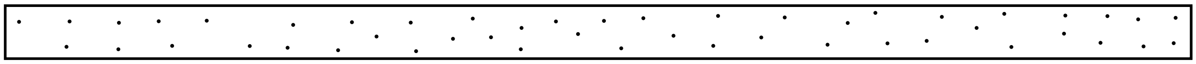
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 0.050 in [1.3 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.031 in [0.8 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 19.



(D) SMALL ROUNDED INDICATIONS

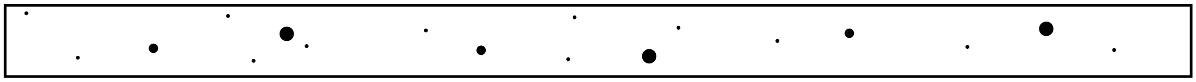
SIZE PERMITTED IS 0.020 in [0.5 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 48.

Notes:

1. The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications 1/64 in [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.015 in^2 [9.7 mm^2] in any 6 in [150 mm] of weld.
4. The acceptance standard for slag inclusions in this assembly is the following:
   (a) Length of each individual slag indication: 5/32 in [4.0 mm] maximum
   (b) Total length of all slag indications: 1/4 in [6.4 mm] maximum

Source: Figure 5 of AWS A5.11/A5.11M:2005.

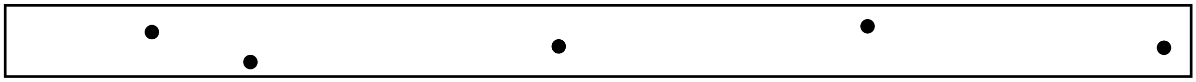
Figure 5—Radiographic Standards for 1/4 in [7 mm] Test Assembly



(A) ASSORTED ROUNDED INDICATIONS

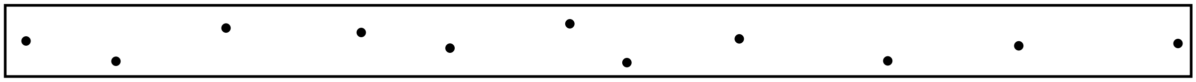
SIZE PERMITTED IS 0.075 in [1.9 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 17, WITH THE FOLLOWING RESTRICTIONS:

- LARGE: UP TO 0.075 in [1.9 mm] – 3 PERMITTED
- MEDIUM: UP TO 0.049 in [1.3 mm] – 3 PERMITTED
- SMALL: UP TO 0.020 in [0.5 mm] – 11 PERMITTED



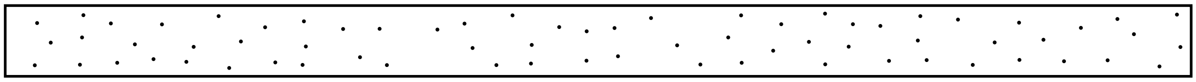
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 0.075 in [1.9 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 5.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.049 in [1.3 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 11.



(D) SMALL ROUNDED INDICATIONS

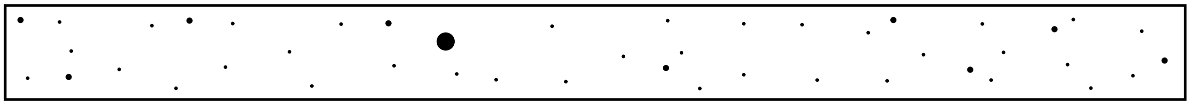
SIZE PERMITTED IS 0.020 in [0.5 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 72.

Notes:

1. The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications 1/64 in [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.023 in^2 [14.8 mm^2] in any 6 in [150 mm] of weld.
4. The acceptance standard for slag inclusions in this assembly is the following:
   (a) Length of each individual slag indication: 7/32 in [5.6 mm] maximum
   (b) Total length of all slag indications: 3/8 in [9.5 mm] maximum

Source: Figure 6 of AWS A5.11/A5.11M:2005.

Figure 6—Radiographic Standards for 3/8 in [10 mm] Test Assembly

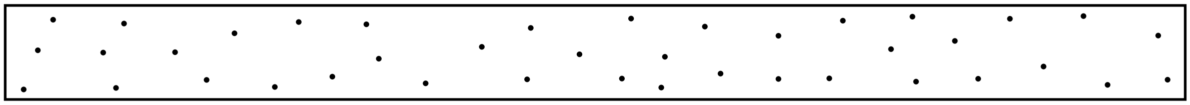


(A) ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.10 in [2.5 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 45, WITH THE FOLLOWING RESTRICTIONS:
  LARGE: UP TO 0.10 in [2.5 mm] – 1 PERMITTED
  MEDIUM: UP TO 0.031 in [0.8 mm] – 9 PERMITTED
  SMALL: UP TO 0.019 in [0.5 mm] – 35 PERMITTED

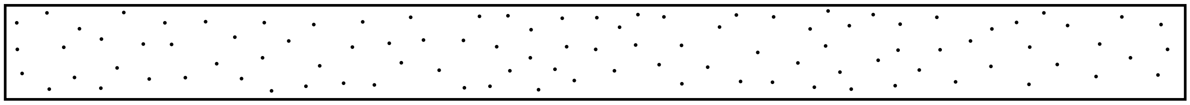
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 0.10 in [2.5 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 4.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.031 in [0.8 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 40.



(D) SMALL ROUNDED INDICATIONS

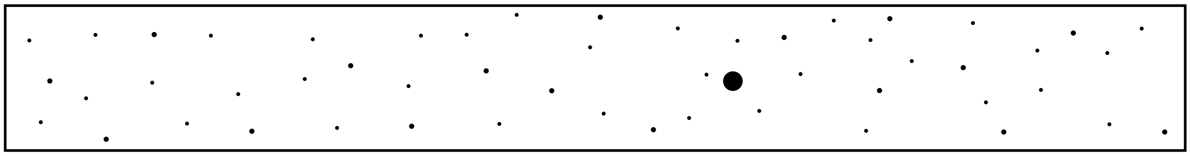
SIZE PERMITTED IS 0.019 in [0.5 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 101.

Notes:

1. The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications 1/64 in [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.030 in^2 [19.4 mm^2] in any 6 in [150 mm] of weld.
4. The acceptance standard for slag inclusions in this assembly is the following:
   (a) Length of each individual slag indication: 7/32 in [5.6 mm] maximum
   (b) Total length of all slag indications: 7/16 in [11 mm] maximum

Source: Figure 7 of AWS A5.11/A5.11M:2005.

Figure 7—Radiographic Standards for 1/2 in [13 mm] Test Assembly



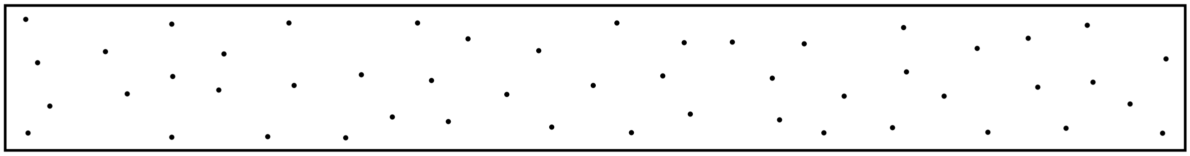
(A) ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.125 in [3.2 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 53, WITH THE FOLLOWING RESTRICTIONS:

LARGE: UP TO 0.125 in [3.2 mm] – 1 PERMITTED
MEDIUM: UP TO 0.034 in [0.9 mm] – 17 PERMITTED
SMALL: UP TO 0.024 in [0.6 mm] – 35 PERMITTED

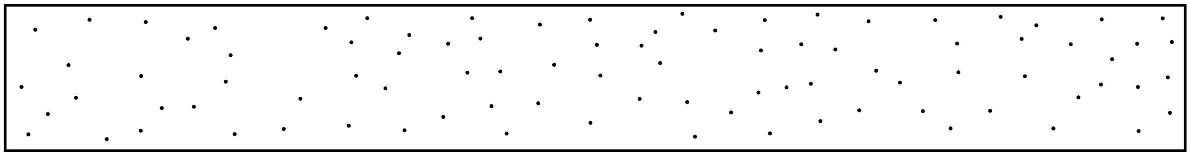
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 0.125 in [3.2 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 4.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.034 in [0.9 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 50.



(D) SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.024 in [0.6 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 90.

Notes:

1. The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications 1/64 in [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.045 in^2 [29.0 mm^2] in any 6 in [150 mm] of weld.
4. The acceptance standard for slag inclusions in this assembly is the following:
   (a) Length of each individual slag indication: 5/16 in [7.9 mm] maximum
   (b) Total length of all slag indications: 15/32 in [11.9 mm] maximum

Source: Figure 8 of AWS A5.11/A5.11M:2005.

Figure 8—Radiographic Standards for 3/4 in [19 mm] Test Assembly

Table 4
All-Weld-Metal Tension Test Requirements

	Tensile Strength, min.		
AWS Classification	ksi	MPa	Elongation[a] Percent, min.
Ni			
ENi-1	60	410	20
NiCr			
ENiCr-4	110	760	—
NiCu			
ENiCu-7	70	480	30
NiCrFe			
ENiCrFe-1 ENiCrFe-2 ENiCrFe-3 ENiCrFe-7 *ENiCrFe-13*	80	550	30
ENiCrFe-4 ENiCrFe-12	95	650	20
ENiCrFe-9 ENiCrFe-10	95	650	25
NiCrFeSi			
ENiCrFeSi-1	90	620	20
NiMo			
ENiMo-8 ENiMo-9	95	650	25
ENiMo-1 ENiMo-3 ENiMo-7 ENiMo-10 ENiMo-11	100	690	25
NiCrMo			
ENiCrMo-11 *ENiCrMo-22*	*85*	*590*	*25*
ENiCrMo-1	90	620	20
ENiCrMo-9	90	620	25
ENiCrMo-6	90	620	35
ENiCrMo-2	95	650	20
ENiCrMo-18	95	650	30
ENiCrMo-12	95	650	35
ENiCrMo-4 ENiCrMo-5 ENiCrMo-7 ENiCrMo-10 ENiCrMo-13 ENiCrMo-17	100	690	25
ENiCrMo-14	100	690	30
ENiCrMo-3	110	760	30
ENiCrMo-19	120	830	20
NiCrCoMo			
ENiCrCoMo-1	90	620	25
NiCrWMo			
ENiCrWMo-1	90	620	20

[a] The elongation shall be determined from the gage length equal to four times the gage diameter.

Table 5
Dimensions of Bend Test Specimens

	Length, min.		Width, min.		Thickness, min.	
	in	mm	in	mm	in	mm
Side[a]	6	150	(b)	(b)	3/8	9.5
Face[a]	6	150	1-1/2	38	3/8	9.5

[a] The radius of the corners of the specimen shall be 1/8 in [3.2 mm] maximum.

[b] The width of the specimen is the thickness of the test assembly from which the specimen is taken (see Figure 2).

13.3 Each specimen, after bending, shall conform to the 3/4 in [19 mm] radius, with an appropriate allowance for springback, and the weld metal shall not contain fissures in excess of those permitted in Table 6 when examined with the unaided eye.

14. Method of Manufacture

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

15. Standard Sizes and Lengths

15.1 Standard sizes (diameter of the core wire) and lengths of electrodes are as shown in Table 7.

15.2 The diameter of the core wire shall not vary more than ±0.003 in [±0.08 mm] from the diameter specified. The length shall not vary more than ±3/8 in [±10 mm] from that specified.

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 electrode.

16.2 The core wire 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 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 3/4 in [19 mm], nor more than 1-1/4 in [32 mm], to provide for electrical contact with the holder.

Table 6
Bend Test Requirements[a]

AWS Classification	Electrode Size		Fissures Permitted		
				Maximum Length[c]	
	in	mm	Maximum Number[b]	in	mm
ENi-1	5/64	2.0	3	1/8	3
	3/32	2.4[d]			
	—	2.5			
	1/8	3.2			
	5/32	4.0	4	1/8	3
	3/16	4.8[d]			
	—	5.0			
ENiCu-7	5/64	2.0	3	3/32	2.5
	3/32	2.4[d]			
	—	2.5			
	1/8	3.2			
	5/32	4.0	4	3/32	2.5
	3/16	4.8[d]			
	—	5.0			
	1/4	6.4[d]			
ENiCrFe-1 ENiCrFe-2 ENiCrFe-4 ENiCrFe-7 ENiCrFe-9 ENiCrFe-10 ENiCrFe-12 *ENiCrFe-13* ENiCrFeSi-1 ENiMo-1 ENiMo-3 ENiMo-7 ENiMo-8 ENiMo-9 ENiMo-10 ENiMo-11 ENiCrMo-1 ENiCrMo-2 ENiCrMo-3 ENiCrMo-4 ENiCrMo-5 ENiCrMo-6 ENiCrMo-7 ENiCrMo-9 ENiCrMo-10 ENiCrMo-11 ENiCrMo-12 ENiCrMo-13 ENiCrMo-14 ENiCrMo-17 ENiCrMo-18 ENiCrMo-19 *ENiCrMo-22* ENiCrCoMo-1 ENiCrWMo-1	5/64	2.0	3	3/32	2.5
	3/32	2.4[d]			
	—	2.5			
	1/8	3.2			
	5/32	4.0			
	3/16	4.8[d]			
	—	5.0			
ENiCrFe-3	5/64	2.0	2	3/32	2.5
	3/32	2.4[d]			
	—	2.5			
	1/8	3.2			
	5/32	4.0			
	3/16	4.8[d]			
	—	5.0			

[a] These requirements apply to both side and face-bend specimens.

[b] The value shown is the maximum number of fissures permitted in the weld metal on the tension side of each bend specimen. The sizes of the fissures are defined in Note c.

[c] The number of fissures referred to in Note b, is for fissures between 1/64 in [0.4 mm] and the length shown in the last column of the table. Those less than 1/64 in [0.4 mm] in length and those on the corners of the specimens shall be disregarded. Bend specimens with fissures longer than the length shown do not meet the requirements of this specification.

[d] Metric sizes not shown in ISO 544.

Table 7
Standard Sizes and Lengths

Electrode Size (Core Wire Diameter)		Standard Lengths[a]									
		ENi-1		ENiCr-4		ENiCu-7		ENiCrFe-1 ENiCrFe-2 ENiCrFe-3 ENiCrFe-4 ENiCrFe-7 ENiCrFe-9 ENiCrFe-10 *ENiCrFe-13* ENiCrMo-3		ENiCrFe-12 ENiMo-1 ENiMo-7 ENiMo-9 ENiMo-11 ENiCrMo-2 ENiCrMo-5 ENiCrMo-7 ENiCrMo-10 ENiCrMo-12[c] ENiCrMo-14 ENiCrMo-18 *ENiCrMo-22* ENiCrWMo-1	ENiCrFeSi-1 ENiMo-3 ENiMo-8 ENiMo-10 ENiCrMo-1 ENiCrMo-4 ENiCrMo-6 ENiCrMo-9 ENiCrMo-11 ENiCrMo-13 ENiCrMo-17 ENiCrMo-19 ENiCrCoMo-1
in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
5/64	2.0	9	230	12	300	9	230	9	230	9	230
3/32	2.4[b]	9 or 12	230 or 300	12	300	9 or 12	230 or 300	9 or 12	230 or 300	9 or 12	230 or 300
—	2.5	—	250	14	350	—	250	—	250	—	250
1/8	3.2	14	350	14	350	14	350	12 or 14	300 or 350	14	350
5/32	4.0	14	350	18	450	14	350	14	350	14	350
3/16[c]	4.8[b,c]	14	350			14	350	14	350	14	350
—	5.0[c]	—	350			—	350	—	—	—	—
1/4	6.4[b]	—	—			14	350	—	—	—	—

[a] Other sizes and lengths shall be as agreed upon by the purchaser and the supplier.
[b] Metric sizes not shown in ISO 544.
[c] The 3/16 in [4.8 or 5.0 mm] diameter is not standard for the ENiCrMo-12 classification.

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 to the point 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 legible imprint of the AWS electrode classification shall be applied to the electrode covering starting within 2-1/2 in [65 mm] of the grip end of the electrode. Additionally, the numerical classification number from ISO 14172 may be applied as a reference designation, provided the requirements of ISO 14172 are satisfied (see A2.4 and Table A.1).

18.2 The numbers and letters of the imprint shall be of bold block type 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.

18.4 The prefix letter “E” in the electrode classification may be omitted from the imprint.

19. Packaging

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

19.2 Package weights shall be as agreed upon by supplier and purchaser.

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) Size and net weight

(4) Lot, control, or heat number

20.2 The appropriate precautionary information[8] given in ANSI Z49.1, latest edition, (as a minimum), shall be prominently displayed in legible print on all packages, including individual unit packages within a larger package.

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[8] Typical examples of “warning labels” 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 Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding

This annex is not part of AWS A5.11/A5.11M:2010, *Specification for Nickel and Nickel-Alloy Welding 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 the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the base metals 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 letter "E," at the beginning of each classification designation stands for electrode.

A2.2 Since the electrodes are classified according to the chemical composition of the weld metal they deposit, the chemical symbol "Ni" appears right after the "E," as a means of identifying the electrodes as nickel-base alloys. The other symbols (Cr, Cu, Fe, Mo, Si, W, and Co) in the designations are intended to group the electrodes according to their principal alloying elements. The individual designations are made up of these symbols and a number at the end of the designation (ENiMo-1 and ENiMo-3, for example). These numbers separate one composition from another, within a group, and are not repeated within that group.

A2.3 From an application point of view, the electrode classifications in this specification have corresponding classifications in AWS A5.14/A5.14M, *Specification for Bare Nickel and Nickel-Alloy Welding Electrodes and Rods*, for those cases in which there is a corresponding application for a bare electrode or rod (ER). Table A.1 correlates the covered electrode classifications in this edition with the corresponding ER classification in AWS A5.14/A5.14M. It also lists the current designation for each classification as it is given in a prominent and pertinent military specification, when such a designation exists.

A2.4 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table A.1 shows those used in ISO 14172 specification for comparison with comparable classifications in this specification. To understand the proposed international designation system, one is referred to Table 10A of the annex of the AWS document IFS:2002, *International Index of Welding Filler Metal Classifications.*

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344). 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/

Table A.1
Comparison of Classifications[a]

Present AWS Classification	UNS Number	Military Designation[b]	Corresponding A5.14/A5.14M[c]	ISO 14172 Designation
ENi-1	W82141	4N11	ERNi-1	ENi 2061
ENiCr-4	W86172	—	ERNiCr-4	—
ENiCu-7	W84190	9N10	ERNiCu-7	ENi 4060
ENiCrFe-1	W86132	3N12	ERNiCrFe-5	ENi 6062
ENiCrFe-2	W86133	4N1A	ERNiCrFe-6	ENi 6133
ENiCrFe-3	W86182	8N12	ERNiCr-3	ENi 6182
ENiCrFe-4	W86134	—	—	ENi 6093
ENiCrFe-7	W86152	—	ERNiCrFe-7	ENi 6152
ENiCrFe-9	W86094	—	—	ENi 6094
ENiCrFe-10	W86095	—	—	ENi 6095
ENiCrFe-12	W86025	—	ERNiCrFe-12	ENi 6025
ENiCrFe-13	*W86155*	—	*ERNiCrFe-13*	—
ENiCrFeSi-1	W86045	—	ERNiCrFeSi-1	—
ENiMo-1	W80001	3N1B	ERNiMo-1	ENi 1001
ENiMo-3	W80004	4N1W	ERNiMo-3	ENi 1004
ENiMo-7	W80665	—	ERNiMo-7	ENi 1066
ENiMo-8	W80008	—	ERNiMo-8	ENi 1008
ENiMo-9	W80009	—	ERNiMo-9	ENi 1009
ENiMo-10	W80675	—	ERNiMo-10	ENi 1067
ENiMo-11	W80629	—	ERNiMo-11	ENi 1069
ENiCrMo-1	W86007	—	ERNiCrMo-1	—
ENiCrMo-2	W86002	—	ERNiCrMo-2	ENi 6002
ENiCrMo-3	W86112	1N12	ERNiCrMo-3	ENi 6625
ENiCrMo-4	W80276	—	ERNiCrMo-4	ENi 6276
ENiCrMo-5	W80002	3N1C	—	ENi 6275
ENiCrMo-6	W86620	—	—	ENi 6620
ENiCrMo-7	W86455	—	ERNiCrMo-7	ENi 6455
ENiCrMo-9	W86985	—	ERNiCrMo-9	ENi 6985
ENiCrMo-10	W86022	—	ERNiCrMo-10	ENi 6022
ENiCrMo-11	W86030	—	ERNiCrMo-11	ENi 6030
ENiCrMo-12	W86032	—	—	ENi 6627
ENiCrMo-13	W86059	—	ERNiCrMo-13	ENi 6059
ENiCrMo-14	W86026	—	ERNiCrMo-14	ENi 6686
ENiCrMo-17	W86200	—	ERNiCrMo-17	ENi 6200
ENiCrMo-18	W86650	—	ERNiCrMo-18	ENi 6650
ENiCrMo-19	W86058	—	ERNiCrMo-19	—
ENiCrMo-22	*W86035*	—	*ERNiCrMo-22*	—
ENiCrCoMo-1	W86117	—	ERNiCrCoMo-1	ENi 6117
ENiCrWMo-1	W86231	—	ERNiCrWMo-1	ENi 6231

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

[b] Designations are from MIL-E-22200/3, *Nickel Base Alloy and Cobalt Base Alloy Covered Welding Electrodes*.

[c] AWS A5.14/A5.14M:2005, *Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*.

A5.01 (ISO 14344). 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). Testing in accordance with any other Schedule in that Table must be specifically required in the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) *certification* that the product meets all of the requirements of the specification. The only testing requirement implicit in this *certification* is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. *Certification* is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01M/A5.01 (ISO 14344).

A5. Ventilation During Welding

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

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

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

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

(4) The proximity of the welders or welding operators to the fumes as they issue from the welding zone, and to the gases and 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 section of that document dealing with ventilation.

A6. Welding Considerations

A6.1 Before welding or heating any nickel-base alloy, the material must be clean. Oil, grease, paint, lubricants, marking pencils, temperature-indicating materials, threading compounds, and other such materials frequently contain sulfur, lead, or silver, which may cause cracking (embrittlement) of the base metal or the weld metal if present during welding or heating.

A6.2 Electrodes of some of the classifications are used for dissimilar metal welds. When making such welds, it is important to obtain as little dilution as possible from the dissimilar metal member (steel, for example). This can be done by traveling slowly to deposit a thicker bead and to dissipate the energy of the arc against the molten weld metal or the nickel base metal, rather than the dissimilar metal member.

A6.3 Most of the electrodes in this specification are intended to be used with DCEP (Direct Current, Electrode Positive) polarity. Some electrodes may be designed to also operate on alternating current which makes them desirable for minimizing arc blow. The electrode manufacturer should be consulted to determine if a particular product is designed to be used with alternating current.

A7. Description and Intended Use of Electrodes

A7.1 ENi-1 Classification. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 95 Ni, and 2.5 Ti. Electrodes of this classification are used for welding wrought and cast forms of commercially pure nickel to themselves and to steel (i.e., joining nickel to steel and surfacing steel with nickel). Typical specifications for this nickel base metal are ASTM B 160, B 161, B 162, and B 163, all of which have UNS Number N02200 or N02201. Electrodes through the 1/8 in [3.2 mm] size can be used in all positions. Electrodes larger than that are used only in the horizontal and flat positions.

A7.2 ENiCr-4 Classification. Electrodes of this classification are primarily used to weld cast grade ASTM A 560. ENiCr-4 is resistant to carburizing furnace atmospheres and fuel ash corrosion which occurs when burning low grade heavy fuels. ENiCr-4 is scale resistant up to 2100°F [1150°C].

A7.3 ENiCu-7 Classification. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 66 Ni, 30 Cu, 3 Mn, and 1 Fe. Electrodes of this classification are used for welding nickel-copper alloys to themselves and to steel, for welding the clad side of joints in steel clad with a nickel-copper alloy, and for surfacing steel with nickel-copper alloy weld metal. Typical specifications for the nickel-copper base metal are ASTM B 127, B 163, B 164, and B 165, all of which have UNS Number N04400.

Electrodes through the 1/8 in [3.2 mm] size can be used in all positions. Electrodes larger than that are used only in the flat and horizontal positions. The weld metal is suitable for service both in the as-welded condition and after an appropriate postweld heat treatment. Qualification tests should be conducted beforehand to make certain the necessary properties can be obtained after the particular heat treatment is employed.

A7.4 ENiCrFe-X Classifications

A7.4.1 ENiCrFe-1. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 70 Ni, 15 Cr, 8 Fe, 3.5 Mn, and 2.5 Nb (Cb) plus Ta. Electrodes of this classification are used for welding nickel-chromium-iron alloys, for the clad side of joints in steel clad with nickel-chromium-iron alloy, and for surfacing steel with nickel-chromium-iron weld metal. The electrodes may be used for applications at temperatures ranging from cryogenic to around 1800°F [980°C]. However, for temperatures above 1500°F [820°C], weld metal produced by these electrodes does not exhibit optimum oxidation resistance and strength. These electrodes are also suitable for joining steel to nickel-base alloys. Typical specifications for the nickel-chromium-iron base metal are ASTM B 163, B 166, B 167, and B 168, all of which have UNS Number N06600. Electrodes through the 1/8 in [3.2 mm] size can be used in all positions. Electrodes larger than that are used only in the horizontal and flat positions.

A7.4.2 ENiCrFe-2. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 70 Ni, 15 Cr, 8 Fe, 2 Mn, 2 Nb plus Ta, and 1.5 Mo. Electrodes of this classification are used for welding nickel-chromium-iron alloys, 9 percent nickel steel, and a variety of dissimilar metal joints (involving carbon steel, stainless steel, nickel, and nickel-base alloys). The base metals can be wrought or cast (welding grade), or both. The electrodes may be used for applications at temperatures ranging from cryogenic to around 1800°F [980°C]. However, for temperatures above 1500°F [820°C], weld metal produced by ENiCrFe-2 does not exhibit optimum oxidation resistance and strength. Typical specifications for the nickel-chromium-iron base metal are ASTM B 163, B 166, B 167, and B 168, all of which have UNS Number N06600. Electrodes through the 1/8 in [3.2 mm] size can be used in all positions. Electrodes larger than that are used only in the horizontal and flat positions.

A7.4.3 ENiCrFe-3. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 65 Ni, 15 Cr, 8 Fe, 7.5 Mn, and 2 Nb plus Ta. Electrodes of this classification are used for welding nickel-chromium-iron alloys, for welding the clad side of joints on steel clad with nickel-chromium-iron alloy, and for surfacing steel with nickel-chromium-iron weld metal, when comparatively high manganese contents are not detrimental. The electrode may be used for applications at temperatures ranging from cryogenic to about 900°F [480°C]. Typical specifications for the nickel-chromium-iron base metal are ASTM B 163, B 166, B 167, and B 168, all of which have UNS Number N06600.

These electrodes can also be used for welding steel to other nickel-base alloys. Fewer fissures are permitted on the bend test for this weld metal than for weld metal of the ENiCrFe-1 and ENiCrFe-2 classifications. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the horizontal and flat positions.

A7.4.4 ENiCrFe-4. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 70 Ni, 15 Cr, 8 Fe, 2.5 Mn, 2.5 Nb plus Ta, and 2.5 Mo. Electrodes of this classification are used for welding 9 percent nickel steel. Typical specifications for the 9% nickel steel base metal are ASTM A 333, A 334, A 353, A 522, and A 553, all of which have UNS Number K81340. The strength of the weld metal is higher than that of the ENiCrFe-2 classification.

A7.4.5 ENiCrFe-7. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 55 Ni, 29 Cr, 9.5 Fe, 3 Mn, and 1.5 Nb plus Ta. Electrodes of this classification are used for welding the nickel-chromium-iron alloy of the UNS Number N06690. Typical specifications for the nickel-chromium-iron base metal are ASTM B 166, B 167, and B 168. The electrodes may also be used for the welding of nickel-chromium-iron alloys to steels and stainless steels, and for corrosion-resistant overlays on steels. Specification of values for boron and zirconium are helpful in reducing the tendency for ductility dip cracking. Electrodes through the 1/8 in [3.2 mm] size can be used in all positions. Electrodes larger than that are used only in the flat and horizontal positions.

A7.4.6 ENiCrFe-9. The nominal composition (wt.-%) of electrodes of this classification is 70 Ni, 14 Cr, 9 Fe, 1.5 Nb plus Ta, and 4 Mo. Electrodes of this classification are used for welding 9 percent nickel steel. Typical specifications for the 9 percent nickel steel base metal are ASTM A 333, A 334, A 353, A 522, and A 553, all of which have UNS Number K81340. Electrodes through the 5/32 in [4.0 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat and horizontal positions.

A7.4.7 ENiCrFe-10. The nominal composition (wt.-%) of electrodes of this classification is 65 Ni, 15 Cr, 10 Fe, 1.5 Nb plus Ta, 3 Mo, and 2 W. Electrodes of this classification are used for welding 9 percent nickel steel. Typical specifications for the 9 percent nickel steel base metal are ASTM A 333, A 334, A 353, A 522, and A 553, all of which have UNS Number K81340. Electrodes through the 5/32 in [4.0 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat and horizontal positions.

A7.4.8 ENiCrFe-12. The nominal chemical composition (wt.-%) of weld metal produced by electrodes of this classification is 63 Ni, 25 Cr, 9.5 Fe, and 2.1 Al. Electrodes of this classification are used for welding UNS Number N06025, welding nickel-chromium-iron to steel and to other nickel base alloys. Typical specifications for the base metal are ASTM B 163, B 166, B 167, B 168, B 366, B 516, B 517, B 546, and B 564, all of which have UNS Number N06025.

A7.4.9 ENiCrFe-13. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 55.5 Ni, 29 Cr, 8.5 Fe, 3.5 Mo, 2.5 Nb. Electrodes of this composition are used for welding nickel-chromium-iron alloy themselves to steels, and to weld clad steels with the nickel-chromium-iron alloy using the SMAW process. This classification provides improved resistance to ductility dip cracking under conditions of high restraint when compared to products offered under ENiCrFe-7. Electrodes through the 1/8 in [3.2 mm] size can be used in all positions. Electrodes larger than that are used only in the flat and horizontal positions. Typical specifications for nickel-chromium-iron base metals are ASTM B 163, B 166, B 167, and B 168, all of which have UNS Number N06690.

A7.5 ENiCrFeSi-1 Classification. The nominal chemical composition (wt-%) of weld metal produced by electrodes of this classification is 46 Ni, 28 Cr, 23 Fe, and 2.75 Si. Electrodes of this classification are used for welding UNS Number N06045, welding nickel-chromium-iron to steel and to other nickel base alloys. Typical specifications for the base metal are ASTM B 163, B 166, B 167, B 168, B 366, B 516, B 517, B 546, and B 564, all of which have UNS Number N06045.

A7.6 ENiMo-X Classifications

A7.6.1 ENiMo-1. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 67 Ni, 28 Mo, and 5 Fe. Electrodes of the ENiMo-1 classification are used for welding nickel-molybdenum alloys as well as the clad side of joints in steel clad with a nickel-molybdenum alloy and for welding nickel-molybdenum alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-molybdenum base metal are ASTM B 333, B 335, B 619, B 622, and B 626, all of which have UNS Number N10001. ENiMo-1 electrodes normally are used only in the flat position.

A7.6.2 ENiMo-3. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 63 Ni, 25 Mo, 5.5 Fe, and 4 Cr. Electrodes of the ENiMo-3 classification are used for welding dissimilar metal combinations of nickel-, cobalt-, and iron-base alloys. These electrodes normally are used only in the flat position.

A7.6.3 ENiMo-7. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 69 Ni, 28 Mo, 1.5 Fe, and 1.5 Mn. Electrodes of the ENiMo-7 classification have controlled low levels of carbon, iron, and cobalt and are used for welding nickel-molybdenum alloys, for welding the clad side of joints in steel clad with a nickel-molybdenum alloy, and for welding nickel-molybdenum alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-molybdenum base metals are ASTM B 333, B 335, B 619, B 622, and B 626, all of which have UNS Number N10665. These electrodes normally are used only in the flat position.

A7.6.4 ENiMo-8. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 70 Ni, 18 Mo, 7 Fe, 3 W, and 2 Cr. Electrodes of this classification are used for welding 9 percent nickel steel, but they can be used in other applications as well. Typical specifications for the 9 percent nickel steel base metal are ASTM A 333, A 334, A 353, A 522, and A 553, all of which have UNS Number K81340. Electrodes through the 5/32 in

[4.0 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat and horizontal positions.

A7.6.5 ENiMo-9. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 70 Ni, 19 Mo, 3 Fe, 3 W, and 1 Cu. Electrodes of this classification are used for welding 9 percent nickel steel, but they can be used in other applications as well. Typical specifications for the 9 percent nickel steel base metal are ASTM A 333, A 334, A 353, A 522, and A 553, all of which have UNS Number K81340. Electrodes through the 5/32 in [4.0 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat and horizontal positions.

A7.6.6 ENiMo-10. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 69 Ni, 28 Mo, 1.5 Cr, 1.5 Fe, and low levels of carbon. The filler materials are used for welding nickel-molybdenum alloys (UNS numbers N10665 and N10675), for welding the clad side of joints in steel clad with a nickel-molybdenum alloy, and for welding nickel-molybdenum alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-molybdenum base metals are ASTM B 333, B 335, B 366, B 564, B 619, B 622, and B 626. These coated electrodes are normally used in the flat position.

A7.6.7 ENiMo-11. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 67Ni, 28 Mo, 3 Fe, 1.3 Cr, and low C. The filler materials are used for welding nickel-molybdenum alloys (UNS Numbers N10665 and N10629), for welding clad side of joints in steel clad with Ni-Mo alloy, and for welding Ni-Mo alloys to steel and to other nickel-base alloys. The ASTM specifications for the Ni-Mo alloys (base metal) are B 333, B 335, B 366, B 564, B 619, B 622, and B 629. These coated electrodes are generally used in flat position.

A7.7 ENiCrMo-X Classifications

A7.7.1 ENiCrMo-1. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 43 Ni, 22 Cr, 19.5 Fe, 6.5 Mo, 2 Nb plus Ta, 2 Cu, and 1.5 Mn. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for welding the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, and for welding nickel-chromium-molybdenum alloy to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 581, B 582, B 619, and B 622, all of which have UNS Number N06007. These electrodes normally are used only in the flat position.

A7.7.2 ENiCrMo-2. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 47 Ni, 22 Cr, 18 Fe, 9 Mo, and 1.5 Co. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for welding the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, and for welding nickel-chromium-molybdenum alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 435, B 572, B 619, B 622, and B 626, all of which have UNS Number N06002. These electrodes normally are used only in the flat position.

A7.7.3 ENiCrMo-3. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 60 Ni, 22 Cr, 9 Mo, 5 Fe, 3.5 Nb plus Ta. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys to themselves and to steel, and for surfacing steel with nickel-chromium-molybdenum weld metal. These electrodes also can be used for welding nickel-base alloys to steel. The electrodes are used in applications where the temperature ranges from cryogenic to 1000°F [540°C]. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 443, B 444, and B 446, all of which have UNS Number N06625. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat and horizontal positions.

A7.7.4 ENiCrMo-4. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 57 Ni, 16 Mo, 15.5 Cr, 5.5 Fe, 4 W, and low C. Electrodes of this classification are used for welding low-carbon nickel-chromium-molybdenum alloy, for welding the clad side of joints in steel clad with low-carbon nickel-chromium-molybdenum alloy, and for welding low-carbon nickel-chromium-molybdenum alloy to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 574, B 575, B 619, B 622, and B 626, all of which have UNS Number N10276. These electrodes normally are used only in the flat position.

A7.7.5 ENiCrMo-5. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 53 Ni, 16 Mo, 15.5 Cr, 5.5 Fe, and 4 W. Electrodes of this classification are used for surfacing steel clad with a nickel-chromium-molybdenum alloy. These electrodes normally are used only in the flat position.

A7.7.6 ENiCrMo-6. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 65 Ni, 14.5 Cr, 7 Fe, 7 Mo, 3 Mn, 1.5 W, and 1.5 Nb plus Ta. Electrodes of this classification are used for welding 9 percent nickel steel, but they can be used in other applications as well. Typical specifications for the 9 percent nickel steel base metal are ASTM A 333, A 334, A 353, A 522, and A 553, all of which have UNS Number K81340. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat and horizontal positions.

A7.7.7 ENiCrMo-7. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 65 Ni, 16 Cr, 15.5 Mo, and 1.5 Fe. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloy, for the welding of the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, and for joining nickel-chromium-molybdenum alloys to alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 574, B 575, B 619, B 622, and B 626, all of which have UNS Number N06455. These electrodes normally are used only in the flat position.

A7.7.8 ENiCrMo-9. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 44 Ni, 22 Cr, 19.5 Fe, 7 Mo, 2 Co, and 2 Cu. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for the welding of the clad side of joints in steel clad with nickel-chromium-molybdenum alloys, and for joining nickel-chromium-molybdenum alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metal are ASTM B 581, B 582, B 619, B 622, and B 626, all of which have UNS Number N06985. These electrodes normally are used only in the flat position.

A7.7.9 ENiCrMo-10. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 56 Ni, 22 Cr, 13 Mo, 4 Fe, and 3 W. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for the welding of the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, to steel and to other nickel-base alloys; and for joining nickel-chromium-molybdenum alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 574, B 575, B 619, B 622, and B 626, all of which have UNS Number N06022. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat position.

A7.7.10 ENiCrMo-11. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 43 Ni, 30 Cr, 15 Fe, 5 Mo, 2 Co, 3 W, and 2 Cu. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for the welding of the clad side of joints in steel clad with nickel-chromium-molybdenum alloys, and for joining nickel-chromium-molybdenum alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metal are ASTM B 581, B 582, B 619, B 622, and B 626, all of which have UNS Number N06030. These electrodes normally are used only in the flat position.

A7.7.11 ENiCrMo-12. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 58 Ni, 21.5 Cr, 9.5 Mo, 3 Fe, and 2 Nb plus Ta. Electrodes of this classification are used for welding chromium-nickel-molybdenum austenitic stainless steels to themselves, to duplex ferritic-austenitic stainless steels, to nickel-chromium-molybdenum alloys, and to steel. The ENiCrMo-12 composition is balanced to provide corrosion-resistant welds for use at temperatures below the creep range of highly alloyed austenitic stainless steels. Typical specifications for the chromium-nickel-molybdenum stainless steel base metals are ASTM A 240, A 167, A 182, A 249, A 276, A 312, A 358, A 473, and A 479, most particularly the grade UNS S31254 contained in those specifications. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Electrodes larger than that can be used only for welding in the flat and horizontal positions.

A7.7.12 ENiCrMo-13. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 59 Ni, 23 Cr, 16 Mo, 1 Fe, and low C. Electrodes of this classification are used to weld low-carbon nickel-chromium-molybdenum alloys, for welding the clad side of joints in steel clad with low-carbon nickel-chromium-molybdenum alloys, and for welding low carbon nickel-chromium-molybdenum alloy to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 574, B 575, B 619, B 622, and B 626, all of which have UNS Number N06059.

A7.7.13 ENiCrMo-14. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 57 Ni, 21 Cr, 16 Mo, and 4 W. Electrodes of this classification are used to weld nickel-chromium-molybdenum alloys (UNS Numbers N06686, N06625, N10276, and N06022) that are used in severe corrosion applications where resistance to reducing, oxidizing, crevice and pitting conditions is required. It is recommended for corrosion-resistant overlay cladding of iron-base metals for the same environments.

A7.7.14 ENiCrMo-17. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 59 Ni, 23 Cr, 16 Mo, and 1.6 Cu. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for the welding of the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, to steel and to other nickel base alloys; and for joining nickel-chromium-molybdenum alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 574, B 575, B 619, B 622, and B 626, all of which have UNS Number N06200. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat position.

A7.7.15 ENiCrMo-18. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 50 Ni, 20 Cr, 13.5 Fe, 11.5 Mo, and 1.5 W. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys like UNS Number N06625, for welding of the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, to steel and to other nickel base alloys; and for joining some other nickel-chromium-molybdenum alloys, such as UNS Numbers N06625, N08825, N06985, N08020, N08926 and N08031. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat position.

A7.7.16 ENiCrMo-19. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 58 Ni, 21 Cr, 20 Mo, and 1 Fe. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for welding of the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, to steel and to other nickel base alloys; and for joining nickel-chromium-molybdenum alloys. Typical specifications for the nickel-chromium-molybdenum base metals are B 574, B 575, B 366, B 564, B 619, B 622, and B 626 all of which are UNS Number N06058. Electrodes through the 1/8 in [3.2mm] size can be used for welding in all positions. Electrodes larger than that are used only in the flat position.

A7.7.17 ENiCrMo-22. *The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 58 Ni, 33 Cr, 8 Mo. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for welding the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, and for welding nickel-chromium-molybdenum alloys to steel and other nickel base alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B 574, B 575, B 619, B 622, and B 626, all of which have UNS Number N06035. These electrodes normally are used only in the flat position.*

A7.8 ENiCrCoMo-1 Classification. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 52 Ni, 23 Cr, 12 Co, 9 Mo, 2 Fe, and 1.5 Mn. Electrodes of this classification are used for welding nickel-chromium-cobalt-molybdenum alloys (UNS Number N06617) to themselves and to steel and for surfacing steel with nickel-chromium-cobalt-molybdenum weld metal. The electrodes are also used for applications where optimum strength and oxidation resistance are required above 1500°F [820°C] up to 2100°F [1150°C], especially when welding on base metals of nickel-iron-chromium alloys. Electrodes through the 1/8 in [3.2 mm] size can be used for welding in all positions. Larger electrodes are used for welding in the flat or horizontal positions.

A7.9 ENiCrWMo-1 Classification. The nominal composition (wt.-%) of weld metal produced by electrodes of this classification is 57 Ni, 22 Cr, 14 W, <5 Co, <3 Fe, and 2 Mo. Electrodes of this classification are used for welding nickel-chromium-tungsten-molybdenum-lanthanum alloy ASTM B 366, B 435, B 564, and B 572 having UNS Number N06230. Electrodes of this classification are generally used only in the flat position.

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, scaling resistance or strength at elevated or cryogenic temperatures may be required.

AWS A5.01M/A5.01 (ISO 14344) contains provisions for ordering such tests. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed upon between supplier and purchaser.

A8.1 Corrosion or Scaling Tests

A8.1.1 Although welds with electrodes in this specification are commonly used in corrosion and heat-resisting applications, tests for those properties are not included in the specification. When required for a particular application, tests can be conducted on specimens taken from either a weld pad or a welded joint. Specimens from a joint are suitable for qualifying the welding procedure (for a specific application involving corrosion or oxidation resistance), but not for qualifying the electrode.

Tests on specimens from a joint have the disadvantage of being a combined test of the properties of the weld metal, the heat-affected zone (HAZ), and the unaffected base metal. With them, it is more difficult to obtain reproducible data (when a difference exists in the properties of the metal in the various parts of the specimen). Specimens taken from a joint have the advantage of being able to duplicate the joint design and the welding sequence planned for fabrication.

A8.1.2 Specimens for testing the corrosion or oxidation resistance of the weld metal alone are prepared by following the procedure outlined in 9.3 and Figure 1 of the specification. The pad size should be at least 3/4 in [19 mm] in height, 2-1/2 in [65 mm] in width, and 1 + 5/8 *n* (in) [25 + 16 n{mm}] in length, 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 of the pad in a manner such that the 2 in [50 mm] dimension of the specimen is parallel with the 2-1/2 in [65 mm] dimension of the pad and the 1/2 in [13 mm] dimension is parallel with the length of the pad.

A8.1.3 The heat treatment, 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 procedures should correspond to *Recommended Practice G4 for Conducting Plant Corrosion Tests* (published by ASTM).

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 Safety and Health Fact Sheets listed in A10.2, ANSI Z49.1[9], and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

Table A.2
Discontinued Classifications

Discontinued Classification	Year Last Published
ENiCu-1	1969
ENiCu-2	1969
ENiCu-3	1964
ENiCu-4	1969
ENiCr-1	1969
ENiMo-2[a]	1964
ENiMoCr-1[b]	1969
ENiCuAl-1	1969

[a] Reclassified as ENiMoCr-1 in 1969.
[b] Reclassified as ENiCrMo-5 in 1976.

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

A10.3 AWS Safety and Health Fact Sheets Index (SHF) [10]

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 Welding 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*

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

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SPECIFICATION FOR TUNGSTEN AND OXIDE DISPERSED TUNGSTEN ELECTRODES FOR ARC WELDING AND CUTTING

SFA-5.12/SFA-5.12M

(Identical with AWS Specification A5.12/A5.12M:2009 (ISO 6848:2004 MOD). In case of dispute, the original AWS text applies.)

SPECIFICATION FOR TUNGSTEN AND OXIDE DISPERSED TUNGSTEN ELECTRODES FOR ARC WELDING AND CUTTING

SFA-5.12/SFA-5.12M

[Identical with AWS Specification A5.12/A5.12M:2009 (ISO 6848:2004 MOD). In case of dispute, the original AWS text applies.]

1. Scope

This Standard specifies requirements for classification of nonconsumable tungsten electrodes for inert gas shielded arc welding, and for plasma welding, cutting, and thermal spraying.

This specification makes use of both International System of Units (SI) and the U.S. Customary Units. 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 A5.12 uses SI Units; and the specification designated A5.12 uses U.S. Customary Units. The later units are shown within brackets [ ] or in appropriate colums in tables and figures. Standard dimensions based on either system may be used for sizing of tungsten electrodes or packaging or both under A5.12M or A5.12 specification.

2. Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

2.1 The following AWS standard[1] is referenced in the mandatory sections of this document:

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

2.2 The following ANSI standard[2] is referenced in the mandatory sections of this document:

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

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

(a) ASTM E 29, *Standard Practice for using Significant Digits in Test Data to Determine Conformance with Specifications*

(b) ASTM F 288, *Standard Specification for Tungsten Wire for Electron Devices and Lamps*

2.4 The following ISO standard[4] is referenced in the mandatory sections of this document:

(a) ISO 31-0:1992, *Quantities and units — Part 0: General principles; and Annex B, Rule A*

3. Classification

3.1 Classification of a tungsten electrode is based upon its chemical composition.

3.2 *The tungsten and oxide dispersed tungsten electrodes covered by this specification are classified using a system that is independent of the U.S. Customary Units and the International System of Units (SI). Classification is according to the chemical composition of the electrode as specified in Table 1. See Clause B7 for classification descriptions.*

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

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

[3] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR TUNGSTEN ELECTRODES

Classification Symbol (ISO 6848 Classification)	Chemical Composition Requirements				Color Code, RGB Color Value, and Color Sample[a]
	Oxide Addition		Impurities, Mass Percent	Tungsten, Mass Percent	
	Principal Oxide	Mass Percent			
EWP (WP)	None	N.A.[b]	0.5 max.	99.5 max.	Green #008000
EWCe-2 *(WCe 20)*	CeO_2	1.8 to 2.2	0.5 max.	Balance	Grey (formerly orange) #808080
EWLa-1 *(WLa 10)*	La_2O_3	0.8 to 1.2	0.5 max.	Balance	Black #000000
EWLa-1.5 *(WLa 15)*	La_2O_3	1.3 to 1.7	0.5 max.	Balance	Gold #FFD700
EWLa-2 *(WLa 20)*	La_2O_3	1.8 to 2.2	0.5 max.	Balance	Blue #0000FF
EWTh-1 *(WTh10)*	ThO_2	0.8 to 1.2	0.5 max.	Balance	Yellow #FFFF00
EWTh-2 *(WTh 20)*	ThO_2	1.7 to 2.2	0.5 max.	Balance	Red #FF0000
(WTh 30)	ThO_2	2.8 to 3.2	0.5 max.	Balance	Violet #EE82EE
EWZr-1 *(WZr 3)*	ZrO_2	0.15 to 0.50	0.5 max.	Balance	Brown #A52A2A
EWZr-8 *(WZr 8)*	ZrO_2	0.7 to 0.9	0.5 max.	Balance	White #FFFFFF
EWG	The manufacturer must identify all additions.	The manufacturer must state the nominal quantity of each addition.	0.5 max.	Balance	The manufacturer may select any color not already in use.

GENERAL NOTE: Intentional additions of "doping oxides" other than indicated for a particular electrode classification is prohibited.

NOTES:

a. RGB color values and color samples can be found at the following website: http://msdn2.microsoft.com/en-us/library/ms531197.aspx

b. N.A. = Not applicable.

3.3 *Electrodes classified under one classification shall not be classified under any other classification in this specification.*

3.4 *No electrode meeting the requirements of any other classification, shall be classified under EWG.*

3.5 *The electrodes classified under this specification are intended for gas tungsten arc welding (GTAW), gas tungsten arc cutting (GTAC), plasma arc welding (PAW), or plasma arc cutting (PAC), but that is not to prohibit their use with any other process for which they are found suitable. See Clause B2 for an explanation of the classification system.*

4. Acceptance

Acceptance of the electrodes shall be in accordance with the provisions of AWS A5.01M:A5.01 (ISO 14344 MOD). See Annex Clause B3 for further information concerning acceptance and testing of material shipped.

5. Chemical Analysis

Chemical analysis shall be performed on specimens of the electrode being classified. Any analytical technique may be used but, in cases of dispute, reference shall be made to established published methods. The referee method shall be ASTM F 288. *The results of the analysis shall meet the requirements of Table 1 for the classification of electrode under test.*

6. Retests

If any test fails to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirements. Specimens for retesting may be taken

TABLE 2
STANDARD DIAMETERS AND LENGTHS

Size				Length			
Diameter, mm	Tolerance, ±mm	Diameter, in.	Tolerance, ±in.	Length, mm	Tolerance, mm	Length, in.	Tolerance, ±in.
0.25[b]	0.02	0.010	0.010	50[b]	±1.5	. . .	. . .
0.30[b]	0.02	. . .	. . .	75[b]	-1.0, +2.5	3	1/16
0.50[b]	0.05	0.020	0.002	150[b]	-1.0, +4.0	6	1/16
1.00[b]	0.05	0.040	0.002	175[b]	-1.0, +6.0	7	1/8
1.50[b]	0.05	0.060[a]	0.002	300[b]	-1.0, +8.0	12	1/8
160[b]	0.05	. . .	. . .	450[b]	-1.0, +8.0	18	1/8
2.00[b]	0.05	. . .	. . .	600[b]	-1.0, +13.0	24	1/8
2.40[b]	0.08	0.093 (3/32)	0.003	. . .	. . .	. . .	. . .
250[b]	0.08	. . .	. . .	. . .	. . .	. . .	. . .
3.00[b]	0.10	. . .	. . .	. . .	. . .	. . .	. . .
3.20[b]	0.10	0.125 (1/8)	0.003	. . .	. . .	. . .	. . .
4.00[b]	0.10	0.156 (5/32)	0.003	. . .	. . .	. . .	. . .
4.80[b]	0.10	0.187 (3/16)	0.003	. . .	. . .	. . .	. . .
5.00[b]	0.10	. . .	. . .	. . .	. . .	. . .	. . .
6.30[b]	0.10	. . .	. . .	. . .	. . .	. . .	. . .
6.40[b]	0.10	0.250 (1/4)	0.003	. . .	. . .	. . .	. . .
8.00[b]	0.10	. . .	. . .	. . .	. . .	. . .	. . .
10.00[b]	0.10	. . .	. . .	. . .	. . .	. . .	. . .

NOTES:

a. Although the metric size 1.6 mm [0.063 in.] is closer to 1/16 in. [0.0625 in.], it has been common industry practice to refer to the U.S. Customary size 0.060 in. as 1/16 in.

b. Standard sizes and lengths in ISO 6848, though tolerances may be tighter in some cases.

from the original test sample or from a new test sample. For chemical analysis, retests need only be for those specific elements that failed to meet their 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 test specimen, or in conducting the tests, 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 prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

7. Marking

In accordance with Table 1, tungsten electrodes shall be marked on the basis of their chemical composition, with one color ring near one end of the electrode. The width of the color ring shall be at least 3 mm [1/8 in]. *Such color coding shall have no adverse effect on the operation or use of the electrode.* Alternatively, tungsten electrodes may have their classification symbols marked on the surface of the electrode near at least one end of the electrode.

8. Standard Sizes and Tolerances

8.1 Electrode Diameters, Lengths, and Tolerances. Standard electrode diameters, lengths, and tolerances are given in Table 2. Other diameters, lengths, and tolerances may be as agreed upon between the purchaser and supplier.

8.2 Finish. *Electrodes shall be supplied with a ground finish. The ground finish designates that the electrode has been cleaned of impurities after it has been centerless ground to a uniform size. It shall be supplied with a bright, polished surface. The maximum surface roughness shall be 0.8 μmRa [32 μin. AARH].*

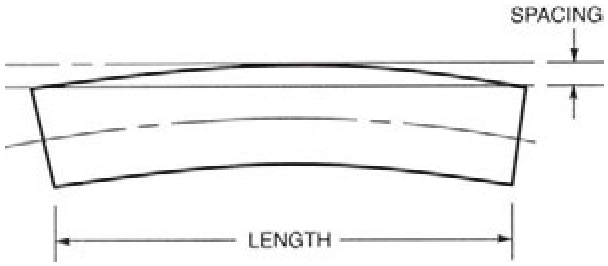
8.3 Electrode Straightness. *The electrodes shall be straight such that any element of its surface, over a specified length, must lie between two parallel lines of a specified spacing where the two lines and the nominal axis of the electrode share a common plane, as shown in Fig. 1. The specified spacing is 0.5 mm [0.020 in.] over a length of 100 mm [4 in.].*

8.4 Electrode Roundness. *Electrodes shall fit through ring gages sized for their maximum allowable diameter according to Table 2.*

9. Rounding-off Procedure

For purposes of determining compliance with the requirements of this Standard, the actual test values

FIG. 1 MEASUREMENT PROCEDURE FOR STRAIGHTNESS



obtained shall be subjected to the rounding-off rules of ISO 31-0:1992, Annex B, Rule A, or ASTM E 29. If the measured values are obtained by equipment calibrated in units other than those of this Standard, the measured values shall be converted to the units of this Standard before rounding off. If an average value is to be compared to the requirements of this Standard, rounding-off shall be done only after calculating the average. In the case where the testing standard cited in the normative references of this Standard contains instructions for rounding off that conflict with the instructions of this Standard, the rounding-off requirements of the testing standard shall apply. The rounded-off results shall fulfill the requirements of the appropriate table for the classification under test.

10. Electrode Quality

The electrode surface shall be free of impurities, undesirable films, foreign inclusions, slivers, cracks, scale and other defects. Electrodes shall be internally free of foreign inclusions or anything else that would adversely affect the operation of the electrode. Oxide additions shall be sufficiently uniformly distributed throughout the electrode so that the operation of the electrode is not adversely affected.

11. Packaging

11.1 Marking of Packages. The following information, as a minimum, shall be legibly marked so as to be visible from the outside of each package:

(a) the number of this Standard, i.e., AWS A5.12M/A5.12:2009 (ISO 6848:2004 MOD)

(b) electrode classification symbol in accordance with Table 1

(c) electrode diameter

(d) electrode length

(e) net quantity of electrodes

(f) supplier's name and trade designation

(g) lot, control, or heat number

11.2 Packing. Tungsten electrodes shall be packed so that their surfaces are protected from all damage or staining when they are properly transported and stored.

11.3 Marking of Overpacking. *Marking of any, or all, overpacking of unit packages with items listed in 11.1 shall be optional with the manufacturer.*

11.4 Warning Label. *The appropriate precautionary information*[5] *as given in ANSI Z49.1, latest edition (as a minimum) or its equivalent, shall be prominently dispayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package.*

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

Annex A
Conditions of Use

(This Annex is not a part of AWS A5.12/A5.12M:2009 [ISO 6848:2004 (MOD)], *Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting,* but is included for informational purposes only.)

A1. Influence of the Type of Current

A1.1 General. The electric arc may be supplied with either direct current or alternating current. Table A1 indicates which type of current is generally more suitable to the type of metal or alloy to be welded.

A1.2 Direct Current Supply. The arc behavior is different depending on whether the electrode is connected to the positive or negative terminal of the power source. With electrode positive (d.c.+) polarity, there is greater output heat at the electrode and less penetration of the work than with electrode negative (d.c.–) polarity. The current-carrying capacity of an electrode of a given size will therefore be lower with positive polarity than with negative polarity.

A1.3 Alternating Current Supply. With alternating current (a.c.) supply, the current changes direction each half-cycle. The arc alternates between electrode positive polarity and electrode negative polarity. The current-carrying capacity of an electrode is then less than when it is used with electrode negative polarity, but greater than when it is used with electrode positive polarity.

A2. Arc Amperage

The electrode size should be selected so that the current value is high enough for the arc to cover the whole area of the electrode tip, which is then heated up to a temperature approaching its melting temperature.

If the current is too low for the electrode size selected, the arc may be erratic.

If, however, the current is too high, it will cause the electrode to overheat and its tip to melt. Drops of molten tungsten may fall into the weld, and the arc will become erratic and unstable. Table A2 provides recommended current ranges depending on the type of power supply and electrode diameter. A high current value provides, in addition to a more stable arc, a higher concentration of heat, but this is limited depending on the conditions of use. An adequate degree of taper of the electrode tip with d.c.– polarity permits improvement of these conditions; e.g., the degree of taper of the electrode tip should be chosen according to the current used. A more obtuse angle is recommended at higher currents for a given electrode diameter.

TABLE A1
SUITABILITY OF CURRENT SUPPLY TYPE

	Direct Current		
Type of Metal or Alloy to Be Welded	Electrode Negative (–)	Electrode Positive (+)	Alternting Current
Aluminum and its alloys, thickness ≤2.5 mm [0.10 in.]	Acceptable	Acceptable	Best
Aluminum and its alloys, thickness >2.5 mm [0.10 in.]	Acceptable	N.R.[a]	Best
Magnesium and its alloys	N.R.	Acceptable	Best
Nonalloy *(carbon)* steels and low alloy steels	Best	N.R.	N.R.
Stainless steels	Best	N.R.	N.R.
Copper	Best	N.R.	N.R.
Bronze	Best	N.R.	Acceptable
Aluminum bronze	Acceptable	N.R.	Best
Silicon bronze	Best	N.R.	N.R.
Nickel and its alloys	Best	N.R.	Acceptable
Titanium and its alloys	Best	N.R.	Acceptable

NOTE:

[a] N.R. = Not recommended.

TABLE A2
APPROXIMATE CURRENT RANGES DEPENDING UPON THE ELECTRODE DIAMETER

Electrode Diameter		Direct Current, A					
		Electrode Negative (−)		Electrode Positive (+)		Alternating Current, A	
		Pure Tungsten	Tungsten With Oxide Additives	Pure Tungsten	Tungsten With Oxide Additives	Pure Tungsten	Tungsten With Oxide Additives
mm	in.						
0.25	0.010	Up to 15	Up to 15	Not applicable	Not applicable	Up to 15	Up to 15
0.30	. . .	Up to 15	Up to 15	Not applicable	Not applicable	Up to 15	Up to 15
0.50	0.020	2 to 20	2 to 20	Not applicable	Not applicable	2 to 15	2 to 15
1.0	0.040	10 to 75	10 to 75	Not applicable	Not applicable	15 to 55	15 to 55
1.5	0.060	60 to 150	60 to 150	10 to 20	10 to 20	45 to 90	60 to 125
1.6	. . .	60 to 150	60 to 150	10 to 20	10 to 20	45 to 90	60 to 125
2.0	. . .	75 to 180	100 to 200	15 to 25	15 to 25	65 to 125	85 to 160
2.4	0.093 (3/32)	120 to 220	150 to 250	15 to 30	15 to 30	80 to 140	120 to 210
2.5	. . .	130 to 230	170 to 250	17 to 30	17 to 30	80 to 140	120 to 210
3.0	. . .	150 to 300	210 to 310	20 to 35	20 to 35	140 to 180	140 to 230
3.2	0.125 (1/8)	160 to 310	225 to 330	20 to 35	20 to 35	150 to 190	150 to 250
4.0	0.156 (5/32)	275 to 450	350 to 480	35 to 50	35 to 50	180 to 260	240 to 350
4.8	0.187 (3/16)	380 to 600	480 to 650	50 to 70	50 to 70	240 to 350	330 to 450
6.33	. . .	550 to 875	650 to 950	65 to 100	65 to 100	300 to 450	430 to 575
6.4	0.250 (1/4)	575 to 900	750 to 1 000	70 to 125	70 to 125	325 to 450	450 to 600
8.0	. . .	. . .	. . .	. . .	. . .	. . .	650 to 830
10.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .

GENERAL NOTES:

(a) The current values are based on the use of argon gas, and these values may vary depending on the type of shielding gas, type of equipment, and application.

(b) If no value is given, no recommendation is available.

Tungsten electrodes when used with alternating current or with direct current positive polarity will form a molten ball on the arcing end of the electrode. A pure tungsten electrode may produce tungsten inclusions in the weld when used on a.c. or d.c.+ without having accurate control of amperage and arc length. The use of zirconiated tungsten will alleviate this problem.

Many modern a.c. welding power supplies allow the balance between the d.c.+ and d.c.– portions of the current cycle to be varied. When the d.c.+ portion of the cycle is increased relative to the d.c.– portion, the recommended average current is decreased somewhat from the ranges given in Table A2. Conversely, when the d.c.– portion is increased relative to the d.c.+ portion, the recommended average a.c. current is increased somewhat from the ranges given in Table A2.

A3. Further Remarks

The choice of an electrode type and size and of the welding current is influenced by the type and thickness of the parent metal to be welded or cut. The capacity of tungsten electrodes to carry current is dependent upon a number of other factors, in particular, the type of equipment used (gas- or water-cooled), the extension of the electrode beyond the nozzle and the welding position used.

An electrode of a given size will have its greatest current-carrying capacity with direct current, electrode negative; less with alternating current, and still less with direct current, electrode positive.

Table A2 lists some typical current values that may be used with argon shielding. However, the other factors mentioned above should be carefully considered before selecting an electrode for a specific application.

Annex B
Analytical Methods

(This Annex is not a part of AWS A5.12/A5.12M:2009 (ISO 6848:2004 MOD), *Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting,* but is included for informational purposes only.)

B1. Introduction

B1.1 The purpose of this guide is to correlate the electrode classifications with their intended applications so the specification can be used effectively.

B1.2 Tungsten electrodes are nonconsumable in that they do not intentionally become part of the weld metal as do electrodes used as filler metals. The function of a tungsten electrode is to serve as one of the terminals of an arc which supplies the heat required for welding or cutting.

B2. Classification

B2.1 The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" at the beginning of the classification designation stands for electrode. The "W" indicates that the electrode is primarily tungsten. The "P" indicates that the electrode is essentially pure tungsten and contains no intentionally added emission enhancing elements. The "Ce," "La," "Th," and "Zr" indicate that the electrode is doped with oxides of cerium, lanthanum, thorium, or zirconium, respectively. The numeral at the end of some of the classifications indicates a different chemical composition level or product within a specific group.

B2.2 "G" Classification

B2.2.1 This specification includes electrodes classified as EWG. 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 other classifications (meaning that the composition of the electrode–in the case of this 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, then, that two electrodes–each bearing the same "G" classification–may be quite different in some certain respect. To prevent the confusion that this situation could create, this specification requires the manufacturer to identify, on the label, the type and nominal content of each doping addition made in the particular product.

B2.2.2 Request for Electrode Classification

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

(2) A request to establish a new electrode classification must be a written request, and it needs to provide sufficient detail to permit the A5 Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

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

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

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

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

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

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

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

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

(d) File the original request.

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

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

B3. Acceptance

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

B4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification identification 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 test required by the specification on material that is representative of that being shipped, and that that material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation.

"Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may, or may not, have been conducted. The basis for the "certification" required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in AWS A5.01M/A5.01 (ISO 14344 MOD).

Electrodes sold as a standard size must also meet the dimensional, surface finish, and identification requirements established in this specification.

B5. Ventilation During Welding

B5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding:

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

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

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

(4) The proximity of the welders or welding operators to the fumes, as the 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

B5.2 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 of that document on Health Protection and Ventilation.

B6. Operation Characteristics

B6.1 The choice of an electrode classification, size, and welding current is influenced by the type and thickness of the base metals being welded. The capacity of tungsten electrodes to carry current is dependent upon numerous factors in addition to the classification and size, including type and polarity of the current, the shielding gas used, the type of equipment (air or water cooled), the extension of the electrode beyond the collet (sleeve or tube that holds the electrode), and the welding position. An electrode of a given size will have its greatest current-carrying capacity with direct current, electrode negative (straight polarity), less with alternating current, and still less with direct current, electrode positive (reverse polarity). Table A2 lists some typical current values that may be used with argon shielding gas. However, the other factors mentioned above should be carefully considered before selecting an electrode for a specific application.

B6.2 Tungsten has an electrical conductivity that is about 30% that of copper and a thermal conductivity that is 40% that of copper. Therefore, there will be more heating as current is passed through the tungsten electrode. When welding with tungsten electrodes, the arc tip should be the only hot part of the electrode; the remainder should be kept as cool as possible.

B6.3 One method of preventing electrode overheating is to keep the extension of the electrode from the collet short. If the extension is too long, even a relatively low current can cause the electrode to overheat and melt above the terminus of the arc. Conversely, if the current density is too low, the arc will be erratic and unstable.

B6.4 Many electrode classifications contain emissive oxide additions. These additions lower the temperature at which the electrode emits electrons, to a temperature below the melting point of tungsten. Such an electrode operates cooler, or it can operate at higher currents, as can be noted from Table A2. Benefits of these additions include easier starting, particularly when using superimposed high frequency, more stable operation, and reduced contamination. These benefits are noted in the description listed for the various classifications containing oxide additives.

B6.5 All tungsten electrodes may be used in a similar manner. However, electrodes of each classification have distinct advantages with respect to other classifications. The following section discusses the specific electrode classifications with regard to their operating characteristics and usability.

B7. Description and Intended Use of Electrodes *(ISO designations are given in parentheses)*

B7.1 EWP *(WP)* Electrode Classification (Green). The EWP electrodes are commercially pure tungsten electrodes (99.5 percent tungsten minimum). Their current-carrying capacity is lower than that of other electrodes. They provide good stability when used with alternating current, either balanced wave or continuously high frequency stabilized. They may be used with direct current and also with either argon or helium, or a combination of both, as a shielding gas. They maintain a clean, balled end, which is preferred for aluminum and magnesium welding. These electrodes have reasonably good resistance to contamination of the weld metal by the electrode, although the oxide containing electrodes are superior in this respect. EWP electrodes are generally used on less critical applications, except for welding aluminum and magnesium. The lower cost EWP electrodes can be used for less critical applications where some tungsten contamination of welds is acceptable.

B7.2 EWCe-2 *(WCe 20)* Electrode Classification (Grey). The EWCe-2 electrodes are tungsten electrodes containing about two percent cerium oxide (CeO_2), referred to as ceria. The EWCe-2 electrodes were first introduced into the United States market in 1987. Several other grades of this type electrode are commercially practical, including electrodes containing one percent CeO_2, but only one grade, EWCe-2, has been incorporated in this specification as having commercial significance.

The advantages of tungsten electrodes containing ceria, compared to pure tungsten, include increased ease of starting, improved arc stability, and reduced rate of vaporization or burn-off. Unlike thoria, ceria is not a radioactive material. These advantages increase with increased ceria content. These electrodes operate successfully with alternating current or direct current, either polarity.

B7.3 EWLa-X Electrode Classifications. The EWLa-X electrodes are tungsten electrodes containing lanthanum oxide, referred to as lanthana. The advantages and operating characteristics of these electrodes are similar to that of the EWCe-2 electrodes. Unlike thoria, lanthana is not a radioactive material.

B7.3.1 EWLa-1 *(WLa 10)* Electrode Classification (Black). The EWLa-1 electrodes are tungsten electrodes which contain nominally 0.8–1.2 weight-percent (wt.-%) lanthanum oxide, referred to as lanthana. The advantages and operating characteristics of this electrode type are very similar to those of EWCe-2 electrodes.

B7.3.2 EWLa-1.5 *(WLa 15)* Electrode Classification (Gold). EWLa-1.5 designates a tungsten electrode containing 1.3–1.7 wt.-% of dispersed lanthanum oxide (La_2O_3) for enhanced arc starting and stability, reduced tip erosion rate, and extended operating current range. These electrodes can be used as nonradioactive substitutes for 2% thoriated tungsten, as the operating characteristics are very similar. Lanthanated tungsten can be used for both DCEN and ac applications.

B7.3.3 EWLa-2 *(WLa 20)* Electrode Classification (Blue). EWLa-2 designates a tungsten electrode containing 1.8–2.2 wt.-% of dispersed lanthanum oxide (La_2O_3). The EWLa-- electrode has the highest volume of oxides of any of the specific single-additive AWS-specified electrodes types, which serves to enhance arc starting and stability, reduce tip erosion rate, and extend operating current range.

Lanthanated tungsten electrodes can be used for both dcen and ac applications.

B7.4 EWTh-X Electrode Classifications. The EWTh-X electrodes are tungsten electrodes containing thorium oxide, referred to as thoria. The thoria in all classes is responsible for increasing the usable life of these electrodes over the EWP electrodes because of their higher electron emission, better arc starting and arc stability. They generally have longer life and provide greater resistance to tungsten contamination of the weld.

SAFETY NOTE

Thoria is a low-level radioactive material. However, if welding is to be performed in confined spaces for prolonged periods of time, or if electrode grinding dust might be ingested, special precautions relative to ventilation should be considered. The user should consult appropriate safety personnel.

The following statement was developed by the International Institute of Welding (IIW) Commission VIII on Health and Safety:

STATEMENT OF COMMISSION VIII ON HEALTH ASPECTS IN THE USE OF THORIATED TUNGSTEN ELECTRODES

"Thorium oxides are found in Thoriated Tungsten Electrodes {up to 4.2% (ISO 6848-WT 40 Electrode)}[6]. Thorium is radioactive and may present hazards by external and internal exposure. If alternatives are technically feasible, they should be used.

"Several studies carried out on Thoriated Electrodes have shown that due to the type of radiation generated, external radiation risks–during storage, welding, or disposal of residues–are negligible under normal conditions of use.

"On the contrary, during the grinding of electrode tips there is generation of radioactive dust, with the risk of internal exposure. Consequently, it is necessary to use local exhaust ventilation to control the dust at the source, complemented if necessary by respiratory protective equipment. The risk of internal exposure during welding is considered negligible since the electrode is consumed at a very slow rate.

"Precautions must be taken in order to control any risks of exposure during the disposal of dust from grinding devices.

"The above statement is based on a considered view of the available reports. Commission VIII will continue to keep these aspects under review."

B7.4.1 EWTh-1 *(WTh 10)* Electrode Classification (Yellow). These electrodes were designed for direct current applications. They have 0.8–1.2 percent of thoria content dispersed throughout their entire length. They maintain a sharpened point well, which is desirable for welding steel. They can be used on alternating current work, but a satisfactory balled end, which is desirable for the welding of nonferrous materials, is difficult to maintain.

B7.4.2 EWTh-2 *(WTh 20)* Electrode Classification (Red). The higher thoria content (1.7–2.2 percent) in the EWTh-2 electrode causes the operating characteristic improvements to be more pronounced than in the lower thoria content EWTh-1.

Should it be desired to use these electrodes for alternating current welding, then balling can be accomplished by briefly, and carefully, welding with direct current electrode positive prior to welding with alternating current. During alternating current welding, the balled end does not melt and so emission is not as good as from a liquid ball on an EWP electrode.

B7.4.3 *(WTh 30)* Electrode Classification (Violet). This 3% thoriated electrode has no commercial significance in the United States.

B7.4 EWZr-X Electrode Classifications

B7.5.1 EWZr-1 *(WZr 3)* Electrode Classification (Brown). The EWZr-1 electrode is a tungsten electrode containing about 0.3% zirconium oxide, referred to as zirconia. This electrode is preferred for applications where tungsten contamination of the weld must be minimized. This electrode performs well when used with alternating current, as it retains a balled end during welding and has a high resistance to contamination.

B7.5.2 EWZr-8 *(WZr 8)* Electrode Classification (White). This 0.8% zirconiated electrode has no commercial significance in the United States.

B7.6 EWG Electrode Classification (manufacturer may select any color not already in use). The EWG electrode is a tungsten electrode containing an additive not specified by an existing classification. The purpose of the addition is to affect the nature or characteristics of the arc, as defined by the manufacturer. Although no additive is specified, the manufacturer must identify any specific additions and the nominal quantities added.

B8. General Recommendations

These recommendations, when followed, should maintain high weld quality and promote welding economy in any specific application.

B8.1 The appropriate current (type and magnitude) should be selected for the electrode size to be used. Too great a current will cause excessive melting, dripping, or

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[6] "Up to 4.2% (ISO 6848-WT 40 Electrode)" was deleted from ISO 6848 at the time of publishing 2004 edition, and it was never in AWS A5.12/A5.12M.

volatilization of the electrode. A welding current which is too low to properly heat the electrode tip may cause instability of the welding arc or inability to maintain a welding arc.

B8.2 The electrode should be properly cut and ground tapered by following the supplier's suggested procedures. Breaking for severing an electrode is not recommended since it may cause a jagged end or a bent electrode, which usually results in a poorly shaped arc and excessive electrode heating.

B8.3 The electrodes should be handled carefully and kept as clean as possible. To obtain maximum cleanliness, they should be stored in their original package until used.

B8.4 The shielding gas flow should be maintained until the electrode has cooled. When the electrodes are properly cooled, the arc end will appear bright and polished. When improperly cooled, the end may oxidize and appear to have a colored film which can, unless removed, adversely affect the weld quality on subsequent welds. All connections, both gas and water, should be checked for tightness. Oxidized, discolored, or otherwise contaminated electrodes will cause difficult arc starting and may prevent starting depending upon conditions and the arc starting method used.

B8.5 The electrode extension within the gas shielding pattern should be kept to a minimum, generally dictated by the application and equipment. This is to ensure protection of the electrode by the gas even at low gas flow rates.

B8.6 The equipment and, in particular, the shielding gas nozzle should be kept clean and free of weld spatter. A dirty nozzle adversely influences the gas shielding. This contributes to improper gas flow patterns and arc wandering, which can result in poor weld quality. It may also contribute to excessive electrode consumption.

B9. Discontinued Classifications

The EWTh-3 classification was discontinued in the ANSI/AWS A5.12-92 revision of this specification, as having no commercial significance. For information about this classification, the user is referred to the ANSI/AWS A5.12-80 revision.

B10. General Safety Considerations

B10.1 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 B5. Safety and health information is available from other sources, including, but not limited to, Safety and Health Fact Sheets listed in B10.3, ANSI Z49.1, and applicable federal and state regulations.

B10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

B10.3 AWS Safety and Health Fact Sheets Index (SHF)[7]

No.	Title
1	Fumes and Gases
2	Radiation
3	Noise
4	Chromium and Nickel in Welding Fume
5	Electric 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

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

SPECIFICATION FOR SURFACING ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.13

(Identical with AWS Specification A5.13-2000. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR SURFACING ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.13

(Identical with AWS Specification A5.13-2000. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of surfacing electrodes for shielded metal arc welding. Solid bare electrodes and rods previously classified in ANSI/AWS A5.13-80 are now either discontinued or reclassified in AWS A5.21:2001, *Specification for Bare Electrodes and Rods for Surfacing* (see Section A8 in the Annex).

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 Sections A5 and A9 in the Annex. Safety and health information is available from other sources, including, but not limited to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

PART A — GENERAL REQUIREMENTS

2. Normative References

2.1 The following AWS standard[1] is referenced in the mandatory section of this standard:

(a) AWS A5.01, *Filler Metal Procurement Guidelines*.

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

2.2 The following ASTM standards[2] are referenced in the mandatory section of this standard:

(a) ASTM A 36/A 36M, *Specification for Structural Steel*.

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

(c) ASTM B 214, *Test Method for Sieve Analysis for Granular Metal Powders*.

(d) ASTM E 29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

(e) ASTM DS-56/SAE HS-1086, *Metals and Alloys in the Unified Numbering System*.

3. Classification

3.1 Except for tungsten carbide electrodes, the surfacing electrodes covered by this specification are classified according to the chemical composition of the undiluted weld metal, as specified in Tables 1, 2, and 3.

3.2 Tungsten carbide surfacing electrodes are classified on the basis of size and chemical composition of the tungsten carbide granules (see Tables 4 and 5).

3.3 Electrodes classified under one classification shall not be classified under any other classification in this specification.

4. Acceptance

Acceptance[3] of the electrodes shall be in accordance with the provisions of AWS A5.01, *Filler Metal Procurement Guidelines*.

5. Certification

By affixing the AWS specification and classification designations to the package, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[4]

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[1] AWS Standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[2] ASTM Standards may be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[3] See Section A3, Acceptance (in Annex A), for further information concerning acceptance, testing of material shipped, and AWS A5.01, Filler Metal Procurement Guidelines.

[4] See Section A4, Certification (in Annex A), for further information concerning certification and the testing called for to meet this requirement.

TABLE 1
IRON BASE SURFACING ELECTRODES—CHEMICAL COMPOSITION REQUIREMENTS[a]

AWS Classification	Annex A Reference	UNS Number [e]	Deposit Composition, weight percent[b, c, d]											
			C	Mn	Si	Cr	Ni	Mo	V	W	Ti	Nb(Cb)	Fe	Other Elements, Total
EFe1	A7.1.1	W74001	0.04-0.20	0.5-2.0	1.0	0.5-3.5	—	1.5	—	—	—	—	Rem	1.0
EFe2	A7.1.1	W74002	0.10-0.30	0.5-2.0	1.0	1.8-3.8	1.0	1.0	0.35	—	—	—	Rem	1.0
EFe3	A7.1.2	W74003	0.50-0.80	0.5-1.5	1.0	4.0-8.0	—	1.0	—	—	—	—	Rem	1.0
EFe4	A7.1.3	W74004	1.0-2.0	0.5-2.0	1.0	3.0-5.0	—	—	—	—	—	—	Rem	1.0
EFe5	A7.1.4	W75110	0.30-0.80	1.5-2.5	0.90	1.5-3.0	—	—	—	—	—	—	Rem	1.0
EFe6	A7.1.5	W77510	0.6-1.0	0.4-1.0	1.0	3.0-5.0	—	7.0-9.5	0.5-1.5	0.5-1.5	—	—	Rem	1.0
EFe7	A7.1.6	W77610	1.5-3.0	0.5-2.0	1.5	4.0-8.0	—	1.0	—	—	—	—	Rem	1.0
EFeMn-A	A7.1.7	W79110	0.5-1.0	12-16	1.3	—	2.5-5.0	—	—	—	—	—	Rem	1.0
EFeMn-B	A7.1.7	W79310	0.5-1.0	12-16	1.3	—	—	0.5-1.5	—	—	—	—	Rem	1.0
EFeMn-C	A7.1.7	W79210	0.5-1.0	12-16	1.3	2.5-5.0	2.5-5.0	—	—	—	—	—	Rem	1.0
EFeMn-D	A7.1.7	W79410	0.5-1.0	15-20	1.3	4.5-7.5	—	—	0.4-1.2	—	—	—	Rem	1.0
EFeMn-E	A7.1.7	W79510	0.5-1.0	15-20	1.3	3.0-6.0	1.0	—	—	—	—	—	Rem	1.0
EFeMn-F	A7.1.7	W79610	0.8-1.2	17-21	1.3	3.0-6.0	1.0	—	—	—	—	—	Rem	1.0
EFeMnCr	A7.1.8	W79710	0.25-0.75	12-18	1.3	13-17	0.5-2.0	2.0	1.0	—	—	—	Rem	1.0
EFeCr-A1A	A7.1.9	W74011	3.5-4.5	4.0-6.0	0.5-2.0	20-25	—	0.5	—	—	—	—	Rem	1.0
EFeCr-A2	A7.1.10	W74012	2.5-3.5	0.5-1.5	0.5-1.5	7.5-9.0	—	—	—	—	1.2-1.8	—	Rem	1.0
EFeCr-A3	A7.1.11	W74013	2.5-4.5	0.5-2.0	1.0-2.5	14-20	—	1.5	—	—	—	—	Rem	1.0
EFeCr-A4	A7.1.9	W74014	3.5-4.5	1.5-3.5	1.5	23-29	—	1.0-3.0	—	—	—	—	Rem	1.0
EFeCr-A5	A7.1.12	W74015	1.5-2.5	0.5-1.5	2.0	24-32	4.0	4.0	—	—	—	—	Rem	1.0
EFeCr-A6	A7.1.13	W74016	2.5-3.5	0.5-1.5	1.0-2.5	24-30	—	0.5-2.0	—	—	—	—	Rem	1.0
EFeCr-A7	A7.1.13	W74017	3.5-5.0	0.5-1.5	0.5-2.5	23-30	—	2.0-4.5	—	—	—	—	Rem	1.0
EFeCr-A8	A7.1.14	W74018	2.5-4.5	0.5-1.5	1.5	30-40	—	2.0	—	—	—	—	Rem	1.0
EFeCr-E1	A7.1.15	W74211	5.0-6.5	2.0-3.0	0.8-1.5	12-16	—	—	—	—	4.0-7.0	—	Rem	1.0
EFeCr-E2	A7.1.15	W74212	4.0-6.0	0.5-1.5	1.5	14-20	—	5.0-7.0	1.5	—	—	—	Rem	1.0
EFeCr-E3	A7.1.15	W74213	5.0-7.0	0.5-2.0	0.5-2.0	18-28	—	5.0-7.0	—	3.0-5.0	—	—	Rem	1.0
EFeCr-E4	A7.1.15	W74214	4.0-6.0	0.5-1.5	1.0	20-30	—	5.0-7.0	0.5-1.5	2.0	—	4.0-7.0	Rem	1.0

NOTES:

a. Solid bare electrodes and rods previously classified in AWS A5.13-80 are now either discontinued or reclassified in AWS A5.21:2001, *Specification for Bare Electrodes and Rods for Surfacing* (see A8 in Annex A).

b. Single values are maximum. Rem = Remainder

c. Electrodes and rods shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

d. Sulfur and phosphorus contents each shall not exceed 0.035%.

e. ASTM/SAE Unified Numbering System for Metals and Alloys.

TABLE 2
NICKEL AND COBALT BASE SURFACING ELECTRODES—CHEMICAL COMPOSITION REQUIREMENTS

			Deposit Composition, weight percent[a, b, c]											
AWS Classification	Annex A Reference	UNS Number[d]	C	Mn	Si	Cr	Ni	Mo	Fe	W	Co	B	V	Other Elements, Total
ECoCr-A	A7.2.1	W73006	0.7- 1.4	2.0	2.0	25-32	3.0	1.0	5.0	3.0-6.0	Rem	—	—	1.0
ECoCr-B	A7.2.2	W73012	1.0-1.7	2.0	2.0	25-32	3.0	1.0	5.0	7.0-9.5	Rem	—	—	1.0
ECoCr-C	A7.2.3	W73001	1.7-3.0	2.0	2.0	25-33	3.0	1.0	5.0	11-14	Rem	—	—	1.0
ECoCr-E	A7.2.4	W73021	0.15-0.40	1.5	2.0	24-29	2.0-4.0	4.5-6.5	5.0	0.50	Rem	—	—	1.0
ENiCr- C	A7.3.1	W89606	0.5-1.0	—	3.5-5.5	12-18	Rem	—	3.5-5.5	—	1.0	2.5-4.5	—	1.0
ENiCrMo-5A	A7.3.2	W80002	0.12	1.0	1.0	14-18	Rem[e]	14-18	4.0-7.0	3.0-5.0	—	—	0.40	1.0
ENiCrFeCo	A7.3.3	W83002	2.2-3.0	1.0	0.6-1.5	25-30	10-33	7.0-10.0	20-25	2.0-4.0	10-15	—	—	1.0

NOTES:

a. Single values are maximum percentages. Rem = Remainder

b. The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

c. Sulfur and phosphorus contents each shall not exceed 0.03%.

d. ASTM/SAE Unified Numbering System for Metals and Alloys.

e. Includes incidental cobalt.

TABLE 3
COPPER BASE SURFACING ELECTRODES—CHEMICAL COMPOSITION REQUIREMENTS

AWS Classification	Annex A Reference	UNS Number[c]	Deposit Composition, weight percent[a, b]										Ti	Other Elements, Total
			Cu	Mn	P	Si	Fe	Al	Zn	Ni[d]	Pb	Sn		
ECuAl-A2[f]	A7.4.1.1	W60617	Rem	g	—	1.5	0.5-5.0	8.5-11.0	g	g	0.02	g	—	0.50
ECuAl-B[f]	A7.4.1.2	W60619	Rem	g	—	1.5	2.5-5.0	11-12	g	g	0.02	g	—	0.50
ECuAl-C	A7.4.1.2	W60625	Rem	—	—	1.0	3.0-5.0	12-13	0.02	—	0.02	—	—	0.50
ECuAl-D	A7.4.1.3	W61625	Rem	—	—	1.0	3.0-5.0	13-14	0.02	—	0.02	—	—	0.50
ECuAl-E	A7.4.1.3	W62625	Rem	—	—	1.0	3.0-5.0	14-15	0.02	—	0.02	—	—	0.50
ECuSi[f]	A7.4.1.4	W60656	Rem	1.5	g	2.4/4.0	0.50	0.01	g	g	0.02	1.5		
ECuSn-A[f]	A7.4.1.5	W60518	Rem	g	0.05-0.35	g	0.25	0.01	g	g	0.02	4.0-6.0	—	0.50
ECuSn-C[f]	A7.4.1.5	W60521	Rem	g	0.05-0.35	g	0.25	0.01	g	g	0.02	7.0-9.0	—	0.50
ECuNi[e, f]	A7.4.1.6	W60715	Rem	1.0-2.5	0.02	0.50	0.40-0.75	—	g	29-33	0.02	g	0.50	0.50
ECuNiAl[f]	A7.4.1.7	W60632	Rem	0.5-3.5	—	1.5	3.0-6.0	8.5-9.5	g	4.0-6.0	0.02	g	—	0.50
ECuMnNiAl[f]	A7.4.1.8	W60633	Rem	11-14	—	1.5	2.0-4.0	7.0-8.5	g	1.5-3.0	0.02	g	—	0.50

NOTES:

a. Single values shown are maximum percentages. Rem = Remainder.

b. The weld metal shall be analyzed for the specific elements for which values, or a "g," are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

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

d. Includes cobalt.

e. Sulfur is restricted to 0.015% maximum.

f. This AWS classification is intended to correspond to the same classification that appears in AWS A5.6, *Specification for Copper and Copper-Alloy Covered Electrodes.* Because of revision dates the composition ranges may not be identical.

g. These elements must be included in "Other Elements, Total."

TABLE 4
MESH SIZE AND QUANTITY OF TUNGSTEN CARBIDE (WC) GRANULES IN THE CORE OF TUNGSTEN CARBIDE ELECTRODES

AWS Classification[a, b]	U.S. Standard Mesh Size of Tungsten Carbide Granules[c]	Quantity of Tungsten Carbide (WC1 + WC2) Granules, Weight Percent
EWCX-12/30	thru 12-on 30	60
EWCX-20/30	thru 20-on 30	60
EWCX-30/40	thru 30-on 40	60
EWCX-40	thru 40	60
EWCX-40/120	thru 40-on 120	60

NOTES:

a. "X" designates the type of tungsten carbide granules; X = 1 for WC1 granules, X = 2 for WC2 granules, X = 3 for a blend of WC1 and WC2 granules.

b. These AWS classifications have been transferred to AWS A5.21:2001 without a change in classification for solid bare electrodes and rods and with the prefix "ERC" for electrode/rod made from metal or flux cored stock.

c. The mesh size of the tungsten carbide granules may vary from that specified above, provided that no more than 5% of the granules are retained on the "thru" sieve, and that no more than 20% passes the "on" sieve.

SI Equivalents	
U.S. Standard Mesh Size	Opening, mm
12	1.70
20	0.85
30	0.60
40	0.43
120	0.13

TABLE 5
CHEMICAL COMPOSITION OF TUNGSTEN CARBIDE (WC) GRANULES

	Composition, weight percent[a]		
Element	WC1	WC2	WC3
C	3.6-4.2	6.0-6.2	
Si	0.3	0.3	
Ni	0.3	0.3	as agreed between purchaser and supplier
Mo	0.6	0.6	
Co	0.3	0.3	
W	94.0 min	91.5 min	
Fe	1.0	0.5	
Th	0.01	0.01	

NOTE:

a. Single values are maximum, unless noted otherwise.

6. Units of Measure and Rounding-Off Procedure

6.1 U.S. Customary Units are the standard units of measure in this specification. The International System of Units (SI) are given as equivalent values to the U.S. Customary Units. The standard sizes and dimensions in the two systems are not identical, and for this reason conversion from a standard size or dimension in one system will not always coincide with a standard size or dimension in the other. Suitable conversions, encompassing standard sizes of both, can be made, however, if appropriate tolerances are applied in each case.

6.2 For the purpose of determining conformance with this specification, 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 value in accordance with the rounding-off method given in ASTM E 29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

7. Summary of Tests

7.1 Except for tungsten carbide electrodes, chemical composition of undiluted weld metal is the only test required for classification of a product under this specification (see Tables 1, 2, and 3).

7.2 Tests required for tungsten carbide electrodes include:

7.2.1 Determination of the amount and mesh size distribution of the tungsten carbide granules (see Table 4). Sieve analysis shall be in accordance with ASTM B 214, *Test Method for Sieve Analysis for Granular Metal Powders*.

7.2.2 Determination of the chemical composition of the tungsten carbide granules (see 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. Material, specimens, or samples for retest may be taken from the original test assembly or sample, or from one or two new test assemblies or samples. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retest 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 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 Assembly

9.1 A sample for chemical analysis is the only test assembly required. The sample may be prepared by any method producing undiluted weld metal. In case of dispute, the weld pad described in 9.2 shall be the referee method.

9.2 The dimensions of the completed pad shall be as shown in Fig. 1 for each size of electrode. Testing of this assembly shall be as specified in Section 10, Chemical Analysis.

9.2.1 Welding shall be done in the flat position using welding conditions specified by the manufacturer.

9.2.2 Postweld heat treatment may be used to facilitate subsequent sampling.

9.3 The base metal shall conform to one of the following specifications or its equivalent:

9.3.1 ASTM A 285/A 285M Grade A (UNS K01700).

9.3.2 ASTM A 36/A 36M (UNS K02600).

10. Chemical Analysis

10.1 For All Except Covered Tungsten Carbide Electrodes

10.1.1 Shielded metal arc welding surfacing electrodes shall be analyzed in the form of undiluted weld metal. The sample shall come from a weld metal pad or ingot.

10.1.2 The top surface of the pad described in Section 9 and shown in Fig. 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.

For electrodes $^3/_{32}$ in. (2.4 mm) in diameter and smaller, the sample shall be taken at least $^1/_2$ in. (13 mm) from the nearest surface of the base metal.

For electrodes $^1/_8$–$^3/_{16}$ in. (3.2–4.8 mm) in diameter, the sample shall be taken at least $^5/_8$ in. (16 mm) from the nearest surface of the base metal.

For electrodes larger than $^3/_{16}$ in. (4.8 mm) in diameter the sample shall be taken at least $^3/_4$ in. (19 mm) from the nearest surface of the base metal.

10.1.3 The sample may be removed from an undiluted weld metal ingot by any convenient method.

10.1.4 The sample shall be analyzed by accepted analytical methods as agreed by the manufacturer and purchaser. The referee method shall be the appropriate ASTM method for the element being determined.

10.1.5 The results of the analysis shall meet the requirements of Tables 1, 2, or 3 for the classification of electrode under test.

10.2 For Tungsten Carbide Electrodes

10.2.1 Chemical composition of tungsten carbide granules shall conform to the requirements of Table 5. Chemical analysis may be made by any suitable method agreed upon by the manufacturer and the purchaser.

10.2.2 Tungsten carbide granules for chemical analysis shall be free of any surface contaminant.

10.2.3 The percentage by weight of the tungsten carbide, as specified in Table 4, can be determined by the following steps:

(a) Record the weight of the tungsten carbide welding electrode after removing any covering present.

(b) Remove the tungsten carbide from the tube and clean it by washing with water and treating with 1-1 hydrochloric acid, as required, to remove any flux, powdered iron, graphite, etc. Heating of the acid may be required. A hot or cold 1-1 hydrochloric acid will not appreciably attack cast tungsten carbide in less than an hour. When handling any acids appropriate safety precautions should be followed.

(c) Dry tungsten carbide by holding in an oven at 250° ± 25°F [120° ± 15°C].

(d) Weigh the cleaned and dried tungsten carbide granules. Calculate the percentage of tungsten carbide from the initial weight of the tube using the following formula:

$$\%\ \text{tungsten carbide granules} =$$

$$\frac{\text{weight of clean and dried tungsten carbide granules}}{\text{weight of electrode after removal of covering}} \times 100$$

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

11. Method of Manufacture

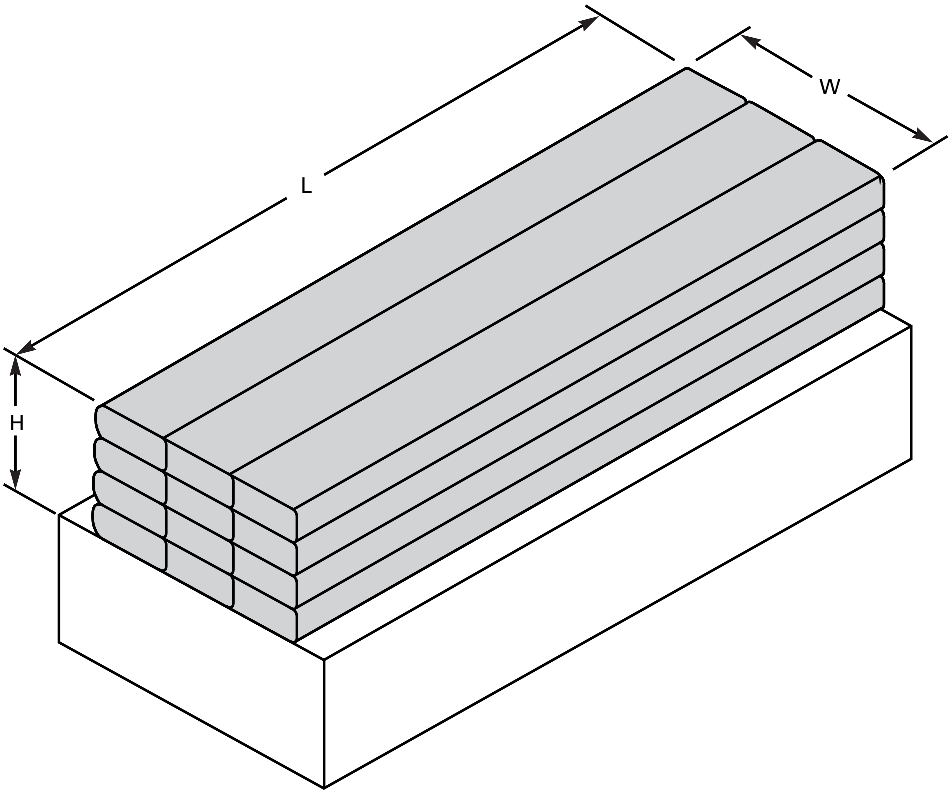
The electrodes classified according to this specification may be manufactured by any method that will produce material which meets the requirements of this specification. For tungsten carbide electrodes, any carbon steel sheath material (typically C1008) that will not alter the matrix significantly may be used.

12. Standard Sizes and Lengths

12.1 Standard sizes (diameter of core wire) and lengths of electrodes shall be as shown in Tables 6, 7, and 8.

12.2 The diameter of solid drawn core wire shall not vary more than ±0.003 in. (±0.08 mm) from the diameter

FIG. 1 PAD FOR CHEMICAL ANALYSIS OF UNDILUTED WELD METAL



Electrode Size, in.	Weld Pad Size in., minimum
5⁄64 (0.078) 3⁄32 (0.094)	L = 1½ W = ½ H = ½
1⁄8 (0.125) 5⁄32 (0.156) 3⁄16 (0.187)	L = 2 W = ½ H = 5⁄8
7⁄32 (0.219) 1⁄4 (0.250) 5⁄16 (0.312)	L = 2½ W = ½ H = ¾

SI Equivalents	
in.	mm
5⁄64	2.0
3⁄32	2.4
1⁄8	3.2
5⁄32	4.0
3⁄16	4.8
7⁄32	5.6
1⁄4	6.4
5⁄16	8.0
½	13
5⁄8	16
¾	19
1½	38
2	50
2½	64

TABLE 6
STANDARD SIZES AND LENGTHS OF COVERED ELECTRODES USING SOLID DRAWN CORE WIRE[a]

Electrode Sizes Diameter of Solid Drawn Core Wire[b]		Standard Lengths	
in.	mm	in.	mm
$^{5}/_{64}$ (0.078)	2.0	9 ± $^{1}/_{4}$	230 ± 6.4
		9 ± $^{1}/_{4}$	230 ± 6.4
$^{3}/_{32}$ (0.094)	2.4	12 ± $^{1}/_{4}$	300 ± 6.4
$^{1}/_{8}$ (0.125)	3.2	14 ± $^{1}/_{4}$	350 ± 6.4
$^{5}/_{32}$ (0.156)	4.0	14 ± $^{1}/_{4}$	350 ± 6.4
		14 ± $^{1}/_{4}$	350 ± 6.4
$^{3}/_{16}$ (0.187)	4.8	18 ± $^{1}/_{4}$	450 ± 6.4
		14 ± $^{1}/_{4}$	350 ± 6.4
$^{1}/_{4}$ (0.250)	6.4	18 ± $^{1}/_{4}$	450 ± 6.4
		14 ± $^{1}/_{4}$	350 ± 6.4
$^{5}/_{16}$ (0.312)	8.0	18 ± $^{1}/_{4}$	450 ± 6.4

NOTES:

a. Other electrode diameters and lengths may be supplied as agreed between the manufacturer and purchaser.

b. Tolerance on the diameter shall be ± 0.003 in. (±0.08 mm).

specified. The length shall not vary more than $\pm^{1}/_{4}$ in. (±6.4 mm) from that specified.

12.3 The diameter of composite or cast core wire (except tungsten carbide) shall not vary more than ±0.02 in. (±0.5 mm). The length shall not vary more than $\pm^{3}/_{8}$ in. (±9.6 mm) from that specified.

12.4 The diameter of tungsten carbide core wire shall not vary more than ±0.04 in. (±1.0 mm) from the nominal diameter. The length shall not vary more than $\pm^{3}/_{8}$ in. (±9.6 mm) from that specified.

13. Core Wire and Covering

Core wire and covering shall be free of defects that would interfere with uniform deposition of the electrode.

14. Exposed Core

14.1 The grip end of each electrode shall be bare (free of covering) for a distance of not less than $^{1}/_{2}$ in. (13 mm), nor more than $1^{1}/_{2}$ in. (38 mm), to provide for electrical contact with the electrode holder.

14.2 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. (3.2 mm) or the diameter of the core wire, whichever is less. Electrodes with chipped coverings near the arc end, baring the core wire slightly more than the prescribed distance, may be accepted provided no chip uncovers more than 50% of the circumference of the core.

14.3 Electrodes with electrically conductive coverings or strike tips may be exempt from the requirements of 14.2 providing they are capable of easy arc starting without stripping.

15. Electrode Identification

15.1 All electrodes, except dip-covered electrodes, shall be identified as follows:

15.1.1 At least one imprint of the electrode classification shall be applied to the electrode covering within $2^{1}/_{2}$ in. (64 mm) of the grip end of the electrode.

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

15.1.3 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.

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

15.2 Identification of dip-covered electrodes shall be as agreed between the purchaser and supplier. Imprinting is not mandatory.

16. Packaging

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

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

17. Marking of Packages

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

(a) AWS specification and classification designations (year of issue may be excluded)

(b) Supplier's name and trade designation

(c) Size and net weight

(d) Lot, control, or heat number

17.2 The appropriate precautionary information[5] as given in ANSI Z49.1,[6] 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.

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

[6] ANSI Z49.1 may be obtained from The American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

TABLE 7
STANDARD SIZES AND LENGTHS FOR COVERED CAST AND COMPOSITE TUBULAR ELECTRODES[a]

Electrode Sizes, Nominal Diameter of Core Wire[b]		Standard Lengths			
		For Cast Electrodes		For Composite Tubular Electrodes	
in.	mm	in.	mm	in.	mm
1/8 (0.125)	3.2	9 to 14 ± 3/8	230 to 350 ± 9.6	9 to 14 ± 3/8	230 to 350 ± 9.6
5/32 (0.156)	4.0	9 to 14 ± 3/8	230 to 350 ± 9.6	9 to 14 ± 3/8	230 to 350 ± 9.6
3/16 (0.187)	4.8	9 to 14 ± 3/8	230 to 350 ± 9.6	9 to 14 ± 3/8	230 to 350 ± 9.6
1/4 (0.250)	6.4	12 to 14 ± 3/8	300 to 350 ± 9.6	14 ± 3/8	350 ± 9.6
1/4 (0.250)	6.4	12 to 14 ± 3/8	300 to 350 ± 9.6	14 ± 3/8	450 ± 9.6
5/16 (0.312)	8.0	12 to 14 ± 3/8	300 to 350 ± 9.6	14 ± 3/8	350 ± 9.6
5/16 (0.312)	8.0	12 to 14 ± 3/8	300 to 350 ± 9.6	18 ± 3/8	450 ± 9.6

NOTES:

a. Other diameter and lengths of electrodes may be supplied as agreed between the manufacturer and the purchaser.

b. Diameter tolerance shall be ± 0.02 in. (±0.5 mm) from the nominal diameter.

TABLE 8
STANDARD SIZES AND LENGTHS FOR COVERED TUNGSTEN CARBIDE (WC) ELECTRODES

Electrode Sizes, Nominal Diameter of Core Wire[a]		Standard Lengths	
in.	mm	in.	mm
3/32 (0.094)	2.4	9 ± 3/8	225 ± 9.6
		14 ± 3/8	350 ± 9.6
1/8 (0.125)	3.2	9 ± 3/8	225 ± 9.6
		14 ± 3/8	350 ± 9.6
5/32 (0.156)	4.0	9 ± 3/8	225 ± 9.6
		14 ± 3/8	350 ± 9.6
3/16 (0.187)	4.8	9 ± 3/8	225 ± 9.6
		14 ± 3/8	350 ± 9.6
1/4 (0.250)	6.4	14 ± 3/8	350 ± 9.6
		18 ± 3/8	450 ± 9.6
5/16 (0.312)	8.0	14 ± 3/8	350 ± 9.6
		18 ± 3/8	450 ± 9.6

NOTE:

a. Diameter shall not vary more than ±0.04 in. (±1.0 mm) from the nominal diameter.

Annex
Guide to AWS Specification for Surfacing Electrodes for Shielded Metal Arc Welding

(This Annex is not a part of AWS A5.13-2000, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*, but is included for information purposes only.)

A1. Introduction

This guide has been prepared as an aid to prospective users of the electrodes covered by the specification in determining the classification of filler metal best suited for a particular application, with due consideration to the particular requirements for that application.

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 letter E at the beginning of each classification designation stands for electrode. The letters immediately after the E are the chemical symbols for the principal elements in the classification. Thus, CoCr is a cobalt-chromium alloy, CuA1 is a copper-aluminum alloy, etc. Where more than one classification is included in a basic group, the individual classifications in the group are identified by the letters, A, B, C, etc., as in ECuSn-A. Further subdividing is done by using a 1, 2, etc., after the last letter, as the 2 in ECuA1-A2. An additional letter or number has been added to some designations if the composition requirements in this specification differ somewhat from those of the earlier versions for electrodes of the same basic classification.

A2.2 Refer to Table Al for a comparison of covered electrode classifications used in ANSI/AWS A5.13-80 and those used in the current document; some classifications have been changed and some have been discontinued.

TABLE A1
ELECTRODE CLASSIFICATION COMPARISON—
A5.13-80 AND A5.13:2000

A5.13-80 Classification	A5.13:2000 Classification[a]
EFe5-A	Deleted
EFe5-B	Similar to EFe6
EFe5-C	Deleted
EFeMn-A	Similar to EFeMn-A
EFeMn-B	Similar to EFeMn-B
EFeCr-A1	Similar to EFeCr-A1A
ECoCr-A	ECoCr-A
ECoCr-B	ECoCr-B
ECoCr-C	ECoCr-C
ECuSi	ECuSi
ECuAl-A2	Similar to ECuAl-A2
ECuAl-B	Similar to ECuAl-B
ECuAl-C	Similar to ECuAl-C
ECuAl-D	Similar to ECuAl-D
ECuAl-E	Similar to ECuAl-E
ECuSn-A	ECuSn-A
ECuSn-C	ECuSn-C
ENiCr-A	Deleted
ENiCr-B	Deleted
ENiCr-C	ENiCr-C

NOTE:

a. The new classification for bare electrodes and rods for surfacing are in the AWS A5.21:2001.

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, shall 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 he normally conducts on material of that classification, as specified in Schedule F, Table 1, of the AWS A5.01. Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been 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 System" in AWS A5.01.

A5. Ventilation During Welding

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

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

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

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

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

(e) 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 particularly drawn to the section of that document on Health Protection and Ventilation.

A6. Welding Considerations

A6.1 Role of Hydrogen in Surfacing. Hydrogen can be detrimental to surfacing deposits. The effect varies widely from one alloy type to another. In general, hydrogen's detrimental effect on microstructure is the most pronounced for martensitic types, with austenitic types being the least affected. Other factors influencing hydrogen's effect include carbon and alloy contents plus in-service welding variables.

In welding there are many sources for hydrogen contamination. Coating moisture is one of the most important. Most electrodes are manufactured and packaged to control moisture. When received, consideration must be given to proper storage to prevent moisture pick-up. During use, improper regard to welding procedure and environmental variables can result in spalling or "hydrogen-induced" (underbead) cracking.

A6.2 Low equipment cost, great versatility, and general convenience make manual shielded metal arc welding very popular. The welding machine, which is essentially a power conversion device, is usually the main item of equipment needed. It may be a motor-generator, transformer, transformer-rectifier combination, or fuel-operated engine combined with a generator. The arc power may be either direct or alternating current. The filler metal is in the form of covered electrodes. (Bare electrode arc welding is a rarity today, though it is feasible with austenitic manganese steel electrodes.) Welding can be done in almost any location and is practicable for a variety of work, ranging from very small to quite large. For some applications, it is the only feasible method; and, for many others (especially where continuous methods do not offer significant benefits), it is the economical choice.

The operation is under the observation and control of the welder, who can easily cover irregular areas and often correct for adverse conditions. It is also helpful if the welder exercises judgment in other matters, such as holding the arc power down to minimize cracking; keeping a short arc and avoiding excessive puddling to minimize the loss of expensive alloying elements in the filler metal; minimizing dilution with base metal; and restricting hydrogen pickup. This process is used extensively for hardfacing, buttering, buildup, and cladding.

Surfacing of carbon and low-alloy steels, high-alloy steels, and many nonferrous metals may be done with the shielded metal arc process. Base metal thicknesses may range from below $^1/_4$–18 in. (6–450 mm) or more. The surfacing metals employed include low- and high-alloy steels, the stainless steels, nickel-base alloys, cobalt-base alloys, and copper-base alloys.

The welding conditions for surfacing are not fundamentally different from those used in welding a joint. The arc and weld pool are shielded by the slag or the gases, or both, produced by the electrode. The type of covering on the electrode has considerable effect on the characteristics of the weld metal. Surfacing can be done on work ranging in size from very small to quite large.

Table A2 shows how the various shielded metal arc process variables affect the three most important surfacing characteristics: dilution, deposition rate, and deposit thickness.

The table indicates only general trends and does not cover questions of weldability or weld soundness. These factors may make it unwise to change only the indicated variable; this in turn may mean that the desired change in dilution, deposition rate, or deposit thickness may not be achieved. For example, a given welding procedure with a

TABLE A2
THE EFFECT OF SHIELDED METAL ARC VARIABLES ON THE THREE MOST IMPORTANT CHARACTERISTICS OF SURFACING

		Influence of Change on		
Variable	Change of Variable[a]	Dilution	Deposition Rate	Deposit Thickness
	AC	Intermediate	Intermediate	Intermediate
Polarity	DCEP	High	Low	Thin
	DCEN	Low	High	Thick
Amperage	High	High	High	Thick
	Low	Low	Low	Thin
Technique	Stringer	High	No effect	Thick
	Weave	Low	No effect	Thin
Bead spacing	Narrow	Low	No effect	Thick
	Wide	High	No effect	Thin
Electrode diameter	Small	High	High	Thick
	Large	Low	Low	Thin
Arc length	Long	Low	No effect	Thin
	Short	High	No effect	Thick
Travel speed	Fast	High	No effect	Thin
	Slow	Low	No effect	Thick

NOTE:

[a] This table assumes that only one variable at a time is changed. However, for acceptable surfacing conditions, a change in one variable may require a change in one or more other variables.

small electrode diameter may produce high dilution. The table indicates that a change to a large size electrode will decrease dilution. This is true, however, only if the amperage, travel speed, position, etc., also remain constant. In many cases, a larger amperage value must be used with the larger electrode size to obtain acceptable weld quality. In this case, the dilution may remain constant or even increase with the change to the larger electrode size.

The process usually achieves a deposition rate from 1–4 lb (0.5–2 kg) per hour at dilution levels from 30–50%.

A7. Description and Intended Use of Surfacing Electrodes

A7.1 Iron-Base Electrodes

A7.1.1 EFe1 and EFe2 Electrodes

A7.1.1.1 Characteristics. Deposits made with these electrodes are a machinery grade steel suitable for application on carbon and alloy steels. With care, they can be applied crack-free. Deposits are machinable with carbide tipped tools. Deposit hardness generally is in the range of 25–50 HRC with EFe2 electrodes providing weld metal with the higher hardness. These deposits contain sufficient alloy to attain full hardness without the need of heat treatment. Abrasion resistance is comparable to heat-treated steels of equal hardness.

A7.1.1.2 Applications. These electrodes are used to restore worn machinery parts to their original dimensions. Deposit surfaces are suitable for metal-to-metal rolling and sliding contact, such as occurs on large, low speed gear teeth, shafts, etc. High compressive strength makes these materials suitable as a base for more abrasion-resistant materials.

A7.1.2 EFe3 Electrodes

A7.1.2.1 Characteristics. Weld metal deposited by these electrodes is an air-hardening tool steel type with high room temperature hardness (55–60 HRC). Deposits can be applied crack-free with careful procedures. The deposits cannot be machined and generally are ground when finishing is required.

A7.1.2.2 Applications. EFe3 electrodes are used to overlay surfaces and edges requiring high hardness and crack-free deposits, such as the edges of tools and dies. Deposits are compatible with many tool steels. Although generally used for metal-to-metal applications, EFe3 weld metal performs well in earth abrasion applications where high impact is encountered.

A7.1.3 EFe4 Electrodes

A7.1.3.1 Characteristics. These electrodes will have a graphitic (black) coating and are suitable for application on cast iron. Although the deposited metal is relatively brittle, crack-free deposits can be made with controlled procedures. Deposits can be machined providing they are slow cooled from an annealing temperature.

A7.1.3.2 Applications. EFe4 weld metal is used to rebuild worn cast iron machinery parts subject to metal-to-metal rolling or sliding contact. Although EFe4 weld deposits are compatible with carbon and low-alloy steel, EFe2 electrodes generally are preferred for such applications.

A7.1.4 EFe5 Electrodes

A7.1.4.1 Characteristics. EFe5 electrodes deposit a cold work type of tool steel. Hardness as-deposited should be in the range of 50–55 HRC. Weld metal deposited by EFe5 electrodes is air-hardening and machinable only after annealing.

A7.1.4.2 Applications. Typical applications include those requiring high compressive strength with moderate abrasion and metal-to-metal wear, such as machine components, shafts, and brake drums.

A7.1.5 EFe6 Electrodes

A7.1.5.1 Characteristics. Weld metal deposited by EFe6 electrodes is a high-speed tool steel with a hardness in range of 60 HRC or higher. The deposit maintains a high degree of hardness to 1100°F (593°C). Weld metal deposited by EFe6 electrodes is air-hardening and is machinable only after annealing.

A7.1.5.2 Applications. Weld deposits may be used for metal-to-metal wear applications at temperatures up to 1100°F (593°C). Typical applications combine high temperature service with severe abrasion and metal-to-metal wear and include shear blades, trimming dies, and punching dies.

A7.1.6 EFe7 Electrodes

A7.1.6.1 Characteristics. EFe7 series electrodes are essentially a higher carbon modification of EFe3 electrodes. Abrasion resistance of the weld deposit is improved with some sacrifice in resistance to impact. Deposits air harden, and a two-layer deposit can be expected to have a hardness of 60 HRC or higher. Stress-relief cracks (checks) typically occur through the overlay. Deposits cannot be machined.

A7.1.6.2 Applications. EFe7 electrodes are used for overlaying surfaces that require good low-stress abrasion resistance. Applications include cement chutes, fan blades, bulldozer blades, and other parts and equipment used for earthmoving or construction. Carbon and alloy steels, tool steels, and stainless steels are compatible base metals.

A7.1.7 EFeMn Series Electrodes (EFeMn-A through EFeMn-F)

A7.1.7.1 Characteristics. Deposits made with EFeMn series electrodes nominally contain 14% manganese, although they may vary from 12–21%. This is an amount sufficient to yield austenitic weld deposits. Austenite is a nonmagnetic, tough form of steel. To preserve the toughness, excessive heat must be avoided during welding. Stringer beads and a block sequence are recommended. The additions of other elements, such as 4% nickel, are made to give more stability to the austenite; chromium, molybdenum, and vanadium are also added singly or in combination of 0.5–8% to increase the yield strength. Abrasion resistance is only a little better than that of low-carbon steel unless there has been sufficient impact to cause work hardening. As-deposited surfaces generally are no harder than HRC 20, but can work harden to HRC 55. Since deposits are difficult to machine, grinding is preferred for finishing.

A7.1.7.2 Applications. These electrodes are used for the rebuilding, repair, and joining of Hadfield austenitic manganese steel. Ability to absorb high impact makes such deposits ideal for the rebuilding of worn rock crushing equipment and parts subject to impact loading, such as railroad frogs.

A7.1.8 EFeMnCr Electrodes

A7.1.8.1 Characteristics. Weld metal deposited by EFeMnCr electrodes have characteristics similar to austenitic manganese deposits. The high chromium content imparts stainless steel qualities. These deposits cannot be flame cut. Although care must be taken in application to avoid heat build-up, deposits are more stable than FeMn series electrodes.

A7.1.8.2 Applications. Like EFeMn type electrodes, EFeMnCr electrodes are used for rebuilding, repair, and joining of equipment made of Hadfield austenitic manganese steel. EFeMnCr electrodes offer the added advantage of being usable for joining austenitic manganese steel both to itself and to carbon steel. EFeMnCr weld metals often are used as a base for surfacing with EFeCr types for parts subject to both wear and impact.

A7.1.9 EFeCr-A1A and EFeCr-A4 Electrodes

A7.1.9.1 Characteristics. Weld metal deposited by these electrodes will contain massive chromium carbides in an austenitic matrix providing excellent wear resistance and toughness. Surface checks are typical and give some degree of stress relief. Deposits cannot be machined and must be ground when finishing is required. To assure the desired deposit composition, two layers are recommended. Additional layers invite spalling and must be applied with caution. Electrodes are suitable for welding on carbon, alloy, and austenitic steels as well as cast irons. The weld metal deposited by EFeCr-A1A electrodes generally provides greater resistance to impact but slightly less abrasion resistance than weld metal deposited by EFeCr-A4 electrodes.

A7.1.9.2 Applications. Deposits frequently are used to surface parts and equipment involved in sliding and crushing of rock, ore, etc., such as bucket lips and teeth, impact hammers, and conveyors. Very low coefficients of friction develop as a result of scouring by earth products.

A7.1.10 EFeCr-A2 Electrodes

A7.1.10.1 Characteristics. The weld metal deposit contains titanium carbide in an austenitic matrix.

It is machinable only by grinding. Build-up should be limited to three layers to minimize relief check cracking.

A7.1.10.2 Applications. This weld metal group may be applied to both carbon steel and austenitic manganese base metal. Deposits frequently are used to hardface mining, construction, earth moving, and quarrying equipment subject to abrasion and moderate impact.

A7.1.11 EFeCr-A3 Electrodes

A7.1.11.1 Characteristics. Filler metal deposited by EFeCr-A3 electrodes is similar to a deposit made using EFeCr-AlA electrodes except, due to the lower manganese content, a martensitic matrix is present, rendering the deposit somewhat brittle. These deposits are not machinable but may be finished by grinding where necessary.

A7.1.11.2 Applications. This weld metal is a general purpose hardfacing alloy for earth abrasion applications and is suitable for low stress scratching abrasion with low impact.

A7.1.12 EFeCr-A5 Electrodes

A7.1.12.1 Characteristics. The weld deposit contains chromium carbide in an austenitic matrix. The nonmagnetic weld metal has fair machinability. Build-up should be restricted to three layers to minimize stress relief checking.

A7.1.12.2 Applications. Surfaced components frequently are used for applications involving frictional metal-to-metal wear or earth scouring under low stress abrasion.

A7.1.13 EFeCr-A6 and EFeCr-A7 Electrodes

A7.1.13.1 Characteristics. These are a higher carbon version of EFeCr-A5 electrodes. The deposit contains hexagonal chromium carbides in an austenitic carbide matrix and has a hardness of 50–60 HRC. Deposits develop stress-relief checks. The addition of molybdenum increases wear resistance to high stress abrasion. The weld metal may be applied on carbon, alloy, or austenitic manganese steel base metal.

A7.1.13.2 Applications. Weld metal is frequently used for applications involving low stress abrasive wear combined with moderate impact.

A7.1.14 EFeCr-A8 Electrodes

A7.1.14.1 Characteristics. EFeCr-A8 is a higher chromium version of EFeCr-A3. The deposit contains hexagonal chromium carbides in an austenitic matrix and has a hardness of 50–60 HRC. The increased chromium content tends to decrease the toughness while increasing the abrasion resistance. Maximum relief checking can be expected. The weld metal may be applied to carbon, alloy, or austenitic manganese base metals.

A7.1.14.2 Applications. Weld metal is frequently used for applications involving low stress abrasion combined with minimum impact.

A7.1.15 EFeCr-EX Series Electrodes

A7.1.15.1 Characteristics. This family of electrodes deposits weld metal containing finely dispersed chromium carbides plus one or more metallic carbides [vanadium, niobium (columbium), tungsten, or titanium]. The resultant deposits are not machinable, and maintain their hot hardness and abrasion resistance to 1200°F (650°C). Deposits stress-relief check readily.

A7.1.15.2 Applications. Equipment subjected to severe high stress abrasion combined with moderate impact may be surfaced with one of the specific grades. Selection of the specific grade will be dependent on local service conditions and the specific application.

A7.2 Cobalt-Base Surfacing Electrodes

A7.2.1 ECoCr-A Electrodes

A7.2.1.1 Characteristics. Weld metal deposited by ECoCr-A electrodes is characterized by a hypereutectic structure consisting of a network of about 13% eutectic chromium carbides distributed in a cobalt-chromium-tungsten solid solution matrix. The result is a material with a combination of overall resistance to low stress abrasive wear coupled with the necessary toughness to resist some degree of impact. Cobalt alloys also are inherently good for resisting metal-to-metal wear, particularly in high load situations that are prone to galling. The high-alloy content of the matrix also affords excellent resistance to corrosion, oxidation, and elevated temperature retention of hot hardness up to a maximum of 1200°F (650°C). These alloys are not subject to allotropic transformation and therefore do not lose their properties if the base metal subsequently is heat treated.

A7.2.1.2 Applications. The alloy is recommended for cases where wear is accompanied by elevated temperatures and where corrosion is involved, or both. Typical applications include automotive and fluid flow valves, chain saw guides, hot punches, shear blades, extruder screws, etc.

A7.2.2 ECoCr-B Electrodes

A7.2.2.1 Characteristics. Weld metal deposited by ECoCr-B electrodes is similar in composition to ECoCr-A deposits except for a slightly higher carbide content (approximately 16 percent). The alloy also has a slightly higher hardness coupled with better abrasive and metal-to-metal wear resistance. Impact and corrosion resistance are lowered slightly. Deposits can be machined with carbide tools.

A7.2.2.2 Applications. ECoCr-B electrodes are used interchangeably with ECoCr-A. Choice will depend on the specific application.

A7.2.3 ECoCr-C Electrodes

A7.2.3.1 Characteristics. This alloy's deposits have a higher carbide content (19%) than those made using either ECoCr-A or ECoCr-B electrodes. In fact, the composition is such that primary hypereutectic carbides are found in the microstructure. This characteristic gives the alloy higher wear resistance, accompanied by reductions in the impact and corrosion resistance. The higher hardness also means a greater tendency to stress crack during cooling. The cracking tendency may be minimized by closely monitoring preheating, interpass temperature, and postheating techniques.

While the cobalt-chromium deposits soften somewhat at elevated temperatures, they normally are considered immune to tempering.

A7.2.3.2 Applications. Weld metal deposited by ECoCr-C electrodes is used to build up mixer rotors and items that encounter severe abrasion and low impact.

A7.2.4 ECoCr-E Electrodes

A7.2.4.1 Characteristics. Welds made using ECoCr-E electrodes have very good strength and ductility at temperatures up to 1600°F (871°C). Deposits are resistant to thermal shock, and oxidizing and reducing atmospheres. Early applications of these types of alloys were found in jet engine components such as turbine blades and vanes.

The deposit is a solid-solution-strengthened alloy with a relatively low weight-percent carbide phase in the microstructure. Hence, the alloy is very tough and will work harden. Deposits possess excellent self-mated galling resistance and also are very resistant to cavitation erosion.

A7.2.4.2 Applications. Welds made using ECoCr-E electrodes are used where resistance to thermal shock is important. Typical applications, similar to those of ECoCr-A deposits, include guide rolls, hot extrusion and forging dies, hot shear blades, tong bits, and valve trim.

A7.2.5 Typical hardness values for multilayer welds made using cobalt base electrodes are:

ECoCr-A	23–47 HRC
ECoCr-B	34–47 HRC
ECoCr-C	43–58 HRC
ECoCr-E	20–32 HRC

Hardness values for single layer deposits will be lower because of dilution from the base metal.

A7.3 Nickel Base Surfacing Electrodes

A7.3.1 ENiCr-C Electrodes

A7.3.1.1 Characteristics. Undiluted weld metal of this composition exhibits a structure consisting of chromium carbides and chromium borides in a nickel-rich matrix. The nickel base and high chromium content give these deposits good heat and corrosion resistance. Care should be taken when cooling hardfacing deposits because of a tendency to stress crack. This alloy possesses excellent resistance to low stress abrasion.

A7.3.1.2 Applications. ENiCr-C weld metal flows very easily, has very high abrasion resistance, and normally takes on a high polish. Typical applications include cultivator sweeps, plow shares, extrusion screws, pump sleeves, pistons, and impellers, capstan rings, glass mold faces, centrifuge filters, sucker pump rods, etc. The deposits have high corrosion resistance and normally require grinding for finishing. Single layer deposits typically have a hardness of 35–45 HRC. Multilayer deposits typically have a hardness of 49–56 HRC.

A7.3.2 ENiCrMo-5A Electrodes

A7.3.2.1 Characteristics. Undiluted weld metal deposited by ENiCrMo-5A electrodes is a solid-solution-strengthened alloy with relatively low weight-percent carbide phase produced through secondary hardening. The resultant deposit is tough and work hardenable.

Deposits have the ability to retain hardness up to 1400°F (760°C). Deposits are machinable with high-speed tool bits and have excellent resistance to high-temperature wear and impact.

A7.3.2.2 Applications. These electrodes are used to rebuild and repair hot extrusion dies, hot forging dies, sizing punches, hot shear blades, guide rolls, tong bits, blast furnace bells, etc.

A7.3.3 ENiCrFeCo Electrodes

A7.3.3.1 Characteristics. Weld metal deposited by these electrodes contain a fairly large volume fraction of hypereutectic chromium carbides distributed throughout the microstructure. The alloy offers many of the same high-performance characteristics of deposits made using ECoCr-C or ENiCr-C electrodes in terms of abrasive wear resistance. The reduced nickel or cobalt content, or both, lowers corrosion properties and galling resistance. The high volume fraction of carbides makes this alloy sensitive to cracking during cooling.

A7.3.3.2 Applications. Welds made using ENiCr-FeCo electrodes are preferred where high abrasion (low impact) is a major factor. Typical applications are feed screws, slurry pumps, and mixer components.

A7.4 Copper-Base Alloy Electrodes

A7.4.1 Introduction. The copper-base alloy electrodes classified by this specification are used to deposit overlays and inlays for bearing, corrosion-resistant, or wear-resistant surfaces.

A7.4.1.1 ECuAl-A2 electrodes are used for surfacing bearing surfaces between the hardness ranges of 130 to 150 HB as well as corrosion-resistant surfaces.

A7.4.1.2 ECuAl-B and ECuAl-C electrodes are used primarily for surfacing bearing surfaces requiring hardness in the range of 140–220 HB. These alloys are not recommended for applications that require resistance to corrosion.

TABLE A3
APPROXIMATE WELD DEPOSIT HARDNESS (SMAW)

AWS Classification	Brinell Hardness[a]	
	3000 kg Load	500 kg Load
ECuAl-A2	130-150	—
ECuAl-B	140-180	—
ECuAl-C	180-220	—
ECuAl-D	230-270	—
ECuAl-E	280-320	—
ECuSi	—	80-100
ECuSn-A	—	70-85
ECuSn-C	—	85-100
ECuNi	—	60-80
ECuNiAl	160-200	—
ECuMnNiAl	160-200	—

NOTE:

a. As-welded condition.

A7.4.1.3 ECuAl-D and ECuAl-E electrodes are used to surface bearing and wear-resistant surfaces requiring hardness in the range of 230–320 HB, such as gears, cams, sheaves, wear plates, dies, etc. These alloys are also used to surface dies that form or draw titanium, low-carbon and stainless steels. These alloys are not recommended for applications that require resistance to corrosion.

A7.4.1.4 The ECuSi electrodes are used primarily for surfacing corrosion-resistant surfaces. Copper-silicon deposits generally are not recommended for bearing service.

A7.4.1.5 Copper-tin (ECuSn) electrodes are used primarily to surface bearing surfaces where the lower hardness of these alloys is required, for surfacing corrosion-resistant surfaces, and, occasionally, for applications requiring wear resistance.

A7.4.1.6 Copper-nickel electrodes (ECuNi) are used for rebuilding 70/30, 80/20, and 90/10% copper-nickel alloy or the clad side of copper-nickel clad steel. Preheating generally is not necessary.

A7.4.1.7 Copper-nickel-aluminum electrodes (ECuNiAl) are used to rebuild nickel-aluminum-bronze castings or wrought components. Typical applications are those requiring a high resistance to corrosion, erosion, or cavitation in salt or brackish water.

A7.4.1.8 ECuMnNiAl electrodes are used to rebuild or surface cast manganese-nickel-aluminum bronze castings or wrought material. Typical applications include those requiring excellent resistance to corrosion, erosion, and cavitation.

A7.4.2 Applications

A7.4.2.1 Hardness Ranges. See Table A3 for typical hardness ranges.

A7.4.2.2 Hot Hardness. The copper-base alloy filler metals are not recommended for use at elevated temperatures. Mechanical properties, especially hardness, will tend to decrease consistently as the temperature increases above 400°F (205°C).

A7.4.2.3 Impact. In general, as the aluminum content increases, impact resistance decreases rapidly. The impact resistance of deposits made by using ECuAl-A2 electrodes will be the highest of the copper-base alloy classifications. Deposits made using ECuSi electrodes have good impact properties. Deposits made using ECuSn electrodes have low impact values.

A7.4.2.4 Oxidation Resistance. Weld metal deposited by any of the ECuAl family of electrodes forms a protective oxide coating upon exposure to the atmosphere. Oxidation resistance of the copper-silicon deposit is fair, while that of copper-tin deposits is comparable to the oxidation resistance of pure copper.

A7.4.2.5 Corrosion Resistance. Several copper base alloy filler metals are used rather extensively to surface areas subject to corrosion from reducing type acids, mild alkalies, and salt water. They should not be used in the presence of oxidizing acids, such as HNO_3, or when sulfur compounds are present. Filler metals producing deposits of higher hardness may be used to surface areas subject to corrosive action as well as erosion from liquid flow for such applications as condenser heads and turbine runners.

A7.4.2.6 Abrasion. None of the copper-base alloy deposits is recommended for use where severe abrasion is encountered in service.

A7.4.2.7 Metal-to-Metal Wear. Copper-aluminum deposits with hardnesses of 130 to approximately 320 HB are used to overlay surfaces subjected to excessive wear from metal-to-metal contact. For example, ECuAl-E electrodes are used to surface dies, and to draw and form stainless and carbon steels and aluminum.

All of the copper-base alloy filler metals classified by this specification are used to deposit overlays and inlays for bearing surfaces, with the exception of the CuSi filler metals. Silicon bronzes are considered poor bearing alloys. Copper-base alloy filler metals selected for a bearing surface should produce a deposit of 50–75 HB under that of the mating part. Equipment should be designed so that the bearing will wear in preference to the mating part.

A7.4.2.8 Mechanical Properties in Compression. Deposits of the ECuAl filler metals have high elastic limits and ultimate strengths in compression ranging from 25 000–65 000 psi (172–448 MPa) and 120 000–171 000 psi (827–1179 MPa), respectively. The elastic limit of ECuSi deposits is around 22 000 psi (152 MPa) with an ultimate strength in compression of 60 000 psi

(414 MPa). The ECuSn deposits will have an elastic limit of 11 000 psi (76 MPa) and an ultimate strength of 32 000 psi (221 MPa).

A7.4.2.9 Machinability. All of these copper-base alloy deposits are machinable.

A7.4.2.10 Heat Treatment. Ordinarily, no heat treatment is needed in surfacing with copper-base alloy filler metals.

A7.4.2.11 Welding Characteristics. To minimize dilution from the base metal when surfacing with copper-base electrodes, the first layer should be deposited using as low an amperage as practical. Excessive base metal dilution can result in reduced machinability and service performance. The manufacturer should be consulted for specific welding parameters.

A7.4.2.12 Preheat. Generally, a preheat is not necessary unless the part is exceptionally large; in this case, a 200°F (93°C) preheat may be desirable to facilitate the smooth flow of the weld metal. At no time should the preheat temperature be above 400°F (205°C) when applying the first layer. On subsequent layers, an interpass temperature of approximately 200°–600°F (93°–316°C) will simplify deposition of the weld metal.

A7.5 Tungsten Carbide Electrodes

A7.5.1 Characteristics. Tungsten carbide covered electrodes contain 60 percent by weight tungsten carbide granules. The WC1 carbide is a mixture of WC and W_2C. The WC2 carbide is macrocrystalline WC. Hardness of the matrix of the deposit can be varied from 30 HRC to 60 HRC depending on welding technique. Hardness of individual carbide particles typically is about 2400 HV20. The abrasion resistance of tungsten carbide deposits is outstanding.

A7.5.2 Applications. Tungsten carbide deposits are applied on surfaces subjected to sliding abrasion combined with limited impact. Such applications are encountered in earth drilling, digging, and farming. Specific tools that may require this type of a surfacing overlay include oil drill bits and tool joints, earth handling augers, excavator teeth, farm fertilizer applicator knives, and cultivator shares.

A8. 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 A4, along with the year in which they were last included in the specification.

A9. General Safety Considerations

NOTE: 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 section A5 and below. Safety and health information is available from other sources, including but not limited to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

A9.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles, or the equivalent, to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flames. Aprons, cape sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load; disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.)

The following sources are for more detailed information on personal protection:

(1) American National Standards Institute. ANSI Z41, *American National Standard for Personal Protection—Protective Footwear.* New York, NY:ANSI.[7]

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[7] ANSI Standards may be obtained from the American National Standards Institute, 11 West 42 Street, New York, NY 10036.

TABLE A4
DISCONTINUED ELECTRODE AND ROD CLASSIFICATIONS[a]

AWS Classification	Last A5.13 (ASTM A 399) Publication Date	AWS Classification	Last A5.13 (ASTM A 399) Publication Date
RFeCr-A2	1956	ERCuAl-A3[c]	1980
EFeCr-A2	1956	RCuAl-C[b]	1980
ECuZn-E	1956	RCuAl-D[b]	1980
RCuAl-B	1970	RCuAl-E[b]	1980
RCuSn-E	1970	ERCuSn-A	1980
ECuSn-E	1970	RCuSn-D[b]	1980
RFe5-A	1980	RNiCr-A[b]	1980
RFe5-B	1980	RNiCr-B[b]	1980
RFeCr-A1	1980	RNiCr-C[b]	1980
RCoCr-A[b]	1980	EFe5-A	1980
RCoCr-B[b]	1980	EFe5-B	1980
RCoCr-C[b]	1980	EFe5-C	1980
RCuZn-E	1980	EFeCr-Al	1980
ERCuSi-A[c]	1980	ENiCr-A	1980
ERCuAl-A2[c]	1980	ENiCr-B	1980

NOTES:

a. See A8, Discontinued Classifications (in the Annex), for information on discontinued classifications.

b. These AWS classifications have been transferred to AWS A5.21:2001 with the revised prefix of "ER" for electrode/rod made from solid stock or prefix of "ERC" for electrode/rod made from metal or flux cored composite stock.

c. These AWS classifications have been transferred to AWS A5.21:2001 without a change in the classification designation for solid bare electrodes and rods or with the prefix "ERC" for electrode/rod made from metal of flux cored stock.

(2) American Welding Society. ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes.* Miami, FL: American Welding Society.[8]

(3) OSHA. *Code of Federal Regulations*, Title 29—Labor, Chapter XVII, Part 1910. Washington, DC: U.S. Government Printing Office.[9]

A9.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

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

The correct cable size should be used since sustained overloading will cause cable failure and can result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards such as ANSI Z49.1, *Safety*

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[8] AWS Standards may be obtained from the American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126.

[9] OSHA Standards may be obtained from the U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

in Welding, Cutting, and Allied Processes, and NFPA No. 70, *The National Electrical Code*, should be followed.[10]

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

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

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

Special precautions should be used when surfacing with electrodes of the EFeMn series and ECuMnNiAl classification. As a group, the fumes from these electrodes are rather voluminous and contain a significant concentration of manganese. Cumulative excessive overexposure to manganese present in welding fumes may affect the central nervous system. Effects may include muscular weakness, poor coordination, difficulty in speaking, and tremors of the arms or legs. These effects are considered irreversible.

The potential short term health effects resulting from excessive overexposure to copper welding fumes can include metal fume fever, muscle ache and respiratory irritation. The long term effects are not known.

The potential short term health effects resulting from excessive overexposure to cobalt welding fumes can include pulmonary irritation, coughing and dermatitis. The possible long term effects include lung fibrosis and respiratory hypersensitivity.

The potential short term effects resulting from excessive overexposure to chromium and nickel in the fume are symptoms such as nausea, headaches, respiratory irritation and skin rash. Some forms of hexavalent chromium and nickel are considered as carcinogens by the National Institute for Occupational Safety and Health (NIOSH). Additional information on the possible effects of exposure to chromium and nickel in the welding fume can be obtained from AWS Safety and Health Fact Sheet No. 4.

The omission of special precautions for other hazardous compounds found in welding fumes is not intended to minimize their potentially harmful effect on one's health.

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

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

(2) The recommended threshold limit values for these fumes and gases may be found in Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment, published by the American Conference of Governmental Industrial Hygienists (ACGIH).[11]

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

(4) Manufacturer's Material Safety Data Sheet (MSDS) for the product.

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

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

A9.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

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

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[10] NFPA documents are available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

[11] ACGIH documents are available from the American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1634.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(1) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(2) Exposed skin should be protected with adequate gloves and clothing as specified in ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

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

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

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

A9.4.3 Ionizing radiation information sources include the following:

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

(2) Manufacturer's product information literature.

A9.4.4 Nonionizing radiation information sources include:

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

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

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

(4) Hinrichs, J.F. "Project Committee on Radiation Summary Report." *Welding Journal* 57(1): 62–65.

(5) Marshall, W.J., D.H. Sliney, et al. Optical radiation levels produced by air-carbon arc cutting processes. *Welding Journal* 59(3): 43–46.

(6) Moss, C. E. and Murray, W.E. Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting. *Welding Journal* 58(9): 37–46.

(7) Moss, C. E. Optical radiation transmission levels through transparent welding curtains. *Welding Journal* 58(3): 69-s to 75-s.

(8) National Technical Information Service. Nonionizing Radiation Protection Special Study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service.[12]

(9) —. Nonionizing Radiation Protection Special Study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service.

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[12] National Technical Information documents are available from the National Technical Information Service, Springfield, VA 22161.

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SPECIFICATION FOR NICKEL AND NICKEL-ALLOY BARE WELDING ELECTRODES AND RODS

SFA-5.14/SFA-5.14M

(Identical with AWS Specification A5.14/A5.14M:2011. In case of dispute, the original AWS text applies.)

Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods

1. Scope

1.1 This specification prescribes requirements for the classification of bare nickel and nickel-alloy welding electrodes, strip electrodes, and welding rods. It includes those compositions where the nickel content exceeds that of any other element.

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

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification with the designation A5.14 uses U.S. Customary Units. The specification A5.14M 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 or both under A5.14 or A5.14M specifications.

2. Normative References

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

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

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

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

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

2.3 The following ANSI standard[2] is referenced in the mandatory sections of this document:

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

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

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

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

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

(2) ASTM E 76, *Standard Test Methods for Chemical Analysis of Nickel-Copper Alloys*

(3) ASTM E 354, *Standard Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys*

(4) ASTM E 1019, *Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques*

(5) ASTM E 1473, *Standard Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys*

2.5 The following ISO standards[4] are referenced in the mandatory sections of this document:

(1) *ISO 80000-1, Quantities and units — Part 1: General*

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

(3) ISO 18274, *Welding consumables — Wire and strip electrodes, wires and rods for arc welding of nickel and nickel alloys — Classifications*

2.6 The following MIL standard[5] is referenced in the mandatory sections of this document:

MIL-E-21562E *Military Specification—Electrodes and Rods—Welding, Bare, Nickel Alloy*

3. Classification

3.1 The welding filler metals covered by this A5.14/A5.14M:2011 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 filler metal, as specified in Table 1.

3.2 A filler metal classified under one classification shall not be classified under any other classification in this specification.

3.3 The filler metals classified under this specification are intended for use with the plasma arc, gas metal arc, gas tungsten arc, and submerged arc welding processes, but this is not to prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance[6] of the filler metal shall be in accordance with the provisions of 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.[7]

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[3] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[4] ISO standards are published by the International Organization of Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

[5] This MIL-E-21562E document are published by the Document Automation and Production Service, 700 Robbins Avenue, Bldg. 4D, Philadelphia, PA 19111-5094; ph: (215) 697-2179; fax: (215) 697-1462; internet: http://assist.daps.dla.mil/quicksearch.

[6] See Annex A, Clause A3, Acceptance, for further information concerning acceptance and testing of the material shipped, and AWS A5.01M/A5.01.

[7] See Clause A4 (in Annex A), Certification, for further information concerning certification and the testing called for to meet this requirement.

Table 1
Chemical Composition Requirements for Nickel and Nickel-Alloy Electrodes and Rods

		Weight Percent[a, b]																
AWS Classification[m]	UNS Number[c]	C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) Plus Ta	Mo	V	W	Other Elements, Total
ERNi-1[k]	N02061	0.15	1.0	1.0	0.03	0.015	0.75	0.25	93.0 min.	—	1.5	2.0 to 3.5	—	—	—	—	—	0.50
ERNiCu-7[k]	N04060	0.15	4.0	2.5	0.02	0.015	1.25	Rem	62.0 to 69.0	—	1.25	1.5 to 3.0	—	—	—	—	—	0.50
ERNiCu-8[k]	N05504	0.25	1.5	2.0	0.03	0.015	1.00	Rem	63.0 to 70.0	—	2.0 to 4.0	0.25 to 1.00	—	—	—	—	—	0.50
ERNiCr-3[k, l]	N06082	0.10	2.5 to 3.5	3.0	0.03	0.015	0.50	0.50	67.0 min.	(e)	—	0.75	18.0 to 22.0	2.0 to 3.0[f]	—	—	—	0.50
ERNiCr-4	N06072	0.01 to 0.10	0.20	0.50	0.02	0.015	0.20	0.50	Rem	—	—	0.3 to 1.0	42.0 to 46.0	—	—	—	—	0.50
ERNiCr-6[k]	N06076	0.08 to 0.15	1.00	2.00	0.03	0.015	0.30	0.50	75.0 min.	—	0.40	0.15 to 0.50	19.0 to 21.0	—	—	—	—	0.50
ERNiCr-7[r]	N06073	0.03	0.50	1.0	0.02	0.015	0.30	0.30	Rem	1.0	0.75 to 1.20	0.25 to 0.75	36.0 to 39.0	0.25 to 1.00	0.50	—	—	0.50
ERNiCrFe-5[k]	N06062	0.08	1.0	6.0 to 10.0	0.03	0.015	0.35	0.50	70.0 min.	(e)	—	—	14.0 to 17.0	1.5 to 3.0[f]	—	—	—	0.50
ERNiCrFe-6[k]	N07092	0.08	2.0 to 2.7	8.0	0.03	0.015	0.35	0.50	67.0 min.	—	—	2.5 to 3.5	14.0 to 17.0	—	—	—	—	0.50
ERNiCrFe-7[j]	N06052	0.04	1.0	7.0 to 11.0	0.02	0.015	0.50	0.30	Rem	—	1.10	1.0	28.0 to 31.5	0.10	0.50	—	—	0.50
ERNiCrFe-7A[j, p]	N06054	0.04	1.0	7.0 to 11.0	0.02	0.015	0.50	0.30	Rem	0.12	1.10	1.0	28.0 to 31.5	0.5 to 1.0	0.50	—	—	0.50
ERNiCrFe-8[k]	N07069	0.08	1.0	5.0 to 9.0	0.03	0.015	0.50	0.50	70.0 min.	—	0.4 to 1.0	2.00 to 2.75	14.0 to 17.0	0.70 to 1.20	—	—	—	0.50

(Continued)

Table 1 (Continued)
Chemical Composition Requirements for Nickel and Nickel-Alloy Electrodes and Rods

		Weight Percent[a, b]																
AWS Classification[m]	UNS Number[c]	C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) Plus Ta	Mo	V	W	Other Elements, Total
ERNiCrFe-11	N06601	0.10	1.0	Rem	0.03	0.015	0.50	1.0	58.0 to 63.0	—	1.0 to 1.7	—	21.0 to 25.0	—	—	—	—	0.50
ERNiCrFe-12	N06025	0.15 to 0.25	0.50	8.0 to 11.0	0.020	0.010	0.5	0.1	Rem	1.0	1.8 to 2.4	0.10 to 0.20	24.0 to 26.0	—	—	—	—	0.50
ERNiCrFe-13[r]	N06055	0.03	1.0	Rem	0.02	0.015	0.50	0.30	52.0 to 62.0	0.10	0.50	0.50	28.5 to 31.0	2.1 to 4.0	3.0 to 5.0	—	—	0.50
ERNiCrFe-14	*N06043*	*0.04*	*3.0*	*7.0 to 12.0*	*0.020*	*0.015*	*0.50*	*0.30*	*Rem.*	—	*0.50*	*0.50*	*28.0 to 31.5*	*1.0 to 2.5*[s]	*0.50*	—	—	*0.50*
ERNiCrFeSi-1	N06045	0.05 to 0.12	1.0	21.0 to 25.0	0.020	0.010	2.5 to 3.0	0.3	Rem	1.0	0.30	—	26.0 to 29.0	—	—	—	—	0.50
ERNiCrFeAl-1	N06693	0.15	1.0	2.5 to 6.0	0.03	0.01	0.5	0.5	Rem	—	2.5 to 4.0	1.0	27.0 to 31.0	0.5 to 2.5	—	—	—	0.50
ERNiFeCr-1[k]	N08065	0.05	1.0	22.0 min.	0.03	0.03	0.50	1.5 to 3.0	38.0 to 46.0	—	0.20	0.6 to 1.2	19.5 to 23.5	—	2.5 to 3.5	—	—	0.50
ERNiFeCr-2[g]	N07718	0.08	0.35	Rem	0.015	0.015	0.35	0.30	50.0 to 55.0	—	0.20 to 0.80	0.65 to 1.15	17.0 to 21.0	4.75 to 5.50	2.80 to 3.30	—	—	0.50
ERNiMo-1	N10001	0.08	1.0	4.0 to 7.0	0.025	0.03	1.0	0.50	Rem	2.5	—	—	1.0	—	26.0 to 30.0	0.20 to 0.40	1.0	0.50
ERNiMo-2	N10003	0.04 to 0.08	1.0	5.0	0.015	0.02	1.0	0.50	Rem	0.20	—	—	6.0 to 8.0	—	15.0 to 18.0	0.50	0.50	0.50
ERNiMo-3	N10004	0.12	1.0	4.0 to 7.0	0.04	0.03	1.0	0.50	Rem	2.5	—	—	4.0 to 6.0	—	23.0 to 26.0	0.60	1.0	0.50
ERNiMo-7	N10665	0.02	1.0	2.0	0.04	0.03	0.10	0.50	Rem	1.0	—	—	1.0	—	26.0 to 30.0	—	1.0	0.50

(Continued)

Table 1 (Continued)
Chemical Composition Requirements for Nickel and Nickel-Alloy Electrodes and Rods

AWS Classification[m]	UNS Number[c]	Weight Percent[a, b]																
		C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) Plus Ta	Mo	V	W	Other Elements, Total
ERNiMo-8	N10008	0.10	1.0	10.0	0.015	0.015	0.50	0.50	60.0 min.	—	—	—	0.5 to 3.5	—	18.0 to 21.0	—	2.0 to 4.0	0.50
ERNiMo-9	N10009	0.10	1.0	5.0	0.015	0.015	0.50	0.3 to 1.3	65.0 min.	—	1.0	—	—	—	19.0 to 22.0	—	2.0 to 4.0	0.50
ERNiMo-10[n]	N10675	0.01	3.0	1.0 to 3.0	0.03	0.01	0.10	0.20	65.0 min.	3.0	0.50	0.20	1.0 to 3.0	0.20	27.0 to 32.0	0.20	3.0	0.50
ERNiMo-11	N10629	0.010	1.0	2.0 to 5.0	0.020	0.010	0.10	0.5	Rem	1.0	0.1 to 0.5	0.30	0.5 to 1.5	0.50	26.0 to 30.0	—	—	0.50
ERNiMo-12[g]	N10242	0.03	0.80	2.0	0.030	0.015	0.80	0.50	Rem	1.0	0.50	—	7.0 to 9.0	—	24.0 to 26.0	—	—	—
ERNiCrMo-1	N06007	0.05	1.0 to 2.0	18.0 to 21.0	0.04	0.03	1.0	1.5 to 2.5	Rem	2.5	—	—	21.0 to 23.5	1.75 to 2.50	5.5 to 7.5	—	1.0	0.50
ERNiCrMo-2	N06002	0.05 to 0.15	1.0	17.0 to 20.0	0.04	0.03	1.0	0.50	Rem	0.5 to 2.5	—	—	20.5 to 23.0	—	8.0 to 10.0	—	0.2 to 1.0	0.50
ERNiCrMo-3[k]	N06625	0.10	0.50	5.0	0.02	0.015	0.50	0.50	58.0 min.	—	0.40	0.40	20.0 to 23.0	3.15 to 4.15	8.0 to 10.0	—	—	0.50
ERNiCrMo-4	N10276	0.02	1.0	4.0 to 7.0	0.04	0.03	0.08	0.50	Rem	2.5	—	—	14.5 to 16.5	—	15.0 to 17.0	0.35	3.0 to 4.5	0.50
ERNiCrMo-7	N06455	0.015	1.0	3.0	0.04	0.03	0.08	0.50	Rem	2.0	—	0.70	14.0 to 18.0	—	14.0 to 18.0	—	0.50	0.50
ERNiCrMo-8	N06975	0.03	1.0	Rem	0.03	0.03	1.0	0.7 to 1.2	47.0 to 52.0	—	—	0.70 to 1.50	23.0 to 26.0	—	5.0 to 7.0	—	—	0.50
ERNiCrMo-9	N06985	0.015	1.0	18.0 to 21.0	0.04	0.03	1.0	1.5 to 2.5	Rem	5.0	—	—	21.0 to 23.5	0.50	6.0 to 8.0	—	1.5	0.50

(Continued)

Table 1 (Continued)
Chemical Composition Requirements for Nickel and Nickel-Alloy Electrodes and Rods

AWS Classification[m]	UNS Number[c]	Weight Percent[a, b]																
		C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) Plus Ta	Mo	V	W	Other Elements, Total
ERNiCrMo-10	N06022	0.015	0.50	2.0 to 6.0	0.02	0.010	0.08	0.50	Rem	2.5	—	—	20.0 to 22.5	—	12.5 to 14.5	0.35	2.5 to 3.5	0.50
ERNiCrMo-11	N06030	0.03	1.5	13.0 to 17.0	0.04	0.02	0.80	1.0 to 2.4	Rem	5.0	—	—	28.0 to 31.5	0.30 to 1.50	4.0 to 6.0	—	1.5 to 4.0	0.50
ERNiCrMo-13	N06059	0.010	0.5	1.5	0.015	0.010	0.10	0.50	Rem	0.3	0.1 to 0.4	—	22.0 to 24.0	—	15.0 to 16.5	—	—	0.50
ERNiCrMo-14	N06686	0.01	1.0	5.0	0.02	0.02	0.08	0.5	Rem	—	0.5	0.25	19.0 to 23.0	—	15.0 to 17.0	—	3.0 to 4.4	0.50
ERNiCrMo-15	N07725	0.03	0.35	Rem	0.015	0.01	0.20	—	55.0 to 59.0	—	0.35	1.0 to 1.7	19.0 to 22.5	2.75 to 4.00	7.0 to 9.5	—	—	0.50
ERNiCrMo-16	N06057	0.02	1.0	2.0	0.04	0.03	1.0	—	Rem	—	—	—	29.0 to 31.0	—	10.0 to 12.0	0.4	—	0.50
ERNiCrMo-17	N06200	0.010	0.5	3.0	0.025	0.010	0.08	1.3 to 1.9	Rem	2.0	0.50	—	22.0 to 24.0	—	15.0 to 17.0	—	—	0.50
ERNiCrMo-18[o]	N06650	0.03	0.5	12.0 to 16.0	0.020	0.010	0.50	0.30	Rem	1.0	0.05 to 0.50	—	19.0 to 21.0	0.05 to 0.50	9.5 to 12.5	0.30	0.5 to 2.5	0.50
ERNiCrMo-19[q]	N06058	0.01	0.5	1.5	0.015	0.010	0.10	0.50	Rem	0.3	0.4	—	20.0 to 23.0	—	19.0 to 21.0	—	0.3	0.50
ERNiCrMo-20	N06660	0.03	0.5	2.0	0.015	0.015	0.5	0.3	Rem	0.2	0.4	0.4	21.0 to 23.0	0.2	9.0 to 11.0	—	2.0 to 4.0	—
ERNiCrMo-21	N06205	0.03	0.5	1.0	0.015	0.015	0.5	0.2	Rem	0.2	0.4	0.4	24.0 to 26.0	—	14.0 to 16.0	—	0.3	—
ERNiCrMo-22	N06035	0.050	0.50	2.00	0.030	0.015	0.60	0.30	Rem	1.00	0.40	0.2	32.25 to 34.25	0.5	7.60 to 9.00	0.20	0.60	0.50

(Continued)

Table 1 (Continued)
Chemical Composition Requirements for Nickel and Nickel-Alloy Electrodes and Rods

		Weight Percent[a, b]																
AWS Classification[m]	UNS Number[c]	C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) Plus Ta	Mo	V	W	Other Elements, Total
ERNiCrCoMo-1	N06617	0.05 to 0.15	1.0	3.0	0.03	0.015	1.0	0.50	Rem	10.0 to 15.0	0.8 to 1.5	0.60	20.0 to 24.0	—	8.0 to 10.0	—	—	0.50
ERNiCoCrSi-1	N12160	0.02 to 0.10	1.0	3.5	0.030	0.015	2.4 to 3.0	0.50	Rem	27.0 to 32.0	0.40	0.20 to 0.60	26.0 to 29.0	0.30	0.7	—	0.5	0.50
ERNiCrWMo-1[h, i]	N06231	0.05 to 0.15	0.3 to 1.0	3.0	0.03	0.015	0.25 to 0.75	0.50	Rem	5.0	0.2 to 0.5	—	20.0 to 24.0	—	1.0 to 3.0	—	13.0 to 15.0	0.50

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[a] The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of the work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

[b] Single values are maximum, except where otherwise specified. Rem = remainder.

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

[d] Includes incidental cobalt.

[e] Co is 0.12 maximum when specified by the purchaser.

[f] MIL-E-21562 grade; Ta is 0.30 maximum.

[g] Boron is 0.006 maximum.

[h] Boron is 0.003 maximum.

[i] La is 0.050 maximum.

[j] Al + Ti is 1.5 maximum.

[k] MIL-E-21562 grade; Pb < 0.010. "Other Elements Total" shall include Pb, Sn, Zn.

[l] MIL-E-21562 grades EN82H or RH82H; Carbon is 0.03 to 0.10.

[m] For strip, the classification designator "R" shall be replaced with "Q."

[n] Ni + Mo is 94.0 to 98.0; Ta is 0.02 maximum; Zr is 0.10 maximum.

[o] Nitrogen is 0.05 to 0.20.

[p] B is 0.005 maximum and Zr is 0.02 maximum.

[q] Nitrogen is 0.02 to 0.15.

[r] B is 0.003 maximum and Zr is 0.02 maximum.

[s] *Ta is 0.10 maximum.*

6. Rounding-Off Procedure

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E 29 or ISO 80000-1, Part 1, General. If the measured values are obtained by equipment calibrated in units other than those of the specified limit, the measured values shall be converted to the units of the specified limit before rounding off. If an average value is to be compared to the specified limit, rounding off shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi for tensile strength for A5.14 [to the nearest 10 MPa for tensile strength for A5.14M] 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

Chemical analysis of the filler metal, or the stock from which it was made, is the only test required for classification of a product under this specification.

8. Retest

If the results of any test fail to meet the requirement of that test, that test shall be repeated twice. The results of both retests shall meet the requirement. Material for retest may be taken from the original test sample or from a new sample. 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 test specimen(s) or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed, or whether test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case, the requirement for doubling of the number of test specimens does not apply.

9. Chemical Analysis

9.1 A sample of the filler metal, or the stock from which it was made, shall be prepared for chemical analysis.

9.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 1473, supplemented by ASTM E 1019 and ASTM E 354 for nickel base alloys, and ASTM E 76 for nickel-copper alloys, as appropriate.

9.3 The results of the analysis shall meet the requirements set forth in Table 1, for the classification of filler metal under test.

10. Method of Manufacture

The filler metals classified according to this specification may be made by any method that will produce material that meets the requirements of this specification.

11. Standard Sizes

11.1 Standard sizes for filler metal in the different package forms (straight lengths, coils with support, coils without support, and spools) (see Clause 13) are shown in Table 2.

11.2 Standard sizes for strip electrodes in coils (see Clause 13) are shown in Table 3.

Table 2
Standard Sizes of Electrodes and Rods[a]

	Diameter		Tolerance[b]	
Standard Package Form	in	mm	in	mm
Straight length,[c] coils with supports and coils without supports	1/16	1.6	±0.002	+0.01, –0.07
	3/32	2.4		
	—	2.5		
	1/8	3.2		
	5/32	4.0		
	3/16	4.8[d]		
	—	5.0		
	1/4	6.4[d]		
Spools	0.020	0.5	+0.001, –0.002	+0.01, –0.04
	0.030	0.8		
	0.035	0.9		
	0.045	1.14[d]		
	—	1.2		
	0.062 (1/16)	1.6		

[a] Dimensions, sizes, tolerances, and package forms other than those shown shall be agreed upon by the purchaser and supplier.
[b] Out of roundness (the difference between the major and minor diameters) shall not exceed one-half of the tolerance.
[c] Length shall be 36 in +0, –1/2 in [900 mm ± 2%].
[d] Metric sizes not shown in ISO 544.

Table 3
Standard Sizes of Strip Electrodes[a,b]

Width		Thickness	
in	mm	in	mm
1.18	30	0.020	0.5
2.36	60		
3.54	90		
4.72	120		

[a] Other sizes shall be as agreed upon by the purchaser and supplier.
[b] Strip electrodes shall not vary more than ±0.008 in [±0.20 mm] in width and more than ±0.002 in [±0.05 mm] in thickness.

12. Finish and Uniformity

12.1 All filler metal 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, the operation of the welding equipment, or the properties of the weld metal.

12.2 Each continuous length of filler metal shall be from a single heat 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.

13. Standard Package Forms

13.1 Standard package forms are straight lengths, coils with support, coils without support, and spools. Standard package dimensions and weights for each form are given in Table 4. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.

Table 4
Standard Package Dimensions and Weights[a]

Bare Wire, Rods

Electrode Size[b]		Net Weight[c]		Width		Diameter[h] Inside		Outside, Max.	
in	mm	lb	kg	in	mm	in	mm	in	mm
Straight Lengths									
1/16–1/4	1.6–6.4	5	2.2	—	—	—	—	—	—
		10	4.5	—	—	—	—	—	—
		25	11	—	—	—	—	—	—
Coils with Support									
1/16–1/4	1.6–6.4	25	11	2.5	65	12	305	17.5	445
		50	23						
1/16–1/4	1.6–6.4	60	27	4.6	120	12	305	17	430
1/16–1/4	1.6–6.4	100	45	5	125	— Not Specified[d] —		31.5	800
		150	68						
		200	91						
Coils without Support									
1/16–1/4	1.6–6.4	— as agreed by the purchaser and supplier —							
Spools[e]									
0.020–0.062	0.5–1.6	2[f]	0.9[f]					4	102
		10[f]	4.5[f]					8	203
		25[g]	11.0[g]					12	305

Strip Electrodes

Strip Width		Net Weight[c]		Diameter[h] Inside	
in	mm	lb	kg	in	mm
1.18	30	60	30	12	300
2.36	60	60	30		
3.54	90	120	55		
4.72	120	120	55		

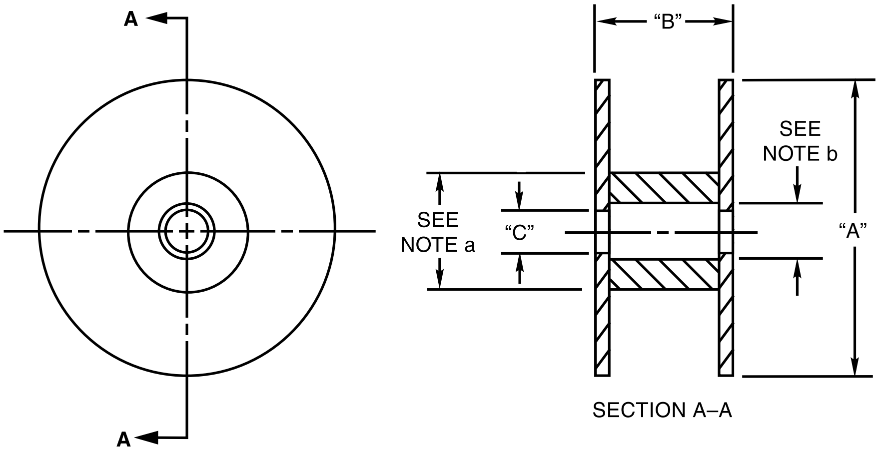
[a] Sizes, weights, and dimensions other than those listed above shall be agreed upon by the purchaser and supplier.
[b] The range is inclusive, as shown in Table 2.
[c] Net weights shall not vary more than ±10%.
[d] The inside diameter of the liner shall be agreed upon by the purchaser and the supplier.
[e] The dimensions of standard spools are specified in Figure 1.
[f] Tolerance is ±20%.
[g] Tolerance is ±20%, except that 20% of any lot may contain spools that vary in net weight from 12.5 lb to 20 lb [5.76 kg to 9.110 kg].
[h] Tolerance is ±1/8 in [±3 mm].

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

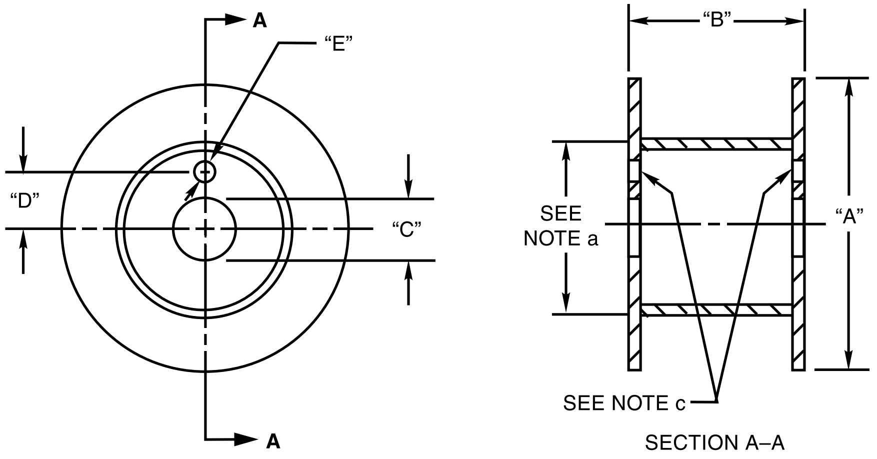
13.3 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal (see Figure 1).

14. Winding Requirements

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



DIMENSIONS OF STANDARD 4 in [100 mm] SPOOL



DIMENSIONS OF STANDARD 8 in AND 12 in [200 mm AND 300 mm] SPOOLS

		DIMENSIONS					
		4 in [100 mm] Spools		8 in [200 mm] Spools		12 in [300 mm] Spools	
		in	mm	in	mm	in	mm
A	Diameter, max.[d]	4.0	100	8.0	200	12	300
B	Width Tolerance	1.75 ±0.03	46 +0, –2	2.16 ±0.03	56 +0, –3	4.0 ±0.06	103 +0, –3
C	Diameter Tolerance	0.63 +0.01, –0	16 +1, –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
E	Diameter[c] Tolerance	—	—	0.44 +0, –0.06	10 +1, –0	0.44 +0, –0.06	10 +1, –0

[a] Outside diameter of barrel shall be such as to permit proper feeding of the filler metals.

[b] 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 core of the spool being less than the inside diameter of the flanges (dimension "C").

[c] Holes are provided on each flange, but they need not be aligned.

[d] 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 1—Dimensions of Standard Spools

14.2 The cast and helix of filler metal in coils shall be such that the filler metal will feed in an uninterrupted manner on automatic and semiautomatic equipment.

14.3 The cast and helix of filler metal on 4 in [100 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) form a circle not less than 2.5 in [60 mm] nor more than 15 in [380 mm] in diameter, and

(2) rise above the flat surface no more than 1/2 in [13 mm] at any location.

14.4 The cast and helix of filler metal on 8 in [200 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) form a circle not less than 10 in [250 mm] nor more than 35 in [890 mm] in diameter, and

(2) rise above the flat surface no more than 3/4 in [19 mm] at any location.

14.5 The cast and helix of filler metal on 12 in [300 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) form a circle not less than 15 in [380 mm] nor more than 50 in [1300 mm] in diameter, and

(2) rise above the flat surface no more than 1 in [25 mm] at any location.

15. Filler Metal Identification

15.1 The product information and the precautionary information required in Clause 17 for marking each package shall also appear on each coil and spool.

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

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

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

16. Packaging

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

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 designation (year of issue may be excluded). Additionally, the numerical classification number from ISO 18274 may be applied as a reference designation, provided the requirements of ISO 18274 are satisfied (see A2.4 in Annex A and Table A.1).

(2) Supplier's name and trade designation

(3) Size and net weight

(4) Lot, control, or heat number

17.2 The appropriate precautionary information[8] given in ANSI Z49.1, latest edition (as a minimum), shall be prominently displayed in legible print on all packages, including individual unit packages within a larger package.

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

Annex A

Guide to AWS Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods

This annex is not part of AWS A5.14/A5.14M:2011, *Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*, but is included for informational purposes only.

A1. Introduction

The purpose of this guide is to correlate the nickel and nickel-alloy bare welding electrodes and rods classifications with their intended applications so they can be used effectively. Reference to appropriate base-metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than a complete listing of the materials for which each filler metal is suitable.

A2. Classification System

A2.1 The system for classifying the filler metals in this specification follows the standard pattern used in other AWS filler metal specifications. The letters "ER" at the beginning of each classification designation stand for electrode and rod, indicating that the filler metal may be used either way. The substitution of the letters "EQ" for "ER" at the beginning of a classification indicates that the product is being supplied as strip electrode (see Table 1, Note m).

A2.2 Since the filler metals are classified according to their chemical composition, the chemical symbol "Ni" appears immediately after the "ER" (or "EQ") as a means of identifying the filler metal as a nickel-base alloy. The other symbols (Al, Cr, Co, Cu, Fe, Mo, Si and W) in the designations are intended to group the filler metals according to their principal alloying elements. The individual designations are made up of these symbols plus a number at the end of the designation (ERNiMo-1 or ERNiMo-2, for example). These numbers separate one composition from another within a group and are not repeated within that group.

A2.3 From an application point of view, most of the filler metal classifications in this specification have a corresponding classification in AWS A5.11/A5.11M, *Specification for Nickel and Nickel-Alloy Covered Welding Electrodes*. For those cases in which there is a corresponding application for a bare electrode or rod "ER" and a covered electrode "E," Table A.1 correlates the "ER" classification in this edition with those in the previous edition of this specification and with the corresponding covered electrode "E" classification in AWS A5.11/A5.11M. It also lists the current designation for each classification as it is given in Military Specification MIL-E-21562E, when such a designation exists.

A2.4 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table A.1 shows those used in ISO 18274 specification for comparison with comparable classifications in this specification. To understand the proposed international designation system, one is referred to Table 10C of the annex of the AWS document IFS:2002, *International Index of Welding Filler Metal Classifications*.

Table A.1
Comparison of Classifications[a]

Present Classification[b]	UNS Number	Military Designation[c]	Corresponding Classification in A5.11/A5.11M	ISO 18274 Designation[d]
ERNi-1	N02061	EN61 & RN61	ENi -1	SNi 2061
ERNiCu-7	N04060	EN60 & RN60	ENiCu-7	SNi 4060
ERNiCu-8	N05504	EN64 & RN64	—	SNi 5504
ERNiCr-3	N06082	EN82 & RN82 EN82H & RN82H	ENiCrFe-3	SNi 6082
ERNiCr-4	N06072	—	—	SNi 6072
ERNiCr-6	N06076	EN6N & RN6N	—	SNi 6076
ERNiCr-7	N06073	—	—	—
ERNiCrFe-5	N06062	EN62 & RN62	ENiCrFe-1	SNi 6062
ERNiCrFe-6	N07092	EN6A & RN6A	ENiCrFe-2	SNi 7092
ERNiCrFe-7	N06052	—	ENiCrFe-7	SNi 6052
ERNiCrFe-7A	N06054	—	—	—
ERNiCrFe-8	N07069	RN69	—	SNi 7069
ERNiCrFe-11	N06601	—	—	SNi 6601
ERNiCrFe-12	N06025	—	ENiCrFe-12	SNi 6025
ERNiCrFe-13	N06055	—	—	—
ERNiCrFe-14	*N06043*	—	—	*SNi 6043*
ERNiCrFeSi-1	N06045	—	ENiCrFeSi-1	—
ERNiCrFeAl-1	N06693	—	—	SNi 6693
ERNiFeCr-1	N08065	RN65	—	SNi 8065
ERNiFeCr-2	N07718	—	—	SNi 7718
ERNiMo-1	N10001	—	ENiMo-1	SNi 1001
ERNiMo-2	N10003	—	—	SNi 1003
ERNiMo-3	N10004	—	ENiMo-3	SNi 1004
ERNiMo-7	N10665	—	ENiMo-7	SNi 1066
ERNiMo-8	N10008	—	ENiMo-8	SNi 1008
ERNiMo-9	N10009	—	ENiMo-9	SNi 1009
ERNiMo-10	N10675	—	ENiMo-10	SNi 1067
ERNiMo-11	N10629	—	ENiMo-11	SNi 1069
ERNiMo-12	N10242	—	—	—
ERNiCrMo-1	N06007	—	ENiCrMo-1	—
ERNiCrMo-2	N06002	—	ENiCrMo-2	SNi 6002
ERNiCrMo-3	N06625	EN625 & RN625	ENiCrMo-3	SNi 6625
ERNiCrMo-4	N10276	—	ENiCrMo-4	SNi 6276
ERNiCrMo-7	N06455	—	ENiCrMo-7	SNi 6455
ERNiCrMo-8	N06975	—	—	SNi 6975
ERNiCrMo-9	N06985	—	ENiCrMo-9	SNi 6985
ERNiCrMo-10	N06022	—	ENiCrMo-10	SNi 6022
ERNiCrMo-11	N06030	—	ENiCrMo-11	SNi 6030
ERNiCrMo-13	N06059	—	ENiCrMo-13	SNi 6059
ERNiCrMo-14	N06686	—	ENiCrMo-14	SNi 6686
ERNiCrMo-15	N07725	—	ENiCrMo-17	SNi 7725
ERNiCrMo-16	N06057	—	ENiCrMo-18	SNi 6057
ERNiCrMo-17	N06200	—	ENiCrMo-19	SNi 6200
ERNiCrMo-18	N06650	—	—	SNi 6650
ERNiCrMo-19	N06058	—	—	—
ERNiCrMo-20	N06660	—	—	SNi 6660
ERNiCrMo-21	N06205	—	—	SNi 6205
ERNiCrMo-22	N06035	—	—	—
ERNiCrCoMo-1	N06617	—	ENiCrCoMo-1	SNi 6617
ERNiCoCrSi-1	N12160	—	—	SNi 6160
ERNiCrWMo-1	N06231	—	ENiCrWMo-1	SNi 6231

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

[b] For strip, the classification designator "R" shall be replaced with "Q."

[c] MIL-E-21562E.

[d] For strip, the classification designator "S" shall be replaced with "B."

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, shall 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 is normally conducted 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 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 tests of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01M/A5.01.

A5. Ventilation During Welding

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

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

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

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

(4) The proximity of the welder or welding operator to the fumes as they issue from the welding zone and to the gases and dust in the space in which the welder is 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 of that document dealing with ventilation.

A6. Welding Considerations

A6.1 The filler metals in this specification can be used with any of a variety of welding processes. Most notable among them are gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), submerged arc welding (SAW), and plasma arc welding (PAW). SAW and PAW are quite specialized, and the supplier of the filler metals should be consulted for recommendations concerning their use. General suggestions are given below for the other two processes.

A6.2 Before welding or heating any nickel-base alloy, the base metal must be clean. Oil, grease, paint, lubricants, marking pencils, temperature indicating materials, threading compounds, and other such materials frequently contain sulfur or lead that may cause cracking (embrittlement) of the base metal or the weld metal if present during welding or heating.

A6.3 For GTAW, direct current–electrode negative (dcen) is used. High-purity grades of either argon or helium (or a combination of the two) are used as a shielding gas.

A6.4 For GMAW, direct current–electrode positive (dcep) is employed. Argon shielding gas is often used, but mixtures of argon and helium are also commonly used.

A7. Description and Intended Use of Electrodes and Rods

A7.1 ERNi-1 Classification. The nominal composition (wt %) of filler metal of this classification is 96 Ni, 3 Ti. Filler metal of this classification is intended for welding wrought and cast forms of commercially pure nickel alloy (ASTM B 160, B 161, B 162, and B 163 having UNS number N02200 or N02201) to itself using the GTAW, GMAW, SAW, and PAW processes. The filler metal contains sufficient titanium to control weld-metal porosity with these welding processes.

A7.2 ERNiCu-X Classifications

A7.2.1 ERNiCu-7 Classification. The nominal composition (wt %) of filler metal of this classification is 65 Ni, 30 Cu, 3 Mn, and 2 Ti. Filler metal of this classification is used for welding nickel-copper alloy (ASTM B 127, B 163, B 164, and B 165 having UNS number N04400) to itself using the GTAW, GMAW, SAW, and PAW processes. The filler metal contains sufficient titanium to control porosity with these welding processes.

A7.2.2 ERNiCu-8 Classification. The nominal composition (wt %) of filler metal of this classification is 66 Ni, 29 Cu, 3 Al, 1 Fe, and 0.5 Ti. Filler metal of this classification is used for welding age-hardening nickel-copper alloy (ASTM F 467 and F 468 having UNS number N05500) to itself using the GTAW, GMAW, SAW, and PAW processes. The filler metal will age harden on heat treatment. For specific information concerning age hardening, consult the supplier or the supplier's technical literature.

A7.3 ERNiCr-X Classifications

A7.3.1 ERNiCr-3. The nominal composition (wt %) of filler metal of this classification is 72 Ni, 20 Cr, 3 Mn, 2.5 Nb plus Ta. Filler metal of this classification is used for welding nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, and B 168 having UNS number N06600) to itself, for the clad side of joints in steel clad with nickel-chromium-iron alloy, for surfacing steel with nickel-chromium-iron weld metal, for dissimilar welding of nickel-base alloys, and for joining steel to stainless steel or nickel-base alloys using the GTAW, GMAW, SAW, and PAW processes.

A7.3.2 ERNiCr-4. The nominal composition (wt %) of filler metal of this classification is 55 Ni, 44 Cr. Filler metal of this classification is used for GTAW of 50/50 nickel/chromium alloy, cladding nickel/chromium alloy onto nickel-iron-chromium tubing, and casting repair. The filler metal is resistant to high-temperature corrosion, including fuel-ash corrosion in atmospheres containing sulfur and vanadium.

A7.3.3 ERNiCr-6. The nominal composition (wt %) of filler metal of this classification is 78 Ni, 20 Cr, 1 Fe, and 0.4 Ti. Filler metal of this classification is used for welding nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, and B 168 having UNS number N06600) to itself, for the clad side of joints in steel clad with nickel-chromium-iron alloy, for surfacing steel with nickel-chromium-iron weld metal, and for joining steel to nickel-base alloys using the GTAW, GMAW, SAW, and PAW processes.

A7.3.4 ERNiCr-7. The nominal composition (wt %) of filler metal of this classification is 60 Ni, 37.5 Cr, 0.95 Al, and 0.6 Nb. Filler metal of this classification is used for the overlay cladding of ferrous materials used in high temperature applications, and the welding of nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, and B 168 having UNS number N06690) to itself, and to steels, using the GTAW, GMAW, SAW, ESW, and PAW processes. Welds made with this composition are particularly resistant to high temperature oxidation, carburization, and sulfidation.

A7.4 ERNiCrFe-X Classifications

A7.4.1 ERNiCrFe-5. The nominal composition (wt %) of filler metal of this classification is 74 Ni, 16 Cr, 8 Fe, 2 Nb plus Ta. Filler metal of this classification is used for welding nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, and B 168 having UNS number N06600) to itself using the GTAW, GMAW, SAW, and PAW processes. The higher niobium content of the filler metal is intended to minimize cracking where high welding stresses are encountered, as in thick-section base metal.

A7.4.2 ERNiCrFe-6. The nominal composition (wt %) of filler metal of this classification is 71 Ni, 16 Cr, 6 Fe, 3 Ti, and 2.5 Mn. Filler metal of this classification is used for cladding steel with nickel-chromium-iron weld metal and for joining steel to nickel-base alloys using the GTAW, GMAW, SAW, and PAW processes. The filler metal will age harden on heat treatment. For specific information concerning age hardening, consult the supplier or the supplier's technical literature.

A7.4.3 ERNiCrFe-7. The nominal composition (wt %) of filler metal of this classification is 60 Ni, 29 Cr, and 9 Fe. Filler metal of this classification is used for welding nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, and B 168 having UNS number N06690) to itself, to steels, to overlay on steels, and to weld steels clad with the nickel-chromium-iron alloys using the GTAW, GMAW, SAW, and PAW processes.

A7.4.4 ERNiCrFe-7A. The nominal composition (wt %) of filler metal of this classification is 60 Ni, 29 Cr, 9 Fe, 0.75 Nb. Filler metal of this composition is used for welding nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, and B 168 having UNS number N06690) to itself, to steels, and to weld overlay steels using the GTAW, GMAW, SAW, ESW, and PAW processes. Welds made with this composition are particularly resistant to ductility-dip-cracking (DDC) and oxide inclusions.

A7.4.5 ERNiCrFe-8. The nominal composition (wt %) of filler metal of this classification is 73 Ni, 15.5 Cr, 7 Fe, 2.4 Ti, 1 Nb, and 0.7 Al. Filler metal of this classification is used for cladding steel with nickel-chromium-iron weld metal and for joining steel to nickel-base alloys using the GTAW, GMAW, SAW, and PAW processes. The weld metal will age harden on heat treatment. For specific information concerning age hardening, consult the supplier or the supplier's technical literature.

A7.4.6 ERNiCrFe-11. The nominal composition (wt %) of filler metal of this classification is 61 Ni, 23 Cr, 14 Fe, and 1.4 Al. Filler metal of this classification is used for welding nickel-chromium-iron-aluminum alloy (ASTM B 166, B 167, and B 168 having UNS number N06601) to itself and to other high-temperature compositions using the GTAW process. It is used for severe applications where the exposure temperature can exceed 2100°F [1150°C].

A7.4.7 ERNiCrFe-12. The nominal chemical composition (wt %) of filler metal of this classification is 63 Ni, 25 Cr, 9.5 Fe, 2.1 Al. Filler metal of this classification is used for welding UNS number N06025, welding nickel-chrome-iron to steel and to other nickel base alloys. The ASTM specifications for UNS number N06025 are B 163, B 166, B 167, B 168, B 366, B 516, B 517, B 546, and B 564.

A7.4.8 ERNiCrFe-13. The nominal composition (wt %) of filler metal of this classification is 55 Ni, 30 Cr, 8 Fe, 4 Mo, and 3 Nb. Filler metal of this classification is used for welding nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, and B 168 having UNS number N06690) to itself, to steels, and to weld overlay steels using the GTAW, GMAW, SAW, ESW, and PAW processes. Welds made with this composition are particularly resistant to ductility-dip-cracking (DDC), and oxide inclusions.

__A7.4.9 ERNiCrFe-14.__ The nominal composition (wt %) of filler metal for this classification is 57 Ni, 30 Cr, 9 Fe, and 1.8 Nb. Filler metal of this classification is used to produce nickel-chromium-iron weld overlays on steel comparable to UNS number N06690. Weld deposits made with this composition are particularly resistant to ductility-dip-cracking (DDC), especially in the case of wire/flux combination.

A7.5 ERNiFeCr-X Classifications

A7.5.1 ERNiFeCr-1. The nominal composition (wt %) of filler metal of this classification is 42 Ni, 30 Fe, 21 Cr, 3 Mo, and 2 Cu. Filler metal of this classification is used for welding the nickel-iron-chromium-molybdenum-copper alloy (ASTM B 423 having UNS number N08825) to itself using the GTAW and GMAW processes.

A7.5.2 ERNiFeCr-2. The nominal composition (wt %) of filler metal of this classification is 52 Ni, 18 Fe, 19 Cr, 5 Nb plus Ta, 3 Mo, 1Ti. Filler metal of this classification is used for welding nickel-chromium-niobium-molybdenum alloy (ASTM B 637 and AMS 5589 having UNS number N07718) to itself using the GTAW processes. The weld metal will age harden on heat treatment. For specific information concerning age hardening, consult the supplier or the supplier's technical literature.

A7.6 ERNiCrFeSi-1 Classification. The nominal chemical composition (wt %) of filler metal of this classification is 46 Ni, 28 Cr, 2.75 Si, 23 Fe. Filler metal of this classification is used for welding nickel-chromium-iron alloy (ASTM B 163, B 166, B 167, B 168, B 366, B 516, B 517, B 546, and B 564 having UNS number N06045) to itself, to steel, and to other nickel base alloys.

A7.7 ERNiCrFeAl-1 Classification. The nominal composition (wt %) of filler metal of this classification is 59 Ni, 29 Cr, 4 Fe, 3 Al. Filler metal of this classification is used for welding nickel-chromium-iron alloy (ASTM B 166, B 167, and B 168 having UNS number N06693) to itself, to steels, and to weld overlay steels using the GTAW and GMAW processes. Welds made with this composition are particularly resistant to metal dusting in chemical and petrochemical applications. The alloy is resistant to carburization, sulfidation, and other high temperature corrosion forms.

A7.8 ERNiMo-X Classifications

A7.8.1 ERNiMo-1. The nominal composition (wt %) of filler metal of this classification is 66 Ni, 28 Mo, and 5.5 Fe. Filler metal of this classification is used for welding nickel-molybdenum alloy (ASTM B 333 having UNS number N10001) to itself using the GTAW and GMAW processes.

A7.8.2 ERNiMo-2. The nominal composition (wt %) of filler metal of this classification is 71 Ni, 16 Mo, 7 Cr, and 3 Fe. Filler metal of this classification is used for welding nickel-molybdenum alloy (ASTM B 366, B 434, and B 573 having UNS number N10003) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-molybdenum weld metal using the GTAW and GMAW processes.

A7.8.3 ERNiMo-3. The nominal composition (wt %) of filler metal of this classification is 63 Ni, 24 Mo, 6 Fe, and 5 Cr. Filler metal of this classification is used for weld repair of various nickel-, cobalt-, and iron-base alloys and for dissimilar joining applications of nickel-, cobalt-, and iron-base alloys.

A7.8.4 ERNiMo-7. The nominal composition (wt %) of filler metal of this classification is 69 Ni, 28 Mo. Filler metal of this classification is used for welding nickel-molybdenum alloy (ASTM B 333 and B 335 having UNS number N10665) to itself and for cladding steel with nickel-molybdenum weld metal using the GTAW and GMAW processes.

A7.8.5 ERNiMo-8. The nominal composition (wt %) of filler metal of this classification is 70 Ni, 19 Mo, 5 Fe, 3 W, and 2 Cr. Filler metal of this classification is used for welding 9% nickel steel (ASTM A 333, A 334, A 353, A 553 having UNS number K81340) to itself using the GTAW and SAW processes.

A7.8.6 ERNiMo-9. The nominal composition (wt %) of filler metal of this classification is 70 Ni, 20 Mo, 1 Fe, and 3 W. Filler metal of this classification is used for welding 9% nickel steel (ASTM A 333, A 334, A 353, and A 553 having UNS number K81340) to itself using the GTAW and SAW processes.

A7.8.7 ERNiMo-10. The nominal composition (wt %) of filler metal of this classification is 68 Ni, 28.5 Mo, 1.5 Cr, 1.5 Fe and low carbon. Filler metal of this classification is used for welding nickel-molybdenum alloy (ASTM B 333, B 335, B 366, B 564, B 619, B 622, and B 626 having UNS number N10675) to itself, for welding the clad side of joints in steel clad with nickel-molybdenum alloy and for welding nickel-molybdenum alloys to steel and to other nickel-base alloys using the GTAW, GMAW, and PAW processes.

A7.8.8 ERNiMo-11. The nominal composition (wt %) of filler metal of this classification is 67 Ni, 28 Mo, 3 Fe, 1.3 Cr and low carbon. Filler metal of this classification is used for welding nickel-molybdenum alloy with a UNS number N10629, covered in ASTM specifications B 333, B 335, B 366, B 564, B 619, B 622, and B 626, to itself, for welding the clad side of joints clad with nickel-molybdenum alloy and for welding Ni-Mo alloys to steel and other nickel base alloys using the GTAW, GMAW, and PAW processes.

A7.8.9 ERNiMo-12. The nominal composition (wt %) of filler metal of this classification is 65 Ni, 25 Mo, 8 Cr. Filler metal of this classification is used for welding nickel-molybdenum alloy (ASTM B 366, B 434, B 564, B 619, B 622, and B 626 having UNS number N10242) to itself and for cladding steel with nickel-molybdenum weld metal using the GTAW and GMAW processes.

A7.9 ERNiCrMo-X Classifications

A7.9.1 ERNiCrMo-1. The nominal composition (wt %) of filler metal of this classification is 44 Ni, 22 Cr, 20 Fe, 6.5 Mo, 2 Nb plus Ta, 2 Cu, 1.5 Mn. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 581 and B 582 having UNS number N06007) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.2 ERNiCrMo-2. The nominal composition (wt %) of filler metal of this classification is 47 Ni, 22 Cr, 18 Fe, 9 Mo, and 1.5 Co. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 366, B 435, and B 572 having UNS number N06002) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.3 ERNiCrMo-3. The nominal composition (wt %) of filler metal of this classification is 61 Ni, 22 Cr, 9 Mo, 3.5 Nb plus Ta. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 443, B 444, and B 446 having UNS number N06625) to itself, to steel, to other nickel-base alloys, for cladding steel with nickel-chromium molybdenum weld metal, and for welding the clad side of joints in steel with nickel-chromium-molybdenum alloy using the GTAW, GMAW, SAW, and PAW processes. This filler metal is recommended for applications where the operating temperature ranges from cryogenic to 1000°F [540°C].

A7.9.4 ERNiCrMo-4. The nominal composition (wt %) of filler metal of this classification is 57 Ni, 16 Cr, 15.5 Mo, 5.5 Fe, and 4 W. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 574, B 575, B 619, B 622, and B 628 having UNS number N10276) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW and GMAW processes.

A7.9.5 ERNiCrMo-7. The nominal composition (wt %) of filler metal of this classification is 65 Ni, 16 Cr, 15.5 Mo, and 2 Fe. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 574, B 575, B 619, B 622, and B 628 having UNS number N06455) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.6 ERNiCrMo-8. The nominal composition (wt %) of filler metal of this classification is 50 Ni, 25 Cr, 17 Fe, 6 Mo, and 1 Cu. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 581, B 582, B 619, B 622, and B 626 having UNS number N06975) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.7 ERNiCrMo-9. The nominal composition (wt %) of filler metal of this classification is 44 Ni, 22 Cr, 20 Fe, 7 Mo, 2 Co, and 2 Cu. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 581, B 582, B 619, B 622, and B 626 having UNS number N06007 or N06985) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.8 ERNiCrMo-10. The nominal composition (wt %) of filler metal of this classification is 56 Ni, 22 Cr, 13 Mo, 4 Fe, and 3 W. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 574, B 575, B 619, B 622, and B 628 having UNS number N06022) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.9 ERNiCrMo-11. The nominal composition (wt %) of filler metal of this classification is 43 Ni, 30 Cr, 15 Fe, 5 Mo, 2 Co, 3 W, and 2 Cu. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 581, B 582, B 619, B 622, and B 626 having UNS number N06030) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.10 ERNiCrMo-13. The nominal composition (wt %) of filler metal of this classification is 59 Ni, 23 Cr, 16 Mo, 1 Fe, and low carbon. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (B 564, B 574, B 575, B 619, B 622, and B 626 having UNS number N06059) to itself, to steel, to other nickel-base alloys, and for cladding steel using the GTAW, GMAW, SAW, and PAW processes.

A7.9.11 ERNiCrMo-14. The nominal composition (wt %) of the filler metal of this classification is 57 Ni, 21 Cr, 16 Mo, and 4 W. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 574, B 575, B 619, B 622, and B 628 having UNS number N06686) to itself, to steel, to other nickel-base alloys, and for cladding steel using the GTAW, GMAW, and SAW processes.

A7.9.12 ERNiCrMo-15. The nominal composition (wt %) of filler metal of this classification is 57 Ni, 21 Cr, 8 Mo, 7 Fe, 3 Nb plus Ta, 1.4 Ti. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 805, UNS number N07725) to itself, and for cladding steel using the GMAW and GTAW processes. The weld metal age hardens on heat treatment. For specific information concerning age hardening, consult the supplier or the supplier's technical literature.

A7.9.13 ERNiCrMo-16. The nominal composition (wt %) of filler metal of this classification is 60 Ni, 30 Cr and 10 Mo. Filler metal of this classification is used for corrosion-resistant (especially excellent to crevice corrosion) overlaying by the GTAW, GMAW, and PAW processes.

A7.9.14 ERNiCrMo-17. The nominal composition (wt %) of filler metal of this classification is 59 Ni, 23 Cr, 16 Mo, 1.6 Cu. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 574, B 575, B 619, B 622, and B 629 having UNS number N06200) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.15 ERNiCrMo-18. The nominal composition (wt %) of filler metal of this classification is 50 Ni, 20 Cr, 11.5 Mo, 14 Fe, and 1.5 W. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloys having UNS number N06650 to itself, to steel, to super-austentic stainless steels, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.16 ERNiCrMo-19. The nominal composition (wt %) of filler metal of this classification is 58 Ni, 21 Cr, 20 Mo, and 1 Fe. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 574, B 575, B 366, B 564, B 619, B 622, and B 626) having UNS N06058 to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, PAW processes.

A7.9.17 ERNiCrMo-20. The nominal composition (wt %) of filler metal of this classification is 64 Ni, 22 Cr, and 9 Mo (niobium free). The properties of this filler metal are suitable to weld super duplex stainless steels for low temperature applications with high impact toughness. Filler metal of this composition is used for welding of nickel-chromium-molybdenum alloys of similar composition as well as for cladding using GTAW, GMAW, SAW, and PAW processes.

A7.9.18 ERNiCrMo-21. The nominal composition (wt %) of filler metal of this classification is 55 Ni, 25 Cr, 15 Mo, 1 Fe. Filler metal of this classification is used for welding of nickel-chromium-molybdenum alloys (ASTM B 574, B 575, B 366, B 564, B 619, B 622, and B 626) having UNS number N06205 to itself, to steel, to other nickel base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW, GMAW, and PAW processes.

A7.9.19 ERNiCrMo-22. The nominal composition (wt %) of filler metal of this classification is 58 Ni, 33 Cr, and 8 Mo. Filler metal of this classification is used for welding nickel-chromium-molybdenum alloy (ASTM B 366, B 434, B 564, B 619, B 622, and B 626 having UNS number N06035) to itself, and for cladding steel with nickel-chromium-molybdenum weld metal using the GTAW and GMAW processes.

A7.10 ERNiCrCoMo-1 Classification. The nominal composition (wt %) of filler metal of this classification is 53 Ni, 23 Cr, 12 Co, 9 Mo, and 1 Fe. Filler metal of this classification is used for welding nickel-chromium-cobalt-molybdenum alloy (UNS number N06617) to itself using the GTAW and GMAW processes.

A7.11 ERNiCoCrSi-1 Classification. The nominal composition (wt %) of filler metal of this classification is 38 Ni, 30 Co, 28 Cr, 2.8 Si and 1 Fe. Filler metal of this classification is used for welding nickel-cobalt-chromium-silicon alloy (ASTM B 435, B 572, B 619, and B 626 having UNS number N12160) to itself using the GTAW, GMAW, and PAW processes. This alloy is sensitive to iron pick-up, therefore its use is not recommended for the welding of the nickel-cobalt-chromium-silicon alloy to iron based alloys.

A7.12 ERNiCrWMo-1 Classification. The nominal composition (wt %) of filler metal of this classification is 57 Ni, 22 Cr, 14 W, 2 Co, 2 Fe, and 2 Mo. Filler metal of this classification is used for welding nickel-chromium-tungsten-molybdenum-lanthanum alloy (ASTM B 366, B 435, B 564, and B 572 having UNS number N06230) to itself using the GTAW and GMAW processes.

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, scaling resistance, or strength at elevated or cryogenic temperatures may be required. AWS A5.01M/A5.01 contains provisions for ordering such tests. This clause is included to give guidance to those who desire to specify such special tests. Those tests shall be conducted as agreed upon between supplier and purchaser.

A8.1 Corrosion or Scaling Tests. Although welds made with electrodes and rods classified in this specification are commonly used in corrosion and heat-resisting applications, tests for those properties are not included in the specification. When required for a particular application, testing can be conducted on specimens taken from either a weld pad or a welded joint.

A8.1.1 Specimens from a joint are suitable for qualifying the welding procedure (for a specific application involving corrosion or oxidation resistance) but not for qualifying the filler metal. Tests on specimens from a joint have the disadvantage of being a combined test of the properties of the weld metal, the heat-affected zone, and the unaffected base metal. With such specimens, it is more difficult to obtain reproducible data (when a difference exists in the properties of the metal in the various parts of the specimen). Specimens taken from a joint do have the advantage of being able to duplicate the joint design and the welding sequence planned for fabrication.

A8.1.2 Specimens for testing corrosion or oxidation resistance of the weld metal alone are prepared by following the procedure normally used for the preparation of pads for chemical analysis (see 9.3 in AWS A5.11/A5.11M). The pad size should be at least 3/4 in [19 mm] in height by 2-1/2 in [65 mm] in width by $(1 + 0.625\ n)$ in $[25 + 16\ n$ mm] in length where n represents the number of specimens required from the pad. Specimens measuring 1/2 in by 2 in by 1/4 in [13 mm by 50 mm by 6.5 mm] are machined from the top of the pad, in a manner such that the 2 in [50 mm] dimension of the specimen is parallel to the 2-1/2 in [65 mm] dimension of the pad and the 1/2 in [13 mm] dimension is parallel with the length of the pad. The heat treatment, 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 procedures should correspond to ASTM G 4, *Recommended Practice for Conducting Plant Corrosion Tests*.

A8.2 Test for Mechanical Properties. The filler metals in this specification are used with a variety of welding processes and procedures. For this reason, weld metal tests have not been included in the specification. The tensile properties, bend ductility, and soundness of welds produced with these filler metals are determined during qualification of the procedure.

Variables in the procedure (current, voltage, and welding speed), in the shielding medium (the specific gas mixture or the flux), in the manual dexterity of the welder, and in the composition of the base metal and the filler metal all influence the results that can be obtained. Typical tensile values for weld metals are shown in Table A.2. When supplementary tests for mechanical properties are specified, the testing procedures should be in accordance with AWS B4.0 or AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*.

A9. Discontinued Classifications

Some classifications have been discontinued from one revision of this specification to another. This resulted from either changes in commercial practice or changes in the classification system used in the specification. The discontinued classifications are listed in Table A.3, along with the year last included in the specification.

A10. Safety Considerations

NOTE: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clause A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A10.2, ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes,[9] *and applicable federal and state regulations.*

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

Table A.2
Typical Weld Metal Tensile Strengths[a]

AWS Classification	Tensile Strength (typical) ksi	Tensile Strength (typical) MPa
ERNi-1	55	380
ERNiCu-7	70	480
ERNiCu-8	100[b]	690[b]
ERNiCr-3	80	550
ERNiCr-4	100	690
ERNiCr-6	80	550
ERNiCr-7	100	690
ERNiCrFe-5	80	550
ERNiCrFe-6	80	550
ERNiCrFe-7	80	550
ERNiCrFe-7A	85	590
ERNiCrFe-8	125[c]	860[c]
ERNiCrFe-11	94	650
ERNiCrFe-12	95	660
ERNiCrFe-13	85	590
ERNiCrFe-14	*80*	*550*
ERNiCrFeSi-1	90	620
ERNiCrFeAl-1	85	590
ERNiFeCr-1	80	550
ERNiFeCr-2	165[d]	1140[d]
ERNiMo-1	100	690
ERNiMo-2	100	690
ERNiMo-3	100	690
ERNiMo-7	110	760
ERNiMo-8	95	660
ERNiMo-9	95	660
ERNiMo-10	110	760
ERNiMo-11	100	690
ERNiMo-12	100	690
ERNiCrMo-1	85	590
ERNiCrMo-2	95	660
ERNiCrMo-3	110	760
ERNiCrMo-4	100	690
ERNiCrMo-7	100	690
ERNiCrMo-8	85	590
ERNiCrMo-9	85	590
ERNiCrMo-10	100	690
ERNiCrMo-11	85	590
ERNiCrMo-13	110	760
ERNiCrMo-14	110	760
ERNiCrMo-15	174[e]	1200[e]
ERNiCrMo-16	85	590
ERNiCrMo-17	100	690
ERNiCrMo-18	95	660
ERNiCrMo-19	120	830
ERNiCrMo-20	110	750
ERNiCrMo-21	115	780
ERNiCrMo-22	85	590
ERNiCrCoMo-1	90	620
ERNiCoCrSi-1	90	620
ERNiCrWMo-1	110	760

[a] Tensile strength in the as-welded condition, unless otherwise specified.

[b] Age-hardened condition: Heat treated at 1475°F [802°C] for 2 hours plus 1100°F [593°C] for 16 hours, then furnace cooled at 25°F [14°C] per hour to 900°F [482°C], then air cooled.

[c] Age-hardened condition: Heat treated at 1950°F [1066°C] for 2 hours plus 1300°F [704°C] for 20 hours, then air cooled.

[d] Age-hardened condition: Heat treated at 1325°F [718°C] for 8 hours, then furnace cooled at 100°F [56°C] per hour to 1150°F [620°C] and held for 8 hours, then air cooled.

[e] Age-hardened condition: Heat treated at 1900°F [1038°C] for 1 hour plus 1350°F [732°C] for 8 hours, then furnace cooled at 100°F [56°C] per hour to 1150°F [621°C] and held for 8 hours, then air cooled.

Table A.3
Discontinued Classifications

Discontinued Classification	Last Year Published
RNi-2	1969
ERNi-3	1969
RNiCu-5	1969
RNiCu-6	1969
RNiCrFe-4	1969
ERNiMo-4[a]	1969
ERNiMo-5	1969
ERNiMo-6[b]	1969

[a] Reclassified as ERNiMo-1 in 1976.
[b] Reclassified as ERNiMo-3 in 1976.

A10.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.2 AWS Safety and Health Fact Sheets Index (SHF)[10]

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 Welding Distance

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

No.	**Title**
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*

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SPECIFICATION FOR WELDING ELECTRODES AND RODS FOR CAST IRON

SFA-5.15

(Identical with AWS Specification A5.15-90 (R2006). In case of dispute, the original AWS text applies.)

SPECIFICATION FOR WELDING ELECTRODES AND RODS FOR CAST IRON

SFA-5.15

[Identical with AWS Specification A5.15-90 (R2006). In case of dispute, the original AWS text applies.]

1. Scope

This specification prescribes requirements for the classification of the following:

(a) Rods for oxyfuel gas welding;

(b) Electrodes for gas metal arc welding;

(c) Electrodes for flux cored arc welding;

(d) Electrodes for shielded metal arc welding.

These filler metals are suitable for welding gray cast iron, malleable cast iron, nodular cast iron, compacted graphite cast iron, and certain alloy cast irons.[1]

PART A — GENERAL REQUIREMENTS

2. Classification

2.1 The electrodes and rods covered by this specification are classified according to chemical composition, as specified in Tables 1A, 1B, and 1C.

2.2 Electrodes and rods classified under one classification shall not be classified under any other classification in this specifications.

2.3 The electrodes and rods classified under this specification are intended for oxyfuel gas welding, shielded metal arc welding, gas metal arc welding, or flux cored arc welding, as applicable, but that is not to prohibit their use with any other process for which they are found suitable.

3. Acceptance

Acceptance[2] of the welding electrodes shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*[3]

4. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[4]

5. Units of Measure and Rounding Off Procedure

5.1 U.S. Customary Units are the standard units of measure in this specification. The SI Units are given as equivalent values to the U.S. Customary Units. The standard sizes and dimensions in the two system are not identical, and for this reason, conversion from a standard size or dimension in one system will not always coincide with a standard size or dimension in the other. Suitable conversions, encompassing standard sizes of both, can be made, however, if appropriate tolerances are applied in each case.

5.2 For the purpose of determining conformance with this specification, 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 value in accordance with the rounding off method given in ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry.*

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[1] Copper-base filler metals frequently used in the braze welding of cast iron are no longer included in this specification. For information pertaining to these materials see A7.6 in the Appendix.

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

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

[4] See Section A4 (in the Appendix) for further information concerning certification and the testing called for to meet this requirement.

TABLE 1A(1)
CHEMICAL COMPOSITION REQUIREMENTS FOR UNDILUTED WELD METAL FOR SHIELDED METAL ARC AND FLUX CORED ARC WELDING ELECTRODES

		Weight Percent(1) (2) (3)										
AWS Classification(4)	UNS Number(5)	C	Mn	Si	P	S	Fe	Ni(6)	Mo	Cu(7)	Al	Other Elements, Total
Shielded Metal Arc Welding Electrodes												
ENi-CI	W82001	2.0	2.5	4.0	. . .	0.03	8.0	85 min.	. . .	2.5	1.0	1.0
ENi-CI-A	W82003	2.0	2.5	4.0	. . .	0.03	8.0	85 min.	. . .	2.5	1.0–3.0	1.0
ENiFe-CI	W82002	2.0	2.5	4.0	. . .	0.03	Rem.	45–60	. . .	2.5	1.0	1.0
ENiFe-CI-A	W82004	2.0	2.5	4.0	. . .	0.03	Rem.	45–60	. . .	2.5	1.0–3.0	1.0
ENiFeMn-CI	W82006	2.0	10–14	1.0	. . .	0.03	Rem.	35–45	. . .	2.5	1.0	1.0
ENiCu-A	W84001	0.35–0.55	2.3	0.75	. . .	0.025	3.0–6.0	50–60	. . .	35–45	. . .	1.0
ENiCu-B	W84002	0.35–0.55	2.3	0.75	. . .	0.025	3.0–6.0	60–70	. . .	25–35	. . .	1.0
Flux Cored Arc Welding Electrodes												
ENiFeT3-CI(8)	W82032	2.0	3.0–5.0	1.0	. . .	0.03	Rem.	45–60	. . .	2.5	1.0	1.0

notes follow on next page

TABLE 1B(1)
CHEMICAL COMPOSITION REQUIREMENTS FOR CORE WIRE FOR SHIELDED METAL ARC WELDING ELECTRODES

		Weight Percent(5)										
AWS Classification(5)	UNS Number(5)	C	Mn	Si	P	S	Fe	Ni	Mo	Cu	Al	Other Elements, Total
Shielded Metal Arc Welding Electrodes												
ESt	K01520	0.15	0.60	0.15	0.04	0.04	Rem.	. . .	. . .	. . .	. . .	. . .

notes follow on next page

PART B — TEST, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

Chemical analysis, as specified in Table 2, of the filler metal or rod stock from which the filler metal is made, or the core wire, or the undiluted weld metal is the only test required for classification of a product under this specification.

7. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both tests shall meet the requirements. Specimens for retest may be taken from the original test assembly or sample, or from new test assemblies or samples. For chemical analysis, retest need only be for those specific elements that failed to meet the test requirement.

8. Weld Test Assembly

8.1 One test assembly is required. It is the weld pad in Fig. 1 for chemical analysis of undiluted weld metal from electrodes for shielded metal arc or flux cored arc welding electrodes, except for the ESt classification for which the core is analyzed.

8.2 Preparation of the weld test assembly shall be as prescribed in para. 8.3 and Fig. 1. The base metal for the assembly shall be gray iron, nodular iron, or carbon steel. Testing of the assembly shall be as prescribed in paras. 9.2 and 9.3.

8.3 Weld Pad. When required by Table 2, a weld pad shall be prepared as specified in Fig. 1. Base metal of any convenient size, of the type specified in para. 8.2, shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple

TABLE 1C
CHEMICAL COMPOSITION REQUIREMENTS FOR RODS AND BARE ELECTRODES

AWS Classification(4)	UNS Number(5)	Weight Percent(1)(2)(3) C	Mn	Si	P	S	Fe	Ni(6)	Mo	Cu(7)	Mg	Al	Ce	Other Elements, Total
Cast Iron Welding Rods for OFW														
RCI	F10090	3.2–3.5	0.60–0.75	2.7–3.0	0.50–0.75	0.10	Rem.	Trace	Trace	. . .	. . .	. . .	. . .	. . .
RCI-A	F10091	3.2–3.5	0.50–0.70	2.0–2.5	0.20–0.40	0.10	Rem.	1.2–1.6	0.25–0.45	. . .	. . .	. . .	. . .	. . .
RCI-B	F10092	3.2–4.0	0.10–0.40	3.2–3.8	0.05	0.015	Rem.	0.50	. . .	. . .	0.04–0.10	. . .	0.20	. . .
Electrodes for Gas Metal Arc Welding														
ERNi-CI	N02215	1.0	2.5	0.75	. . .	0.03	4.0	90 min.	. . .	4.0	. . .	. . .	. . .	1.0
ERNiFeMn-CI	N02216	0.50	10–14	1.0	. . .	0.03	Rem.	35–45	. . .	2.5	. . .	1.0	. . .	1.0

NOTES:
(1) The weld metal, core wire, or the filler metal, as specified, shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.
(2) Single values shown are maximum, unless otherwise noted.
(3) "Rem." stands for Remainder.
(4) Copper-base filler metals frequently used in the braze welding of cast irons are no longer included in this specification. For information pertaining to these materials see A7.6.
(5) SAE/ASTM Unified Numbering System for Metals and Alloys.
(6) Nickel plus incidental cobalt.
(7) Copper plus incidental silver.
(8) No shielding gas shall be used for classification ENiFeT3-CI.

beads and multiple layers to obtain undiluted weld metal. The preheat temperature shall not be less than 60°F (16°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. The dimensions of the completed pad shall be as shown in Fig. 1, for each size of electrode. Testing of this assembly shall be as specified in para. 9.2.

TABLE 2
REQUIRED TESTS

AWS Classification	Chemical Analysis of Undiluted Weld Metal from Weld Pad(1)	Chemical Analysis of Filler Metal(1)
ENi-CI	Required	N.R.
ENi-CI-A	Required	N.R.
ENiFe-CI	Required	N.R.
ENiFe-CI-A	Required	N.R.
ENiFeMn-CI	Required	N.R.
ENiCu-A	Required	N.R.
ENiCu-B	Required	N.R.
ENiFeT3-CI	Required	N.R.
RCI	N.R.	Required
RCI-A	N.R.	Required
RCI-B	N.R.	Required
ERNi-CI	N.R.	Required
ERNiFeMn-CI	N.R.	Required
ESt	N.R.	Required(2)

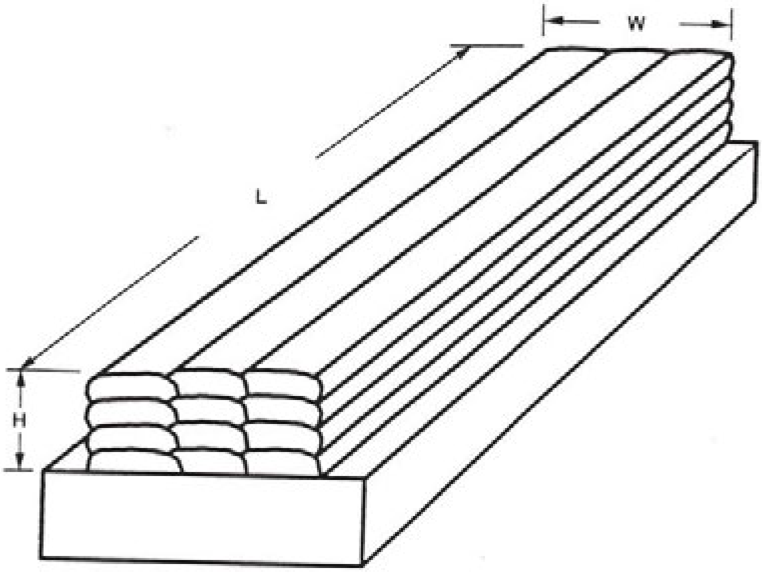
NOTES:
(1) "N.R." means that the test is not required.
(2) Chemical requirements for the ESt classification are based on the composition of the core wire without any flux coatings.

9. Chemical Analysis

9.1 For solid filler metal classified in Table 1A, and the core wire for electrodes classified in Table 1B, a sample of the filler metal, core wire, or the rod stock from which the filler metal or core wire is made, shall be prepared for chemical analysis. Solid filler metal, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the filler metal is analyzed for elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for other elements. Rod stock analyzed for elements not in the coating may be analyzed prior to applying the coating.

9.2 For electrodes classified in Table 1A, a sample shall be analyzed in the form of weld metal, not filler metal. The sample for analysis shall be taken from weld metal obtained with the filler metal. The sample shall come

FIG. 1 PAD FOR CHEMICAL ANALYSIS OF UNDILUTED WELD METAL



Shielded Metal Arc Welding		
Electrode Diameter	Minimum Height (H)	Minimum Length (L)
1/8 in. (3.2 mm) and less	1/2 in. (13 mm)	1-1/2 in. (38 mm)
Greater than 1/8 in. (3.2 mm)	7/8 in. (22 mm)	2 in. (51 mm)

Flux Cored Arc Welding			
Electrode Diameter	Minimum Height (H)	Minimum Length (L)	Min. No. of Layers
.052 in. (1.3 mm) and less	5/8 in. (16 mm)	3 in. (76 mm)	4
Greater than .052 in. (1.3 mm)	1 in. (25 mm)	4 in. (102 mm)	4

GENERAL NOTE: The width (W) of the weld metal shall be sufficient for the method of analysis. No shielding gas shall be used for classification ENiFeT3-CI.

from a weld pad as shown in Fig. 1. The top surface of the pad described in para. 8.3 and shown in Fig. 1 shall be removed, 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.

For covered electrodes 1/8 in. (3.2 mm) and smaller and flux cored electrodes .052 in. (1.3 mm) diameter and smaller, the sample shall be taken at least 7/16 in. (11 mm) from the nearest surface of the base metal. For covered electrodes larger than 1/8 in. (3.2 mm) diameter and flux cored electrodes larger than .052 in. (1.3 mm), the sample shall be taken at least 9/16 in. (14 mm) from that surface.

9.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be the appropriate one of the following:[5]

(a) ASTM E 39, Standard Method for Chemical Analysis of Nickel;

(b) ASTM E 76, Standard Methods for Chemical Analysis of Nickel-Copper Alloys;

(c) ASTM E 350, Standard Method for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron;

(d) ASTM E 351, Standard Methods for Chemical Analysis of Cast Iron—All types;

(e) ASTM E 353, Standard Methods for Chemical Analysis of Stainless Heat Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys;

(f) ASTM E 354, Standard Method for Chemical Analysis of High Temperature Electric, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys.

9.4 The results of the analysis shall meet the requirements of Table 1 for the classification of filler metal under test.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

10. Welding Rods

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

10.2 Standard Sizes and Lengths. Standard sizes for welding rod shall be as shown in Table 3.

10.3 Finish and Uniformity. All 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.

TABLE 3
STANDARD SIZES AND LENGTHS OF WELDING RODS(1)

AWS Classification	Size, in.	Size Tolerance, in.	Length, in.	Length Tolerance, in.
RCI	1/8 round	±1/32	18	+1/2, −2
	1/8 square	±1/32	20	+1/4, −2
	3/16, 1/4, 5/16, 3/8, 1/2, round or square	±1/32	24	±1/4, −2
RCI-A	1/8 3/16, 1/4, 5/16, 3/8, 1/2, round or square	±1/32	24	+1/4, −2
RCI-B	3/16, 1/4, 3/8, 1/2 round or square	1/32	24	+1/4, −2

NOTE:

(1) Sizes and lengths other than these shall be as agreed to by supplier and purchaser.

SI Equivalents	
in.	mm
1/32 (0.031)	0.8
1/8 (0.125)	3.2
5/32 (0.156)	4.0
3/16 (0.188)	4.8
1/4 (0.250)	6.4
5/16 (0.313)	8.0
3/8 (0.375)	9.5
1/2 (0.500)	12.7
2	51
18	450
20	500
24	600

10.4 Standard Package Forms. Standard package forms are straight lengths. Standard package dimensions are not specified. Welding rods shall be packed in containers of 5, 10, 25, 30, 50, 60, or 100 lb (2.5, 4.5, 11, 14, 23, 27 or 45 g) net weight. Other package weights shall be as agreed upon by supplier and purchaser.

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

10.6 Marking of Packages

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

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[5] ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

(a) AWS specification and classification designations (year of issue may be excluded);

(b) Supplier's name and trade designation;

(c) Size and net weight;

(d) Lot, control, or heat number.

10.6.2 Marking of any overpacking of unit packages with the items listed in para. 10.6.1 shall be optional with the manufacturer.

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

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be dangerous to health.

HEAT RAYS (INFRARED RADIATION from flame or hot metal) can injure eyes.

- Before use read and understand the manufacturer's instructions, the Manufacturers Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the flame, or both, to keep fumes and gases from your breathing zone and the general area.
- Wear correct eye, ear and body protection.
- See American National Standard Z49.1, *Safety in Welding and Cutting,* published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135, and OSHA Safety and Health Standards, 29 CFR 1910, available from the Government Printing Office, Washington, DC 20402

DO NOT REMOVE THIS INFORMATION

11. Shielded Metal Arc Welding Electrodes

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

11.2 Standard Sizes and Lengths

11.2.1 Standard sizes (diameter of the core wire) and lengths for electrodes are shown in Table 4.

11.2.2 The diameter of the core wire shall not vary more than ±0.003 in. (0.08 mm) from the diameter specified. The length shall not vary more than ±1/4 in. (±6.4 mm) from that specified.

11.3 Core Wire and Covering

11.3.1 The core wire and covering shall be free of defects that would interfere with uniform deposition of the electrode.

TABLE 4
STANDARD SIZES AND LENGTHS FOR SHIELDED METAL ARC WELDING ELECTRODES

AWS Classification	Diameter, in.	Size Tolerance, in.	Length, in.	Length Tolerance, in.
ENi-CI ENi-CI-A	3/32	±0.003	9, 12, and 14	±1/4
ENiFe-CI ENiFe-CI-A ENiFeMn-CI ESt	1/8, 5/32, 3/16, 1/4	±0.003	12 and 14	±1/4
ENiCu-A ENiCu-B	3/32, 1/8, 5/32, 3/16	±0.003	12 and 14	±1/4

GENERAL NOTE: Sizes and lengths other than these shall be available as agreed upon by the supplier and purchaser.

SI Equivalents	
in.	mm
0.003	0.08
3/32	2.4
1/8	3.2
5/32	4.0
3/16	4.8
1/4	6.4
9	230
12	300
14	350

11.3.2 The core wire 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:

(a) seven percent of the mean dimension in sizes 3/32 in. (2.4 mm) and smaller;

(b) five percent of the mean dimension in sizes 1/8 in. (3.2 mm) and 5/32 in. (4.0 mm), and;

(c) 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.

11.3.3 The covering of electrodes shall be such that it is not readily damaged by ordinary handling.

11.4 Exposed Core

11.4.1 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. (32 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.

11.4.2 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. (3.2 mm) or the diameter of the core wire, whichever is less. Electrodes with chipped covering near the arc end, baring the core wire no more than the lesser of $^1/_2$ in. (13 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.

11.5 Electrode Identification. All electrodes shall be identified as follows:

11.5.1 At least one imprint of the electrode classification shall be applied to the electrode covering within $2^1/_2$ in. (65 mm) of the grip end of the electrode.

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

11.5.3 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.

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

11.6 Packaging

11.6.1 Electrodes shall be suitably packaged to protect against damage during shipment and storage under normal conditions.

11.6.2 Standard package weights shall be as specified in para. 10.4 or as agreed upon by supplier and purchaser.

11.7 Marking of Packages

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

(a) AWS specification and classification designations (year of issue may be excluded);

(b) Supplier's name and trade designation;

(c) Size and net weight;

(d) Lot, control, or heat number.

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

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be dangerous to health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can kill.

- Before use read and understand the manufacturer's instructions, the Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone, and the general area.
- Wear correct eye, ear and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding and Cutting,* published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135; and OSHA Safety and Health Standards, 29 CFR 1910, available from the Government Printing Office. Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

12. Gas Metal Arc and Flux Cored Arc Welding Electrodes

12.1 Method of Manufacture. The filler metals classified according to this specification may be manufactured by any method that will produce filler metals that meet the requirements of this specification.

12.2 Standard Sizes. Standard sizes for filler metal in different package forms (coils with support, coils without support, spools, and drums) shall be as shown in Table 5.

12.3 Finish and Uniformity

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

12.3.2 Each continuous length of filler metal shall be from a single 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.

12.3.3 The core ingredients of flux cored arc welding electrodes 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.

12.4 Standard Package Forms

12.4.1 Standard package forms are coil with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Tables 6 and 7. Package forms, sizes, and weights other than these shall be as agreed between purchaser and manufacturer.

TABLE 5
STANDARD SIZES AND TOLERANCES FOR GAS METAL ARC AND FLUX CORED ARC WELDING ELECTRODES

Standard Package Form	Standard Sizes Diameter			Tolerance	
	in.		mm	in.	mm
Coils With Support	. . .	.035	0.9		
Spools	. . .	.045	1.1	±0.002	±0.051
	. . .	.052	1.3		
	$\frac{1}{16}$	.063	1.6		
Coils Without Support,	$\frac{5}{64}$	0.078	2.0		
Coils With Support,	$\frac{3}{32}$	0.094	2.4		
Spools,	$\frac{7}{64}$	0.109	2.8	±0.003	±0.076
Drums		.120	3.0		
Coils With Support	$\frac{1}{8}$	0.125	3.2		
Drums	$\frac{5}{32}$	0.156	4.0	±0.004	±0.10

GENERAL NOTE: Dimensions and tolerances other than those shown shall be as agreed between the purchaser and supplier.

TABLE 6
STANDARD DIMENSIONS FOR COILS WITH AND WITHOUT SUPPORT AND DRUMS

Coils Without Support		Coils With Support				Drums	
Inside Diameter of Coil,		Inside Diameter of Liner		Width of Wound Electrode, max,		Outside Diameter	
in.	mm	in.	mm	in.	mm	in.	mm
12	300	12 ± $\frac{1}{8}$	300 ± 3.2	4$\frac{5}{8}$	120	15$\frac{1}{2}$	390
22$\frac{1}{2}$	570					20	510
						23	580

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

12.4.3 Spools shall be designed (see Fig. 2 and Fig. 3) and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

12.5 Winding Requirements

12.5.1 The filler metal shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end welding is to begin with) shall be identified so it can be located readily and shall be fastened to avoid unwinding.

12.5.2 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 semiautomatic and automatic equipment.

12.6 Filler Metal identification

12.6.1 The product information and the precautionary information required in para. 12.8 for marking each package shall also appear on each coil, each spool, and each drum.

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

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

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

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

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

TABLE 7
STANDARD PACKAGE DIMENSIONS AND WEIGHTS[1]

	Package Size			
	ID		Net Weight of Electrode,[2]	
Type of package	in.	mm	lb	kg
Coils Without Support	12	300	50	23
	22½	570	100	45
Coils With Support	12	300	50	27
			60	23
Spools	12	300	25	11
	14	360	50	23
			60	27
	30	760	600	273
Drums	15½	390	200	90
	20	510	500	230
	23	580	1100	500

NOTES:

(1) Sizes and net weights other than those specified shall be as agreed between supplier and purchaser.

(2) Net weights shall not vary more than ±10% percent.

12.8 Marking of Packages

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

(a) AWS specification and classification designations (year of issue may be excluded);

(b) Supplier's name and trade designation;

(c) Size and net weight;

(d) Lot, control, or heat number.

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

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be dangerous to health.

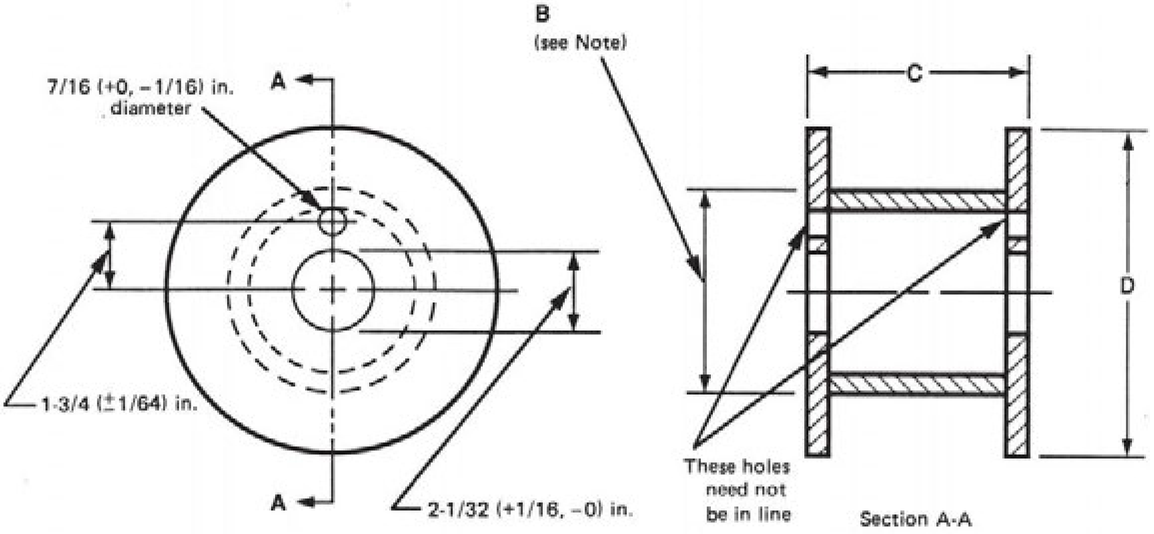
ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can kill.

- Before use read and understand the manufacturer's instructions, the Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone, and the general area.
- Wear correct eye, ear and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding and Cutting,* published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135; OSHA Safety and Health Standards, 29 CFR 1910, available from the U.S. Printing Office. Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

FIG. 2 DIMENSIONS OF 12 AND 14 IN. (300 AND 360 MM) SPOOLS



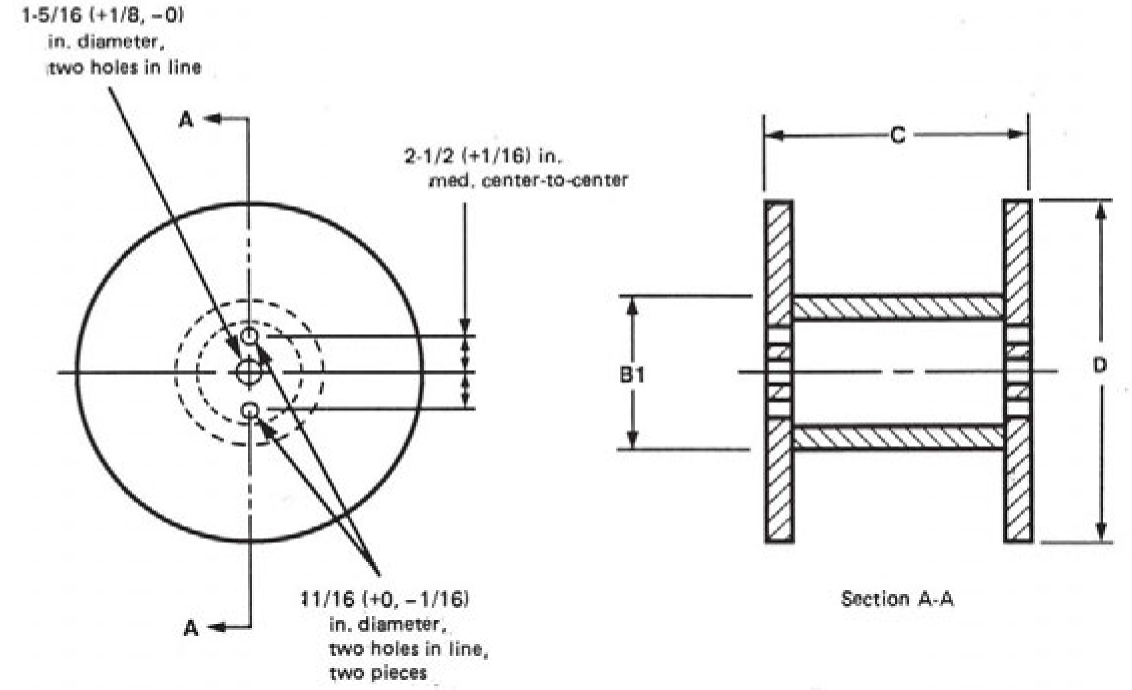
NOTE: Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.

Dimensions		
Spool size	C	D, maximum
in.	in.	in.
12	4 ± 1/16	12
14	4 ± 1/16	14

Si Equivalents

in.	mm
1/64 (.016)	0.4
1/32 (.031)	0.8
1/16 (.062)	1.6
7/16 (.438)	11.1
1/2 (.500)	13
3/4 (.750)	19.0
1	25.4
2	50.8
4	102
12	305
14	356

FIG. 3 DIMENSIONS OF 30 IN. (760 MM) SPOOLS



GENERAL NOTE: Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.

Dimensions		
Spool size	D	C, maximum
in.	in.	in.
30	30 ± 1/2	13 ± 1/2

Si Equivalents

in.	mm
1/16 (.016)	0.4
1/8 (.125)	3.2
5/16 (.312)	7.9
1/2 (.500)	12.7
11/16 (.688)	17.5
1	25.4
2	50.8
13	330
30	762

Appendix
Guide to AWS A5.15-90, Specification for Welding Electrodes and Rods for Cast Iron

[This Appendix is not a part of ANSI/AWS A5.15-90 (R2006), *Specification for Welding Electrodes and Rods for Cast Iron,* but is included for informational purposes only.[6]]

A1. Introduction

The purpose of this Appendix is to correlate the classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done, and when it would be helpful. Such references are intended only as examples rather than complete listings of the base metal for which each filler metal is suitable.

A2. Classification System

A2.1 The system for identifying welding rod and electrode classifications used in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" at the beginning of each classification designation stands for electrode, the letters "ER" at the beginning of each classification designation stands for a filler metal which is suitable for use as either an electrode or rod, and the letter "R"at the beginning of each classification designation stands for welding rod. The next letters in the filler metal designation are based on the chemical composition of the filler metal or undiluted weld metal. Thus, NiFe is a nickel-iron alloy, NiCu is a nickel-copper alloy, etc. Where different compositional limits in filler metals of the same alloy family result in more than one classification, the individual classifications are differentiated by the designators "A"or "B", as in ENiCu-A and ENiCu-B.

A2.2 For flux cored electrodes the designator "T" indicates a tubular electrode. The number "3" indicates that the electrode is used primarily without an external shielding gas.

A2.3 Most of the classifications within this specification contain the usage designator "CI" after the hyphen which indicates that these filler metals are intended for cast iron applications. The usage designator is included to eliminate confusion with other filler metal classifications from other specifications which are designed for alloys other than cast irons. The two exceptions, ENiCu-A and ENiCu-B, preceded the introduction of the usage designator and have never had the "CI" added.

A2.4 The chemical symbols have been used in all the filler metals except the cast iron and mild steel groups. Since there are no chemical symbols for cast iron and mild steel, the letters "CI" and "St" have been assigned to this group to designate cast iron and mild steel filler metals, respectively. The suffixes "A" and "B" are used to differentiate two alloys of the cast iron filler metals from other cast iron rod classifications.

A3. Acceptance

A3.1 Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines,* as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing normally conducted on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. Testing in accordance with any other Schedule in that Table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

A4. Certification

A4.1 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.

A4.2 The only testing requirement implicit in this certification is that the manufacturer has actually conducted

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[6] For additional information, refer to AWS D11.2, Guide for Welding Iron Castings.

the test 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 System" in ANSI/AWS A5.01.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes to which welders and welding operators can be exposed during welding:

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

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

(c) Rate of evolution of fumes, gases, or dusts, according to the materials and processes involved;

(d) The proximity of the welder and welding operators 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;

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

A5.2 American National Standard Z49.1, *Safety in Welding and Cutting* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section entitled Health Protection and Ventilation.

A6. Welding Considerations

A6.1 Welding Considerations for Electrodes

A6.1.1 The casting skin should be removed from the weld area by machining, grinding, chipping or other suitable means. When repairing casting defects, care should be exercised to ensure removal of any defective metal to sound base metal before welding. Also, all oil grease, dirt, or other foreign material should be eliminated by the use of suitable solvents. If oil, grease, or solvents have impregnated the casting, heat should be applied to the area to be welded until volatilization is no longer observed. A temperature of 750°F (400°C) generally is sufficient for this operation. If the casting is too greasy, flash heating the welding surfaces to about 1000°F (540°C) should drive off the grease in a gaseous state.

A6.1.2 For V-groove welds, the edges should be beveled to form a 60 to 80 degree groove angle. For very thick base metal, a U-groove weld with a 20-25 degree groove angle and a groove radius of at least $^3/_{16}$ to $^1/_2$ in. (4.8 to 13 mm) should be used.

A6.1.3 Welding currents should be within the range recommended by the supplier of the electrode, and as low as possible, consistent with smooth operation, good bead contour, and securing good fusion of the groove face. If welding is in other than the flat and horizontal positions, the recommended currents should be reduced to some extent for vertical position and overhead position welding.

A6.1.4 The electrode should be manipulated so that the width of the weld bead is no greater than three times the nominal diameter of the electrode being used. If a large cavity must be filled, the sides may be surfaced, and the cavity gradually filled toward the center of the repaired area.

A6.1.5 When continuous welding is employed, heat input from the previous passes serves as moderate preheating or to maintain the preheat temperature. Use of preheating is not always necessary, but it is often used. In large castings, it may occasionally be found desirable to use intermittent welding to provide a more even temperature distribution, keeping the casting warm to the touch, but not permitting it to get too hot.

A6.1.6 The hardness of the heat-affected zone is a function of the composition and cooling rate of the base metal. An increase in the cooling rate for a given composition will increase the hardness of the heat-affected zone. Thus, any steps taken to retard the cooling rate such as preheating or the use of insulating material combined with preheating will be beneficial in lowering the hardness of the heat-affected zone. The hardness of the weld metal depends to a great extent upon the amount of dilution, and can be controlled within reasonable limits during welding. Single layer weld metal which has high dilution may have a hardness as high as 350 Brinell for ENiFe-CI, ENiFe-CI-A, and ESt electrodes, and around 210 Brinell for the ENi-CI, ENi,-CI-A, and ENiCu-B weld metal.

Moderately thick weld beads, where the dilution is reduced by directing the arc onto the weld pool, or the later layers of multiple-layer welds, may give lower hardness ranges. Typical ranges for mechanical properties of undiluted filler metal are listed in Table A1.

A6.1.7 Preheating is especially helpful in overcoming the differential mass effect encountered when welding a thick to a thin base metal. The use of preheat in conjunction with welding for pressure tightness also increases the resistance to cracking at the weld interface. Judicious use of preheating when welding cast iron will permit the weld and surrounding area to cool at a more uniform rate.

TABLE A1
TYPICAL MECHANICAL PROPERTIES OF UNDILUTED WELD METAL

Electrode	Tensile Strength		Yield Strength 0/2% offset		Elongation % in 2 in.	Hardness BHN
	ksi	MPa	ksi	MPa		
RCI	20–25	138–172	. . .	. . .	. . .	150–210
RCI-A	35–40	241–276	. . .	. . .	. . .	225–290
RCI-B (As-welded)	80–90	552–621	70–75	483–517	3–5	220–310
RCI-B (Annealed)	50–60	345–414	40–45	276–310	5–15	150–200
ESt	. . .	. . .	. . .	. . .	. . .	250–400
ENi-CI	40–65	276–448	38–60	262–414	3–6	135–218
ENi-CI-A	40–65	276–448	38–60	262–414	3–6	135–218
ENiFe-CI	58–84	400–579	43–63	296–434	6–18	165–218
ENiFe-CI-A	58–84	400–579	43–63	296–434	4–12	165–218
ENiFeMn-CI	75–95	517–655	60–70	414–483	10–18	165–210
ENiFeT3-CI	65–80	448–552	40–55	276–379	12–20	150–165
ERNiFeMn-CI	75–100	517–689	65–80	448–552	15–35	165–210

A6.1.8 Peening often is used to reduce stresses and decrease distortion. Peening should be done with repeated moderate blows of a round-nose or needle tool with sufficient force to move the metal, but not enough to rupture it. Peening should be done while the metal is still above 1000°F (540°C). Peening is not recommended for root beads or weld beads at the weld face.

A6.1.9 The possibility of cracking makes it generally advisable in welding any sizable casting to employ studs that fasten the weld to the unaffected base metal below the weld interface. Studs are usually $^1/_4$ to $^5/_8$ in. (6.4 to 16 mm) in diameter, projecting $^3/_{16}$ to $^1/_4$ in. (4.8 to 6.4 mm) above the surface to be welded, and screwed or pressed in to a depth at least equal to their diameter. The cross-sectional area of the studs should be 25 to 35% of the area of the weld surface.

A6.2 Welding Considerations for Rods Classified as RCI and RCI-A

A6.2.1 The casting should be prepared as described in A6.1.1.

A6.2.2 Castings to be welded with a V-groove should have the edges beveled to form a 60 to 90 degree include angle. The groove should have a root face greater than zero, so that there is less difficulty in aligning the joint members and there is no melting through of the entire thickness.

A6.2.3 Next, the casting should be preheated as a whole, or locally in critical sections, if a closed or rigid construction is involved. Ideally this involves preheating the entire casting to 800 to 1050°F (430 to 566°C), or in the case of alloy castings, as high as 1250°F (677°F). The preheating not only tends to equalize expansion and contraction stresses and ensure the machinability of the final weld, but also enables the weld to be made more rapidly. Such preheating preferably should be done in a charcoal fire or a furnace. In the case of small castings, however, preheating with a welding torch may be employed.

A6.2.4 A neutral oxyfuel gas flame is preferred for welding cast iron. Some authorities, however, recommended the occasional use of a reducing flame where decarburization is to be avoided. A flux is required. The purpose of the flux is to increase the fluidity of the iron silicate slag that forms on the weld pool.

A6.2.5 After the groove has been beveled and cleaned, and the casting preheated, the welding torch is directed over an area extending 1 in. (25 mm) around the weld until the entire area is a dull red. Then the flame is directed at the bottom of the groove, keeping the tip of the cone $^1/_8$ to $^1/_4$ in. (3.2 to 6.4 mm) from the metal, until a weld pool approximately 1 in. (25 mm) long has been formed. The flame is then gradually moved from side to side until the groove faces begin to melt into the weld pool. The flame is directed on the rod, and filler metal is added to the weld pool. The groove faces are melted ahead of the advancing pool. The thickness of each layer of weld metal should not exceed $^3/_8$ in. (9.5 mm).

A6.2.6 In the case of rigid structures requiring extensive machining, it is advisable to stress relieve at the preheat temperature after welding. In any case, the casting should be allowed to cool slowly by furnace cooling, or by covering with, or immersion in, an insulating material such as dry sand.

A6.3 Welding Considerations for RCI-B Rods

A6.3.1 Preparation of castings for welding is similar to that called for in A6.2.1 and A6.2.2. Preheating should be uniform.

A6.3.2 The application of RCI-B welding rods is the same as that described for the other RCI filler metals. The weld zone can withstand higher residual stresses without cracking. However, it is advisable to apply slow cooling to prevent stress cracks in the base metal. It is recommended that residual stress be reduced by preheating castings uniformly to 1600°F (870°C), and providing slow furnace cooling by covering with, or immersion in, an insulating material such as dry sand. After such treatment, the castings will withstand exposure to considerable thermal expansion and will permit heavy machining.

A7. Description and Intended Use of Electrodes and Rods for Welding Cast Iron

The following are guidelines for the application of welding rods and welding electrodes in conjunction with various types of cast iron. These guidelines are general and subject to modification based on the experience of the welder and information supplied by the filler metal manufacturer. Only rods employed in conjunction with an oxyfuel gas heat source, and electrodes intended for the SMAW, GMAW, or FCAW processes are discussed. This limitation, defined in the scope, is not intended to deter a prospective user from considering other welding processes for which these filler metals might prove satisfactory.

A7.1 Cast Iron Welding Rods

A7.1.1 RCI (Cast Iron) Classification

A7.1.1.1 Ordinary machinable gray iron castings may vary from 20 to 40 ksi (140 to 280 MPa) tensile strength, and 150 to 250 Brinell hardness. The use of a gray iron welding rod for oxyfuel gas welding can produce a machinable weld metal of the same color, composition and structure as the base metal. The weld, if properly made, may be as strong as the original casting. See Table A1.

A7.1.1.2 RCI welding rods are used for filling in or building up new or worn castings, and for general fabrication, salvage and repair.

A7.1.2 RCI-A (Cast Iron) Classification

A7.1.2.1 This cast iron welding rod contains small amounts of molybdenum and nickel, which give it a slightly higher melting point than the ordinary cast iron welding rod, RCI. The molten weld metal is more fluid. Welding can be done more rapidly.

A7.1.2.2 The RCI-A welding rod (with a weld metal hardness of approximately 230 Brinell) may be used if an alloy cast iron is being welded, and when greater tensile strength and finer grain structure are desired. The weld metal is generally considered machinable.

A7.1.3 RCI-B (Nodular Cast Iron) Classification. These nodular (ductile) cast iron welding rods are capable of producing sound weld metal when used to weld higher-strength gray iron, malleable, and nodular iron castings with the oxyfuel gas process. Under optimum conditions, the welds produced have mechanical properties of 60 000 psi (410 MPa) minimum ultimate tensile strength; 45 000 psi (310 MPa) minimum yield strength; 5 to 15 percent elongation; and a maximum Brinell hardness of 200. These mechanical properties are due to the fact that most of the graphite content in the weld metal is in nodular form, which results in good ductility and machining properties for the weld. Color match to the base metal generally is good.

A7.2 Nickel-Base Electrodes for SMAW of Cast Irons. Arc welding with nickel-base covered electrodes is widely employed for welding cast iron. Weld metal made with these electrodes, even without preheating, usually can be machined (the heat affected zone may not be machinable). Welding is fairly rapid when compared to processes such as oxyfuel gas welding. Although welding in the flat position only is required in this specification, some electrodes may be capable of use in other positions. Tensile properties are not specified for the nickel base SMAW electrodes classified in this specification. The tensile and yield strengths may vary widely among manufacturers as shown in Table A1. The filler metal supplier or manufacturer should be contacted for product recommendations.

A7.2.1 ENi-CI (Nickel) Classification. This electrode can be used to join ordinary gray irons to themselves, or to other ferrous and nonferrous materials, and to reclaim or repair castings. Satisfactory welds can be produced on small and medium size castings where the welding stresses are not overly severe, or where the phosphorus content of the iron is not high. Because of lower strength than the ENiFe-CI and lower ductility of the weld metal, these electrodes should be used only in applications where maximum machinability of highly diluted filler metal is necessary. Otherwise, the ENiFe-CI classification is preferred. The ENi-CI classification may also be used on malleable or ductile iron.

A7.2.2 ENi-CI-A (Nickel) Classification. ENi-CI-A electrodes frequently are used interchangeably with ENi-CI electrodes. The covering of ENi-CI electrodes contains more aluminum to improve operating characteristics such as slag coverage and flowability. However, the aluminum becomes an alloy of the weld metal and may affect ductility.

A7.2.3 ENiFe-CI (Nickel-Iron) Classification. This electrode may be used for making repair welds on, as well as for joining, work pieces of various types of cast iron, including nodular iron, and for welding them to steel and some nonferrous base metals. Castings containing phosphorus levels higher than normal (approximately 0.20% phosphorus) are more readily welded using these electrodes than with an electrode of the ENi-CI classification. Experience has shown that satisfactory welds can be made on thick and highly restrained weldments, and on high-strength and engineering grades of cast iron.

A7.2.4 ENiFe-CI-A (Nickel-Iron) Classification. ENiFe-CI-A electrodes frequently are used interchangeably with ENiFe-CI electrodes. The covering of ENiFe-CI-A electrodes contains more aluminum to improve operating characteristics such as slag coverage and flowability. However, the aluminum becomes an alloy of the weld metal and may affect ductility.

A7.2.5 ENiFeMn-CI (Nickel-Iron Manganese) Classification. This electrode has a nominal addition of 12% manganese to the nickel iron system which improves the flow of the molten metal and somewhat increases the crack resistance of the weld metal. The manganese also increases the tensile strength and improves ductility, which provides properties closer to those of the higher strength grades of nodular cast iron base metals than can be achieved with the ENiFe-CI. ENiFeMn-CI electrodes are also used for surfacing to improve wear resistance or for buildup.

A7.2.6 ENiCu-A and ENiCu-B (Nickel-Copper) Classification. These electrodes have been used in many of the same applications as the ENi-Fe-CI, ENiFe-CI-A, and ENiFeMn-CI electrodes. They are used to produce a low depth of fusion weld, since high dilution by the base metal may cause weld cracking.

A7.3 ESt (Steel) Classification for SMAW of Cast Iron

A7.3.1 This covered electrode for all welding positions is designed specifically for the welding of cast iron. It has a low-melting-point covering and differs from the ordinary mild steel electrodes included in ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.* Weld metal from this electrode is not readily machinable.

A7.3.2 Since it is virtually impossible to prevent the formation of a hard zone or layer in the weld metal because of dilution from the base metal, this type of electrode is largely confined to the repair of small pits and cracks, with some application in the repair of castings that require no postweld machining. Since the shrinkage of steel is greater than that of cast iron, high stresses develop as the weld cools. Residual stresses may be severe enough to cause cracking.

A7.3.3 Preheating is employed only when necessary to prevent excessive stresses in other parts of the casting. ESt electrodes generally are used at low amperage to minimize the dilution effect in the fusion zone and consequent weld and base metal cracking. The usual recommended amperages are 60 to 95 amps for $\frac{3}{32}$ in. (2.4 mm), 80 to 110 amps for $\frac{1}{8}$ in. (3.2 mm), and 110 to 150 amps for $\frac{5}{32}$ in. (4.0 mm) electrodes using dcep (electrode positive) or ac. The beads should be short and widely separated, to distribute the heat, and each bead should be peened lightly. The slag volume is low but very alkaline. Residual slag should be removed completely if the weld area is to be painted.

A7.4 Nickel-Base Filler Metal for GMAW of Cast Iron. Only gas metal arc welding of classifications ERNiFeMn-CI and ERNi-CI are addressed by this specification. The requirements for rods for gas tungsten arc welding and other welding methods have not been included. Since these filler metals could be manufactured as rods, they have been assigned the “ER” designation.

A7.4.1 ERNiFeMn-CI (Nickel-Iron-Manganese) Classification. This solid continuous bare electrode can be used for the same applications as the ENiFeMn-CI covered SMAW electrode. The strength and ductility of this classification makes it suitable for welding the higher strength grades of nodular iron castings.

A7.4.2 ERNi-CI (Nickel) Classification. This solid continuous bare electrode is composed of essentially pure nickel (99%) and contains no deoxidizers. The electrode is used to weld iron castings when weld metal with highly diluted filler metal is to be machined.

A7.4.3 Shielded Gases. Shielding gases should be used as recommended by the manufacturer.

A7.5 Nickel-Base Electrode for FCAW of Cast Iron. The ENiFeT3-CI (nickel-iron electrode) is a continuous flux cored electrode that has been designed to operate without an external shielding gas. For this reason, it is commonly referred to as a self-shielded flux-cored electrode, but it may also be used with an external shielding gas if recommended by the manufacturer. The composition of this classification is similar to that of an ENiFe-CI except for a higher manganese content. It can be used in the same types of applications as the ENiFe-CI electrode. It is generally used for thick base metal or where processes can be automated. This electrode contains 3-5% manganese to aid in resisting weld metal hot cracking and to improve strength and ductility of the weld metal.

TABLE A2
COPPER-BASE WELDING ELECTRODES AND RODS FROM AWS SPECIFICATIONS SUITABLE FOR WELDING CAST IRONS

Classification	Type	Specification
Cast Filler Metals (OFW)		
RBCuZn-A	Naval brass	A5.27
RCuZn-B	Low fuming brass [Ni]	A5.27
RCuZn-C	Low fuming brass	A5.27
RBCuZn-D	Nickel brass	A5.27
Covered Electrodes (SMAW)		
ECuSn-A	Phosphor bronze	A5.6
ECuSn-C	Copper-tin	A5.6
ECuAl-A2	Copper-aluminum	A5.6

GENERAL NOTES:
(a) ANSI/AWS A5.6, Specification for Covered Copper and Copper Alloy Arc Welding Electrodes.
(b) ANSI/AWS A5.27, Specification for Copper and Copper Alloy Rods for Oxyfuel Gas Welding.

A7.6 In addition to the electrodes and rods classified in this specification, a number of copper-base welding rods frequently are used for braze welding cast iron. The lower temperatures associated with depositing these filler metals and their generally low strength and high ductility frequently offers advantages when welding cast iron. Copper-base welding electrodes and rods have been classified in other specifications and are listed in Table A2 for reference purposes.

A8. Postweld Heat Treatment

Postweld heat treatment may also be used to improve the machineability of the heat-affected zone adjacent to the weld metal. Tempering beads sometimes are employed to achieve the desired improvement. These beads, consisting entirely of filler metal and a previous bead, are made in such a manner that the heat input tempers any martensite present from a previous bead.

SPECIFICATION FOR TITANIUM AND TITANIUM-ALLOY WELDING ELECTRODES AND RODS

(**15**)

SFA-5.16/SFA-5.16M

(Identical with AWS Specification A5.16/A5.16M:2013. In case of dispute, the original AWS text applies.)

Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods

1. General Requirements

1.1 Scope. This standard specifies requirements for the classification of solid wire electrodes, solid wires and rods for fusion welding of titanium and titanium-alloys. The classification *of the solid wires and cut lengths and spools of wire is* based on their chemical composition.

For titanium welding consumables, the compositions of the wire electrodes for *the gas metal arc welding (GMAW) process* are the same as *for the gas tungsten arc welding (GTAW) process*, the plasma arc *welding (PAW) process, the* laser beam *welding (LBW) process*, and *other* fusion welding processes. *Therefore, the use of the word "wires/rods" in this classification refers to both "wire electrodes" and "wires and rods" in this standard.*

NOTE: In this standard, the word "titanium" is used for "titanium and titanium-alloys."

The classification of titanium wires/rods is based upon the chemical composition of the wires/rods.

1.2 Units of Measure. *This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently when referring to material properties. Standard dimensions based on either system may be used for sizing of electrodes or packaging or both under A5.16 or A5.16M specifications.*

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.*

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) Material 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 following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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[1] *AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.*

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

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

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

2.2 *The following ANSI standard[2] is referenced in the mandatory sections of this document:*

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

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

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

ASTM E539, Standard Test Method for Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry

ASTM E1409, Standard Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

ASTM E1447, Standard Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

ASTM E1941, Standard Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis

ASTM E2371, Standard Test Method for Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma Spectrometry

ASTM E2626, Standard Guide for Spectrometric Analysis of Reactive and Refractory Metals

2.4 *The following ISO standards[4] are referenced in the mandatory sections of this document:*

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

ISO 14344, Welding consumables-Procurement of filler materials and fluxes

ISO 80000–1:2009, Quantities and units — Part 1: General

3. Classification

The welding consumables may be classified with a numerical and/or an AWS designation.

1. *Numerical designation:*
   a. The first part *indicates the product form as solid wires or rods,* see 4.1.
   b. The second part gives a *numerical* symbol indicating the chemical composition of the *solid* wire/*rod*, see Table 1.
2. *AWS designation:*
   a. *The AWS classification includes the product form as part of the classification designator.*

4. Symbols and Requirements

4.1 Symbols for the Product *Form*

The symbol for the solid wire and rod shall be S. *If numerical designations are used there is no additional symbol when AWS classification is used.*

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[2] *This ANSI standard is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.*

[3] *This ASTM standards is published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959.*

[4] *ISO standards are published by the International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56 CH-1211 Geneva 20, Switzerland.*

Table 1
Symbols for Chemical Composition and Composition Requirements

AWS Classification	*UNS Number*	Chemical Alloy Symbol	Chemical Composition Requirements, % (by mass)[a, b, c, d]											
			C	O	N	H	Fe	Al	V	Pd	Ru	Ni	Mo	Other
ERTi-1	R50100	Ti99,8	0.03	0.03 to 0.10	0.012	0.005	0.08	—	—	—	—	—	—	—
ERTi-2	R50120	Ti99,6	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	—	—	—	—	—
ERTi-3	R50125	Ti99,5	0.03	0.13 to 0.20	0.02	0.008	0.16	—	—	—	—	—	—	—
ERTi-4	R50130	Ti99,3	0.03	0.18 to 0.32	0.025	0.008	0.25	—	—	—	—	—	—	—
ERTi-5	R56402	TiAl6V4B	0.05	0.12 to 0.20	0.030	0.015	0.22	5.50 to 6.75	3.50 to 4.50	—	—	—	—	—
ERTi-7	R52401	TiPd0,2A	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	0.12 to 0.25	—	—	—	—
ERTi-9[e]	R56321	TiAl3V2,5A	0.03	0.06 to 0.12	0.012	0.005	0.20	2.5 to 3.5	2.0 to 3.0	—	—	—	—	—
ERTi-11	R52251	TiPd0,2	0.03	0.03 to 0.10	0.012	0.005	0.08	—	—	0.12 to 0.25	—	—	—	—
ERTi-12	R53401	TiNi0,7Mo0,3	0.03	0.08 to 0.16	0.015	0.008	0.15	—	—	—	—	0.6 to 0.9	0.2 to 0.4	—
ERTi-13	R53423	TiNi0,5	0.03	0.03 to 0.10	0.012	0.005	0.08	—	—	—	0.04 to 0.06	0.4 to 0.6	—	—
ERTi-14	R53424	TiNi0,5A	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	—	0.04 to 0.06	0.4 to 0.6	—	—
ERTi-15A	R53416	TiRu0,05Ni0,5	0.03	0.13 to 0.20	0.02	0.008	0.16	—	—	—	0.04 to 0.06	0.4 to 0.6	—	—
ERTi-16	R52403	TiPd0,06A	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	0.04 to 0.08	—	—	—	—
ERTi-17	R52253	TiPd0,06	0.03	0.03 to 0.10	0.012	0.005	0.08	—	—	0.04 to 0.08	—	—	—	—
ERTi-18	R56326	TiAl3V2,5Pd	0.03	0.06 to 0.12	0.012	0.005	0.20	2.5 to 3.5	2.0 to 3.0	0.04 to 0.08	—	—	—	—
ERTi-19	R58641	TiV8Cr6Mo4Zr4Al3	0.03	0.06 to 0.10	0.015	0.015	0.20	3.0 to 4.0	7.5 to 8.5	—	—	—	3.5 to 4.5	Cr: 5.5 to 6.5 Zr: 3.5 to 4.5
ERTi-20	R58646	TiV8Cr6Mo4Zr4Al3Pd	0.03	0.06 to 0.10	0.015	0.015	0.20	3.0 to 4.0	7.5 to 8.5	0.04 to 0.08	—	—	3.5 to 4.5	Cr: 5.5 to 6.5 Zr: 3.5 to 4.5
ERTi-21	R58211	TiMo15Al3Nb3	0.03	0.10 to 0.15	0.012	0.005	0.20 to 0.40	2.5 to 3.5	—	—	—	—	14.0 to 16.0	Nb: 2.2 to 3.2 Si: 0.15 to 0.25
ERTi-23	R56408	TiAl6V4A	0.03	0.03 to 0.11	0.012	0.005	0.20	5.5 to 6.5	3.5 to 4.5	—	—	—	—	—
ERTi-24	R56415	TiAl6V4Pd	0.05	0.12 to 0.20	0.030	0.015	0.22	5.5 to 6.7	3.5 to 4.5	0.04 to 0.08	—	—	—	—
ERTi-25	R56413	TiAl6V4Ni0,5Pd	0.05	0.12 to 0.20	0.030	0.015	0.22	5.5 to 6.7	3.5 to 4.5	0.04 to 0.08	—	0.3 to 0.8	—	—
ERTi-26	R52405	TiRu0,1A	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	—	0.08 to 0.14	—	—	—
ERTi-27	R52255	TiRu0,1	0.03	0.03 to 0.10	0.012	0.005	0.08	—	—	—	0.08 to 0.14	—	—	—
ERTi-28	R56324	TiAl3V2,5Ru	0.03	0.06 to 0.12	0.012	0.005	0.20	2.5 to 3.5	2.0 to 3.0	—	0.08 to 0.14	—	—	—
ERTi-29	R56414	TiAl6V4Ru	0.03	0.03 to 0.11	0.012	0.005	0.20	5.5 to 6.5	3.5 to 4.5	—	0.08 to 0.14	—	—	—
ERTi-30	R53531	TiCo0,5	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	0.04 to 0.08	—	—	—	Co: 0.20 to 0.80
ERTi-31	R53533	TiCo0,5A	0.03	0.13 to 0.20	0.02	0.008	0.16	—	—	0.04 to 0.08			—	Co: 0.20 to 0.80
ERTi-32	R55112	TiAl5V1SnMo1Zr11	0.03	0.05 to 0.10	0.012	0.008	0.20	4.5 to 5.5	0.6 to 1.4	—	—	—	0.6 to 1.2	Zr: 0.6 to 1.4 Si: 0.06 to 0.14 Sn: 0.6 to 1.4

Table 1
Symbols for Chemical Composition and Composition Requirements

			Chemical Composition Requirements, % (by mass)[a, b, c, d]											
AWS Classification	*UNS Number*	Chemical Alloy Symbol	C	O	N	H	Fe	Al	V	Pd	Ru	Ni	Mo	Other
ERTi-33	R53443	TiNi0,45Cr0,15	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	0.01 to 0.02	0.02 to 0.04	0.35 to 0.55	—	Cr: 0.1 to 0.2
ERTi-34	R53444	TiNi0,45Cr0,15A	0.03	0.13 to 0.20	0.02	0.008	0.16	—	—	0.01 to 0.02	0.02 to 0.04	0.35 to 0.55	—	Cr: 0.1 to 0.2
ERTi-36	R58451	TiNb45	0.03	0.06 to 0.12	0.02	0.0035	0.03	—	—	—	—	—	—	Nb: 42.0 to 47.0
ERTi-38	R54251	TiAl4V2Fe	0.05	0.20 to 0.27	0.02	0.010	1.2 to 1.8	3.5 to 4.5	2.0 to 3.0	—	—	—	—	—

[a] Single values are maxima, unless otherwise noted.

[b] The remainder of the alloy is titanium.

[c] Analysis of *Fe and* the interstitial elements C, O, H, and N shall be conducted on samples of rod/wire taken after the rod/wire has been reduced to its final diameter and all processing operations have been completed. Analysis of the other elements may be conducted on *these* same samples or it may have been conducted on samples taken from the ingot or the rod stock from which the rod/wire is made. In case of dispute, samples from the finished rod/wire shall be the referee method.

[d] Any element intentionally added (O, Fe, N, and C) shall be measured and reported. Residual elements, total, shall not exceed 0.20 percent, with no single element exceeding 0.05 percent, except for yttrium, which shall not exceed 0.005 percent. Residual elements need not be reported unless specifically required by the purchaser. A residual element is any element present in the metal in small quantities that is inherent in the sponge or scrap additions, but not intentionally added. In titanium these elements include, among others, aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, and cobalt.

[e] *Formerly ERTi-9 ELI*

4.2 Symbol for the Chemical Composition

The numerical symbol*s or AWS Classification* in Table 1 indicate*s* the chemical composition of the solid wire or rod, determined under conditions given in Clause 6. The first two digits indicate the alloy group. See Annex A for an explanation of the numerical symbols. *The second column (AWS A5.16/A5.16M Classification) is for reference to previous revisions of this specification.*

4.3 Rounding-Off Procedure

For the purpose 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, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications or* Rule A *in Clause B.3* of ISO 80000–1:2009 *(the results are the same).* If the measured values are obtained by equipment calibrated in units other than those of this standard, the measured values shall be converted to the units of this standard before rounding-*off*. If an average value is to be compared to the requirements of this standard, rounding-*off* shall be done only after calculating the average. In the case where the testing standard cited in the normative references of this standard contains instructions for rounding-*off* that conflict with the instructions of this standard, the rounding-*off* requirements of the testing standard shall apply. The rounded-off results shall fulfill the requirements of the appropriate table for the classification under test.

5. Mechanical Properties

Mechanical properties of weld metal or welded joints are not part of this classification.

6. Chemical Analysis

Chemical analysis shall be performed on specimens of the product or the stock from which it is made. See also footnote c to Table 1. *Many approved* analytical techniques *are applicable* but, in case of a dispute, reference shall be made to established published methods, agreed *upon* between the contracting parties.

7. Retest

If any test fails to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for the retest may be taken from the original test sample or from a new test sample. For chemical analysis, retests need be only for those specific elements that failed to meet their 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 sample or test specimen(s), or in conducting the tests, 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 prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

8. Technical Delivery Conditions

Technical delivery conditions shall meet the requirements in *AWS A5.01M/A5.01(ISO 14344 MOD) and AWS A5.02/A5.02M*, or ISO 544 and ISO 14344.

9. Designation

The designation of solid wire electrodes, solid wires and rods shall follow the principles given in the examples below.

EXAMPLE 1: A solid wire (S) for fusion welding that has a chemical composition within the limits for the alloy Ti 6402 (TiAl6V4B) of Table 1 is designated as follows:

Solid wire ISO 24034— ***ERTi-5***

or alternatively:

Solid wire ISO 24034— ***ERTi-5 (TiAl6V4B)***

EXAMPLE 2

(AWS wire designation): A solid rod (S) for fusion welding is designated as follows:

Solid rod— ***Ti-12***

or alternatively:

Solid rod— ***ERTi-12***

Where, for the two examples:

ISO 24034	is the number of the International Standard;
S	is the product form (see 4.1);
Ti 6402	*is the numerical symbol for welding consumable (see Table 1);*
ERTi-5	*is the AWS Classification of the welding consumable (See Table 1);*
TiAl6V4B	is the optional chemical symbol for chemical composition 6402 (see Table 1).

National Annexes

Annex D (Informative)

Guide to AWS Specification for Titanium and Titanium–Alloy Welding Electrodes and Rods

This annex is not part of AWS A5.16/A5.16M:2013 (ISO 24034:2010 MOD), *Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods*, but is included for informational purposes only.

D1. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344 MOD), Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes 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. Testing in accordance with any other Schedule in that Table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

D2. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification. The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. Certification is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in AWS A5.01M/A5.01 (ISO 14344 MOD).

D3. Ventilation During Welding

D3.1 *Five major factors govern the quantity of fumes to which welders and welding operators are exposed during welding:*

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

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

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

(4) The proximity of the welders or welding operators to the fumes as the 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.

D3.2 *American National Standard Z49.1, Safety in Welding, Cutting, and Allied Processes discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section of that document, entitled "Ventilation." Further details about ventilation can be found in AWS F3.2 Ventilation Guide for Welding Fume.*

D4. Welding Considerations

D4.1 *Titanium and titanium-alloys can be welded by gas tungsten arc, gas metal arc, plasma arc, laser beam, and electron beam welding processes. Titanium is a reactive metal and is sensitive to embrittlement by oxygen, nitrogen, and hydrogen, at elevated temperatures. Consequently, the metal must be protected from atmospheric contamination. This can be provided by shielding the metal with welding grade inert gas as specified in AWS A5.32M/A5.32 (ISO 14175 MOD), Welding Consumables-Gases and Gas Mixtures for Fusion Welding and Allied Processes for classes SE-A or SG-He or having mixtures of these single shielding gas classes surrounding the arc and molten or just solidified but still hot weld metal. Welding can also be done remotely in a chamber or in a glove bag. These chambers can be purged of air and back filled with inert gas, or, if they are rigid gas tight walls, can be evacuated to at least* 10^{-4} *torr [0.013 Pa] to remove any air contaminants.*

During arc welding, the titanium should be shielded from the ambient air atmosphere until it has cooled below about 800°F [430°C]. Adequate protection by auxiliary inert gas shielding can be provided when welding is being performed in ambient air atmosphere. Ventilation and exhaust at the arc must be carried out in such a manner that the protective inert gas shielding (arc shielding, trailing shielding, or root shielding) is not impaired.

D4.2 *The titanium metal should be free of thick oxide and chemically clean prior to welding, as contamination from oxide, water, grease, or dirt will also cause embrittlement.*

D4.3 *Titanium welding rods should be chemically clean and free of heavy oxide, absorbed moisture, grease, and dirt. If the hot end of the filler metal is removed from the gas shield prior to cooling and then reused, it contributes to weld contamination. Welding rod should be added by technique that keeps the hot end within the torch gas blanket. If the rod tip becomes contaminated, the discolored end should be cut off before reusing.*

D5. Discontinued Classifications

Some classifications have been discontinued from one revision of this specification to another. This resulted from either changes in commercial practice or changes in the classification system used in the specification. The discontinued classifications are listed in Table D.1, along with the year last included in the specification.

Table D.1
Discontinued Titanium Filler Metal Classifications

AWS Classification	*Last Year Published*
ERTi-6	*1990*
ERTi-6ELl	*1990*
ERTi-15	*1990*
ERTi-8Al-2Cb-1Ta-1Mo-1V	*1970*
ERTi-8Al-1Mo-1V	*1970*
ERTi-13V-11Cr-3Al	*1970*

D6. Special Tests

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. AWS A5.01M/A5.01 (ISO 14344 MOD) provides a means by which such tests can be incorporated into the purchase order. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

D7. General Safety Considerations

D7.1 *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 E3. Safety and health information is available from other sources, including, but not limited to the Safety and Health Fact Sheets listed in E7.3, ANSI Z49.1, and applicable federal and state regulations.*

D7.2 Safety and Health Fact Sheets. *The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org.* The Safety and Health Fact Sheets are revised and additional sheets added periodically.

D7.3 AWS Safety and Health Fact Sheets Index (SHF)[6]

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 and Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Under Development*
27	*Thoriated Tungsten Electrodes*
28	*Under Development*
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*

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[6] *AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.*

SPECIFICATION FOR CARBON STEEL ELECTRODES AND FLUXES FOR SUBMERGED ARC WELDING

SFA-5.17/SFA-5.17M

(Identical with AWS Specification A5.17/A5.17M-97 (R2007). In case of dispute, the original AWS text applies.)

SPECIFICATION FOR CARBON STEEL ELECTRODES AND FLUXES FOR SUBMERGED ARC WELDING

SFA-5.17/SFA-5.17M

[Identical with AWS Specification A5.17/A5.17M-97 (R2007). In case of dispute, the original AWS text applies.]

1. Scope

This specification prescribes requirements for the classification of carbon steel electrodes (both solid and composite) and fluxes for submerged arc welding.

This document is the first of the A5.17 specifications which is a combined specification providing for classification utilizing a system based upon U.S. Customary Units, or utilizing a system based upon the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other, without combining values in any way. In selecting rational metric units, ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry,* is used where suitable. Tables and figures make use of both U.S. Customary Units and SI Units which, with the application of the specified tolerances, provides for interchangeability of products in both U.S. Customary and SI Units.

(a) Paragraphs, tables and figures which carry the suffix letter "U" are applicable only to those products classified to the system based upon U.S. Customary Units under the A5.17 specification.

(b) Paragraphs, tables and figures which carry the suffix letter "M" are applicable only to those products classified to the system based upon the International System of Units (SI), under the A5.17M specification.

(c) Paragraphs, tables and figures which do not have either the suffix letter "U" or the suffix letter "M" are applicable to those products classified under either the U.S. Customary Units System or the International System of Units (SI).

PART A — GENERAL REQUIREMENTS

2. Normative References

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

(a) ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry.*

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

(c) ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*

(d) ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.*

(e) ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds.*

2.2 The following ASTM standards[2] are referenced in the mandatory sections of this document:

(a) ASTM A29/A29M, *Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished.*

(b) ASTM A36/A36M, *Specification for Carbon Structural Steel.*

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

(d) ASTM A515/A515M, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service.*

(e) ASTM A516/A516M, *Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.*

(f) ASTM DS-56, SAE HS-1086, *Metals and Alloys in the Unified Numbering System.*

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

(h) ASTM E142, *Method for Controlling Quality of Radiographic Testing.*

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[1] AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[2] ASTM standards can be obtained from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

2.3 The following ISO standards[3] are referenced in the mandatory section of this document.

(a) ISO 864, *Arc Welding — Solid and Tubular Cored Wires which Deposit Carbon and Carbon-Manganese Steel — Dimensions of Wires, Spools, Rims and Coils.*

3. Classification

3.1U The welding electrodes and fluxes covered by the A5.17 specification utilize a classification system based upon U.S. Customary Units and are classified according to the following:

(a) The mechanical properties of the weld metal obtained with a combination of a particular flux and a particular classification of electrode, as specified in Tables 5U and 6U.

(b) The condition of heat treatment in which those properties are obtained, as specified in 9.4 (and shown in Fig. 1U).

(c) The chemical composition of the electrode (for solid electrodes) as specified in Table 1, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 2.

3.1M The welding electrodes and fluxes covered by the A5.17M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the following:

(a) The mechanical properties of the weld metal obtained with a combination of a particular flux and a particular classification of electrode, as specified in Tables 5M and 6M.

(b) The condition of heat treatment in which those properties are obtained, as specified in 9.4 (and shown in Fig. 1M).

(c) The chemical composition of the electrode (for solid electrodes) as specified in Table 1, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 2.

3.2 Solid electrodes classified under one classification shall not be classified under any other classification in this specification, except that solid electrodes meeting the chemical composition requirements of both the EL8 and EL12 classifications (Table 1) may be given both classifications. Composite electrodes may be classified under more than one classifications when used with different fluxes. Fluxes may be classified under any number of classifications, for weld metal in either or both the as-welded and postweld heat-treated conditions, using different electrode classifications. Flux-electrode combinations may be classified under A5.17 with U.S. Customary Units, A5.17M using the International System of Units (SI), or both. Flux-electrode combinations classified under both A5.17 and A5.17M must meet all requirements for classification under each system. The classification systems are shown in Figs. 1U and 1M.

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

4. Acceptance

Acceptance of the electrodes and fluxes shall be in accordance with the provisions of the latest edition of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines* (see Annex A3).

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 Annex A4).

6. Units of Measure and Rounding-Off Procedure

6.1 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 A5.17 uses U.S. Customary Units. The specification with the designation A5.17M uses SI Units. The latter are shown in appropriate columns in the tables or figures or are shown within brackets [] when used in the text. Figures in parentheses (), following the U.S. Customary Units, are calculated equivalent SI values for the specified dimensions. Figures in brackets [], following U.S. Customary Units used in the text, are rational SI Units.

6.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi for tensile and yield strength for A5.17 [to the nearest 10 MPa for tensile and yield strength for A5.17M] and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities in accordance with the rounding-off method given in ASTM E29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*

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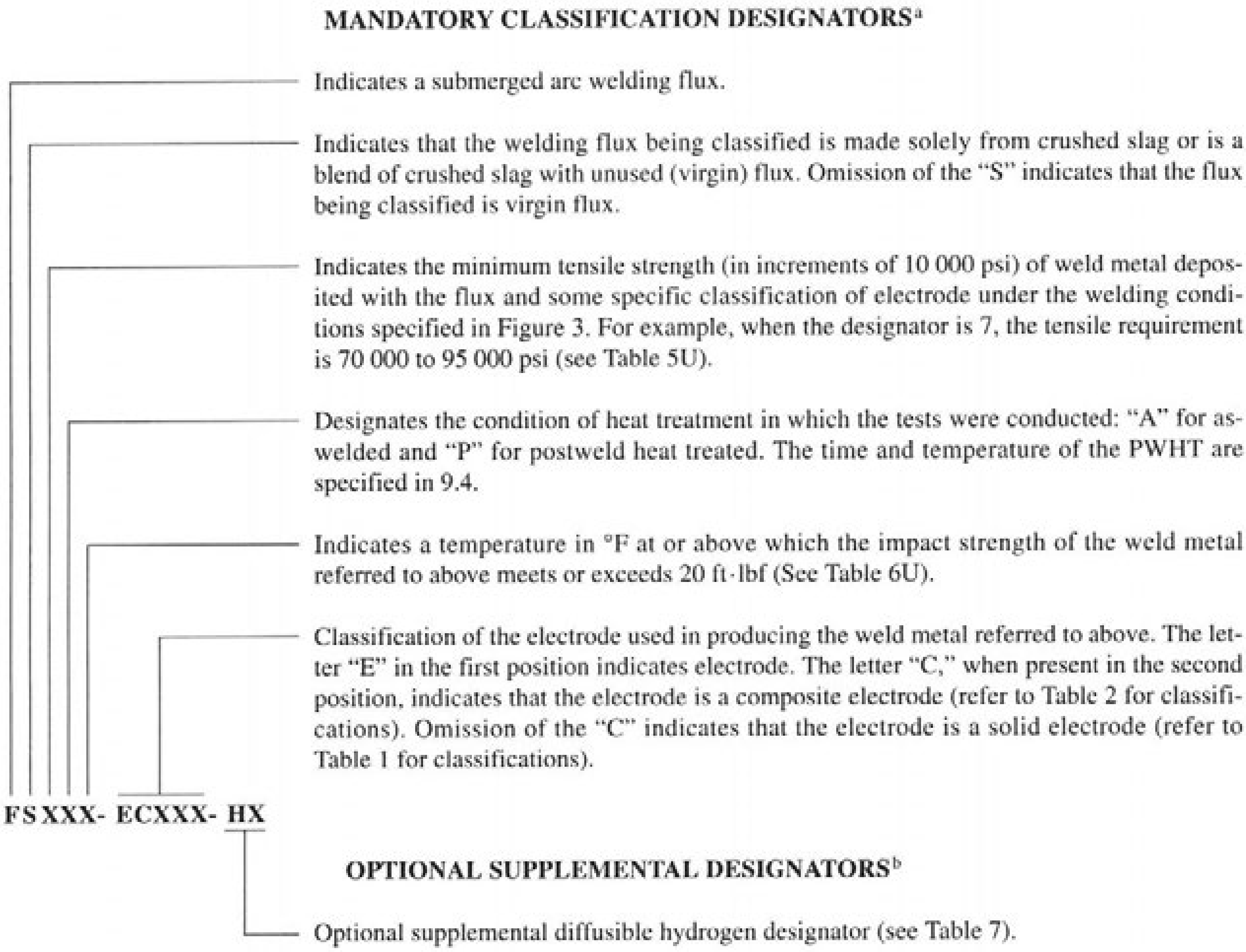
[3] ISO standards may be obtained from American National Standards Institute (ANSI), 11 West 42nd St., 13th Floor, New York, NY 10036-8002.

FIG. 1U A5.17 CLASSIFICATION SYSTEM FOR U.S. CUSTOMARY UNITS



MANDATORY CLASSIFICATION DESIGNATORS[a]

Indicates a submerged arc welding flux.

Indicates that the welding flux being classified is made solely from crushed slag or is a blend of crushed slag with unused (virgin) flux. Omission of the "S" indicates that the flux being classified is virgin flux.

Indicates the minimum tensile strength (in increments of 10 000 psi) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 3. For example, when the designator is 7, the tensile requirement is 70 000 to 95 000 psi (see Table 5U).

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

Indicates a temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf (See Table 6U).

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C," when present in the second position, indicates that the electrode is a composite electrode (refer to Table 2 for classifications). Omission of the "C" indicates that the electrode is a solid electrode (refer to Table 1 for classifications).

FSXXX- ECXXX- HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 7).

Notes:

(a) The combination of these designators constitutes the flux-electrode classification.

(b) These designators are optional and do not constitute a part of the flux-electrode classification.

Examples

F7A6-EM12K is a complete designation for a flux-electrode combination. It refers to a flux that will produce weld metal which, in the as-welded condition, will have a tensile strength of 70 000 to 95 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –60°F when produced with an EM12K electrode under the conditions called for in this specification. The absence of an "S" in the second position indicates that the flux being classified is a virgin flux.

F7P4-EC1 is a complete designation for a flux-composite electrode combination when the trade name of the electrode used in the classification is indicated as well [see 17.4.1(3)]. It refers to a virgin flux that will produce weld metal with that electrode which, in the postweld heat treated condition, will have a tensile strength of 70 000 to 95 000 psi and Charpy V-notch energy of at least 20 ft·lbf at –40° F under the conditions called for in this specification.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES

Electrode Classification	UNS Number(3)	wt. percent(1) (2)						
		C	Mn	Si	S	P	Cu(4)	Ti
Low-Manganese Electrodes								
EL8	K01008	0.10	0.25/0.60	0.07	0.030	0.030	0.35	—
EL8K	K01009	0.10	0.25/0.60	0.10/0.25	0.030	0.030	0.35	—
EL12	K01012	0.04/0.14	0.25/0.60	0.10	0.030	0.030	0.35	—
Medium-Manganese Electrodes								
EM11K	K01111	0.07/0.15	1.00/1.50	0.65/0.85	0.030	0.025	0.35	—
EM12	K01112	0.06/0.15	0.80/1.25	0.10	0.030	0.030	0.35	—
EM12K	K01113	0.05/0.15	0.80/1.25	0.10/0.35	0.030	0.030	0.35	—
EM13K	K01313	0.06/0.16	0.90/1.40	0.35/0.75	0.030	0.030	0.35	—
EM14K	K01314	0.06/0.19	0.90/1.40	0.35/0.75	0.025	0.025	0.35	0.03/0.17
EM15K	K01515	0.10/0.20	0.80/1.25	0.10/0.35	0.030	0.030	0.35	—
High-Manganese Electrodes								
EH10K	K01210	0.07/0.15	1.30/1.70	0.05/0.25	0.025	0.025	0.35	—
EH11K	K11140	0.07/0.15	1.40/1.85	0.80/1.15	0.030	0.030	0.35	—
EH12K	K01213	0.06/0.15	1.50/2.00	0.25/0.65	0.025	0.025	0.35	—
EH14	K11585	0.10/0.20	1.70/2.20	0.10	0.030	0.030	0.35	—
EG	Not Specified							

NOTES:

(1) The electrode shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50 percent.

(2) Single values are maximum.

(3) SAE/ASTM Unified Numbering System for Metals and Alloys.

(4) The copper limit includes any copper coating that may be applied to the electrode.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR COMPOSITE ELECTRODE WELD METAL

Electrode Classification	UNS Number(4)	wt. percent(1) (2) (3)					
		C	Mn	Si	S	P	Cu
EC1	W06041	0.15	1.80	0.90	0.035	0.035	0.35
ECG	Not Specified						

NOTES:

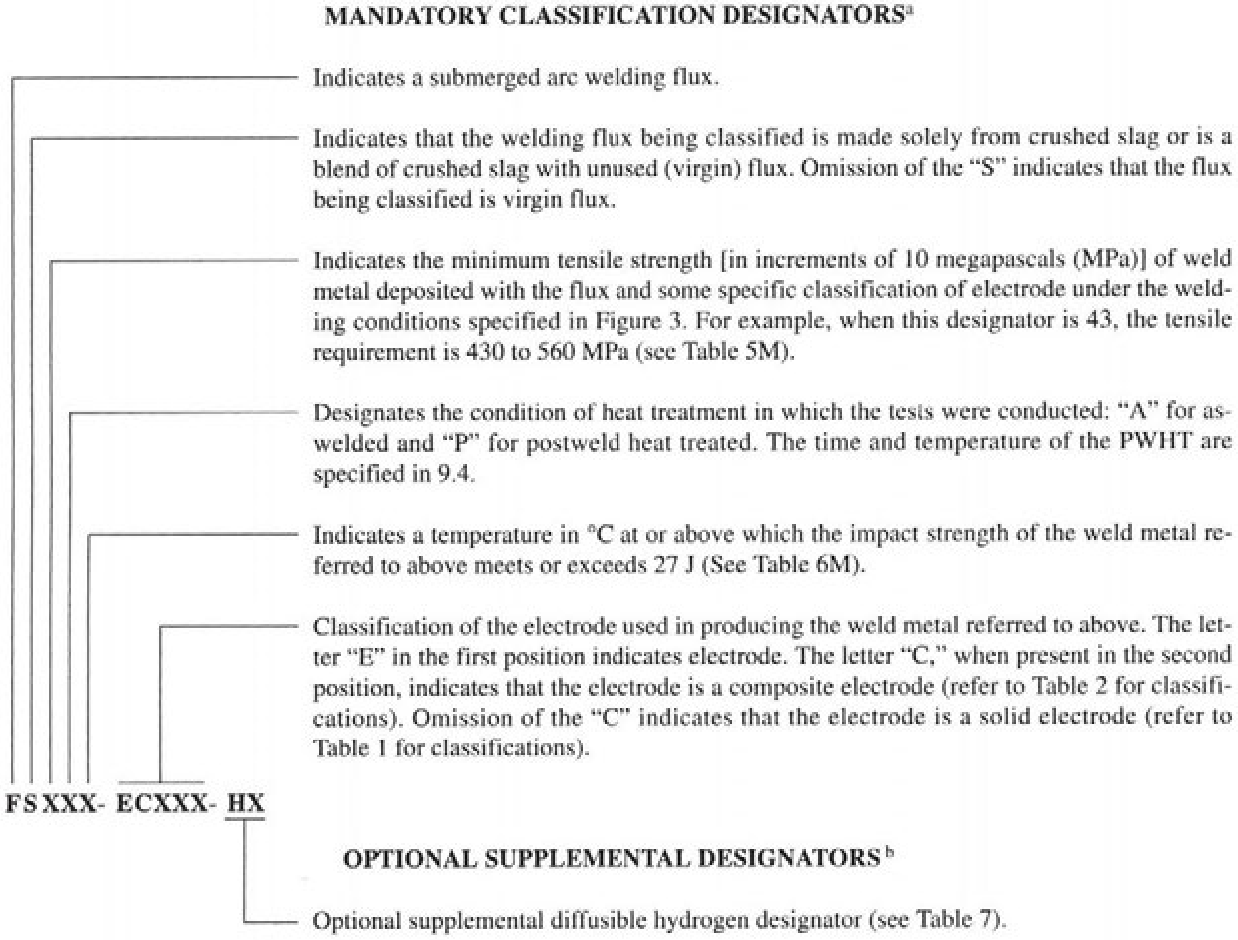
(1) The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50 percent.

(2) Single values are maximum.

(3) As a substitute for the weld pad in Figure 2, the sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen (see 12.1) or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 3. In case of dispute, the weld pad shall be the reference method.

(4) SAE/ASTM Unified Numbering System for Metals and Alloys.

FIG. 1M A5.17M CLASSIFICATION SYSTEM FOR THE INTERNATIONAL SYSTEM OF UNITS (SI)



MANDATORY CLASSIFICATION DESIGNATORS[a]

Indicates a submerged arc welding flux.

Indicates that the welding flux being classified is made solely from crushed slag or is a blend of crushed slag with unused (virgin) flux. Omission of the "S" indicates that the flux being classified is virgin flux.

Indicates the minimum tensile strength [in increments of 10 megapascals (MPa)] of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 3. For example, when this designator is 43, the tensile requirement is 430 to 560 MPa (see Table 5M).

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

Indicates a temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J (See Table 6M).

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C," when present in the second position, indicates that the electrode is a composite electrode (refer to Table 2 for classifications). Omission of the "C" indicates that the electrode is a solid electrode (refer to Table 1 for classifications).

FSXXX- ECXXX- HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 7).

Notes:

(a) The combination of these designators constitutes the flux-electrode classification.

(b) These designators are optional and do not constitute a part of the flux-electrode classification.

Examples

F43A2-EM12K is a complete designation for a flux-electrode combination. It refers to a flux that will produce weld metal which, in the as-welded condition, will have a tensile strength of 430 to 560 MPa and Charpy V-notch impact strength of at least 27 J at –20°C when produced with an EM12K electrode under the conditions called for in this specification. The absence of an "S" in the second position indicates that the flux being classified is a virgin flux.

F48P6-EC1 is a complete designation for a flux-composite electrode combination when the trade name of the electrode used in the classification is indicated as well [see 17.4.1(3)]. It refers to a virgin flux that will produce weld metal with that electrode which, in the postweld heat treated condition, will have a tensile strength of 480 to 660 MPa and Charpy V-notch energy of at least 27 J at –60°C under the conditions called for in this specification.

TABLE 3
TESTS REQUIRED FOR CLASSIFICATION

AWS Classification	Chemical Analysis		Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
	Electrode	Weld Metal				
All Solid Electrodes	Required	Not Required	Not Required	Not Required	Not Required	Not Required
All Composite Electrodes	Not Required	Required	Not Required	Not Required	Not Required	Not Required
All Flux-Solid Electrode Combinations	Not Required	Not Required	Required	Required	Required[a]	[b]
All Flux-Composite Electrode Combinations	Not Required	Not Required	Required	Required	Required[a]	[b]

NOTES:

a. When the "Z" impact designator (no impact requirement — Table 6U and 6M) is used, the Impact Test is not required.

b. Diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Section A3 and A6.4 in the Annex).

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

7. Summary of Tests

The tests required for classification of solid electrodes, composite electrodes, and flux-electrode combinations are specified in Table 3.

7.1 Electrodes

7.1.1 Solid Electrodes. Chemical analysis of the electrode is the only test required for classification of a solid electrode under this specification. The chemical analysis of the rod stock from which the electrode is made may also be used, provided the electrode manufacturing process does not alter the chemical composition.

7.1.2 Composite Electrodes. Chemical analysis of weld metal produced with the composite electrode and a particular flux is the only test required for classification of a composite electrode under this specification.

7.2 Fluxes. The tests specified in Table 3 determine the mechanical properties and soundness of the weld metal obtained with a particular flux-electrode combination. The base metal for the test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 13.

7.3 Flux classification is based upon a $^5/_{32}$ in. [4.0 mm] electrode size as standard. If this size electrode is not manufactured, the closest size shall be used for classification tests. See Note d of Fig. 3B.

8. Retest

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

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

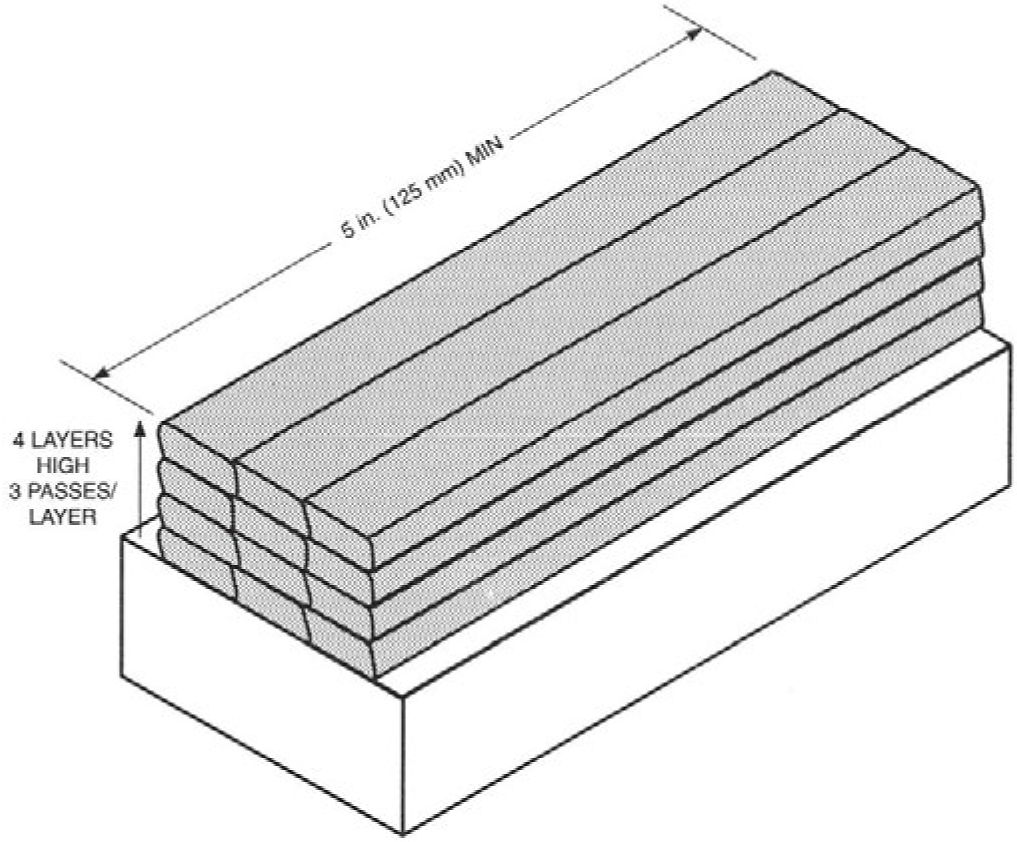
9. Weld Test Assemblies

9.1 Requirements for Classification

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

9.1.2 Classification of Composite Electrodes. The chemical analysis of weld metal produced with the composite electrode and a particular flux is required for classification of a composite electrode under this specification. The weld test assembly, shown in Fig. 2, is used to meet this requirement for the classification of composite electrodes. Figure 2 is the weld pad test assembly for chemical analysis of weld metal. As an alternative to the weld pad, the sample for chemical analysis of composite electrode weld metal may be taken from the groove weld in Fig. 3A. Note c to Table 2 allows the sample for chemical analysis in the case of a composite electrode to be taken from the reduced section of the fractured tension test specimen of Fig. 5 or from a corresponding location (or any location above it) in the weld metal in the groove weld in Fig. 3A. In case of dispute, the weld pad shall be the referee method.

FIG. 2 WELD PAD FOR CHEMICAL ANALYSIS OF WELD METAL



GENERAL NOTES:

(1) Width and thickness of the base-metal plate may be any dimensions suitable for the electrode diameter and current in use.

(2) Weld beads shall be deposited without oscillation. The welding conditions shall be in accordance with the manufacturer's recommendations.

(3) The first and last 2 in. [50 mm] of the weld length shall be discarded. The top surface shall be removed, and chemical analysis samples shall be taken from the underlying metal of the fourth layer of the weld pad.

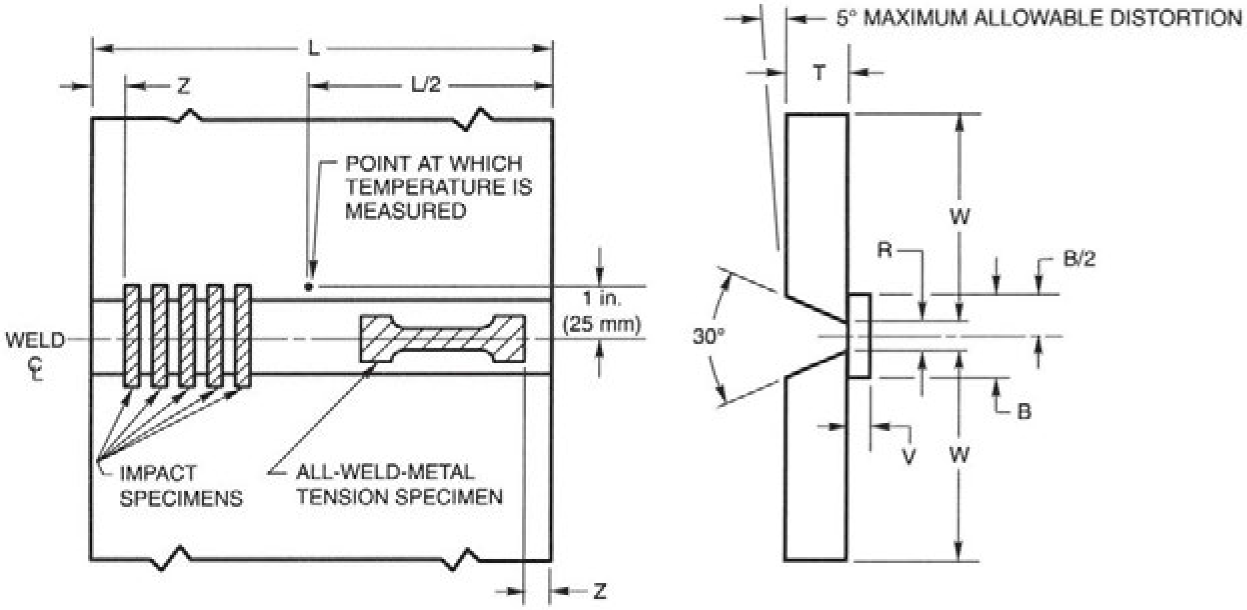
9.1.3 Classification of Flux-Electrode Combinations. One groove weld test assembly is required for each classification of a flux-solid electrode combination or a flux-composite electrode combination. This is the groove weld in Fig. 3A for mechanical properties and soundness of weld metal.

9.2 Preparation. Preparation of each weld test assembly shall be as prescribed in 9.3 and 9.4. The base metal for the weld pad and groove weld assemblies shall be as required in Table 4 corresponding to the tests to be conducted and shall meet the requirements of the appropriate ASTM specification shown in Table 4, or an equivalent specification. Testing of the assemblies shall be as prescribed in Sections 10 through 13.

9.3 Weld Pad. For composite electrodes only, a weld pad shall be prepared as specified in Fig. 2, except when either alternative in 9.1.2 is selected. Base metal of any convenient size, and of the type specified in Table 4, shall be used as the base metal for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position, three passes per layer, four layers high, using the flux for which classification of the composite electrode is intended. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C]. The slag shall be removed after each pass. The pad may be quenched in water between passes but shall be dry before the start of each pass. Testing of this assembly shall be as specified in Section 10, Chemical Analysis.

9.4 Groove Weld for Mechanical Properties and Soundness. For classification of a flux-electrode combination, a test assembly shall be prepared and welded as specified in Fig. 3A using base metal of the appropriate type specified in Table 4. Prior to welding, the assembly may be preset so that the welded joint will be sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 degrees of plane.

FIG. 3A GROOVE WELD TEST ASSEMBLY



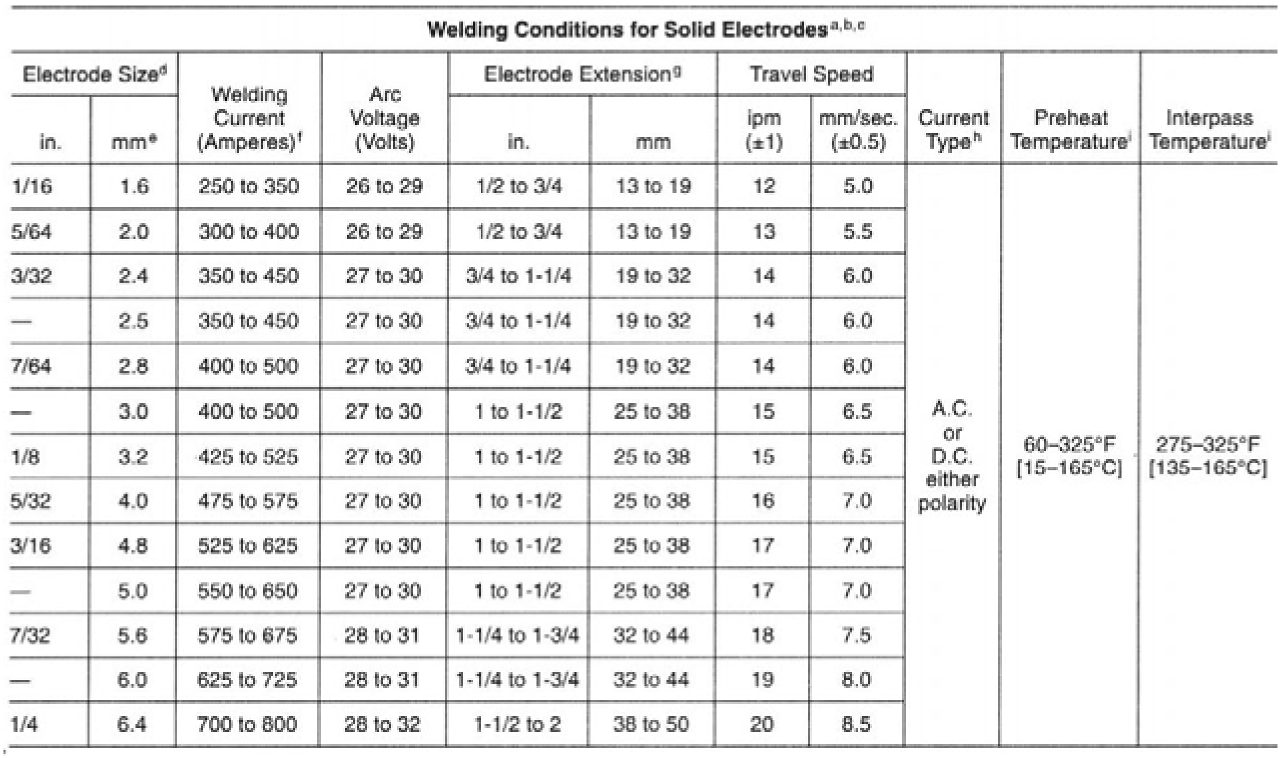
(A) JOINT CONFIGURATION AND LOCATION OF TEST SPECIMENS

(B) LOCATION OF IMPACT TEST SPECIMENS

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

Letter	Dimensions	in.	mm
L	Length (min)	12	305
T	Thickness	1 ± 1/16	25 ± 1.5
W	Width (min)	5	127
V	Backup Thickness	1/2 ± 1/16	13 ± 1.5
D	Specimen Center	3/8 ± 1/32	9.5 ± 1.0
B	Backup Width (min)	2	50
R	Root Opening	1/2 ± 1/16	13 ± 1.5
Z	Discard (min)	1	25

FIG. 3B GROOVE WELD TEST WELDING PARAMETERS



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

Electrode Size[d]		Welding Current (Amperes)[f]	Arc Voltage (Volts)	Electrode Extension[g]		Travel Speed		Current Type[h]	Preheat Temperature[i]	Interpass Temperature[i]
in.	mm[e]			in.	mm	ipm (±1)	mm/sec. (±0.5)			
1/16	1.6	250 to 350	26 to 29	1/2 to 3/4	13 to 19	12	5.0	A.C. or D.C. either polarity	60–325°F [15–165°C]	275–325°F [135–165°C]
5/64	2.0	300 to 400	26 to 29	1/2 to 3/4	13 to 19	13	5.5			
3/32	2.4	350 to 450	27 to 30	3/4 to 1-1/4	19 to 32	14	6.0			
—	2.5	350 to 450	27 to 30	3/4 to 1-1/4	19 to 32	14	6.0			
7/64	2.8	400 to 500	27 to 30	3/4 to 1-1/4	19 to 32	14	6.0			
—	3.0	400 to 500	27 to 30	1 to 1-1/2	25 to 38	15	6.5			
1/8	3.2	425 to 525	27 to 30	1 to 1-1/2	25 to 38	15	6.5			
5/32	4.0	475 to 575	27 to 30	1 to 1-1/2	25 to 38	16	7.0			
3/16	4.8	525 to 625	27 to 30	1 to 1-1/2	25 to 38	17	7.0			
—	5.0	550 to 650	27 to 30	1 to 1-1/2	25 to 38	17	7.0			
7/32	5.6	575 to 675	28 to 31	1-1/4 to 1-3/4	32 to 44	18	7.5			
—	6.0	625 to 725	28 to 31	1-1/4 to 1-3/4	32 to 44	19	8.0			
1/4	6.4	700 to 800	28 to 32	1-1/2 to 2	38 to 50	20	8.5			

NOTES:

(a) Values specified in inches or ipm apply to A5.17. Values specified in mm or mm/sec apply to A5.17M.

(b) These welding conditions are intended for machine or automatic welding with straight progression (no weaving). Welding shall be performed in the flat position. The first layer shall be produced in either 1 or 2 passes. All other layers shall be produced in 2 or 3 passes per layer except the last, which shall be produced in 3 or 4 passes. The completed weld shall be at least flush with the surface of the test plate.

(c) Welding conditions for composite electrodes shall be as agreed between purchaser and supplier.

(d) Classification is based on the properties of weld metal with $^5/_{32}$ in. [4.0 mm] electrodes or the closest size manufactured, if $^5/_{32}$ in. [4.0 mm] is not manufactured. The conditions given above for sizes other than $^5/_{32}$ in. [4.0 mm] are to be used when classification is based on those sizes, or when they are required for lot acceptance testing under A5.01, *Filler Metal Procurement Guidelines* (unless other conditions are specified by the purchaser).

(e) 4.8 mm, 5.6 mm, and 6.4 mm are not included as standard sizes in ISO 864:1988.

(f) Lower currents may be used for the first layer.

(g) The electrode extension is the contact tube-to-work distance. When an electrode manufacturer recommends a contact tube-to-work distance outside the range shown, that recommendation shall be followed ±$^1/_4$ in. [6.5 mm].

(h) In case of dispute, DCEP (direct current-electrode positive) shall be used as the referee current.

(i) The first bead shall be produced with the assembly at any temperature between 60 and 325°F [15 to 165°C]. Welding shall continue, bead by bead, until a temperature within the interpass temperature range has been attained. Thereafter, production of subsequent beads may begin only when the assembly is within the interpass temperature range. The point of temperature measurement shall be at the mid-length of the test assembly, approximately 1 in. [25 mm] from the weld centerline.

TABLE 4
BASE METALS FOR TEST ASSEMBLIES

Test Assembly	Type	ASTM Specification[1]	UNS Number[2]
Weld Pad for Chemical Analysis	Carbon Steel	A29 Grade 1015	G10150
		A29 Grade 1020	G10200
		A36	K02600
		A285 Grade A	K01700
		A285 Grade B	K02200
		A285 Grade C	K02801
		A285 Grade D	K02702
		A515 Grade 70	K03101
		A516 Grade 70	K02700
Groove Weld of Figure 3	Carbon Steel	A36	K02600
		A285 Grade A	K01700
		A285 Grade B	K02200
		A285 Grade C	K02801
		A285 Grade D	K02702
		A515 Grade 70	K03101
		A516 Grade 70	K02700

NOTES:

(1) Chemically equivalent steel may be used. In case of dispute, ASTM A36 shall be used as the referee steel.

(2) As classified in ASTM DS-56, SAE HS-1 Metals and Alloys in the Unified Numbering System.

A welded test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assembly is prohibited. Testing shall be as specified in Sections 10 through 13, with the assembly in either the as-welded or the postweld heat-treated condition, according to the classification of the weld metal (See Figs. 1U and 1M).

When the tests are to be conducted in each condition (as-welded and postweld heat treated), two such assemblies, or one single assembly of sufficient length to provide the specimens required for both conditions, shall be prepared. In the latter case, the single assembly shall be cut transverse to the weld into two pieces; one of the pieces shall be tested in the as-welded condition, and the other piece shall be heat treated prior to testing.

Any test assembly to be heat treated shall be heat treated at 1150 ± 25°F [620 ± 15°C] for one hour (−0, +15 minutes). The furnace shall be at a temperature not higher than 600°F [315°C] when the test assembly is placed in it. The heating rate, from that point to the 1150 ± 25°F [620 ± 15°C] holding temperature, shall not exceed 400°F per hour [220°C per hour]. When the holding time has been completed, the assembly shall be allowed to cool in the furnace to a temperature below 600°F [315°C] at a rate not exceeding 350°F per hour [195°C per hour]. The assembly may be removed from the furnace at any temperature below 600°F [315°C] and allowed to cool in still air, to room temperature.

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

10. Chemical Analysis

10.1 For solid electrodes, a sample of the electrode shall be prepared for chemical analysis. The rod stock from which the electrode is made may also be used for chemical analysis, provided the electrode manufacturing process does not alter the chemical composition. Solid electrodes, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the electrode is analyzed for elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for other elements. Rod stock may be analyzed prior to coating for those elements not added in the coating. In this case, the analysis of the elements in the electrode coating must be made on the finished electrode.

10.2 Composite electrodes shall be analyzed in the form of weld metal. The sample for analysis shall be taken from weld metal obtained with the electrode and the flux with which it is classified. The sample shall come from the weld pad in Fig. 2, from the reduced section of the fractured tension test specimen (see 12.1), or from a corresponding location (or any location above it) in the weld metal in the groove weld in Fig. 3A. In case of dispute, the weld pad shall be the referee method.

The top surface of the pad described in 9.3 and shown in Fig. 2 shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal of the fourth layer of the weld pad by any appropriate mechanical means. The sample shall be free of slag.

The alternatives to the weld pad outlined above and in 9.1.2 shall be prepared for analysis by any appropriate mechanical means.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be the procedure in the latest edition of ASTM E350, *Testing Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron.*

10.4 The results of the analysis shall meet the requirements of Table 1 or 2, as applicable, for the classification of electrode under test.

11. Radiographic Test

11.1 The groove weld described in 9.4 and shown in Fig. 3A 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. 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 E142, *Method for Controlling Quality of Radiographic Testing.* 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 the following:

(a) No cracks, no incomplete fusion, and no incomplete penetration

(b) No slag inclusions longer than $^5/_{16}$ in. [8 mm] or no groups of slag inclusions in line that have an aggregate length greater than 1 in. [25 mm] in a 12 in. [300 mm] length except when the distance between the successive inclusions exceeds 6 times the length of the longest inclusion in the group, and

(c) No rounded indications in excess of those permitted by the radiographic standards in Fig. 4

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 3 times its width. Rounded indications may be circular, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present.

11.3.2 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 One all-weld-metal standard round tensile specimen, as specified in the Tension Tests section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in 9.4 and shown in Fig. 3A. The tensile specimen shall have a nominal diameter of 0.500 in. [12.5 mm] and a nominal gage length-to-diameter ratio of 4:1.

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

12.3 The results of the tension test shall meet the requirements specified in Table 5U or Table 5M, as applicable.

13. Impact Test

13.1 For those classifications for which impact testing is specified in Table 3, five Charpy V-notch impact specimens, as specified in the Fracture Toughness Testing of Welds section of ANSI/AWS B4.0, shall be machined from the test assembly shown in Fig. 3A.

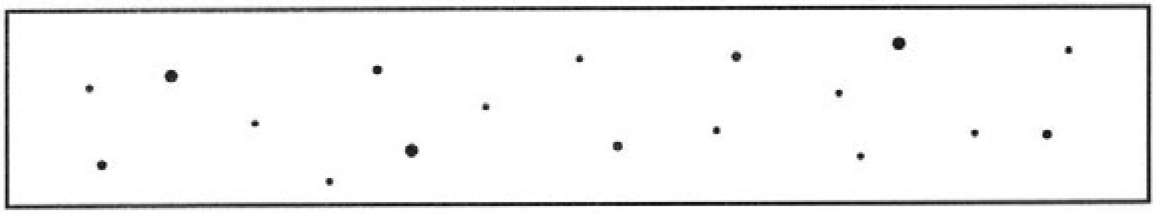
The Charpy V-notch specimens shall have the notched surface and the surface to be struck parallel within 0.002 in. [0.05 mm]. The other two surfaces shall be square with the notched or struck surface within ±10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at minimum 50 times magnification on either a shadowgraph or a metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the impact test section of ANSI/AWS B4.0. The test temperature shall be as specified in Table 6U or Table 6M, as applicable, for the classification under test.

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

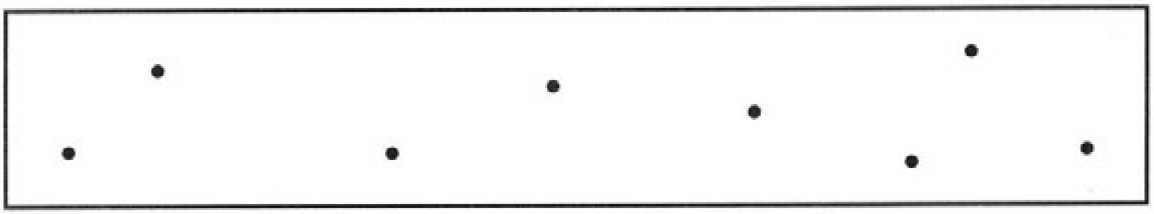
FIG. 4 RADIOGRAPHIC STANDARDS FOR ROUNDED INDICATION



(A) ASSORTED ROUNDED INDICATIONS

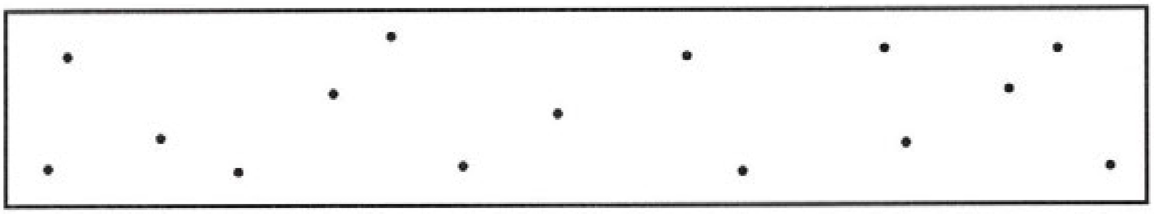
SIZE PERMITTED IS 1/64 in. [0.4 mm] TO 1/16 in. [1.6 mm]
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD = 18,
WITH THE FOLLOWING RESTRICTIONS:

LARGE: 3/64 in. [1.2 mm] TO 1/16 in. [1.6 mm] = 3 PERMITTED.
MEDIUM: 1/32 in. [0.8 mm] TO 3/64 in. [1.2 mm] = 5 PERMITTED.
SMALL: 1/64 in. [0.4 mm] TO 1/32 in. [0.8 mm] = 10 PERMITTED.



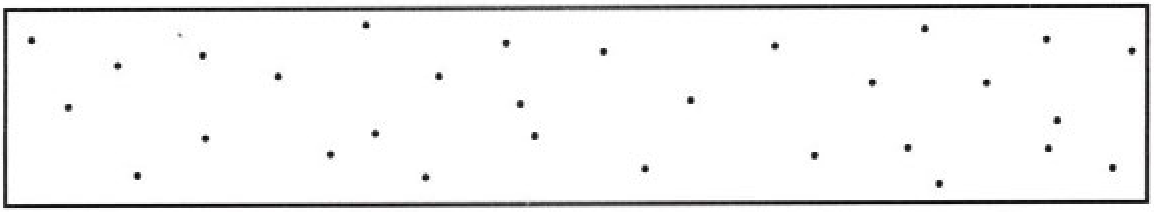
(B) LARGE ROUNDED INDICATIONS

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



(C) MEDIUM ROUNDED INDICATIONS

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



(D) SMALL ROUNDED INDICATIONS

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

NOTES:

(1) The chart which is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used for determination of conformance with this specification. Rounded indications smaller than $^1/_{64}$ in. [0.4 mm] shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.

(2) These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those usually encountered in general fabrication. They are equivalent to the Grade 1 standards of ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.*

TABLE 5U
A5.17 TENSION TEST REQUIREMENTS

Flux-Electrode Classification[1]	Tensile Strength, psi	Yield Strength,[2] psi	Elongation,[2] %
F6XX-EXXX	60 000–80 000	48 000	22
F7XX-EXXX	70 000–95 000	58 000	22

NOTES:

(1) The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter "C" will appear after the "E" as part of the classification designation when the electrode being classified is a composite electrode. The letter "X" used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the electrode. See Figure 1U for a complete explanation of the classification designators.

(2) Minimum requirements. Yield strength at 0.2 percent offset and elongation in 2 in. gage length.

TABLE 5M
A5.17M TENSION TEST REQUIREMENTS

Flux-Electrode Classification[1]	Tensile Strength, MPa	Yield Strength,[2] MPa	Elongation,[2] %
F43XX-EXXX	430–560	330	22
F48XX-EXXX	480–660	400	22

NOTES:

(1) The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter "C" will appear after the "E" as part of the classification designation when the electrode being classified is a composite electrode. The letter "X" used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the electrode. See Figure 1M for a complete explanation of the classification designators.

(2) Minimum requirements. Yield strength at 0.2 percent offset and elongation in 51 mm gage length.

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

14. Diffusible Hydrogen Test

14.1 For each flux-electrode combination to be identified by a diffusible hydrogen designator, that combination shall be tested in the as-manufactured condition according to one of the methods given in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. The welding procedure shown in Fig. 3B for the Groove Weld Test assembly shall be used for the diffusible hydrogen test. The travel speed, however, may be increased up to a maximum of 28 in./min [12 mm/s]. This adjustment in travel speed is permitted in order to establish a weld bead width that is appropriate for the specimen. The electrode, flux, or both, may be baked to restore the moisture content before testing to the as-manufactured condition. When this is done, the baking time and temperature shall be noted on the test report. The

TABLE 6U
A5.17 IMPACT TEST REQUIREMENTS(1) (2)

Digit	Maximum Test Temperature, °F	Minimum Average Energy Level
0	0	20 ft · lbf
2	−20	
4	−40	
5	−50	
6	−60	
8	−80	
Z	No impact requirements	

NOTES:

(1) Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate digit from the table above (Table 6U), as indicated in Figure 1U.

(2) Weld metal from a specific flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table (i.e., weld metal meeting the requirements for digit 5 also meets the requirements for digits 4, 2, 0, and Z).

TABLE 6M
A5.17M IMPACT TEST REQUIREMENTS(1) (2)

Digit	Maximum Test Temperature, °C	Minimum Average Energy Level
0	0	27 Joules
2	−20	
3	−30	
4	−40	
5	−50	
6	−60	
Z	No impact requirements	

NOTES:

(1) Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate digit from the table above (Table 6M), as indicated in Figure 1M.

(2) Weld metal from a specific flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table (i.e., weld metal meeting the requirements for digit 5 also meets the requirements for digits 4, 3, 2, 0 and Z).

TABLE 7
DIFFUSIBLE HYDROGEN REQUIREMENTS(1)

AWS Flux-Electrode Combination Classification	Optional Supplemental Diffusible Hydrogen Designation(2)	Average Diffusible Hydrogen Maximum(3) (mL/100g Deposited Metal)
All	H16	16.0
All	H8	8.0
All	H4	4.0
All	H2	2.0

NOTES:

(1) Diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Section A3 and A6.4 in the Annex).

(2) This designator is added to the end of the complete flux-electrode classification (see Figures 1U and 1M).

(3) Flux-electrode combinations meeting requirements for an H2 designator also meet the requirements for H4, H8, and H16. Flux-electrode combinations meeting requirements for an H4 designator also meet the requirements for H8 and H16. Flux-electrode combinations meeting the requirements for an H8 designator also meet the requirements for H16.

manufacturer of the electrode, flux, or both, should be consulted for their recommendation regarding the time and temperature for restoring their products to the as-manufactured condition. The diffusible hydrogen designator may be added to the classification designation according to the average test values as compared to the requirements of Table 7.

14.2 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of moisture per pound [1.5 grams of moisture per kg] of dry air at the time of welding. The actual atmospheric conditions shall be reported along with the average diffusible hydrogen value for the test according to ANSI/AWS A4.3.

14.3 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided that the actual test results satisfy the diffusible hydrogen requirements for a given designator, as specified in Table 7.

TABLE 8U
A5.17 STANDARD ELECTRODE SIZES AND TOLERANCES(1)

	Tolerances (± in.)	
Diameter (in.)	Solid (E)	Composite (EC)
$\frac{1}{16}$ or 0.062	0.002	0.003
$\frac{5}{64}$ or 0.078	0.002	0.003
$\frac{3}{32}$ or 0.094	0.002	0.003
$\frac{7}{64}$ or 0.109	0.003	0.004
$\frac{1}{8}$ or 0.125	0.003	0.004
$\frac{5}{32}$ or 0.156	0.004	0.005
$\frac{3}{16}$ or 0.188	0.004	0.005
$\frac{7}{32}$ or 0.219	0.004	0.005
$\frac{1}{4}$ or 0.250	0.004	0.005

NOTE:

(1) Other sizes and tolerances may be supplied as agreed between purchaser and supplier.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

15. Method of Manufacture

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

15.1 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as *crushed slag*. Crushed slag and blends of crushed slag with unused (virgin) flux may be classified as a welding flux under this specification. The letter "S" shall be used as a mandatory classification designator as shown in Figs. 1U and 1M when the flux being classified is a crushed slag or is a blend of crushed slag with virgin flux. (See A6.1.5 in the Annex.)

16. Electrode Requirements

16.1 Standard Sizes. Standard sizes for electrodes in the different package forms (coils with support, coils without support, and drums) are shown in Table 8U or Table 8M, as applicable.

16.2 Finish and Uniformity

16.2.1 The electrode shall have a smooth finish which is free from slivers, depressions, scratches, scale, seams and laps (exclusive of the longitudinal joint in composite electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

16.2.2 Each continuous length of electrode shall be from a single heat or lot of material. Welds, when present,

TABLE 8M
A5.17M STANDARD ELECTRODE SIZES AND TOLERANCES[1]

	Tolerance (mm)	
Diameter (mm)	Solid (E)	Composite (EC)
1.6 2 2.4 2.5 2.8	±0.04	+0.04, −0.05
3 3.2 4 4.8 5 5.6 6 6.4	±0.06	+0.06, −0.08

NOTE:

(1) Other sizes and tolerances may be supplied as agreed between purchaser and supplier.

shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic and semiautomatic equipment.

16.2.3 Core ingredients in composite electrodes 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.

16.2.4 A suitable protective coating, such as copper, may be applied to any electrode covered in this specification.

16.3 Standard Package Forms

16.3.1 Standard package forms are coils with support, coils without support, and drums. Standard package dimensions and weights for each form are given in Table 9. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.

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

16.3.3 Drums shall be designed and constructed to prevent distortion of the electrode during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

16.4 Winding Requirements

16.4.1 The electrode shall be wound so that kinks, waves, sharp bends, or wedging are not encountered, leaving the electrode free to unwind without restriction. The outside end of the electrode (the end with which welding is to begin) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

16.4.2 The cast and helix of the electrode in coils and drums shall be such that the electrode will feed in an uninterrupted manner in automatic and semiautomatic equipment.

16.5 Electrode Identification

16.5.1 The product information and the precautionary information required in 16.7 for marking each package shall appear also on each coil and drum.

16.5.2 Coils without support shall be identified by a tag containing this information securely attached to the inside end of the coil.

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

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

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

16.7 Marking of Packages

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

(a) AWS specification and classification number (year of issue may be excluded)

(b) Supplier's name and trade designation

(c) In the case of a composite electrode, the trade designation of the flux (or fluxes) with which its weld metal composition meets the requirements of Table 2

(d) Size and net weight

(e) Lot, control or heat number.

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

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES and GASES can be hazardous to your health.

TABLE 9
STANDARD DIMENSIONS AND WEIGHTS$^{(1)\,(2)}$

	Electrode Size$^{(3)}$		Net Weight of Coil$^{(4)}$		Inside Diameter of Liner		Width of Coil, Max.		Outside Diameter of Coil, Max.	
	in.	mm	lb	kg	in.	mm	in.	mm	in.	mm
Coils with Support	1/16–1/4	. . .	25 50 60 65	. . .	12 ± 1/8	. . .	2½ or 4⅝	. . .	17½ or 17	
	. . .	1.6–6.4	. . .	12 15 20 25 30	. . .	300 + 15, −0	. . .	(5)	. . .	(5)
	3/32–1/4	. . .	100 150 200	. . .	(5)	. . .	5	. . .	31½	
	. . .	2.4–6.4	. . .	45 70 90 100	. . .	610 ± 10	. . .	130	. . .	800
Coils without Support	1/16–1/4	1.6–6.4	As agreed between purchaser and supplier							
Drums	1/16–1/4	1.6–6.4	As agreed between purchaser and supplier							

NOTES:
(1) Values specified in "in." or "lb" apply to A5.17. Values specificed in "mm" or "kg" apply to A5.17M.
(2) Other dimensions and weights may be supplied as agreed between purchaser and supplier.
(3) The range is inclusive.
(4) Net weights shall not vary more than ± 10 percent.
(5) This dimension shall be agreed between purchaser and supplier.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can KILL.

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

DO NOT REMOVE THIS INFORMATION

17. Flux Requirements

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

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

17.3 Packaging

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

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

17.4 Marking of Packages

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

(a) AWS specification and classification (year of issue may be excluded)

(b) Supplier's name and trade designation (In the case of crushed slags, the crusher, not the original producer, shall be considered the supplier. See also Annex A6.1.5.)

(c) The trade designation of each composite electrode with which the flux manufacturer has classified the flux, if applicable

(d) Net weight

(e) Lot, control, or heat number

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

17.4.2 All packages of flux shall be marked as required in 16.7.2 for the electrodes.

Annex
Guide to AWS Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

[This Annex is not a part of AWS A5.17/A5.17M-97 (R2007), *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding,* but is included for information purposes only.]

A1. Introduction

The purpose of this guide is to correlate the electrode and flux classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the base metals for which each electrode and flux combination is suitable.

A2. Classification System

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

The letter "L" indicates that the solid electrode is comparatively low in manganese content. The letter "M" indicates a medium manganese content, while the letter "H" indicates a comparatively high manganese content. The one or two digits following the manganese designator indicate the nominal carbon content of the electrode. The letter "K," which appears in some designations, indicates that the electrode is made from a heat of silicon-killed steel. Solid electrodes are classified only on the basis of their chemical composition, as specified in Table 1 of this specification.

A composite electrode is indicated by the letter "C" after the "E" and a numerical suffix. The composition of a composite electrode may include metallic elements in the core material that are also present as oxides, fluorides, etc., of those same elements. Therefore, the chemical analysis of a composite electrode may not be directly comparable to an analysis made on a solid electrode. For this reason, the composition of composite electrodes is not used for classification purposes under this specification, and the user is referred to weld metal composition (Table 2) with a particular flux, rather than to electrode composition.

A2.2 "G" Classification and the Use of "Not Specified" and "Not Required"

A2.2.1 This specification includes filler metals classified as "EG" or "ECG." The "G" indicates that the filler metal is of a general classification. It is "general" because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent, in establishing this classification, is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal — in the case of the example — does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification without awaiting revision. This means, then, that two filler metals — each bearing the same "G" classification — may be quite different in some certain respect (chemical composition, again, for example).

A2.2.2 The point of difference (although not necessarily the amount of the 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 normally is required to be conducted 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. The purchaser may want to incorporate that information, via ANSI/AWS A5.01, *Filler Metal Procurement Guidelines,* in the purchase order.

A2.2.3 Request for Filler Metal Classification

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

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

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

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

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

(3) Send a copy of the request to the Chair of the Committee on Filler Metals and the particular Subcommittee involved.

(4) File the original request.

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

(d) 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, for action.

(e) 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 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 Classification of Fluxes. Fluxes are classified on the basis of the mechanical properties of the weld metal they produce, with some certain classification of electrode, under the specific test conditions called for in Part B of this specification.

A2.3.1U As examples of A5.17 U.S. Customary Unit classifications, consider the following:

F7A2-EH14
FS6A0-EM13K
F7P6-EM12K
F7P4-EC1

The prefix "F" designates an unused (virgin) flux. The prefix "FS" designates a flux that is made solely from crushed slag or is a blend of crushed slag with virgin flux. This is followed by a single digit representing the minimum tensile strength required of the weld metal in 10 000 psi increments.

When the letter "A" follows the strength designator, it indicates that the weld metal was tested (and is classified) in the as-welded condition. When the letter "P" follows the strength designator, it indicates that the weld metal was tested (and is classified) after postweld heat treatment called for in the specification. The digit that follows the "A" or "P" will be a number or the letter "Z." This digit refers to the impact strength of the weld metal. Specifically, it designates, on the Fahrenheit scale, a temperature at (and above) which the weld metal meets, or exceeds, the required 20 ft·lbf Charpy V-notch impact strength (except for the letter "Z," which indicates that no impact requirement is specified — see Table 6U).[4] These mechanical property designations are followed by the designation of the electrode used in classifying the flux (see Tables 1 and 2). The suffix (EH14, EM12K, EC1, etc.) included after the hyphen refers to the electrode classification with which the flux will deposit weld metal that meets the specified mechanical properties when tested as called for in the specification.

A2.3.1M As examples of A5.17M International System of Units (SI) classifications, consider the following:

F43A3-EM13K
FS43A0-EM11K
F48P5-EH12K

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[4] Note that except for digit "4" the same designator for impact strength in Tables 6U and 6M signify different temperatures. For example, "6" in Table 6U signifies a maximum test temperature of −60°F, whereas the same designator in Table 6M signifies a maximum test temperature of −60°C, equivalent to −76°F.

The prefix "F" designates a virgin flux. The prefix "FS" designates a flux that is made solely from crushed slag or is a blend of crushed slag with virgin flux. This is followed by two digits representing the minimum tensile strength required of the weld metal in 10 MPa increments.

When the letter "A" or "P" follows the strength designators, it indicates, as it does in the A5.17 classification system, the weld metal was tested (and is classified) in either the as-welded (A) or postweld heat-treated (P) condition. The digit that follows the "A" or "P" will be a number or the letter "Z." This digit refers to the impact strength of the weld metal.

Specifically, it designates, on the Celsius scale, a temperature at (and above) which the weld metal meets, or exceeds, the required 27 J Charpy V-notch impact strength (except for the letter "Z," which indicates that no impact requirement is specified — see Table 6M). These mechanical property designations are followed by the designation of the electrode used in classifying the flux (see Tables 1 and 2). The suffix (EM13K, EH12K, etc.) included after the hyphen refers to the electrode classification with which the flux will deposit weld metal that meets the specific mechanical properties when tested as called for in the specification.

A2.3.2 It should be noted that flux of any specific trade designation may have many classifications. The number is limited only by the number of different electrode classifications and the condition of heat treatment (as-welded and postweld heat treated) with which the flux can meet the classification requirements. The flux marking lists at least one, and may list all, classifications to which the flux conforms. It should also be noted that the specific usability (or operating) characteristics of various fluxes of the same classification may differ in one respect or another.

A2.3.3 Solid electrodes having the same classification are interchangeable when used with a specific flux; composite electrodes may not be.

A2.4 International Designation System. An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for steel filler metals. In that system, the initial "S" designates a solid wire or rod followed by a four-digit number. Composite wires are designated with an initial "T."

TABLE A1
COMPARISON OF ELECTRODE DESIGNATIONS

AWS Classification	Proposed ISO No.[(1)]
EL8	S1100
EL8K	S1110
EL12	S1000
EM11K	S2030
EM12	S2000
EM12K	S2010
EM13K	S2020
EM14K	S2021
EM15K	S2210
EH10K	S3000
EH11K	S3030
EH12K	S3010
EH14	S4000

NOTE:
(1) Based on IIW Doc. XII-1232-91.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with the latest edition of ANSI/AWS A5.01, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, in accordance with ANSI/AWS A5.01.

In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing is normally conducted on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. Testing in accordance with any other Schedule in that Table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of that 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 System" in ANSI/AWS A5.01.

A5. Ventilation During Welding

A5.1 The following are five major factors which govern the quantity of fumes to which welders and welding operators can be exposed during welding:

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

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

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

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

(e) The ventilation provided to the space in which the welding is done

A5.2 American National Standard ANSI/ASC 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 particularly drawn to the section dealing with ventilation.

A6. Welding Considerations

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

A6.1.1 Neutral Fluxes. Neutral fluxes are those which will not produce any significant change in the weld metal chemical analysis as a result of a large change in the arc voltage, and thus, the arc length.

The primary use for neutral fluxes is in multipass welding, especially when the base metal exceeds 1 in. [25 mm] in thickness.

Note the following considerations concerning neutral fluxes:

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

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

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

A6.1.2 Active Fluxes. Active fluxes are those which contain small amounts of manganese, silicon, or both. These deoxidizers are added to the flux to provide improved resistance to porosity and weld cracking caused by contaminants on or in the base metal.

The primary use for active fluxes is to make single-pass welds, especially on oxidized base metal. Note the following considerations concerning active fluxes:

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

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

A6.1.3 Alloy Fluxes. Alloy fluxes are those which can be used with a carbon steel electrode to make alloy weld metal. The alloys for the weld metal are added as ingredients in the flux.

The primary use for alloy fluxes is to weld low-alloy steels and for hardfacing. As such, they are outside of the scope of this specification. See the latest edition of ANSI/AWS A5.23/A5.23M, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding,* for a more complete discussion of alloy fluxes.

A6.1.4 Wall Neutrality Number. The Wall Neutrality Number (N) is a convenient relative measure of flux neutrality. The Wall Neutrality Number addresses fluxes and electrodes for welding carbon steel with regard to the weld metal manganese and silicon content. It does not address alloy fluxes. For a flux-electrode combination to be considered neutral, it should have a N of 35 or less. The lower the number, the more neutral is the flux.

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

(a) A weld pad of the type shown in Fig. 2 is welded with the flux-electrode combination being tested. The welding parameters shall be as specified in Fig. 3B for the weld test plate for the diameter electrode being used.

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

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

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

$$N = 100\,(\left|\Delta\%\text{Si}\right| + \left|\Delta\%\text{Mn}\right|)$$

where $\Delta\%$ Si is the difference in silicon content of the two pads, and $\Delta\%$ Mn is the corresponding difference in manganese content.

A6.1.5 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as *crushed slag*. This is different from a recycled flux which was never fused into a slag and can often be collected from a clean surface and reused without crushing. Crushed slag and blends of crushed slag with unused (virgin) flux may be classified as a welding flux under this specification, but shall not be considered to be the same as virgin flux.

Although it is possible to crush and reuse submerged arc slag as a welding flux, the crushed slag, regardless of any addition of virgin flux to it, is a new and chemically different flux. This is because the slag formed during submerged arc welding does not have the same chemical composition or welding characteristics as the virgin flux. Its composition is affected by the composition of the original flux, chemical reactions which occur due to the welding arc, the base metal and electrode compositions, and the welding parameters.

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

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

A6.1.6 Closed-Loop, Crushed Slags. Slag generated by a fabricator from a specific brand of flux under controlled welding conditions and crushed for subsequent reuse by the same fabricator is defined as *closed-loop, crushed slag*.

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

A6.2 Choice of Electrodes. In choosing an electrode classification for submerged arc welding of carbon steel, the most important considerations are the manganese and silicon contents in the electrode, the effect of the flux on recovery of manganese and silicon in the weld metal, whether the weld is to be single pass or multipass, and the mechanical properties expected of the weld metal.

A certain minimum weld-metal manganese content is necessary to avoid centerline cracking. This minimum depends upon restraint of the joint and upon the weld-metal composition. In the event that centerline cracking is encountered, especially with a low-manganese electrode (see Table 1) and neutral flux, a change to a higher manganese electrode, a change to a more active flux, or both, may eliminate the problem.

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

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

The EM14K electrodes are alloyed with small amounts of titanium, although they are considered as carbon steel electrodes. The titanium functions to improve strength and notch toughness under certain conditions of high-heat input welding or PWHT. The manufacturer's recommendations should be consulted.

Electrodes of the EH12K classification are high Mn electrodes with the Mn and Si balanced to enhance impact properties on applications that require high deposition rates or multiple arc procedures, or both, in both the as-welded and postweld heat-treated conditions.

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

A6.3 Mechanical Properties of Submerged Arc Welds. Tables 5U and 6U (for the U.S. Customary Units classification system) and Tables 5M and 6M (for the International System of Units classification system) of this specification list the mechanical properties required of weld metal from flux-electrode classifications (the electrodes are classified in Tables 1 and 2). The mechanical properties are determined from specimens prepared according to the procedure called for in the specification. That procedure minimizes dilution from the base metal and thereby more accurately reflects the properties of the undiluted weld metal from each flux-electrode combination.

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

Submerged arc welds are not always made with the multipass procedure required in the specification. They frequently are made in a single pass, at least within certain limits on the thickness of the base metal. When a high level of notch toughness is required, multipass welds may be necessary.

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

The weld metal properties in this specification are determined either in the as-welded condition or after a postweld heat treatment (one hour at 1150°F [620°C]), or both. Most of the weld metals are suitable for service in either condition, but the specification cannot cover all of the conditions that such weld metals may encounter in fabrication and service. For this reason, the classifications in this specification require that the weld metals be produced and tested under certain specific conditions.

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

Postweld heat-treatment times in excess of the 1 hour used for classification purposes in this specification (conventionally, 20 to 30 hours for very thick sections) may have a major influence on the strength and toughness of the weld metal. Both can be substantially reduced. The user needs to be aware of this and of the fact that the mechanical properties of carbon steel weld metal produced with other procedures may differ from the properties required by Tables 5U and 6U or Tables 5M and 6M of this specification, as applicable.

A6.4 Diffusible Hydrogen. The submerged arc welding process can be used to provide low-hydrogen weld deposits when care is taken to maintain the flux and electrode in a dry condition. In submerged arc welding with carbon steel electrodes and fluxes classified in this specification, weld metal or heat-affected zone cracking associated with diffusible hydrogen tends to become more of a problem with increasing weld-metal strength, increasing heat-affected zone hardness, increasing diffusible hydrogen content, decreasing preheat and interpass temperature, and decreasing time at or above the interpass temperature during and after welding. The detection of hydrogen cracking may be delayed for several hours after cooling due to the time required for the crack to grow to a size which can be detected by routine inspection methods. It may appear as transverse weld cracks, longitudinal centerline cracks (especially in root beads), and toe or underbead cracks in the heat-affected zone.

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 a particular flux-electrode combination. Accordingly, the use of optional supplemental designators for diffusible hydrogen is introduced to indicate the maximum average value obtained under a clearly defined test condition in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding.*

The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values from those indicated by the designator. The use of a reference atmospheric condition during welding is necessitated because the arc always is imperfectly shielded. Moisture from the air, distinct from that in the electrode or flux, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining a suitable depth of flux cover (normally 1 to 1-$\frac{1}{2}$ in. [25 to 38 mm]) in front of the electrode during welding.

Nevertheless, some air will mix with the flux cover and add its moisture to the other sources of diffusible hydrogen.

It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. For this reason, it is appropriate to specify a reference atmospheric condition. The reference atmospheric condition of 10 grains of moisture per lb [1.5 grams of moisture per kilogram] of dry air is equivalent to 10 percent relative humidity at 68°F [20°C].

A7. General Safety Considerations

A7.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles or equivalent to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection.

Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load. Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (*Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.*)

The following sources are for more detailed information on personal protection:

(a) American National Standards Institute. ANSI/ASC Z41.1, *Safety-Toe Footwear*. New York, NY: American National Standards Institute.[5]

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

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

(d) Occupational Safety and Health Administration. *Code of Federal Regulations,* Title 29 Labor, Chapter XVII, Part 1910. Washington, D.C.: U.S. Government Printing Office.[6]

A7.2 Electrical Hazards. Electric shock can kill; however, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous

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[5] ANSI documents are available from the American National Standards Institute, 11 West 42 Street, 13th Floor, New York, NY 10036.

[6] OSHA documents are available from U.S. Government Printing Office, Washington, DC 20402.

arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity.

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

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

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

A7.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles that originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal and base metal, welding process, current level, arc length, and other factors.

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

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

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

(a) The permissible exposure limits required by OSHA can be found in *Code of Federal Regulations*, Title 29, Chapter XVII, Part 1910. The OSHA General Industry Standards are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

(b) The recommended threshold limit values for fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634.

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

(d) Manufacturer's Material Safety Data Sheet for the product.

A7.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

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

A7.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A7.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base-metal composition, fluxes, and any coating or plating on the base metal. Some processes, such as resistance welding and cold pressure welding, ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc welding when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(a) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather, are intended to protect passersby from incidental exposure.

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

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

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

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

A7.4.3 Ionizing radiation information sources include the following:

(a) AWS F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(b) Manufacturer's product information literature.

A7.4.4 The following include nonionizing radiation information sources:

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

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

(c) —. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. (published by AWS) Miami, FL: American Welding Society.

(d) Hinrichs, J. F. Project Committee on Radiation — Summary Report. *Welding Journal*, January 1978.

(e) Moss, C. E. "Optical Radiation Transmission Levels through Transparent Welding Curtains." *Welding Journal*, March 1979.

(f) Moss, C. E., and Murray, W. E. "Optical Radiation Levels Produced in Gas Welding, Torch Brazing, and Oxygen Cutting." *Welding Journal*, September 1979.

(g) Marshall, W. J., Sliney, D. H., et al. "Optical Radiation Levels Produced by Air-Carbon Arc Cutting Processes," *Welding Journal*, March 1980.

(h) National Technical Information Service. Nonionizing radiation protection special study no. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service. ADA-033768.

(i) —. Nonionizing radiation protection special study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service, ADA-043023.

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SPECIFICATION FOR CARBON STEEL ELECTRODES AND RODS FOR GAS SHIELDED ARC WELDING

SFA-5.18/SFA-5.18M

(Identical with AWS Specification A5.18/A5.18M:2005. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR CARBON STEEL ELECTRODES AND RODS FOR GAS SHIELDED ARC WELDING

SFA-5.18/SFA-5.18M

(Identical with AWS Specification A5.18/A5.18M:2005. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel electrodes (solid, composite stranded, and composite metal cored) and rods (solid) for gas metal arc (GMAW), gas tungsten arc (GTAW), and plasma arc (PAW) welding.

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

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.18 uses U.S. Customary Units. The specification A5.18M 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 electrodes or packaging or both under the A5.18 or A5.18M specifications.

PART A — GENERAL REQUIREMENTS

2. Normative References

2.1 ASTM Standards. [1] The following ASTM standards are referenced in the mandatory sections of this document.

(a) A 36/A 36M, *Specification for Carbon Structural Steel*

(b) A 285/A 285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

(c) A 515/A 515M, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

(d) A 516/A 516M, *Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

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

(f) E 350, *Standard Method for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

(g) E 1032, *Standard Test Method for Radiographic Examination of Weldments*

2.2 AWS Standards. [2] The following AWS standards are referenced in the mandatory sections of this document.

(a) AWS A5.01, *Filler Metal Procurement Guidelines*

(b) AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*

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

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

2.3 ANSI Standard. [3] The following ANSI standard is referenced in the mandatory sections of this document.

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

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[1] ASTM Standards can be obtained from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[2] AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] ANSI standards are published by the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES AND RODS

AWS Classification[b]		UNS[c]	Weight Percent[a]												
A5.18	A5.18M	Number	C	Mn	Si	P	S	Ni	Cr	Mo	V	Cu[d]	Ti	Zr	Al
				0.90	0.40								0.05	0.02	0.05
ER70S-2	ER48S-2	K10726	0.07	to	to	0.025	0.035	0.15	0.15	0.15	0.03	0.50	to	to	to
	—	—	—	1.40	0.70	—	—	—	—	—	—	—	0.15	0.12	0.15
			0.06	0.90	0.45										
ER70S-3	ER48S-3	K11022	to	to	to	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
	—	—	0.15	1.40	0.75										
			0.06	1.00	0.65										
ER70S-4	ER48S-4	K11132	to	to	to	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
	—	—	0.15	1.50	0.85										
			0.06	1.40	0.80										
ER70S-6	ER48S-6	K11140	to	to	to	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
	—	—	0.15	1.85	1.15										
			0.07	1.50	0.50										
ER70S-7	ER48S-7	K11125	to	to	to	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
	—	—	0.15	2.00[e]	0.80										
ER70S-G	ER48S-G	—						Not Specified[f]							

NOTES:

a. Single values are maximum.

b. The letter "N" as a suffix to a classification indicates that the weld metal is intended for the corc belt region of nuclear reactor vessels, as described in the Annex to the specification. This suffix changes the limits on the phosphorus and copper as follows:
P = 0.012% maximum
Cu = 0.08% maximum

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

d. Copper due to any coating on the electrode or rod plus the copper content of the filler metal itself, shall not exceed the stated 0.50% max.

e. In this classification, the maximum Mn may exceed 2.0%. If it does, the maximum C must be reduced 0.01% for each 0.05% increase in Mn or part thereof.

f. Chemical requirements are not specified but there shall be no intentional addition of Ni, Cr, Mo, or V. Composition shall be reported. Requirements are those agreed to by the purchaser and the supplier.

2.4 ISO Specification. [4] The following ISO standard is referenced in the mandatory sections of this document.

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

3. Classification

3.1 The solid electrodes (and rods) covered by the A5.18 specification utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition of the electrode, as specified in Table 1, and the as-welded mechanical properties of the weld metal, as specified in Tables 3 and 4. The composite stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4 and the shielding gas employed.

3.1M The solid electrodes (and rods) covered by the A5.18M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the chemical composition of the electrode, as specified in Table 1, and the mechanical properties of the weld metal, as specified in Tables 3 and 4. The composite stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon the International System of Units (SI) and are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4 and the shielding gas employed.

3.2 Electrodes and rods classified under one classification shall not be classified under any other classification in this specification, except that composite stranded electrodes or composite metal cored electrodes classified as E70C-XC [E48C-XC] may also be classified as E70C-XM [E48C-XM], or vice versa, provided the product meets the requirements of both classifications.

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[4] ISO standards are published by the International Organization for Standardization, 1 rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL FROM COMPOSITE ELECTRODES

AWS Classification[a]		UNS Number[b]	Shielding Gas[c]	Weight Percent[d]									
A5.18	A5.18M			C	Mn	Si	S	P	Ni[c]	Cr[e]	Mo[e]	V[c]	Cu
Multiple Pass Classifications													
E70C-3X	E48C-3X	W07703	75-80% Ar/Balance CO_2 or CO_2	0.12	1.75	0.90	0.03	0.03	0.50	0.20	0.30	0.08	0.50
E70C-6X	E48C-6X	W07706	75-80% Ar/Balance CO_2 or CO_2	0.12	1.75	0.90	0.03	0.03	0.50	0.20	0.30	0.08	0.50
E70C-G(X)	E48C-G(X)	—	f	Not Specified[g]									
Single Pass Classifications													
E70C-GS(X)	E48C-GS(X)	—	f	Not Specified[h]									

NOTES:

a. The final X shown in the classification represents a "C" or "M" which corresponds to the shielding gas with which the electrode is classified. The use of "C" designates 100% CO_2 shielding (AWS A5.32 Class SG-C). "M" designates 75-80% Ar/balance CO_2 (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25). For E70C-G [E48C-G] and E70C-GS [E48C-GS], the final "C" or "M" may be omitted if these gases are not used for classification.

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

c. Use of a shielding gas other than that specified will result in different weld metal composition.

d. Single values are maximums.

e. The sum of Ni, Cr, Mo, and V shall not exceed 0.50%.

f. Shielding gas shall be as agreed upon between purchaser and supplier, unless designated by the C or M suffix.

g. Composition shall be reported; the requirements are those agreed to between purchaser and supplier.

h. The composition of weld metal from this classification is not specified since electrodes of this classification are intended only for single pass welds. Dilution, in such welds, usually is quite high.

TABLE 3
TENSION TEST REQUIREMENTS (AS WELDED)

AWS Classification[a]			Tensile Strength (minimum)		Yield Strength[b] (minimum)		Elongation[b] Percent (minimum)
A5.18	A5.18M	Shielding Gas	psi	MPa	psi	MPa	
ER70S-2 ER70S-3 ER70S-4 ER70S-6 ER70S-7	ER48S-2 ER48S-3 ER48S-4 ER48S-6 ER48S-7	CO_2[c]	70 000	480	58 000	400	22
ER70S-G	ER48S-G	d	70 000	480	58 000	400	22
E70C-3X E70C-6X	E48C-3X E48C-6X	75-80% Ar/balance CO_2 or CO_2	70 000	480	58 000	400	22
E70C-G(X)	E48C-G(X)	d	70 000	480	58 000	400	22
E70C-GS(X)	E48C-GS(X)	d	70 000	480	Not Specified		Not Specified

NOTES:

a. The final X shown in the classification represents a "C" or "M" which corresponds to the shielding gas with which the electrode is classified. The use of "C" designates 100% CO_2 shielding (AWS A5.32 Class SG-C); "M" designates 75-80% Ar/balance CO_2 (AWS A5.32 Class, SG-AC-Y, where Y is 20 of 25). For E70C-G [E48C-G] and E70C-GS [E48C-GS], the final "C" or "M" may be omitted.

b. Yield strength at 0.2% offset and elongation in 2 in. [50 mm] gage length (or 1.4 in. [36 mm] gage length for the 0.350 in. [9.0 mm] tensile specimen recommended in A4.2 for the optional in A4.2 for the optional acceptance test using gas tungsten arc).

c. CO_2 = carbon dioxide shielding gas (AWS A5.32 Class SG-C). The use of CO_2 for classification purposes shall not be construed to preclude the use of Ar/CO_2 (AWS A5.32 Class SG-AC-Y) or Ar/O_2 (AWS A5.32 Class SG-AO-X) shielding gas mixtures. A filler metal tested with gas blends, such as Ar/O_2, or Ar/CO_2 may result in weld metal having higher strength and lower elongation. Testing with 100% argon shielding (AWS A5.32 Class SG-A) is required when classification testing is based on GTAW only (see A4.2 in Annex A).

d. Shielding gas shall be as agreed to between purchaser and supplier, unless designated by the C or M suffix.

TABLE 4
IMPACT TEST REQUIREMENTS (AS WELDED)

AWS Classification		Average Impact Strength[a,b] (Minimum)	
A5.18	A5.18M	A5.18	A5.18M
ER70S-2	ER48S-2	20 ft•lbf at -20°F	27 J at -30°C
ER70S-3	ER48S-3	20 ft•lbf at 0°F	27 J at -20°C
ER70S-4	ER48S-4	Not Required	Not Required
ER70S-6	ER48S-6	20 ft•lbf at -20°F	27 J at -30°C
ER70S-7	ER48S-7	20 ft•lbf at -20°F	27 J at -30°C
ER70S-G	ER48S-G	As agreed between supplier and purchaser	
E70C-G(X)	E48C-G(X)	As agreed between supplier and purchaser	
E70C-3X	E48C-3X	20 ft•lbf at 0°F	27 J at -20°C
E70C-6X	E48C-6X	20 ft•lbf at -20°F	27 J at -30°C
E70C-GS(X)	E48C-GS(X)	Not Required	Not Required

NOTES:

a. Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 20 ft•lbf [27 J]; one of the three remaining values may be lower than 20 ft-lbf [27 J], but not lower than 15 ft•lbf [20 J]. The average of the three shall not be less than the 20 ft•lbf [27 J] specified.

b. For classifications with the "N" (nuclear) designation, three additional specimens shall be tested at room temperature. Two of the three shall equal, or exceed, 75 ft•lbf [100 J], and the third shall not be lower than 70 ft•lbf [95 J]. The average of the three shall equal, or exceed, 75 ft•lbf [100 J].

3.3 The welding electrodes and rods classified under this specification are intended for gas shielded arc welding, but that is not to prohibit their use with any other process (or any other shielding gas, or combination of shielding gases) for which they are found suitable.

4. Acceptance

Acceptance[5] of the electrodes and rods 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.[6]

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] for tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E 29.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the chemical composition, the mechanical properties, and soundness of the weld metal. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 14. See Section A4.2 in the Annex for requirements for classification based on gas tungsten arc welding (GTAW) only.

7.2 The optional test for diffusible hydrogen in Section 15, Diffusible Hydrogen Test, is not required for classification (see note c 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 from one or two new test assemblies. For chemical analysis, retest need be only for those specific elements that failed to meet their 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

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[5] See Section A3, Acceptance (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

[6] See Section A4, Certification (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

TABLE 5
REQUIRED TESTS

AWS Classification		Chemical Analysis						Diffusible
A5.18	A5.18M	Electrode	Weld Metal	Radiographic Test	Tension Test	Bend Test	Impact Test	Hydrogen Test
				Solid Electrodes				
ER70S-2	ER48S-2	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-3	ER48S-3	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-4	ER48S-4	Required	Not Required	Required	Required	Not Required	Not Required	c
ER70S-6	ER48S-6	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-7	ER48S-7	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-G	ER48S-G	Required	Not Required	Required	Required	Not Required	Not Required	c
				Composite Electrodes				
E70C-3X	E48C-3X	Not Required	Required	Required	Required	Not Required	Required	c
E70C-6X	E48C-6X	Not Required	Required	Required	Required	Not Required	Required	c
E70C-G(X)	E48C-G(X)	Not Required	Required	Required	Required	Not Required	Not Required	c
E70C-G(X)[a]	E48C-GS(X)[a]	Not Required	Not Required	Not Required	Required [b]	Required	Not Required	c

NOTES:

a. Intended for single pass welding.

b. Transverse tension test. All others are all-weld-metal tension tests.

c. Optional diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (also see A2.2 and A8.2 in Annex A).

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 proper prescribed procedures. In that case, the requirement for doubling the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 At least one weld test assembly is required, and two may be required (depending on the electrode — solid as opposed to composite — and the manner in which the sample for chemical analysis is taken), as specified in Table 5. They are as follows:

(a) The groove weld in Fig. 1 for mechanical properties and soundness of the weld metal for both composite and solid electrodes (see Section A4.2 in the Annex for requirements for classification based on gas tungsten arc welding only), or the groove weld in Fig. 2 for mechanical properties of composite stranded and composite metal cored electrodes designated for single pass applications only.

(b) The weld pad in Fig. 3 for chemical analysis of the weld metal from composite stranded and composite metal cored electrodes.

The sample for chemical analysis of weld metal from composite electrodes may be taken from the reduced section of the fractured all-weld-metal tension test specimen or from the corresponding location (or any location above it) in the groove weld in Fig. 1, thereby avoiding the need to make a weld pad. In case of dispute, the weld pad in Fig. 3 shall be the referee method.

Chemical analysis of weld metal from composite stranded and composite metal cored electrodes designated for single pass applications should not be obtained from the groove weld in Fig. 2 due to the high amount of base metal dilution.

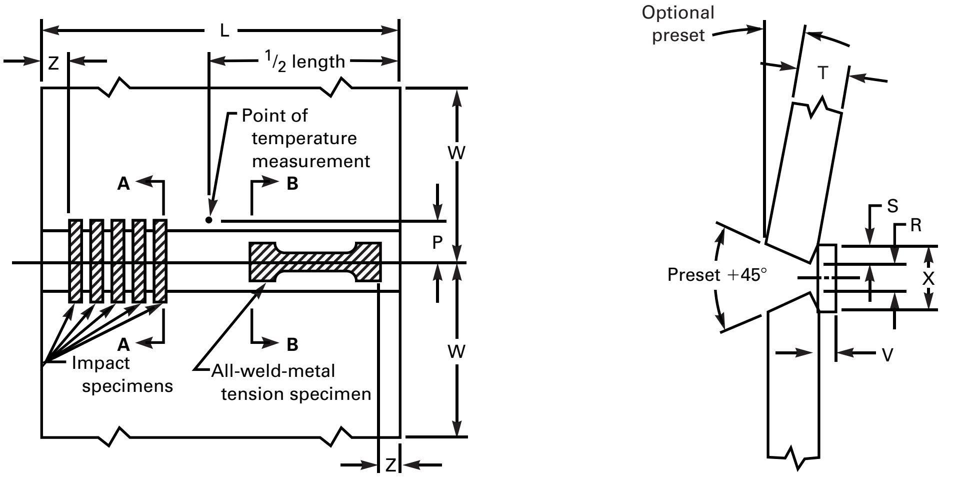
9.2 Preparation of each weld test assembly shall be as prescribed in 9.3 and 9.4. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the ASTM specification shown there, or an equivalent specification. Testing of the assembly shall be as prescribed in 10.2, 10.3, and Sections 11 through 14.

9.3 Groove Weld

9.3.1 For all classifications except E70C-GS(X) [E48C-GS(X)], a test assembly shall be prepared and welded as specified in Fig. 1, using base metal of the appropriate type specified in Table 6. The electrode used shall be 0.045 in. or $^{1}/_{16}$ in. [1.2 mm or 1.6 mm] size (or the size the manufacturer produces that is closest to one of these, if these sizes are not produced). See Section A4.2 in the Annex for requirements for classification based on gas tungsten arc welding (GTAW) only.

Welding shall be in the flat position, and the assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5 degrees. An assembly that is warped more than 5 degrees out of plane shall be discarded. Test assemblies shall not be straightened. The test assembly shall be tack welded at room temperature and welding shall

FIG. 1 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS

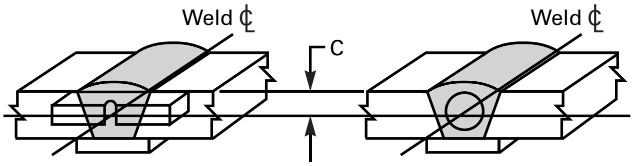


(A) Test Plate Showing Location of Test Specimens

(B) Groove Preparation of Test Plate

Dimensions

		in.	mm
C	Specimen center	$\frac{3}{8}$	9.5
L	Length, min.	10	250
P	Point of temperature measurement	1	25
R	Root opening	$\frac{1}{2}$	13
S	Backup strip overlap, min.	$\frac{1}{4}$	6
V	Backup strip thickness, min.	$\frac{3}{8}$	9
X	Backup strip width, min.	1	25
T	Thickness	$\frac{3}{4}$	19
W	Width, min.	5	125
Z	Discard, min.	1	25



Section A–A

(C) Orientation of Impact Specimen

Section B–B

(D) Location of All-Weld-Metal Tension Specimen

Test Conditions for Solid Electrodes[1,2]

Standard size [Note (3)]	0.045 in.	[1.2 mm]	$\frac{1}{16}$	[1.6 mm]
Shielding gas [Note (4)]	CO_2	CO_2	CO_2	CO_2
Wire feed speed	450 in./min ± 5%	[190 mm/sec] ± 5%	240 in./min ± 5%	[100 mm/sec] ± 5%
Nominal arc voltage	27 to 31 V	27 to 31 V	26 to 30 V	26 to 30 V
Resulting current, DCEP [Note (5)] (DCEP = electrode positive)	260 to 290 A	260 to 290 A	330 to 360A	330 to 360 A
Tip-to-work distance [Note (6)]	$\frac{3}{4} \pm \frac{1}{8}$ in.	[19 ± 3 mm]	$\frac{3}{4} \pm \frac{1}{8}$ in.	[19 ± 3 mm]
Travel speed	13 ± 1 in./min	[5.5 ± 0.5 mm/sec]	13 ± 1 in./min	[5.5 ± 0.5 mm/sec]

GENERAL NOTES:

(a) Base metal shall be as specified in Table 6.

(b) The surfaces to be welded shall be clean.

(c) Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.

NOTES:

(1) Test conditions for composite electrodes shall be as recommended by the manufacturer.

(2) Preheat and interpass temperatures for both solid and composite electrodes shall be as specified in 9.3.1.

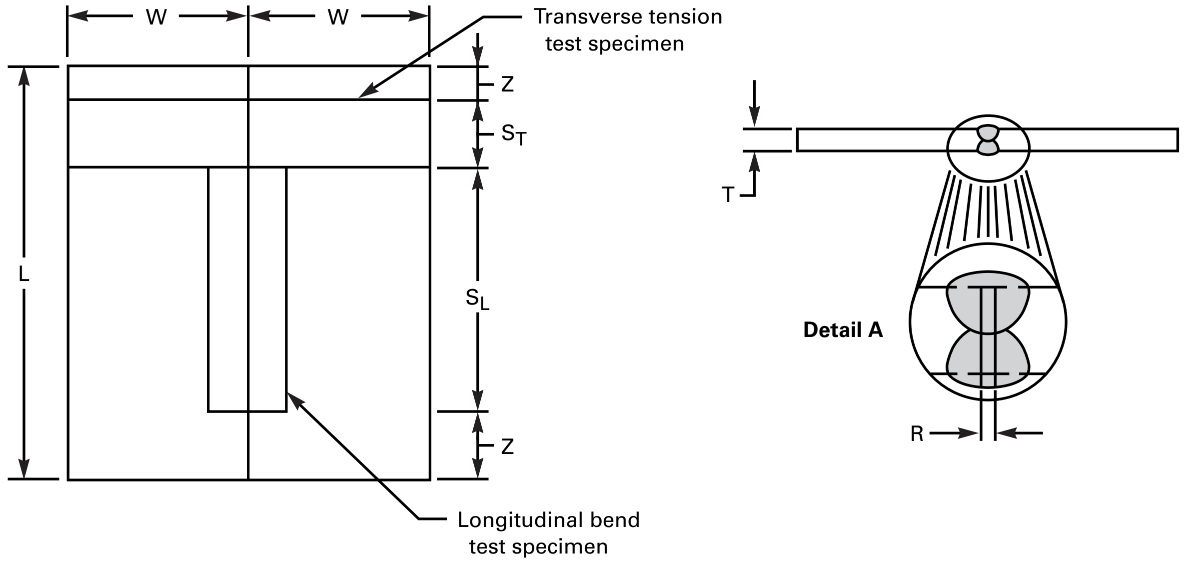
(3) If sizes other than 0.045 in. and $\frac{1}{16}$ in. [1.2 mm and 1.6 mm] are tested, wire feed speed (and resulting current), arc voltage, and tip-to-work distance shall be changed as needed. This joint configuration is not recommended for electrode sizes smaller than 0.035 in. [0.9 mm].

(4) If shielding gases or blends other than CO_2 (AWS A5.32 Class SG-C) are used, the wire feed speed (and resulting current), arc voltage, and travel speed are to be as agreed to between purchaser and supplier.

(5) The required combination of electrode feed rate, arc voltage, and tip-to-work distance should produce welding currents in the ranges shown. Currents substantially outside these ranges suggest errors in feed rate, tip-to-work distance, voltage settings, or in instrumentation.

(6) Distance from the contact tip to the work, not from the shielding gas cup to the work.

FIG. 2 GROOVE WELD TEST ASSEMBLY FOR TRANSVERSE TENSION AND LONGITUDINAL GUIDED BEND TESTS



Dimensions			
		in.	mm
L	Length, min.	10	250
W	Width, min	4	100
R	Root opening, max.	$^1/_{16}$	1.5
S_T	Transverse specimen	2	50
S_L	Longitudinal specimen	6	150
T	Thickness	$^1/_4$	6.4
Z	Discard, min.	1	25

GENERAL NOTES:

(a) Base metal shall be as specified in Table 6.

(b) The surfaces to be welded shall be clean.

(c) Detail A shows the completed joint and approximate weld configuration.

(d) Test conditions shall be as recommended by the manufacturer and shall be made available to the purchaser upon request.

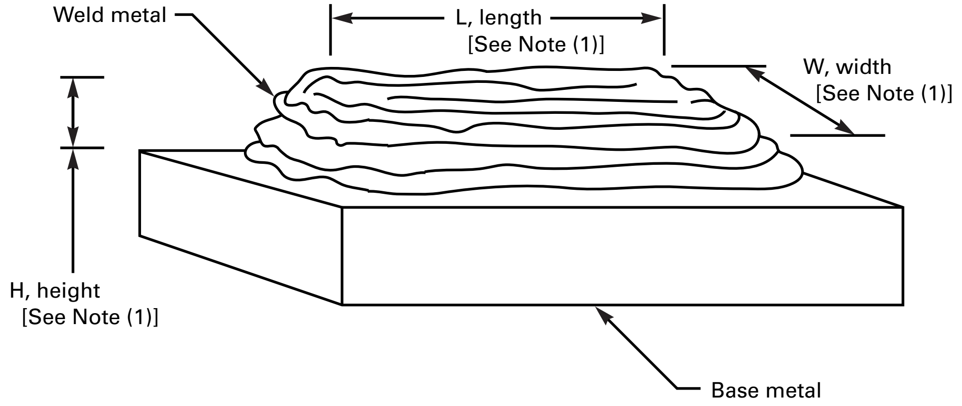
begin at that temperature (60°F [15°C] minimum). Welding shall continue until the assembly has reached a maximum interpass temperature of 325°F [165°C], measured by temperature indicating crayons or surface thermometers at the location shown in Fig. 1.

For the remainder of the weld, a minimum preheat temperature of 275°F [135°C] and maximum interpass temperature of 325°F [165°C] shall be maintained. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be preheated to a temperature of 300° ± 25°F [150° ± 15°C] before welding is resumed. When welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Sections 11, Radiographic Test; 12, Tension Test; and 14, Impact Test. All testing will be performed in the as-welded condition except for the optional aging of the all-weld-metal tension test specimen specified in 12.1.1.

9.3.2 For single-pass electrodes classification E70C-GS(X) [E48C-GS(X)] a test assembly using base metal as specified in Table 6 shall be prepared and welded as shown in Fig. 2. After tack welding the plates at each end, the test assembly shall be welded in the flat position, with one bead on each side. Welding shall begin with the assembly at room temperature (60°F [15°C] minimum). When the weld bead has been completed on one side, the assembly shall be turned over and the bead deposited on that side, as shown in Fig. 2. This sequence shall not be interrupted. The electrode size shall be 0.045 in. or $^1/_{16}$ in. [1.2 mm or 1.6 mm] (or the size the manufacturer produces that is closest to one of these, if these sizes are not produced).

After welding has been completed and the assembly has cooled in still air at room temperature, the assembly shall be prepared and tested as specified in 12.2 and Section 13, Bend Test. All testing shall be performed in the as-welded

FIG. 3 PAD FOR CHEMICAL ANALYSIS OF WELD METAL FROM COMPOSITE ELECTRODES



GENERAL NOTES:

(a) Base metal of any convenient size, of any type specified in Table 6, shall be used as the base for the weld pad.

(b) The surface of the base metal on which the filler metal is to be deposited shall be clean.

(c) The pad shall be welded in the flat position with successive layers to obtain weld metal of sufficient height.

(d) 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.

(e) The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C].

(f) Any slag shall be removed after each pass.

(g) The test assembly may be quenched in water between passes to control interpass temperature.

NOTE:

(1) The minimum completed pad size shall be at least four layers in height (H). Length (L), after allowance for start and stop areas, and width (W) shall be sufficient to perform analysis. The sample for analysis shall be taken a least $^3/_8$ in. [9.5 mm] above the original base metal surface.

TABLE 6
BASE METAL FOR TEST ASSEMBLIES

AWS Classifications	ASTM Specification	UNS Number
All, except E70C-GS(X) [E48C-GS(X)]	A36,	K02600
	A285 Grade C,	K02801
	A515 Grade 70, or	K03101
	A516 Grade 70	K02700
E70C-GS(X) [E48C-GS(X)]	A515 Grade 70 or	K03101
	A516 Grade 70	K02700

condition except for the optional aging of the bend test specimen specified in 13.2.

9.4 Weld Pad. A weld pad shall be prepared using composite stranded and composite metal cored electrodes as shown in Fig. 3, except when, as permitted in 9.1, the sample for analysis is taken from the groove weld (Fig. 1) or the fractured all-weld-metal tension test specimen. Base metal of any convenient size which will satisfy the minimum requirements of Fig. 3, and is of a type specified in Table 6, shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal (4 layers minimum thickness). The electrode size shall be 0.045 in. or $^1/_{16}$ in. [1.2 mm or 1.6 mm] or the size that the manufacturer produces that is closest to one of these, if these sizes are not produced. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C]. Any slag shall be removed after each pass. The pad may be quenched in water between passes (temperature of the water not specified). The dimensions of the completed pad shall be as shown in Fig. 3. Testing of this assembly shall be as specified in 10.2 and 10.3. The results shall meet the requirements of 10.4.

10. Chemical Analysis

10.1 A sample of the solid electrode or rod shall be prepared for chemical analysis. Solid filler metal, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the filler metal is analyzed for elements other than those in the coating, the coating shall be removed, if its presence affects the results of the analysis for the other elements.

10.2 For composite stranded of metal cored filler metals, the sample for analysis shall be taken from weld metal produced with the filler metal, not the filler metal itself. The sample for analysis shall be taken from weld metal obtained with the electrode and a shielding gas as specified in Tables 2 and 3. The sample may be taken from the weld pad prepared in accordance with 9.4, from an area of the groove weld as specified in 9.1, or from the reduced section of the fractured tension test specimen. In case of dispute, the weld pad is the referee method.

The top surface of the pad described in 9.4 and shown in Fig. 3 shall be removed and discarded. A sample for analysis shall be obtained from the underlying metal, no closer than $^3/_8$ in. [9.5 mm] to the surface of the base metal in Fig. 3, by any appropriate mechanical means. The sample shall be free of slag. When the sample is taken from the groove weld or the reduced section of the fractured tension test specimen, that material shall be prepared for analysis by any suitable mechanical means.

10.3 The sample obtained as specified in 10.1 or 10.2 shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 350.

10.4 The results of the analysis shall meet the requirements of Table 1 for solid electrodes or Table 2 for composite electrodes for the classification of electrode under test.

11. Radiographic Test

11.1 The groove weld described in 9.3.1 and shown in Fig. 1 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding $^3/_{32}$ in. [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of $^1/_{16}$ in. [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than $^1/_{16}$ in. [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

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

11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Fig. 4. In evaluating the radiograph, 1 in. [25 mm] of the weld on each end of the test assembly shall be disregarded.

A rounded indication is an indication (on the radiograph) whose length is no more than 3 times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be of porosity or slag. Indications whose largest dimension does not exceed $^1/_{64}$ in. [0.4 mm] shall be disregarded. Test assemblies with indications larger than the largest indications permitted in the radiographic standards (Fig. 4) do not meet the requirements of this specification.

12. Tension Test

12.1 One all-weld-metal round tension test specimen, as specified in the Tension Tests section of AWS B4.0 or B4.0M, shall be machined from the groove weld described in 9.3.1, and shown in Fig. 1, as required in Table 5. The tensile specimen shall have a nominal diameter of 0.500 in. [12.5 mm] and a nominal gage length-to-diameter ratio of 4:1. Other dimensions of the tension test specimen shall be as specified in the Tension Test section of AWS B4.0 or B4.0M.

12.1.1 After machining, but before testing, the specimens from composite electrodes only may be aged at 200° to 220°F [95° to 105°C] for up to 48 hr, then allowed to cool to room temperature. Refer to A8.3 for a discussion on the purpose of aging.

12.1.2 The specimen shall be tested in the manner described in the tension test section of AWS B4.0 or B4.0M.

12.1.3 The results of the all-weld-metal tension test shall meet the requirements specified in Table 3. Test reports shall indicate if the specimen was tested in the aged condition (composite electrodes only).

12.2 One transverse rectangular tension test specimen, as specified in the Tension Tests section of AWS B4.0 or B4.0M, shall be machined from the groove weld described in 9.3.2, and shown in Fig. 2, as required in Table 5. The transverse tensile specimen shall have a nominal thickness of $^1/_4$ in. [6.5 mm] and reduced width of $1^1/_2$ in. [38 mm] and a minimum length of 8 in. [200 mm]. Other dimensions of the transverse tension test specimen shall be as specified in the Tension Test section of AWS B4.0 or B4.0M.

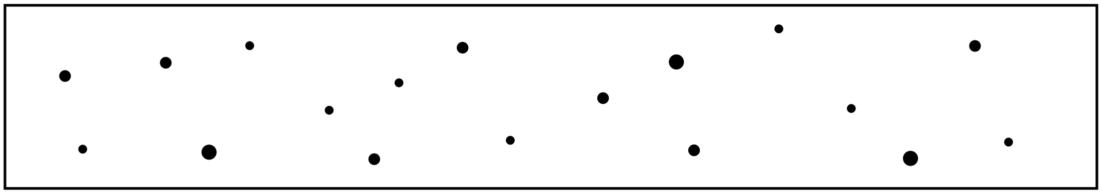
12.2.1 The specimen shall be tested in the as-welded (unaged) condition in the manner described in the tension test section of AWS B4.0 or B4.0M.

12.2.2 The results of the transverse tension test shall meet the requirements specified in Table 3. A test specimen that fractures in the base metal shall be considered to have met those requirements.

13. Bend Test

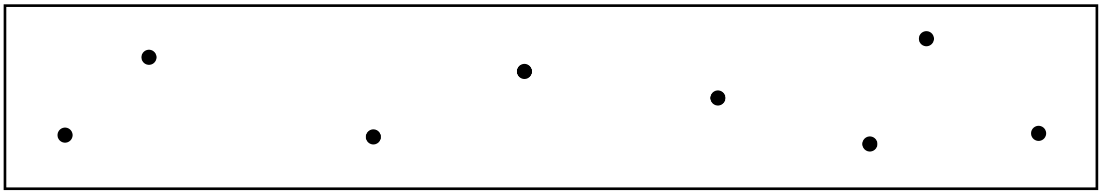
13.1 One longitudinal face bend test specimen, as specified in the Bend Tests section of AWS B4.0 or B4.0M, shall be machined from the groove weld test assembly

FIG. 4 RADIOGRAPHIC ACCEPTANCE STANDARDS



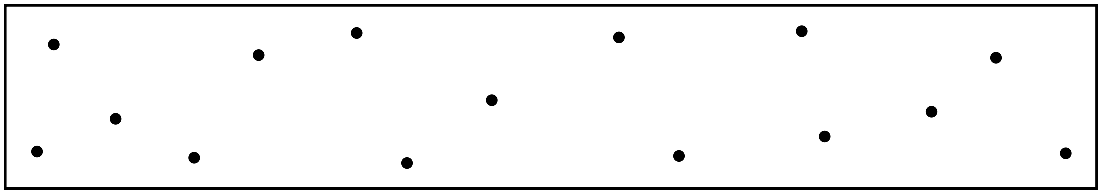
(a) Assorted Rounded Indications

Size $^1/_{64}$ in. (0.4 mm) to $^1/_{16}$ in. (1.6 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 18, with the following restrictions:
Maximum number of large $^3/_{64}$ in. (1.2 mm) to $^1/_{16}$ in. (1.6 mm) in diameter or in length indications = 3.
Maximum number of medium $^1/_{32}$ in. (0.8 mm) to $^3/_{64}$ in. (1.2 mm) in diameter or in length indications = 5.
Maximum number of small $^1/_{64}$ in. (0.4 mm) to $^1/_{32}$ in. (0.8 mm) in diameter or in length indications = 10.



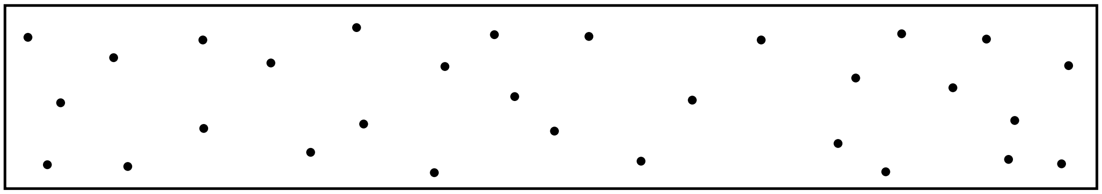
(b) Large Rounded Indications

Size $^3/_{64}$ in. (1.2 mm) to $^1/_{16}$ in. (1.6 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 8.



(c) Medium Rounded Indications

Size $^1/_{32}$ in. (0.8 mm) to $^3/_{64}$ in. (1.2 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 15.



(d) Small Rounded Indications

Size $^1/_{64}$ in. (0.4 mm) to $^1/_{32}$ in. (0.8 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 30.

GENERAL NOTES:

(a) 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.

(b) Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.

(c) Indications whose largest dimension does not exceed $^1/_{64}$ in. [0.4 mm] shall be disregarded.

(d) These standards are equivalent to the Grade 1 standards for AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

described in 9.3.2, and shown in Fig. 2, as required in Table 5. The longitudinal face bend specimen shall have a nominal thickness of $^{1}/_{4}$ in. [6.5 mm], a specimen width of $1^{1}/_{2}$ in. [38 mm] and a minimum length of 6 in. [150 mm]. Other dimensions of the longitudinal bend test specimen shall be as specified in the Bend Test section of AWS B4.0 or B4.0M.

13.2 After machining, but before bending, the specimen may be aged at 200° to 220°F [95° to 105°C] for up to 48 hr, then allowed to cool to room temperature. Refer to A8.3 for a discussion on the purpose of aging.

13.3 The specimen shall be tested in the manner described in the bend test section of AWS B4.0 or B4.0M, by bending it on any of the standard bend test jigs shown there. The bend radius shall be $^{3}/_{4}$ in. [19 mm]. Positioning of the specimen shall be such that the bead with the greater surface discontinuities, if any, is in tension.

13.4 After bending, each specimen shall conform to the $^{3}/_{4}$ in. [19 mm] radius, with appropriate allowance for springback, and the weld metal shall not contain openings in excess of $^{1}/_{8}$ in. [3.2 mm] on the convex surface.

14. Impact Test

14.1 For those classifications for which impact testing is required in Table 5, five Charpy V-notch impact test specimens, as specified in the Fracture Toughness Testing of Welds section of AWS B4.0 or B4.0M, shall be machined from the test assembly shown in Fig. 1.

The Charpy V-Notch specimens shall have the notched surface and the surface to be struck parallel within 0.002 in. [0.05 mm]. The other two surfaces shall be square with the notched or struck surface within ±10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50 times magnification on either a shadowgraph or metallograph. 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 section of AWS B4.0 or B4.0M. The test temperature shall be that specified in Table 4 for the classification under test.

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

TABLE 7
OPTIONAL DIFFUSIBLE HYDROGEN REQUIREMENTS

AWS Classifications	Optional Supplemental Diffusible Hydrogen Designator[a,b]	Average Diffusible Hydrogen, Maximum (mL/100g Deposited Metal)[c]
All	H16	16.0
All	H8	8.0
All	H4	4.0

NOTES:

a. See Note c to Table 5.

b. This designator is added to the end of the complete electrode classification designation.

c. Some classifications may not be capable of meeting the lower average diffusible hydrogen levels (H8 and H4).

14.4 For classifications with the "N" (nuclear) designation, three additional specimens shall be prepared. These specimens shall be tested at room temperature. Two of the three shall equal, or exceed, 75 ft-lbf [100 J], and the third shall not be lower than 70 ft-lbf [95 J]. The average of the three shall equal, or exceed, 75 ft-lbf [100 J].

15. Diffusible Hydrogen Test

15.1 For each electrode to be designated by an optional supplemental diffusible hydrogen designator, the 0.045 in. or $^{1}/_{16}$ in. [1.2 mm or 1.6 mm] size, or the size that the manufacturer produces that is closest to one of these sizes if the specified sizes are not produced, shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results which satisfy the requirements of Table 7, the optional supplemental diffusible hydrogen designator may be added at the end of the classification.

15.2 Testing shall be done without rebaking or otherwise conditioning the electrode, unless the manufacturer recommends otherwise. If the electrode is rebaked, that fact, along with the method used for rebaking, shall be noted on the test report.

15.3 For purposes of certifying compliance with optional diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of water vapor per pound [1.43 g/kg] of dry air at the time of welding. The actual atmospheric conditions shall be reported, along with the average value for the test, according to AWS A4.3.[7]

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[7] See A8.2 (in Annex A).

15.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable optional supplemental designator. Likewise, if the actual test results for an electrode meet the requirements for the lower, or lowest hydrogen designator, as specified in Table 7, the electrode also meets the requirements of all higher hydrogen designators in Table 7 without need to retest.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

16. Method of Manufacture

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

17. Standard Sizes

Standard sizes for electrodes and rods in the different package forms (straight lengths, coils with support, coils without support, drums, and spools — see Section 19, Standard Package Forms) are as shown in Table 8.

18. Finish and Uniformity

18.1 All electrodes and rods shall have a smooth finish which is free from slivers, depressions, scratches, scale, seams, laps (exclusive of the longitudinal joint in composite metal cored electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

18.2 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.

18.3 The components in composite electrodes (including the core ingredients in metal cored electrodes) 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.

18.4 A suitable protective coating may be applied to any filler metal in this specification. Copper may be used as a coating for any classification except one that carries the suffix "N" (nuclear) in its designation.

19. Standard Package Forms

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

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

19.3 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal. Standard spools are shown in Figs. 5A and 5B.

20. Winding Requirements

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

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

20.3 The cast and helix of solid filler metal on 4 in. [100 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will:

(a) form a circle not less than 4 in. [100 mm] nor more than 9 in. [230 mm] in diameter

(b) rise above the flat surface no more than $^1/_2$ in. [13 mm] at any location

20.4 The cast and helix of solid filler metal on all other package forms shall be such that a specimen long enough to produce a single loop, when cut from the package and laid unrestrained on a flat surface, will:

(a) form a circle not less than 12 in. [300 mm] for 0.030 in. [0.8 mm] and smaller sizes; or not less than 15 in. [380 mm] for 0.035 in. [0.9 mm] and larger sizes

(b) rise above the flat surface no more than 1 in. [25 mm] at any location

Certain bulk packages may contain wire that has been elastically twisted or otherwise treated to provide straight

TABLE 8
STANDARD SIZES[a]

				Tolerances			
		Diameter		Solid		Composite	
Standard Package Forms		in.	mm	in.	mm	in.	mm
Straight Lengths[b]		0.045	—	±0.001	—	±0.002	—
		—	1.2	—	+0.01,–0.04	—	+0.02,–0.05
	1/16	0.062	1.6	±0.002	+0.01,–0.04	±0.002	+0.02,–0.06
	5/64	0.078	2.0	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	3/32	0.094	2.4	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	1/8	0.125	3.2	±0.002	+0.01,–0.07	±0.003	+0.02,–0.07
	5/32	0.156	4.0	±0.002	+0.01,–0.07	±0.003	+0.02,–0.07
	3/16	0.188	4.8[c]	±0.002	+0.01,–0.07	±0.003	+0.06,–0.08
Coils With and Without Support		0.030	0.8	±0.001	+0.01,–0.04	±0.002	+0.02,–0.05
		0.035	0.9	±0.001	+0.01,–0.04	±0.002	+0.02,–0.05
		—	1.0	—	+0.01,–0.04	—	+0.02,–0.05
		0.045	—	±0.001	—	±0.002	—
		—	1.2	—	+0.01,–0.04	—	+0.02,–0.05
		0.052	—	±0.002	—	±0.002	—
		—	1.4	—	+0.01,–0.04	—	+0.02,–0.05
	1/16	0.062	1.6	±0.002	+0.01,–0.04	±0.002	+0.02,–0.06
	5/64	0.078	2.0	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	3/32	0.094	2.4	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	7/64	0.109	2.8	±0.002	+0.01,–0.07	±0.003	+0.02,–0.06
	1/8	0.125	3.2	±0.002	+0.01,–0.07	±0.003	+0.02,–0.07
Drums		0.035	0.9	±0.001	+0.01,–0.04	±0.002	+0.02,–0.05
		—	1.0	—	+0.01,–0.04	—	+0.02,–0.05
		0.045	—	±0.001	—	±0.002	—
		—	1.2	—	+0.01,–0.04	—	+0.02,–0.05
		0.052	—	±0.002	—	±0.002	—
		—	1.4	—	+0.01,–0.04	—	+0.02,–0.05
	1/16	0.062	1.6	±0.002	+0.01,–0.04	±0.002	+0.02,–0.06
	5/64	0.078	2.0	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	3/32	0.094	2.4	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	7/64	0.109	2.8	±0.002	+0.01,–0.07	±0.003	+0.02,–0.06
	1/8	0.125	3.2	±0.002	+0.01,–0.07	±0.003	+0.02,–0.07
Spools		0.020	0.5[c]	±0.001	+0.01,–0.03	±0.002	+0.02,–0.05
		0.025	0.6	±0.001	+0.01,–0.03	±0.002	+0.02,–0.05
		0.030	0.8	±0.001	+0.01,–0.04	±0.002	+0.02,–0.05
		0.035	0.9	±0.001	+0.01,–0.04	±0.002	+0.92,–0.05
		—	1.0	—	+0.01,–0.04	—	+0.02,–0.05
		0.045	—	±0.001	—	±0.002	—
		—	1.2	—	+0.01,–0.04	—	+0.02,–0.05
		0.052	—	±0.002	—	±0.002	—
		—	1.4	—	+0.01,–0.04	—	+0.02,–0.05
	1/16	0.062	1.6	±0.002	+0.01,–0.04	±0.002	+0.02,–0.06
	5/64	0.078	2.0	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	3/32	0.094	2.4	±0.002	+0.01,–0.04	±0.003	+0.02,–0.06
	7/64	0.109	2.8	±0.002	+0.01,–0.07	±0.003	+0.02,–0.06

NOTES:

a. Dimensions, sizes, tolerances, and package forms other than those shown shall be as agreed by purchaser and supplier.

b. Length shall be 36 in. ± 1/2 in. [900 + 25,–0 mm].

c. Not shown as standard metric size in ISO 544:2003.

TABLE 9
PACKAGING REQUIREMENTS[a]

	Package Size[d]			Net Weight of Electrode[b]	
Type of Package	in.		mm	lb.	kg
Coils without Support	As specified by purchaser[c]			As specified by purchaser[c]	
Coils with Support	6-¾	ID	170	14	6
(see below)	12	ID	300	25, 30, 50, 60, and 65	10, 15, 25, and 30
Spools	4	OD	100	1-½ and 2-½	0.5 and 1.0
	8	OD	200	10, 12, and 15	4.5, 5.5, and 7
	12	OD	300	25, 30, 35, and 44	10, 15, and 20
	14	OD	350	50 and 60	20 and 25
	22	OD	560	250	100
	24	OD	610	300	150
	30	OD	760	600, 750, and 1000	250, 350, and 450
Drums	15-½	OD	400	As specified by purchaser[c]	
	20	OD	500	As specified by purchaser[c]	
	23	OD	600	300 and 600	150 and 300
Straight Lengths	36 long	. . .	900 long	2, 5, 10, and 50	1, 2, 5, and 20

Coils with Support—Standard Dimensions and Weights

			Coil Dimensions			
	Coil Net Weight[b]		Inside Diameter of Liner		Width of Wound Electrode	
Electrode Size	lb.	kg	in.	mm	in., max.	mm, max.
All	14	6	6-¾ ± ⅛	170 ± 3	3	75
	25 and 30	10 and 15	12 ± ⅛	300 +3,−10	2-½ or 4-⅝	65 or 120
	50, 60, and 65	20, 25, and 30	12 ± ⅛	300 +3,−10	4-⅝	120

NOTES:

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

b. Tolerance on net weight shall be ± 10 precent.

c. As agreed between supplier and purchaser.

d. ID = inside diameter
OD = outside diameter

wire feed. Wire from these packages will not form a circle when cut. Traditional cast and helix measurements may have no relevance. Wire thus treated shall conform only to the winding requirements of 20.1 and 20.2. Any method of wire form inspection shall be as agreed between purchaser and supplier.

21. Filler Metal Identification

21.1 The product information and the precautionary information required in Section 23 for marking each package shall also appear on each coil, spool, and drum.

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

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

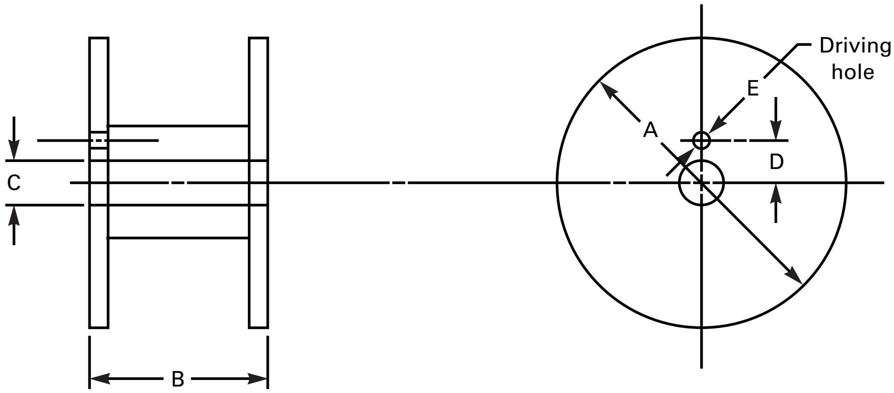
21.4 Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

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

22. Packaging

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

FIG. 5A STANDARD SPOOLS — DIMENSIONS OF 4, 8, 12, AND 14 IN. [100, 200, 300, AND 350 MM] SPOOLS



		Dimensions							
		4 in. (100 mm) Spools		8 in. (200 mm) Spools		12 in. (300 mm) Spools		14 in. (350 mm) Spools	
		in.	mm	in.	mm	in.	mm	in.	mm
A	Diameter, max. [Note (1)]	4.0	102	8.0	203	12	305	14	355
B	Width	1.75	46	2.16	56	4.0	103	4.0	103
	Tolerance	±0.03	+0, −2	±0.03	+0, −3	±0.06	+0, −3	±0.06	+0, −3
C	Diameter	0.63	16	2.03	50.5	2.03	50.5	2.03	50.5
	Tolerance	+0.01, −0	+1, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0
D	Distance between axes	—	—	1.75	44.5	1.75	44.5	1.75	44.5
	Tolerance			±0.02	±0.5	±0.02	±0.5	±0.02	±0.5
E	Diameter [Note (2)]	—	—	0.44	10	0.44	10	0.44	10
	Tolerance			+0, −0.06	+1, −0	+0, −0.06	+1, −0	+0, −0.06	+1, −0

GENERAL NOTES:

(a) Outside diameter of barrel shall be such as to permit feeding of the filler metals.

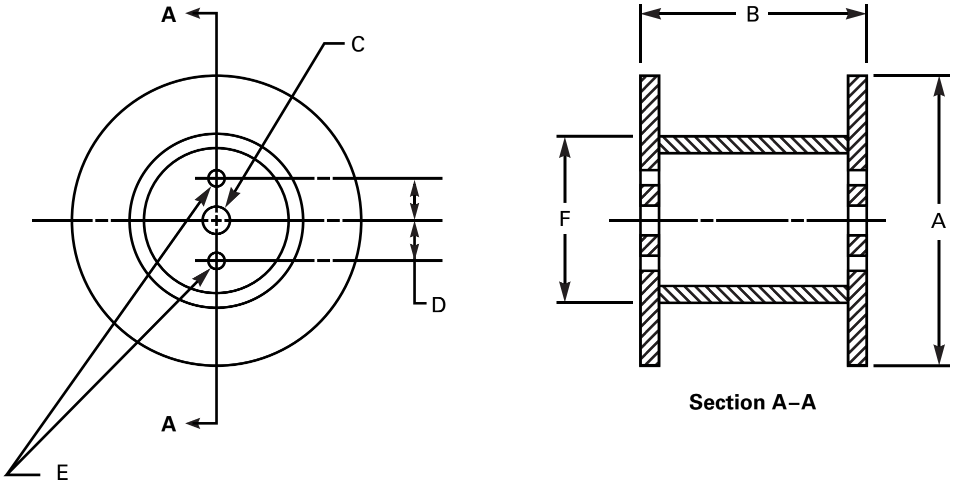
(b) Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside of the diameter of the barrel being less than the inside diameter of the flanges.

NOTES:

(1) Metric dimensions and tolerances conform to ISO 864 except the "A" specifies ± tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

(2) Holes are provided on each flange, but they need not be aligned. No driving holes required for 4 in. [100 mm] spools.

FIG. 5B STANDARD SPOOLS — DIMENSIONS OF 22, 24, AND 30 IN. [560, 610, AND 760 MM] SPOOLS



		Dimensions					
		22 in. [560 mm] Spools		24 in. [610 mm] Spools		30 in. [760 mm] Spools	
		in.in.	mm	in.	mm	in.	mm
A	Diameter, max.	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 (1)] 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

GENERAL NOTES:

(a) Outside diameter of barrel, dimension F, shall be such as to permit proper feeding of the electrode.

(b) 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 of the diameter of the barrel being less than the inside diameter of the flanges.

NOTE:

(1) Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

23. Marking of Packages

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

(a) AWS specification (year of issue may be excluded) and AWS classification numbers, along with any optional supplemental designators, if applicable

(b) Supplier's name and trade designation

(c) Size and net weight (see 6.1)

(d) Lot, control, or heat number

23.2 The appropriate precautionary information[8] given in ANSI Z49.1, latest edition, (as a minimum), shall be prominently displayed in legible print on all packages, including individual unit packages within a larger package.

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[8] Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumable used with certain processes.

Annex A
Guide to AWS Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding

(This Annex is not a part of AWS A5.18/A5.18M:2005, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding,* but is included for information purposes only.)

A1. Introduction

The purpose of this guide is to correlate the electrode and rod classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable.

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 as shown in Fig. A1.

A2.2 The prefix "E" designates an electrode as in other specifications. The letters "ER" indicate that the filler metal may be used either as an electrode or a rod. For A5.18, the number 70 indicates the required minimum tensile strength, as a multiple of 1000 psi, of the weld metal in a test weld made in accordance with specification A5.18. Similarly, for A5.18M, the number 48 indicates the required minimum tensile strength, as a multiple of 10 MPa, of the weld metal in a test weld made in accordance with specification A5.18M.

The letter "S" designates a solid electrode or rod.

The letter "C" designates a composite electrode. The digit following the hyphen, 2, 3, 4, 6, 7, G, or GS, indicates the chemical composition and/or impact testing requirements specified in Tables 1 through 5.

In the case of some composite stranded and metal cored electrodes, the letter "M" or "C" will follow, indicating the type of shielding gas.

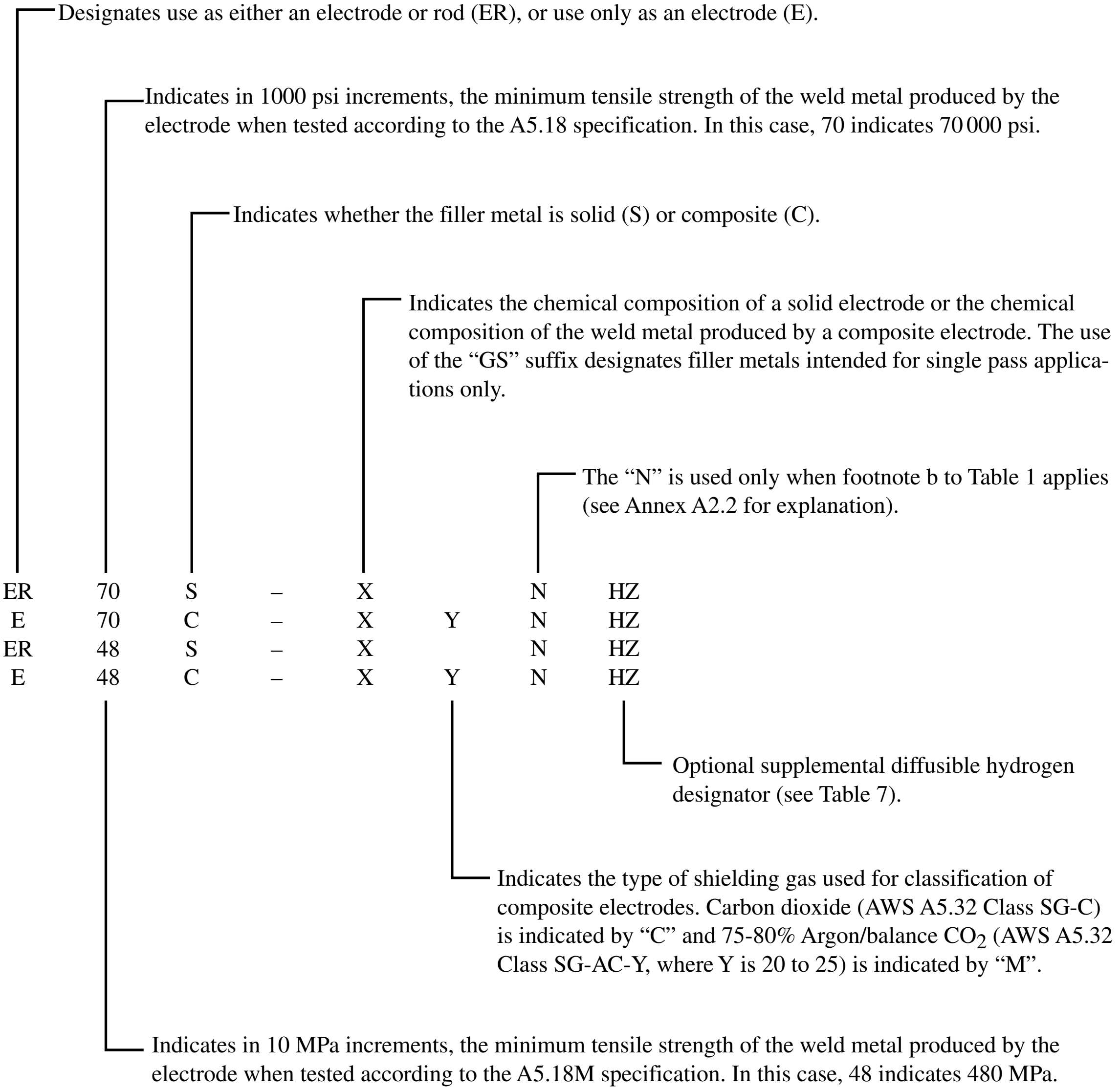
The addition of the letter "N" as a suffix to a classification indicates that the electrode is intended for certain very special welds in nuclear applications. These welds are found in the core belt region of the reactor vessel. This region is subject to intense neutron radiation, and it is necessary, therefore, that the phosphorus, vanadium, and copper contents of the weld metal be limited in order to resist neutron radiation-induced embrittlement. It is also necessary that the weld metal has a high upper shelf energy level in order to withstand some embrittlement, yet remain serviceable over the years.

Optional designators are also used in this specification in order to identify electrodes and rods that have met mandatory classification requirements and certain supplementary requirements as agreed to between the supplier and purchaser. An optional supplemental diffusible hydrogen designator (H16, H8, or H4) may follow the classification designation, indicating whether the electrode will meet a maximum hydrogen level of 16, 8, or 4 mL/100g of deposited metal when tested as outlined in AWS A4.3. Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 7, are also understood to be able to meet any higher hydrogen limits without necessarily being designated as such.

A2.3 "G" Classification

A2.3.1 This specification includes filler metals classified as ER70S-G [ER48S-G], E70C-G [E48C-G], and E70C-GS [E48C-GS]. The "G" (multiple pass) or "GS" (single pass) indicates that the filler metal is of a "general" classification. It is general because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing these classifications is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal — one that otherwise would have to await a revision of the specification — to be classified

FIG. A1 CLASSIFICATION SYSTEM



Designates use as either an electrode or rod (ER), or use only as an electrode (E).

Indicates in 1000 psi increments, the minimum tensile strength of the weld metal produced by the electrode when tested according to the A5.18 specification. In this case, 70 indicates 70 000 psi.

Indicates whether the filler metal is solid (S) or composite (C).

Indicates the chemical composition of a solid electrode or the chemical composition of the weld metal produced by a composite electrode. The use of the "GS" suffix designates filler metals intended for single pass applications only.

The "N" is used only when footnote b to Table 1 applies (see Annex A2.2 for explanation).

ER	70	S	–	X		N	HZ
E	70	C	–	X	Y	N	HZ
ER	48	S	–	X		N	HZ
E	48	C	–	X	Y	N	HZ

Optional supplemental diffusible hydrogen designator (see Table 7).

Indicates the type of shielding gas used for classification of composite electrodes. Carbon dioxide (AWS A5.32 Class SG-C) is indicated by "C" and 75-80% Argon/balance CO_2 (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25) is indicated by "M".

Indicates in 10 MPa increments, the minimum tensile strength of the weld metal produced by the electrode when tested according to the A5.18M specification. In this case, 48 indicates 480 MPa.

immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some particular respect (chemical composition, again, for example).

A2.3.2 The point of difference (although not necessarily the amount of the 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:

(a) 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.

(b) Not Required is used in those areas of the specification that refer to the tests that must be conducted in order to classify a filler metal. 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 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. They may want to incorporate that information (via AWS A5.01, *Filler Metal Procurement Guidelines*) into the purchase order.

A2.3.3 Request for Filler Metal Classification

A2.3.3.1 When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

A2.3.3.2 A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need.

In particular, the request needs to include:

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

(b) Any 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 requester for further information.

A2.3.3.3 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 shall 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 the Chair of the particular Subcommittee involved;

(d) file the original request;

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

A2.3.3.4 All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requester of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chair of the Committee on Filler Metals and Allied Materials, for action.

A2.3.3.5 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.

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, shall 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

A4.1 The act of placing the AWS specification and classification designations and optional supplemental designators, if applicable, on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this "certification" is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped, and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01, *Filler Metal Procurement Guidelines*.

A4.2 (Optional) At the option and expense of the purchaser, acceptance may be based on the results of any or all of the tests required by this specification made on the GTAW test assembly described in Fig. A2.

One all-weld-metal round tension test specimen, as specified in the Tension Tests section of AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in Fig. A2. The tensile specimen shall have a nominal diameter of 0.350 in. [9.0 mm] and a nominal gage length-to-diameter ratio of 4:1. The specimen shall be tested as specified in 12.1. Other dimensions of the tension test specimen shall be as specified in the Tension Test section of AWS B4.0 or B4.0M.

The Charpy V-Notch specimens shall be specified in Section 14. Composite electrodes are normally not recommended for GTAW or PAW.

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:

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

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

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

(d) the proximity of the welders or welding operators 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;

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

A5.2 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 Health Protection and Ventilation in that document.

A6. Welding Considerations

A6.1 Gas metal arc welding (GMAW) can be divided into three categories based on the mode of metal transfer. These modes are (1) spray (conventional or pulsed), (2) globular, and (3) short circuiting transfer. In the spray, pulsed spray, and globular modes, transfer occurs as distinct droplets that are detached from the electrode, transferring along the arc column into the weld pool. In the short circuiting mode, the metal is deposited during frequent short circuiting of the electrode in the molten pool.

A6.2 Spray Transfer

A6.2.1 The spray transfer mode, for carbon steel, is most commonly obtained with argon shielding gas mixtures with up to 5% of oxygen (AWS A5.32 Class SG-AO-X, where X is 1 to 5) or up to 15% carbon dioxide (AWS A5.32 Class SG-AC-Y, where Y is 5 to 15). A characteristic of this shielding gas is the smooth arc plasma through which hundreds of very fine droplets are transferred to the weld pool each second.

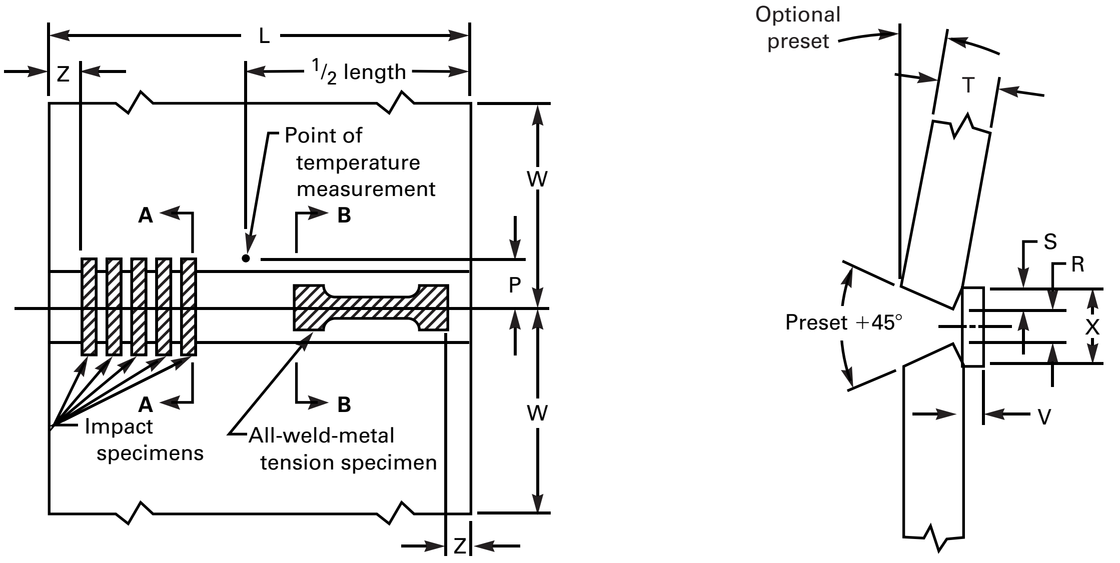
A6.2.2 Spray transfer with argon-oxygen (AWS A5.32 Class SG-AO-X) or argon-carbon dioxide (AWS A5.32 Class SG-AC-Y) shielding gas is, primarily, a function of current density, polarity, and resistance heating of the electrode. The high droplet rate (approximately 250 droplets per second) develops suddenly above a critical current level, commonly referred to as the transition current (for each size of electrode). Below this current, the metal is transferred in drops generally larger in diameter than the electrode and at a rate of from 10 to 20 per second (globular transfer). The transition current is also dependent, to some extent, on the chemical composition of the electrode. For $^1/_{16}$ in. [1.6 mm] diameter carbon steel electrodes, a transition current of 270 amperes [direct current, electrode positive (dcep)] is common. Alternating current is not recommended for this type of welding because it does not produce a stable arc.

A6.2.3 Pulsed Spray. Metal transfer in pulsed spray welding is similar to that of the spray transfer described above, but it occurs at a lower average current. The lower average current is made possible by rapid pulsing of the welding current between a high level, where metal will transfer rapidly in the spray mode, and a low level, where no transfer will take place. At a typical rate of 60 to 120 pulses per second, a melted drop is formed by the low current arc, which is then "squeezed off" by the high current pulse. This permits all-position welding.

A6.3 Globular Transfer. The mode of transfer that characterizes 100% CO_2 (AWS A5.32 Class SG-C) as a shielding gas is globular. Common practice with globular transfer is to use low arc voltage to minimize spatter. This shortens the arc length causing the arc to be "buried" and results in deeper penetration and better containment of spatter within the weld pool. Electrodes of 0.045 in. through $^1/_{16}$ in. [1.2 mm through 1.6 mm] diameter normally are used at welding currents in the range of 275 to 400 amperes (dcep), for this type of transfer. The rate at which droplets (globules) are transferred ranges from 20 to 70 per second, depending on the size of the electrode, the amperage, polarity, and arc voltage.

A6.4 Short Circuiting Transfer. This mode of transfer is obtained with small diameter electrodes (0.030 to 0.045 in. [0.8 to 1.2 mm]) using low arc voltages and amperages, and a power source designed for short circuiting transfer. The electrode short-circuits to the weld metal, usually at a rate of from 50 to 200 times per second. Metal is transferred with each short circuit, but not across the arc. Short circuiting gas metal arc welding of carbon steel is done most commonly with mixtures of argon and CO_2

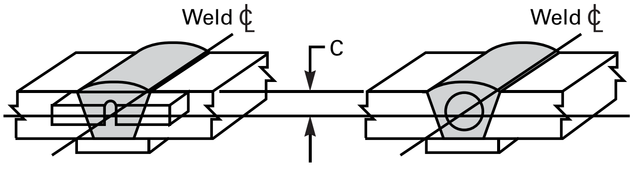
FIG. A2 OPTIONAL GTAW GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS



(A) Test Plate Showing Location of Test Specimens

(B) Groove Preparation of Test Plate

Dimensions		in.	mm
C	Specimen center	¼	6.5
L	Length, min.	10	250
P	Point of temperature measurement	1	25
R	Root opening	¼	6.5
S	Backup strip overlap, min.	⅜	9
V	Backup strip thickness, min.	¼	6.5
X	Backup strip width, min.	1	25
T	Thickness	½	13
W	Width, min.	5	125
Z	Discard, min.	1	25



Section A–A

(C) Orientation of Impact Specimen

Section B–B

(D) Location of All-Weld-Metal Tension Specimen

Test Conditions for Solid Rods[1,2]

Standard size [Note (2)]	3/32 in.	[2.4 mm]	⅛ in.	[3.2 mm]
Shielding gas [Note (3)]	Argon	Argon	Argon	Argon
Nominal arc voltage	13 to 16 V	13 to 16 V	16 to 19 V	16 to 19 V
Nominal current, DCEN (DCEN = electrode negative)	220 to 250 A	220 to 250 A	250 to 280 A	250 to 280 A
Preheat temperature	275°F minimum	[135°C] minimum	275°F minimum	[135°C] minimum
Interpass temperature	325°F maximum	[165°C] maximum	325°F maximum	[165°C] maximum
Travel speed	4 to 6 in./min	[2.0 ± 0.4 mm/sec]	4 to 6 in./min	[2.0 ± 0.4 mm/sec]

GENERAL NOTES:

(a) Base metal shall be as specified in Table 6.

(b) The surfaces to be welded shall be clean.

(c) Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.

NOTES:

(1) Test conditions for composite electrodes used as rods shall be as recommended by the manufacturer.

(2) If sizes other than those shown above are tested, nominal current and arc voltage shall be changed as needed.

(3) AWS A5.32 Class SG-A.

(AWS A5.32 Class SG-AC-Y) as the shielding gas or with CO_2 (AWS A5.32 Class SG-C) alone. The penetration of such welds is greater with CO_2 than it is with argon-CO_2 mixtures. Mixtures of 50 to 80% argon with CO_2 remainder (AWS A5.32 Class SG-AC-Y, where Y is 20 to 50) can be advantageous for thin material. However shielding gas mixtures of 50% to 70% argon with CO_2 remainder (AWS A5.32 Class SG-AC-Y, where Y is 30 to 50) are unstable in the gaseous state and must be mixed from single gas components immediately prior to use. They provide low penetration, higher short circuiting rates, and lower minimum currents and voltages than CO_2 alone does. This can be an advantage in welding thin plate.

A7. Description and Intended Use of Electrodes and Rods

A7.1 ER70S-2 [ER48S-2]. Electrodes and rods of the ER70S-2 [ER48S-2] classification are primarily used for single-pass welding of killed, semi-killed, and rimmed steels, but may be used for some multipass applications. Because of the added deoxidants, these filler metals can be used for welding steels that have a rusty or dirty surface, with a possible sacrifice of weld quality depending on the condition of the surface. ER70S-2 [ER48S-2] filler metals are used extensively to produce high quality, high toughness welds with the GTAW process. These filler metals are also well suited for use in single side, melt through welding without a protective root shielding gas on the backside of the joint. Typical specifications for these steels are ASTM A 36, A 285-C, A 515-55, and A 516-70, which have UNS numbers K02600, K02801, K02001, and K02700, respectively.

A7.2 ER70S-3 [ER48S-3]. Electrodes and rods of the ER70S-3 [ER48S-3] classification are intended for welding single-pass and multi-pass welds. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classification. Electrodes of the ER70S-3 [ER48S-3] classification are the most widely used of the GMAW electrodes classified under this specification.

A7.3 ER70S-4 [ER48S-4]. Electrodes and rods of the ER70S-4 [ER48S-4] classification are intended for welding steel where conditions require more deoxidation than is provided by the ER70S-3 [ER48S-3] filler metal. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classification. This classification does not require impact testing.

A7.4 ER70S-6 [ER48S-6]. Electrodes and rods of the ER70S-6 [ER48S-6] classification are intended for both single- and multiple-pass welding. They are especially suited for sheet metal applications, where smooth weld beads are desired, and structural and plate steels that have moderate amounts of rust or mill scale. These electrodes permit the use of higher current ranges with either CO_2 (AWS A5.32 Class SG-C) shielding gas or with mixtures of argon and oxygen (AWS A5.32 Class SG-AO-X) or argon and carbon dioxide (AWS A5.32 Class SG-AC-Y). However, these electrodes do require a higher level of oxidation than the previously described electrodes when using either binary or ternary argon shielding gas mixtures per the AWS A5.32 specification. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classification.

A7.5 ER70S-7 [ER48S-7]. Electrodes and rods of the ER70S-7 [ER48S-7] classification are intended for single- and multiple-pass welding. They may permit welding with higher travel speeds compared with ER70S-3 filler metals. They also provide somewhat better wetting action and bead appearance when compared with those filler metals. These electrodes permit the use of higher current ranges with either CO_2 (AWS A5.32 Class SG-C) shielding gas or with mixtures of argon and oxygen (AWS A5.32 Class SG-AO-X) or argon and carbon dioxide (AWS A5.32 Class SG-AC-Y). However, these electrodes do require a higher level of oxidation (more CO_2 or O_2) like the previously described electrode when using either binary or ternary argon shielding gas mixtures per the AWS A5.32 specification. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classifications.

A7.6 ER70S-G [ER48S-G] and E70C-G [E48C-G]. Electrodes and rods of the ER70S-G [ER48S-G] and electrodes of the E70C-G [E48C-G] classifications are those filler metals not included in the preceding classes and for which only certain mechanical property requirements are specified. Electrodes of the E70C-G [E48C-G] classification may be classified with either CO_2 (AWS A5.32 Class SG-C) or 75–80% Ar/balance CO_2 (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25) as shown by the “C” or “M” suffix. Absence of the C or M suffix means that the shielding gas used for testing was not one of the above AWS classes and the electrode manufacturer should be consulted for the recommended shielding gas to be used. The electrodes are intended for both single-and multiple-pass applications. The filler metal supplier should be consulted for the composition, properties, characteristics, and intended use of these classifications (see A2.3 for further information).

A7.7 E70C-GS [E48C-GS]. Electrodes of the E70C-GS [E48C-GS] classification are composite stranded or metal cored electrodes intended for only single-pass applications. The electrodes may be classified with either CO_2 (AWS A5.32 Class SG-C) or 75–80% Ar/balance CO_2 (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25) as shown by the “C” or “M” suffix. Absence of the C or M suffix means that the shielding gas used for testing was not one of the above AWS classes and the electrode manufacturer should be consulted for the recommended shielding gas to be used. The filler metal supplier should be consulted for the properties, characteristics, and intended use of these classifications. These electrodes may have higher alloy contents which improve single pass applications (such as tolerance to mill scale, etc.) but could preclude their use on multiple-pass applications due to higher alloy recovery.

A7.8 E70C-3 [E48C-3] and E70C-6 [E48C-6]. Electrodes of the E70C-3 [E48C-3] and E70C-6 [E48C-6] classifications are composite stranded or metal cored electrodes intended for both single- and multiple-pass applications. They are characterized by a spray arc and excellent bead wash characteristics. The electrodes may be classified with either CO_2 (AWS A5.32 Class SG-C) or 75–80% Ar/balance CO_2 (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25) as shown by the "C" or "M" suffix. Classification E70C-3 [E48C-3] requires impacts at 0°F [−20°C] while E70C-6 [E48C-6] requires impacts at −20°F [−30°C].

A8. Special Tests

A8.1 It is recognized that supplementary tests may be required for certain applications. In such cases, additional tests to determine specific properties such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, may be required. AWS A5.01, *Filler Metal Procurement Guidelines*, contains provisions for ordering such tests. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

A8.2 Diffusible Hydrogen

A8.2.1 Hydrogen induced cracking of weld metal or the heat-affected zone generally is not a problem with plain carbon steels containing 0.3 percent or less carbon, nor 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.

A8.2.2 Gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) are generally considered to be low hydrogen welding processes. However, as the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. It may be appropriate to evaluate the diffusible hydrogen produced during welding with these processes. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in root beads), and toe or underbead cracks in the heat-affected zone.

A8.2.3 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 supplemental designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.

Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 7, are also understood to meet any higher electrode hydrogen limits, even though these are not necessarily designated along with the electrode classification. Therefore, for example an electrode designated as "H4" also meets the "H8" and "H16" requirements without being designated as such.

A8.2.4 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

A8.2.5 The use of a reference atmospheric condition during welding is necessary because the arc is always imperfectly shielded. Moisture from the air, distinct from that in the electrode or gas, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining a suitable gas flow rate and as short an arc length as possible consistent with a steady arc. At times, some air will mix with the gas and add its moisture to the other sources of diffusible hydrogen. It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. For this reason, it is appropriate to specify a reference atmospheric condition. The reference atmospheric condition of 10 grains of moisture per pound [1.43 grams per kilogram] of dry air is equivalent to 10% relative humidity at 70°F [18°C] at 29.92 in. Hg [760 mm] barometric pressure. Actual conditions, measured using a calibrated psychrometer, that equal or exceed this reference condition provide assurance that the conditions during welding will not diminish the final results of the test.

A8.3 Aging of Tensile and Bend 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 towards its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. This specification permits the aging of the tensile test specimens and bend test specimens

TABLE A1
DISCONTINUED ELECTRODE CLASSIFICATIONS

Discontinued Classification	Last Published	Discontinued Classification	Last Published
E-60S-1	1965	E70S-1	1969
E-60S-2	1965	E70S-1B[b]	1969
E-60S-3	1965	E70S-2[c]	1969
E-70T-1[a]	1965	E70S-3[c]	1969
E-70T-2[a]	1965	E70S-4[c]	1969
E-70T-3[a]	1965	E70S-5	1969
E-70T-4[a]	1965	E70S-6[c]	1969
E-70T-5[a]	1965	E70S-G[c]	1969
E-70T-G[a]	1965	E70U-1	1969
		ER70S-5	1993

NOTES:

a. These flux-cored electrode classifications were transferred to AWS A5.20-69 and continue to be included in the revisions to that specification.

b. This electrode classification was transferred to the new AWS A5.28 specification where it is classified as ER80S-D2.

c. These electrode classifications were changed to the new classification ER70S-X and remain in the current revision of the specification as such.

(from composite electrodes only) at elevated temperatures for up to 48 hours before subjecting them to testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrode deposits, especially when testing high strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds.

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 in Table A1 have been discontinued over the life of this specification (along with the year in which they were last included in the specification).

A10. General Safety Information

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 Section A5 and below. Safety and health information is available from other sources, including but not limited to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*,[9] and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[10]

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 Space
12	Contact Lens Wear
13	Ergonomics in the Welding Envirionment
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 Proposal 65
24	Fluxes for Arc Welding and Brazing: Safe Handling and Use
25	Metal Fuyme Fever
27	Thoriated Tungsten Electrodes
29	Grounding of Portable and Vehicle Mounted Welding Generators

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

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

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SPECIFICATION FOR CARBON STEEL ELECTRODES FOR FLUX CORED ARC WELDING

SFA-5.20/SFA-5.20M

(Identical with AWS Specification A5.20/A5.20M:2005. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR CARBON STEEL ELECTRODES FOR FLUX CORED ARC WELDING

SFA-5.20/SFA-5.20M

(Identical with AWS Specification A5.20/A5.20M:2005. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel electrodes for flux cored arc welding (FCAW) either with or without shielding gas. (Metal cored carbon steel electrodes are classified according to AWS A5.18/A5.18M.)[1]

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in the nonmandatory Annex Sections A5 and A9. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1[2] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.20 uses U.S. Customary Units. The specification A5.20M uses SI Units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing of electrodes or packaging or both under the A5.20 and A5.20M specifications.

2. Normative References

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

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

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

(b) AWS A5.01, *Filler Metal Procurement Guidelines*

(c) AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*

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

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

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

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

(a) ASTM A 36/A 36M, *Specification for Carbon Structural Steel*

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

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

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[1] AWS standards can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group company, 15 Inverness Way East, Englewood, CO 80112-5776.

[2] ANSI standards can be obtained from the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, and Global Engineering Documents, an Information Handling Services (IHS) Group company, 15 Inverness Way East, Englewood, CO 80112-5776.

[3] ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

TABLE 1U
SFA-5.20 MECHANICAL PROPERTY REQUIREMENTS

AWS Classification(s)	Tensile Strength, ksi	Minimum Yield Strength[a], ksi	Minimum % Elongation[b]	Minimum Charpy V-Notch Impact Energy
E7XT-1C, -1M	70–95	58	22	20 ft·lbf at 0°F
E7XT-2C[c], -2M[c]	70 min.	Not Specified	Not Specified	Not Specified
E7XT-3[c]	70 min.	Not Specified	Not Specified	Not Specified
E7XT-4	70–95	58	22	Not Specified
E7XT-5C, -5M	70–95	58	22	20 ft·lbf at −20°F
E7XT-6	70–95	58	22	20 ft·lbf at −20°F
E7XT-7	70–95	58	22	Not Specified
E7XT-8	70–95	58	22	20 ft·lbf at −20°F
E7XT-9C, -9M	70–95	58	22	20 ft·lbf at −20°F
E7XT-10[c]	70 min.	Not Specified	Not Specified	Not Specified
E7XT-11	70–95	58	20[d]	Not Specified
E7XT-12C, -12M	70–90	58	22	20 ft·lbf at −20°F
E6XT-13[c]	60 min.	Not Specified	Not Specified	Not Specified
E7XT-13[c]	70 min.	Not Specified	Not Specified	Not Specified
E7XT-14[c]	70 min.	Not Specified	Not Specified	Not Specified
E6XT-G	60–80	48	22	Not Specified
E7XT-G	70–95	58	22	Not Specified
E6XT-GS[c]	60 min.	Not Specified	Not Specified	Not Specified
E7XT-GS[c]	70 min.	Not Specified	Not Specified	Not Specified

NOTES:

a. Yield strength at 0.2% offset.

b. In 2 in. gage length when a 0.500 in. nominal diameter tensile specimen and nominal gage length to diameter ratio of 4:1 (as specified in the Tension Tests section of AWS B4.0) is used.

c. These classifications are intended for single pass welding. They are not for multiple pass welding. Only tensile strength is specified and, for this reason, only transverse tension and longitudinal guided bends are required (see Table 3).

d. In 1 in. gage length when a 0.250 in. nominal diameter tensile specimen is used as permitted for 0.045 in. and smaller sizes of the E7XT-11 classification.

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

(e) ASTM A 830/A 830M, *Standard Specification for Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements*

(f) ASTM DS-56 (or SAE HS-1086), *Metals & Alloys in the Unified Numbering System*

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

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

(i) ASTM E 1032, Standard Test Method for Radiographic Examination of Weldments

2.4 The following ISO standard[4] is referenced in the mandatory sections of this document.

(a) ISO 544, *Welding consumables—Technical delivery conditions for welding filler metals—Type of product, dimensions, tolerances and marking*

2.5 The following FEMA (Federal Emergency Management Agency) document[5] is referenced in the mandatory sections of this document.

(a) FEMA 353, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications*

3. Classification

3.1 The flux cored electrodes covered by the A5.20 specification utilize a classification system based upon the U.S. Customary Units and are classified according to the mechanical properties of the weld metal as specified in Table 1U as shown in Fig. 1.

3.1M The flux cored electrodes covered by the A5.20M specification utilize a classification system based upon the

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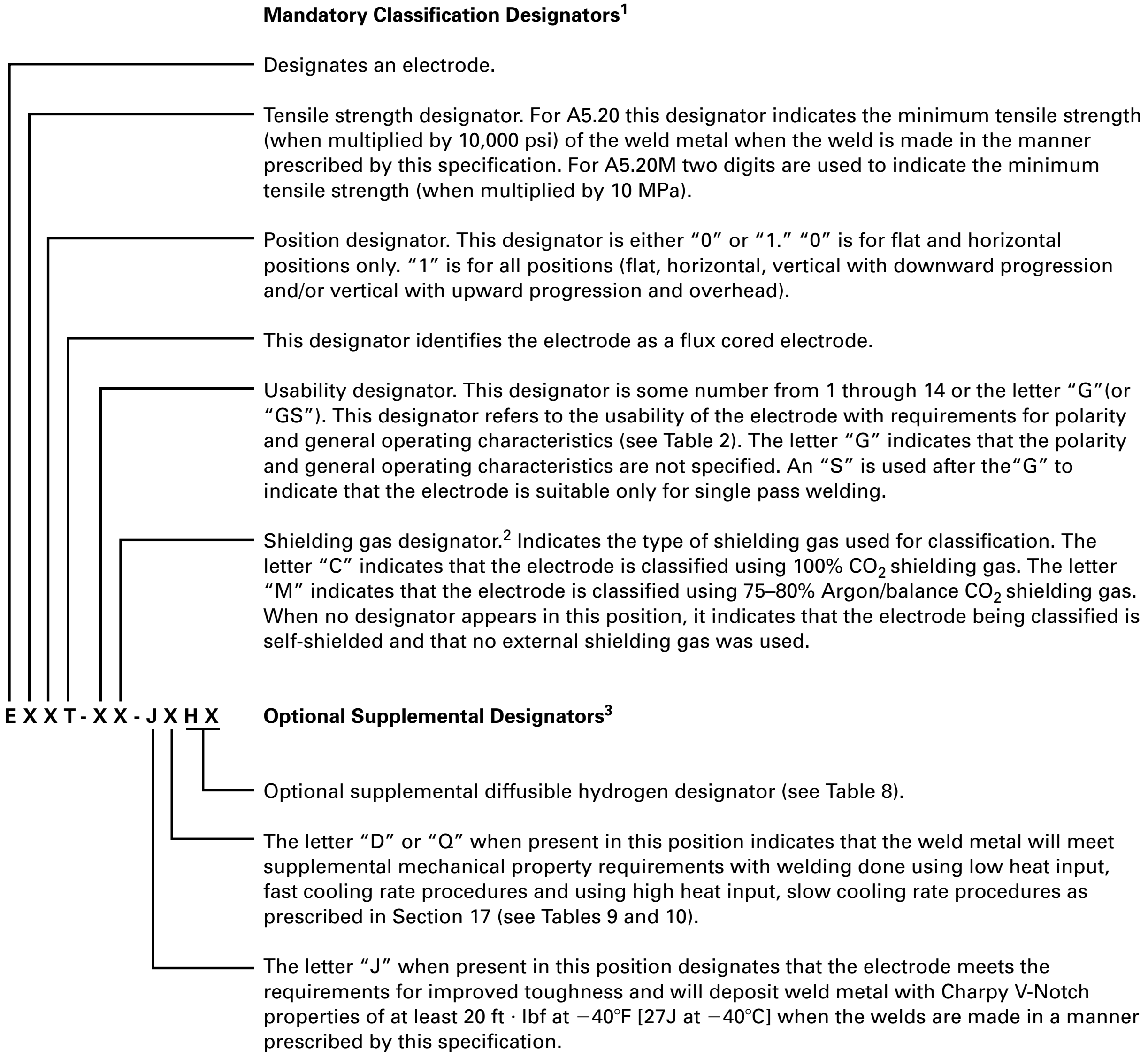
[4] ISO standards may be obtained from the American National Standards Institute (ANSI), 25 West 43rd Street, Fourth Floor, New York, NY 10036.

[5] FEMA documents can be obtained from FEMA Publications, P.O. Box 2012, Jessup, MD 20794.

FIG. 1 A5.20/A5.20M CLASSIFICATION SYSTEM



Mandatory Classification Designators[1]

Designates an electrode.

Tensile strength designator. For A5.20 this designator indicates the minimum tensile strength (when multiplied by 10,000 psi) of the weld metal when the weld is made in the manner prescribed by this specification. For A5.20M two digits are used to indicate the minimum tensile strength (when multiplied by 10 MPa).

Position designator. This designator is either "0" or "1." "0" is for flat and horizontal positions only. "1" is for all positions (flat, horizontal, vertical with downward progression and/or vertical with upward progression and overhead).

This designator identifies the electrode as a flux cored electrode.

Usability designator. This designator is some number from 1 through 14 or the letter "G"(or "GS"). This designator refers to the usability of the electrode with requirements for polarity and general operating characteristics (see Table 2). The letter "G" indicates that the polarity and general operating characteristics are not specified. An "S" is used after the"G" to indicate that the electrode is suitable only for single pass welding.

Shielding gas designator.[2] Indicates the type of shielding gas used for classification. The letter "C" indicates that the electrode is classified using 100% CO_2 shielding gas. The letter "M" indicates that the electrode is classified using 75–80% Argon/balance CO_2 shielding gas. When no designator appears in this position, it indicates that the electrode being classified is self-shielded and that no external shielding gas was used.

Optional Supplemental Designators[3]

Optional supplemental diffusible hydrogen designator (see Table 8).

The letter "D" or "Q" when present in this position indicates that the weld metal will meet supplemental mechanical property requirements with welding done using low heat input, fast cooling rate procedures and using high heat input, slow cooling rate procedures as prescribed in Section 17 (see Tables 9 and 10).

The letter "J" when present in this position designates that the electrode meets the requirements for improved toughness and will deposit weld metal with Charpy V-Notch properties of at least 20 ft · lbf at −40°F [27J at −40°C] when the welds are made in a manner prescribed by this specification.

NOTES:

1. The combination of these designators constitutes the flux cored electrode classification.
2. See AWS A5.32/A5.32M.
3. These designators are optional and do not constitute a part of the flux cored electrode classification.

TABLE 1M
A5.20M MECHANICAL PROPERTY REQUIREMENTS

AWS Classification(s)	Tensile Strength, (MPa)	Minimum Yield Strength[a], (MPa)	Minimum % Elongation[b]	Minimum Charpy V-Notch Impact Energy
E49XT-1C, -1M	490-670	390	22	27 Joules at −20°C
E49XT-2C[c], -2M[c]	490 min.	Not Specified	Not Specified	Not Specified
E49XT-3[c]	490 min.	Not Specified	Not Specified	Not Specified
E49XT-4	490-670	390	22	Not Specified
E49XT-5C, -5M	490-670	390	22	27 Joules at −30°C
E49XT-6	490-670	390	22	27 Joules at −30°C
E49XT-7	490-670	390	22	Not Specified
E49XT-8	490-670	390	22	27 Joules at −30°C
E49XT-9C, -9M	490-670	390	22	27 Joules at −30°C
E49XT-10[c]	490 min.	Not Specified	Not Specified	Not Specified
E49XT-11	490-670	390	20[d]	Not Specified
E49XT-12C, -12M	490-620	390	22	27 Joules at −30°C
E43XT-13[c]	430 min.	Not Specified	Not Specified	Not Specified
E49XT-13[c]	490 min.	Not Specified	Not Specified	Not Specified
E49XT-14[c]	490 min.	Not Specified	Not Specified	Not Specified
E43XT-G	430-600	330	22	Not Specified
E49XT-G	490-670	390	22	Not Specified
E43XT-GS[c]	430 min.	Not Specified	Not Specified	Not Specified
E49XT-GS[c]	490 min.	Not Specified	Not Specified	Not Specified

NOTES:

a. Yield strength at 0.2% offset.

b. In 50 mm gage length when a 12.5 mm nominal diameter tensile specimen and nominal gage length to diameter ratio of 4:1 (as specified in the Tension Tests section of AWS B4.0M) is used.

c. These classifications are intended for single pass welding. They are not for multiple pass welding. Only tensile strength is specified and, for this reason, only traverse tension and longitudinal guided bends are required (see Table 3).

d. In 25 mm gage length when a 6.5 mm nominal diameter tensile specimen is used as permitted for 1.2 mm and smaller sizes of the E49XT-11 classification.

International System of Units (SI) and are classified according to the mechanical properties of the weld metal as specified in Table 1M as shown in Fig. 1.

3.1.1 Flux cored electrodes classified for multiple-pass welding are classified according to the following:

(a) The as-welded mechanical properties of the weld metal obtained with a particular shielding gas, if any, as specified in Table 1U [Table 1M].

(b) The positions of welding for which the electrode is suitable, as shown in Table 2 and Fig. 1.

(c) Certain usability characteristics of the electrode (including the presence or absence of a shielding gas) as specified in Table 2 and Fig. 1.

3.1.2 Flux cored electrodes classified for single pass welding are classified in the as-welded condition according to the following:

(a) The tensile properties of the weld metal obtained with a particular shielding gas, if any, as specified in Table 1U [Table 1M].

(b) The positions of welding for which the electrode is suitable, as shown in Fig. 1.

(c) Certain usability characteristics of the electrode (including the presence or absence of a shielding gas), as specified in Table 2 and Fig. 1.

3.2 Electrodes classified under one classification shall not be classified under any other classification in this specification with the exceptions that (1) an electrode may be classified with 100% CO_2 (AWS A5.32/A5.32M Class SG-C) shielding gas (“C” designator) and with a 75-80% argon/balance CO_2 (AWS A5.32/A5.32M Class SG-AC-25 or SG-AC-20) gas mixture (“M” designator) and (2) an E7XT-1C, -1M [E49XT-1C, -1M] may also be classified as an E7XT-9C, -9M [E49XT-9C, -9M] and/or E7XT-12C, -12M [E49XT-12C, -12M] providing the electrode meets all the requirements of each classification.

Electrodes may be classified under A5.20 using U.S. Customary Units or under A5.20M using the International System of Units (SI), or they may be classified under both systems. Electrodes classified under either classification systems must meet all requirements for classification under that system. The classification system is shown in Fig. 1.

TABLE 2
ELECTRODE USABILITY REQUIREMENTS

Usability Designator	AWS Classification		Position of Welding[a,b]	External Shielding[c]	Polarity[d]	Application[e]
	A5.20	A5.20M				
1	E70T-1C	E490T-1C	H, F	CO_2	DCEP	M
	E70T-1M	E490T-1M	H, F	75–80 Ar/bal CO_2		
	E71T-1C	E491T-1C	H, F, VU, OH	CO_2		
	E71T-1M	E491T-1M	H, F, VU, OH	75–80 Ar/bal CO_2		
2	E70T-2C	E490T-2C	H, F	CO_2	DCEP	S
	E70T-2M	E490T-2M	H, F	75–80 Ar/bal CO_2		
	E71T-2C	E491T-2C	H, F, VU, OH	CO_2		
	E71T-2M	E491T-2M	H, F, VU, OH	75–80 Ar/bal CO_2		
3	E70T-3	E490T-3	H, F	None	DCEP	S
4	E70T-4	E490T-4	H, F	None	DCEP	M
5	E70T-5C	E490T-5C	H, F	CO_2		M
	E70T-5M	E490T-5M	H, F	75–80 Ar/bal CO_2	DCEP	
	E71T-5C	E491T-5C	H, F, VU, OH	CO_2	DCEP or DCEN[f]	
	E71T-5M	E491T-5M	H, F, VU, OH	75–80 Ar/bal CO_2		
6	E70T-6	E490T-6	H, F	None	DCEP	M
7	E70T-7	E490T-7	H, F	None	DCEN	M
	E71T-7	E491T-7	H, F, VU, OH			
8	E70T-8	E490T-8	H, F	None	DCEN	M
	E71T-8	E491T-8	H, F, VU, OH			
9	E70T-9C	E490T-9C	H, F	CO_2	DCEP	M
	E70T-9M	E490T-9M	H, F	75–80 Ar/bal CO_2		
	E71T-9C	E491T-9C	H, F, VU, OH	CO_2		
	E71T-9M	E491T-9M	H, F, VU, OH	75–80 Ar/bal CO_2		
10	E70T-10	E490T-10	H, F	None	DCEN	S
11	E70T-11	E490T-11	H, F	None	DCEN	M
	E71T-11	E491T-11	H, F, VD, OH	None		
12	E70T-12C	E490T-12C	H, F	CO_2	DCEP	M
	E70T-12M	E490T-12M	H, F	75–80 Ar/bal CO_2		
	E71T-12C	E491T-12C	H, F, VU, OH	CO_2		
	E71T-12M	E491T-12M	H, F, VU, OH	75–80 Ar/bal CO_2		
13	E61T-13	E431T-13	H, F, VD, OH	None	DCEN	S
	E71T-13	E491T-13				
14	E71T-14	E491T-14	H, F, VD, OH	None	DCEN	S
G	E60T-G	E430T-G	H, F	Not Specified	Not Specified	M
	E70T-G	E490T-G				
	E61T-G	E431T-G	H, F, VD or VU, OH	Not Specified	Not specified	M
	E71T-G	E491T-G				
	E60T-GS	E430T-GS	H, F	Not Specified	Not Specified	S
	E70T-GS	E490T-GS				
	E61T-GS	E431T-GS	H, F, VD or VU, OH	Not Specified	Not specified	S
	E71T-GS	E491T-GS				

TABLE 2
ELECTRODE USABILITY REQUIREMENTS (CONT'D)

NOTES:
a. H = horizontal position, F = flat position, OH = overhead position, VD = vertical position with downward progression, VU = vertical position with upward progression.
b. Electrode sizes suitable for out-of-position welding, i.e., welding positions other than flat or horizontal, are usually those sizes that are smaller than the $^{3}/_{32}$ in. (2.4 mm) size or nearest size called for in 9.4.1 for the groove weld. For that reason, electrodes meeting the requirements for the groove weld tests and the fillet weld tests may be classified as EX1T-XX (where X represents the tensile strength, usability and shielding gas, if any, designators) regardless of their size. See Section A7 in the Annex and Figure 1 for more information.
c. Properties of weld metal from electrodes that are used with external shielding gas employed. Electrodes classified with a specified shielding gas should not be used with other shielding gases without first consulting the manufacturer of the electrode.
d. The term "DCEP" refers to direct current electrode positive (dc, reverse polarity).
The term "DCEN" refers to direct current electrode negative (dc, straight polarity).
e. M = single or multiple pass, S = single pass only (see Section A7 in the Annex).
f. Some EX1T-5C and EX1T-5M electrodes may be recommended for use on DCEN for improved out-of-position welding. Consult the manufacturer for the recommended polarity.

3.3 The electrodes classified under this specification are intended for flux cored arc welding, either with or without an external shielding gas. Electrodes intended for use without external shielding gas, or with the shielding gas specified in Table 2, are not prohibited from use with any other process or shielding gas for which they are found suitable.

4. Acceptance

Acceptance[6] of the welding electrodes 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[7].

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1,000 psi for tensile and yield strength for A5.20 [or to the nearest 10 MPa for tensile and yield strength for A5.20M] and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities in accordance with the rounding-off method given in ASTM E 29.

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 3. The purpose of these tests is to determine the mechanical properties, soundness, and chemical composition of the weld metal, and the usability of the electrode. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 15.

7.2 This document provides for four supplemental tests which are not required for classification but which are included for optional supplemental designators as agreed to between the purchaser and supplier.

7.2.1 The supplemental test for diffusible hydrogen is described in Section 16 and utilizes designators H16, H8, or H4.

7.2.2 The optional supplemental designator "J" may be used to indicate that the electrode being classified meets the requirements for improved toughness and will deposit weld metal with Charpy V-Notch properties at least 20 ft•lbf at -40°F [27J at -40°C°] when welds are made in a manner prescribed by this specification.

7.2.3 The optional supplemental designators "D" or "Q" may be used to indicate conformance to the radiographic requirements of this specification and to the all-weld mechanical property requirements specified in Table 10 when the weld metal is deposited (1) using the low heat input, fast cooling rate procedure and (2) using the high heat input, slow cooling rate procedure specified in Section 17 and Table 9. The "D" designator is intended to identify those E7XT-X, -XC, or -XM flux cored electrodes that meet the recommendations for mechanical properties in FEMA 353 when the welds are made in a manner prescribed in FEMA 353. The "Q" designator is intended to identify those E7XT-X, -XC, or -XM flux cored electrodes that meet the additional anticipated requirements of the U.S. Navy.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests

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[6] See Section A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

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

TABLE 3
TESTS REQUIRED FOR CLASSIFICATION[a]

AWS Classification(s)	Chemical Analysis	Radiographic Test	Tension Test	Impact Test	Bend Test	Fillet Weld Test[b]
EXXT-1C, -1M	R	R	R	R	NR	R
EXXT-4	R	R	R	NR	NR	R
EXXT-5C, -5M	R	R	R	R	NR	R
EXXT-6	R	R	R	R	NR	R
EXXT-7	R	R	R	NR	NR	R
EXXT-8	R	R	R	R	NR	R
EXXT-9C, -9M	R	R	R	R	NR	R
EXXT-11	R	R	R	NR	NR	R
EXXT-12C, -12M	R	R	R	R	NR	R
EXXT-G	R	R	R	NR	NR	R
EXXT-2C[d], -2M[d]	NR	NR	R[c]	NR	R	R
EXXT-3[d]	NR	NR	R[c]	NR	R	NR
EXXT-10[d]	NR	NR	R[c]	NR	R	NR
EX1T-13[d]	NR	NR	R[c]	NR	R	R
EX1T-14[d]	NR	NR	R[c]	NR	R	R
EXXT-GS[d]	NR	NR	R[c]	NR	R	R

NOTES:

a. The letter "R" indicates that the test is required. "NR" indicates the test is not required.

b. For the fillet weld test, electrodes classified for downhand welding (EX0T-XX electrodes) shall be tested in the horizontal position. Electrodes classified for all-position welding (EX1T-XX electrodes) shall be tested in both the vertical and overhead positions(see 9.4.3).

c. Transverse tension test. All others require all-weld-metal tension test.

d. Intended for single pass welding.

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

In the event that, during preparation or after 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 the number of test specimens does not apply.

9. Test Assemblies

9.1 One or more of the following four test assemblies are required, depending on the classification of the electrode and the manner in which the tests are conducted:

(a) The weld pad in Fig. 2 for chemical analysis of the weld metal

(b) For multiple-pass electrodes, the test assembly in Fig. 3 for mechanical properties and soundness of the weld metal

(c) For single pass electrodes, the test assembly in Fig. 4 for mechanical properties

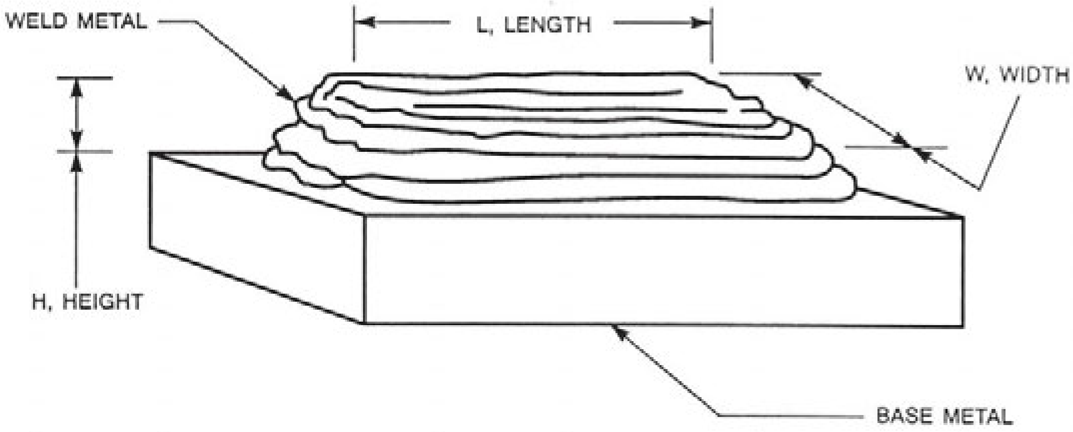
(d) The fillet weld test assembly in Fig. 5, for usability of the electrode

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 Fig. 3, 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 test assembly shall be as specified in 9.3 through 9.4.3. The base metal for each assembly shall be as required in Table 4 and shall meet the requirements of any one of the appropriate ASTM specifications shown there, or an equivalent specification. Testing of the welded test assemblies shall be as specified in Sections 10 through 15.

9.3 Weld Pad. A weld pad shall be prepared as specified in Fig. 2, except when either 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 Fig. 3) is selected. Base metal of any convenient size of the type specified in Table 4 shall be used as the base metal for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal ($\frac{1}{2}$ in.

FIG. 2 PAD FOR CHEMICAL ANALYSIS OF DEPOSITED WELD METAL

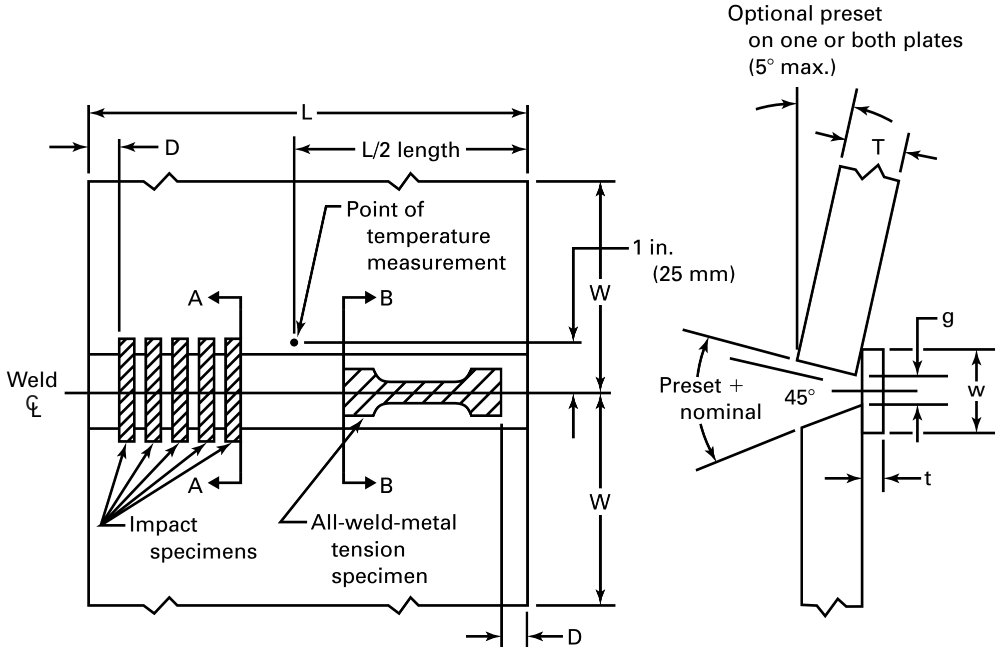


Weld Pad Size, Minimum					
Length, L		Width, W		Height, H	
in.	mm	in.	mm	in.	mm
$1\frac{1}{2}$	38	$\frac{1}{2}$	12	$\frac{1}{2}$	12

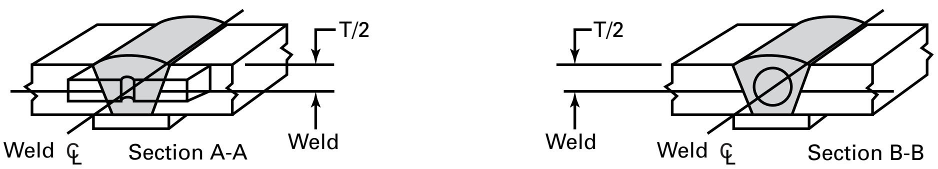
NOTES:

1. Base metal of any convenient size, of the type specified in Table 4, 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, using shielding gas (if any), using the polarity as specified in Table 2 and following the heat input requirements specified in Table 5.
4. 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 with the amperage employed. The weave shall be limited to 6 times the electrode diameter.
5. The preheat temperature shall not be less than 60°F (15°C) and the interpass temperature shall not exceed 325°F (165°C).
6. The test assembly may be quenched in water (temperature unimportant) between passes to control interpass temperature.
7. The minimum completed pad size shall be that shown above. The sample to be tested in Section 10 shall be taken from weld metal that is at least $\frac{3}{8}$ in. [10 mm] above the original base metal surface.

FIG. 3 TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS OF WELD METAL



(a) Test Plate Showing Location of Test Specimens



(b) Orientation of Impact Test Specimen

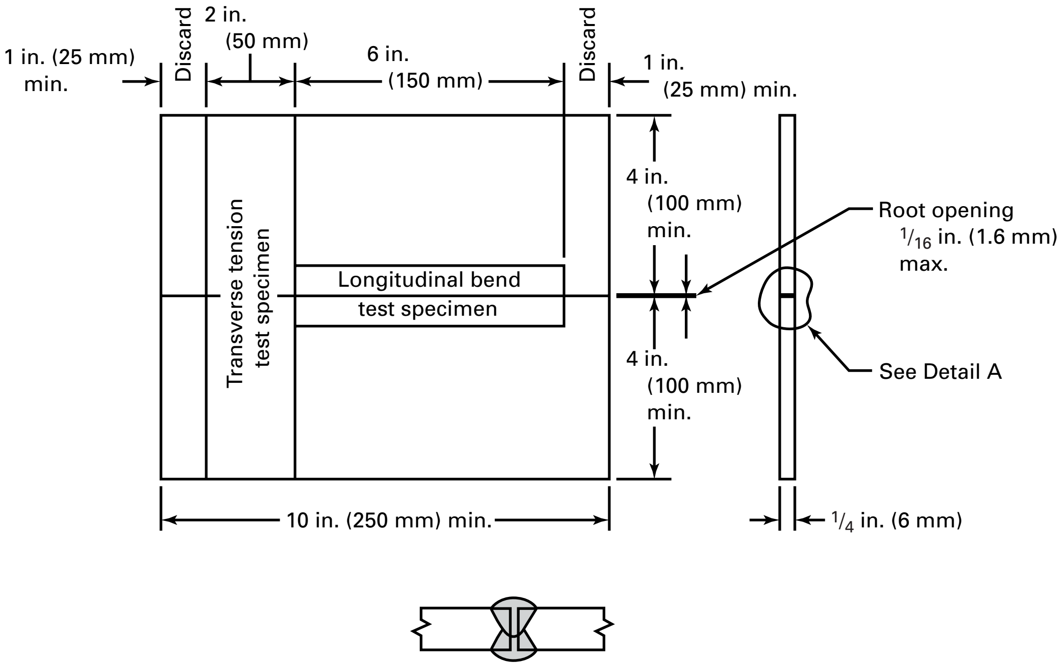
(c) Location of All-Weld-Metal Tension Test Specimen

L Test Plate Length (min.)	W Test Plate Width (min.)	T Test Plate Thickness	D Discard (min.)	I Bevel Angle	g Root Opening	w Backup Width (min.)	t Backup Thickness (min.)
10 in. [250 mm]	6 in. [150 mm]	$\frac{3}{4} \pm \frac{1}{32}$ in. [20 ± 1mm]	1 in. [25 mm]	22.5° ± 2°	$\frac{1}{2}$ − 0 in. + $\frac{1}{16}$ in. [12 − 0 mm + 1 mm]	Approx. 2 × g	$\frac{1}{4}$ in. [6 mm]

NOTE:

1. Test plate thickness shall be $\frac{1}{2}$ in. [12 mm] and the maximum root opening shall be $\frac{1}{4}$ in. −0 in. +$\frac{1}{16}$ in. [6 mm −0 mm, +1 mm] for 0.045 in. [1.2 mm] and smaller diameters of the EXXT-11 electrode classifications.

FIG. 4 TEST ASSEMBLY FOR TRANSVERSE TENSION AND LONGITUDINAL GUIDED BEND TESTS FOR WELDS MADE WITH SINGLE-PASS ELECTRODES

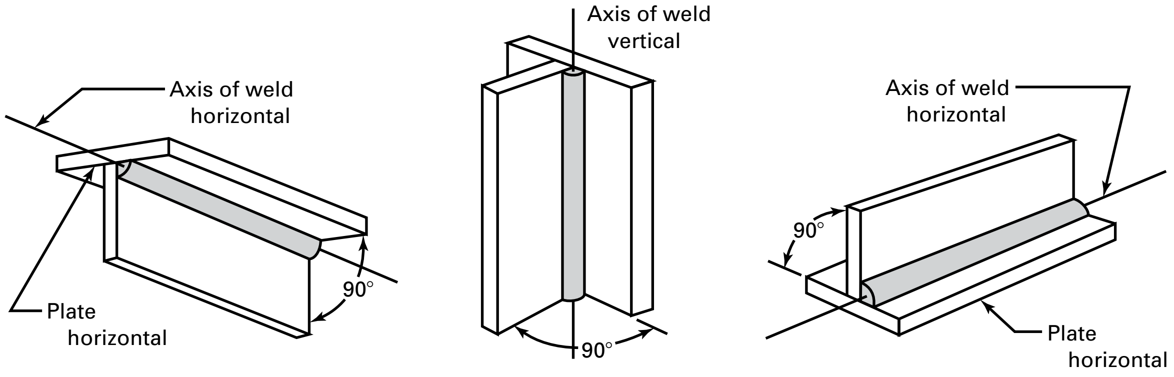


Detail A

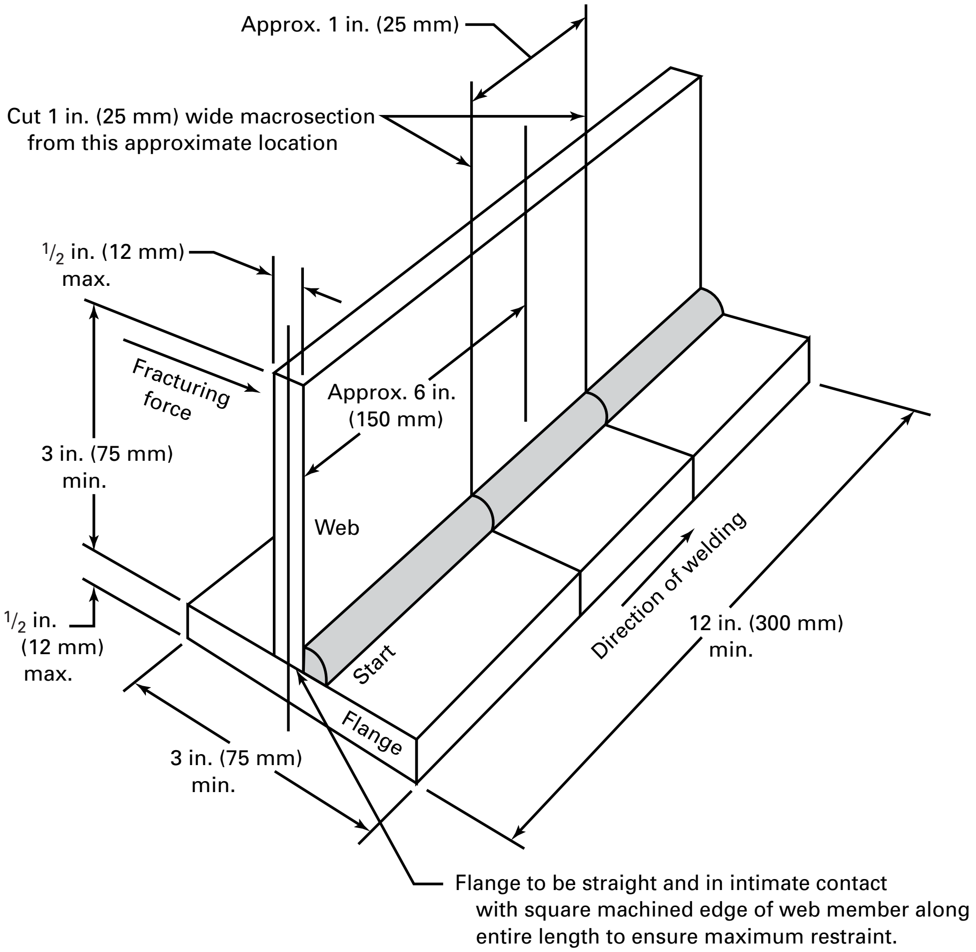
NOTES:

1. Detail A shows the completed joint and approximate weld configuration.
2. Plate thickness may be reduced to $^3/_{16}$ in. [5 mm] for electrode of 0.068 in. [1.7 mm] diameter or smaller.

FIG. 5 FILLET WELD TEST ASSEMBLY



(a) Overhead Fillet Welds **(b) Vertical Fillet Welds** **(c) Horizontal Fillet Welds**



NOTES:

1. If the web and flange thicknesses are less than or equal to $^1/_4$ in. [6 mm], the web and flange widths shall be 2 in. [50 mm] minimum.
2. The test plate thickness shall be $^3/_{16}$ in. [5 mm] for the EXXT-3 electrode classifications.

TABLE 4
BASE METAL FOR TEST ASSEMBLIES

AWS Classification(s)	ASTM Specification	UNS Number[a]
EXXT-1C, -1M	A36/A36M,	K02600
EXXT-4	A285/A285M Grade C,	K02801
EXXT-5C, -5M	A515/A515M Grade 70,	K03101
EXXT-6	A516/A516M Grade 70,	K02700
EXXT-7	A830/A830M Grade 1015,	G10150
EXXT-8	A830/A830M Grade 1018, or	G10180
EXXT-9C, -9M	A830/A830M Grade 1020	G10200
EXXT-11		
EXXT-12C, -12M		
EXXT-G		
EXXT-2C, -2M,	A515/A515M Grade 70 or	K03101
EXXT-3,	A516/A516M Grade 70	K02700
EXXT-10,		
EXXT-13,		
EXXT-14,		
EXXT-GS		

NOTES:

a. According to ASTM DS-56 (or SAE HS-1086).

b. For the fillet weld test, any of the base metals listed in this table may be used for any classification.

[12 mm] minimum thickness). The welding procedure used for the weld pad shall satisfy the heat input requirements specified in Table 5. The preheat temperature shall not be less than 60°F [15°C] and the inter-pass temperature shall not exceed 325°F [165°C]. The slag shall be removed after each pass. The pad may be quenched in water between passes. The dimensions of the completed pad shall be as shown in Fig. 2. Testing of this assembly shall be as specified in Section 10.

9.4 Weld Test Assemblies

9.4.1 Test Assembly for Multipass Electrodes. For multipass electrodes (EXXT-1X, EXXT-4, EXXT-5X, EXXT-6, EXXT-7, EXXT-8, EXXT-9X, EXXT-11, EXXT-12X, and EXXT-G) one or two groove weld test assemblies shall be prepared and welded as specified in Fig. 3, 9.4.1.1, and Table 5, using the base metal of the appropriate type specified in Table 4. The electrode diameter for one test assembly shall be $^{3}/_{32}$ in. [2.4 mm] or the largest diameter manufactured. The electrode diameter for the other test assembly shall be 0.045 in. [0.2 mm] or the smallest size manufactured. If the maximum diameter manufactured is $^{1}/_{16}$ in. [1.6 mm] or less only the largest diameter need be tested. The electrode polarity shall be as specified in Table 2.Testing of the assemblies shall be in the as-welded condition and as specified in Table 3.

9.4.1.1 Welding shall be in the flat position and the assembly shall be restrained (or preset as shown in Fig. 3) during welding to prevent warpage in excess of 5 deg. An assembly that is warped more than 5 deg from plane shall be discarded. It shall not be straightened.

Welding shall begin at 60°F [15°C] minimum. Welding shall continue until the assembly has reached a temperature of 300°F ± 25°F [150°C ± 15°C], measured by temperature indicating crayons or surface thermometers at the location shown in Fig. 3. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air. The assembly shall be heated to a temperature of 300°F ± 25°F [150°C ± 15°C] before welding is resumed.

9.4.2 Test Assembly for Single Pass Electrodes. For single pass electrodes a butt joint test assembly using base metal as specified in Table 4 shall be prepared and welded as specified in Fig. 4 and 9.4.2.1. After tack welding the plates at each end, the test assembly shall be welded in the flat position with one bead on each side.

9.4.2.1 Welding shall begin with the assembly at 60°F [15°C] minimum. When the weld bead has been completed on the face side, the assembly shall be turned over and the bead deposited on the root side, as shown in Fig. 4. This sequence shall not be interrupted. The electrode size shall be either $^{3}/_{32}$ in. [2.4 mm] diameter or the size the manufacturer produces that is closest to the $^{3}/_{32}$ in. [2.4 mm] diameter. The welding polarity shall be as shown in Table 2 for the classification being tested. After welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Sections 12 and 13, in the as-welded condition (except for the aging of the bend test specimen specified in 13.2).

9.4.3 Fillet Weld Test Assembly. Test assemblies shall be prepared and welded as specified in Table 3 and

TABLE 5
HEAT INPUT REQUIREMENTS AND SUGGESTED PASS AND LAYER SEQUENCE FOR MULTIPLE PASS ELECTRODE CLASSIFICATIONS

Diameter		Required Average Heat Input [a, b, c, d]		Suggested Passes per Layer		Suggested Number of Layers
in.	mm	kJ/in	kJ/mm	Layer 1	Layer 2 to Top	
≤ 0.030 0.035	≤ 0.8 0.9	20-35	0.8-1.4	1 or 2	2 or 3	6 to 9
. . . 0.045 . . .	1.0 . . . 1.2	25-50	1.0-2.0	1 or 2	2 or 3	6 to 9
0.052 . . . 1⁄16	. . . 1.4 1.6	25-55	1.0-2.2	1 or 2	2 or 3	5 to 8
0.068 . . . 0.072 5⁄64 (0.078)	. . . 1.8 . . . 2.0	35-65	1.4-2.6	1 or 2	2 or 3	5 to 8
3⁄32 (0.094)	2.4	40-65	1.6-2.6	1 or 2	2 or 3	4 to 8
7⁄64 (0.109)	2.8	50-70	2.0-2.8	1 or 2	2 or 3	4 to 7
0.120 1⁄8 (0.125)	. . . 3.2	55-75	2.2-3.0	1 or 2	2	4 to 7
5⁄32 (0.156)	4.0	65-85	2.6-3.3	1	2	4 to 7

NOTES:

a. The calculation to be used for heat input is:

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

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

b. Does not apply to the first layer. The first layer shall have a maximum of two passes.

c. The average heat input is the calculated average for all passes excluding the first layer.

d. A non-pulsed, constant voltage (CV) power source shall be used.

shown in Fig. 5, using any of the base metals listed in Table 4. When specified for an EX0T-XX classification, the test assembly shall be welded in the horizontal position. When specified for an EX1T-XX classification, two test assemblies are required, one welded in the vertical position and one welded in the overhead position. The progression for vertical welding shall be either upward or downward depending on the classification (see Table 2).

Before assembly, the standing member (web) shall have one edge prepared throughout its length and the base member (flange) side shall be straight, smooth and clean. The test plates shall be assembled as shown in Fig. 5. When assembled, the faying surfaces shall be in intimate contact along the entire length of the joint. The test assembly shall be secured with tack welds deposited at each end of the weld joint.

The welding procedure and the size of the electrode to be tested shall be as selected by the manufacturer. The fillet weld shall be a single pass weld deposited in either the semiautomatic or mechanized mode as selected by the manufacturer. The fillet weld size shall not be greater than 3⁄8 in. [10 mm]. The fillet weld shall be deposited only on one side of the joint as shown in Fig. 5. Weld cleaning shall be limited to chipping, brushing, and needle scaling. Grinding, filing, or other metal cutting of the fillet weld face is prohibited. The testing of the assembly shall be as specified in Section 15.

10. Chemical Analysis

10.1 When specified in Table 3, the sample for analysis shall be taken from weld metal produced with the flux cored electrode and the shielding gas, if any, with which it is classified. The sample shall be taken from a weld pad, or the reduced section of the fractured tension test specimen, or from a corresponding location or any location above it in the groove weld in Fig. 3. In case of dispute, the weld pad shall be the referee method.

10.2 The top surface of the pad described in 9.3 and shown in Fig. 2 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. The sample shall be taken at least $^3\!/_8$ in. [10 mm] from the nearest surface of the base metal. The sample from the reduced section of the fractured tension test specimen or from a corresponding location in the groove weld in Fig. 3 be prepared for analysis by any suitable mechanical means.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 350.

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

11. Radiographic Test

11.1 The welded test assembly described in 9.4.1 and shown in Fig. 3 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding $^3\!/_{32}$ in. [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of $^1\!/_{16}$ in. [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than $^1\!/_{16}$ in. [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

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

11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows:

(a) no cracks, no incomplete fusion, and no incomplete penetration,

(b) no slag inclusions longer than $^1\!/_4$ in. [6 mm] or one-third 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 6 times the length of the longest inclusion in the group, and

(c) no rounded indications in excess of those permitted by the radiographic standards in Fig. 8.

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 indication may be of porosity or slag. Test assemblies with indications larger than the large indications permitted in the radiographic standard (Fig. 8) do not meet the requirements of this specification.

12. Tension Test

12.1 For multiple pass electrode classifications one all-weld-metal tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly described in 9.4.1 and shown in Fig. 3. The tension test specimen shall have a nominal diameter of 0.500 in. [12.5 mm] (or 0.250 in. [6.5 mm] for some electrodes as indicated in Tables 1U and 1M) and a nominal gage length to diameter ratio of 4:1.

12.1.1 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 A8.3 for a discussion of the purpose of aging.

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

12.1.3 The results of the all-weld-metal tension test shall meet the requirements specified in Table 1U or Table 1M, as applicable.

12.2 For single pass electrode classifications, one transverse tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly described in 9.4.2 and shown in Fig. 4. The transverse rectangular tension specimen shall be a full thickness specimen machined transverse to the weld with a nominal reduced section width of 1.50 in. [38 mm].

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

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

TABLE 6
WELD METAL CHEMICAL COMPOSITION REQUIREMENTS FOR CLASSIFICATION TO SFA-5.20/SFA-5.20M

AWS A5.20 Classification	AWS A5.20M Classification	UNS Number[a]	Weight Percent[b,c]										
			C	Mn	Si	S	P	Cr[d]	Ni[d]	Mo[d]	V[d]	Al[d,e]	Cu[d]
E7XT-1C, -1M	E49XT-1C, -1M	W07601	0.12	1.75	0.90	0.03	0.03	0.20	0.50	0.30	0.08	—	0.35
E7XT-5C, -5M	E49XT-5C, -5M	W07605											
E7XT-9C, -9M	E49XT-9C, -9M	W07609											
E7XT-4	E49XT-4	W07604	0.30	1.75	0.60	0.03	0.03	0.20	0.50	0.30	0.08	1.8	0.35
E7XT-6	E49XT-6	W07606											
E7XT-7	E49XT-7	W07607											
E7XT-8	E49XT-8	W07608											
E7XT-11	E49XT-11	W07611											
EXXT-G	—	—	(f)	1.75	0.90	0.03	0.03	0.20	0.50	0.30	0.08	1.8	0.35
E7XT-12C, -12M	E49XT-12C, -12M	W07612	0.12	1.60	0.90	0.03	0.03	0.20	0.50	0.30	0.08	—	0.35
E6XT-13	E43XT-13	W06613	Not Specified[h]										
E7XT-2C, -2M	E49XT-2C, -2M	W07602											
E7XT-3	E49XT-3	W07603											
E7XT-10	E49XT-10	W07610											
E7XT-13	E49XT-13	W07613											
E7XT-14	E49XT-14	W07614											
EXXT-GS	—												

NOTES:

a. According to ASTM DS-56 (or SAE HS-1086).

b. The weld metal shall be analyzed for the specific elements for which values are shown in this table. The total of all elements listed in this table shall not exceed 5%.

c. Single values are maximums.

d. The analysis of these elements shall be reported only if intentionally added.

e. Applicable to self-shielded electrodes only. Electrodes intended for use with gas shielding normally do not have significant additions of aluminum.

f. The limit for gas shielded electrodes is 0.18% maximum. The limit for self-shielded electrodes is 0.30% maximum.

g. The composition of weld metal is not meaningful since electrodes of these classifications are intended only for single pass welds. Dilution from the base metal in such welds usually is quite high (see A6 in the Annex).

13. Bend Test

13.1 One longitudinal face bend test specimen, as required in Table 3, shall be machined from the welded test assembly described in 9.4.2 and shown in Fig. 4. The dimensions of the specimen shall be as shown in Fig. 4. Other dimensions of the bend specimen shall be as specified in the Bend Test section of AWS B4.0 or B4.0M.

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 A8.3 for a discussion on the purpose of aging.

13.3 The specimen shall be tested in the manner described in the Bend Test section of AWS B4.0 or B4.0M by bending it uniformly through 180 deg over a $\frac{3}{4}$ in. [19 mm] radius using any suitable jig as specified in the Bend Test section of B4.0 or B4.0M. Positioning of the longitudinal face bend specimen shall be such that the weld face of the last side welded is in tension.

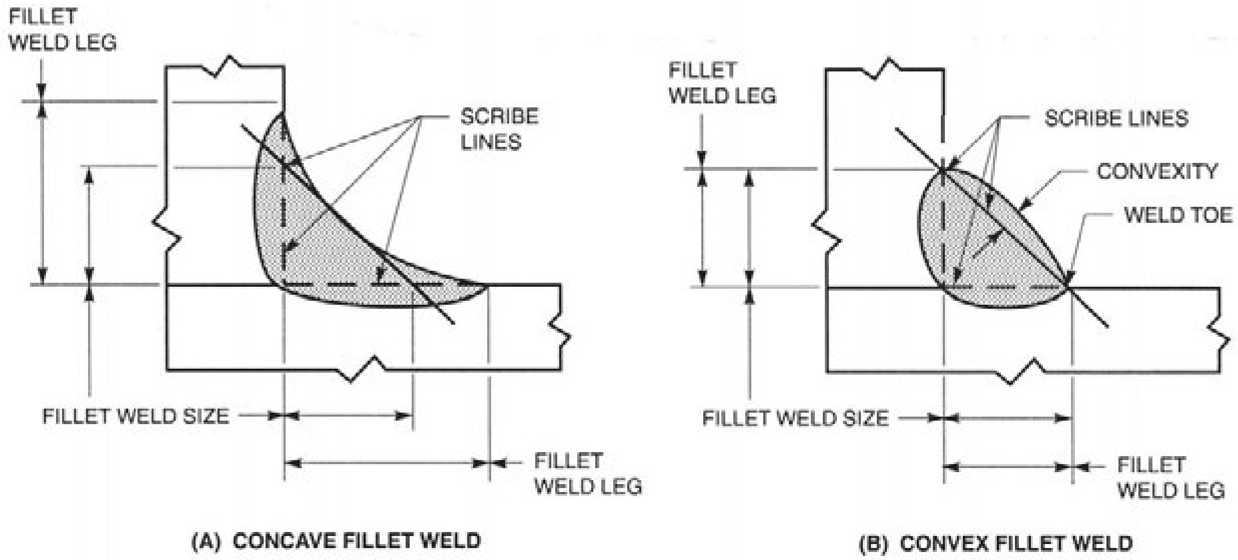
13.4 The specimen, after bending, shall conform to the $\frac{3}{4}$ in. [19 mm] radius, with an appropriate allowance for spring back, and the weld metal shall not show any crack or other open defect exceeding $\frac{1}{8}$ in. [3.2 mm] in any direction when examined with the unaided eye. Cracks in the base metal shall be disregarded, as long as they do not enter the weld metal. When base metal openings or cracks enter the weld metal, the test shall be considered invalid. Specimens in which this occurs shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of specimens required in Section 8 does not apply.

14. Impact Test

14.1 Five full-size Charpy V-Notch impact specimens, as specified in the Fracture Toughness Test section of AWS B4.0 or B4.0M shall be machined from the welded test assembly shown in Fig. 3 for those classifications for which impact testing is required in Table 1U [Table 1M] and Table 3 or when the optional supplemental designator "J", "D," or "Q" is utilized.

The Charpy V-Notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in. [0.05 mm]. The other two surfaces of the

FIG. 6 DIMENSIONS OF FILLET WELDS



NOTES:
1. Fillet weld size is the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section.
2. Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes.
3. Fillet weld leg is the distance from the joint root to the toe of the fillet weld.

specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50X magnification on either a shadowgraph or metallograph. 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 AWS B4.0 or B4.0M. The test temperature shall be that specified in Table 1U [Table 1M], 7.2.2, or Table 10, as applicable, for the classification or optional supplemental designator under test.

14.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft•lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft•lbf [20 J] and the average of the three shall be not less than the required 20 ft•lbf [27 J] energy level. For the "D" and "Q" optional supplemental designators the requirements shown in Table 10 shall apply.

15. Fillet Weld Test

15.1 The fillet weld test, when required in Table 3, shall be made in accordance with 9.4.3 and Fig. 5. The entire face of the completed fillet shall be examined visually. 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, a specimen containing approximately 1 in. [25 mm] of the weld (in the lengthwise direction) shall be prepared as shown in Fig. 5. One cross-sectional surface of the specimen shall be polished and etched, and then examined as required in 15.2.

15.2 Scribe lines shall be placed on the prepared surface, as shown in Fig. 6, and the leg lengths and convexity of the fillet shall be determined to the nearest $^1/_{64}$ in. [0.5 mm] by actual measurement. These dimensions shall meet the requirements specified in Table 7 for convexity, fillet size and permissible difference in the length of the legs.

15.3 The remaining two sections of the test assembly shall be broken longitudinally through the fillet weld by a force exerted as shown in Fig. 5. When necessary, to facilitate fracture through the fillet, one or more of the following procedures may be used:

(a) A reinforcing bead, as shown in Fig. 7(A), may be added to each leg of the fillet.

(b) The position of the web on the flange may be changed, as shown in Fig. 7(B).

(c) The face of the fillet may be notched, as shown in Fig. 7(C).

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

TABLE 7
DIMENSIONAL REQUIREMENTS FOR FILLET WELD USABILITY TEST SPECIMENS

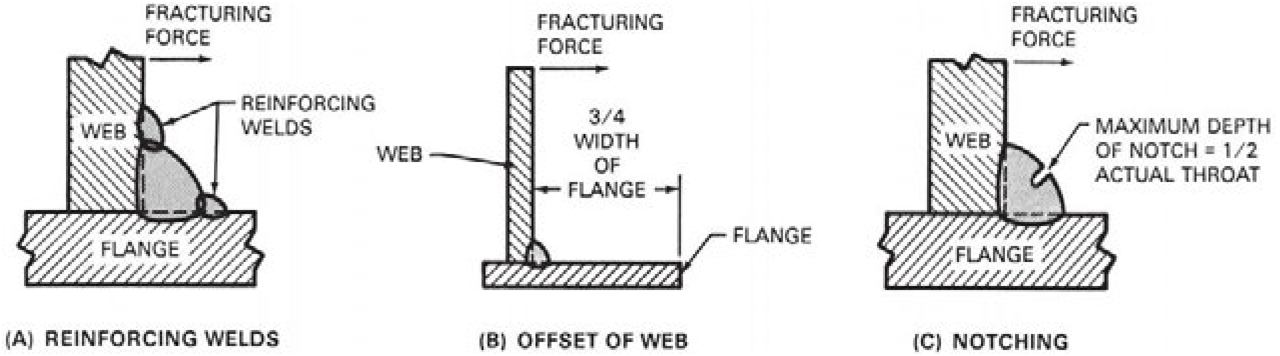
Measured Fillet Weld Size[a]		Maximum Convexity[a,b]		Maximum Difference Between Fillet Weld Legs[a]	
in.	mm	in.	mm	in.	mm
1/8	3.0	5/64	2.0	1/32	1.0
9/64	3.5	5/64	2.0	3/64	1.0
5/32	4.0	5/64	2.0	3/64	1.0
11/64	4.5	5/64	2.0	1/16	1.5
3/16	. . .	5/64	. . .	1/16	. . .
13/64	5.0	5/64	2.0	5/64	2.0
7/32	5.5	5/64	2.0	5/64	2.0
15/64	6.0	5/64	2.0	3/32	2.5
1/4	6.5	5/64	2.0	3/32	2.5
17/64	. . .	3/32	. . .	7/64	. . .
9/32	7.0	3/32	2.5	7/64	3.0
19/64	7.5	3/32	2.5	1/8	3.0
5/16	8.0	3/32	2.5	1/8	3.0
21/64	8.5	3/32	2.5	9/64	3.5
11/32	9.0	3/32	2.5	9/64	4.0
23/64	. . .	3/32	. . .	5/32	. . .
3/8	9.5	3/32	2.5	5/32	4.0

NOTES:

a. All measurements shall be rounded to the nearest 1/64 in. (0.5 mm).

b. Maximum convexity for EXXT-5C, -5M electrodes may be 1/32 in. (0.8 mm) larger than the listed requirements.

FIG. 7 ALTERNATE METHODS FOR FACILITATING FILLET WELD FRACTURE



(A) REINFORCING WELDS (B) OFFSET OF WEB (C) NOTCHING

completed. In this case, the doubling of the specimens required in Section 8, Retest, does not apply.

15.4 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 percent of the total length of the weld. Slag beyond the vertex of the isosceles triangle with the hypotenuse as the face, as shown in Fig. 6, shall not be considered incomplete fusion.

16. Diffusible Hydrogen Test

16.1 Either the $^3/_{32}$ in. [2.4 mm] or the largest diameter and either the 0.045 in. [1.2 mm] or the smallest diameter of an electrode to be identified by an optional, supplemental, diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. If the maximum diameter manufactured is $^1/_{16}$ in. [1.6 mm] or less, only the largest diameter need be tested. A mechanized welding system shall be used for the diffusible hydrogen test. Based upon the average value of test results which satisfy the requirements of Table 8, the appropriate diffusible hydrogen designator may be added at the end of the classification.

16.2 Testing shall be done with electrode from a previously unopened container. Conditioning of the electrode prior to testing is not permitted. Conditioning can be construed to be any special preparation or procedure, such as baking the electrode, which the user would not usually practice. The shielding gas, if any, used for classification

TABLE 8
OPTIONAL HYDROGEN LIMITS FOR WELD METAL[a]

Optional Supplemental Diffusible Hydrogen Designator[b,c,d]	Average Diffusible Hydrogen, Max.[e,f] mL/100 g Deposited Metal
H16	16.0
H8	8.0
H4	4.0

NOTES:

a. Limits on diffusible hydrogen when tested in accordance with AWS A4.3 as specified in Section 16.

b. See Fig. 1.

c. The lower diffusible hydrogen levels (H8 and H4) may not be available in some classifications (see A8.2.7)

d. Electrodes which satisfy the diffusible hydrogen limits for the H4 designator also satisfy the limits for the H8 and H16 designators. Electrodes which satisfy the diffusible hydrogen limits for the H8 category also satisfy the limits for the H16 designator.

e. These hydrogen limits are based on welding in air containing a maximum of 10 grains of water per pound (1.43 g/kg) of dry air. Testing at any higher atmospheric moisture level is acceptable, provided these limits are satisfied (see 16.4 and 16.5).

f. The maximum average diffusible hydrogen requirement for electrodes identified with the "Q" optional, supplemental designator shall be either 5.0 mL/100 g deposited metal or 8.0 mL/100 g deposited metal when testing according to the provisions of this specification (see 16.3).

purposes shall also be used for the diffusible hydrogen test. Welds for hydrogen determination shall be made at a wire feed rate (or welding current) which is based upon the manufacturer's recommended operating range for the electrode size and type being tested. When using wire feed rate, the minimum wire feed rate to be used for the diffusible hydrogen test is given by the equation shown below. When using welding current, the equation shown is modified by substituting "welding current" wherever "WFR" appears. The voltage shall be as recommended by the manufacturer for the wire feed rate (or welding current) used for the test. The contact tip-to-work distance (CTWD) shall be at the minimum recommended by the manufacturer for the wire feed rate (or welding current) used for the test (see 16.3 for "Q" designator requirements). The travel speed used shall be as required to establish a weld bead width that is appropriate for the specimen. See A8.2.7.

$$\mathrm{WFR_{min}} = \mathrm{WFR_{mfg.min}} + 0.75\ (\mathrm{WFR_{mfg.max}} - \mathrm{WFR_{mfg.min}})$$

where:

$\mathrm{WFR_{mfg.max}}$ = the minimum wire feed rate to be used for the diffusible hydrogen test

$\mathrm{WFR_{mfg.min}}$ = the minimum wire feed rate recommended by the manufacturer

$\mathrm{WFR_{mfg.max}}$ = the maximum wire feed rate recommended by the manufacturer

16.3 For the hydrogen testing of electrodes to be identified with the "Q" optional, supplemental designator the CTWD shall be $\frac{5}{8}$ in. [16 mm] maximum for electrode diameters smaller than $\frac{1}{16}$ in. [1.6 mm], $\frac{3}{4}$ in. [20 mm] maximum for $\frac{1}{16}$ in. [1.6 mm] diameter, and 1 in. [25 mm] maximum for electrode diameters larger than $\frac{1}{16}$ in. [1.6 mm]. Electrodes identified with the "Q" optional supplemental designator shall have a maximum average diffusible hydrogen of either 5.0 mL/100 g deposited metal or 8.0 mL/100 g deposited metal when tested according to the provisions of this specification. No optional, supplemental hydrogen designator is used for "Q" designated electrodes satisfying a maximum average diffusible hydrogen limit of 5.0 mL/100g deposited metal. "Q" designated electrodes which have average diffusible hydrogen levels over 5.0 mL/100 g deposited metal but which satisfy a maximum average diffusible hydrogen limit of 8.0 mL/100 g deposited metal shall be identified with the "H8" optional, supplemental hydrogen designator (see Fig. 1). Electrodes which satisfy a maximum average diffusible hydrogen requirement of 5.0 mL/100 g deposited metal also satisfy the requirement for the "H8" designator.

16.4 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 A8.2.5). The actual atmospheric conditions shall be reported along with the average value for the tests according to AWS A4.3.

16.5 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. If the actual test results for an electrode meet the requirements for the lower, or lowest hydrogen designator, as specified in Table 8, the electrode also meets the requirements for all higher designators in Table 8 without need to retest.

17. "D" and "Q" Optional Supplemental Designator Tests

17.1 Each diameter of an electrode to be identified with either the "D" or "Q" optional supplemental designator (see Fig. 1) shall be tested using both (1) a low heat input, fast cooling rate procedure and (2) a high heat input, slow cooling rate procedure as outlined in 17.2, 17.3, 17.4, 17.5, and Table 9.

17.1.1 The test assembly using base metal as specified in Table 4 shall be prepared as shown in Fig. 3. The assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5 deg. An assembly that is

TABLE 9
PROCEDURE REQUIREMENTS FOR "D" AND "Q" OPTIONAL SUPPLEMENTAL DESIGNATORS

Optional Supplemental Designator	Procedure Heat Input (Fast or Slow Cooling Rate)	Preheat Temperature °F[°C]	Interpass Temperature °F[°C]	Heat Input Requirement for Any Single Pass[a]	Required Average Heat Input for All Passes[a]
D	low (fast cooling rate)	70° ± 25°F [20° ± 15°C]	200° ± 25°F [90° ± 15°C]	For electrode diameters < $^{3}/_{32}$ in. [2.4 mm]	
				33 kJ/in. [1.3 kJ/mm] maximum	30 + 2, −5 kJ/in. [1.2 + 0.1, −0.2 kJ/mm]
				For electrode diameters ≥ $^{3}/_{32}$ in. [2.4 mm]	
				44 kJ/in. [1.7 kJ/mm] maximum	40 +2, −5 kJ/in. [1.6 +0.1, −0.2 kJ/mm]
	high (slow cooling rate)	300° ± 25°F [150° ± 15°C]	500° ± 50°F [260° ± 25°C]	75 kJ/in. [3.0 kJ/mm] minimum	80 +5, −2 kJ/in. [3.1 +0.2, −0.1 kJ/mm]
Q	low (fast cooling rate)	70° ± 25°F [20° ± 15°C]	150°F max. [65°C max.]	33 kJ/in. [1.3 kJ/mm] minimum	30 +2, −5 kJ/in. [1.2 +0.1, −0.2 kJ/mm]
	high (slow cooling rate)	300° ± 25°F [150° ± 15°C]	300° ± 25°F [150° ± 15°C]	60 kJ/in. [2.4 kJ/mm] minimum	70 +5, −2 kJ/in. [2.8 +0.2, −0.1 kJ/mm]

NOTE:

a. Does not apply to fisrst layer. The first layer may have one or two passes.

warped more than 5 deg from plane shall be discarded. It shall not be straightened.

17.1.2 The low heat input, fast cooling rate groove weld for both the "D" and "Q" designators shall be welded in the 1G position.

17.1.3 The high heat input, slow cooling rate groove weld for both the "D" and "Q" designators shall be welded in the 1G position for electrodes classified for flat and horizontal welding (position designator "0").

For electrodes classified for all-position welding (position designator "1") the high heat input, slow cooling rate groove weld shall be made in the 3G position with upward progression.

17.2 When testing for the "D" designator, the welding of the low heat input, fast cooling rate groove weld shall begin with the test assembly at 70°F ± 25°F [20°C ± 15°C]. Welding shall continue until the assembly has reached the interpass temperature of 200°F ± 25°F [90°C ± 15°C]. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt the welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature within the interpass temperature range before welding is resumed.

For electrode diameters less than $^{3}/_{32}$ in. [2.4 mm] the average heat input for all passes, exclusive of the first layer, shall be 30 +2, -5 kJ/in. [1.2 + 0.1, -0.2 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 33 kJ/in. [1.3 kJ/mm] heat input. See Table 9.

For electrode diameters $^{3}/_{32}$ in. [2.4 mm] or larger the average heat input for all passes, exclusive of the first layer, shall be 40 +2, -5 kJ/in. [1.6 +0.1, -0.2 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 44 kJ/in. [1.7 kJ/mm] heat input. See Table 9.

17.3 When testing for the "D" designator, the welding of the high heat input, slow cooling rate groove weld shall begin with the test assembly preheated to 300°F ± 25°F [150°C ± 15°C] prior to welding. Welding shall continue until the test assembly has reached the interpass temperature of 500°F ± 50°F [260°C ± 25°C]. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature within the interpass temperature range before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 80 +5, -2 kJ/in. [3.1 +0.2, -0.1 kJ/ mm]. No individual pass, exclusive of the first layer, shall be made at less than 75 kJ/in. [3.0 kJ/mm] heat input. See Table 9.

17.4 When testing for the "Q" designator, the welding of the low heat input, fast cooling rate groove weld shall begin with the test assembly at 70°F ± 25°F [20°C ± 15°C]. Welding shall continue until the test assembly has reached the maximum interpass temperature of 150°F [65°C]. This maximum interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air

TABLE 10
MECHANICAL PROPERTY REQUIREMENTS FOR "D" AND "Q" OPTIONAL SUPPLEMENTAL DESIGNATORS

Optional Supplemental Designator	Tensile Test Requirements	Minimum Charpy V-Notch Requirements
D	58 ksi [400 MPa] min. yield strength 70 ksi [490 MPa] min. tensile strength 22% min. % elongation in 2 in. [50 mm]	40 ft•lbf at +70°F [54J at +20°C] (see Notes a, b)
Q	58 to 80 ksi [400–550 MPa] yield strength for high heat input, slow cooling rate test 90 ksi [620 MPa] max. yield strength for low heat input, fast cooling rate test 22% min. % elongation in 2 in. [50 mm] (see Note c)	20 ft•lbf at −20°F [27J at −30°C] (see Note d)

NOTES:

a. Five specimens are to be tested. The lowest and highest values obtained from each of five specimens from a single test plate shall be disregarded. Two of the remaining three values shall equal, or exceed, the specified toughness of 40 ft•lbf [54 J] energy level at the testing temperature. One of the three may be lower, but not lower than 30 ft•lbf [41 J], and the average of the three shall not be less than the required 40 ft•lbf [54 J] energy level.

b. The electrode shall also meet a minimum toughness requirement of 20 ft•lbf at 0°F [27 J at −18°C] when tested according to the standard A5.20 [A5.20M] classification test requirements.

c. Tensile specimens shall not be aged when testing for the "Q" designator.

d. Five specimens shall be tested. One of the five specimens may be lower than the specified 20 ft•lbf [27 J] energy level, but not lower than 15 ft•lbf [20 J], and the average of the five shall not be less than the required minimum 20 ft•lbf [27 J] energy level.

at room temperature. The assembly shall be heated to the maximum interpass temperature before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 30 +2, -5 kJ/in. [1.2 +0.1, -0.2 kJ/ mm]. No individual pass, exclusive of the first layer, shall exceed 33 kJ/in. [1.3 kJ/mm] heat input. See Table 9.

17.5 When testing for the "Q" designator, the welding of the high heat input, slow cooling rate groove weld shall begin with the test assembly preheated to 300°F ± 25°F [150°C ± 15°C] prior to welding. An interpass temperature of 300°F ± 25°F [150°C ± 15°C] shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature within the interpass temperature range before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 70 +5, -2 kJ/in. [2.8 +0.2, -0.1 kJ/ mm]. No individual pass, exclusive of the first layer, shall be made at less than 60 kJ/in. [2.4 kJ/mm] heat input. See Table 9.

17.6 After welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as shown in Fig. 3 and as specified in Sections 11, 12, and 14. The tension and impact tests shall meet the requirements specified in Table 10 for the "D" or "Q" designator, as applicable.

17.7 When certifying an electrode for the "D" or "Q" optional supplemental designator the average heat input used, exclusive of the first layer, for both the low heat input, fast cooling rate and high heat input, slow cooling rate groove welds shall be clearly stated on the test report(s).

18. 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.

19. Standard Sizes

Standard sizes for filler metal in the different package forms such as coils with support, coils without support, drums, and spools are as shown in Table 11.

20. Finish and Uniformity

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

20.2 Each continuous length of electrode shall be from a single lot of material as defined in AWS A5.01, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic and semiautomatic equipment.

20.3 Core ingredients shall be distributed with sufficient uniformity throughout the length of the electrodes so

TABLE 11
STANDARD SIZES AND TOLERANCES OF ELECTRODES[a]

U.S. Customary Units		International System of Units (SI)[b]	
Diameter (in.)	Tolerance (in.)	Diameter (mm)	Tolerance (mm)
0.030	±0.002	0.8	+0.02/-0.05
0.035	±0.002	0.8	+0.02/-0.05
0.040	±0.002	1.0	+0.02/–0.05
0.045	±0.002	. . .	. . .
. . .	. . .	1.2	+0.02/-0.05
0.052	±0.002	. . .	. . .
. . .	. . .	1.4	+0.02/-0.05
1/16 (0.062)	±0.002	1.6	+0.02/-0.06
0.068	±0.003	. . .	. . .
. . .	. . .	1.8	+0.02/-0.06
0.072	±0.003	. . .	. . .
5/64 (0.078)	±0.003	2.0	+0.02/-0.06
3/32 (0.094)	±0.003	2.4	+0.02/-0.06
7/64 (0.109)	±0.003	2.8	+0.02/-0.06
0.120	±0.003	. . .	. . .
1/8 (0.125)	±0.003	3.2	+0.02/-0.07
5/32 (0.156)	±0.003	4.0	+0.02/-0.07

NOTES:

a. Electrodes produced in sizes other than those shown may be classified by using similar tolerances as shown.

b. The tolerances shown are as prescribed in ISO 544.

as not to adversely affect the performance of the electrode or the properties of the weld metal.

20.4 A suitable protective coating may be applied to any electrode in this specification.

21. Standard Package Forms

21.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 12 and Figs. 9 and 10. Package forms, sizes, and weights other than these shall be as agreed by purchaser and supplier.

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

21.3 Spools shall be designed and constructed to prevent distortion of the electrode during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

22. Winding Requirements

22.1 Electrodes on spools and in coils (including drums) shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the electrode free to unwind without restriction. The outside end of the electrode (the end with which welding is to begin) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

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

23. Filler Metal Identification

23.1 The product information and the precautionary information required in Section 25, Marking of Packages, for marking each package shall also appear on each coil, spool, and drum.

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

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

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

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

24. Packaging

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

TABLE 12
PACKAGING REQUIREMENTS[a]

Type of Package		Package Size[b] in.	Package Size[b] mm	Net Weight of Electrode[c] lb	Net Weight of Electrode[c] kg
Coils without Support		(See Note d)		(See Note d)	
Coils with Support (see below)	ID	6-3/4	170	14	6
	ID	12	300	25, 30, 50, and 60	10, 15, 25, and 30
Spools	OD	4	100	1-1/2 and 2-1/2	0.5 and 1.0
	OD	8	200	10, 15, and 22	4.5, 5.5, and 7
	OD	12	300	25, 30, 35, and 44	10, 15, and 20
	OD	14	350	50 and 60	20 and 25
	OD	22	560	250	100
	OD	24	610	300	150
	OD	30	760	600, 750, and 1000	250, 350, and 450
Drums	OD	15-1/2	400	(See Note c)	
	OD	20	500	(See Note c)	
	OD	23	600	300 and 600	140 and 270

Coils with Support — Standard Dimensions and Weights[a]

	Coil Net Weight[c]		Coil Dimensions			
			Inside Diameter of Liner		Width of Wound Electrode, max.	
Electrode Size	lb	kg	in.	mm	in.	mm
All	14	6	6-3/4 ± 1/8	170 ± 3	3	75
	25 and 30	10 and 15	12 ± 1/8	300 +3, -10	2-1/2 or 4-5/8	65 or 120
	50, 60, and 65	20, 25, and 30	12 ± 1/8	300 +3, -10	4-5/8	120

NOTES:

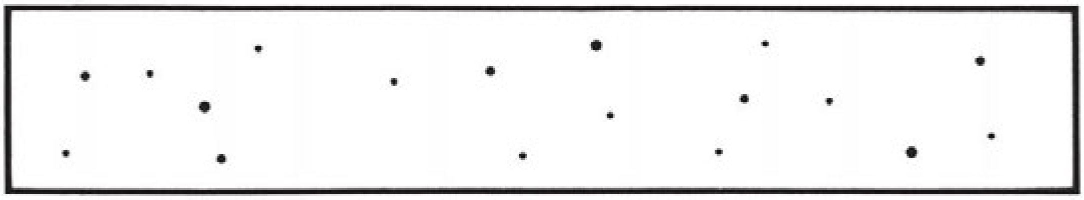
a. Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser.

b. ID = inside diameter, OD = outside diameter.

c. Tolerance on net weight shall be ±10 percent.

d. As agreed between supplier and purchaser.

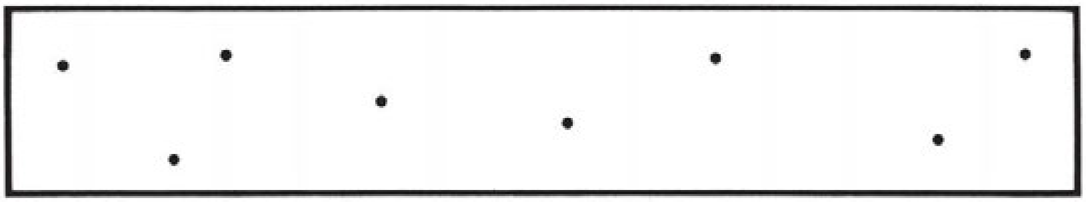
FIG. 8 RADIOGRAPHIC STANDARDS FOR TEST ASSEMBLY IN FIGURE 3



(A) ASSORTED ROUNDED INDICATIONS

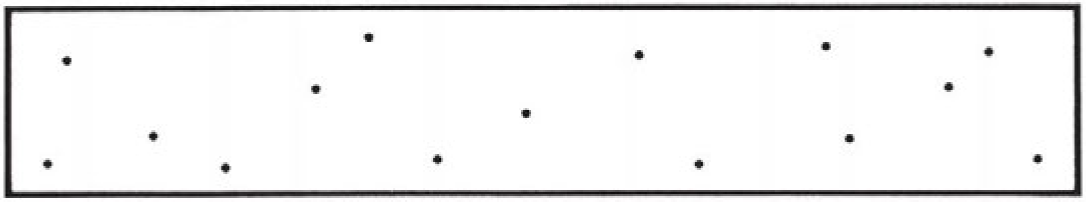
SIZE 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 10.



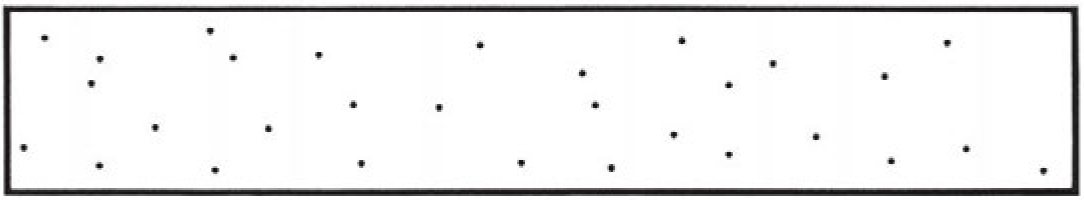
(B) LARGE ROUNDED INDICATIONS

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



(C) MEDIUM ROUNDED INDICATIONS

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



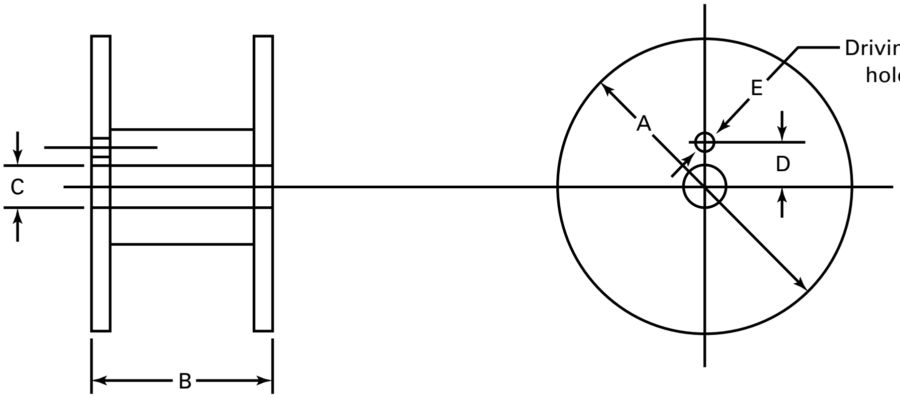
(D) SMALL ROUNDED INDICATIONS

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

GENERAL NOTES:

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

FIG. 9 STANDARD SPOOLS — DIMENSIONS OF 4, 8, 12, AND 14 IN. [100, 200, 300, AND 350 MM] SPOOLS



		Dimensions							
		4 in. [100 mm] Spools		8 in. [200 mm] Spools		12 in. [300 mm] Spools		14 in. [350 mm] Spools	
		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	1.75	46	2.16	56	4.0	103	4.0	103
	Tolerance	±0.03	+0, −2	±0.03	+0, −3	±0.06	+0, −3	±0.06	+0, −3
C	Diameter	0.63	16	2.03	50.5	2.03	50.5	2.03	50.5
	Tolerance	+0.01, −0	+1, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0
D	Distance between axes	—	—	1.75	44.5	1.75	44.5	1.75	44.5
	Tolerance			±0.02	±0.5	±0.02	±0.5	±0.02	±0.5
E	Diameter [Note (3)]	—	—	0.44	10	0.44	10	0.44	10
	Tolerance			+0, −0.06	+1, −0	+0, −0.06	+1, −0	+0, −0.06	+1, −0

NOTES:

(1) Outside diameter of barrel shall be such as to permit feeding of the filler metals.

(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 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.

25. Marking of Packages

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

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

(b) Supplier's name and trade designation

(c) Size and net weight

(d) Lot, control, or heat number

25.2 The appropriate precautionary information[8] given in ANSI Z49.1, latest edition (as a minimum) or its equivalent, shall be prominently displayed in legible print on all packages of flux cored electrodes, including individual unit packages enclosed within a larger package.

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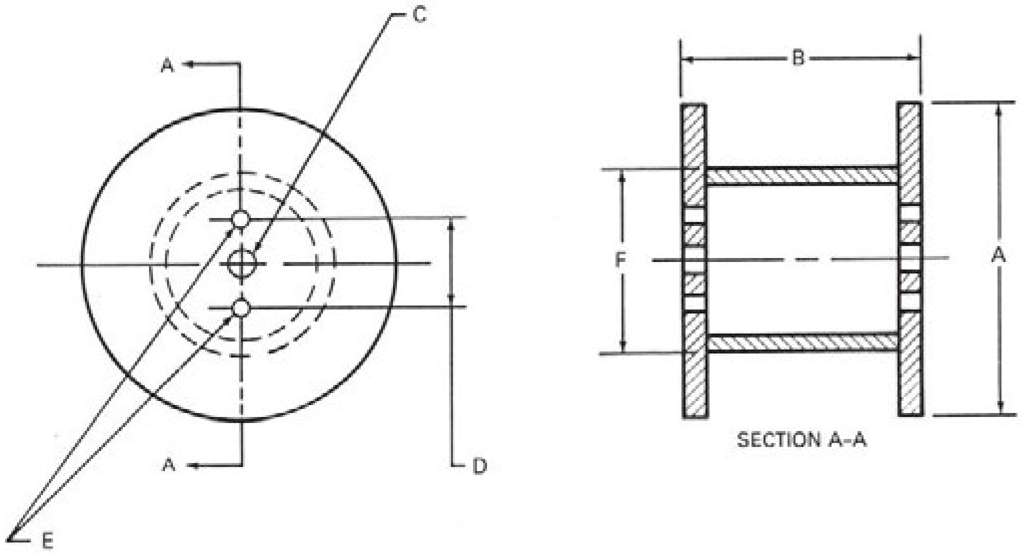
[8] Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

FIG. 10 STANDARD SPOOLS — DIMENSIONS OF 22, 24, AND 30 IN. [560, 610, AND 760 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	22	560	24	610	30	760
B	Width	12	305	13.5	345	13.5	345
C	Diameter	1.31	35.0	1.31	35.0	1.31	35.0
	Tolerance	+0.13, -0	±1.5	+0.13, -0	±1.5	+0.13, -0	±1.5
D	Distance, Center-to-Center	2.5	63.5	2.5	63.5	2.5	63.5
	Tolerance	±0.1	±1.5	±0.1	±1.5	±0.1	±1.5
E	Diameter [Note (3)]	0.69	16.7	0.69	16.7	0.69	16.7
	Tolerance	+0, -0.06	±0.7	+0, -0.06	±0.7	+0, -0.06	±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 the 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.

Annex A
Guide to AWS Specification for Carbon Steel Electrodes for Flux Cored Arc Welding

(This Annex is not part of AWS A5.20/A5.20M:2005, *Specification for Carbon Steel Electrodes for Flux Cored 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 the specification can be used effectively. This guide provides examples rather than complete listings of the materials and applications for which each filler metal is suitable.

A2. Classification System

A2.1 Classification of Electrodes. The system for identifying the electrode classifications in the A5.20 and A5.20M specifications follows, for the most part, the standard pattern used in other AWS filler metal specifications. An illustration of this system is given in Fig. 1.

AWS documents have traditionally used the letter "X" (or series of X's) as generic designators to represent each of the (non-fixed) designators used in the classification or for optional supplemental designators.

A2.2 Some of the classifications are intended to weld only in the flat and horizontal positions (EX0T-5C, -5M, for example). Others are intended for welding in all positions (EX1T-1C, -1M, for example). As in the case of covered electrodes, the smaller sizes of flux cored electrodes are the ones used for out-of-position work. Flux cored electrodes larger than $^5/_{64}$ in. [2.0 mm] in diameter are usually used for horizontal fillets and flat position welding.

A2.3 Optional Supplemental designators are also used in this specification in order to identify electrode classifications that have met certain supplemental requirements as agreed to between the supplier and the purchaser. The optional supplemental designators are not part of the electrode classification.

A2.3.1 This specification has included the use of optional designators for diffusible hydrogen (see Table 8 and A8.2) to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3. Electrodes that are designated as meeting the lower or lowest hydrogen limits as specified in Table 8 are understood to be able to meet any higher hydrogen limits when tested in accordance with Section 16. For example, see footnote "d" of Table 8.

A2.3.2 The A5.20/A5.20M specification has established multiple pass classification requirements using a test assembly as shown in Fig. 3 using downhand welding procedures with heat inputs as shown in Table 5. In addition, this specification has included the optional supplemental designators "J," "D," and "Q" to indicate conformance to optional, supplemental mechanical property requirements.

A2.3.2.1 In order to include product with improved toughness at lower temperature an optional supplemental designator, "J," has been added to identify electrodes which, when tested, produce weld metal which exhibits 20 ft•lbf at -40°F [27 J at -40°C]. The user is cautioned that although improved weld metal toughness will be evidenced when welding is performed under conditions specified in this specification, other applications of the electrode, such as long-term postweld heat treatment or vertical up welding with higher heat input, may produce results markedly different from the improved toughness levels given. The users should always perform their own mechanical properties verification testing.

A2.3.2.2 Two optional, supplemental designators have been added to identify electrodes which, when testing using both low heat input, fast cooling rate welding procedures and high heat input, slow cooling rate welding procedures, will conform to the classification radio-graphic requirements and to the tension test and Charpy V-Notch requirements specified in Table 10 (see Section 17). The first optional, supplemental designator, "D," is intended to demonstrate conformance to the FEMA guidelines for the welding of steel moment-frame connections for seismic applications as indicated in FEMA 353. The second of these optional, supplemental designators, "Q," is intended to demonstrate conformance to certain requirements for the welding of Navy ships.

A2.4 "G" Classification

A2.4.1 These specifications include electrodes classified as E6XT-G, E6XT-GS, E7XT-G, and E7XT-GS. The "G" or "GS" 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 (description of usability and/or operating polarity, for example) from all other classifications can still be classified according to this 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 electrodes-each bearing the same "G" classification-may be quite different in some certain respect (usability characteristics and polarity, again, for example).

A2.4.2 The point of difference (although not necessarily the amount of that difference) between an electrode of a "G" classification and an electrode of a similar classification without the "G" (or even with it, for that matter) will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

(a) "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.

(b) "Not Required" is used in those areas of the specification that refer to the tests that must be conducted in order to classify an electrode. 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 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 A5.01) in the purchase order.

A2.5 Request for Filler Metal Classification

A2.5.1 When an electrode cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that electrode. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that electrode as long as the electrode is of commercial significance.

A2.5.2 A request to establish a new electrode classification must be a written request and needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

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

(b) Any conditions for conducting the tests used to demonstrate that the product meets classification requirements.

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

(d) Proposed ASME "F" Number, if appropriate.

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.

A2.5.3 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 the Chair of the particular subcommittee involved.

(d) File the original request.

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

A2.5.4 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.

A2.5.5 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

TABLE A1
COMPARISON OF CLASSIFICATIONS [a,b]

ISO		AWS	
17632-A	17632-B	A5.20	A5.20M
T42 X R X	T49XT1-XXX	E7XT-1X	E49XT-1X
T4T Z R N	T49T2-XX	E7XT-2X	E49XT-2X
T4T Z V N	T49T3-XN	E7XT-3	E49XT-3
T42 Z W N	T49XT4-XNX	E7XT-4	E49XT-4
T42 X B X	T49XT5-XXX	E7XT-5X	E49XT-5X
T42 X Y N	T49XT6-XNX	E7XT-6	E49XT-6
T42 X W N	T49XT7-XNX	E7XT-7	E49XT-7
T42 X Y N	T49XT8-XNX	E7XT-8	E49XT-8
...	...	E7XT-9X	E49XT-9X
T4T Z V N	T49T10-XN	E7XT-10	E49XT-10
T42 X W N	T49XT11-XNX	E7XT-11	E49XT-11
T42 X R X	T49XT12-XXX	E7XT-12X	E49XT-12X
T4T Z V N	T49T13-XN	E7XT-13	E49XT-13
T4T Z V N	T49T14-XN	E7XT-14	E49XT-14

NOTES:

a. From Table 2 of IFS:2002

b. AWS publication IFS:2002 in electronic format (CD-ROM) available from Global Engineering Documents, an Information Handling Services (IHS) Group company, 15 Inverness Way East, Englewood, Colorado 80112-5776; telephones: (800) 854-7179, (303) 397-7956; fax: (303) 397-2740; Internet: www–global.ihs.com.

the option of the American Welding Society, as deemed appropriate.

A2.6 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table A1 shows those used in ISO 17632. To understand the proposed designation system as applied to ISO 17632B, one is referred to Table 2 and the Annex of AWS document IFS:2002: International Index of Welding Filler Metal Classifications.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01 as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01. 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 A5.01. 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 supplemental designators, if applicable, on the packaging enclosing the products, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of that specification.

The only testing requirement implicit in this "certification" is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the "certification" required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS 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 can be exposed during welding. These are:

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

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

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

(d) The proximity of the welders or welding operators 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.

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

A5.2 American National Standard Z49.1 discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section in that document on Health Protection and Ventilation.

A6. Welding Considerations

A6.1 When examining the properties required of weld metal as a result of the tests made according to this specification, it should be recognized that in production, where the conditions and procedures may differ from those in this specification (electrode size, amperage, voltage, type and amount of shielding gas, position of welding, contact tip to work distance (CTWD), plate thickness, joint geometry, preheat and interpass temperatures, travel speed, surface condition, base metal composition and dilution, for example), the properties of the weld metal may also differ. Moreover, the difference may be large or small.

A6.2 Since it has not been possible to specify one single, detailed, welding procedure for all products classified under any given classification in this specification, details of the welding procedure used in classifying each product should be recorded by the manufacturer and made available to the user, on request. The information should include each of the welding parameters referred to in A6.1 above, as well as the actual number of passes and layers required to complete the weld test assembly.

A6.3 The toughness requirements for the different classifications in this specification can be used as a guide in the selection of electrodes for applications requiring some degree of low temperature notch toughness. For an electrode of any given classification, there can be a considerable difference between the impact test results from one assembly to another, or even from one impact specimen to another, unless particular attention is given to the manner in which the weld is made and prepared (even the location and orientation of the specimen within the weld), the temperature of testing, and the operation of the testing machine.

A6.4 Hardenability. There are inherent differences in the effect of the carbon content of the weld deposit on hardenability, depending on whether the electrode was gas shielded or self-shielded. Gas shielded electrodes generally employ a Mn-Si deoxidation system. The carbon and alloy content affects hardenability in a manner which is typical of many carbon equivalent formulas published for carbon steel. Most self-shielded electrodes utilize an aluminum-based deoxidation system to provide for protection and deoxidation. One of the effects of the aluminum is to modify the effect of carbon on hardenability which will, therefore, be lower than the carbon content would indicate based on typical carbon equivalent formulas.

A7. Description and Intended Use of Flux Cored Electrodes

This specification contains many different classifications of flux cored electrodes. The usability designation (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or the letter “G” or the letters “GS”) in each classification indicates a general grouping of electrodes that contain similar flux or core components and which have similar usability characteristics, except for the “G” classification where usability characteristics may differ between similarly classified electrodes.

A7.1 EXXT-1C and EXXT-1M Classifications. Both the EXXT-1C and EXXT-1M electrodes have similar type slags and are designed for single and multiple pass welding using DCEP. The larger diameters (usually $^5/_{64}$ in. [2.0 mm] and larger) are typically used for welding in the flat position and for welding fillet welds in the horizontal position. The smaller diameters (usually $^1/_{16}$ in. [1.6 mm] and smaller) are typically used for welding in all positions. These electrodes are characterized by a spray transfer, low spatter loss, flat to slightly convex bead contour, and a moderate volume of slag, which completely covers the weld bead. Electrodes of this classification have a rutile base slag and have the ability to produce high deposition rates.

Electrodes in the EXXT-1C group are classified with CO_2 shielding gas (AWS A5.32/A5.32M, Class SG-C). However, other gas mixtures such as argon-CO_2 (AWS A5.32/A5.32M, Class SG-AC-25 or SG-AC-20) may be used to improve usability, especially for out-of-position applications, when recommended by the manufacturer. Increasing the amount of argon in the argon-CO_2 mixture will increase the manganese and silicon contents, along with certain other alloys such as chromium, in the weld metal. The increase in manganese, silicon, or other alloys will increase the yield and tensile strengths and may affect impact properties.

Electrodes in the EXXT-1M group are classified with 75% to 80% argon/balance CO_2 shielding gas. Increasing the amount of argon in the argon-CO_2 mixture will reduce the manganese and silicon losses, along with losses of certain other elements such as chromium, that occur in the welding arc. The resulting increase of manganese, silicon, or other elements will increase the yield and tensile strengths and may affect impact properties.

A7.2 EXXT-2C and EXXT-2M Classification. Electrodes of these classifications are essentially EXXT-1C and EXXT-1M with higher manganese or silicon, or both, and are designed primarily for single pass welding in the flat position and for welding fillet welds in the horizontal position. The higher levels of deoxidizers in these classifications allow single pass welding of heavily oxidized or rimmed steel.

Weld metal composition requirements are not specified for single-pass electrodes, since checking the composition of the undiluted weld metal will not provide an indication of the composition of a single-pass weld. These electrodes give good mechanical properties in single-pass welds.

The manganese content and the tensile strength of the weld metal of multiple-pass welds made with EXXT-2C and EXXT-2M electrodes will be high. These electrodes can be used for welding base metals which have heavier mill scale, rust, or other foreign matter that cannot be tolerated by some electrodes of the EXXT-1C or EXXT-1M classifications. The arc transfer, welding characteristics and deposition rates of these electrodes, however, are similar.

A7.3 EXXT-3 Classification. Electrodes of this classification are self-shielded, used on DCEP and have a spray-type transfer. The slag system is designed to make very high welding speeds possible. The electrodes are used for single-pass welds in the flat, horizontal, and vertical (up to 20 deg incline) positions (downward progression) on sheet metal. Since these electrodes are sensitive to the effects of base metal quenching, they are not generally recommended for the following:

(a) T- or lap joints in materials thicker than $^3/_{16}$ in. [5 mm]

(b) Groove, edge, or corner joints in materials thicker than $^1/_4$ in. [6 mm]

The electrode manufacturer should be consulted for specific recommendations.

A7.4 EXXT-4 Classification. Electrodes of this classification are self-shielded, operate on DCEP, and have a globular type transfer. The basic slag system is designed to make very high deposition rates possible and to produce a weld that is very low in sulfur for improved resistance to hot cracking. These electrodes produce welds with low penetration enabling them to be used on joints with varying gaps and for single and multiple pass welding.

A7.5 EXXT-5C and EXXT-5M Classifications. Electrodes of the EXXT-5C and EXXT-5M classifications are used primarily for single and multiple pass welds in the flat position and for welding fillet welds in the horizontal position using DCEP or DCEN, depending on the manufacturer's recommendation. These electrodes are characterized by a globular transfer, slightly convex bead contour, and a thin slag that may not completely cover the weld bead. These electrodes have lime-fluoride base slag. Weld deposits produced by these electrodes typically have impact properties and hot and cold crack resistance that are superior to those obtained with rutile base slags. Some of these electrodes, using DCEN, can be used for welding in all positions. However, the operator appeal of these electrodes is not as good as that of those with rutile base slags.

Electrodes of the EXXT-5C classifications are designed to be used with CO_2 shielding gas (AWS A5.32/A5.32M, Class SG-C); however, as with the EXXT-1C classification, argon-CO_2 mixtures may be used to reduce spatter, when recommended by the manufacturer. Increasing the amount of argon in the argon-CO_2 mixture will increase the manganese and silicon contents, along with certain other alloys, which will increase the yield and tensile strengths and may affect impact properties.

Electrodes of the EXXT-5M classification are designed for use with 75% to 80% argon/balance CO_2 shielding. Their use with gas mixtures having reduced amounts of argon with CO_2 shielding gas will result in some deterioration in arc characteristics, an increase in spatter, and a reduction in manganese, silicon, and certain other alloy elements in the weld metal. This reduction in manganese, silicon, or other alloys will decrease the yield and tensile strengths and may affect impact properties.

A7.6 EXXT-6 Classification. Electrodes of this classification are self-shielded, operate on DCEP, and have a spray-type transfer. The slag system is designed to give good low temperature impact properties, good penetration into the root of the weld, and excellent slag removal, even in a deep groove. These electrodes are used for single and multiple pass welding in flat and horizontal positions.

A7.7 EXXT-7 Classification. Electrodes of this classification are self-shielded, operate on DCEN and have a small droplet to spray type transfer. The slag system is designed to allow the larger sizes to be used for high deposition rates in the horizontal and flat positions, and to allow the smaller sizes to be used for all welding positions. The electrodes are used for single and multiple pass welding and produce very low sulfur weld metal which is very resistant to hot cracking.

A7.8 EXXT-8 Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a small droplet to spray type transfer. These electrodes are suitable for all welding positions, and the weld metal has very good low temperature notch toughness and crack resistance. These electrodes are used for single and multiple pass welds.

A7.9 EXXT-9C and EXXT-9M Classifications. Electrodes of the EXXT-9C group are classified with CO_2 shielding gas (AWS A5.32/A5.32M, Class SG-C). However, gas mixtures of argon-CO_2 are sometimes used to improve usability, especially for out-of-position applications. Increasing the amount of argon in the argon-CO_2 mixture will affect the weld metal analysis and mechanical properties of weld metal deposited by these electrodes, just as it will for weld metal deposited by EXXT-1C and EXXT-1M electrodes (see A7.1).

Electrodes of the EXXT-9M group are classified with a 75-80% argon/balance CO_2 shielding gas (AWS A5.32/A5.32M, Class SG-AC-25 or SG-AC-20). Their use with argon/CO_2 shielding gas mixtures having reduced amounts of argon, or with CO_2 shielding gas, may result in some deterioration of arc characteristics and out-of-position welding characteristics. In addition, a reduction of the manganese and silicon contents in the weld will result, which will have some effect on properties of weld metal from these electrodes, just as it will on properties of weld metal deposited by EXXT-1C and EXXT-1M electrodes (see A7.1).

Both the EXXT-9C and EXXT-9M electrodes are designed for single and multiple pass welding. The larger diameters (usually $^5\!/_{64}$ in. [2.0 mm] and larger) are used for welding in the flat position and for welding fillet welds in the horizontal position. The smaller diameters (usually $^1\!/_{16}$ in. [1.6 mm] and smaller) are often used for welding in all positions.

The arc transfer, welding characteristics, and deposition rates of the EXXT-9C and EXXT-9M electrodes are similar to those of the EXXT-1C or EXXT-1M classifications (see A7.1). EXXT-9C and EXXT-9M electrodes are essentially EXXT-1C and EXXT-1M electrodes that deposit weld metal with improved impact properties. Some electrodes in this classification require that joints be relatively clean and free of oil, excessive oxide, and scale in order that welds of radiographic quality can be obtained.

A7.10 EXXT-10 Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a small droplet transfer. The electrodes are used for single-pass welds at high travel speeds on material of any thickness in the flat, horizontal, and vertical (up to 20 deg incline) positions.

A7.11 EXXT-11 Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a smooth spray-type transfer. They are general purpose electrodes for single- and multiple-pass welding in all positions. Their use is generally not recommended on thicknesses greater than $^3\!/_4$ in. [19 mm]. The electrode manufacturer should be consulted for specific recommendations.

A7.12 EXXT-12C and EXXT-12M Classifications. Electrodes of these classifications are essentially EXXT-1C and EXXT-1M electrodes and are similar in arc transfer, welding characteristics and deposition rates; however, they have been modified to improve impact toughness and to meet the lower manganese requirements of the A-No. 1 Analysis Group in the ASME Boiler and Pressure Vessel Code, Section IX. They, therefore, have an accompanying decrease in tensile strength and hardness. Since welding procedures influence all-weld-metal properties, users are urged to check hardness on any application where a maximum hardness level is a requirement.

A7.13 EXXT-13 Classifications. Electrodes of this classification are self-shielded and operate on DCEN and are usually welded with a short-arc transfer. The slag system is designed so that these electrodes can be used in all positions for the root pass on circumferential pipe welds.

The electrodes can be used on all pipe wall thicknesses, but are only recommended for the first pass. They generally are not recommended for multiple-pass welding.

A7.14 EXXT-14 Classification. Electrodes of this classification are self-shielded, operate on DCEN and have a smooth spray-type transfer. They are intended for single-pass welding. The slag system is designed with characteristics so that these electrodes can be used to weld in all positions and also to make welds at high speed. They are used to make welds on sheet metal up to $^3\!/_{16}$ in. [5 mm] thick, and often are specifically designed for galvanized, aluminized, or other coated steels. Since these welding electrodes are sensitive to the effects of base metal quenching, they are not generally recommended for the following:

(a) T- or lap joints in materials thicker than $^3\!/_{16}$ in. [5 mm]

(b) Groove, edge, or corner joints in materials thicker than $^1\!/_4$ in. [6 mm]

The electrode manufacturer should be consulted for specific recommendations.

A7.15 EXXT-G Classification. This classification is for multiple pass electrodes that have usability characteristics not covered by any presently defined classification. Except for chemical requirements to assure a carbon steel deposit and the tensile strength, which is specified, the requirements for this classification are not specified. They are those that are agreed to by the purchaser and the supplier.

A7.16 EXXT-GS Classification. This classification is for single pass electrodes that have usability characteristics not covered by any presently defined classification. Except for the tensile strength, which is specified, the requirements for this classification are not specified. They are agreed upon by the purchaser and supplier.

A8. Special Tests

A8.1 It is recognized that supplementary tests may need to be conducted to determine the suitability of these welding electrodes for applications involving properties such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, wear resistance, and suitability for welding combinations of dissimilar metals. Supplemental requirements as agreed between purchaser and supplier may be added to the purchase order following the guidance of AWS A5.01.

A8.2 Diffusible Hydrogen Test

A8.2.1 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, nor 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.

A8.2.2 As the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in the root beads), and toe or underbead cracks in the heat-affected zone.

A8.2.3 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.

A8.2.4 Most flux cored electrodes deposit weld metal having diffusible hydrogen levels of less than 16 mL/100 g of deposited metal. For that reason, flux cored electrodes are generally considered to be low hydrogen. However, some commercially available products will, under certain conditions, produce weld metal with diffusible hydrogen levels in excess of 16 mL/100 g of deposited metal. Therefore it may be appropriate for certain applications to utilize the optional supplemental designators for diffusible hydrogen when specifying the flux cored electrodes to be used.

A8.2.5 The use of a reference atmospheric condition during welding is necessitated because the arc is subject to atmospheric contamination when using either self-shielded or gas-shielded flux cored electrodes. 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.

A8.2.6 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator. The welding consumable is not the only source of diffusible hydrogen in the welding process. In actual practice, the following may contribute to the hydrogen content of the finished weldment.

(a) Surface Contamination. Rust, primer coating, anti-spatter compounds, dirt and grease can all contribute to diffusible hydrogen levels in practice. Consequently, standard diffusible hydrogen tests for classification of welding consumable require test material to be free of contamination. AWS A4.3 is specific as to the cleaning procedure for test material.

(b) Atmospheric Humidity. The welding arc is subject to atmospheric contamination when using either a self-shielded or gas shielded welding consumable. Moisture from the air, distinct from that in the welding consumable, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. AWS A4.3 has established a reference atmospheric condition at which the contribution to diffusible hydrogen from atmospheric humidity is considered to be negligible. This influence of atmospheric humidity also can be minimized by maintaining as short an arc length as possible consistent with a steady arc. For flux cored electrodes arc length is controlled primarily by arc voltage. 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.

(c) Shielding Gas. The reader is cautioned that the shielding gas itself can contribute significantly to diffusible hydrogen. Normally, welding grade shielding gases are intended to have very low dew points and very low impurity levels. This, however, is not always the case. Instances have occurred where a contaminated gas cylinder resulted in a significant increase of diffusible hydrogen in the weld metal. Further, moisture permeation through some hoses and moisture condensation in unused gas lines can become a source of diffusible hydrogen during welding. In case of doubt, a check of gas dew point is suggested. A dew point of −40°F [−40°C] or lower is considered satisfactory for most applications.

(d) Absorbed/Adsorbed Moisture. Flux cored electrodes can absorb/adsorb moisture over time which contributes to diffusible hydrogen levels. This behavior is well documented for shielded metal arc electrode coverings exposed to the atmosphere. Hydration of oxide films and lubricants on solid electrode surfaces under what may be considered "normal" storage conditions has also been reported to influence diffusible hydrogen. Moisture absorption/adsorption can be particularly significant if material is stored in a humid environment in damaged or open packages, or if unprotected for long periods of time. In the worst case of high humidity, even overnight exposure of unprotected electrodes can lead to a significant increase of diffusible hydrogen. For these reasons, indefinite periods of storage should be avoided. The storage and handling practices necessary to safeguard the condition of a welding consumable will vary from one product to another even within a given classification. Therefore, the consumable manufacturer should always be consulted for recommendations on storage and handling practice. In the event the electrode has been exposed, the manufacturer should be consulted regarding probable damage to its controlled hydrogen characteristics and possible reconditioning of the electrode.

(e) Effect of Welding Process Variables. Variations in welding process variables (e.g., amperage, voltage, contact tip to work distance (CTWD), type of shielding gas, current type/polarity, single electrode vs. multiple electrode welding, etc.) are all reported to influence diffusible hydrogen test results in various ways. For example, with respect to CTWD, a longer contact tip to work distance will promote more preheating of the electrode, causing some removal of hydrogen-bearing compounds (e.g., moisture, lubricants, etc.) before they reach the arc. Consequently, the result of longer contact tip to work distance can be to reduce diffusible hydrogen. However, excessive contact tip to work distances with external gas shielded welding processes may cause some loss of shielding if the contact tip is not adequately recessed in the gas cup. If shielding is disturbed, more air may enter the arc and increase the diffusible hydrogen. This may also cause porosity due to nitrogen pickup.

Since welding process variables can have a significant effect on diffusible hydrogen test results, it should be noted that an electrode meeting the H4 requirements, for example, under the classification test conditions should not be expected to do so consistently under all welding conditions. Some variation should be expected and accounted for when making welding consumable selections and establishing operating ranges in practice.

A8.2.7 As indicated in A8.2.6(e), the welding procedures used with flux cored electrodes will influence the values obtained on a diffusible hydrogen test. To address this, the AWS A5M Subcommittee on Carbon and Low Alloy Steel Electrodes for Flux Cored Arc Welding has incorporated into its specification test procedure requirements for conducting the diffusible hydrogen test when determining conformance to the hydrogen optional supplemental designator requirements shown in Table 8. See Section 16.

A8.2.8 Not all classifications may be available in the H16, H8, or H4 diffusible hydrogen levels. The manufacturer of a given electrode should be consulted for availability of products meeting these limits.

A8.3 Aging of Tensile Specimens. Weld metal may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases toward its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. The A5.20 and A5.20M specifications permit the aging of the tensile test specimens at elevated temperatures not exceeding 220°F [105°C] for up to 48 hours before cooling them to room temperature and subjecting them to tension testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing.

Aging treatments are sometimes used for low hydrogen electrode deposits, especially when testing high strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a high 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.

A9. General Safety Considerations

NOTE: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not addressed herein. Some safety and health information is available from other sources, including, but not limited to, the Safety and Health Fact Sheets listed in A9.2, ANSI Z49.1, and applicable federal and state regulations.

A9.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A9.2 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	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 Safety and Health Documents
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 Allied Processes
25	Metal Fume Fever
27	Thoriated Tungsten Electrodes
29	Grounding of Portable and Vehicle Mounted Welding Generators

A10. Discontinued Classifications

E60T-7 and E60T-8 have been discontinued and replaced with E7XT-7 and E7XT-8 respectively.

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SPECIFICATION FOR BARE ELECTRODES AND RODS FOR SURFACING

SFA-5.21

(Identical with AWS Specification A5.21:2011. In case of dispute, the original AWS text applies.)

Specification for Bare Electrodes and Rods for Surfacing

1. Scope

1.1 This specification prescribes the requirements for the classification of bare electrodes and rods for surfacing. The specification does not provide for classification of electrode-flux combinations for submerged arc welding.

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

1.3 *This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material. The specification with the designation A5.21 uses U.S. Customary Units. The specification A5.21M 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 or both under A5.21 or A5.21M specifications.*

2. Referenced Documents

The following documents are referenced within this publication. 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 AWS Standards[2]

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

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

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

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

2.2 ANSI Standards

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

2.3 ASTM Standards[3]

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

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

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

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

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

ASTM B 214, *Standard Test Method for Sieve Analysis of Metal Powders*

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

2.4 ISO Standards[4]

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

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

3. Classification

3.1 The surfacing electrodes and rods covered by this specification are classified according to the following:

3.1.1 Solid surfacing electrodes and rods are classified on the basis of the composition of the material as manufactured (or the stock from which it was made) (see Tables 1, 2, and 4).

3.1.2 Metal cored and flux cored composite (tubular) surfacing electrodes and rods, except for tungsten carbide rods, are classified on the basis of the composition of an undiluted weld deposit, as shown in Tables 1, 3, and 4.

3.1.3 Tubular tungsten carbide surfacing rods are classified on the basis of the mesh range, quantity, and composition of the tungsten carbide granules, as shown in Tables 5 and 6.

3.2 Material classified under one classification shall not be classified under any other classification in this specification.

4. Acceptance

Acceptance[5] of the welding electrodes and rods shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344).

5. Certification[6]

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

6. Rounding-Off Procedure

For purposes of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E 29 or ISO 80000-1, 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 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.

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[4] ISO standards are published by the *International Organization for Standardization, 1, rue de Varembé*, Case postale 56, CH-1211 Geneva 20, Switzerland.

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

[6] See Clause A4, Certification, for further information concerning certification and the testing specified to meet this requirement.

Table 1
Solid and Cored Iron Base Electrodes and Rods—Chemical Composition Requirements[a]

		UNS Numbers[b]		Composition, Weight Percent[c, d, e, f]									
AWS Classification[g]	Annex A Reference	Solid	Cored	C	Mn	Si	Cr	Ni	Mo	V	W	Fe	Other Elements, Total[b]
ERFe-1	A7.1.1	T74000	W74030	0.04–0.20	0.5–2.0	1.0	0.5–3.5	—	1.5	—	—	Rem	1.0
ERFe-1A	A7.1.1	T74001	W74031	0.05–0.25	1.7–3.5	1.0	0.5–3.5	—	—	—	—	Rem	1.0
ERFe-2	A7.1.1	T74002	W74032	0.10–0.30	0.5–2.0	1.0	1.8–3.8	1.0	1.0	0.35	—	Rem	1.0
ERFe-3	A7.1.2	T74003	W74033	0.50–0.80	0.5–1.5	1.0	4.0–8.0	—	1.0	—	—	Rem	1.0
ERFe-5	A7.1.3	T74005	W74035	0.50–0.80	1.5–2.5	0.9	1.5–3.0	—	—	—	—	Rem	1.0
ERFe-6	A7.1.4	T75006	W77530	0.6–1.0	0.4–1.0	1.0	3.0–5.0	—	7.0–9.5	0.5–1.5	0.5–1.5	Rem	1.0
ERFe-8	A7.1.5	T75008	W77538	0.30–0.60	1.0–2.0	1.0	4.0–8.0	—	1.0–2.0	0.50	1.0–2.0	Rem	1.0
ERFeMn-C	A7.1.6	—	W79230	0.5–1.0	12–16	1.3	2.5–5.0	2.5–5.0	—	—	—	Rem	1.0
ERFeMn-F	A7.1.6	—	W79630	0.7–1.1	16–22	1.3	2.5–5.0	1.0	—	—	—	Rem	1.0
ERFeMn-G	A7.1.6	—	W79231	0.5–1.0	12–16	1.3	2.5–5.0	1.0	—	—	—	Rem	1.0
ERFeMn-H	A7.1.6	—	W79232	0.30–0.80	12–16	1.3	4.5–7.5	2.0	—	—	—	Rem	1.0
ERFeMnCr	A7.1.7	—	W79730	0.25–0.75	12–18	1.3	11–16	2.0	2.0	—	—	Rem	1.0
ERFeCr-A	A7.1.8	—	W74531	1.5–3.5	0.5–1.5	2.0	8.0–14.0	—	1.0	—	—	Rem	1.0
ERFeCr-A1A	A7.1.9	—	W74530	3.5–5.5	4.0–6.0	0.5–2.0	20–25	—	0.50	—	—	Rem	1.0
ERFeCr-A3A	A7.1.10	—	W74533	2.5–3.5	1.5–3.5	0.5–2.0	14–20	—	—	—	—	Rem	1.0
ERFeCr-A4	A7.1.9	—	W74534	3.5–4.5	1.5–3.5	1.5	23–29	—	1.0–3.0	—	—	Rem	1.0
ERFeCr-A5	A7.1.11	—	W74535	1.5–2.5	0.5–1.5	2.0	24–32	4.0	4.0	—	—	Rem	1.0
ERFeCr-A9	A7.1.12	—	W74539	3.5–5.0	0.5–1.5	2.5	24–30	—	—	—	—	Rem	1.0
ERFeCr-A10	A7.1.13	—	W74540	5.0–7.0	0.5–2.5	1.5	20–25	—	—	—	—	Rem	1.0

[a] Covered composite iron base electrodes that were included in AWS A5.21-80, *Specification for Bare Surfacing Electrodes and Rods*, were deleted from A5.21:2001. They are now in AWS A5.13:2000, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*.

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

[c] Single values are maximum. Rem = Remainder.

[d] Electrodes and rods shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

[e] Sulfur and phosphorus contents shall not exceed 0.035% each.

[f] For solid electrodes and rods, composition is that of the electrode itself or the stock from which it was made. For metal cored or flux cored electrodes, the composition is that of a weld deposit prepared in accordance with 9.3.

[g] For metal cored and flux cored composite (tubular) electrodes and rods, insert "C" in the classification designation immediately following the "R."

[h] Aluminum and magnesium contents of weld metal deposited by self-shielding electrodes shall not be included in the value of "Other Elements, Total."

Table 2
Solid Cobalt and Nickel Base Bare Electrodes and Rods—Chemical Composition Requirements

			Composition, Weight Percent[a,b,c]											
AWS Classification	Annex A Reference	UNS Number[d]	C	Mn	Si	Cr	Ni	Mo	Fe	W	Co	B	V	Other Elements, Total
ERCoCr-A	A7.2.1	R30006	0.9–1.4	1.0	2.0	26–32	3.0	1.0	3.0	3.0–6.0	Rem	—	—	0.50
ERCoCr-B	A7.2.2	R30012	1.2–1.7	1.0	2.0	26–32	3.0	1.0	3.0	7.0–9.5	Rem	—	—	0.50
ERCoCr-C	A7.2.3	R30001	2.0–3.0	1.0	2.0	26–33	3.0	1.0	3.0	11.0–14.0	Rem	—	—	0.50
ERCoCr-E	A7.2.4	R30021	0.15–0.45	1.5	1.5	25–30	1.5–4.0	4.5–7.0	3.0	0.50	Rem	—	—	0.50
ERCoCr-F	A7.2.5	R30002	1.5–2.0	1.0	1.5	24–27	21–24	1.0	3.0	11–13	Rem	—	—	0.50
ERCoCr-G	A7.2.6	R30014	3.0–4.0	1.0	2.0	24–30	4.0	1.0	3.0	12–16	Rem	—	—	0.50
ERNiCr-A	A7.3.1	N99644	0.20–0.60	—	1.2–4.0	6.5–14.0	Rem[e]	—	1.0–3.5	—	—	1.5–3.0	—	0.50
ERNiCr-B	A7.3.1	N99645	0.30–0.80	—	3.0–5.0	9.5–16.0	Rem[e]	—	2.0–5.0	—	—	2.0–4.0	—	0.50
ERNiCr-C	A7.3.1	N99646	0.50–1.00	—	3.5–5.5	12–18	Rem[e]	—	3.0–5.5	—	—	2.5–4.5	—	0.50
ERNiCr-D	A7.3.4	N99647	0.6–1.1	—	4.0–6.6	8.0–12.0	Rem[e]	—	1.0–5.0	1.0–3.0	0.10	0.35–0.60	—	0.50
ERNiCr-E	A7.3.4	N99648	0.1–0.5	—	5.5–8.0	15–20	Rem[e]	—	3.5–7.5	0.5–1.5	0.10	0.7–1.4	—	Sn = 0.5–0.9 Others = 0.50
ERNiCrMo-5A	A7.3.2	N10006	0.12	1.0	1.0	14–18	Rem[e]	14–18	4.0–7.0	3.0–5.0	—	—	0.40	0.50
ERNiCrFeCo	A7.3.3	F46100	2.5–3.0	1.0	0.6–1.5	25–30	10–33	7–10	20–25	2.0–4.0	10–15	—	—	0.50

[a] Single values are maximum. Rem = Remainder.

[b] Electrodes and rods shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for “Other Elements, Total” in the last column of the table.

[c] Sulfur and phosphorus content shall not exceed 0.03% each.

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

[e] Includes incidental cobalt.

Table 3
Metal Cored and Flux Cored Composite Cobalt and Nickel-Base Bare Electrodes and Rods—Chemical Composition Requirements

			Composition, Weight Percent[a,b,c]											
AWS Classification[d]	Annex A Reference	UNS Number[e]	C	Mn	Si	Cr	Ni	Mo	Fe	W	Co	B	V	Other Elements, Total
ERCCoCr-A	A7.2.1	W73036	0.7–1.4	2.0	2.0	25–32	3.0	1.0	5.0	3.0–6.0	Rem	—	—	1.0
ERCCoCr-B	A7.2.2	W73042	1.2–2.0	2.0	2.0	25–32	3.0	1.0	5.0	7–10	Rem	—	—	1.0
ERCCoCr-C	A7.2.3	W73031	2.0–3.0	2.0	2.0	25–33	3.0	1.0	5.0	11–14	Rem	—	—	1.0
ERCCoCr-E	A7.2.4	W73041	0.15–0.40	2.0	1.5	25–30	1.5–4.0	4.5–7.0	5.0	0.50	Rem	—	—	1.0
ERCCoCr-G	A7.2.6	W73032	3.0–4.0	1.0	2.0	24–30	4.0	1.0	5.0	12–16	Rem	—	—	1.0
ERCNiCr-A	A7.3.1	W89634	0.20–0.60	—	1.2–4.0	6.5–14.0	Rem[f]	—	1.0–3.5	—	—	1.5–3.0	—	1.0
ERCNiCr-B	A7.3.1	W89635	0.30–0.80	—	3.0–5.0	9.5–16.0	Rem[f]	—	2.0–5.0	—	—	2.0–4.0	—	1.0
ERCNiCr-C	A7.3.1	W89636	0.50–1.00	—	3.0–5.5	12–18	Rem[f]	—	3.0–5.5	—	—	2.5–4.5	—	1.0
ERCNiCrMo-5A	A7.3.2	W80036	0.12	1.0	2.0	14–18	Rem[f]	14–18	4.0–7.0	3.0–5.0	—	—	0.40	1.0
ERCNiCrFeCo	A7.3.3	W83032	2.2–3.0	1.0	2.0	25–30	10–33	7–10	20–25	2.0–4.0	10–15	—	—	1.0

[a] Single values are maximum. Rem = Remainder.

[b] Electrodes and rods shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for “Other Elements, Total” in the last column of the table.

[c] Sulphur and phosphorus contents shall not exceed 0.03% each.

[d] The designator “C” following ER indicates that the electrode or rod is a metal cored or flux cored composite (tubular) product.

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

[f] Includes incidental cobalt.

Table 4
Solid and Cored Copper Base Electrodes and Rods—Chemical Composition Requirements

AWS Classification[e]	Annex A Reference	UNS Numbers[a]		Composition, Weight Percent[b,c,d]									
		Solid	Cored	Fe	Cu	Al	Zn	Si	Pb	Sn	P	Mn	Other Elements, Total[f]
ERCuAl-A2[g]	A7.4.1.1	C61800	W60618	0.5–1.5	Rem	8.5–11.0	0.02	0.10	0.02	—	—	—	0.50
ERCuAl-A3[g]	A7.4.1.2	C62400	W60624	2.0–4.5	Rem	10.0–11.5	0.10	0.10	0.02	—	—	—	0.50
ERCuAl-C	A7.4.1.3	C62580	W60626	3.0–5.0	Rem	12–13	0.02	0.04	0.02	—	—	—	0.50
ERCuAl-D	A7.4.1.3	C62581	W61626	3.0–5.0	Rem	13–14	0.02	0.04	0.02	—	—	—	0.50
ERCuAl-E	A7.4.1.3	C62582	W62626	3.0–5.0	Rem	14–15	0.02	0.04	0.02	—	—	—	0.50
ERCuSi-A[g]	A7.4.1.4	C65600	W60657	0.50	Rem	0.01	1.0	2.8–4.0	0.02	1.0	—	1.5	0.50
ERCuSn-A[g]	A7.4.1.5	C51800	W60518	—	Rem	0.01	—	—	0.02	4.0–6.0	0.10–0.35	—	0.50
ERCuSn-D	A7.4.1.5	C52400	W60524	—	88.5 min.	0.01	—	—	0.05	9.0–11.0	0.10–0.35	—	0.50

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

[b] Single values are maximum, except where otherwise specified. Rem = Remainder.

[c] Electrodes and rods shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

[d] For solid electrodes and rods, composition is that of the electrode itself or the stock from which it was made. For metal cored or flux cored electrodes, the composition is that of a weld deposit prepared in accordance with 9.3 or 9.4.

[e] For metal cored and flux cored composite (tubular) electrodes and wires, insert "C" in the classification designation immediately following the "R."

[f] Sulfur content shall not exceed 0.015%.

[g] These AWS classifications are intended to correspond to the same classification that appears in AWS A5.7/A5.7M, *Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*. Due to possible ongoing revisions, the composition ranges may not be identical.

Table 5
Mesh Size and Quantity of Tungsten Carbide (WC) Granules in the Core of Tungsten Carbide Bare Rods and Electrodes

AWS Classification[a,b,c]	U.S. Standard Mesh Size of Tungsten Carbide Granules[d]	Quantity of Tungsten Carbide (WC1 + WC2) Granules, Weight Percent[e]	SI Equivalents U.S. Standard Mesh Size	SI Equivalents Opening, mm
(ER/R)WCX-12/30	thru 12–on 30	60	12	1.70
(ER/R)WCX-20/30	thru 20–on 30	60	20	0.85
(ER/R)WCX-30/40	thru 30–on 40	60	30	0.6
(ER/R)WCX-40	thru 40	60	40	0.43
(ER/R)WCX-40/120	thru 40–on 120	60	120	0.13

[a] "X" designates the type of tungsten carbide granules; X = 1 for WC1 granules, X = 2 for WC2 granules, X = 3 for a blend of WC1 and WC2 granules.
[b] The C normally present in composite designations can be deleted in these classifications, as tungsten carbide electrodes and rods are only composite.
[c] See A7.5 in Annex A.
[d] The mesh size of the tungsten carbide granules may vary from that specified above, provided that no more than 5.0% of the granules is retained on the "thru" sieve and that no more than 20.0% passes the "on" sieve.
[e] The tolerance +2.0%, –1.5% of the amount specified.

Table 6
Chemical Composition Requirements for Tungsten Carbide Granules

Element	WC1	WC2	WC3
	Composition, Weight Percent[a]		
C	3.6–4.2	6.0–6.2	As agreed upon between the purchaser and supplier
Si	0.3	0.3	
Ni	0.3	0.3	
Mo	0.6	0.6	
Co	0.3	0.3	
W	94.0 min.	91.5 min.	
Fe	1.0	1.0	
Th	0.01	0.01	

[a] Single values are maximum, unless noted otherwise.

7. Summary of Tests

7.1 Solid Electrodes or Rods. Chemical analysis of the filler metal itself (or the stock from which it is made) is the only test required for classification of a product under this specification.

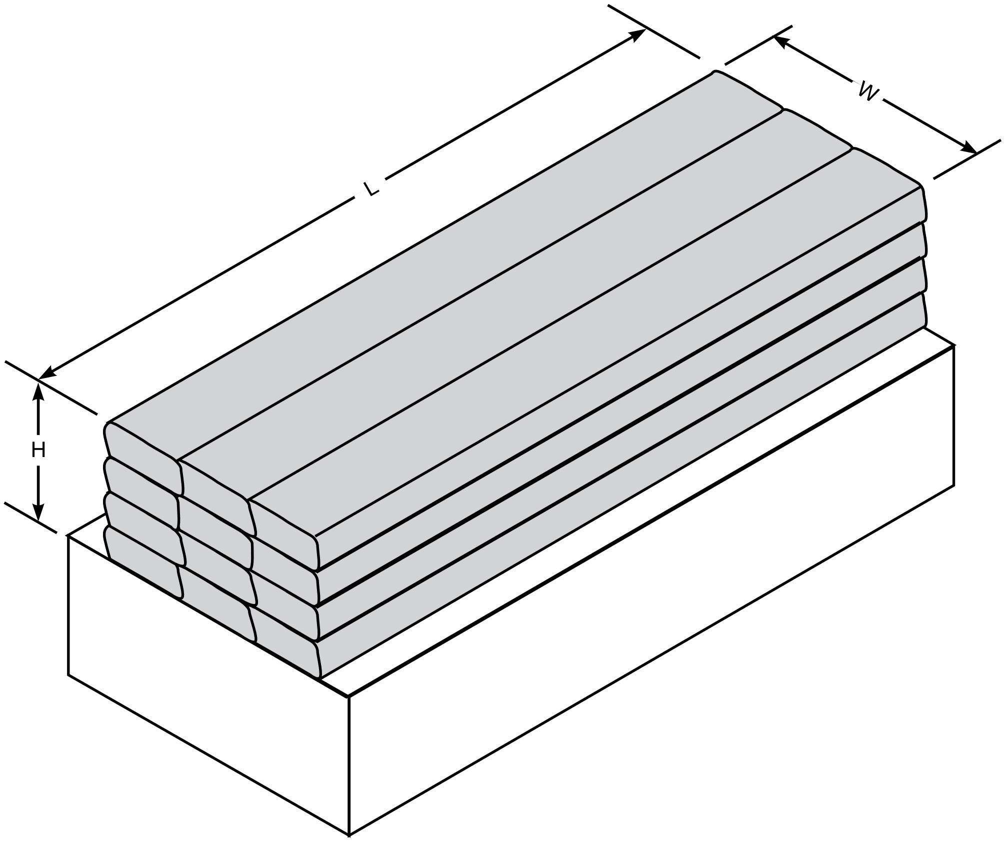
7.2 Metal Cored and Flux Cored Composite (Tubular) Electrodes and Rods

7.2.1 Chemical analysis of a pad of undiluted weld metal, as shown in Figure 1, or a fused sample as agreed upon by the supplier and purchaser, is the only test required for classification. In case of dispute, the weld pad described in 9.3 shall be the referee method.

7.3 Tungsten Carbide Rods

7.3.1 The amount and mesh size distribution of the tungsten carbide granules shall be determined (see Table 5). Sieve analysis shall be in accordance with ASTM B 214.

7.3.2 Chemical analysis of the tungsten carbide granules shall be determined (see Table 6).



Electrode Size		Weld Pad Size, minimum	
in	mm	in	mm
0.045	1.2	L = 2	50
0.052	1.3	W = 1/2	13
1/16 (0.062)	1.6	H = 1/2	13
5/64 (0.078)	2.0		
3/32 (0.094)	2.4	L = 3	75
—	2.5	W = 1/2	13
7/64 (0.109)	2.8	H = 5/8	16
0.120	3.0		
1/8 (0.125)	3.2		
5/32 (0.156)	4.0		
3/16 (0.187)	4.8	L = 3	75
0.197	5.0	W = 1/2	13
0.238	6.0	H = 3/4	19
1/4 (0.250)	6.4		
5/16 (0.312)	8.0		

Source: AWS A5.21:2001, Figure 1.

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material, specimens, or samples for retest may be taken from the original test assembly or sample, or from one or two new test assemblies or samples. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retest 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 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. Chemical Composition Requirements

9.1 For solid drawn bare surfacing electrodes or rods, a sample of the filler metal or the stock from which it is made, shall be prepared for chemical analysis. Solid filler metal, when analyzed for elements that are present in a coating (copper flashing for example), shall be analyzed without removing the coating. When the filler metal is analyzed for elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for other elements. Rod stock may be analyzed prior to coating for those elements not added in the coating.

9.2 *For cast bare surfacing electrodes or rods, the chemical analysis sample shall be prepared from the as-manufactured material only.*

9.3 For composite metal cored electrodes or rods other than tungsten carbide rods (see 9.5), samples for chemical analysis may be obtained by any method producing undiluted weld metal *or ingot* as agreed upon between the purchaser and supplier. A weld pad *may be prepared using* the welding process for which it was designed to operate (Figure 1). In case of a dispute, the weld pad shall be the referee method.

9.3.1 For flux cored composite electrodes and rods, including self-shielded electrodes, the sample for chemical analysis shall be obtained from an undiluted weld pad (see Figure 1) deposited with the welding process for which it was designed.

9.3.2 The dimensions of the completed pad shall be as shown in Figure 1 for each size of electrode. Testing shall be as specified in 9.3.5.

9.3.3 The weld pad test assembly shall be welded in the flat position using welding conditions specified by the manufacturer.

9.3.4 The base metal shall conform to one of the following specifications or its equivalent:

9.3.4.1 ASTM A 285/A 285M

9.3.4.2 ASTM A 36/A 36M

9.3.5 *The top surface of the pad or ingot shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal by any appropriate means. Postweld heat treatment may be used to facilitate this removal procedure. Chemical analysis may be made by any suitable method as agreed upon between the purchaser and supplier. The referee method shall be the appropriate ASTM method for the element being determined.*

9.4 The results of the analysis shall meet the requirements in either Table 1, 2, 3, or 4, for the classification of bare surfacing electrode or rod under test.

9.5 Tungsten Carbide Electrodes and Rods

9.5.1 Weight-percentage of the tungsten carbide particles, as specified in Table 5, shall be determined by the following steps:

(1) Record the weight of the tungsten carbide welding electrode or rod sample to the nearest tenth of a gram.

(2) Remove the tungsten carbide from the tube and clean it by washing with water and treating with 1-1 hydrochloric acid, as required, to remove any flux, powdered iron, graphite, etc. Heating of the acid may be required. Hot or cold 1-1 hydrochloric acid will not appreciably attack cast tungsten carbide in less than an hour. When handling any acids, appropriate safety precautions should be followed.

(3) Wash and rinse the tungsten carbide particles thoroughly with tap water.

(4) Dry the tungsten carbide particles by holding in an oven at 250°F ± 25°F [120°C ± 15°C] for a minimum period of one hour.

(5) Weigh the cleaned and dried tungsten carbide particles, and calculate the percentage of tungsten carbide from the initial weight of the tube, using the formula:

$$\%\text{ of tungsten carbide particles} = \frac{\text{weight of clean and dried tungsten carbide particles}}{\text{weight of bare electrode or rod sample}} \times 100$$

9.5.2 Chemical composition of tungsten carbide particles shall conform to the requirements of Table 6. Chemical analysis may be made by any suitable method as agreed upon between the purchaser and supplier. Tungsten carbide particles for chemical analysis shall be free of any surface contaminants.

10. Method of Manufacture

The electrodes and rods classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification. For tungsten carbide rods, any carbon steel sheath material that will not significantly alter the matrix of the deposit may be used.

11. Standard Sizes and Lengths

Standard sizes and lengths of electrodes and rods shall be as shown in Tables 7, 8, and 9.

12. Finish and Uniformity

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

13. Standard Package Forms

Standard package dimensions and weights and other requirements for each form shall be as specified in 4.3 of AWS A5.02/A5.02M.

14. Winding Requirements

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

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

15. Filler Metal Identification

15.1 Filler metal identification, product information and the precautionary information shall be as specified in 4.5.2 through 4.5.6 of AWS A5.02/A5.02M.

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

Table 7
Standard Sizes for Bare Electrodes and Rods Using Solid Drawn or Composite (Tubular) Wire[a,b]

Diameter		Tolerance	
in	mm	in	mm
0.045	—	±0.002	—
—	1.2	—	+0.02, −0.05
0.052	1.3[c]	±0.002	—
—	1.4	—	+0.02, −0.05
1/16 (0.062)	1.6	±0.002	+0.02, −0.06
5/64 (0.078)	2.0	±0.003	+0.02, −0.06
3/32 (0.094)	2.4	±0.003	+0.02, −0.06
—	2.5	—	+0.02, −0.06
7/64 (0.109)	2.8	±0.003	+0.02, −0.06
0.120	3.0	±0.003	+0.02, −0.06
1/8 (0.125)	3.2	±0.005	+0.02, −0.07
5/32 (0.156)	4.0	±0.005	+0.02, −0.07
3/16 (0.188)	4.8[c]	±0.005	—
—	5.0	—	+0.02, −0.08
—	6.0	—	+0.02, −0.08
1/4 (0.250)	6.4[c]	±0.005	—
5/16 (0.312)	8.0	±0.005	+0.02, −0.08

[a] Other diameter electrodes may be supplied as agreed upon between the manufacturer and purchaser.

[b] Electrode and rod length may be supplied as agreed upon between the manufacturer and purchaser.

[c] Nonstandard size in ISO 544.

Table 8
Standard Sizes for Cast Electrodes and Rods[a,b]

Nominal Diameter		Tolerance	
in	mm	in	mm
3/32 (0.094)	2.4	±0.02	±0.5
1/8 (0.125)	3.2	±0.02	±0.5
5/32 (0.156)	4.0	±0.02	±0.5
3/16 (0.188)	—	±0.02	—
—	5.0	—	±0.5
1/4 (0.250)	6.4	±0.03	±0.8
5/16 (0.312)	8.0	±0.03	±0.8

[a] Other diameter electrodes or rods may be supplied as agreed upon between the manufacturer and purchaser.

[b] Electrode and rod length may be supplied as agreed upon between the manufacturer and purchaser.

Table 9
Standard Sizes for Tungsten Carbide (WC) Rods

Nominal Diameter[a]		
in	mm	Length
1/8 (0.125)	3.2	See Note b
5/32 (0.156)	4.0	
3/16 (0.188)	—	
—	5.0	
1/4 (0.250)	6.4	
5/16 (0.312)	8.0	
3/8 (0.375)	9.5	

[a] Diameter tolerance is ±1/16 (0.063) in [±1.6 mm] from the nominal diameter.

[b] Rod length may be supplied as agreed upon between the purchaser and supplier.

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

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

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

16. Packaging

16.1 *Filler metal in all product forms, excepting welding rods in straight lengths, shall be packaged in accordance with 4.3 of AWS A5.02/A5.02M.*

16.2 Packaging of straight lengths of bare welding rods shall be as agreed upon between the purchaser and supplier.

17. Marking of Packages

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

17.2 The appropriate precautionary information[7] 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 and rods, including individual unit packages within a larger package.

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[7] 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 Bare Electrodes and Rods for Surfacing

This annex is not part of AWS A5.21/A5.21M: 2011, *Specification for Bare Electrodes and Rods for Surfacing*, but is included for informational purposes only.

A1. Introduction

This guide has been prepared as an aid to prospective users of the electrodes and rods covered by the specification in determining the classification of filler metal best suited for a particular application, with due consideration to the particular requirements for that application.

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 letters ER at the beginning of each classification designation stand for electrode and rod, indicating that the filler metal may be used either way. The letter R alone means the electrode may be used only as a welding rod. The designator C, when it appears after ER or R, indicates that the electrode or rod is either a metal cored or flux cored composite (tubular) electrode or rod.

A2.2 The letters immediately after the R, RC, ER, or ERC are the chemical symbols for the principal elements in the classification. Thus, CoCr is a cobalt-chromium alloy; CuAl is a copper-aluminum alloy, etc. Where more than one classification is included in a basic group, the individual classifications in the group are identified by the letters, A, B, C, etc., as in ERCuSn-A. Further subdivision is done by using a 1, 2, etc., after the last letter, as the “2” in ERCuAl-A2. An additional letter or number has been added to some designations if the composition requirements in this specification differ somewhat from those of the earlier versions for electrodes of the same basic classification.

A2.3 For SMAW applications, many classifications in this specification have a corresponding classification in A5.13/A5.13M, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*.

A2.4 Request for Filler Metal Classification

(1) When a surfacing electrode or rod cannot be classified as given in this specification, the manufacturer may request that a classification be established for that welding electrode. The manufacturer may do this by following the procedure given here.

(2) A request to establish a new electrode or rod classification must be a written request, and must provide sufficient detail to permit the AWS A5 Committee on Filler Metals and Allied Materials or the subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request needs to state the variables and their limits, for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed. In particular, the request needs to include:

(a) All classification requirements as given for existing classifications, such as chemical composition ranges 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 Descriptions and Intended Use, which parallels that for existing classifications, for that clause of the annex.

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

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

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

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

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

(c) Send a copy of the request to the Chair of the A5 Committee on Filler Metals and Allied Materials, and the Chair of the particular subcommittee involved.

(d) File the original request.

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

(4) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chair of the A5 Committee on Filler Metals and Allied Materials, for action.

(5) The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each A5 Committee on Filler Metals and Allied Materials meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

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 he 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 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 System" in AWS A5.01M/A5.01 (ISO 14344).

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fume to which welders and welding operators are exposed during welding. These are as follows:

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

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

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

(4) The proximity of the welder or welding operator to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which he is working

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

A5.2 American National Standard ANSI Z49.1 discusses the ventilation that is required during welding and should be referred to for details. Attention is particularly drawn to the section entitled "Ventilation." *See also AWS F3.2,* Ventilation Guide for Weld Fumes, *for more detailed description of ventilation options.*

A6. Surfacing Considerations

A6.1 Role of Hydrogen in Surfacing. Hydrogen can be detrimental to surfacing deposits. The effect varies widely from one alloy type to another. In general, hydrogen's detrimental effect on microstructure is most pronounced for martensitic types, with austenitic types being the least affected. Other factors influencing hydrogen's effect include carbon and alloy contents plus in-service welding variables.

In welding there are many sources for hydrogen contamination with moisture being one of the most important. Most electrodes and welding rods are manufactured and packaged to control moisture. When received, consideration must be given to proper storage to prevent moisture pick-up. During use, improper regard to welding procedure and environment variables can result in spalling or "hydrogen-induced" (underbead) cracking. In austenitic materials, excessive hydrogen can manifest itself as porosity in the deposit.

A6.2 For additional surfacing considerations refer to the appropriate volume of the AWS *Welding Handbook*.

A7. Description and Intended Use of Electrodes and Rods for Surfacing

A7.1 Iron Base Electrodes and Rods

A7.1.1 ERFe-1, ERFe-1A, and ERFe-2 Electrodes

A7.1.1.1 Characteristics. Deposits made with these electrodes and rods are a machinery-grade steel suitable for application on carbon and alloy steels. With care, they can be applied crack-free. Deposits are machinable with carbide tipped tools. Deposit hardness generally is in the range of 25–50 HRC with ERFe-2 filler metal providing weld metal with the higher hardness. These deposits contain sufficient alloy to attain full hardness without the need of heat treatment. Abrasion resistance is comparable to heat treated steels of equal hardness.

A7.1.1.2 Applications. These electrodes and rods are used to restore worn machinery parts to their original dimensions. Deposit surfaces are suitable for metal-to-metal rolling and sliding contact such as occurs on large low speed gear teeth, shafts, etc. High compressive strength makes these materials suitable as a base for more abrasion resistant materials.

A7.1.2 ERFe-3 Electrodes and Rods

A7.1.2.1 Characteristics. Weld metal deposited by these electrodes and rods is an air-hardening tool steel type with high room-temperature hardness (55–60 HRC). Deposits can be applied crack-free with careful procedures. The deposits cannot be machined and generally are ground when finishing is required.

A7.1.2.2 Applications. ERFe-3 electrodes and rods are used to overlay surfaces and edges requiring high hardness and crack-free deposits such as the edges of tools and dies. Deposits are suitable for subsequent surfacing with high-nickel alloys and many tool steels. Although generally used for metal-to-metal applications, the weld metal performs well in earth-abrasion applications where high impact is encountered.

A7.1.3 ERFe-5 Electrodes and Rods

A7.1.3.1 Characteristics. These electrodes and rods deposit a cold work tool steel weld metal. Hardness as deposited should be in the range of 50–55 HRC. Weld metal deposited by ERFe-5 electrodes is air hardening and machinable only after annealing. Typical deposit characteristics include high compressive strength with moderate abrasion resistance.

A7.1.3.2 Applications. These electrodes are used for metal-to-metal wear applications such as machine components, shafts, brake drums, and knife edges.

A7.1.4 ERFe-6 Electrodes and Rods

A7.1.4.1 Characteristics. Weld metal deposited by ERFe-6 electrodes and rods is a high-speed tool steel with a hardness in the range of 60 HRC or higher. The deposit maintains a high degree of hardness to 1100°F [600°C]. Weld metal deposited by ERFe-6 electrodes is air hardening and is machinable only after annealing.

A7.1.4.2 Applications. Weld deposits may be used for metal-to-metal wear applications at temperatures to 1100°F [600°C]. Typical applications combine high-temperature service with moderate abrasion and severe metal-to-metal wear.

A7.1.5 ERFe-8 Electrodes and Rods

A7.1.5.1 Characteristics. Weld metal deposited by ERFe-8 electrodes and rods is similar to an H12 hot work tool steel with an as-deposited hardness of 54–60 HRC. The microstructure consists of martensite plus alloy carbides to produce a tough, hard deposit on either carbon or low-alloy steel base metal. Proper preheating (consult the manufacturer) is essential to ensure crack-free deposits. The deposit may be finished by grinding.

A7.1.5.2 Applications. This composition is used for overlaying surfaces subjected to moderate abrasive wear with high impact. Applications typically include machine tools and components subject to sliding metal-to-metal wear.

A7.1.6 ERFeMn Series Electrodes and Rods (except ERFeMnCr)

A7.1.6.1 Characteristics. Deposits made with these electrodes and rods nominally contain 14% manganese, although they may vary from 12% to 22%. This is an amount sufficient to yield austenitic weld deposits. Austenite is a nonmagnetic, tough form of steel. To preserve the toughness, excessive heat must be avoided during welding. Stringer beads and skip welding are recommended. The additions of other alloys, such as 4% nickel, are made to give more stability to the austenite. Chromium and molybdenum can also be added to increase the yield strength. Abrasion resistance is only a little better than that of low-carbon steel unless there has been sufficient impact to cause work hardening. As deposited, surfaces generally are no harder than 20 HRC, but can work harden to 55 HRC. Deposits are difficult to machine; grinding is preferred for finishing.

Weld metal deposited by ERFeMn-F electrodes differ from the other austenitic manganese classifications in that a one layer deposit will be fully austenitic when deposited on carbon steel or low-alloy steel base metal. This is the direct result of the higher carbon and manganese contents of the filler metal.

A7.1.6.2 Applications. These electrodes are used for the rebuilding, repair, and joining of austenitic manganese steels. Ability to absorb high impact makes such deposits ideal for rebuilding of worn rock-crushing equipment and parts subject to impact loading such as railroad frogs.

A7.1.7 ERFeMnCr Electrodes and Rods

A7.1.7.1 Characteristics. Weld metal deposited by ERFeMnCr electrodes have similar characteristics to those of the austenitic manganese deposits. The high-chromium content improves the stability of austenite when compared to ERFeMn deposits. These deposits cannot be flame cut, and care must be taken in application to avoid heat build-up.

A7.1.7.2 Applications. Like ERFeMn-type electrodes and rods, ERFeMnCr electrodes and rods are used for rebuilding, repair, and joining of equipment made from austenitic manganese steels. ERFeMnCr electrodes and rods offer the added advantage of being usable for joining austenitic manganese steel both to itself and to carbon steel. ERFeMnCr weld metals often are used as a base for surfacing with ERFeCr-AX(X) types for parts subject to both abrasion and impact.

A7.1.8 ERFeCr-A Electrodes and Rods

A7.1.8.1 Characteristics. Weld metal deposited by these electrodes and rods will contain moderate amounts of chromium carbides in a high-carbon austenitic matrix. Two layers are recommended to maintain uniform hardness and deposit composition. Additional layers may be prone to spalling and should be applied with caution. The deposit provides greater impact resistance but decreased abrasion resistance as compared to other ERFeCr-X(X) classifications. The deposits should be ground if finishing is required as they are not readily machined or flame cut. Weld metal deposited by ERFeCr-A electrodes may be applied to carbon, low-alloy, austenitic manganese steel, and austenitic stainless steel base metals.

A7.1.8.2 Applications. A general purpose hardfacing alloy which can be used where limited stress-relief cracks (checks) are acceptable but severe abrasion is not encountered.

A7.1.9 ERFeCr-A1A and ERFeCr-A4 Electrodes and Rods

A7.1.9.1 Characteristics. Weld metal deposited by these electrodes and rods will contain massive chromium carbides in an austenitic matrix providing excellent wear resistance and fair toughness. Surface checks are normal and give a degree of stress relief. Deposits cannot be machined and must be ground when finishing is required. To achieve the desired composition, a minimum of two layers is usually recommended. Additional layers may be prone to spalling and must be applied with caution. These electrodes are suitable for welding on carbon, low-alloy, and austenitic steels and cast irons. The weld metal deposited by ERFeCr-AlA electrodes generally provides greater impact resistance than ERFeCr-A4.

A7.1.9.2 Applications. Typical applications include bucket lips and teeth, impact hammers, and conveyors used for crushing and transporting rock, ore, etc. Very low coefficients of friction develop as a result of scouring by earth products.

A7.1.10 ERFeCr-A3A Electrodes and Rods

A7.1.10.1 Characteristics. The microstructure of weld metal deposited by ERFeCr-A3A electrodes and rods resembles that of white cast iron. The deposit has higher toughness than weld metal deposited by ERFeCr-A1A, ERFeCr-A4, ERFeCr-A9, or ERFeCr-A10 electrodes, but is accompanied by a reduction in abrasion resistance.

A7.1.10.2 Applications. This weld metal is a general-purpose hardfacing alloy typically used as a final overlay on roll crushers, hammer mill hammers, and cone crushers over a build-up of austenitic manganese steel material.

A7.1.11 ERFeCr-A5 Electrodes and Rods

A7.1.11.1 Characteristics. The weld deposit contains chromium carbide in an austenitic matrix. The nonmagnetic weld metal has fair machinability. Build-up should be restricted to three layers to minimize relief checking.

A7.1.11.2 Applications. Components surfaced with these electrodes and rods are frequently used for applications involving metal-to-metal friction wear or earth scouring under low-stress abrasive conditions.

A7.1.12 ERFeCr-A9 Electrodes and Rods

A7.1.12.1 Characteristics. The deposit contains hexagonal chromium carbides in an austenitic matrix with a hardness of 50–60 HRC. Deposits develop relief checks. The weld metal may be applied on carbon or low-alloy steel, austenitic manganese steel, or austenitic stainless steel base metal.

A7.1.12.2 Applications. These electrodes are frequently used for applications involving abrasive wear combined with moderate impact.

A7.1.13 ERFeCr-A10 Electrodes and Rods

A7.1.13.1 Characteristics. Weld metal deposited by these electrodes and rods contains massive hexagonal carbides in an austenite-carbide matrix. The deposit has a hardness of 58–63 HRC which is maintained to a temperature of 1400°F [760°C]. The deposit cannot be flame cut. Finishing is by grinding only.

The composition provides the ultimate in low stress abrasion resistance, but with reduced impact resistance. Deposit thickness should not exceed two layers.

A7.1.13.2 Applications. Deposits of this type may be used in the most severe abrasive applications that involve minimal impact. Typical applications include coal pulverizing and handling equipment, glass sand handling equipment, and certain high-temperature applications.

A7.2 Cobalt Base Electrodes and Rods

A7.2.1 ERCoCr-A Electrodes and Rods

A7.2.1.1 Characteristics. Weld metals deposited by ERCoCr-A electrodes and rods are characterized by a hypoeutectic structure, consisting of a network of about 13% eutectic chromium carbides distributed in a cobalt-chromium-tungsten solid solution matrix. The result is a material with a combination of overall resistance to low stress abrasive wear, with the necessary toughness to resist some degree of impact. Cobalt alloys also are inherently good for resisting metal-to-metal wear, particularly in high load situations that are prone to galling. The high-alloy content of the matrix also affords excellent resistance to corrosion, oxidation, and elevated temperature retention of hot hardness up to a maximum of 1200°F [650°C]. These alloys are not subject to allotropic transformation and therefore do not lose their properties if the base metal is subsequently heat treated.

A7.2.1.2 Applications. The alloy is recommended for cases where wear is accompanied by elevated temperatures and where corrosion is involved, or both. Some typical applications are automotive and fluid flow valves, chain saw guides, hot punches, shear blades, and extruder screws.

A7.2.2 ERCoCr-B Electrodes and Rods

A7.2.2.1 Characteristics. Weld metal deposited by ERCoCr-B electrodes and rods is similar in composition to deposits made using ERCoCr-A electrodes and rods except for a slightly higher percentage (approximately 16%) of carbides. The alloy also has a slightly higher hardness and better abrasive and metal-to-metal wear resistance. Impact and corrosion resistance are lowered slightly. Deposits can be machined with carbide tools.

A7.2.2.2 Applications. ERCoCr-B electrodes and rods are used interchangeably with ERCoCr-A electrodes and rods. Choice will depend on the specific application.

A7.2.3 ERCoCr-C Electrodes and Rods

A7.2.3.1 Characteristics. This alloy has a higher percentage (approximately 19%) of carbides than deposits made using either ERCoCr-A or ERCoCr-B class. In fact, the composition is such that primary hypereutectic carbides are found in the microstructure. This characteristic gives the alloy higher wear resistance accompanied by reductions in the impact and corrosion resistance. The higher hardness also means a greater tendency to check during cooling. The checking tendency may be minimized by closely monitoring preheating, interpass temperature, and postheating techniques.

While the cobalt-chromium deposits soften somewhat at elevated temperatures, they normally are considered immune to tempering.

A7.2.3.2 Applications. Weld metal deposited by ERCoCr-C electrodes and rods is used to build-up items such as mixers, rotors, or wherever harsh abrasion and low impact are encountered.

A7.2.4 ERCoCr-E Electrodes and Rods

A7.2.4.1 Characteristics. Welds made using ERCoCr-E electrodes and rods have very good strength and ductility in temperatures up to 2100°F [1150°C]. Deposits are resistant to thermal shock and oxidizing and reducing atmospheres. Early applications of these types of alloys were found in jet engine components such as turbine blades and vanes.

The deposit is a solid solution strengthened alloy with a relatively low weight-percent carbide phase in the microstructure. Hence, the alloy is very tough and will work harden. Deposits possess excellent self-mated galling resistance and also are very resistant to cavitation erosion.

A7.2.4.2 Applications. Welds made using ERCoCr-E electrodes and rods are used where the resistance to thermal shock is important. Typical applications, similar to those of deposits made using ERCoCr-A electrodes and rods, include guide rolls, hot extrusion and forging dies, hot shear blades, tong bits, valve trim, etc.

A7.2.5 ERCoCr-F Electrodes and Rods

A7.2.5.1 Characteristics. ERCoCr-F differs from the other cobalt chrome tungsten alloys due to the addition of over 20% nickel. This alloy was developed to impart additional oxidation and corrosion resistance, especially where lead additives are made to automotive engine fuels. Other properties, such as hot hardness, metal-to-metal wear resistance, and thermal fatigue, are similar to type ERCoCr-A type deposits.

A7.2.5.2 Applications. ERCoCr-F is used almost exclusively on automotive (gasoline) exhaust valves, especially on air-cooled (higher operating temperature) engines. Most surfacing is done with automatic equipment by the original equipment manufacturer, and very little by the maintenance market. Both oxyfuel gas welding (OFW) and gas tungsten arc welding (GTAW) are used.

A7.2.6 ERCoCr-G Electrodes and Rods

A7.2.6.1 Characteristics. ERCoCr-G is a higher carbon and tungsten version of ERCoCr-C that imparts excellent abrasion resistance under high loads. The increase in the volume fraction of primary carbides also increases the average hardness and adhesive wear resistance. This type of material is sensitive to cracking in the weld deposits and therefore, preheat and interpass temperatures as well as cooling rate must be closely controlled.

A7.2.6.2 Applications. ERCoCr-G is used extensively on bearing areas of tri-cone type drilling tools. Application is typically by manual or automated gas tungsten arc welding (GTAW) and oxyfuel gas welding (OFW).

A7.2.7 Typical hardness values for multilayer welds made using cobalt base electrodes and rods are as follows:

CoCr-A	23–47 HRC
CoCr-B	34–47 HRC
CoCr-C	43–58 HRC
CoCr-E	20–35 HRC
CoCr-F	32–46 HRC
CoCr-G	52–60 HRC

A7.3 Nickel Base Electrodes and Rods

A7.3.1 ERNiCr-A, -B, and -C Electrodes and Rods

A7.3.1.1 Characteristics. Undiluted weld metals of these compositions exhibit a structure consisting of borides and chromium carbides in a nickel-rich matrix. The nickel-base and high-chromium content gives these deposits good heat and corrosion resistance. Care should be taken when cooling these deposits because of a tendency to stress crack. These alloys possess excellent resistance to low-stress abrasion which increases with increasing boron content in the deposit.

Weld metal deposited by these electrodes and rods flows very easily, has very high abrasion resistance, and normally takes on a high polish.

The deposits have high corrosion resistance and normally require grinding for finishing. Single-layer deposits typically have hardness between 35 and 45 HRC. Multilayer deposits typically have hardness between 49 and 56 HRC.

A7.3.1.2 Applications. Typical applications include cultivator sweeps, plow shares, extrusion screws, pump sleeves, pistons, impellers, capstan rings, glass mold faces, centrifuge filters, and sucker pump rods.

A7.3.2 ERNiCrMo-5A Electrodes and Rods

A7.3.2.1 Characteristics. Weld metal of this composition is a solid solution strengthened alloy with a relatively low weight-percent carbide phase. The resultant deposit is tough and work hardening.

Deposits have the ability to retain hardness to 1400°F [760°C]. Deposits are machinable with high-speed tool bits and have excellent resistance to high-temperature wear and impact.

A7.3.2.2 Applications. These electrodes are used to rebuild and repair hot extrusion and forging dies, sizing punches, hot shear blades, guide rolls, tong bits, blast furnace bells, etc.

A7.3.3 ERNiCrFeCo Electrodes and Rods

A7.3.3.1 Characteristics. Filler metal deposited by these electrodes is a nickel-chromium-iron-cobalt base alloy containing a fairly large volume fraction of hypereutectic chromium carbides distributed throughout the microstructure. The alloy offers many of the same high performance characteristics of deposits made using ERCoCr-C or ERNiCr-C electrodes or rods in terms of abrasive wear resistance. The reduced content of nickel or cobalt, or both, lowers corrosion properties and galling resistance. The high volume fraction of carbides makes this alloy sensitive to cracking during cooling.

Hardness values for single layer deposits will be lower because of dilution from the base metal.

A7.3.3.2 Applications. Welds made using ERNiCrFeCo electrodes or rods are preferred where high abrasion with low impact is a major factor. Typical applications are feed screws, slurry pumps, and mixer components.

A7.3.4 ERNiCr-D and E Electrodes and Rods

A7.3.4.1 Characteristics. Undiluted weld metals of these compositions with Si/B greater than 3.3 exhibit a structure consisting of a nickel solid solution, a binary eutectic of nickel solid solution and nickel silicide; and a ternary eutectic of nickel solid solution, nickel silicide, and nickel boride. There are also carbide and boride particles dispersed in the matrix. The microstructures differ from those of ERNiCr-A, B, and C in that the brittle binary eutectic of nickel solid solution and nickel boride does not form, thus improving the cracking resistance during welding.

A7.3.4.2 Applications. Welds of these compositions are used for hardfacing the trims of fluid control valves. In the nuclear industry, they are used to replace cobalt-containing weld overlays in order to reduce the cobalt content in the process stream.

A7.4 Copper Base Electrodes and Rods

A7.4.1 Introduction. The copper base solid welding materials classified by this specification are used to deposit overlays for bearings and wear-resistant surfaces and to resist corrosion.

A7.4.1.1 ERCuAl-A2 filler metal is used for building up bearing surfaces between the hardness range of 130–150 HB. It is also used for wear-resistant surfaces as well as for corrosion-resistant surfaces subject to saltwater and many commonly used acids.

A7.4.1.2 ERCuAl-A3 filler metal deposits produce a deposit of high strength and good ductility with a nominal hardness of 166 HB. This alloy is ideal for bearing surfaces requiring high strength and good ductility such as for a forge press piston.

A7.4.1.3 ERCuAl-C, ERCuAl-D, ERCuAl-E, filler metals have excellent wear-resisting characteristics and are used where extreme wear and high pressure are encountered in service. ERCuAl-D and ERCuAl-E are also used for fabricating new or rebuilding worn ferrous dies used for forming or drawing titanium, and low-carbon and stainless steel. These alloys are not recommended for corrosion. Typical hardness levels for ERCuAl-C, ERCuAl-D and ERCuAl-E are 250–290 HB, 310–350 HB, and 340–380 HB, respectively.

A7.4.1.4 ERCuSi-A (copper-silicon) filler metal is used primarily for corrosion-resistant surfaces. Copper silicon deposits are generally not suited for bearing service applications.

A7.4.1.5 ERCuSn-A, ERCuSn-D (copper-tin) filler metal is primarily used to build-up bearing surfaces where lower hardness is required. This alloy is used for corrosion-resistant surfaces, and occasionally, for wear-resistance applications. The higher tin content of ERCuSn-D weld deposits has improved wear resistance but also has increased hot shortness of the alloys.

A7.4.2 Applications

A7.4.2.1 Hot Hardness. The copper base filler metals are not recommended for use at elevated temperatures. Mechanical properties will generally degrade as the temperature increases above 400°F [200°C]

A7.4.2.2 Abrasion. Copper-base weld deposits are not recommended for use where severe abrasion is encountered in service.

A7.4.2.3 Metal to Metal Wear. Bearing surface overlays are often designed with preferential wear requirements. To do this with copper-base alloys, select a material that will result in a weld deposit of 50–75 points Brinell softer than the mating surface. This will assure a preferential wear system.

A7.4.2.4 Machinability. All of the copper-base weld deposits are machinable.

A7.4.2.5 Preparation and Welding Characteristics. The base metal should be machined or ground prior to application of the first pass. The weld deposits should be wire brushed or ground between passes. The first pass should be applied at the low end of amperage to minimize dilution. Excessive base metal dilution can result in reduced machinability and service performance. The manufacturer should be consulted for specific welding parameters.

A7.4.2.6 Preheat. Preheating may be desirable depending on the base metal to be overlaid. Generally, no preheat is necessary on low carbon steel. Medium-to-high carbon steel may require 300°F–600°F [150°C–315°C] preheat, depending on the carbon content. On subsequent layers, an interpass temperature of 500°F [260°C] should not be exceeded. The manufacturer should be consulted for complicated overlays.

A7.5 Tungsten Carbide Electrodes and Rods

A7.5.1 Characteristics. Tungsten carbide electrodes and rods classified in this specification contain 60% by weight of tungsten carbide particles. The WC1 carbide is a mixture of WC and W_2C. The WC2 carbide is macrocrystalline WC. Hardness of the matrix of the deposit can be varied from 30–60 HRC depending on welding technique. Hardness of individual carbide particles typically is about 2400 HV20.

Abrasion resistance of tungsten carbide deposits is outstanding.

A7.5.2 Applications. Tungsten carbide deposits are applied on surfaces subject to sliding abrasion combined with a limited amount of impact. Such applications are encountered in earth drilling, digging, and farming. Specific tools that may require this type of a surfacing overlay include oil drill bits and tool joints, earth handling augers, excavator teeth, farm fertilizer applicator knives, and cultivator shares.

A8. Suggested Methods for Preparation of Fused Samples for Analysis

A8.1 The determination of the chemical composition of the as-manufactured solid bare electrodes and rods presents no technical difficulties. The filler metal, in the form of a solid wire, may be subdivided for analysis by any convenient method, and all samples or chips will be representative of the lot of filler metal. Difficulties are encountered in obtaining a representative sample of metal cored and flux cored composite (tubular) electrodes and rods. Some filler metal of the composite type is in the form of a tubular wire, the core of which is filled with a mixture of particles, often unbonded. Samples obtained by merely cutting or subdividing the composite type of filler metal may not prove representative of the filler metal due to the possible loss of some of the core material at the ends of the sample. Therefore, the sheath and core of composite-type welding electrodes and welding rods must be combined before a sample representative of the filler metal can be obtained. To accomplish this, the specification requires the preparation of an essentially homogeneous fused sample of the metal cored electrode or rod and a weld metal pad of the flux cored composite (tubular) electrode or rod. These samples can then be subdivided by routine methods.

A8.2 Preparation of a fused sample by gas tungsten arc welding using argon or helium shielding gas will transfer essentially all of the components of the composite-type welding rods through the arc. Some slight loss in carbon will occur, but such loss will never be greater than would be encountered in an actual welding operation, regardless of process. Nonmetallic ingredients, if present in the core, will form a slag on the top of the deposit which must be removed and discarded. The specification classifies the filler metals only on the basis of metallic chemical composition. Gas tungsten arc welded fused samples should not be prepared using composite tubular electrodes of the self-shielded type as the formation of reactive gases will cause instabilities in the arc.

A8.3 The sample of fused filler metal must be large enough to provide the amount of undiluted material required by the chemist for analysis. No size or shape of deposited pads has been specified because these are immaterial if the deposit is truly undiluted.

A8.4 A sample made using the composite type filler metal which has been fused in a copper mold will be undiluted since there will be essentially no admixture with base metal.

A8.5 A sample made using the composite type filler metal deposited on a steel base plate, Figure 1, will become diluted and contaminated by admixture with the base metal. Such a deposit will have to be multilayered to overcome this dilution. To ensure an undiluted sample, the pad will need to be 1/2 in [13 mm] minimum height for electrode diameters 0.045 in–1/16 in [1.2 mm–1.6 mm], 5/8 in [16 mm] minimum height for electrode diameters 5/64 in–0.120 in [2.0 mm–3.0 mm], and 3/4 in [19 mm] minimum height for larger electrode sizes.

A8.6 Assurance that an undiluted sample is being obtained from the chosen size of pad at the selected distance above the base can be obtained by analyzing chips removed from successively lower layers of the pad. Layers which are undiluted will all have the same chemical composition. Therefore, the determination of identical compositions for two successive layers of deposited filler metal will provide evidence that the last layer is undiluted.

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 used in the specification. The classifications that have been discontinued are listed in Table A.1, along with the year 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 and below. Safety and health information is available from other sources, including but not limited to ANSI Z49.1, and applicable federal and state regulations.

Table A.1
Discontinued and Transferred Electrode and Rod Classifications[a]

AWS Classification	Last A5.21 Publication Date
RFe5-A	1980
RFe5-B	1980
RFeCr-A1	1980
EFe5-A	1980
EFe5-B	1980
EFe5-C	1980
EFeMn-A[b]	1980
EFeMn-B[b]	1980
EFeCr-A1	1980
RWC-5/8	1980
RWC-8/12	1980
RWC-12/20	1980
RWC-30	1980
EWC-12/30[c]	1980
EWC-20/30[c]	1980
EWC-30/40[c]	1980
EWC-40[c]	1980
EWC-40/120[c]	1980

[a] See Clause A9, Discontinued Classifications (in Annex A), for information on discontinued classifications.

[b] These AWS classifications have been transferred to AWS A5.13 without a change in classification designation.

[c] These AWS classifications have been transferred to AWS A5.13 with a change in classification to EWCX-X/X.

A10.2 ***Safety and Health Fact Sheets.*** *The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.*

A10.3 *AWS Safety and Health Fact Sheet Index (SHF)*[8]

No.	*Title*
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding & Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Arc Viewing Distance*
27	*Thoriated Tungsten Electrodes*
28	*Oxyfuel Safety: Check Valves and Flashback Arrestors*
29	*Grounding of Portable and Vehicle Mounted Welding Generators*
30	*Cylinders: Safe Storage, Handling, and Use*
31	*Eye and Face Protection for Welding and Cutting Operations*
33	*Personal Protective Equipment (PPE) for Welding & Cutting*
34	*Coated Steels: Welding and Cutting Safety Concerns*
36	*Ventilation for Welding & Cutting*
37	*Selecting Gloves for Welding & Cutting*

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

SPECIFICATION FOR STAINLESS STEEL FLUX CORED AND METAL CORED WELDING ELECTRODES AND RODS

(15)

SFA-5.22/SFA-5.22M

(Identical with AWS Specification A5.22/A5.22M:2012. In case of dispute, the original AWS text applies.)

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

1. Scope

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

The chromium content of undiluted weld metal from these electrodes and rods is not less than 10.5% nominal and the iron content exceeds that of any other element. For purposes of classification, the iron content shall be derived as the balance element when all other elements are considered to be set at their specified minimum values.

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

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

2. Normative References

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

2.1 The following AWS standards[2] are referenced in the mandatory sections of this document:

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

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

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

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

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

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

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

2.2 The following ANSI standard[3] is referenced in the mandatory sections of this document.

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

2.3 The following ASTM standards[4] are referenced in the mandatory sections of this document:

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

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

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

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

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

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

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

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

2.4 The following ISO standard[5] is referenced in the normative sections of this document:

ISO 80000-1, *Quantities and units*

3. Classification

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

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

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

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

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

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

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

AWS Classification[c]	UNS Number[d]	Weight Percent[a, b]											
		C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si	P	S	N	Cu	Other[e]
E307TX-X	W30731	0.13	18.0–20.5	9.0–10.5	0.5–1.5	—	3.30–4.75	1.0	0.04	0.03	—	0.75	—
E308TX-X	W30831	0.08	18.0–21.0	9.0–11.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308HTX-X	W30831	0.04–0.08	18.0–21.0	9.0–11.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308LTX-X	W30835	0.04	18.0–21.0	9.0–11.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308MoTX-X	W30832	0.08	18.0–21.0	9.0–11.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E308LMoTX-X	W30838	0.04	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309TX-X	W30931	0.10	22.0–25.0	12.0–14.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309HTX-X	W30931	0.04–0.10	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309LTX-X	W30935	0.04	22.0–25.0	12.0–14.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309MoTX-X	W30939	0.12	21.0–25.0	12.0–16.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309LMoTX-X	W30938	0.04	21.0–25.0	12.0–16.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309LNiMoTX-X	W30936	0.04	20.5–23.5	15.0–17.0	2.5–3.5	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E309LNbTX-X	W30932	0.04	22.0–25.0	12.0–14.0	*0.75*	0.70–1.00	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E310TX-X	W31031	0.20	25.0–28.0	20.0–22.5	*0.75*	—	1.0–2.5	1.0	0.03	0.03	—	0.75	—
E312TX-X	W31331	0.15	28.0–32.0	8.0–10.5	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E316TX-X	W31631	0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E316HTX-X	W31631	0.04–0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5-2.5	1.0	0.04	0.03	—	0.75	—
E316LTX-X	W31635	0.04	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E317LTX-X	W31735	0.04	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	1.0	0.04	0.03	—	0.75	—
E347TX-X	W34731	0.08	18.0–21.0	9.0–11.0	0.75	8 × C min. – 1.0 max.	0.5–2.5	1.0	0.04	0.03	—	0.75	
E347HTX-X	W34731	0.04–0.08	18.0–21.0	9.0–11.0	0.75	8 × C min. – 1.0 max.	0.5–2.5	1.0	0.04	0.03	—	0.75	
E409TX-X	W40931	0.10	10.5–13.5	0.60	*0.75*	—	0.80	1.0	0.04	0.03	—	0.75	Ti =10 × C min. – 1.5 max.
E409NbTX-X	W40957	0.10	10.5–13.5	0.6	0.5	8 × C min. – 1.5 max.	1.2	1.0	0.04	0.03	—	0.5	—

(Continued)

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

AWS Classification[c]	UNS Number[d]	Weight Percent[a, b]											
		C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si	P	S	N	Cu	Other[e]
E410TX-X	W41031	0.12	11.0–13.5	0.60	0.75	—	1.2	1.0	0.04	0.03	—	0.75	—
E410NiMoTX-X	W41036	0.06	11.0–12.5	4.0–5.0	0.40–0.70	—	1.0	1.0	0.04	0.03	—	0.75	—
E430TX-X	W43031	0.10	15.0–18.0	0.60	0.75	—	1.2	1.0	0.04	0.03	—	0.75	—
E430NbTX-X	W43057	0.10	15.0–18.0	0.6	0.5	0.5–1.5	1.2	1.0	0.04	0.03	—	0.5	—
E2209TX-X	W39239	0.04	21.0–24.0	7.5–10.0	2.5–4.0	—	0.5–2.0	1.0	0.04	0.03	0.08–0.20	0.75	—
E2307TX-X	*S82371*	*0.04*	*22.5–25.5*	*6.5–10.0*	*0.8*	—	*2.0*	*1.0*	*0.03*	*0.02*	*0.10–0.20*	*0.50*	—
E2553TX-X	W39533	0.04	24.0–27.0	8.5–10.5	2.9–3.9	—	0.5–1.5	0.75	0.04	0.03	0.10–0.25	1.5–2.5	—
E2594TX-X	W39594	0.04	24.0–27.0	8.0–10.5	2.5–4.5	—	0.5–2.5	1.0	0.04	0.03	0.20–0.30	1.5	W=1.0
EGTX-X[g]		Not Specified											
E307T0–3	W30733	0.13	19.5–22.0	9.0–10.5	0.5–1.5	—	3.30–4.75	1.0	0.04	0.03	—	*0.75*	—
E308T0-3	W30833	0.08	19.5–22.0	9.0–11.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E308HT0-3	W30833	0.04–0.08	19.5–22.0	9.0–11.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E308LT0-3	W30837	0.04	19.5–22.0	9.0–11.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E308MoT0-3	W30839	0.08	18.0–21.0	9.0–11.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E308HMoT0-3	W30830	0.07–0.12	19.0–21.5	9.0–10.7	1.8–2.4	—	1.25–2.25	0.25–0.80	0.04	0.03	—	*0.75*	—
E308LMoT0-3	W30838	0.04	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E309T0-3	W30933	0.10	23.0–25.5	12.0–14.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E309LT0-3	W30937	*0.04*	23.0–25.5	12.0–14.0	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E309MoT0-3	W30939	0.12	21.0–25.0	12.0–16.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E309LMoT0-3	W30938	0.04	21.0–25.0	12.0–16.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E309LNbT0-3	W30934	*0.04*	23.0–25.5	12.0–14.0	*0.75*	0.70–1.00	0.5–2.5	1.0	0.04	0.03	—	*0.75*	
E310T0-3	W31031	0.20	25.0–28.0	20.0–22.5	*0.75*	—	1.0–2.5	1.0	0.03	0.03	—	*0.75*	—
E312T0-3	W31231	0.15	28.0–32.0	8.0–10.5	*0.75*	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E316T0-3	W31633	0.08	18.0–20.5	11.0–14.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E316LT0-3	W31637	0.04	18.0–20.5	11.0–14.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E316LKT0-3[f]	W31630	0.04	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—

(Continued)

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

AWS Classification[c]	UNS Number[d]	Weight Percent[a, b]											
		C	Cr	Ni	Mo	Nb Plus Ta	Mn	Si	P	S	N	Cu	Other[e]
E317LT0-3	W31737	*0.04*	18.5–21.0	13.0–15.0	3.0–4.0	—	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E347T0-3	W34733	0.08	19.0–21.5	9.0–11.0	*0.75*	8 × C min. – 1.0 Max.	0.5–2.5	1.0	0.04	0.03	—	*0.75*	—
E409T0-3	W40931	0.10	10.5–13.5	0.60	*0.75*	—	0.80	1.0	0.04	0.03	—	*0.75*	Ti = 10 × C min. – 1.5 max.
E410T0-3	W41031	0.12	11.0–13.5	0.60	*0.75*	—	1.0	1.0	0.04	0.03	—	0.75	—
E410NiMoT0-3	W41036	0.06	11.0–12.5	4.0–5.0	0.40–0.70	—	1.0	1.0	0.04	0.03	—	0.75	—
E430T0-3	W43031	0.10	15.0–18.0	0.60	*0.75*	—	1.0	1.0	0.04	0.03	—	0.75	—
E2209T0-3	W39239	0.04	21.0–24.0	7.5–10.0	2.5–4.0	—	0.5–2.0	1.0	0.04	0.03	0.08–0.20	0.75	—
E2307T0-3	*S82371*	*0.04*	*22.5–25.5*	*6.5–10.0*	*0.8*	—	*2.0*	*1.0*	*0.03*	*0.02*	*0.10–0.20*	*0.50*	—
E2553T0-3	W39533	0.04	24.0–27.0	8.5–10.5	2.9–3.9	—	0.5–1.5	0.75	0.04	0.03	0.10–0.25	1.5–2.5	—
E2594T0-3	W39594	0.04	24.0–27.0	8.0–10.5	2.5–4.5	—	0.5–2.5	1.0	0.04	0.03	0.20–0.30	1.5	W = 1.0
EGTX-3[g]		Not Specified											
R308LT1-5	W30835	0.03	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.2	0.04	0.03	—	*0.75*	—
R309LT1-5	W30935	0.03	22.0–25.0	12.0–14.0	*0.75*	—	0.5–2.5	1.2	0.04	0.03	—	*0.75*	—
R316LT1-5	W31635	0.03	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.2	0.04	0.03	—	*0.75*	—
R347T1-5	W34731	0.08	18.0–21.0	9.0–11.0	0.75	8 × C min. – 1.0 max.	0.5–2.5	1.2	0.04	0.03	—	*0.75*	—
RGT1-5[g]		Not Specified											

[a] The weld metal shall be analyzed for the specific elements in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50%.

[b] Single values shown are maximum.

[c] In this table, the “X” following the “T” refers to the position of welding (1 for all-position operation or 0 for flat or horizontal operation) and the “X” following the dash refers to the shielding medium (-1 or -4) as shown in the AWS Classification column in Table 2).

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

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

[f] This alloy is designed for cryogenic applications.

[g] See A2.2.7 and A2.2.8.

Notes:

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

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

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

(Continued)

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

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

(Continued)

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

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

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

[b] Single values shown are maximum percentages.

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

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

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

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

[g] See A2.2.7 and A2.2.8.

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

Table 2
Required Shielding Medium, Polarity, and Welding Process

AWS Classification[a]	External Shielding Gas[b]	Welding Polarity	Welding Process
EXXXTX-1	CO_2[d]	DCEP	FCAW
EXXXTX-3	none (self-shielded)	DCEP	FCAW
EXXXTX-4	75%–80% Argon/remainder CO_2[e]	DCEP	FCAW
RXXXT1-5	100% Argon[f]	DCEN	GTAW
EXXXTX-G	Not Specified[c]	Not Specified[c]	FCAW
RXXXT1-G	Not Specified[c]	Not Specified[c]	GTAW
ECXXX	Argon with up to 2% O_2[g]	DCEP	GMAW
	100% Argon[f]	DCEN	GTAW

[a] The letters "XXX" stand for the designation of the chemical composition (see Table 1). The "X" after the "T" designates the position of operation. A "0" indicates flat or horizontal operation; a "1" indicates all position operation. Refer to Figure A.1 and Clause A2 for a complete description of this classification system.

[b] The requirement for the use of a specified external shielding gas shall not be construed to restrict the use of any other medium for which the electrodes are found suitable, for any application other than the classification tests.

[c] See A2.2.7 to A2.2.9 for additional information.

[d] AWS A5.32/A5.32M Class C1.

[e] AWS A5.32/A5.32M Class M21.

[f] AWS A5.32/A5.32M Class I1.

[g] AWS A5.32/A5.32M Class I1 or M13.

Table 3
Examples of Potentially Occurring Dual Classified Electrodes

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

4. Acceptance

Acceptance[6] of the material shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

5. Certification

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

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

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

6. Rounding-Off Procedure

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

7. Summary of Tests

The tests required for each classification are specified in Table 4. The purpose of these tests is to determine the chemical composition, the mechanical properties, the usability, and the soundness of the weld metal. The base metal for the weld test assemblies, the welding and testing procedures to be employed and the results required are given in Clauses 9 through 15.

Chemical analysis is required for each size of electrode and rod. The tests for mechanical properties and soundness are conducted on weld metal from the 1/16 in [1.6 mm] size of electrode and rod. In any case in which that size is not manufactured, the size closest to it that is manufactured shall be used for the classification tests. The bend tests are conducted on the largest size manufactured. When required by Table 4, the fillet weld tests shall be conducted on the largest size and smallest size manufactured.

8. Retest

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

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

Table 4
Required Tests

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

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

[b] NR = not required (see A2.2.8)

[c] Impact testing is required when the optional supplemental designator "J" is added to the classification. See Figure A.1.

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

9. Test Assemblies

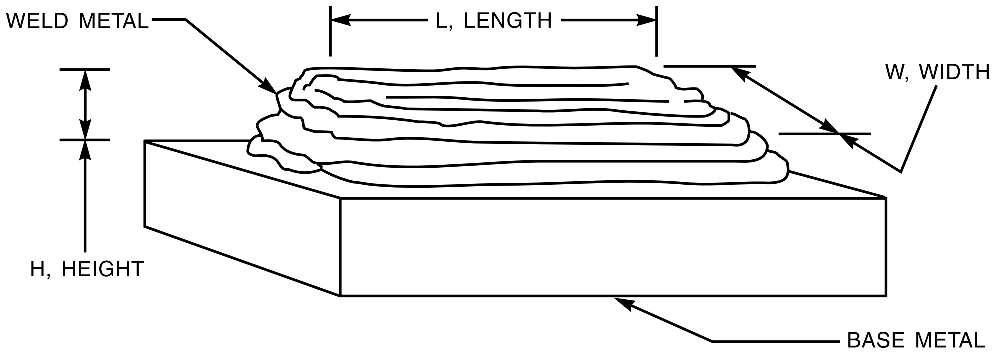
9.1 Between one and four test assemblies are required (according to the classification under test) for the tests specified in Table 4. They are as follows:

(1) The weld pad in Figure 1 for chemical analysis of undiluted weld metal, or a fused sample of a metal cored electrode

(2) The groove weld in Figure 2 for tension, impact, and radiographic testing of the weld metal

(3) The groove weld in Figure 3A for the face bend test, or Figure 3B for the root bend test

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



	Diameter		Weld Pad Size, Minimum						Minimum Distance of Sample from Surface of Base Plate	
			L		W		H			
AWS Classification	in	mm	in	mm	in	mm	in	mm	in	mm
E3XXTX-X E316LKT0-3 E4XXTX-X E2XXXTX-X ECXXX[a]	0.035 0.045 0.052	0.9 1.2 1.4	3	75	3/4	19	1/2	13	3/8	10
	1/16 5/64	1.6 2.0	3	75	3/4	19	5/8	16	1/2	13
	3/32 7/64	2.4 2.8	3-1/2	88	1	25	3/4	19	5/8	16
R3XXT1-5	5/64 0.087 3/32	2.0 2.2 2.4	3	75	3/4	19	3/8	10	1/4	7

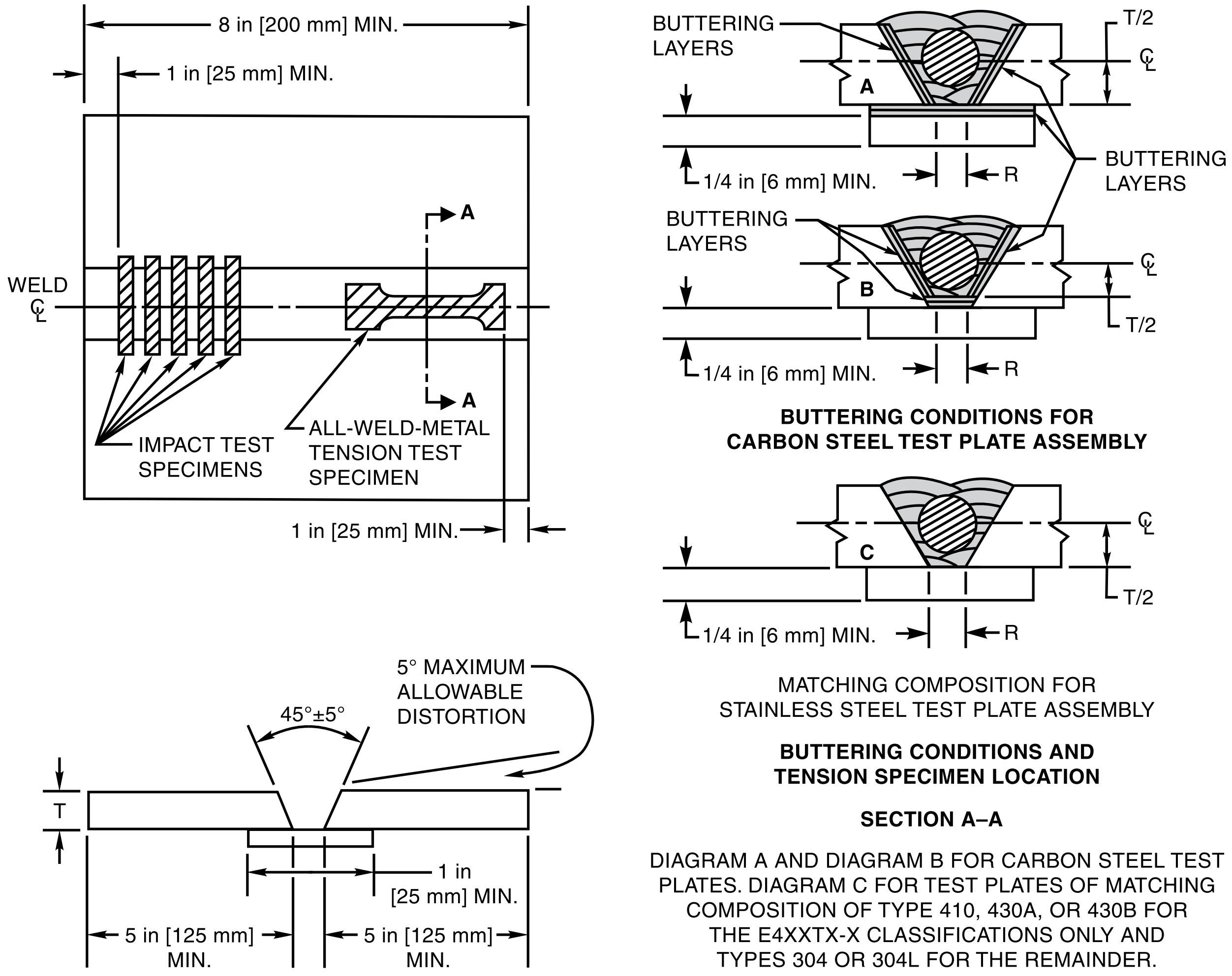
[a] Refer to 10.2 for alternative to the pad for chemical analysis.

Notes:

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

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

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal



BUTTERING CONDITIONS AND TENSION SPECIMEN LOCATION

SECTION A–A

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

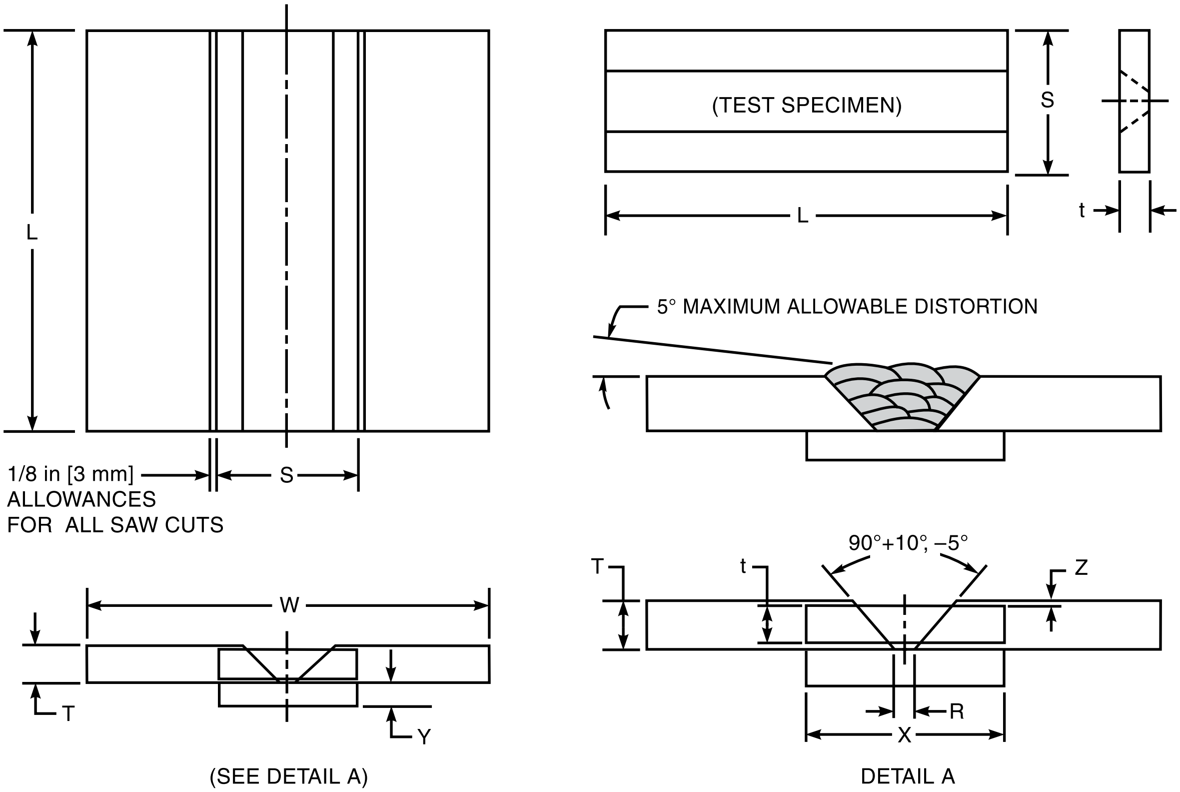
AWS Classification	Diameter		(T) Plate Thickness		(R) Root Openings		Recommended Passes per Layer		Recommended Number of Layers
	in	mm	in	mm	in	mm	Layer 1 and 2	Layer 3 to Top	
E3XXTX-X E316LKT0-3 E4XXTX-X E2XXXTX-X	0.035	0.9	1/2	12	3/8	10	1 or 2	2, 3, or 4	6 to 9
	0.045 0.052 1/16 5/64 3/32	1.2 1.4 1.6 2.0 2.4	3/4	20	3/8	10	1 or 2	2 or 3^{a}	5 to 8
	7/64 1/8 5/32	2.8 3.2 4.0	3/4	20	3/8	10	1 or 2	2 or 3^{a}	4 to 6
R3XXT1-5	5/64 0.087 3/32	2.0 2.2 2.4	1/2	12	1/4	6	1 or 2	2 or 3^{a}	5 to 8

[a] Final layer may be 4 passes.

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

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

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



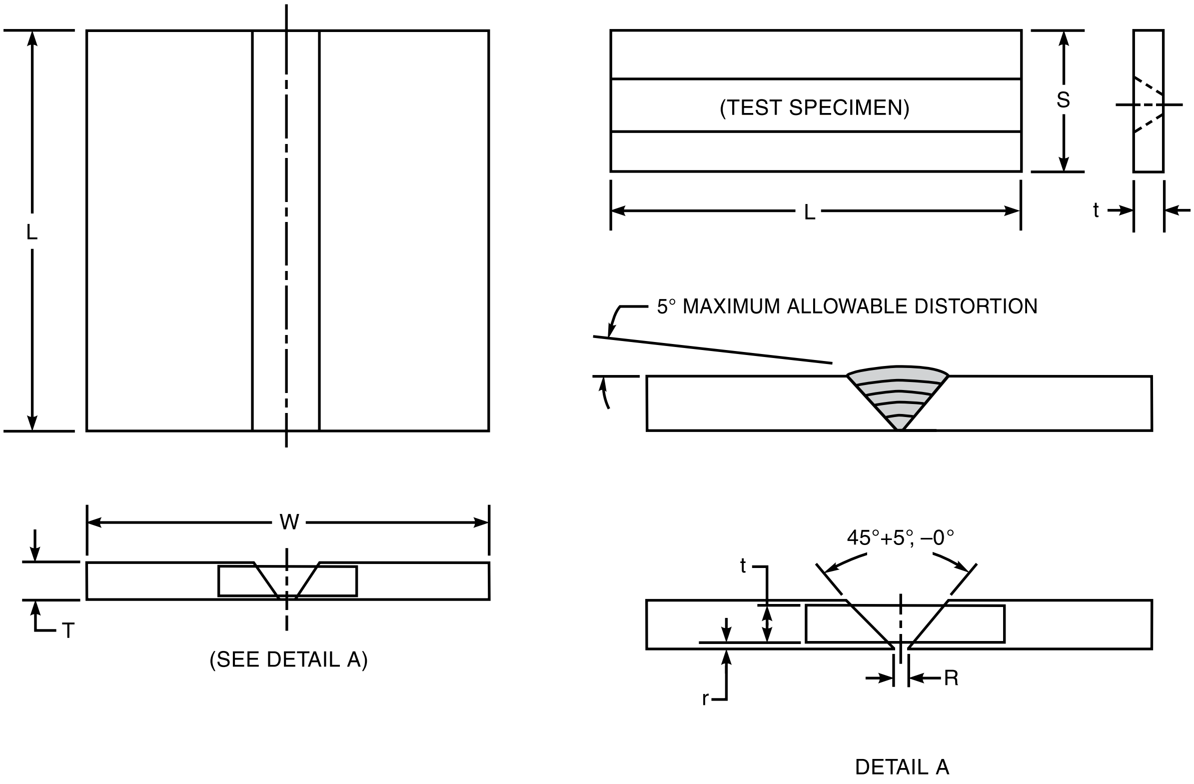
DIMENSIONS			
		in	mm
L	Length	6 min.	150 min.
R	Root opening	1/4 min.	6 min.
S	Specimen Width	2 ± 1/8	50 ± 3
T	Thickness	1/2	12
t	Specimen Thickness	3/8 min.	9.5 min.
W	Width	6 min.	150 min.
X	Backing Bar Width	2 max.	50 max.
Y	Backing Bar Thickness	1/4 min.	6 min.
Z	Specimen Location	1/16 min.	1.5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

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

[a] Top layer must be 2 passes minimum.

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

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



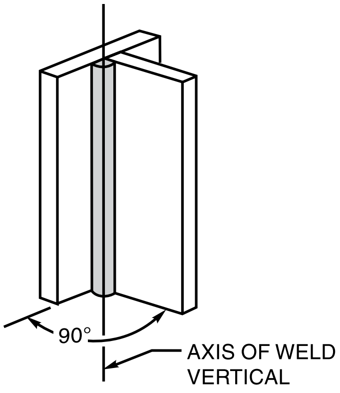
Note: Remove amount of material necessary to clean up root surface. Material removed should not exceed 1/64 in [0.4 mm].

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

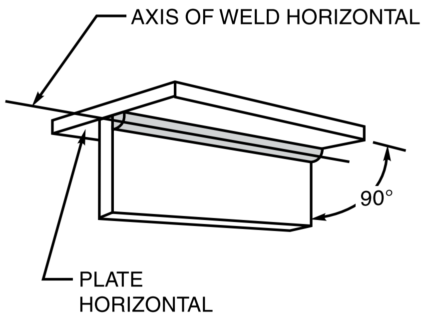
	Diameter		Passes per Layer		
AWS Classification	in	mm	Layer 1	Layer 2	Layer 3 to Completion
R3XXT1-5	5/64 0.087 3/32	2.0 2.2 2.4	1	1	As required

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

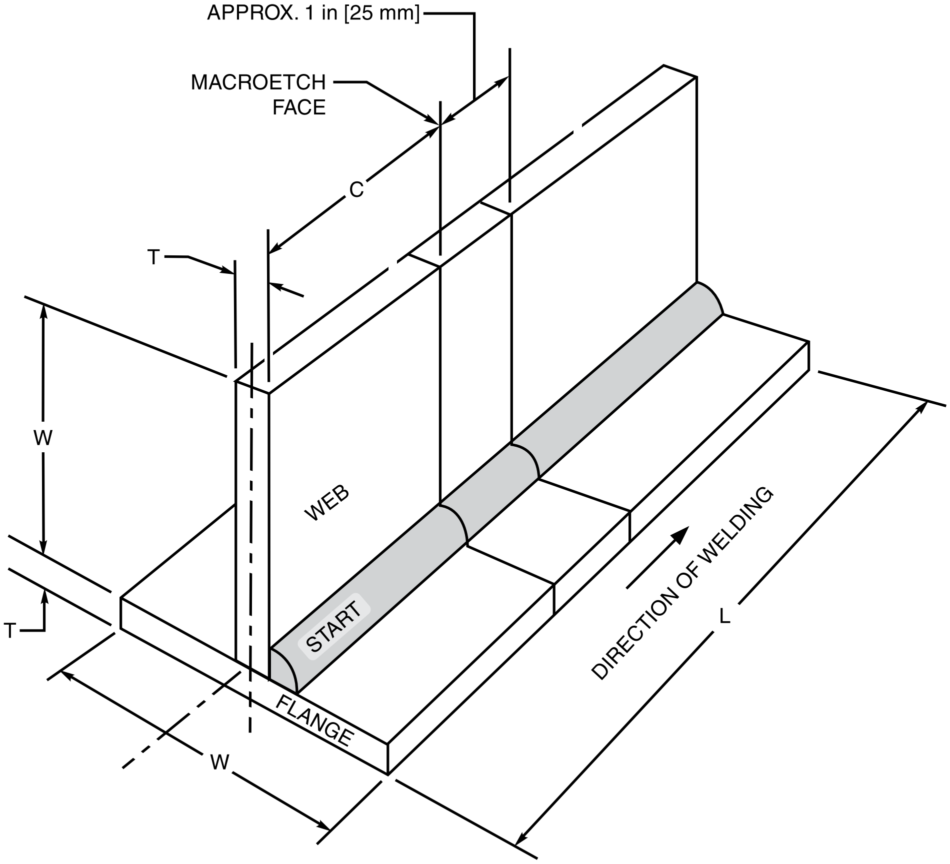
Figure 3B—Groove Weld Test Assembly for Root Bend Test



VERTICAL WELDING TEST POSITION – 3F



OVERHEAD WELDING TEST POSITION – 4F



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

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

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

Figure 4—Preparation of Fillet Weld Test Specimen

The sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the groove weld in Figure 2, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

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

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

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

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

(2) For all other classifications—ASTM A 240, Types 304 or 304L

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

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

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

(1) For E4XXTX-X classifications—ASTM A 240, Types 410, 430A, or 430B

(2) For all other electrode/rod classifications—ASTM A 240, Types 304 or 304L

9.3 Weld Pad

9.3.1 A weld pad shall be prepared as shown in Figure 1 (except when one of the alternatives to a weld pad in 9.1 or one of the methods given in 10.2 is selected). Base metal as specified in 9.2 shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple beads and multiple layers to obtain undiluted weld metal. The preheat temperature shall be not less than 60°F [15°C]. The slag shall be removed after each pass. The amperage or wire feed speed and the arc voltage shall be as recommended by the manufacturer. The shielding medium and polarity shall be as specified in Table 2. The pad may be quenched in water between passes (if the pad is to be used for ferrite determination, see A6.9). The dimensions of the completed pad shall be as shown in Figure 1, for each size of electrode or rod. Testing of this assembly shall be as specified in Clause 10.

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

9.4 Groove Weld

9.4.1 For Mechanical Properties and Soundness

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

9.4.1.2 The test assembly shall be welded in the flat position using the process, shielding medium, and polarity shown in Table 2, and the amperage or wire feed speed and arc voltage recommended by the manufacturer. The test assembly shall be preset or sufficiently restrained during welding to prevent warpage in excess of 5°. A welded test assembly that has warped more than 5° shall be discarded. Welded test assemblies shall not be straightened.

9.4.1.3 The preheat and interpass temperatures shall be as specified in Table 5. These temperatures are measured mid-length of the assembly at a distance of 1 in [25 mm] from the centerline of the weld. These temperatures are also

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

	Temperature			
	Minimum		Maximum	
AWS Classification[a]	°F	°C	°F	°C
E2XXXTX-X	60	15	300	150
E3XXTX-X	60	15	300	150
R3XXT1-5	60	15	300	150
E4XXTX-X[b]	300	150	500	260
EXXXTX-G	Not Specified			

[a] In this table, the "X" following the "T" refers to the position of welding (1 for all-position or 0 for flat or horizontal operation) and the "X" following the dash refers to the shielding medium (-1, -3, or -4) as shown in the AWS Classification.

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

required for all buttering passes. After each pass, the assembly shall be allowed to cool in air (not quenched in water) to a temperature within the range specified in Table 5.

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

9.4.2 Bend Test

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

9.4.2.2 The test assembly shall be welded in the flat position using the shielding medium, polarity, and welding process specified in Table 2, and the amperage or wire feed speed and arc voltage recommended by the manufacturer. The test assembly shall be preset or sufficiently restrained to prevent warpage in excess of 5°. A welded test assembly that has warped more than 5° shall be discarded. Weld test assemblies shall not be straightened.

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

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

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

9.5 Fillet Weld

9.5.1 Fillet weld tests, when required by Table 4, shall be performed in the vertical and overhead positions. A test assembly shall be prepared and welded as shown in Figure 4 using base metal of the appropriate type specified in 9.2, and using the shielding medium and polarity shown in Table 2 and the amperage or wire feed speed and arc voltage recommended by the manufacturer. Testing of the assembly shall be as specified in Clause 15.

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

9.5.3 A single-pass fillet weld shall be deposited on one side of the joint. When welding in the vertical position, the welding shall progress upwards.

Table 6
Tension Test Requirements

AWS Classification[a]	Tensile Strength, min.		Elongation, min.	Postweld Heat Treatment
	ksi	MPa	Percent	
E307TX-X	85	590	30	None
E308TX-X	80	550	*30*	None
E308HTX-X	80	550	*30*	None
E308LTX-X	75	520	*30*	None
E308MoTX-X	80	550	*30*	None
E308LMoTX-X	75	520	*30*	None
E309TX-X	80	550	30	None
E309HTX-X	80	550	30	None
E309LNbTX-X	75	520	30	None
E309LTX-X	75	520	30	None
E309MoTX-X	80	550	25	None
E309LMoTX-X	75	520	25	None
E309LNiMoTX-X	75	520	25	None
E310TX-X	80	550	30	None
E312TX-X	95	660	22	None
E316TX-X	75	520	30	None
E316HTX-X	75	520	30	None
E316LTX-X	70	485	30	None
E317LTX-X	75	520	20	None
E347TX-X	75	520	30	None
E347HTX-X	75	520	30	None
E409TX-X	65	450	15	None
E409NbTX-X	65	450	15	(d)
E410TX-X	75	520	20	(b)
E410NiMoTX-X	110	760	15	(c)
E430TX-X	65	450	20	(d)
E430NbTX-X	65	450	13	(d)
E2209TX-X	100	690	20	None
E2307TX-X	*100*	*690*	*20*	*None*
E2553TX-X	110	760	15	None
E2594TX-X	110	760	15	None
E316LKT0-3	70	485	30	None
E308HMoT0-3	80	550	30	None
EGTX-X	Not Specified			
R308LT1-5	75	520	*30*	None
R309LT1-5	75	520	30	None
R316LT1-5	70	485	30	None
R347T1-5	75	520	30	None

[a] In this table, the “X” following the “T” refers to the position of welding (1 for all-position or 0 for flat or horizontal operation) and the “X” following the dash refers to the shielding medium (-1, -3, or -4) as shown in the AWS Classification.

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

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

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

10. Chemical Analysis

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

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

10.1.2 The sample for analysis of weld metal from the pad shall be taken from material above the third layer of weld metal and at least the minimum height above the base metal as specified in Figure 1. The sample shall be free of slag and all other foreign materials. The sample shall come from above the eighth layer for weld metal from the low-carbon classifications when base metals containing more than 0.03% carbon are used for the pad.

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

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

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

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

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

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

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

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

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

11. Radiographic Test

11.1 When required in Table 4, the groove weld described in 9.4.1 and shown in Figure 2 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.4 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

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

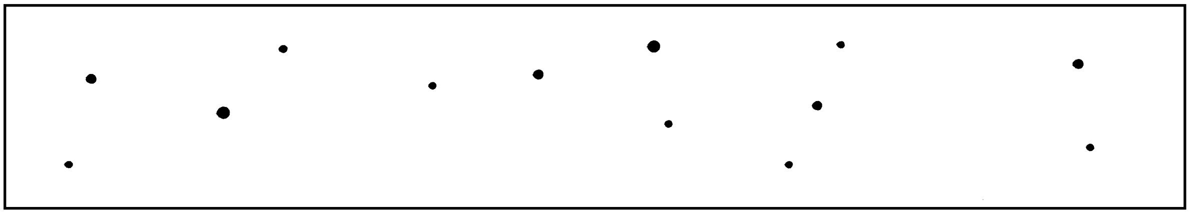
11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows none of the following:

(1) cracks

(2) incomplete fusion

(3) incomplete penetration

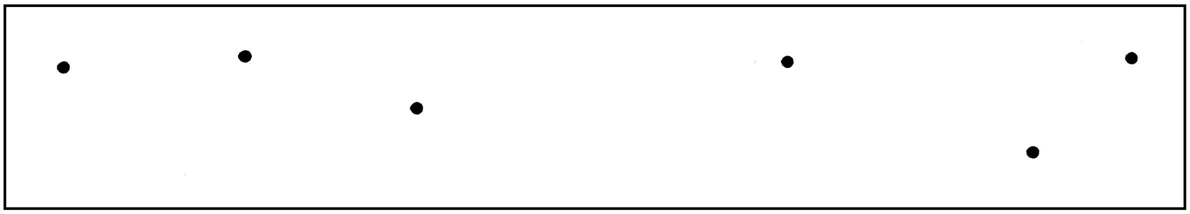
(4) rounded indications in excess of those permitted by the radiographic standards in Figure 5A or 5B, as applicable



(A) ASSORTED ROUNDED INDICATIONS

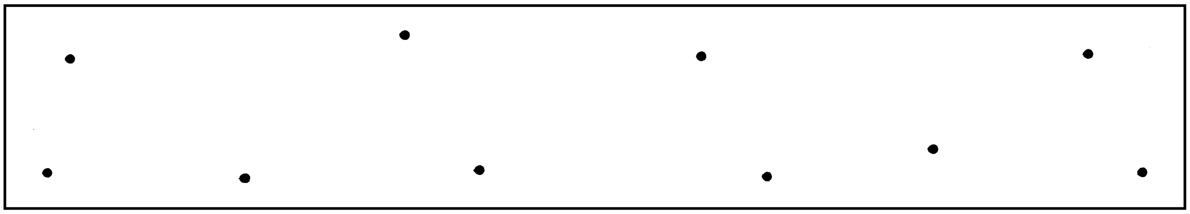
SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 13 WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 2.
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 4.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 7.



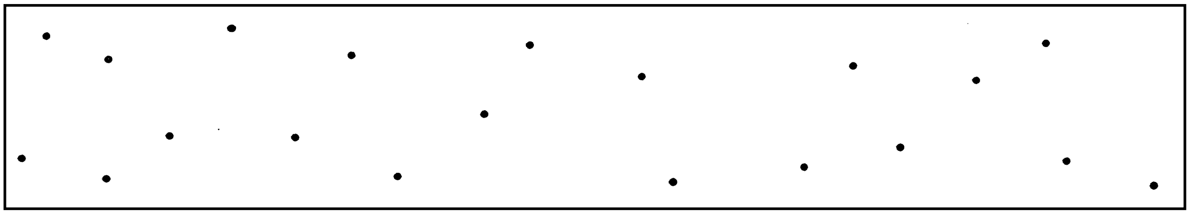
(B) LARGE ROUNDED INDICATIONS

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



(C) MEDIUM ROUNDED INDICATIONS

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



(D) SMALL ROUNDED INDICATIONS

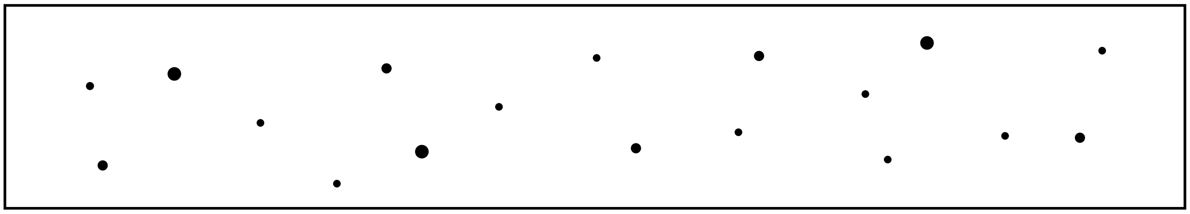
SIZE 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 20.

Notes:

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

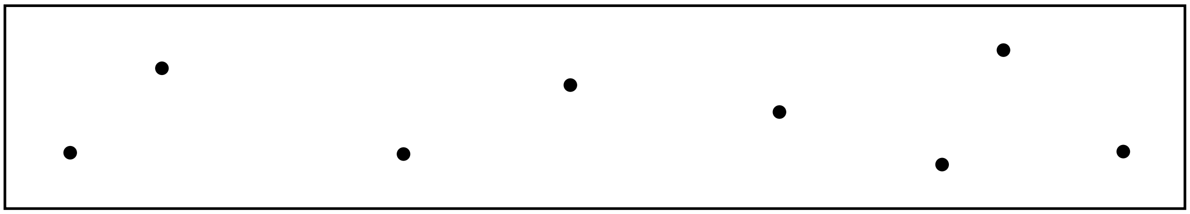
Source: AWS A5.4/A5.4M:2006, Figure 5A.

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



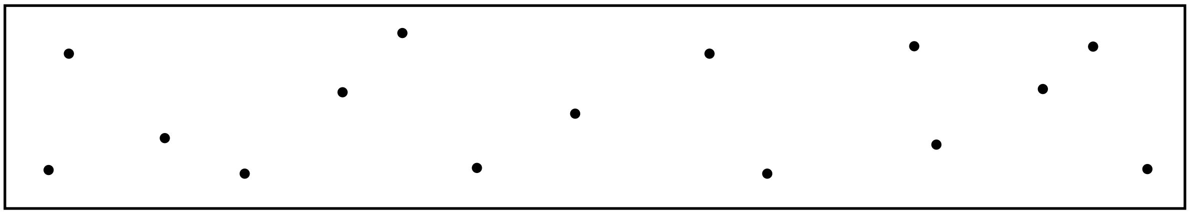
(A) ASSORTED ROUNDED INDICATIONS

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



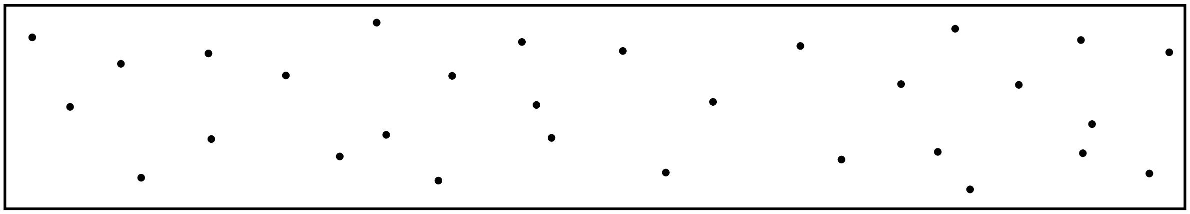
(B) LARGE ROUNDED INDICATIONS

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



(C) MEDIUM ROUNDED INDICATIONS

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



(D) SMALL ROUNDED INDICATIONS

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

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

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

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

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

(5)(b) in any 6 in [150 mm] length of the 3/4 in [20 mm] thick test assembly: no individual slag inclusion in excess of 9/32 in [7.1 mm] and a maximum total length of 15/32 in [12 mm] for all slag inclusions.

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

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

11.3.2 Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications in excess of the sizes permitted in the radiographic standards do not meet the requirements of this specification.

12. Tension Test

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

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

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

13. Bend Test

13.1 Electrodes

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

13.1.2 Backing strip and weld reinforcement shall be removed by machining. Grinding of the face surface of the specimen shall follow. The corners on the face side of the specimen shall be slightly rounded by filing or grinding. The longitudinal face bend test specimen shall be uniformly bent through 180° over a radius of 3/4 in [19 mm]. Typical bending jigs are shown in AWS B4.0 or B4.0M. The specimen shall be positioned so that the face of the weld is in tension.

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

13.2 Rods

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

13.2.2 Weld reinforcement shall be removed by machining. Grinding of both faces of the specimen shall follow. All corners on the root side of the specimen shall be slightly rounded by filing or grinding. The longitudinal root bend specimen shall be bent uniformly through 180° over a radius of 3/4 in [19 mm]. Typical bending jigs are shown in AWS B4.0 or B4.0M. The specimen shall be positioned so that the root of the weld is in tension.

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

14. Impact Test

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

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

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

15. Fillet Weld Test

15.1 The fillet weld test, when required in Table 4, shall be made in accordance with 9.5 and Figure 4. The entire face of the completed fillet weld shall be examined visually. The weld shall be free from cracks or other open defects that would affect the strength of the weld. After the visual examination, a cross section shall be taken as shown in Figure 4. The cross-sectional surface shall be ground smooth and etched, and then examined as required in 15.2.

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

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

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

15.2.3 The fillet weld shall show no evidence of cracks.

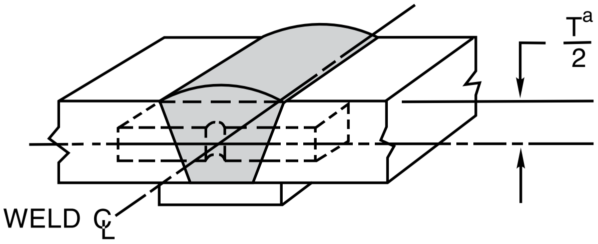
15.2.4 The weld shall be reasonably free from undercutting, overlap, trapped slag, and porosity.

16. Method of Manufacture

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

17. Standard Sizes

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

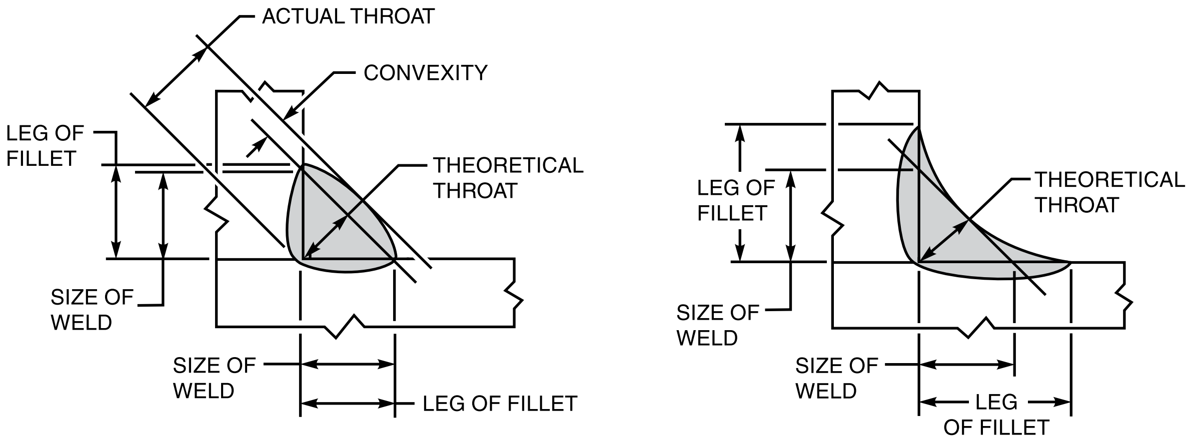


[a] If buttering is used in preparation of the test plate (see Figure 2) the T/2 dimension may need to be reduced to assure that none of the buttering becomes part of the notch area of the impact specimen.

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

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

Figure 6—Orientation and Location of Impact Test Specimen



CONVEX FILLET **CONCAVE FILLET**

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in	mm	in	mm	in	mm
1/8 or less	3.0 or less	5/64	2.0	1/32	1.0
9/64	3.5	5/64	2.0	3/64	1.0
5/32	4.0	5/64	2.0	3/64	1.0
11/64	4.5	5/64	2.0	1/16	1.5
3/16	5.0	5/64	2.0	1/16	1.5
13/64	5.0	5/64	2.0	5/64	2.0
7/32	5.5	5/64	2.0	5/64	2.0
15/64	6.0	5/64	2.0	3/32	2.5
1/4	6.5	5/64	2.0	3/32	2.5
17/64	6.5	3/32	2.5	7/64	3.0
9/32	7.0	3/32	2.5	7/64	3.0
19/64	7.5	3/32	2.5	1/8	3.0
5/16	8.0	3/32	2.5	1/8	3.0
21/64	8.5	3/32	2.5	9/64	3.5
11/32	8.5	3/32	2.5	9/64	3.5
23/64	9.0	3/32	2.5	5/32	4.0
3/8 or more	9.5 or more	3/32	2.5	5/32	4.0

Notes:

1. Size of fillet weld = leg length of largest inscribed isosceles right triangle.
2. Fillet weld size, convexity, and leg lengths of fillet welds shall be determined by actual measurement (nearest 1/64 [0.5 mm]) on a section laid out with scribed lines shown.

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

Figure 7—Fillet Weld Test Specimen and Dimensional Requirements

18. Finish and Uniformity

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

19. Standard Package Forms

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

20. Winding Requirements

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

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

21. Filler Metal Identification

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

22. Packaging

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

23. Marking of Packages

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

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

Annex A (Informative)

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

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

A1. Introduction

The purpose of this guide is to correlate the electrode and rod classifications with their intended applications so the specification can be used effectively. Appropriate base metal specifications are referenced whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable. This specification includes welding rods classified as R3XXT1-5. These are flux cored welding rods which can be used for GTAW of the root pass of stainless steel pipe without the use of a back shielding gas.

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

A2. Classification System

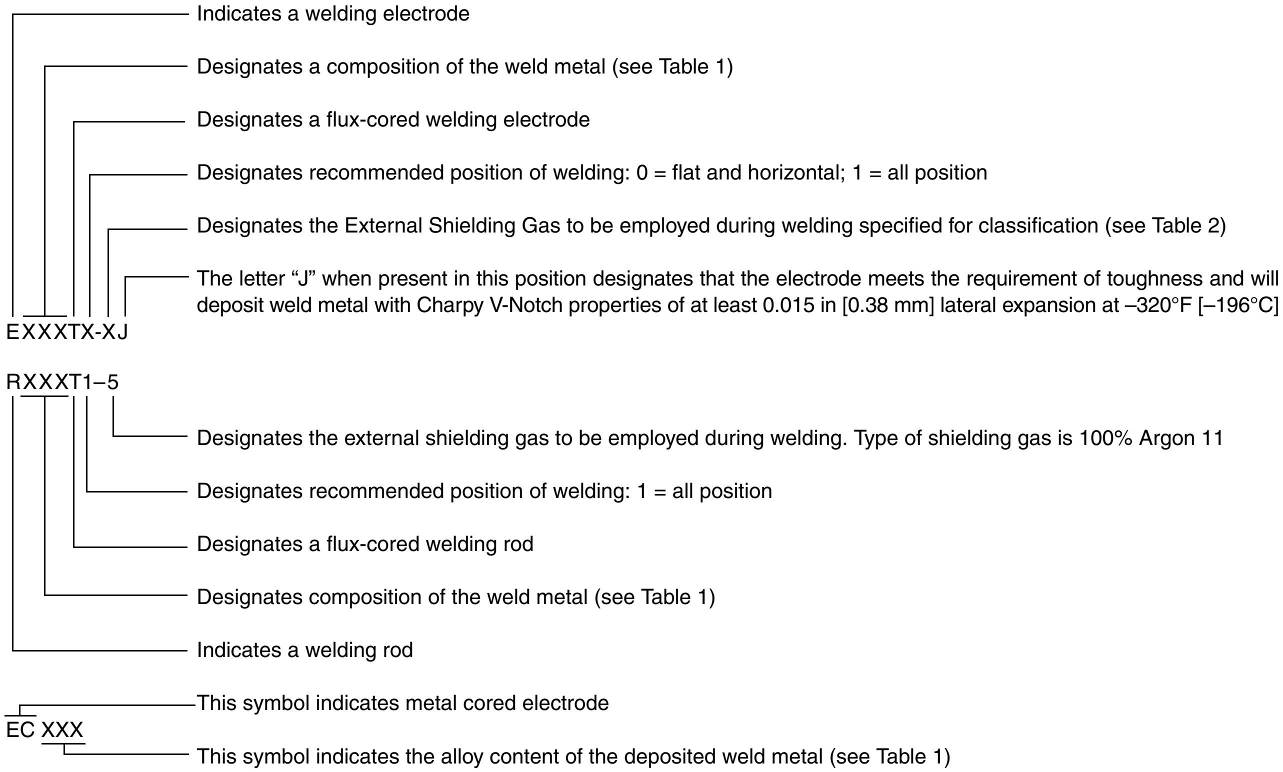
A2.1 The system for identifying the electrode and rod classifications in this specification follows the standard pattern used in other AWS filler metal specifications.

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

A2.2.1 The chemical composition is identified by a three-digit or four-digit number, and, in some cases, additional chemical symbols and the letters "L" or "H." The numbers generally follow the pattern of the AISI numbering system for heat- and corrosion-resisting steels; however, there are exceptions. In some classifications additional chemical symbols are used to signify modifications of basic alloy types. The letter "L" denotes low-carbon content in the deposit. The letter "H" denotes carbon content in the upper part of the range that is specified for the corresponding standard alloy type.

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

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



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

Figure A.1—Classification Systems

A2.2.3 Following the chemical composition designation comes the letter "T," which signifies that the product is a flux cored electrode or rod. Following the "T" is a 1 or 0 indicating the recommended position of welding. Following the position indicator and a dash, are the numerals "1," "3," "4," or "5" or the letter "G." The numerals "1," "4," and "5" identify the shielding gas required for classification of the electrode or rod. The numeral "3" signifies that an external shielding gas is not employed and that the weld puddle is shielded by the atmosphere and slag generated by the flux core. The letter "G" signifies that the shielding medium is not specified and is agreed upon between the purchaser and supplier. Refer to A2.2.7 for a further explanation of the "G" classification and its implications.

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

(1) EXXXT0-X	Designates a welding electrode designed for welding in the flat or horizontal positions.
(2) EXXXT1-X	Designates a welding electrode designed for welding in all positions.
(3) R3XXT1-5	Designates a welding rod designed for welding in all positions.

A2.2.5 As shown in Table 2, the shielding designation for a particular classification indicates the external shielding gas to be employed for classification of the electrode/rod. This does not exclude the use of alternate gas mixtures as agreed upon between the purchaser and supplier. The use of alternate gas mixtures may have an effect on welding characteristics, deposit composition, and mechanical properties of the weld, such that classification requirements may not be met.

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

A2.2.7 This specification includes filler metals classified EGTX-X, EXXXTX-G, RGT1-5 and ECG. The "G" indicates that the filler metal is of a "general" classification. It is general because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing these classifications is to provide a means by which filler metals that differ in one respect or another (chemical composition or shielding gas) from all other classifications (meaning that the composition of the filler metal or shielding gas does not meet that specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal—one that otherwise would have to await a revision of the specification—to be classified immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some certain respect (chemical composition or shielding gas).

A2.2.8 The point of difference (although not necessarily the amount of that difference) between filler metal of a "G" classification and filler metal of a similar classification without the "G" (or even with it, for that matter) will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

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

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

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

A2.2.9 Request for Filler Metal Classification

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

(2) A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the AWS A5 Committee on Filler Metals and Allied Materials or the AWS Subcommittee involved to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

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

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

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

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

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

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

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

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

(d) File the original request.

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

(4) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chair of the Committee and the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chair of the AWS A5 Committee on Filler Metals and Allied Materials for action.

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

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

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

A3. Acceptance

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

In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of AWS A5.01M/A5.01(ISO 14344 MOD). Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

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

AWS A5.22/A5.22M	AWS A5.4/A5.4M[a]	AWS A5.9/A5.9M	ISO 17633-A[b]	ISO 17633-B[c]
E307TX-X	E307-XX	ER307	—	TS307 F X X
E308TX-X	E308-XX	ER308, ER308Si	—	TS308 F X X
E308HTX-X	E308H-XX	ER308H, ER19-10H	—	TS308H F X X
E308LTX-X	E308L-XX	ER308L, ER308LSi	T 19 9 L X X X	TS308L F X X
E308MoTX-X	E308Mo-XX	ER308Mo	—	TS308Mo F X X
E308LMoTX-X	E308LMo-XX	ER308LMo	—	TS308LMo F X X
E309TX-X	E309-XX	ER309, ER309Si	—	TS309 F X X
E309HTX-X	E309H-XX	—	—	—
E309LTX-X	E309L-XX	ER309L, ER309LSi	T 23 12 L X X X	TS309L F X X
E309MoTX-X	E309Mo-XX	ER309Mo	—	TS309Mo F X X
E309LMoTX-X	E309LMo-XX	ER309LMo	T 23 12 2 L X X X	TS309LMo F X X
E309LNiMoTX-X	—	—	—	—
E309LNbTX-X	—	—	—	TS309LNb F X X
E310TX-X	E310-XX	ER310	T 25 20 X X X	TS310 F X X
E312TX-X	E312-XX	ER312	T 29 9 X X X	TS312 F X X
E316TX-X	E316-XX	ER316, ER316Si	—	TS316 F X X
E316HTX-X	E316H-XX	ER316H	—	TS316H F X X
E316LTX-X, E316LKT0-3	E316L-XX	ER316L, ER316LSi	T 19 12 3 L X X X	TS316L F X X
E317LTX-X	E317L-XX	ER317L	T 19 13 4 N L X X X	TS317L F X X
E347TX-X	E347-XX	ER347, ER347Si	T 19 9 Nb X X X	TS347 F X X
E347HTX-X	—	—	—	—
E409TX-X	—	ER409	T 13 Ti X X X	TS409 F X X
E409NbTX-X	E409Nb-XX	ER409Nb	—	TS409Nb F X X
E410TX-X	E410-XX	ER410	T 13 X X X	TS410 F X X
E410NiMoTX-X	E410NiMo-XX	ER410NiMo	T 13 4 X X X	TS410NiMo F X X
E430TX-X	E430-XX	ER430	T 17 X X X	TS430 F X X
E430NbTX-X	E430Nb-XX	—	—	TS430Nb F X X
E2209TX-X	E2209-XX	ER2209	T 22 9 3 N L X X X	TS2209 F X X
E2307TX-X	*E2307-XX**	*ER2307*	*T 23 7 N L*	—
E2553TX-X	E2553-XX	ER2553	—	—
E2594TX-X	E2594-XX, E2595-XX	ER2594	—	—
EGTX-X	—	—	T Z X X X	—
R308LT1-5	E308L-XX	ER308L	—	TS308L R I 1
R309LT1-5	E309L-XX	ER309L	—	TS309L R I 1
R316LT1-5	E316L-XX	ER316L	—	TS316L R I 1
R347T1-5	E347-XX	ER347	—	TS347 R I 1
EC209	E209-XX	EC209	—	—
EC218	—	EC218	—	—
EC219	E219-XX	EC219	—	—
EC240	E240-XX	EC240	—	—
EC307	E307-XX	EC307	—	—
EC308	E308-XX	EC308	—	—
EC308Si	E308-XX	EC308Si	—	—
EC308H	E308H-XX	EC308H	—	—
EC308L	E308L-XX	EC308L	T 19 9 L M X X	TS308L M X X
EC308LSi	E308L-XX	EC308LSi	T 19 9 L M X X	—
EC308Mo	E308Mo-XX	EC308Mo	—	TS308Mo M X X
EC308LMo	E308LMo-XX	EC308LMo	—	—
EC309	E309-XX	EC309	—	—
EC309Si	E309-XX	EC309Si	—	—
EC309L	E309L-XX	EC309L	T 23 12 L M X X	TS309L M X X

(Continued)

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

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

*Expected to be included in next editions.

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

[b] In the ISO 17633-A classification designations, the last three symbols (where X stands for any symbol) indicate, respectively, the type of electrode core (R means rutile, slow freezing; P means rutile, fast freezing; M means metal core; U means self-shielding; Z means an unspecified type), the shielding gas for classification (M21 means argon plus 15% to 25% CO_2, C means CO_2; M13 means argon plus up to 3% oxygen; and NO means no shielding gas), and position of welding (1 means all positions including vertical down; 2 means all positions except vertical down; 3 means flat and horizontal only; 4 means flat only; and 5 means flat, horizontal and vertical down).

[c] In the ISO 17633-B classification designations, the last three symbols (where X stands for any symbol) indicate, respectively, the type of electrode or rod (F means flux cored; M means metal cored; and R means a rod for GTAW), the shielding gas for classification (M21 means argon plus 20% to 25% CO_2; C means CO_2; M13 means argon plus up to 3% oxygen, I1 means 100% argon; NO means no shielding gas; and G means an unspecified shielding gas), and position of welding (0 means flat and horizontal only, 1 means all positions).

The only testing requirement implicit in this “certification” is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. (Representative material, in this case, is any production run of that classification using the same formulation.) “Certification” is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may, or may not, have been conducted. The basis for the “certification” required by the specification is the classification test of “representative material” cited above, and the “Manufacturer’s Quality Assurance System” in AWS A5.01M/A5.01(ISO 14344 MOD).

A5. Ventilation During Welding

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

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

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

(3) Rate of evolution of fumes, gases, or dust, according to the materials and processes involved

(4) The proximity of the welders or welding operators to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which they are working

(5) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the clause on ventilation in that document. See also AWS F3.2, *Ventilation Guide for Weld Fume*, for more detailed descriptions of ventilation options.

A6. Ferrite in Weld Deposits

A6.1 Ferrite is known to be very beneficial in reducing the tendency for cracking or fissuring in weld metals; however, it is not essential. Millions of pounds of fully austenitic weld metal have been used for years and have provided satisfactory service performance. Generally, ferrite is helpful when the welds are restrained, the joints are large, and when cracks or fissures adversely affect service performance. Ferrite increases the weld strength level. Ferrite may have a detrimental effect on corrosion resistance in some environments. It also is generally regarded as detrimental to toughness in cryogenic service, and in high temperature service where it can transform into the brittle sigma phase.

A6.2 Ferrite can be measured on a relative scale by means of various magnetic instruments. However, work by the Subcommittee for Welding of Stainless Steel of the High Alloys Committee of the Welding Research Council (WRC) established that the lack of a standard calibration procedure resulted in a very wide spread of readings on a given specimen when measured by different laboratories. A specimen averaging 5.0% ferrite based on the data collected from all the laboratories was measured as low as 3.5% by some and as high as 8.0% by others. At an average of 10%, the spread was 7.0% to 16.0%. In order to substantially reduce this problem, the WRC Subcommittee published *Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*[8] on July 1, 1972.

In 1974 the AWS extended this procedure and prepared AWS A4.2, *Standard Procedure for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Steel Weld Metal*. All instruments used to measure the ferrite content of AWS classified stainless electrode products are to be traceable to the latest revision of this AWS standard.

A6.3 The WRC Subcommittee also adopted the term *Ferrite Number* (FN) to be used in place of % ferrite, to clearly indicate that the measuring instrument was calibrated to the WRC procedure. The Ferrite Number, up to 10 FN, is to be considered equal to the “% ferrite” term previously used. It represents a good average of commercial U.S. and world

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[8] Welding Research Council, P.O. Box 201547, Shaker Heights, OH 44120.

practice on the % ferrite. Through the use of standard calibration procedures, differences in readings due to instrument calibration are expected to be reduced to about ±5%, or at the most, ±10% of the measured ferrite value.

A6.4 In the opinion of the WRC Subcommittee, it has been impossible, to date, to accurately determine the true absolute ferrite content of stainless steel weld metals.

A6.5 Even on undiluted pads, ferrite variations from pad to pad must be expected due to slight changes in welding and measuring variables. On a large group of pads from one heat or lot and using a standard pad welding and preparation procedure, two sigma values indicate that 95% of the tests are expected to be within a range of approximately ±2.2 FN to about 8 FN. If different pad welding and preparation procedures are used, these variations will increase.

A6.6 Even larger variations may be encountered if the welding technique allows excessive nitrogen pickup, in which case the ferrite can be much lower than it should be. High nitrogen pickup can cause a typical 8 FN deposit to drop to 0 FN. A nitrogen pickup of 0.10% will typically decrease the FN by about 8.

A6.7 Plate materials tend to be balanced chemically to have an inherently lower ferrite content than matching weld metals. Weld metal diluted with plate metal will usually be somewhat lower in ferrite than the undiluted weld metal, though this does vary depending on the amount of dilution and the composition of the base metal.

A6.8 In the normally austenitic (types 3XX) filler metals, many types, such as filler metals of types 310, 320, 320LR, 330, 383, and 385, are fully austenitic. The filler metals of type E316 group can be made with little or no ferrite when required for improved corrosion resistance in certain media, and in high temperature and cryogenic applications where ferrite can be detrimental. It also can be obtained in a higher ferrite form, usually over 4 FN, if desired. The remaining normally austenitic (types 3XX) filler metals can be made in low-ferrite versions, but commercial practice usually involves ferrite control above 4 FN. Because of chemical composition limits covering these grades and various manufacturing limits, most lots will be under 10 FN and are unlikely to go over 15 FN commercially. Filler metals of types 312, 2209, 2553, and 2594 generally are quite high in ferrite, usually over 30 FN.

A6.9 When it is desired to measure ferrite content, the following procedure is recommended:

A6.9.1 The same weld pads, as detailed in 9.3, may be used to measure the ferrite level, provided the last two or three layers are prepared as described in A6.9.3 and A6.9.4. Otherwise, the pads shall be made as detailed on Figure 1 and prepared as described in A6.9.2 through A6.9.4. The base plate may be of Type 301, 302, or 304 conforming to ASTM Specification A 167 or A 240, or carbon steel. If the base plate contains more that 0.03% carbon and is used for the low-carbon classifications (classifications with up to 0.04% carbon maximum), then the pad shall have a minimum of nine layers. This is required to assure a low-carbon weld metal deposit.

A6.9.2 The weld pad must be built to a minimum height of 1/2 in [13 mm] when using Type 301, 302, or 304 base plate. When using a carbon steel base, the weld pad must have a minimum height of 5/8 in [16 mm] to eliminate dilution effects.

A6.9.3 The pad must be welded in the flat position using multiple layers, with at least the last 2 layers deposited using stringer beads. The measurable length between start and stop on the last two layers must be 2 in [50 mm] minimum. The weld layers used for the buildup may be deposited with a weave. The amperage or wire feed speed, the arc voltage, and the contact tip to workpiece distance shall be as recommended by the manufacturer of the electrode. The shielding medium, polarity, and welding process shall be as shown in Table 2. Each pass must be cleaned prior to depositing the next pass. The welding direction should be alternated from pass to pass. The weld stops and starts must be located at the ends of the weld buildup. Between passes, the weld pad may be cooled by quenching in water not sooner than 20 seconds after the completion of each pass. The last two layers must have a maximum interpass temperature of 300°F [150°C]. The last pass must be air cooled to below 800°F [425°C] prior to quenching in water.

The weld deposit can be built up between two copper bars laid parallel on the base plate. The spacing between the copper bars is dependent on the size of the electrode and the type or size of welding gun used. Care must be taken to make sure the arc does not impinge on the copper bars resulting in copper dilution in the weld metal.

A6.9.4 The completed weld pad must have the surface prepared so that it is smooth with all traces of weld ripple removed and must be continuous in length where measurements are to be taken. This can be accomplished by any suitable means providing the surface is not heated in excess during the machining operation (excessive heating may affect the final ferrite reading). The width of the prepared surface shall not be less than 1/8 in [3 mm].

The surface can be prepared by draw filing using a mill bastard file held on both sides of the weld with the long axis of the file perpendicular to the long axis of the weld. Files shall either be new or shall have only been used on austenitic stainless steel. Filing must be accomplished by smooth draw-filing strokes (one direction only) along the length of the weld while applying a firm downward pressure. If the ferrite content is 30 FN or greater, the surface must be ground to a 600 grit [P1200] finish.

A6.9.5 A minimum of six ferrite readings must be taken on the filed or ground surface along the longitudinal axis of the weld pad with an instrument calibrated in accordance with the procedures specified in AWS A4.2M (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal* (latest edition). The six or more readings obtained must be averaged to give the final result.

A6.10 The ferrite content of welds may be calculated from the chemical composition of the weld deposit. This can be done from the WRC-1992 Diagram[9] (Figure A.2) which predicts ferrite in Ferrite Number (FN). It is a slight modification of the WRC-1988 Diagram[10] to take into account the effect of copper originally proposed by Lake. Studies within the WRC Subcommittee on Welding Stainless Steel and within Commission II of the International Institute of Welding show a closer agreement between measured and predicted ferrite contents using the WRC-1988 Diagram than when using the previously used DeLong Diagram. The WRC-1992 Diagram may not be applicable to compositions greater

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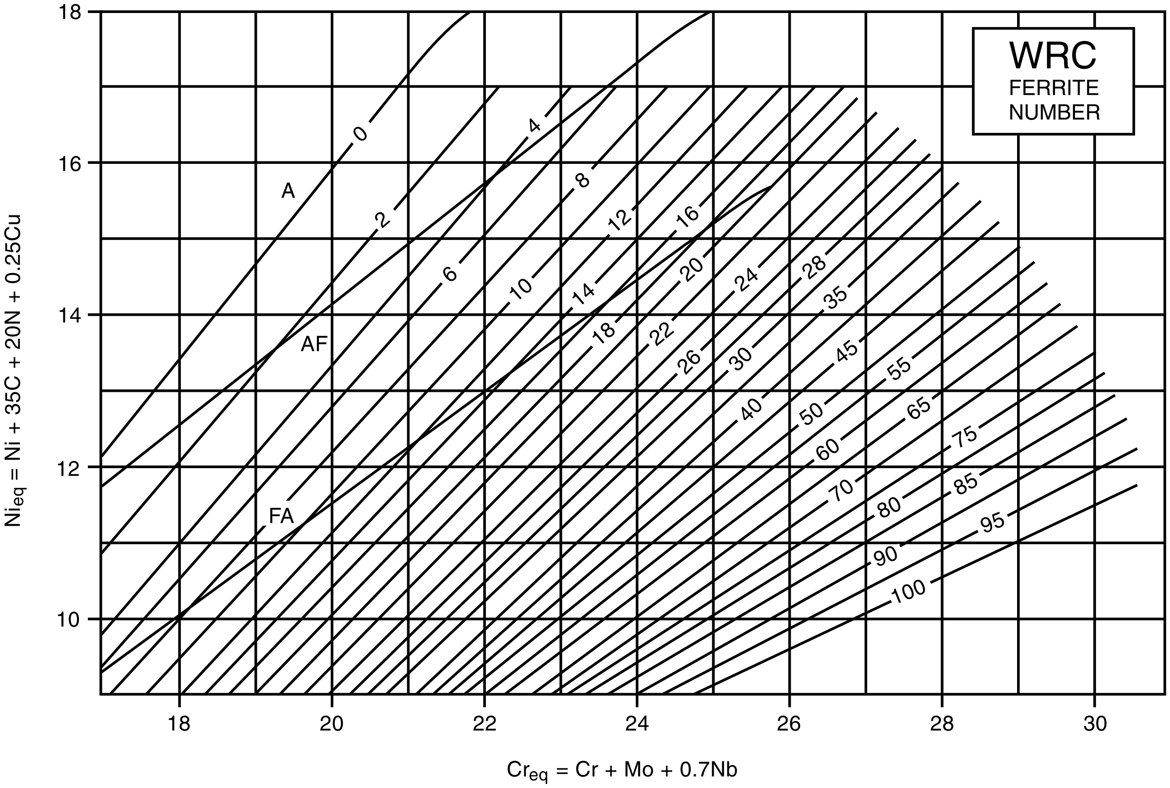
[9] Kotecki, D. J. and Siewert, T. A., "WRC-1992 Constitution Diagram for Stainless Steel Weld Metals: A Modification of the WRC-1988 Diagram." *Welding Journal* 71(5): 171-s–178-s (1992).

[10] McCowan, C. N., Siewert, T. A., and Olson, D. L. 1989. WRC Bulletin 342, Stainless Steel Weld Metal: Prediction of Ferrite Content, Welding Research Council.



Source: AWS A5.4/A5.4M:2006, Figure A.3.

Figure A.2—WRC-1992 Diagram for Stainless Steel Weld Metal than 0.3% nitrogen, 1% silicon, or greater than 10% manganese. For stainless steel compositions not alloyed with Cu, the predictions of the 1988 and 1992 diagrams are identical.

The differences between measured and calculated ferrite are somewhat dependent on the ferrite level of the deposit, increasing the ferrite level increases the variance. The agreement between the calculated and measured ferrite values is also strongly dependent on the quality of the chemical analysis. Variations in the results of the chemical analyses encountered from laboratory to laboratory can have significant effects on the calculated ferrite value, changing it as much as 4 to 8 FN

A7. Ferrite and Compositional Concerns for ECXXX Metal Cored Electrodes

A7.1 The welding process used and the welding conditions and technique have a significant influence on the chemical composition and the ferrite content of the weld deposit in many instances. These influences must be considered by the user if the weld deposit must meet specific chemical or Ferrite Number limits. The purpose of A7.2.1 through A7.2.3 is to present some general information on the effect of common arc welding processes on the chemical composition and the ferrite content of weld deposits made with filler metal classified in this specification.

A7.2 The chemical composition of a given weld deposit has the capability of providing an approximately predictable Ferrite Number for the undiluted deposit, as described in A6.10, with the limitations discussed here. However, important changes in the chemical compositions can occur from wire to deposit as described in A7.2.1 through A7.2.3.

A7.2.1 Gas Tungsten Arc Welding. This welding process involves the least change in the chemical composition from wire to deposit, and hence produces the smallest difference between the ferrite content calculated from the wire analysis and that measured on the undiluted deposit. There is some loss of carbon in gas tungsten arc welding—about half of the carbon content above 0.02%. Thus, a wire of 0.06% carbon will typically produce a deposit of 0.04% carbon. There is also some nitrogen pickup—a gain of 0.02%. The change in other elements is not significant in the undiluted weld metal.

A7.2.2 Gas Metal Arc Welding. For this process, typical carbon losses are low, only about one quarter those of the gas tungsten arc welding process. However, the typical nitrogen pick up is much higher than in gas tungsten arc welding, and it should be estimated at about 0.04% (equivalent to about 3 or 4 FN loss) unless specific measurements on welds for a particular application establish other values. Nitrogen pickup in this process is very dependent upon the welding technique and may go as high as 0.15% or more. This may result in little or no ferrite in the weld deposits of filler metals such as EC 308 and EC 309. Some slight oxidation plus volatilization losses may occur in manganese, silicon, and chromium contents.

A7.2.3 Submerged Arc Welding. Submerged arc welds show variable gains or losses of alloying elements, or both depending on the flux used. All fluxes produce some changes in the chemical composition as the electrode is melted and deposited as weld metal. Some fluxes deliberately add alloying elements such as niobium (columbium) and molybdenum; others are very active in the sense that they deplete significant amounts of certain elements that are readily oxidized, such as chromium. Other fluxes are less active and may contain small amounts of alloys to offset any losses and thereby, produce a weld deposit with a chemical composition close to the composition of the electrode. If the flux is active or alloyed, changes in the welding conditions, particularly voltage, will result in significant changes in the chemical composition of the deposit. Higher voltages produce greater flux/metal interactions and, for example, in the case of an alloy flux, greater alloy pickup. When close control of ferrite content is required, the effects of a particular flux/electrode combination should be evaluated before any production welding is undertaken due to the effects as shown in Table A.2.

A7.3 Bare solid filler metal wire, unlike covered electrodes and bare composite cored wires, cannot be adjusted for ferrite content by means of further alloy additions by the electrode producer, except through the use of flux in the submerged arc welding process. Thus, if specific FN ranges are desired, they must be obtained through wire chemical composition selection. This is further complicated by the changes in the ferrite content from wire to deposit caused by the welding process and techniques, as previously discussed.

A7.4 In the 300 series filler metals, the compositions of the bare filler metal wires in general tend to cluster around the midpoints of the available chemical ranges. Thus, the potential ferrite for the 308, 308L, and 347 wires is approximately

Table A.2
Variations of Alloying Elements for Submerged Arc Welding

Element	Typical Change from Wire to Deposit
Carbon	Varies. On “L” grades, usually a gain: +0.01% to +0.02%; on non-L grades, usually a loss: up to –0.02%.
Silicon	Usually a gain: +0.3% to +0.6%.
Chromium	Usually a loss, unless a deliberate addition is made to the flux: –0.5% to –3.0%.
Nickel	Little change, unless a deliberate addition is made to the flux.
Manganese	Varies: –0.5% to +0.5%.
Molybdenum	Little change, unless a deliberate addition is made to the flux.
Niobium	Usually a loss, unless a deliberate addition is made to the flux: –0.1% to –0.5%.

10 FN, for the 309 wire approximately 12 FN, and for the 316 and 316L wires approximately 5 FN. Around these midpoints, the ferrite contents may be ±7 FN or more, but the chemical compositions of these filler metals will still be within the chemical limits specified in this specification.

A7.5 In summary, the ferrite potential of a filler metal afforded by this chemical composition will, except for a few instances in submerged arc welding, be modified downward in the deposit due to changes in the chemical composition which are caused by the welding process and the technique used.

A8. Description and Intended Use of Electrodes and Rods

A8.1 Composition Considerations

A8.1.1 The chemical composition requirements for these electrodes and rods are patterned after those of AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, and AWS A5.9/A5.9M, *Specification for Bare Stainless Steel Electrodes and Rods* (see Table A.1).

A8.1.2 The chemical composition requirements of the EXXXTX-1 and EXXXTX-4 classifications are very similar. The requirements of the EXXXT0-3 classifications are different from those of the previous two. The EXXXT0-3 deposits usually have higher nitrogen content. This means that, in order to control the ferrite content of the weld metal, the chemical compositions of the EXXXT0-3 deposits usually have higher Cr/Ni ratios than those of the EXXXTX-1 and EXXXTX-4 deposits.

Since the atmosphere generated by E316LKT0-3 electrodes more efficiently shields the arc from nitrogen pickup than that produced by other EXXXT0-3 electrodes, the Cr/Ni ratio can be the same as for EXXXTX-1 deposits without a loss of ferrite control.

A8.1.3 The chemical composition requirements for metal cored electrodes are identical to those which were previously in the AWS A5.9/A5.9M specification. The most common use of metal cored electrodes is for single pass welds on thin wall tubing used in automotive exhaust systems. These are most commonly the ferritic stainless steel compositions 409, 409Nb, 430, and 439. Because they are used almost exclusively single pass, mechanical properties depend strongly upon the composition of the base metal. Accordingly, mechanical properties are not specified for these compositions.

A8.1.4 Bismuth (Bi) in Flux Cored Stainless Steel Electrodes. For many years, bismuth in one form or another has been added to the core ingredients of many, but by no means all, stainless steel flux cored electrodes for the purpose of improved slag release. In such electrodes, the weld metal typically retains about 0.02% (200 ppm) of bismuth. Bismuth is a surface active element which, under prolonged exposure to temperatures above about 750°F [400°C], can segregate to grain boundaries and promote premature failure under sustained tensile loading. Accordingly, stainless steel electrodes containing bismuth additions should not be used for such high temperature service or postweld heat treatment above about 900°F [500°C]. Instead, stainless steel flux cored electrodes providing no more than 0.002% (20 ppm) Bi in the weld metal should be specified. For further information, see Welding Research Council Bulletin 460 High Temperature Cracking and Properties of Stainless Steel Flux Cored Welds and Effects of Bismuth[11] and International Institute of Welding Document IX-1873-97, *Effect of Bismuth on Reheat Cracking Susceptibility in Type 308 FCAW Weld Metal*.

A8.2 Intended Use of Flux Cored Electrodes and Rods. In the following, the final X of the classification refers to -1, -3, or -4.

A8.2.1 E307TX-X. The nominal composition (wt %) of this weld metal is 19 Cr, 9.7 Ni, 1.0 Mo, and 4 Mn. These electrodes are used primarily for moderate strength welds with good crack resistance between dissimilar steels, such as welding austenitic manganese steel to carbon steel forgings or castings.

A8.2.2 E308TX-X. The nominal composition (wt %) of this weld metal is 19.5 Cr and 10 Ni. Electrodes of this classification are most often used to weld base metal of similar composition such as AISI Types 301, 302, 304, 305, and 308.

A8.2.3 E308HTX-X. The composition of this weld metal is the same as that of E308TX-X except for carbon content which is in the high end of the range, 0.04 wt % to 0.08 wt %. Carbon content in this range provides higher tensile and creep strength at elevated temperatures. These electrodes are used primarily for welding type 304H base metal.

A8.2.4 E308LTX-X. The composition of this weld metal is the same as that of E308TX-X, except for carbon content. By specifying low carbon in this alloy, it is possible to obtain resistance to intergranular corrosion due to carbide precipitation without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, is not as strong at elevated temperature as the E308 and niobium stabilized alloys.

A8.2.5 E308MoTX-X. The composition of this weld metal is the same as that of E308TX-X weld metal, except for the addition of 2 wt %–3 wt % molybdenum. This electrode is recommended for welding CF8M stainless steel castings, as it matches the base metal with regard to chromium, nickel, and molybdenum.[12] This grade may also be used for welding wrought metals such as Type 316 when ferrite content higher than attainable with E316TX-X electrodes is desired.

A8.2.6 E308LMoTX-X. The composition of this weld metal is the same as that of E308MoTX-X weld metal, except for the lower carbon content. These electrodes are recommended for welding CF3M stainless steel castings, to match the base metal with regard to chromium, nickel, and molybdenum. This grade may also be used for welding wrought metals such as type 316L stainless when ferrite content higher than attainable with E316LTX-X electrodes is desired.

A8.2.7 E309TX-X. The nominal composition (wt %) of this weld metal is 23.5 Cr and 13 Ni. Electrodes of this classification commonly are used for welding similar alloys in wrought or cast forms. They are used in welding dissimilar metals, such as joining Type 304 to mild steel, welding the stainless steel side of Type 304 clad steels, and applying stainless steel sheet linings to carbon steel sheets. Occasionally, they are used to weld Type 304 base metals where severe corrosion conditions exist that require higher alloy content weld metal.

A8.2.8 E309HTX-X. The composition of this weld metal is the same as that of E309TX-X except for carbon content which is at the high end of the range, 0.04%–0.10%. Carbon content in this range provides higher tensile and creep strength at elevated temperatures. This together with a lower ferrite content makes these electrodes suitable for the welding of 24 Cr 12 Ni wrought and cast grades for corrosion and oxidation resistance. High carbon castings to ACI's HH grade should be welded with an electrode that is similar to the casting composition.

A8.2.9 E309LTX-X. The composition of the weld metal is the same as E309TX-X, except for the carbon content. By specifying low carbon in this alloy, it is possible to obtain resistance to intergranular corrosion due to carbide precipitation without the use of stabilizers such as niobium or titanium. This low carbon alloy, however, is not as strong at elevated temperature as Type 309 or the niobium stabilized modification. A primary application of this alloy is the first layer cladding of carbon steel if no niobium additions are required.

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[11] WRC documents are published by Welding Research Council, P.O. Box 201547, Shaker Heights, OH 44120.

[12] CF8M and CF3M are designations of ASTM A 351, *Standard Specification for Steel Castings, Austenitic, for Pressure-Containing Parts.*

A8.2.10 E309MoTX-X. The composition of this weld metal is the same as that of E309TX-X weld metal, except for the addition of 2 wt %–3 wt % molybdenum. These electrodes are used to join stainless steel to carbon and low-alloy steels for service below 600°F [315°C], and for overlaying of carbon and low-alloy steels. The presence of molybdenum provides pitting resistance in a halide environment and helps provide high temperature ductility in dissimilar joints. The ferrite level for this electrode deposit is approximately 18 FN.

A8.2.11 E309LMoTX-X. The composition of this weld metal is the same as E309MoTX-X weld metal, except for the lower carbon content. These electrodes are used to join stainless steel to carbon and low-alloy steels for service below 600°F [316°C], and for overlaying of carbon and low-alloy steels. The presence of molybdenum provides pitting resistance in a halide environment and helps provide high temperature ductility in dissimilar joints. The ferrite level for this electrode deposit is approximately 20 FN.

A8.2.12 E309LNiMoTX-X. The composition of this weld metal is essentially the same as E309LMoTX-X except for the lower chromium and higher nickel content. The purpose of this modification is to achieve a lower deposit ferrite content (typically 8-12 FN) when compared to E309LMoTX-X (approximately 20 FN). This chemistry is required by the pulp and paper industry for joining applications.

A8.2.13 E309LNbTX-X. The composition of this weld metal is the same as E309LTX-X weld metal, except for the addition of 0.7 wt % to 1.0 wt % Nb. These electrodes are used to overlay carbon and low-alloy steels and produce a niobium stabilized first layer on such overlays.

A8.2.14 E310TX-X. The nominal composition (wt %) of this weld metal is 26.5 Cr and 21 Ni. These electrodes are most often used to weld base metals of similar compositions.

A8.2.15 E312TX-X. The nominal composition (wt %) of this weld metal is 30 Cr and 9 Ni. These electrodes most often are used to weld dissimilar metal compositions of which one component is high in nickel. This alloy gives a two-phase weld deposit with substantial amounts of ferrite in an austenitic matrix. Even with considerable dilution by austenite-forming elements, such as nickel, the microstructure remains two-phase and thus highly resistant to weld metal cracks and fissures.

A8.2.16 E316TX-X. The nominal composition (wt %) of this weld metal is 18.5 Cr, 12.5 Ni, and 2.5 Mo. Electrodes of this classification usually are used for welding similar alloys (about 2 wt % molybdenum). These electrodes have been used successfully in applications involving special alloys for high-temperature service. The presence of molybdenum provides increased creep resistance at elevated temperatures and pitting resistance in a halide environment.

A8.2.17 E316HTX-X. The composition of this weld metal is the same as that of E316TX-X except for carbon content which is in the high end of the range, 0.04 wt % to 0.08 wt %. Carbon content in this range provides higher tensile and creep strength at elevated temperatures. These electrodes are used primarily for welding type 316H base metal.

A8.2.18 E316LTX-X. The composition of this weld metal is the same as E316TX-X electrodes, except for the lower carbon content. By specifying low carbon in this alloy, it is possible to obtain resistance to intergranular corrosion due to carbide precipitation without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, is not as strong at elevated temperatures as the niobium stabilized alloys.

A8.2.19 E317LTX-X. The nominal composition (wt %) of this weld metal is 19.5 Cr, 13 Ni, and 3.5 Mo. These electrodes usually are used for welding alloys of similar composition and are usually limited to severe corrosion applications. Low carbon (0.04 wt % maximum) in this filler metal reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, may not be so strong at elevated temperatures as the niobium stabilized alloys or Type 317.

A8.2.20 E347TX-X. The nominal composition (wt %) of this weld metal is 19.5 Cr and 10 Ni with Nb added as a stabilizer. The alloy is often referred to as a stabilized Type 308 alloy, indicating that it normally is not subject to intergranular corrosion from carbide precipitation. Electrodes of this classification usually are used for welding chromium-nickel stainless steel base metals of similar composition stabilized either with niobium or titanium.

Although niobium is the stabilizing element usually specified in 347 alloys, it should be recognized that tantalum may also be present. Tantalum and niobium are almost equally effective in stabilizing carbon and in providing high-temperature strength. The usual commercial practice is to report niobium as the sum of the niobium plus tantalum. Crack sensitivity of the weld may increase substantially, if dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit.

A8.2.21 E347HTX-X. The composition of this weld metal is the same as that of E347TX-X, except for carbon content which is at the high end of the range, 0.04 wt % to 0.08 wt %. Carbon content in this range provides higher tensile and creep strength at elevated temperatures. These electrodes are used primarily for welding Type 347H base metal.

A8.2.22 E409TX-X. The nominal composition (wt %) of this weld metal is 12 Cr with Ti added as a stabilizer. These electrodes, which produce a ferritic microstructure, often are used to weld base metal of similar composition.

A8.2.23 E409NbTX-X. This classification is the same as E409TX-X, except that niobium is used instead of titanium to achieve similar results. Applications are the same as for E409TX-X filler metals.

A8.2.24 E410TX-X. This 12 Cr (wt %) alloy is an air-hardening steel, and therefore, requires preheat and postheat treatments in order to achieve welds of adequate ductility for most engineering purposes. The most common application of electrodes of this classification is for welding alloys of similar composition. They also are used for surfacing of carbon steels to resist corrosion, erosion, or abrasion, such as that occurs in valve seats and other valve parts.

A8.2.25 E410NiMoTX-X. The nominal composition (wt %) of this weld metal is 11.5 Cr, 4.5 Ni, and 0.55 Mo. This electrode generally is used to weld CA6NM castings or similar materials.[13] These electrodes are modified to contain less chromium and more nickel to eliminate ferrite in the microstructure, as ferrite has a deleterious effect on mechanical properties. Postweld heat treatment in excess of 1150°F [620°C] may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A8.2.26 E430TX-X. This is a nominal 16.5 (wt %) Cr alloy. The composition is balanced by providing sufficient chromium to give adequate corrosion resistance for the usual applications and yet retain sufficient ductility in the heat-treated condition. (Excessive chromium will result in lower ductility.)

Welding with E430TX-X electrodes may produce a partially hardened microstructure that requires preheating and a postweld heat treatment. Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A8.2.27 E430NbTX-X. The composition of this weld metal is very similar to that deposited by E430 electrodes, except for the addition of niobium. The weld deposit is a ferritic microstructure with fine grains. Preheat and postweld heat treatment are required to achieve welds of adequate ductility for many engineering purposes. These electrodes are used for the welding of Type 430 stainless steel. They are also used for the first layer in the welding of Type 405 and 410 clad steels.

A8.2.28 E2209TX-X. The nominal composition (wt %) of this weld metal is 22 Cr, 8.5 Ni, 3.5 Mo, and 0.15 N. This electrode is used to join duplex stainless steel base metals containing approximately 22 wt % chromium. The microstructure of the weld deposit consists of a mixture of austenite and ferrite. Because of the two-phase structure, the alloy is one of the family of duplex stainless steel alloys. The alloy has good resistance to stress corrosion cracking and pitting corrosion attack. If post weld annealing is required, this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A8.2.29 E2307TX-X. *The nominal composition (wt %) of this weld metal is 24 Cr, 8.5 Ni, and 0.15 N. Electrodes of this classification are used for welding lean duplex stainless steel such as UNS S32101 and S32304. Weld metal deposited by these electrodes has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited with E2307 filler metal combines increased tensile strength and improved resistance to stress corrosion cracking as compared to those properties in 308L weld metal.*

A8.2.30 E2553TX-X. The nominal composition (wt %) of this weld metal is 25.5 Cr, 9.5 Ni, 3.4 Mo, 2 Cu, and 0.18 N. This electrode is used to join duplex stainless steel base metals containing approximately 25 wt % chromium. The microstructure of the weld deposit consists of a mixture of austenite and ferrite. Because of the two-phase microstructure, this alloy is one of the family of duplex stainless steel alloys. Duplex stainless steels combine high tensile and yield

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[13] CA6NM is a designation of ASTM A 352, *Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service*.

strengths with improved resistance to pitting corrosion and stress corrosion cracking. If postweld annealing is required, this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A8.2.31 E2594TX-X. The nominal composition (wt %) of this classification is 25.5 Cr, 9.3 Ni, 3.5 Mo, and 0.25 N. The sum of the 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 "superduplex stainless steel." This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride containing environments. It is designed for the welding of superduplex stainless steels UNS S32750 and S32760 (wrought) and for UNS J93380 and J93404 (cast). It can also be used for the welding of UNS S32550, J93370, and J93372 when not subject to sulfurous or sulfuric acids in service. It can also be used for the welding of low alloy steels to duplex stainless steels as well as to weld 'standard' duplex stainless steels such as UNS S32205 and J92205 although the weld metal impact toughness may be inferior to that from E2209TX-X electrodes. If postweld annealing is required, this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A8.2.32 E308HMoT0-3. The composition of this weld metal is the same as that of E308MoTX-X, except that the carbon content is higher than the E308MoT0-3 range. The higher carbon content provides higher strength at elevated temperatures. The primary use of this electrode is for the welding of armor steel.

A8.2.33 E316LKT0-3. The composition of this weld metal is the same as E316LTX-X. These electrodes, however, are "self-shielding" and are used primarily for welding stainless steels for cryogenic service. Although the nominal chromium, nickel, and molybdenum content of E316LKT0-3 filler metal is essentially the same as the other E316 grades, special attention is given to it in order to maximize low-temperature toughness. Minimizing the content of carbon and nitrogen improves the toughness. Low nitrogen content is achieved by providing a more efficient slag system than is employed with EXXXT0-3 self-shielding electrodes. Delta ferrite in the weld metal has an adverse effect on toughness; therefore, the chemical composition of the weld metal is balanced to provide low maximum ferrite content (3 FN or less). Fully austenitic weld metal is preferred from a toughness standpoint; however, it is recognized that the tendency for weld metal fissuring is greater in fully austenitic weld metals.

A8.2.34 R308LT1-5. The nominal composition (wt %) of this weld metal is 18.5 Cr and 10 Ni with carbon held to 0.03% maximum. This flux cored rod is used primarily for root pass welding of Type 304 or 304L stainless steel joints when an inert gas backing purge is either not possible or not desirable. This rod can only be used with the GTAW process, but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A8.2.35 R309LT1-5. The nominal composition (wt %) of this weld metal is 23.5 Cr and 13 Ni with carbon held to 0.03% maximum. This flux cored filler rod is used primarily for the root pass welding of carbon steel to austenitic stainless steel when inert gas backing purge is either not possible or not desirable. The high Cr and Ni content allow dilution with carbon steel while still producing a weld metal with sufficient alloy to provide stable austenite with a little ferrite despite normal dilution from the carbon steel side of the joint. This rod can only be used with the GTAW process, but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A8.2.36 R316LT1-5. The nominal composition (wt %) of this weld metal is 18.5 Cr, 13 Ni, and 2.5 Mo with C held to 0.03% maximum. This flux cored filler rod is used primarily for the root pass welding of Type 316 or 316L stainless steel joints when inert gas backing purge is either not possible or not desirable. This rod can only be used with the GTAW process but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A8.2.37 R347T1-5. The nominal composition (wt %) of this weld metal is 19.5 Cr and 10 Ni with Nb added as a stabilizer. This flux cored filler rod is used primarily for the root pass welding of Types 321 and 347 stainless steel joints when inert gas backing purge is either not possible or not desirable. This rod can only be used with the GTAW process, but caution is advised as it will produce a slag cover which must be removed before additional weld layers can be deposited. It is recommended that the manufacturer's instructions and guidelines be followed when using this rod.

A8.3 Intended Use of Metal Cored Electrodes

A8.3.1 EC209. The nominal composition (wt %) of this classification is 22 Cr, 11 Ni, 5.5 Mn, 2 Mo, and 0.20 N. Filler metals of this classification are most often used to weld UNS S20910 base metal. This alloy is a nitrogen-strengthened, austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperatures. Weldments in the as-welded condition made using this filler metal are not subject to carbide precipitation. Nitrogen alloying reduces the tendency for carbon diffusion and thereby increases resistance to intergranular corrosion.

The EC209 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications when used with the gas metal arc welding process.

The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.2 EC218. The nominal composition (wt %) of this classification is 17 Cr, 8.5 Ni, 8 Mn, 4 Si, and 0.13 N. Filler metals of this classification are most often used to weld UNS S21800 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperature. Nitrogen alloying in this base composition results in significant improvement in wear resistance in particle-to-metal and metal-to-metal (galling) applications when compared to the more conventional austenitic stainless steels such as Type 304. The EC218 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.3 EC219. The nominal composition (wt %) of this classification is 20 Cr, 6 Ni, 9 Mn, and 0.20 N. Filler metals of this classification are most often used to weld UNS S21900 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperatures.

Weldments made using this filler metal are not subject to carbide precipitation in the as-welded condition. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increases resistance to intergranular corrosion.

The EC219 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosive applications when used with the gas metal arc welding process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.4 EC240. The nominal composition (wt %) of this classification is 18 Cr, 5 Ni, 12 Mn, and 0.20 N. Filler metal of this classification is most often used to weld UNS S24000 and UNS S24100 base metals. These alloys are nitrogen-strengthened austenitic stainless steels exhibiting high strength and good toughness over a wide range of temperatures. Significant improvement of wear resistance in particle-to-metal and metal-to-metal (galling) applications is a valuable characteristic when compared to the more conventional austenitic stainless steels such as Type 304. Nitrogen alloying reduces the tendency toward intergranular carbide precipitation in the weld area by inhibiting carbon diffusion thereby reducing the possibility for intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. In addition, weldments in Type 240 exhibit improved resistance to transgranular stress corrosion cracking in hot aqueous chloride-containing media. The EC240 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3.5 EC307. The nominal composition (wt %) of this classification is 21 Cr, 9.5 Ni, 4 Mn, and 1 Mo. Filler metals of this classification are used primarily for moderate-strength welds with good crack resistance between dissimilar steels such as austenitic manganese steel and carbon steel forgings or castings.

A8.3.6 EC308. The nominal composition (wt %) of this classification is 21 Cr and 10 Ni. Commercial specifications for filler and base metals vary in the minimum alloy requirements; consequently, the names 18-8, 19-9, and 20-10 are often associated with filler metals of this classification. This classification is most often used to weld base metals of similar composition, in particular, Type 304.

A8.3.7 EC308Si. This classification is the same as EC308, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces low ferrite or fully austenitic weld metal, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.8 EC308H. This classification is the same as EC308, except that the allowable carbon content has been restricted to the higher portion of the 308 range. Carbon content in the range of 0.04–0.08 provides higher strength at elevated temperatures. This filler metal is used for welding 304H base metal.

A8.3.9 EC308L. This classification is the same as EC308, except for the carbon content. Low carbon (0.03% maximum) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. Strength of this low-carbon alloy, however, is less than that of the niobium-stabilized alloys or Type 308H at elevated temperatures.

A8.3.10 EC308LSi. This classification is the same as EC308L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.11 EC308Mo. This classification is the same as EC308, except for the addition of molybdenum. It is used for welding ASTM CF8M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for welding wrought materials such as Type 316 (UNS31600) stainless when ferrite content in excess of that attainable with the EC316 classification is desired.

A8.3.12 EC308LMo. This classification is used for welding ASTM CF3M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for welding wrought materials such as Type 316L stainless when a ferrite in excess of that attainable with EC316L is desired.

A8.3.13 EC309. The nominal composition (wt %) of this classification is 24 Cr and 13 Ni. Filler metals of this classification are commonly used for welding similar alloys in wrought or cast form. Occasionally, they are used to weld Type 304 and similar base metals where severe corrosion conditions exist requiring higher alloy weld metal. They are also used in dissimilar metal welds, such as joining Type 304 to carbon steel, welding the clad side of Type 304 clad steels, and applying stainless steel sheet linings to carbon steel shells.

A8.3.14 EC309Si. This classification is the same as EC309, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.3.15 EC309L. This classification is the same as EC309, except for the carbon content. Low carbon (0.03% max.) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. Strength of this low-carbon alloy, however, may not be as great at elevated temperatures as that of the niobium-stabilized alloys or EC309.

A8.3.16 EC309LSi. This classification is the same as EC309L, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.17 EC309Mo. This classification is the same as EC309, except for the addition of 2.0% to 3.0% molybdenum to increase its pitting corrosion resistance in halide-containing environments. The primary application for this filler metal is surfacing of base metals to improve their corrosion resistance. The EC309Mo is used to achieve a single-layer overlay with a chemical composition similar to that of a 316 stainless steel. It is also used for the first layer of multilayer overlays with filler metals such as EC316 or EC317 stainless steels. Without the first layer of 309Mo, elements such as chromium and molybdenum might be reduced to unacceptable levels in successive layers by dilution from the base metal. Other applications include the welding of molybdenum-containing stainless steel linings to carbon steel shells, the joining of carbon steel base metals which had been clad with a molybdenum-containing stainless steel, and the joining of dissimilar base metals such as carbon steel to Type 304 stainless steel, for service below 600°F [315°C].

A8.3.18 EC309LMo. This classification is the same as an EC309Mo, except for lower maximum carbon content (0.03%). Low-carbon contents in stainless steels reduce the possibility of chromium carbide precipitation and thereby increase weld metal resistance to intergranular corrosion. The EC309LMo is used in the same type of applications as the

EC309Mo, but where excessive pickup of carbon from dilution by the base metal, where intergranular corrosion from carbide precipitation, or both are factors to be considered in the selection of the filler metal. In multilayer overlays, the low carbon EC309LMo is usually needed for the first layer in order to achieve low carbon contents in successive layers with filler metals such as EC316L or EC317L.

A8.3.19 EC310. The nominal composition (wt %) of this classification is 26.5 Cr and 21 Ni. Filler metal of this classification is most often used to weld base metals of similar composition.

A8.3.20 EC312. The nominal composition (wt %) of this classification is 30 Cr and 9 Ni. Filler metal of this classification was originally designed to weld cast alloys of similar composition. It also has been found to be valuable in welding dissimilar metals such as carbon steel to stainless steel, particularly those grades high in nickel. This alloy gives a two-phase weld deposit with substantial percentages of ferrite in an austenite matrix. Even with considerable dilution by austenite-forming elements such as nickel, the microstructure remains two-phase and thus highly resistant to weld metal cracks and fissures.

A8.3.21 EC316. The nominal composition (wt %) of this classification is 19 Cr, 12.5 Ni, and 2.5 Mo. This filler metal is used for welding Type 316 and similar alloys. It has been used successfully in certain applications involving special base metals for high-temperature service. The presence of molybdenum provides creep resistance at elevated temperatures and pitting resistance in a halide atmosphere.

Rapid corrosion of EC316 weld metal may occur when the following three factors co-exist:

(1) The presence of a continuous or semi-continuous network of ferrite in the weld metal microstructure

(2) A composition balance of the weld metal giving a chromium-to-molybdenum ratio of less than 8.2 to 1

(3) Immersion of the weld metal in a corrosive medium. Attempts to classify the media in which accelerated corrosion will take place by attack on the ferrite phase have not been entirely successful. Strong oxidizing and mildly reducing environments have been present where a number of corrosion failures were investigated and documented. The literature should be consulted for latest recommendations.

A8.3.22 EC316Si. This classification is the same as EC316, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.23 EC316H. This filler metal is the same as EC316, except that the allowable carbon content has been restricted to the higher portion of the 316 range. Carbon content in the range of 0.04 wt % to 0.08 wt % provides higher strength at elevated temperatures. This filler metal is used for welding 316H base metal.

A8.3.24 EC316L. This classification is the same as EC316, except for the carbon content. Low carbon (0.03% maximum) in this filler metal reduces the possibility of intergranular chromium carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This filler metal is primarily used for welding low-carbon molybdenum-bearing austenitic alloys. This low-carbon alloy, however, is not as strong at elevated temperature as the niobium-stabilized alloys or Type EC316H.

A8.3.25 EC316LSi. This classification is the same as EC316L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity is somewhat higher than that of lower silicon content weld metal.

A8.3.26 EC316LMn. The nominal composition (wt %) of this classification is 19 Cr, 15 Ni, 7 Mn, 3 Mo, and 0.2 N. This is a fully austenitic alloy with a typical ferrite content of 0.5 FN maximum. One of the primary uses of this filler metal is for joining similar and dissimilar cryogenic steels for applications down to –452°F (–269°C). This filler metal also exhibits good corrosion resistance in acids and seawater, and is particularly suited for corrosion conditions found in urea synthesis plants. It is also nonmagnetic. The high Mn content of the alloy helps to stabilize the austenitic microstructure and aids in hot cracking resistance.

A8.3.27 EC317. The nominal composition (wt %) of this classification is 19.5 Cr, 14 Ni, and 3.5 Mo, somewhat higher than EC316. It is usually used for welding alloys of similar composition. EC317 filler metal is utilized in severely corrosive environments where crevice and pitting corrosion are of concern.

A8.3.28 EC317L. This classification is the same as EC317, except for the carbon content. Low carbon (0.03% maximum) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, may not be as strong at elevated temperature as the niobium-stabilized alloys or Type 317.

A8.3.29 EC318. This composition is identical to EC316, except for the addition of niobium. Niobium provides resistance to intergranular chromium carbide precipitation and thus increased resistance to intergranular corrosion. Filler metal of this classification is used primarily for welding base metals of similar composition.

A8.3.30 EC320. The nominal composition (wt %) of this classification is 20 Cr, 34 Ni, 2.5 Mo, and 3.5 Cu, with Nb added to provide resistance to intergranular corrosion. Filler metal of this classification is primarily used to weld base metals of similar composition for applications where resistance to severe corrosion involving a wide range of chemicals, including sulfuric and sulfurous acids and their salts, is required. This filler metal can be used to weld both castings and wrought alloys of similar composition without postweld heat treatment. A modification of this classification without niobium is available for repairing castings which do not contain niobium, but with this modified composition, solution annealing is required after welding.

A8.3.31 EC320LR (Low Residuals). This classification has the same basic composition as EC320; however, the elements C, Si, P, and S are specified at lower maximum levels and the Nb and Mn are controlled within narrower ranges. These changes reduce the weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals. Consequently, welding practices typically used for austenitic stainless steel weld metals containing ferrite can be used in bare filler metal welding processes such as gas tungsten arc and gas metal arc welding. EC320LR filler metal has been used successfully in submerged arc overlay welding, but it may be prone to cracking when used for joining base metal by the submerged arc process. EC320LR weld metal has a lower minimum tensile strength than EC320 weld metal.

A8.3.32 EC321. The nominal composition (wt %) of this classification is 19.5 Cr and 9.5 Ni, with titanium added. The titanium acts in the same way as niobium in Type 347 in reducing intergranular chromium carbide precipitation and thus increasing resistance to intergranular corrosion. The filler metal of this classification is used for welding chromium-nickel stainless steel base metals of similar composition, using an inert gas shielded process. It is not suitable for use with the submerged arc process because only a small portion of the titanium will be recovered in the weld metal.

A8.3.33 EC330. The nominal composition (wt %) of this classification is 35.5 Ni and 16 Cr. Filler metal of this type is commonly used where heat and scale resisting properties above 1800°F (980°C) are required, except in high-sulfur environments, as these environments may adversely affect elevated temperature performance. Repairs of defects in alloy castings and the welding of castings and wrought alloys of similar composition are the most common applications.

A8.3.34 EC347. The nominal composition (wt %) of this classification is 20 Cr and 10 Ni, with Nb added as a stabilizer. The addition of niobium reduces the possibility of intergranular chromium carbide precipitation and thus susceptibility to intergranular corrosion. The filler metal of this classification is usually used for welding chromium-nickel stainless steel base metals of similar composition stabilized with either Nb or Ti. Although Nb is the stabilizing element usually specified in Type 347 alloys, it should be recognized that tantalum (Ta) is also present. Ta and Nb are almost equally effective in stabilizing carbon and in providing high-temperature strength. If dilution by the base metal produces a low ferrite or fully austenitic weld metal, the crack sensitivity of the weld may increase substantially.

A8.3.35 EC347Si. This classification is the same as EC347, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of lower silicon content weld metal.

A8.3.36 EC383. The nominal composition (wt %) of this classification is 27.5 Cr, 31.5 Ni, 3.7 Mo, and 1 Cu. Filler metal of this classification is used to weld UNS N08028 base metal to itself, or to other grades of stainless steel. EC383 filler metal is recommended for sulfuric and phosphoric acid environments. The elements C, Si, P, and S are specified at low maximum levels to minimize weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals.

A8.3.37 EC385. The nominal composition (wt %) of this classification is 20.5 Cr, 25 Ni, 4.7 Mo, and 1.5 Cu. ER385 filler metal is used primarily for welding of ASTM B 625, B 673, B 674, and B 677 (UNS N08904) materials for the handling of sulfuric acid and many chloride containing media. EC385 filler metal may also be used to join Type 317L material where improved corrosion resistance in specific media is needed. EC385 filler metal may be used for joining UNS N08904 base metals to other grades of stainless steel. The elements C, S, P, and Si are specified at lower maximum levels to minimize weld metal hot cracking and fissuring (while maintaining corrosion resistance) frequently encountered in fully austenitic weld metals.

A8.3.38 EC409. This 12 Cr alloy (wt %) differs from Type 410 material because it has a ferritic microstructure. The titanium addition forms carbides to improve corrosion resistance, increase strength at high temperature, and promote the ferritic microstructure. EC409 filler metals may be used to join matching or dissimilar base metals. The greatest usage is for applications where thin stock is fabricated into exhaust system components.

A8.3.39 EC409Nb. This classification is the same as EC409, except that niobium is used instead of titanium to achieve similar results. Oxidation losses across the arc generally are lower. Applications are the same as those of EC409 filler metals.

A8.3.40 EC410. This 12 Cr alloy (wt %) is an air-hardening steel. Preheat and postweld heat treatments are required to achieve welds of adequate ductility for many engineering purposes. The most common application of filler metal of this type is for welding alloys of similar composition. It is also used for deposition of overlays on carbon steels to resist corrosion, erosion, or abrasion.

A8.3.41 EC410NiMo. The nominal composition (wt %) of this classification is 12 Cr, 4.5 Ni, and 0.55 Mo. It is primarily designed for welding ASTM CA6NM castings or similar material, as well as light-gauge 405, 410, and 410S base metals. Filler metal of this classification is modified to contain less chromium and more nickel to eliminate ferrite in the microstructure as it has a deleterious effect on mechanical properties. Final postweld heat treatment should not exceed 1150°F [620°C], as higher temperatures may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A8.3.42 EC420. This classification is similar to EC410, except for slightly higher chromium and carbon contents. EC420 is used for many surfacing operations requiring corrosion resistance provided by 12% chromium along with somewhat higher hardness than weld metal deposited by EC410 electrodes. This increases wear resistance.

A8.3.43 EC430. This is a 16 wt % Cr alloy. The composition is balanced by providing sufficient chromium to give adequate corrosion resistance for the usual applications, and yet retain sufficient ductility in the heat-treated condition (excessive chromium will result in lower ductility). Welding with filler metal of the EC430 classification usually requires preheating and postweld heat treatment.

Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A8.3.44 EC439. This is an 18 wt % Cr alloy that is stabilized with titanium. EC439 provides improved oxidation and corrosion resistance over EC409 in similar applications. Applications are the same as those of EC409 filler metals where thin stock is fabricated into exhaust system components.

A8.3.45 EC439Nb. This classification is the same as EC439, except that niobium is used instead of titanium to achieve similar results. Oxidation loss across the arc for Nb is generally lower than Ti loss in EC439. Applications for EC439Nb filler metal are generally similar to EC439. Its major use is in automotive exhaust systems components.

A8.3.46 EC446LMo. The nominal composition (wt %) of this classification (formerly listed as EC26-1) is 26 Cr and 1 Mo. It is used for welding base metal of the same composition with inert gas shielded welding processes. Due to the high purity of both base metal and filler metal, cleaning of the parts before welding is most important. Complete coverage by shielding gas during welding is extremely important to prevent contamination by oxygen and nitrogen. Nonconventional gas shielding methods (leading, trailing, and back shielding) often are employed.

A8.3.47 EC630. The nominal composition (wt %) of this classification is 16.4 Cr, 4.7 Ni, and 3.6 Cu. The composition is designed primarily for welding ASTM A 564 Type 630 and some other precipitation-hardening stainless steels. The composition is modified to prevent the formation of ferrite networks in the martensitic microstructure which have a deleterious effect on mechanical properties. Dependent on the application and weld size, the weld metal may be used as-welded; welded and precipitation hardened; or welded, solution treated, and precipitation hardened.

A8.3.48 EC19-10H. The nominal composition (wt %) of this classification is 19 Cr and 10 Ni and is similar to ER308H, except that the chromium content is lower and there are additional limits on Mo, Nb, and Ti. This lower limit of Cr and additional limits on other Cr equivalent elements allows a lower ferrite range to be attained. A lower ferrite level in the weld metal decreases the chance of sigma embrittlement after long-term exposure at temperatures in excess of 1000°F [540°C]. This filler metal should be used in conjunction with welding processes and other welding consumables which do not deplete or otherwise significantly change the amount of chromium in the weld metal. If used with submerged arc welding, a flux that neither removes nor adds chromium to the weld metal is highly recommended.

This filler metal also has the higher carbon level required for improved creep properties in high-temperature service. The user is cautioned that actual weld application qualification testing is recommended in order to be sure that an acceptable weld metal carbon level is obtained. If corrosion or scaling is a concern, special testing, as outlined in Clause A10, Special Tests, should be included in application testing.

A8.3.49 EC16-8-2. The nominal composition (wt %) of this classification is 15.5 Cr, 8.5 Ni, and 1.5 Mo. Filler metal of this classification is used primarily for welding stainless steel such as types 16-8-2, 316, and 347 for high-pressure, high-temperature piping systems. The weld deposit usually has a Ferrite Number no higher than 5 FN. The deposit also has good hot-ductility properties which offer greater freedom from weld or crater cracking even under restraint conditions. The weld metal is usable in either the as-welded condition or solution-treated condition. This filler metal depends on a very carefully balanced chemical composition to develop its fullest properties. Corrosion tests indicate that the 16-8-2 weld metal may have less corrosion resistance than 316 base metal, depending on the corrosive media. Where the weldment is exposed to severe corrodants, the surface layers should be deposited with a more corrosion-resistant filler metal.

A8.3.50 EC2209. The nominal composition (wt %) of this classification is 22.5 Cr, 8.5 Ni, 3 Mo, and 0.15 N. Filler metal of this classification is used primarily to weld duplex stainless steels which contain approximately 22% chromium such as UNS S31803 and S32205. Deposits of this alloy have "duplex" microstructures consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting.

A8.3.51 EC2553. The nominal composition (wt %) of this classification is 25.5 Cr, 5.5 Ni, 3.4 Mo, 2 Cu, and 0.2 N. Filler metal of this classification is used primarily to weld duplex stainless steels UNS S32550 which contain approximately 25% chromium. Deposits of this alloy have a "duplex" microstructure consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting.

A8.3.52 EC2594. The nominal composition (wt %) of this classification is 25.5 Cr, 9.2 Ni, 3.5 Mo, and 0.25 N. The sum of the Cr + 3.3(Mo + 0.5 W) + 16 N, known as the Pitting Resistance Equivalent Number (PREN), is at least 40, thereby allowing the weld metal to be called a 'superduplex stainless steel'. This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride-containing environments. It is designed for the welding of superduplex stainless steels UNS S32750 and 32760 (wrought), and UNS J93380 and J93404 (cast). It can also be used for the welding of UNS S32550, J93370, and J93372 when not subject to sulfurous or sulfuric acids in service. It can also be used for welding carbon and low alloy steels to duplex stainless steels as well as to weld 'standard' duplex stainless steel such as UNS S32205 and J92205, especially for root runs in pipe.

A8.3.53 EC33-31. The nominal composition (wt %) of this classification is 33 Cr, 31Ni, and 1.6 Mo, with low carbon. The filler metal is used for welding nickel-chromium-iron alloy (UNS R20033) to itself and to carbon steel, and for weld overlay on boiler tubes. The weld metal is resistant to high temperature corrosive environments of coal fired power plant boilers.

A8.3.54 EC3556. The nominal composition (wt %) of this classification is 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, and 2.5 W. Filler metal of this classification is used for welding 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W (UNS R30556) base metal to itself, for joining steel to other nickel alloys, and for surfacing steel by the gas tungsten arc, gas metal arc, and plasma arc welding processes. The filler metal is resistant to high-temperature corrosive environments containing sulfur. Typical specifications for 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W base metal are ASTM B 435, B 572, B 619, B 622, and B 626 (UNS R30556).

A9. Special Tests

A9.1 Mechanical Properties. It is recognized that supplementary tests may be required for certain applications. In such cases, tests to determine specific properties such as strength at elevated or cryogenic temperatures may be required. For impact testing at any temperature, the requirements of Impact Test (Clause 14) for specimen type and size should be followed. AWS A5.01M/A5.01 contains provisions for ordering such tests. This clause is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

Tests of joint specimens may be desired when the intended application involves the welding of dissimilar metals. Procedures for the mechanical testing of such joints should be in accordance with AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*. Tests of joint specimens may be influenced by the properties of the base metal and may not provide adequate tests of the weld metal. Such tests should be considered as tests for qualifying the electrodes or rods. Where fabrication codes require testing welds in heat-treated conditions other than those specified in Table 6, all-weld-metal tests of heat-treated specimens may be desired. For the preparation of such specimens the procedures outlined in 9.4 should be used.

A9.2 Corrosion or Scaling Tests. Although welds made with electrodes or rods covered by this specification commonly are used in corrosion- or heat-resisting applications, it is not practical to require tests for corrosion or scale resistance on welds or weld metal specimens. Such special tests pertinent to the intended application may be conducted as agreed upon between the purchaser and supplier. This subclause is included for the guidance of those who desire such special tests.

A9.2.1 Corrosion or scaling tests of joint specimens have the advantage that the joint design and welding procedure can be made identical to those being used in fabrication. However, the user must be aware that these are tests of the combined properties of the weld metal, the heat-affected zone of the base metal, and the unaffected base metal. It is difficult to obtain reproducible data when a difference exists between the corrosion or oxidation rates of the various metal structures (weld metal, heat-affected zone, and unaffected base metal). Test samples cannot be readily standardized if welding procedure and joint design are to be considered variables. Joint specimens for corrosion tests should not be used for qualifying the electrode.

A9.2.2 All-weld-metal specimens for testing corrosion or scale resistance are prepared by following the procedure outlined for the preparation of pads for chemical analysis (see Clause 9). The pad size should be at least 3/4 in [19 mm] in height by 2-1/2 in [65 mm] wide by 1 +n5/8 in [25 + n16 mm] long, where "n" represents the number of specimens required from the pad. Specimens measuring 1/2 × 2 × 1/4 in [13 x 51 × 6.4 mm] are machined from the top surface of the pad in such a way that the 2 in [51 mm] dimension of the specimen is parallel to the 2-1/2 in [65 mm] width dimension of the pad and the 1/2 in [13 mm] dimension is parallel to the length of the pad.

A9.2.3 The heat treatments, surface finish, and marking of the specimens prior to testing should be in accordance with standard practices for tests of similar alloys in the wrought or cast forms. The testing procedure should correspond to ASTM G 4, *Standard Method for Conducting Corrosion Tests in Plant Equipment*, or ASTM A 262, *Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels*.

A10. Discontinued Classifications

The classifications that have been discontinued are listed in Table A.3 along with the year in which they were last included in this specification.

A11. General Safety Considerations

A11.1 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clause A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A11.2, ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*,[14] and applicable federal and state regulations.

A11.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

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[14] ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Table A.3
Discontinued Classifications

Classification	Year of Last Publication
EXXXT-2	1980
E309LCbTX-X[a]	1995
E410NiTiTX-X	1995
E410NiTiT0-3	1995
E502TX-X[b]	1995
E505TX-X[b]	1995

[a] E309LCbTX-X is now E309LNbTX-X.

[b] Classifications E502TX-X and E505TX-X have been moved from this revision to AWS A5.29/5.29M as new classifications E8XTX-B6/E8XTX-B6L and E8XTX-B8/E8XTX-B8L, respectively.

A11.3 AWS Safety and Health Fact Sheets Index (SHF)[15]

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding & Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Arc Viewing Distance*
27	*Thoriated Tungsten Electrodes*
28	*Oxyfuel Safety: Check Valves and Flashback Arrestors*
29	*Grounding of Portable and Vehicle Mounted Welding Generators*
30	*Cylinders: Safe Storage, Handling, and Use*
31	*Eye and Face Protection for Welding and Cutting Operations*
33	*Personal Protective Equipment (PPE) for Welding & Cutting*
34	*Coated Steels: Welding and Cutting Safety Concerns*
36	*Ventilation for Welding & Cutting*
37	*Selecting Gloves for Welding & Cutting*

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[15] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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SPECIFICATION FOR LOW-ALLOY STEEL ELECTRODES AND FLUXES FOR SUBMERGED ARC WELDING

SFA-5.23/SFA-5.23M

(Identical with AWS Specification A5.23/A5.23M:2011. In case of dispute, the original AWS text applies.)

Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel and low-alloy steel electrodes (both solid and composite) and fluxes for submerged arc welding. Multiple pass flux–electrode classifications include requirements for low-alloy weld metal composition. Two-run flux–electrode classifications, which are also permitted under this specification, have no requirements for weld metal composition. The multiple pass classification of flux–electrode combinations for carbon steel submerged arc welding is not within the scope of this specification but remains with AWS A5.17/A5.17M, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding.*

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in the nonmandatory Annex Clauses A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.23 uses U.S. Customary Units. The specification A5.23M uses SI units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing of electrodes or packaging or both under specification A5.23 or A5.23M.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the referenced standard applies.

2.1 The following AWS standards[1] are referenced in the mandatory clauses of this document:

AWS A1.1, *Metric Practice Guide for the Welding Industry*

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*

AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

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[1] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

AWS A5.01M/A5.01 (ISO 14344 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

AWS A5.02/A5.02M:2007, *Filler Metal Standard Sizes, Packaging and Physical Attributes*

AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

AWS F3.2, *Ventilation Guide for Weld Fumes*

2.2 The following ANSI standard is referenced in the mandatory clauses of this document:

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*[2]

2.3 The following ASTM standards[3] are referenced in the mandatory clauses of this document:

ASTM A 36/A 36M, *Standard Specification for Carbon Structural Steel*

ASTM A 131/A 131M, *Standard Specification for Structural Steel for Ships*

ASTM A 203/A 203M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

ASTM A 204/A 204M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum*

ASTM A 285/A 285M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength.*

ASTM A 387/A 387M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium–Molybdenum*

ASTM A 514/A 514M, *Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Quenching*

ASTM A 515/A 515M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate-and Higher-Temperature Service*

ASTM A 516/A 516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.*

ASTM A 517/A 517M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered*

ASTM A 533/A 533M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese–Molybdenum and Manganese–Molybdenum–Nickel*

ASTM A 537/A 537M, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon–Manganese–Silicon Steel*

ASTM A 543/A 543M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Nickel–Chromium–Molybdenum*

ASTM A 572/A 572M, *Standard Specification for High-Strength Low-Alloy Columbium–Vanadium Structural Steel*

ASTM A 588/A 588M, *Standard Specification for High-Strength Low-Alloy Structural Steel,up to 50 ksi [345 MPa] Minimum Yield Point with Atmospheric Corrosion Resistance*

ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

ASTM E 350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

ASTM E 1032, *Standard Test Method for Radiographic Examination of Weldments*

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[2] This ANSI standard is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] ASTM standards are published by the ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959.

2.4 The following ISO standards[4] are referenced in the mandatory clauses of this document.

ISO 544, *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances, and marking*.

ISO 80000-1, *Quantities and units*

3. Classification

3.1 The submerged arc welding electrodes and fluxes covered by the A5.23 specification utilize a classification system based upon the U.S. Customary Units and are classified according to the following:

(1) The mechanical properties of the weld metal obtained from a multiple pass groove weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1 and 2.

AND/OR

The mechanical properties of the weld metal obtained from a two-run butt weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1 and 2.

Table 1
A5.23 Tension Test Requirements

Flux–Electrode Classifications[a]		Tensile Strength[b] (psi)	Yield Strength[b] (0.2% Offset) (psi)	Elongation[b] (%)
Multiple Pass Classifications	F7XX-EXX-XX	70 000–95 000	58 000	22
	F8XX-EXX-XX	80 000–100 000	68 000	20
	F9XX-EXX-XX	90 000–110 000	78 000	17
	F10XX-EXX-XX	100 000–120 000	88 000	16
	F11XX-EXX-XX	110 000–130 000	98 000	15[c]
	F12XX-EXX-XX	120 000–140 000	108 000	14[c]
	F13XX-EXX-XX	130 000–150 000	118 000	14[c]
Two-Run Classifications	F6TXX-EXX	60 000	50 000	22
	F7TXX-EXX	70 000	60 000	22
	F8TXX-EXX	80 000	70 000	20
	F9TXX-EXX	90 000	80 000	17
	F10TXX-EXX	100 000	90 000	16
	F11TXX-EXX	110 000	100 000	15
	F12TXX-EXX	120 000	110 000	14
	F13TXX-EXX	130 000	120 000	14

[a] The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter "C" will appear after the "E" as part of the classification designation when the electrode used is a composite electrode. For two-run classifications, the letter "G" will appear after the impact designator (immediately before the hyphen) to indicate that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel, as agreed between purchaser and supplier. The letter "X" used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the weld metal. See Figure 1 or 2, as applicable, for a complete explanation of the classification designators.

[b] For multiple pass classifications, the requirements listed in the table for yield strength and % elongation (in 2 in gauge length) are minimum requirements. For two-run classifications, the requirements listed for tensile strength, yield strength, and % elongation (in 1 in gauge length) are all minimum requirements.

[c] Elongation may be reduced by one percentage point for F11XX-EXX-XX, F11XX-ECXX-XX, F12XX-EXX-XX, F12XX-ECXX-XX, F13XX-EXX-XX, and F13XX-ECXX-XX weld metals in the upper 25% of their tensile strength range.

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[4] ISO standards are published by the International Organization of Standardization, 1, ch. De la Voie-Creuse, Case Postale 56, CH-1211 Geneva 20, Switzerland.

Table 1M
A5.23M Tension Test Requirements

Flux–Electrode Classifications[a]		Tensile Strength[b] (MPa)	Yield Strength[b] (0.2% Offset) (MPa)	Elongation[b] (%)
Multiple Pass Classifications	F49XX-EXX-XX	490–660	400	22
	F55XX-EXX-XX	550–700	470	20
	F62XX-EXX-XX	620–760	540	17
	F69XX-EXX-XX	690–830	610	16
	F76XX-EXX-XX	760–900	680	15[c]
	F83XX-EXX-XX	830–970	740	14[c]
	F90XX-EXX-XX	900–1040	810	14[c]
Two-Run Classifications	F43TXX-EXX	430	350	22
	F49TXX-EXX	490	415	22
	F55TXX-EXX	550	490	20
	F62TXX-EXX	620	555	17
	F69TXX-EXX	690	625	16
	F76TXX-EXX	760	690	15
	F83TXX-EXX	830	760	14
	F90TXX-EXX	900	830	14

[a] The letter “S” will appear after the “F” as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter “C” will appear after the “E” as part of the classification designation when the electrode used is a composite electrode. For two-run classifications, the letter “G” will appear after the impact designator (immediately before the hyphen) to indicate that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel, as agreed between purchaser and supplier. The letter “X” used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the weld metal. See Figure 1M or 2M, as applicable, for a complete explanation of the classification designators.

[b] For multiple pass classifications, the requirements listed in the table for yield strength and % elongation (in 50 mm gauge length) are minimum requirements. For two-run classifications, the requirements listed for tensile strength, yield strength, and % elongation (in 25 mm gauge length) are all minimum requirements.

[c] Elongation may be reduced by one percentage point for F76-EXX-XX, F76-ECXX-XX, F83XX-EXX-XX, F83XX-ECXX-XX, F90XX-EXX-XX, and F90XX-ECXX-XX weld metals in the upper 25% of their tensile strength range.

Table 2
Impact Test Requirements

A5.23 Requirements			A5.23M Requirements		
A5.23 Impact Designator[a,b]	Maximum Test Temperature[c] (°F)	Minimum Average Energy Level	A5.23M Impact Designator[a,b]	Maximum Test Temperature[c] (°C)	Minimum Average Energy Level
0	0	20 ft·lbf	0	0	27 J
2	–20		2	–20	
4	–40		3	–30	
5	–50		4	–40	
6	–60		5	–50	
8	–80		6	–60	
10	–100		7	–70	
15	–150		10	–100	
Z	No Impact Requirements		Z	No Impact Requirements	

[a] Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate designator from this table, as indicated in Figure 1, 1M, 2, or 2M, as applicable.

[b] When classifying flux–electrode combinations to A5.23 using U.S. Customary Units, the Impact Designator indicates the impact test temperature in °F. When classifying to A5.23M using the International System of Units (SI) the Impact Designator indicates the impact test temperature in °C. With the exception of the Impact Designator “4”, a given Impact Designator will indicate different temperatures depending upon whether classification is according to A5.23 in U.S. Customary Units or according to A5.23M in the International System of Units (SI). For example, a “2” Impact Designator when classifying to A5.23 indicates a test temperature of –20°F. When classifying to A5.23M the “2” Impact Designator indicates a test temperature of –20°C, which is –4°F.

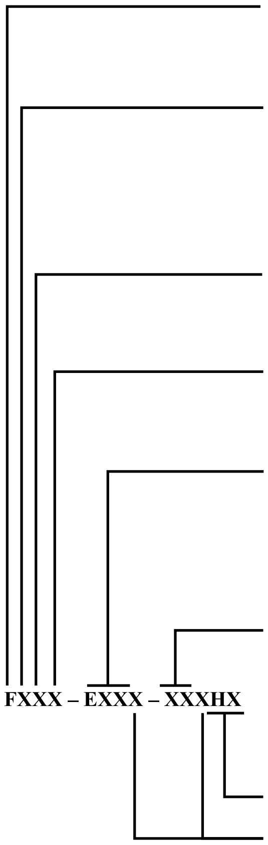
[c] Weld metal from a specific flux–electrode combination that meets the impact requirements at a given temperature also meets the requirements at all higher temperatures in this table. For example, weld metal meeting the A5.23 requirements for designator “5” also meets the requirements for designators 4, 2, 0, and Z. [Weld metal meeting the A5.23M requirements for designator “5” also meets the requirements for designators 4, 3, 2, 0, and Z].

(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 or 9.5, as applicable (and as shown in Figure 1 or 2, as applicable).

(3) For multiple pass classifications, the chemical composition of the weld metal obtained with the combination of a particular flux and a particular classification of electrode as specified in Table 3. Two-run classifications have no requirement for weld metal composition under this specification (see Figure 1 or 2, as applicable).

(4) The chemical composition of either the electrode (for solid electrodes) as specified in Table 4, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 3.

MANDATORY CLASSIFICATION DESIGNATORS[a]



The letter "F" indicates a submerged arc flux. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux.

Indicates the minimum tensile strength (in increments of 10 000 psi) of weld metal deposited with the flux and some classification of electrode under the welding conditions specified in Figure 4 and Table 6. Two digits are used for weld metal of 100 000 psi tensile strength and higher. For example, when this designator is 8, the tensile requirement is 80 000 to 100 000 psi. When this designator is 11, the tensile requirement is 110 000 to 130 000 psi (see Table 1).

Designates the condition of heat treatment under which the tests were conducted: "A" is for as-welded and "P" for postweld heat treated. The time and temperature for PWHT are specified in 9.4 and Table 9.

Indicates the temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf. Two digits are used for test temperatures of –100°F or lower (see Table 2).

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C" will appear after the "E" as part of the electrode classification when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

Indicates the chemical composition of the weld metal obtained with the flux and the electrode. Two or more letters and/or digits are used (see Table 3).

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

Optional supplemental designator for special limits on residuals. An "N", when it appears after the electrode designation or after the weld metal composition designation, indicates conformance to special requirements for nuclear applications (see Table 4, Note c, and Table 3, Note c). An "R" indicates conformance to special requirements for step cooling applications (see Table 4, Note h, and Table 3, Note i).

[a] The combination of these designators constitutes the flux–electrode classification.
[b] These designators are optional and do not constitute a part of the flux–electrode classification.

EXAMPLE

F9P0-EB3-B3 is a complete designation for a flux–electrode combination. It refers to a flux that will produce weld metal which, in the postweld heat-treated condition, will have a tensile strength of 90 000 to 110 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at 0°F when produced with an EB3 electrode under the conditions called for in this specification. The composition of the weld metal will meet the requirements for a B3 designation as specified in Table 3.

Source: Figure 1 of AWS A5.23/A5.23M:2007

Figure 1 — A5.23 Multiple Pass Classification System for U.S. Customary Units

MANDATORY CLASSIFICATION DESIGNATORS[a]

The letter "F" indicates a submerged arc flux. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or blend of crushed slag with unused (virgin) flux.

Two digits indicate the minimum tensile strength (in increments of 10 megapascals [MPa]) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 4 and Table 6. For example, when this designator is 55, the tensile requirement is 550 MPa to 700 MPa (see Table 1M).

Designates the condition of heat treatment in which the tests were conducted: "A" is for as-welded and "P" is for postweld heat treated. The time and temperature of the PWHT are specified in 9.4 and Table 9.

Indicates the temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J. Two digits are used for the –100°C test temperature (see Table 2).

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C" will appear after the "E" as part of the electrode classification when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

Indicates the chemical composition of the weld metal obtained with the flux and the electrode. Two or more letters and/or digits are used (see Table 3).

FXXXX – EXXX – XXXHX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental hydrogen designator (see Table 10).

Optional supplemental designator for special limits on residuals. An "N", when it appears after the electrode designation or after the weld metal composition designation, indicates conformance to special requirements for nuclear applications (see Table 4, Note c and Table 3, Note c). An "R" indicates conformance to special requirements for step cooling applications (see Table 4, Note h and Table 3, Note i).

[a] The combination of these designators constitutes the flux–electrode classification.

[b] These designators are optional and do not constitute a part of the flux–electrode classification.

EXAMPLE

F62P2-EB3-B3 is a complete designation for a flux–electrode combination. It refers to a flux that will produce weld metal which, in the postweld heat-treated condition, will have a tensile strength of 620 MPa to 760 MPa and Charpy V-notch impact strength of at least 27 J at –20°C when produced with an EB3 electrode under the conditions called for in this specification. The composition of the weld metal will meet the requirements for a B3 designation as specified in Table 3.

Source: Figure 1M of AWS A5.23/A5.23M:2007.

Figure 1M — A5.23M Multiple Pass Classification System for the International System of Units (SI)

MANDATORY CLASSIFICATION DESIGNATORS[a]

The letter “F” indicates a submerged arc welding flux. The letter “S” will appear after the “F” as part of the classification designation when the flux being classified is a crushed slag or blend of crushed slag with unused (virgin) flux.

Indicates the minimum tensile strength (in increments of 10 000 psi) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 5 and Table 7. One or two digits may be used depending on the strength level, as indicated in Table 1. The “T” at the end of the designator identifies the classification as a two-run classification. For example, when this designator is “7T,” the two-run classification tensile requirement is 70 000 psi minimum. When this designator is “10T,” the tensile requirement is 100 000 psi minimum.

Designates the condition of heat treatment in which the tests were conducted: “A” for as-welded and “P” for postweld heat treated. The PWHT procedure is specified in 9.5.

Indicates the temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf. Two digits are used for test temperatures of –100 °F or lower (see Table 2).

The letter “G,” when it appears in this position, indicates that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel as agreed between purchaser and supplier.

Classification of the electrode used in producing the weld metal referred to above. The letter “E” in the first position indicates electrode. The letter “C” will appear after the “E” as part of the electrode classification when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

FXTXXG – EXX – HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

[a] The combination of these designators constitutes the flux–electrode classification.

[b] These designators are optional and do not constitute a part of the flux–electrode classification.

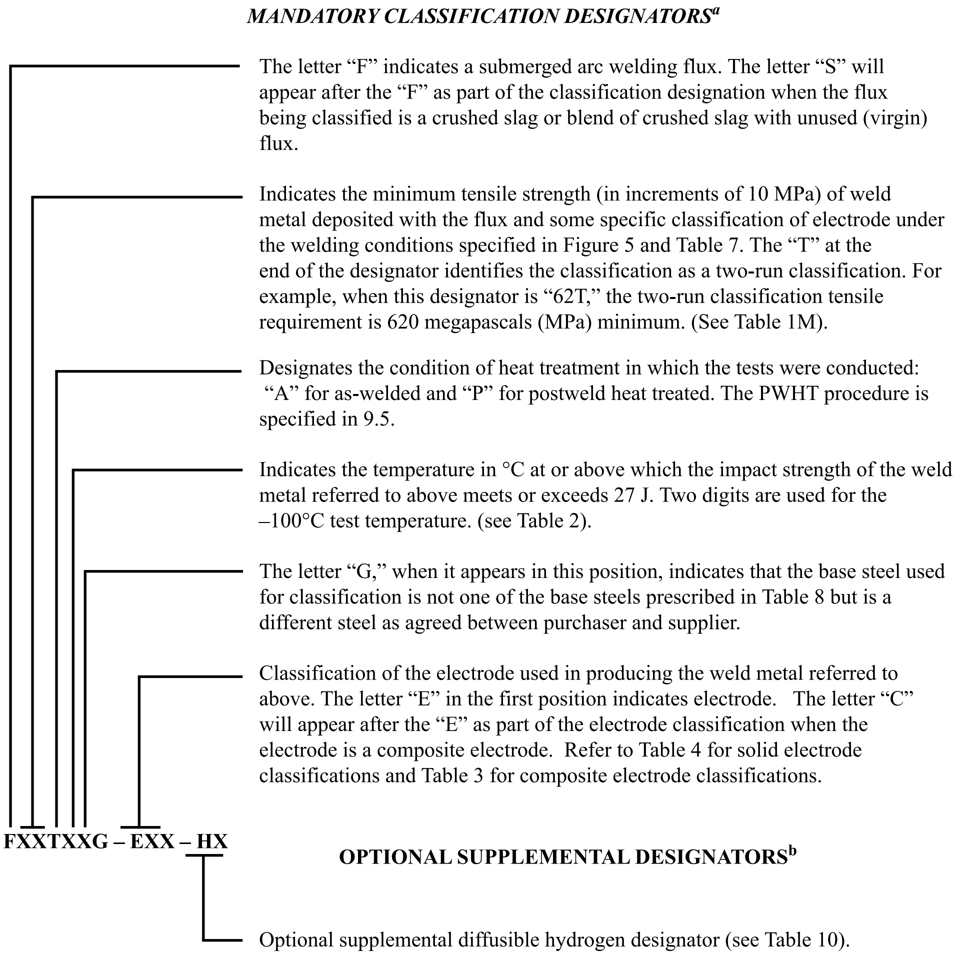
EXAMPLE

F7TA4-EM12K is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EM12K electrode to weld the base plate prescribed in Table 8 in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 70 000 psi and Charpy V-Notch impact strength of at least 20 ft·lbf at –40°F.

F10TP2G-EA3 is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EA3 electrode in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the postweld heat-treated condition having a minimum tensile strength of 100 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –20°F. The “G” in the classification indicates that the base steel used is not as prescribed in Table 8 but is some other steel as agreed between purchaser and supplier

Source: Figure 2 of AWS A5.23/A5.23M:2007.

Figure 2 — A5.23 Two-Run Classification System for U.S. Customary Units



MANDATORY CLASSIFICATION DESIGNATORS[a]

The letter "F" indicates a submerged arc welding flux. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or blend of crushed slag with unused (virgin) flux.

Indicates the minimum tensile strength (in increments of 10 MPa) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 5 and Table 7. The "T" at the end of the designator identifies the classification as a two-run classification. For example, when this designator is "62T," the two-run classification tensile requirement is 620 megapascals (MPa) minimum. (See Table 1M).

Designates the condition of heat treatment in which the tests were conducted: "A" for as-welded and "P" for postweld heat treated. The PWHT procedure is specified in 9.5.

Indicates the temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J. Two digits are used for the –100°C test temperature. (see Table 2).

The letter "G," when it appears in this position, indicates that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel as agreed between purchaser and supplier.

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C" will appear after the "E" as part of the electrode classification when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

FXXTXXG – EXX – HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

[a] The combination of these designators constitutes the flux–electrode classification.

[b] These designators are optional and do not constitute a part of the flux–electrode classification.

EXAMPLES

F55TA3-EM12K is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EM12K electrode to weld the base plate prescribed in Table 8 in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 550 MPa and Charpy V-notch impact strength of at least 27 J at –30°C.

F62TP4G-EA1 is a complete designation for a flux–electrode two-run classification. It refers to a flux that, when used with an EA1 electrode in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the postweld heat-treated condition having a minimum tensile strength of 620 MPa and Charpy V-notch impact strength of at least 27 J at –40°C. The "G" in the classification indicates that the base steel used is not as prescribed in Table 8 but is some other steel as agreed between purchaser and supplier.

Source: Figure 2M of AWS A5.23/A5.23M:2007.

Figure 2M — A5.23M Two-Run Classification System for the International System of Units (SI)

Table 3
Chemical Composition Requirements for Weld Metal[a]

Weld Metal Designation[b,c]	UNS Number[d]	Weight Percent[e,f,g]									
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other[h]
A1	W17041	0.12	1.00	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A2	W17042	0.12	1.40	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A3	W17043	0.15	2.10	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A4	W17044	0.15	1.60	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
B1	W51040	0.12	1.60	0.80	0.030	0.030	0.40–0.65	—	0.40–0.65	0.35	—
B2[i]	W52040	0.05–0.15	1.20	0.80	0.030	0.030	1.00–1.50	—	0.40–0.65	0.35	—
B2H	W52240	0.10–0.25	1.20	0.80	0.020	0.020	1.00–1.50	—	0.40–0.65	0.35	V: 0.30
B3[i]	W53040	0.05–0.15	1.20	0.80	0.030	0.030	2.00–2.50	—	0.90–1.20	0.35	—
B4	W53340	0.12	1.20	0.80	0.030	0.030	1.75–2.25	—	0.40–0.65	0.35	—
B5	W51340	0.18	1.20	0.80	0.030	0.030	0.40–0.65	—	0.90–1.20	0.35	—
B6	W50240	0.12	1.20	0.80	0.030	0.030	4.50–6.00	—	0.40–0.65	0.35	—
B6H	W50140	0.10–0.25	1.20	0.80	0.030	0.030	4.50–6.00	—	0.40–0.65	0.35	—
B8	W50440	0.12	1.20	0.80	0.030	0.030	8.00–10.00	—	0.80–1.20	0.35	—
B23	*K20857*	*0.04–0.12*	*1.00*	*0.80*	*0.015*	*0.020*	*1.9–2.9*	*0.50*	*0.30*	*0.25*	*W: 1.50–2.00* *V: 0.15–0.30* *Nb: 0.02–0.10* *B: 0.006* *Al: 0.04* *N: 0.07*
B24	*K20885*	*0.04–0.12*	*1.00*	*0.80*	*0.015*	*0.020*	*1.9–2.9*	*0.30*	*0.80–1.20*	*0.25*	*V: 0.15–0.30* *Nb: 0.02–0.10* *Ti: 0.10* *B: 0.006* *Al: 0.04* *N: 0.05*
B91	W50442	*0.08–*0.13	*1.20*[j]	0.80	0.010	0.010	*8.0–10.5*	*0.80*[j]	0.85–1.20	0.25	Nb: *0.02*–0.10 N: *0.02*–0.07 V: 0.15–0.25 Al: 0.04
F1	W21150	0.12	0.70–1.50	0.80	0.030	0.030	0.15	0.90–1.70	0.55	0.35	—
F2	W20240	0.17	1.25–2.25	0.80	0.030	0.030	—	0.40–0.80	0.40–0.65	0.35	—
F3	W21140	0.17	1.25–2.25	0.80	0.030	0.030	—	0.70–1.10	0.40–0.65	0.35	—

Table 3 (Continued)
Chemical Composition Requirements for Weld Metal[a]

Weld Metal Designation[b,c]	UNS Number[d]	Weight Percent[e,f,g]									
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other[h]
F4	W20440	0.17	1.60	0.80	0.035	0.030	0.60	0.40–0.80	0.25	0.35	Ti + V + Zr: 0.03
F5	W22540	0.17	1.20–1.80	0.80	0.020	0.020	0.65	2.00–2.80	0.30–0.80	0.50	—
F6	W22640	0.14	0.80–1.85	0.80	0.020	0.030	0.65	1.50–2.25	0.60	0.40	—
M1	W21240	0.10	0.60–1.60	0.80	0.030	0.030	0.15	1.25–2.00	0.35	0.30	Ti + V + Zr: 0.03
M2	W21340	0.10	0.90–1.80	0.80	0.020	0.020	0.35	1.40–2.10	0.25–0.65	0.30	Ti + V + Zr: 0.03
M3	W22240	0.10	0.90–1.80	0.80	0.020	0.020	0.65	1.80–2.60	0.20–0.70	0.30	Ti + V + Zr: 0.03
M4	W22440	0.10	1.30–2.25	0.80	0.020	0.020	0.80	2.00–2.80	0.30–0.80	0.30	Ti + V + Zr: 0.03
M5	W21345	0.12	1.60–2.50	0.50	0.015	0.015	0.40	1.40–2.10	0.20–0.50	0.30	Ti: 0.03 V: 0.02 Zr: 0.02
M6	W21346	0.12	1.60–2.50	0.50	0.015	0.015	0.40	1.40–2.10	0.70–1.00	0.30	Ti: 0.03 V: 0.02 Zr: 0.02
Ni1	W21040	0.12	1.60[k]	0.80	0.025	0.030	0.15	0.75–1.10	0.35	0.35	Ti + V + Zr: 0.05
Ni2	W22040	0.12	1.60[k]	0.80	0.025	0.030	—	2.00–2.90	—	0.35	—
Ni3	W23040	0.12	*1.60*[k]	0.80	0.025	0.030	0.15	2.80–3.80	—	0.35	—
Ni4	W21250	0.14	1.60	0.80	0.025	0.030	—	1.40–2.10	0.10–0.35	0.35	—
Ni5	W21042	0.12	*1.60*[k]	0.80	0.025	0.030	—	0.70–1.10	0.10–0.35	0.35	—
Ni6	*W21042*	*0.14*	*1.60*[k]	*0.80*	*0.025*	*0.030*	—	*0.70–1.10*	*0.10–0.35*	*0.35*	—
W	W20140	0.12	0.50–1.60	0.80	0.030	0.035	0.45–0.70	0.40–0.80	—	0.30–0.75	—
G	As Agreed between Supplier and Purchaser										

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[a] These requirements are applicable to both flux–solid electrode and flux–composite electrode combinations.

[b] The weld metal designation for composite electrodes is obtained by placing an "EC" before the appropriate electrode designation.

[c] The letter "N" when added as a suffix is an optional supplemental designator indicating that the limits on the phosphorous, vanadium, and copper are as follows: P = 0.012% max., V = 0.05% max., and Cu = 0.08% max. Additional requirements are given in 13.4. See A2.1 in Annex A for a discussion of the intended use of "N" designator electrodes.

[d] Refer to ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System*.

[e] The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50%.

[f] Single values are maximum.

[g] As a substitute for the weld pad in Figure 3, the sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen (see 10.2) or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 4. In case of dispute, the weld pad shall be the referee method.

[h] *Analysis for B is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.0010%.*

[i] The letter "R" when added as a suffix is an optional supplemental designator indicating that the limits on sulfur, phosphorous, copper, arsenic, tin, and antimony are as follows: S = 0.010% max., P = 0.010% max., Cu = 0.15% max., As = 0.005% max., Sn = 0.005% max., and Sb = 0.005% max. These reduced residual limits are necessary to meet the "X" factor requirements for step cooling applications.

[j] Mn + Ni = 1.40% maximum (see A7.2.3.1 in Annex A).

[k] Manganese in the Ni1, Ni2, *Ni3, Ni5, and Ni6* designated weld metals may be 1.80% maximum when the carbon is restricted to 0.10% maximum.

Table 4
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a,b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EL8[g]	K01008	0.10	0.25–0.60	0.07	0.030	0.030	—	—	—	0.35	—	—
EL8K[g]	K01009	0.10	0.25–0.60	0.10–0.25	0.030	0.030	—	—	—	0.35	—	—
EL12[g]	K01012	0.04–0.14	0.25–0.60	0.10	0.030	0.030	—	—	—	0.35	—	—
EM11K[g]	K01111	0.07–0.15	1.00–1.50	0.65–0.85	0.030	0.025	—	—	—	0.35	—	—
EM12[g]	K01112	0.06–0.15	0.80–1.25	0.10	0.030	0.030	—	—	—	0.35	—	—
EM12K[g]	K01113	0.05–0.15	0.80–1.25	0.10–0.35	0.030	0.030	—	—	—	0.35	—	—
EM13K[g]	K01313	0.06–0.16	0.90–1.40	0.35–0.75	0.030	0.030	—	—	—	0.35	—	—
EM14K[g]	K01314	0.06–0.19	0.90–1.40	0.35–0.75	0.025	0.025	—	—	—	0.35	—	Ti: 0.03–0.17
EM15K[g]	K01515	0.10–0.20	0.80–1.25	0.10–0.35	0.030	0.030	—	—	—	0.35	—	—
EH10K[g]	K01210	0.07–0.15	1.30–1.70	0.05–0.25	0.025	0.025	—	—	—	0.35	—	—
EH11K[f]	K11140	0.06–0.15	1.40–1.85	0.80–1.15	0.030	0.030	—	—	—	0.35	—	—
EH12K[g]	K01213	0.06–0.15	1.50–2.00	0.20–0.65	0.025	0.025	—	—	—	0.35	—	—
EH14[g]	K11585	0.10–0.20	1.70–2.20	0.10	0.030	0.030	—	—	—	0.35	—	—
EA1	K11222	0.05–0.15	0.65–1.00	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA1TiB	*K11020*	0.05–0.15	0.65–1.00	*0.35*	0.025	0.025	—	—	0.45–0.65	0.35	—	Ti: 0.05–0.30 B: 0.005–0.030
EA2TiB	*K11126*	0.05–0.17	0.95–1.35	*0.35*	0.025	0.025	—	—	0.45–0.65	0.35	—	Ti: 0.05–0.30 B: 0.005–0.030
EA2	K11223	0.05–0.17	0.95–1.35	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA3	K11423	0.05–0.17	1.65–2.20	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA3K	K21451	0.05–0.15	1.60–2.10	0.50–0.80	0.025	0.025	—	—	0.40–0.60	0.35	—	—
EA4	K11424	0.05–0.15	1.20–1.70	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EB1	K11043	0.10	0.40–0.80	0.05–0.30	0.025	0.025	0.40–0.75	—	0.45–0.65	0.35	—	—

Table 4 (Continued)
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a,b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EB2[h]	K11172	0.07–0.15	0.45–1.00	0.05–0.30	0.025	0.025	1.00–1.75	—	0.45–0.65	0.35	—	—
EB2H	K23016	0.28–0.33	0.45–0.65	0.55–0.75	0.015	0.015	1.00–1.50	—	0.40–0.65	0.30	0.20–0.30	—
EB3[h]	K31115	0.05–0.15	0.40–0.80	0.05–0.30	0.025	0.025	2.25–3.00	—	0.90–1.10	0.35	—	—
EB5	K12187	0.15–0.23	0.40–0.70	0.40–0.60	0.025	0.025	0.45–0.65	—	0.90–1.20	0.30	—	—
EB6	S50280	0.10	0.35–0.70	0.05–0.50	0.025	0.025	4.50–6.50	—	0.45–0.70	0.35	—	—
EB6H	S50180	0.25–0.40	0.75–1.00	0.25–0.50	0.025	0.025	4.80–6.00	—	0.45–0.65	0.35	—	—
EB8	S50480	0.10	0.30–0.65	0.05–0.50	0.025	0.025	8.00–10.50	—	0.80–1.20	0.35	—	—
EB23	*K20857*	*0.05–0.12*	*1.10*	*0.50*	*0.015*	*0.015*	*1.9–3.0*	*0.50*	*0.50*	*0.10*	*0.15–0.30*	*W: 1.50–2.00* *Nb: 0.02–0.10* *B: 0.006* *Al: 0.04* *N: 0.05*
EB24	*K20885*	*0.04–0.12*	*1.00*	*0.50*	*0.015*	*0.020*	*1.9–3.0*	*0.30*	*0.80–1.20*	*0.10*	*0.15–0.30*	*Nb: 0.02–0.10* *Ti: 0.10* *B: 0.006* *Al: 0.04* *N: 0.07*
EB91	S50482	0.07–0.13	1.25[i]	0.50	0.010	0.010	8.50–10.50	1.00[i]	0.85–1.15	0.10	0.15–0.25	Nb: 0.02–0.10 N: 0.03–0.07 Al: 0.04
EF1	K11160	0.07–0.15	0.90–1.70	0.15–0.35	0.025	0.025	—	0.95–1.60	0.25–0.55	0.35	—	—
EF2	K21450	0.10–0.18	1.70–2.40	0.20	0.025	0.025	—	0.40–0.80	0.40–0.65	0.35	—	—
EF3	K21485	0.10–0.18	1.50–2.40	0.30	0.025	0.025	—	0.70–1.10	0.40–0.65	0.35	—	—
EF4	K12048	0.16–0.23	0.60–0.90	0.15–0.35	0.030	0.025	0.40–0.60	0.40–0.80	0.15–0.30	0.35	—	—
EF5	K41370	0.10–0.17	1.70–2.20	0.20	0.015	0.010	0.25–0.50	2.30–2.80	0.45–0.65	0.50	—	—
EF6	K21135	0.07–0.15	1.45–1.90	0.10–0.30	0.015	0.015	0.20–0.55	1.75–2.25	0.40–0.65	0.35	—	—
EM2[j]	K10882	0.10	1.25–1.80	0.20–0.60	0.015	0.010	0.30	1.40–2.10	0.25–0.55	0.25	0.05	Ti: 0.10 Zr: 0.10 Al: 0.10
EM3[j]	K21015	0.10	1.40–1.80	0.20–0.60	0.015	0.010	0.55	1.90–2.60	0.25–0.65	0.25	0.04	Ti: 0.10 Zr: 0.10 Al: 0.10

Table 4 (Continued)
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a,b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EM4[j]	K21030	0.10	1.40–1.80	0.20–0.60	0.015	0.010	0.60	2.00–2.80	0.30–0.65	0.25	0.03	Ti: 0.10 Zr: 0.10 Al: 0.10
ENi1	K11040	0.12	0.75–1.25	0.05–0.30	0.020	0.020	0.15	0.75–1.25	0.30	0.35	—	—
ENi1K	K11058	0.12	0.80–1.40	0.40–0.80	0.020	0.020	—	0.75–1.25	—	0.35	—	—
ENi2	K21010	0.12	0.75–1.25	0.05–0.30	0.020	0.020	—	2.10–2.90	—	0.35	—	—
ENi3	K31310	0.13	0.60–1.20	0.05–0.30	0.020	0.020	0.15	3.10–3.80	—	0.35	—	—
ENi4	K11485	0.12–0.19	0.60–1.00	0.10–0.30	0.020	0.015	—	1.60–2.10	0.10–0.30	0.35	—	—
ENi5	K11240	0.12	1.20–1.60	0.05–0.30	0.020	0.020	—	0.75–1.25	0.10–0.30	0.35	—	—
ENi6	*K11240*	*0.07–0.15*	*1.20–1.60*	*0.05–0.30*	*0.020*	*0.020*	—	*0.75–1.25*	*0.10–0.30*	*0.35*	—	—
EW	K11245	0.12	0.35–0.65	0.20–0.35	0.030	0.025	0.50–0.80	0.40–0.80	—	0.30–0.80	—	—
EG	Not Specified											

[a] The electrode shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50%.

[b] Single values are maximum.

[c] The letter "N", when added as a suffix to the electrode classification, is an optional supplemental designator indicating that the limits on phosphorous, vanadium, and copper are as follows: P = 0.012% max., V = 0.05% max., and Cu = 0.08% max. See A2.1 in the Annex for a discussion of the intended use of "N" designator electrodes.

[d] Refer to ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*

[e] The copper limit includes any copper coating that may be applied to the electrode.

[f] *Analysis for B is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.0010%.*

[g] This electrode is also classified under AWS A5.17/A5.17M. It is included in this specification because it can be used with an alloy flux to deposit some of the weld metals designated in Table 3. In addition, this carbon steel electrode can be used for the two-run classification of flux–electrode combinations according to the provisions of this specification.

[h] The letter "R" when added as a suffix is an optional supplemental designator indicating that the limits on sulfur, phosphorous, copper, arsenic, tin, and antimony are as follows: S = 0.010% max., P = 0.010% max., Cu = 0.15% max., As =0.005% max., Sn = 0.005% max., and Sb = 0.005% max. These reduced residual limits are necessary to meet "X" factor requirements for step cooling applications.

[i] See A7.2.3.1 in Annex A for a discussion of the B91 alloy and recommendation regarding the Mn + Ni level achieved in the weld deposit. See also Note j of Table 3 for limits on the Mn + Ni content of the B91 weld deposit.

[j] The composition ranges of classifications with the "EM" prefix are intended to conform to the ranges of similar electrodes in the military specifications.

3.1M The submerged arc welding electrodes and fluxes covered by the A5.23M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the following:

(1) The mechanical properties of the weld metal obtained from a multiple pass groove weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1M and 2.

AND/OR

The mechanical properties of the weld metal obtained from a two-run butt weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1M and 2.

(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 or 9.5, as applicable (and as shown in Figure 1M or 2M, as applicable).

(3) For multiple pass classifications, the chemical composition of the weld metal obtained with the combination of a particular flux and a particular classification of electrode as specified in Table 3. Two-run classifications have no requirement for weld metal composition under this specification (see Figure 1M or 2M, as applicable).

(4) The chemical composition of either the electrode (for solid electrodes) as specified in Table 4 or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 3.

3.2 Flux–electrode combinations may be classified under A5.23 with U.S. Customary Units, under A5.23M using the International System of Units (SI), or both. Flux–electrode combinations classified under both A5.23 and A5.23M must meet all requirements for classification under each system. The classification systems are shown in Figures 1 and 1M (multiple pass) and in Figures 2 and 2M (two-run).

3.3 The electrodes and fluxes classified under this specification are intended for submerged arc welding, but that is not to prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance[5] of the electrodes and fluxes shall be in accordance with the provisions of AWS A5.01 or the tests and requirements of this specification.

5. Certification

By affixing the AWS specification and classification designations to the packaging or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification[6]

6. Rounding-Off Procedure

For purposes of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E 29 or ISO 80000-1, Part 1: General (the results are the same). If the measured values are obtained by equipment calibrated in units other than those of the specified limit, the measured values shall be converted to the units of the specified limit before rounding off. If an average value is to be compared to the specified limit, rounding off shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1 000 psi (1 ksi) for tensile or yield strength for A5.23 [to the nearest 10 MPa for tensile or yield strength for A5.23M] and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded-off results shall fulfill the requirements for the classification under test.

7. Summary of Tests

7.1 Electrodes. Chemical analysis of the electrode is the only test required for classification of a solid electrode under this specification. The chemical analysis of the rod stock from which the solid electrode is made may also be used provided the electrode manufacturing process does not alter the chemical composition. For composite electrodes, chemical analysis of the weld metal produced with the composite electrode and a particular flux is required.

7.2 Fluxes. The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the mechanical properties and soundness of the weld metal. The base metal for test assemblies, the preparations of the test samples, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 14.

7.3 Flux classification is based upon a 5/32 in [4.0 mm] electrode size as standard. If this size electrode is not manufactured, the closest size shall be used for classification tests (see Table 6, Note d, and Table 7, Note d).

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[5] See A3 in Annex A for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

[6] See A4 in Annex A for further information concerning certification and the testing called for to meet this requirement.

Table 5
Tests Required for Classification

AWS Classification	Chemical Analysis		Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
	Electrode	Weld Metal				
All Solid Electrodes	Required	Not Required	Not Required	Not Required	Not Required	Not Required
All Composite Electrodes	Not Required	Required	Not Required	Not Required	Not Required	Not Required
All Flux–Solid or Composite Electrode Multiple Pass Classifications	Not Required	Required	Required	Required	Required[a]	(Note b)
All Flux–Solid or Composite Electrode Two-Run Classifications	Not Required	Not Required	Required	Required	Required[a]	(Note b)

[a] When the "Z" impact designator (no impact requirement – Table 2) is used, the Impact Test is not required.

[b] Diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Clauses A3 and A9 in Annex A).

Table 6
Welding Parameters for Multiple Pass Groove Weld Test Assembly

Welding Conditions for Solid Electrodes[a,b,c]

Electrode Size[d]		Welding Current (amperes)[f]	Arc Voltage (volts)	Electrode Extension[g]		Travel Speed		Current Type[h]	Preheat and Interpass Temperatures
in	mm			in	mm	ipm (±1)	mm/sec. (±0.5)		
1/16	1.6	250–350	26–29	1/2 to 3/4	13–19	12	5.0	AC or DC either polarity	Refer to Table 9 for the Preheat and Interpass Temperatures Applicable to the Weld Metal Being Classified
5/64	2.0	300–400	26–29	1/2 to 3/4	13–19	13	5.5		
3/32	2.4	350–450	27–30	3/4 to 1–1/4	19–32	14	6.0		
—	2.5	350–450	27–30	3/4 to 1–1/4	19–32	14	6.0		
7/64	2.8	400–500	27–30	3/4 to 1–1/4	19–32	14	6.0		
—	3.0	400–500	27–30	1 to 1–1/2	25–38	15	6.5		
1/8	3.2	425–525	27–30	1 to 1–1/2	25–38	15	6.5		
5/32	4.0	475–575	27–30	1 to 1–1/2	25–38	16	7.0		
3/16	4.8[e]	525–625	27–30	1 to 1–1/2	25–38	17	7.0		
—	5.0	550–650	27–30	1 to 1–1/2	25–38	17	7.0		
7/32	5.6[e]	575–675	28–31	1–1/4 to 1–3/4	32–44	18	7.5		
—	6.0	625–725	28–31	1–1/4 to 1–3/4	32–44	19	8.0		
1/4	6.4[e]	700–800	28–32	1–1/2 to 2	38–50	20	8.5		

[a] Values specified in inches or ipm apply to A5.23. Values specified in mm or mm/sec apply to A5.23M.

[b] These welding conditions are intended for machine or automatic welding with straight progression (no weaving). Welding shall be performed in the flat position. The first layer shall be produced in either 1 or 2 passes. All other layers shall be produced in 2 or 3 passes per layer except the last, which shall be produced in 2, 3, or 4 passes. The completed weld shall be at least flush with the surface of the test plate.

[c] Welding conditions for composite electrodes shall be as agreed between purchaser and supplier.

[d] Classification is based on the properties of weld metal with 5/32 in [4.0 mm] electrodes or the closest size manufactured, if 5/32 in [4.0 mm] is not manufactured. The conditions given for sizes other than 5/32 in [4.0 mm] are to be used when classification is based on those sizes, or when they are required for lot acceptance testing under AWS A5.01 (unless otherwise specified by the purchaser).

[e] 4.8 mm, 5.6 mm, and 6.4 mm are not included as standard sizes in ISO 544:2003.

[f] Lower currents may be used for the first layer.

[g] The electrode extension is the contact tube-to-work distance. When an electrode manufacturer recommends a contact tube-to-work distance outside the range shown, that recommendation shall be followed ±1/4 in [6.5 mm].

[h] In case of dispute, DCEP (direct current electrode positive) shall be used as the referee current.

Table 7
Welding Parameters for Two-Run Weld Test Assembly[a,b]

Electrode Diameter		Procedure	Preheat/Interbead	Heat Input[d]
in	mm	Type[c]	Temperature	(each pass)
5/32[e]	4.0[e]	DCEP (single electrode) or AC (single electrode) or DCEP lead, AC trail (tandem) or AC lead, AC trail (tandem)	212 °F [115 °C] Maximum	55–80 kJ/in [2.2–3.1 kJ/mm]

[a] The test assembly shall be welded in the flat position in two runs, one from each side. The welding procedures shall be in conformance with the requirements of this table and shall be consistent with accepted welding practice. The procedure used shall ensure adequate tie-in of the weld beads made from each side. The requirements listed apply to both solid electrodes and composite electrodes.

[b] These welding conditions are intended for machine or automatic welding with straight progression (no weaving).

[c] Single electrode procedures with either DCEP (direct current, electrode positive) or AC (alternating current) or two-electrode tandem procedures (DCEP/AC or AC/AC) may be used for classification purposes. The procedure type used shall be the same for both weld passes. In case of dispute, DCEP shall be used as the referee current.

[d] The calculation to be used for heat input is:

$$(1)\ \text{Heat Input (kJ/in)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (in/min)} \times 1000} \quad \text{or} \quad \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (in)} \times 1000}$$

or

$$(2)\ \text{Heat Input (kJ/mm)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (mm/min)} \times 1000} \quad \text{or} \quad \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (mm)} \times 1000}$$

For two-wire tandem procedures the heat input is the arithmetic sum of the heat inputs calculated for each electrode.

[e] Classification is based upon the properties of the weld made with 5/32 in [4.0mm] electrodes or the closest size manufactured, if 5/32 in [4.0 mm] is not manufactured. An alternate electrode diameter may also be required, in some cases, for lot acceptance testing under AWS A5.01, unless other conditions are specified by the purchaser. The heat input requirements specified above for 5/32 in [4.0 mm] shall be used when using alternate diameters of electrode.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material, specimens, or samples for retest may be taken from the original test assembly or sample or from one or two new test assemblies or samples. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

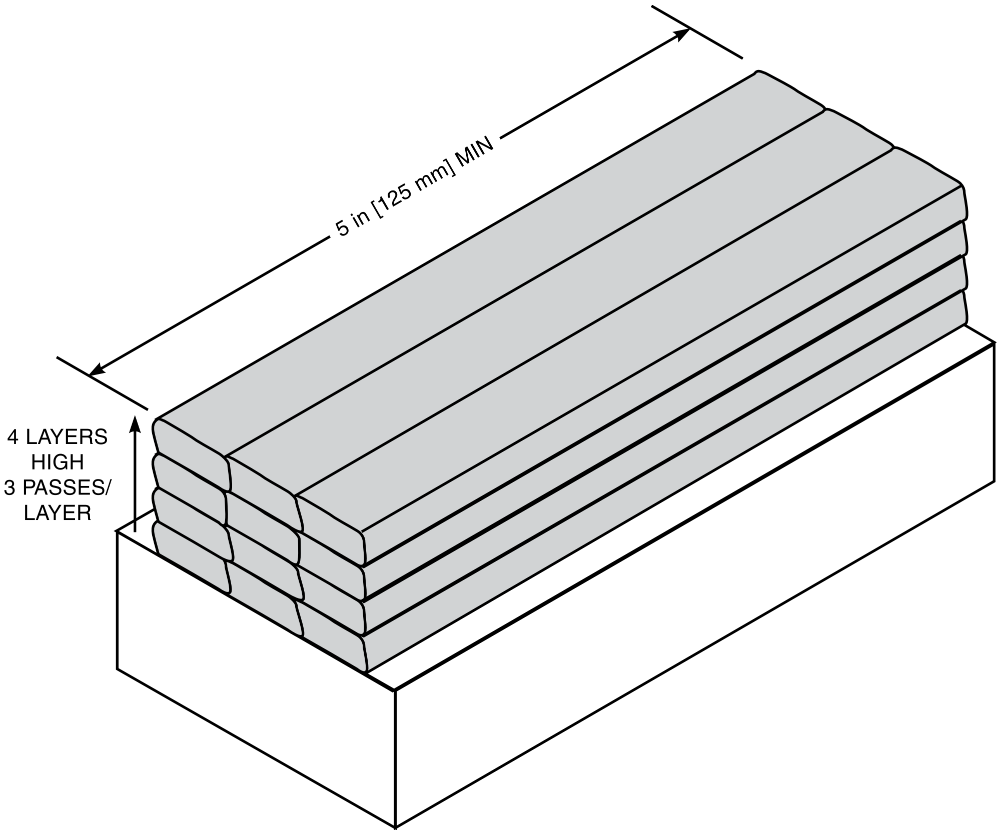
In the event that, during preparation or after the completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the weld test assembly or test specimen(s) or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed or whether test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 Requirements for Classification

9.1.1 Classification of Solid Electrodes. No weld test assembly is required for classification of solid electrodes.

9.1.2 Classification of Composite Electrodes. The chemical analysis of weld metal produced with the composite electrode and a particular flux is required for classification of a composite electrode under this specification. The weld test assembly, shown in Figure 3, is used to meet this requirement for the classification of composite electrodes. Figure 3 is



Notes:

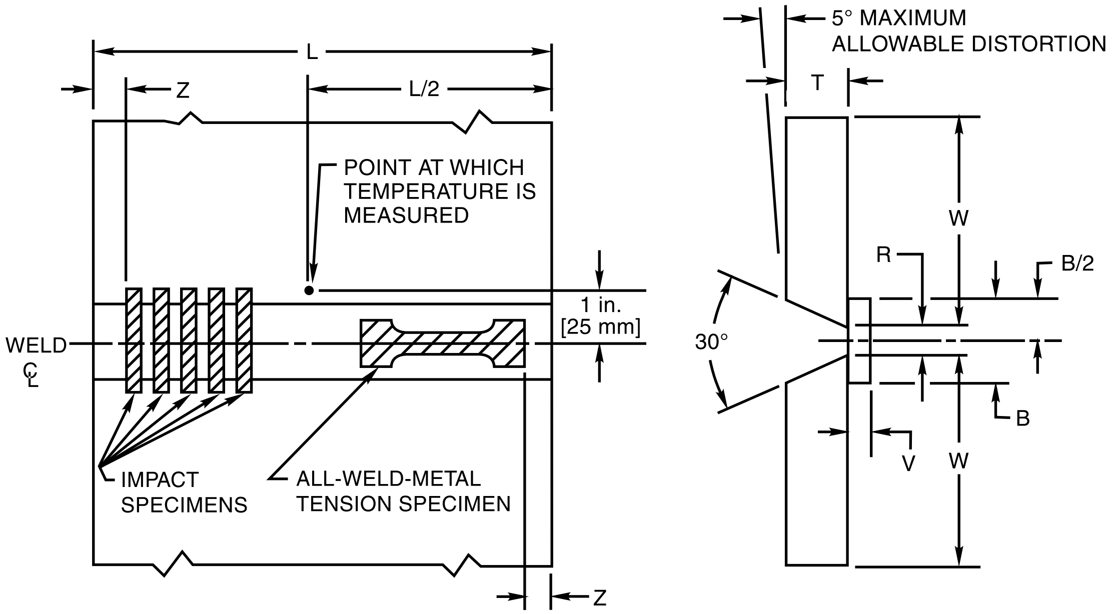
1. Width, thickness, and length of the base metal plate may be any dimensions suitable for the electrode diameter and welding procedure. The base plate shall be of the type specified in Table 8 for the applicable weld metal designation.
2. Weld beads shall be deposited without oscillation. The welding conditions shall be in accordance with the welding parameters specified in Table 6 for the multiple pass groove weld.
3. The first and last 2 in [50 mm] of the weld length shall be discarded. The top surface shall be removed, and chemical analysis shall be taken from the underlying metal of the fourth layer of the weld pad.

Source: Figure 3 of AWS A5.23/A5.23M:2007.

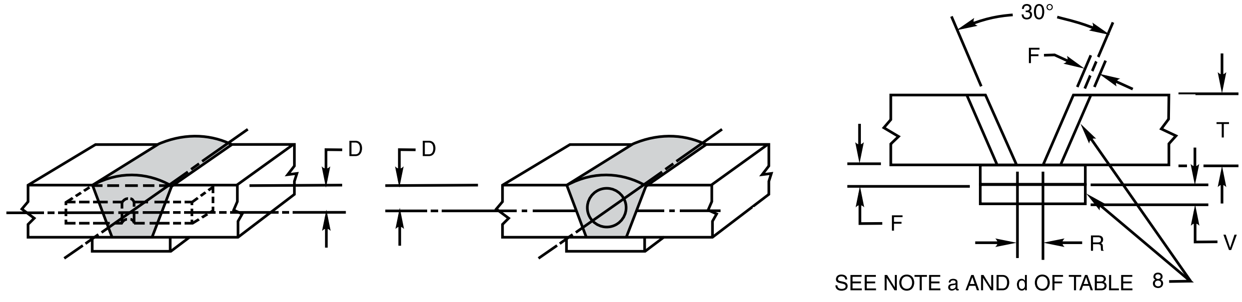
Figure 3 — Weld Pad for Chemical Analysis of Weld Metal

the weld pad test assembly for chemical analysis of weld metal. The welding parameters for the multiple pass groove weld, as specified in Table 6, shall be used for the weld pad. As an alternative to the weld pad, the sample for chemical analysis of composite electrode weld metal may be taken from the groove weld in Figure 4. Note g of Table 3 allows the sample for chemical analysis in the case of a composite electrode to be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 4. In case of dispute, the weld pad shall be the referee method.

9.1.3 Classification of Flux–Electrode Combinations. One groove weld test assembly is required for each multiple pass classification of a flux–solid electrode combination or a flux–composite electrode combination. This is the groove weld in Figure 4 for mechanical properties and soundness of weld metal. A second test assembly, the weld pad in Figure 3, is required for chemical analysis of the weld metal. However, Note g to Table 3 allows the sample for chemical analysis to be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 4, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method. One butt weld test assembly is required for each two-run



(A) JOINT CONFIGURATION AND LOCATION OF TEST SPECIMENS



(B) LOCATION OF IMPACT TEST SPECIMENS

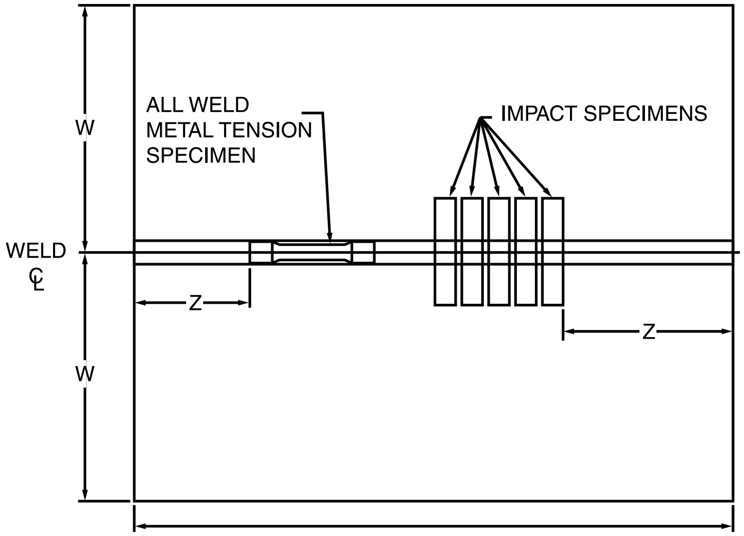
(C) LOCATION OF ALL-WELD-METAL TENSION TEST SPECIMEN

(D) BUTTERED GROOVE

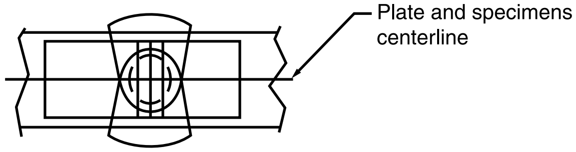
LETTER	DIMENSIONS	in	mm
L	Length (min)	12	305
T	Thickness	1 ± 1/16	25 ± 1.5
W	Width (min)	5	127
D	Specimen Center	3/8 ± 1/32	9.5 ± 1.0
B	Backup Width (min)	2	50
R	Root Opening	1/2 ± 1/16	13 ± 1.5
Z	Discard (min)	1	25
V	Backup Thickness:		
	Without buttering (min)	1/2	13
	With buttering (min)	3/8	9.5
F	Buttering Thickness (min)	1/8	3.2

Source: Figure 4 of AWS A5.23/A5.23M:2007.

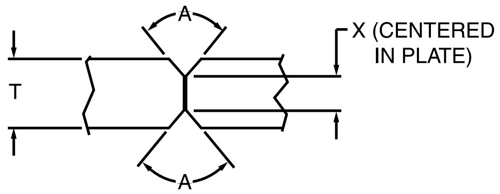
Figure 4 Multiple Pass Groove Weld Test Assembly



(A) LOCATION OF TEST SPECIMENS



(B) LOCATION OF IMPACT AND TENSION TEST SPECIMENS



(C) JOINT CONFIGURATION

Dimension	Description		
A	Bevel angel (max.)	90°	90°
L	Length (min.)	12 in	300 mm
T	Thickness	1/2 in ± 1/16 in	12 mm ± 1.5 mm
W	Width (min.)	5 in	125 mm
X	Land (min.)	3/16 in	5 mm
Z	Discard (min.)	1 in	25 mm

Source: Figure 5 of AWS A5.23/A5.23M:2007.

Figure 5 Two-Run Weld Test Assembly

classification of a flux–solid electrode combination or flux–composite electrode combination. This is the two-run weld test assembly in Figure 5 for mechanical properties and soundness of weld metal.

9.2 Preparation. Preparation of each weld test assembly shall be as prescribed in 9.3, 9.4, and 9.5. The base metal for the weld pad, the multiple pass groove weld, and the two-run weld assemblies, shall be as required in Table 8 according to the tests to be conducted and shall meet the requirements of the appropriate ASTM specification shown in Table 8, or an equivalent specification. Testing of the assemblies shall be as prescribed in Clauses 10 through 13.

9.3 Weld Pad. For composite electrodes or for any flux–electrode multiple pass classification, a weld pad shall be prepared as specified in Figure 3, except when either alternative in 9.1.2 or 9.1.3 is selected. Base metal of any convenient

Table 8
Base Metals for Test Assemblies

Classification Type	Weld Metal Designation	Base Metal	
		ASTM Standard[a,b]	UNS Number[c]
Multiple Pass Classifications	A1, A2, A3, and A4	A204 Grade A	K11820
	B2, B2H, and B5	A387 Grade 11	K11789
	B3 and B4	A387 Grade 22	K21590
	B6 and B6H	A387 Grade 5	S50200
	B8	A387 Grade 9	S50400
	B23	*See Note a*	*See Note a*
	B24	*See Note a*	*See Note a*
	B91	A387 Grade 91	S50460
	F1, *F2, F3*, and F4	A537 Class 1 or 2, or A 533 (any type or grade in this specification)	K12437, K12521, K12539, K12529, K12554
	F5 and F6	A514 or A517 (any type or grade in this specification	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, or K21650
	M1, M2, M3, M4, M5, and M6	A514 or A517 (any type or grade in this specification), or A543 Type B or C	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, K21650, or K42339
	Nil	A516 Grade 60, 65, or 70, A537 Class 1 or 2	K02100, K02403, K02700, or K12437
	Ni2	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, or K22103
	Ni3	A203 Grade D or E	K31718 or K32018
	Ni4, Ni5, and *Ni6*	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, K22103
	W	A572 or A588 (any type or in this specification)	K02303, K02304, K02305, K02306, K11430, K12040, K12043, or K11538
	G	(Note d)	
Two-Run Classifications[e]	Not Applicable	A131 Grade AH36	K11852
		A516 Grade 70	K02700

[a] For multiple pass flux–electrode classifications, ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70 may be used for any weld metal classification in this specification. In that case, the groove faces and the contacting face of the backing shall be buttered as shown in Figure 4, using a flux–electrode combination of the same weld metal composition as that specified for the combination being tested, or using an electrode of the specified composition classified in another AWS low-alloy steel filler metal specification. Alternately, for the indicated weld metal classification, the corresponding base metals may be used for weld test assemblies without buttering. In case of dispute, buttered A36 shall be the referee material.

[b] Chemically equivalent steels in other U.S. customary grades or in any metric grades, whose properties are expressed in SI units, may also be used.

[c] As classified in ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*

[d] For the "G" classification (multiple pass flux–electrode classifications only), ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70 may be used; however, the groove weld faces and the contacting face of the backing shall be buttered as shown in Figure 4, using either the flux–electrode combination being classified or using a matching composition in another AWS low-alloy filler metal specification. Alternatively, base metal for which the flux–electrode combination is recommended by the manufacturer can be used for this test.

[e] Base metal different from that prescribed in this table may be used for two-run classification purposes, as agreed between supplier and purchaser. This substitution of base metal is indicated by the addition of a "G" to the classification as indicated in Figures 2 and 2M.

size, and of the type specified in Table 8, shall be used as the base metal for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position, three passes per layer, four layers high. For classifying composite electrodes, the flux for which the composite electrode is intended shall be used. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 300°F [150°C]. The welding parameters for the groove weld, as specified in Table 6, shall be used. The slag shall be removed after each pass. The pad may be quenched in water between passes but shall be dry before the start of each pass. Testing of this assembly shall be as specified in Clause 10, Chemical Analysis.

9.4 Groove Weld for Multiple Pass Classifications

9.4.1 For mechanical properties and soundness testing for the multiple pass classification of a flux–electrode combination, a test assembly shall be prepared and welded as specified in Figure 4 and Table 6 using base metal of the appropriate type specified in Table 8. Prior to welding, the assembly may be preset so that the welded joint will be sufficiently flat after welding to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5° of plane. A welded test assembly that is more than 5° out of plane shall be discarded. Straightening of the test assembly is prohibited. Testing shall be as specified in Clauses 10 through 13, with the assembly in either the as-welded or the postweld heat-treated condition, according to the classification of the weld metal (See Figures 1 and 1M).

9.4.1.1 When postweld heat treatment (PWHT) is required, the heat treatment shall be applied to the test assembly before the specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination.

9.4.1.2 Any multiple pass groove weld test assembly to be heat treated shall be heat treated at the temperature specified in Table 9 for the applicable weld metal designation. The furnace shall be at a temperature not higher than 600°F [315°C] when the test assembly is placed in it. The temperature of the test assembly shall be raised at a rate of 150°F to 500°F [85°C to 280°C] per hour to the holding temperature specified in Table 9. This temperature shall be maintained for 1 hour (–0, +15 minutes), except when as indicated in Note e of Table 9.

9.4.1.3 The test assembly shall then be allowed to completely cool in the furnace at a rate not greater than 350°F [200°C] per hour or may be removed from the furnace when the temperature of the furnace has reached 600°F [315°C] and allowed to further cool in still air.

Table 9
Preheat, Interpass, and Postweld Heat Treatment Temperatures for Multiple Pass Classifications[a,b]

Weld Metal Designation	Preheat and Interpass Temperature[c]		Postweld Heat Treatment Temperature[d]	
	°F	°C	°F	°C
A1, A2, A3, A4, B1, B5, Ni1, Ni2, Ni3, Ni4, Ni5, *Ni6*, F1, F2, F3	300 ± 25	150 ± 15	1150 ± 25	620 ± 15
B2, B2H	300 ± 25	150 ± 15	1275 ± 25	690 ± 15
B3, B4	400 ± 25	205 ± 15	1275 ± 25	690 ± 15
B6, B6H, B8	400 ± 100	205 ± 50	1375 ± 25	745 ± 15
B91	500 ± 100	260 ± 50	1400 ± 25[e]	760 ± 15[e]
B23, B24	*425 ± 50*	*210 ± 20*	*1365 ± 25*[e]	*740 ± 15*[e]
F4[f], F5[f], F6[f]	300 ± 25	150 ± 15	1050 ± 25	565 ± 15
M1[f], M2[f], M3[f], M4[f], M5[f], M6[f], W[f]	300 ± 25	150 ± 15	1125 ± 25	605 ± 15
G	Not Specified			

[a] These temperatures are specified for fluxes and electrodes tested and classified under this specification and are not necessarily for production use. The specific requirements for production welding shall be determined by the user. They may or may not differ from those called for here (see A8 in Annex A).

[b] The preheat, interpass, and postweld heat treatment temperatures, as applicable, for multiple pass flux–electrode classifications are listed for specific weld metal compositions as shown (see 9.4). For two-run classifications the preheat and interpass temperatures are specified in Table 7, and the postweld heat treatment requirements are given in 9.5.

[c] The preheat and interpass temperatures listed here shall be used for the test assemblies regardless of whether the flux–electrode combination is classified in the as-welded or postweld heat-treated condition. They are required for purposes of uniformity and may or may not be indicative of those that might be satisfactory for fabrication of any particular weldment. The fabricator shall determine what is required for the application (see also A8 in Annex A).

[d] Unless noted otherwise, weld metal specimens for flux–electrode combinations classified in the postweld heat-treated condition shall be heat treated for 1 hour at the temperature shown for that classification (see 9.4).

[e] PWHT at specified temperature for 2 hours –0, +15 minutes.

[f] These classifications are normally used in the as-welded condition.

9.5 Butt Weld for Two-Run Classifications

9.5.1 For mechanical properties and soundness testing for the two-run classification of a flux–electrode combination, a test assembly shall be prepared and welded as specified in Figure 5 and Table 7 using base metal of the appropriate type specified in Table 8. Prior to welding, the assembly may be preset such that the welded joint will be sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint sufficiently flat after welding. Straightening of the test assembly is prohibited. Testing shall be as specified in Clauses 11 through 13, with the assembly in either the as-welded or postweld heat-treated condition, according to the classification of the weld metal (see Figures 2 and 2M).

9.5.1.1 When PWHT is required, the heat treatment shall be applied to the test assembly before the specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination.

9.5.1.2 Any two-run butt weld test assembly to be heat treated shall be heat treated at 1150°F ± 25°F [620°C ± 15°C] for 30 minutes (–0, +7 minutes). The furnace shall be at a temperature not higher than 600°F [315°C] when the test assembly is placed in it. The temperature of the test assembly shall be raised at a rate of 150°F to 500°F [85°C to 280°C] per hour. The above PWHT procedure also applies to FXTPXG-EXX flux–electrode classifications unless otherwise specified by the purchaser.

9.5.1.3 The test assembly shall then be allowed to completely cool in the furnace at a rate not greater than 350°F [200°C] per hour or may be removed from the furnace when the temperature of the furnace has reached 600°F [315°C] and allowed to further cool in still air.

9.6 Diffusible Hydrogen. In those cases in which an optional supplemental diffusible hydrogen designator is to be added to the flux–electrode classification designation, four diffusible hydrogen test assemblies shall be prepared, welded, and tested as specified in Clause 14, Diffusible Hydrogen Test.

10. Chemical Analysis

10.1 For solid electrodes, a sample of the electrode, or the rod stock from which it is made, shall be prepared for chemical analysis. Solid electrodes, when analyzed for elements that are present in a coating (e.g., copper flashing), shall be analyzed without removing the coating. When the electrode is analyzed for elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for other elements. Rod stock analyzed for elements not in the coating may be analyzed prior to reducing the rod to the finished electrode diameter and applying the coating.

10.2 For composite electrodes and for the multiple pass classification of flux–electrode combinations, the sample for analysis shall be taken from the weld pad in Figure 3, from the reduced section of the fractured tension test specimen in Figure 4, or from a corresponding location (or any location above it) in the weld metal in the butt weld in Figure 4. Weld metal from the butt weld used for two-run classification (Figure 5) may not be used for the purpose of classifying composite electrodes.

The top surface of the pad described in 9.3 and shown in Figure 3 shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal of the fourth layer of the weld pad by any appropriate mechanical means. The sample shall be free of slag. The sample shall be taken at least 3/8 in [10 mm] from the nearest surface of the base metal. The sample from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the groove weld in Figure 4 shall be prepared for analysis by any suitable mechanical means.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be the procedure in the latest edition of ASTM E 350.

10.4 For solid electrodes, the results of the electrode analysis shall meet the requirements of Table 4 for the classification of electrode under test. For composite electrodes and for the multiple pass classification of flux–electrode combinations, the results of the weld metal analysis shall meet the requirements of Table 3 for the applicable weld metal designation.

11. Radiographic Test

11.1 The groove weld for multiple pass classifications described in 9.4 and shown in Figure 4 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing or buildup removal, or both. The thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] so that the thickness of the prepared radiographic test specimen equals at least the thickness of the base metal minus 1/16 in [1.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

The butt weld for two-run classifications described in 9.5 and shown in Figure 5 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, both ends of the test joint may be trimmed off to remove run-on and run-off tabs, if any, and any excess weld joint material and the surfaces of both weld beads may be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate buildup removal. The thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] so that the thickness of the prepared radiographic test specimen equals at least the thickness of the base metal minus 1/16 in [1.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 1032. The quality level of inspection shall be 2-2T.

11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows:

(1) no cracks, no incomplete fusion, and no incomplete penetration;

(2) no slag inclusions longer than 1/4 in [6 mm] or 1/3 of the thickness of the weld, whichever is greater, or no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld except when the distance between the successive inclusions exceeds six times the length of the longest inclusion in the group; and

(3) no rounded indications in excess of those permitted by the radiographic standards in Figure 6.

In evaluating the radiograph for the multiple pass groove weld, 1 in [25 mm] of the weld on each end of the test assembly shall be disregarded. For the two-run butt weld, evaluation shall be made on a 10 in [250 mm] continuous length, as a minimum.

11.3.1 The alternative method of evaluation involves calculation of the total area of the rounded indications as they appear on the radiograph. This total area, in any 6 in [150 mm] of the weld, shall not exceed 6% of the thickness of the test assembly.

11.3.2 A rounded indication is an indication (on the radiograph) whose length is no more than 3 times its width. Rounded indications may be circular, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be of porosity or slag inclusions.

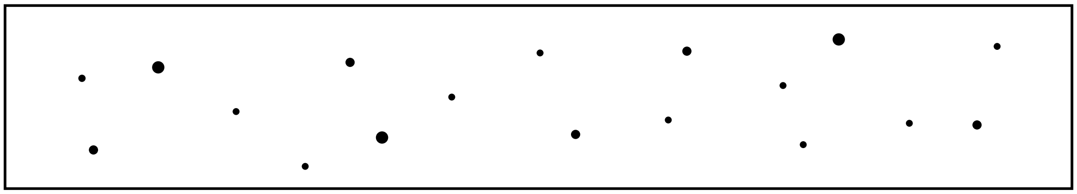
11.3.3 The total area of the rounded indications for the alternative method shall not exceed the values given in Note 3 to the radiographic standards (Figure 6A through 6D). Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications larger than the large indications permitted in the radiographic standards do not meet the requirements of this specification.

12. Tension Test

12.1 For multiple pass classifications, one all-weld metal tension test specimen, as specified in the Tension Tests clause of AWS B4.0 or B4.0M, shall be machined from the groove weld described in 9.4 and shown in Figure 4. The tensile specimen shall have a nominal diameter of 0.500 in [12.5 mm] and a nominal gage length to diameter ratio of 4:1.

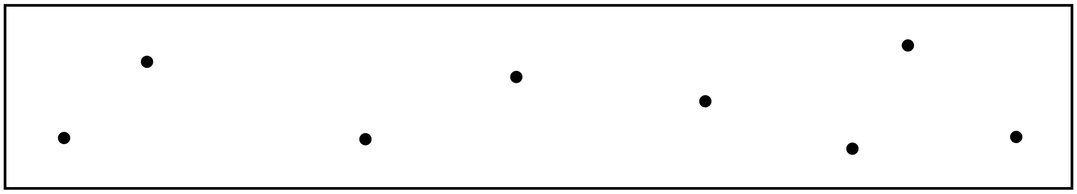
12.1.1 For flux–electrode combinations classified in the postweld heat treated condition, the weld metal shall be heat-treated as shown in Table 9 before final machining of the specimen (refer to 9.4.1.1).

12.1.2 After machining, but before testing, the specimen for all flux–electrode classifications, except those classified in the postweld heat-treated condition, may be aged at temperatures up to 220 °F [105 °C] for up to 48 hours, then allowed to cool to room temperature (refer to A9.5 in the Annex A for a discussion on the purpose of aging).



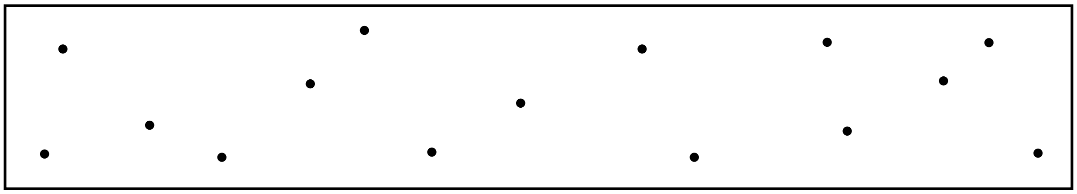
(A) ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 18,
WITH THE FOLLOWING RESTRICTIONS:
LARGE : 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] = 3 PERMITTED.
MEDIUM: 1/32 inTO 3/64 in [0.8 mm TO 1.2 mm] = 5 PERMITTED.
SMALL: 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] = 10 PERMITTED.



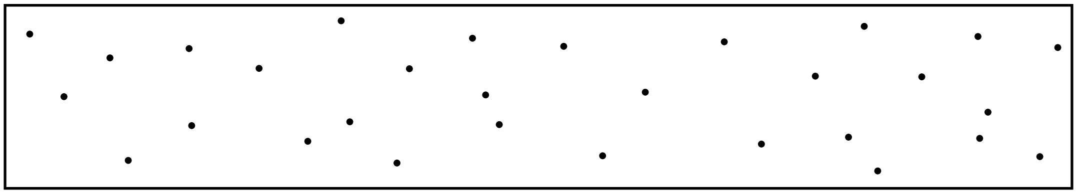
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 15.



(D) SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm]
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD = 30.

Notes:

1. The chart which is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used for determination of conformance with this specification. Rounded indications smaller than 1/64 in [0.4 mm] shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those usually encountered in general fabrication. They are equivalent to the Grade 1 standards of AWS A5.1/A5.1M.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.0150 in^2 [10 mm^2] in any 6 in [150 mm] of weld.

Source: Figure 6 of AWS A5.23/A5.23M:2007.

Figure 6 Radiographic Standards for Rounded Indications

12.1.3 The specimen shall be tested in the manner described in the Tension Test clause of the latest edition of AWS B4.0 or B4.0M.

12.1.4 The results of the tension test shall meet the requirements specified in Table 1 or Table 1M, as applicable.

12.2 For two-run classifications, one longitudinal tension test specimen, as specified in the Tension Test clause of AWS B4.0 or B4.0M, shall be machined from the butt weld described in 9.5 and shown in Figure 5. The tensile specimen shall have a nominal diameter of 0.250 in [6.0 mm] and a nominal gage length to diameter ratio of 4:1. The reduced section of the longitudinal tensile specimen shall be located entirely within the weld zone.

12.2.1 For flux–electrode combinations classified in the postweld heat-treated condition, the weld metal shall be heat treated as shown in 9.5.1.2 and 9.5.1.3 before final machining of the specimen.

12.2.2 After machining, but before testing, the specimen for all flux–electrode classifications, except those classified in the postweld heat-treated condition, may be aged at temperatures up to 220 °F [105 °C] for up to 48 hours, then allowed to cool to room temperature. If the specimen is aged, that fact, together with the manner of aging, shall be recorded on the test certificate. Refer to A9.5 in Annex A for a discussion on the purpose of aging.

12.2.3 The specimen shall be tested in the manner described in the Tension Test clause of AWS B4.0 or B4.0M.

12.2.4 The results of the tension test shall meet the requirements specified in Table 1 or Table 1M, as applicable.

13. Impact Test

13.1 Five full-size Charpy V-Notch impact specimens, as specified in the Fracture Toughness Test clause of AWS B4.0 or B4.0M, shall be machined from the test assembly shown in Figure 4 or 5, as applicable, for those classifications for which impact testing is required in Table 5. The Charpy V-Notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree. The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50× magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the fracture toughness test clause of AWS B4.0 or B4.0M. The test temperature shall be that as specified in Table 2 for the classification under test.

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft·lbf [20 J], and the average of the three shall be not less than the required 20 ft·lbf [27 J] energy level.

13.4 For classification with the "N" (nuclear) designation, three additional specimens shall be prepared. These specimens shall be tested at room temperature. Two of the three shall equal or exceed 75 ft·lbf [102 J], and the third shall not be lower than 70 ft·lbf [95 J]. The average of the three shall equal or exceed 75 ft·lbf [102 J].

14. Diffusible Hydrogen Test

14.1 Each flux–electrode combination to be identified by an optional supplemental diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results which satisfy the requirements of Table 10, the appropriate diffusible hydrogen designator may be added to the end of the classification.

14.2 The welding procedure shown in Table 6 for the multiple pass groove weld test assembly shall be used for the diffusible hydrogen test. The travel speed, however, may be increased up to a maximum of 28 in/min [12 mm/s]. This adjustment in travel speed is permitted in order to establish a weld bead width that is appropriate for the specimen. The flux, electrode, or both, may be baked before testing to restore the moisture content to the as-manufactured condition. When this is done, the baking time and temperature shall be noted on the test report. The manufacturer of the flux, electrode, or both, should be consulted for their recommendation regarding the time and temperature for restoring their products to the as-manufactured condition.

Table 10
Diffusible Hydrogen Requirements[a]

AWS A5.23/A5.23M Flux–Electrode Classifications	Optional Supplemental Diffusible Hydrogen Designator[b]	Average Diffusible Hydrogen, Maximum[c] (ml/100 g Deposited Metal)
All	H16	*16*
	H8	*8*
	H4	*4*
	H2	*2*

[a] The diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Clauses A3 and A9 in Annex A).

[b] This designator is added to the end of the flux–electrode classification (see Figure 1, 1M, 2, or 2M, as applicable).

[c] Flux–electrode combinations meeting the requirements for an H2 designator also meet the requirements for H4, H8, and H16. Flux–electrode combinations meeting requirements for an H4 designator also meet the requirements for H8 and H16. Flux–electrode combinations meeting the requirements for an H8 designator also meet the requirements for H16.

14.3 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of ten (10) grains of moisture/lb [1.43 g/kg] of dry air at the time of welding. The actual atmospheric conditions shall be reported along with the average diffusible hydrogen value for the test according to AWS A4.3.

14.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the actual test results for a flux–electrode combination meet the requirements for the lower or lowest hydrogen designator, as specified in Table 10, the flux–electrode combination also meets the requirements for all higher designators in Table 10 without need to retest.

15. Method of Manufacture

The electrodes and fluxes classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification.

15.1 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as crushed slag. Crushed slag and blends of crushed slag with the original brand of unused (virgin) flux may be classified as welding flux under this specification. When classifying a blend of crushed slag with virgin flux, the ratio of the blend mixture shall not vary from nominal by more than 10% of the minor component. For example, a nominal blend of 40% crushed slag with 60% virgin flux shall contain at least 36%, but no more than 44% crushed slag. The classification of more than one blend ratio of crushed slag with the original brand of unused (virgin) flux is permitted under this specification. In each case, however, the nominal blend ratio shall be noted on the packaging or on the corresponding lot certificate, as applicable (see A6.1.4 in Annex A).

16. Electrode Requirements

16.1 Standard Sizes. Standard sizes for electrodes in the different package forms (coils with support, coils without support, spools, and drums) are as specified in AWS A5.02/A5.02M.

16.2 Finish and Uniformity

16.2.1 Finish and uniformity shall be specified in sub-clause 4.2 of AWS A5.02/A5.02M:2007.

16.3 Standard Package Forms

16.3.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights and other requirements for each form shall be as specified in sub-clause 4.3 of AWS A5.02/A5.02M:2007. Package forms and sizes other than these shall be as agreed between purchaser and supplier.

16.4 Winding Requirements

16.4.1 Winding requirements shall be as specified in sub-sub-clause 4.4.1 of AWS A5.02/A5.02M:2007.

16.4.2 The cast and helix of the electrode shall be as specified in sub-sub-clause 4.4.2 of AWS A5.02/A5.02M:2007.

16.5 Electrode Identification

16.5.1 The product information and the precautionary information shall be as specified in sub-clause 4.5 of AWS A5.02/A5.02M:2007.

16.6 Packaging. Electrodes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

16.7 Marking of Packages

16.7.1 The product information (as a minimum) shall be as specified in sub-sub-clause 4.6.1 of AWS A5.02/A5.02M:2007. (For flux–composite electrode classifications, the trade designation of the flux (or fluxes) with which its weld metal composition meets the requirements of Table 3 shall be included.

17. Flux Requirements

17.1 Form and Particle Size. Flux shall be granular in form and shall be capable of flowing freely through the flux feeding tubes, valves, and nozzles of standard submerged arc welding equipment. Particle size is not specified here, but, when it is addressed, it shall be a matter of agreement between the purchaser and the supplier.

17.2 Usability. The flux shall permit the production of uniform, well shaped beads that merge smoothly with each other and the base metal. Undercut, if any, shall not be so deep or so widespread that a subsequent bead will not remove it.

17.3 Packaging

17.3.1 Flux shall be suitably packaged to ensure against damage during shipment.

17.3.2 Flux, in its original unopened container, shall withstand storage under normal conditions for at least six months without damage to its welding characteristics or the properties of the weld. Heating of the flux to assure dryness may be necessary when the very best properties (of which the materials are capable) are required. For specific recommendations, consult the manufacturer.

17.4 Marking of Packages

17.4.1 The product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package shall be specified as in sub-sub-clause 4.6.1 of AWS A5.02/A5.02M:2007:

(1) AWS specification and classification along with the applicable optional, supplemental designator(s) (year of issue may be excluded). For flux–composite electrode classifications the trade designation of the composite electrode shall be indicated. It is not required that all of the classifications published for the flux (with different electrodes, with and without PWHT, etc.) be included on the packaging.

(2) Supplier's name, trade designation, and country of manufacture: In the case of crushed slags (or blends of crushed slag with virgin flux), the crusher (or crusher/blender), not the original producer, shall be considered the supplier. Crushed slag or a blend of crushed slag with virgin flux shall have a unique trade designation that clearly differentiates it from the original virgin flux used in its manufacture (see also A6.1.4 in the Annex A).

(3) Net weight.

(4) Lot, control, or heat number.

(5) Particle size, if more than one particle size of flux of that trade designation is produced.

17.4.2 The appropriate precautionary information as given in ANSI Z49.1, latest edition (as a minimum), or its equivalent, shall be prominently displayed in legible print on all packages of flux.

Annex A (Informative)

Guide to AWS Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

This annex is not part of AWS A5.23/A5.23M:2011, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, but is included for informational purposes only.

A1. Introduction

The purpose of this guide is to correlate the electrode and flux classifications with their intended applications so the specification can be used effectively. Appropriate base metal specifications are referred to whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each flux or electrode is suitable.

A2. Classification System

A2.1 Classification of Electrodes. The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" (or "EC" for composite electrodes) at the beginning of each classification designation stands for electrode. The remainder of the designation indicates the chemical composition of the electrode or, in the case of composite electrodes, the chemical composition of the weld metal obtained with a particular flux (see Figure 1, 1M, 2, or 2M, as applicable).

For solid carbon steel electrodes, the letter "L" after the "E" indicates that the solid electrode is comparatively low in manganese content. The letter "M" after the "E" indicates medium manganese content, while the letter "H" after the "E" indicates comparatively high manganese content. The one or two digits following the manganese designator indicate the nominal carbon content of the electrode. Note that the above indicators of manganese and carbon content are not applicable to solid low-alloy steel electrodes. For solid low-alloy steel electrodes, one or two letters after the "E" are used to indicate the general alloy type. Subsequent digits identify the specific classification. The letter "K," which appears as a suffix in some designations, indicates that the electrode is made from a heat of silicon-killed steel. Solid carbon and low-alloy steel electrodes are classified only on the basis of their chemical composition, as specified in Table 4 of this specification.

A composite electrode is indicated by the letter "C" after the "E" and a numeric or alphanumeric suffix. The composition of a composite electrode may include metallic elements in the core material that are also present as oxides, fluorides, etc., of those same elements. Therefore, the chemical analysis of a composite electrode may not be directly comparable to an analysis made on a solid electrode. For this reason, the composition of composite electrodes is not used for classification purposes under this specification, and the user is referred to weld metal composition (Table 3) with a particular flux, rather than to electrode composition.

As examples, consider the following electrode designations: EL12, EM12K, EB3, EM3, and ECB3. As in other specifications, the prefix "E" designates an electrode. The EL12 and EM12K are solid carbon steel electrodes and the EB3 and EM3 are solid low-alloy steel electrodes. Their compositions are given in Table 4. The ECB3, however, is a composite electrode as indicated by the "C" after the "E." Composite electrodes are classified by the composition of the weld metal produced with a specific flux as shown in Table 3. An ECB3 electrode, therefore, is a composite electrode which, when used with a particular flux, will produce weld metal meeting the requirements for a B3 deposit as shown in Table 3.

The letter "N" when added as a suffix is an optional supplemental designator indicating that the electrode is intended for certain very special welds in nuclear applications. These welds are found in the core belt region of the reactor vessel. This region is subject to intense neutron radiation, and it is necessary, therefore, that the phosphorus, vanadium, and copper contents of this weld metal be limited in order to resist neutron radiation-induced embrittlement. It is also necessary that the weld metal have a high upper-shelf energy level in order to withstand some embrittlement, yet remain serviceable over the years. These electrodes are not required elsewhere; however, they could be used where that weld metal with an exceptionally high upper-shelf energy level is required.

A2.2 "G" Classification

A2.2.1 This specification includes electrode classified as "EG" (or "ECG"). The "G" indicates that the electrode is of a *general* classification. It is *general* because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent, in establishing this classification, is to provide a means by which electrodes that differ in one respect or another (e.g., chemical composition) from all other classifications (meaning that the composition of the electrode—in the case of the example—does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful electrode—one that otherwise would have to wait for a revision of the specification—to be classified immediately, under the existing specification. This means, then, that two electrodes—each bearing the same "G" classification—may be quite different in some certain respects (e.g., chemical composition, again).

A2.2.2 For the two-run classification a "G" is used in the classification designation when, as agreed between the supplier and purchaser, a difference in base material from that specified is used for qualification. See second example in Figures 2 and 2M.

A2.2.3 The point of difference (although not necessarily the amount of that difference) between an electrode of a "G" classification and an electrode of a similar classification without the "G" (or even with it, for that matter) will be readily apparent from the use of the words not required and not specified in the specification. The use of these words is as follows:

Not Specified is used in those areas of the specification that refer to the results of some particular test. It indicates that the requirements for that test are not specified for that particular classification.

Not Required is used in those areas of the specification that refer to the tests that must be conducted in order to classify a welding flux or electrode. It indicates that that test is not required because the requirements (results) for the test have not been specified for that particular classification. Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a flux or electrode to that classification. When a purchaser wants the information provided by that test, in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of the product. The purchaser will have to establish with that supplier just what the testing procedure and the acceptance requirements are to be, for that test. The purchaser may want to incorporate that information via AWS A5.01M/A5.01 (ISO 14344 MOD), in the purchase order.

A2.2.4 Request for Filler Metal Classification

(1) When a flux or electrode cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that flux or electrode. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the A5 Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that flux or electrode, as long as the flux or electrode is of commercial significance.

(2) A request to establish a new electrode classification must be a written request, and it needs to provide sufficient detail to permit the A5 Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

- (a) All classification requirements as given for existing classifications such as chemical composition ranges and mechanical property requirements.
- (b) Any conditions for conducting the tests used to demonstrate that the product meets the classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)
- (c) Information on descriptions and intended use, which parallels that for existing classifications, for that clause of the Annex.

(d) *Actual test data for all tests required for classification according to the requirements of the specification for a minimum of two production heats/lots must be provided. In addition, if the filler metal specification is silent regarding mechanical properties, test data submitted shall include appropriate weld metal mechanical properties from a minimum of two production heats/lots.*

(e) A request for a new classification without the above information will be considered incomplete. The Secretary will return the request to the requester for further information.

(3) The request should be sent to the Secretary of the A5 Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will:

(a) Assign an identifying number to the request. This number will include the date the request was received.

(b) Confirm receipt of the request and give the identification number to the person who made the request.

(c) Send a copy of the request to the Chair of the A5 Committee on Filler Metals and Allied Materials and the Chair of the particular Subcommittee involved.

(d) File the original request.

(e) Add the request to the log of outstanding requests.

(4) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner," and the Secretary shall report these to the Chair of the AWS A5 Committee on Filler Metals and Allied Materials for action.

(5) The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each AWS A5 Committee on Filler Metals and Allied Materials meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A2.3 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table A.1 shows those used in ISO 14171, ISO 24598, and ISO 26304 for comparison with comparable classifications in this specification. To understand the published international designation system, refer to Tables 7A, 7B, and 7C and the Annex of AWS publication IFS:2002, *International Index of Welding Filler Metal Classifications.* National specifications from many industrial countries are also found in Tables 7A, 7B, and 7C of that publication.

A2.4 Classification of Fluxes. Fluxes are classified on the basis of the mechanical properties of the weld metal they produce, with a certain classification of electrode, under the specific test conditions called for in this specification. Multiple pass flux–electrode classifications also have requirements for weld metal composition. Two-run flux–electrode classifications have no requirements for weld deposit composition under this specification (refer to Figure 1, 1M, 2, or 2M, as applicable).

A2.4.1 It should be noted that flux of any specific trade designation may have many classifications. The number is limited only by the number of different electrode classifications and the condition of heat treatment (as-welded and postweld heat treated) with which the flux can meet the classification requirements. The flux marking lists at least one and may list all classifications to which the flux conforms. It should also be noted that the specific usability (or operating) characteristics of the various fluxes of the same classification may differ in one respect or another.

A2.4.2 Solid electrodes having the same classification are usually interchangeable when used with a specific flux. Composite electrodes may not be.

A3. Acceptance

Acceptance of all fluxes and electrodes classified under this specification is in accordance with the tests and requirements of this specification. Any testing a purchaser requires of the supplier, for fluxes or electrodes shipped in accordance with this specification, needs to be clearly stated in the purchase order, according to the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD). In the absence of any such statement in the purchase order, the supplier may ship the flux or electrode with whatever testing the supplier normally conducts on flux or electrode of that classification, as specified in Schedule

Table A.1
Comparison of Solid Electrode Designations[a]

AWS A5.23/A5.23M Classification	ISO 14171[b] Designation	ISO 24598[c] Designation	ISO 26304[d] Designation			
	ISO 14171-A	ISO 14171-B	ISO 24598-A	ISO 24598-B	ISO 26304-A	ISO 26304-B
EL8[e]	S1	(SU11)	—	—	—	—
EL8K[e]	S1Si1	SU12	—	—	—	—
EL12[e]	S1	SU11	—	—	—	—
EM11K[e]	—	SU25	—	—	—	—
EM12[e]	S2	SU22	—	—	—	—
EM12K[e]	S2Si	SU21	—	—	—	—
EM13K[e]	S2Si2	SU25	—	—	—	—
EM14K[e]	—	SU24	—	—	—	—
EM15K[e]	S2Si	(SU21)	—	—	—	—
EH10K[e]	S3Si	SU32	—	—	—	—
EH11K[e]	—	SU31	—	—	—	—
EH12K[e]	S4Si	SU42	—	—	—	—
EH14[e]	—	SU41	—	—	—	—
EA1	—	SU1M3	(SMo)	SU1M3	—	—
EA1TiB	—	—	—	—	—	—
EA2	S2Mo	SU2M3	SMo	SU2M3	—	—
EA3	S4Mo	SU4M3	—	SU4M3	—	—
EA3K	—	SU4M31	—	SU4M32	—	—
EA4	S3Mo	SU3M3	SMnMo	SU3M3	—	—
EB1	—	—	—	SUCM	—	—
EB2	—	—	SCrMo1	SU1CM	—	—
EB2H	—	—	—	SU1CMVH	—	—
EB3	—	—	SCrMo2	SU2C1M	—	—
EB5	—	—	—	SUC1MH	—	—
EB6	—	—	SCrMo5	SU5CM	—	—
EB6H	—	—	—	SU5CMH	—	—
EB8	—	—	SCrMo9	SU9C1M	—	—
EB23	—	—	—	—	—	—
EB24	—	—	—	—	—	—
EB91	—	—	—	SU9C1MV	—	—
EF1	—	—	—	—	S2Ni1Mo	SUN2M2
EF2	—	—	—	—	—	SUN1M3
EF3	—	—	—	—	—	SUN2M33
EF4	—	—	—	—	—	SUN1C1M1
EF5	—	—	—	—	—	SUN5CM3
EF6	—	—	—	—	—	SUN4C1M3
EM2	—	—	—	—	—	SUN3M2
EM3	—	—	—	—	—	SUN4C1M2
EM4	—	—	—	—	—	SUN5C1M3
ENi1	S2Ni1	SUN2	—	—	—	—
ENi1K	—	SUN21	—	—	—	—
ENi2	—	SUN5	—	—	—	—
ENi3	S2Ni3	SUN7	—	—	—	—
ENi4	—	SUN4M1	—	—	—	SUN4M1
ENi5	—	SUN2M1	—	—	—	SUN2M1
ENi6	—	—	—	—	—	—
EW	SUNCC1	—	—	—	—	—

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[a] The requirements for the equivalent classifications shown are not necessarily identical in every respect.

[b] ISO 14171, *Welding consumables – Wire electrodes and wire-flux combinations for submerged arc welding of non alloy and fine grain steels – Classification*, is a cohabitation document providing classification utilizing a system based upon the yield strength and the average impact energy for

all-weld metal of 47J (ISO 14171-A), or utilizing a system based upon the tensile strength and the average impact energy for all-weld metal of 27J (ISO 14171-B).

[c] ISO 24598 *Welding consumables – Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of creep-resisting steels – Classification*, is a cohabitation document. The classification according to system A is mainly based on EN 12070. The classification according to system B is mainly based upon standards used around the Pacific Rim.

[d] ISO 26304, *Welding consumables – Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of high strength steels – Classification*, is a cohabitation document. The classification according to system A is mainly based on EN 14295. The classification according to system B is mainly based upon standards used around the Pacific Rim.

[e] These solid wire electrode classifications also appear in AWS A5.17/A5.17M.

F, Table 1, of AWS A5.01M/A5.01 (ISO 14344 MOD). Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations (and optional supplemental designators, if applicable) on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all the requirements of the specification. The only testing requirement implicit in this *certification* is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that that material met the requirements of the specification. (Representative material, in this case, is material from any production run of that classification using the same formulation.) *Certification* is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the *certification* required by the specification is the classification test of *representative material* cited above and the Manufacturer's Quality Assurance Program in AWS A5.01M/A5.01 (ISO 14344 MOD).

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding. They are:

(1) dimensions of the space in which the welding is done (with special regard to the height of the ceiling);

(2) number of welders and welding operators working in that space;

(3) rate of evolution of fumes, gases, or dust, according to the materials and processes used;

(4) the proximity of the welders or welding operators to the fumes, as these fumes issue from the welding zone, and to the gases and dusts in the space in which they are working; and

(5) the ventilation provided to the space in which the welding is done.

A5.2 American National Standard ANSI Z49.1, published by the American Welding Society, discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the Clause on Ventilation in that document. Further details about ventilation can be found in AWS F3.2.

A.6 Description and Intended Use

A6.1 Types of Flux. Submerged arc welding fluxes are granular, fusible mineral compounds of various proportions and quantities, manufactured by any of several different methods. In addition, some fluxes may contain intimately mixed metallic ingredients to deoxidize the weld pool. Any flux is likely to produce weld metal of somewhat different composition from that of the electrode used with it due to chemical reactions in the arc and sometimes to the presence of metallic ingredients in the flux. A change in the arc voltage during welding will change the quantity of flux interacting with a given quantity of electrode and may, therefore, change the composition of the weld metal. This latter change provides a means of describing fluxes as "neutral," "active," or "alloy."

A6.1.1 Neutral Fluxes. Neutral fluxes are those which will not produce any significant change in the weld metal chemical analysis as a result of a large change in the arc voltage and, thus, the arc length. The primary use for neutral fluxes is in multiple pass welding, especially when the base metal exceeds 1 in [25 mm] in thickness. Note the following considerations concerning neutral fluxes:

(1) Since neutral fluxes contain little or no deoxidizers, they must rely on the electrode to provide deoxidation. Single-pass welds with insufficient deoxidation on heavily oxidized base metal may be prone to porosity, centerline cracking, or both.

(2) While neutral fluxes do maintain the chemical composition of the weld metal even when the voltage is changed, it is not always true that the chemical composition of the weld metal is the same as the chemical composition of the electrode used. Some neutral fluxes decompose in the heat of the arc and release oxygen, resulting in a lower carbon value in the weld metal than the carbon content of the electrode itself. Some neutral fluxes contain manganese silicate which can decompose in the heat of the arc and add some manganese and silicon to the weld metal even though no metallic manganese or silicon was added to these particular fluxes. These changes in the chemical composition of the weld metal are fairly consistent, even when there are large changes in voltage.

(3) Even when a neutral flux is used to maintain the weld metal chemical composition through a range of welding voltages, weld properties such as strength level and impact properties can change because of changes in other welding parameters such as depth of fusion, heat input, and number of passes.

A6.1.2 Active Fluxes. Active fluxes are those which contain small amounts of manganese, silicon, or both. These deoxidizers are added to the flux to provide improved resistance to porosity and weld cracking caused by contaminants on or in the base metal. The primary use for active fluxes is to make single-pass welds, especially on oxidized base metal. Note the following considerations concerning active fluxes:

(1) Since active fluxes do contain some deoxidizers, the manganese, silicon, or both in the weld metal will vary with changes in arc voltage. An increase in manganese or silicon increases the strength and hardness of the weld metal in multiple pass welds but may lower the impact properties. For this reason, the voltage may need to be more tightly controlled for multiple pass welds with active fluxes than when using neutral fluxes.

(2) Some fluxes are more active than others. This means they offer more resistance to porosity due to base metal surface oxides in single-pass welds than a flux which is less active, but may pose more problems in multiple pass welding.

A6.1.3 Alloy Fluxes. Alloy fluxes are those which can be used with a carbon steel electrode to make alloy weld metal. The alloys for the weld metal are added as ingredients in the flux. As with active fluxes, where the recovery of manganese and silicon is affected significantly by arc voltage, so with alloy fluxes, the recovery of alloy elements from the flux is affected significantly by the arc voltage. With alloy fluxes, the manufacturer's recommendations should be closely followed if desired weld metal compositions are to be obtained. The use as a welding flux of crushed slags generated from alloy flux is not recommended.

A6.1.4 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as a *crushed slag*. This is different from a recycled flux which was never fused into a slag and can often be collected from a clean surface and reused without crushing. Crushed slags and blends of crushed slag with unused (virgin) flux may be classified as a welding flux under this specification, but shall not be considered to be the same as a virgin flux. Although it is possible to crush and reuse submerged arc slag as a welding flux, the crushed slag, regardless of any addition of virgin flux to it, is a new and chemically different flux. This is because the slag formed during submerged arc welding does not have the same chemical composition or welding characteristics as the virgin flux. Its composition is affected by the composition of the original flux, chemical reactions which occur due to the welding arc, the base metal and electrode compositions, and the welding parameters.

Blends of crushed slag with the original brand of virgin flux from which it was generated cannot be assumed to conform to the classification of either component, even when both the crushed slag and virgin flux conform to the same classification (except for the "S" designator). It shall be the responsibility of the crusher or fabricator partner, who performs the blending, to verify that any intended blend of crushed slag with the original brand of virgin flux is in full conformance with the classification requirements of this specification.

As with any flux product, the manufacturer (crusher) shall follow a detailed processing procedure with controlled input material, preparation, crushing, and blending, which will ensure that a standard quality of output welding flux product is attained that meets the requirements for the classification.

A6.1.4.1 Closed Loop Crushed Slags. Slag generated by a fabricator from a specific brand of flux under controlled welding conditions, segregated at all points during collection and processing from other sources of slag or contaminants, crushed by the fabricator or another crushing organization, possibly blended with a specific virgin flux and returned to the same fabricator for use as a welding flux, is defined as closed loop crushed slag.

Closed-loop crushed slags or blends of closed-loop crushed slag with the original brand of virgin flux ensure better control of input material by virtue of the inherent partnering of the fabricator with the crusher. In some instances, these partners may be one and the same. If blending of crushed slag with virgin flux is done, changes in the original brand of virgin flux or in the blending ratio can affect the quality of the final product.

A6.2 Wall Neutrality Number. The Wall Neutrality Number (*N*) is a convenient relative measure of flux neutrality. The Wall Neutrality Number addresses fluxes and electrodes for welding carbon steel with regard to the weld metal manganese and silicon content. It does not address alloy fluxes. For a flux–electrode combination to be considered neutral, it should have an *N* value of 35 or lower. The lower the number, the more neutral the flux.

Determination of the Wall Neutrality Number can be done in accordance with the following:

(1) A weld pad of the type shown in Figure 3 is welded with the flux–electrode combination being tested. The welding parameters shall be as specified in Table 6 for the groove weld test assembly for the diameter of electrode being used.

(2) A second weld pad is welded using the same parameters, except that the arc voltage is increased by 8 volts.

(3) The top surface of each of the weld pads is ground or machined smooth to clean metal. Samples sufficient for analysis are removed by machining. Weld metal is analyzed only from the top (fourth) layer of the weld pad. The samples are analyzed separately for silicon and manganese.

(4) The Wall Neutrality Number depends on the change in silicon, regardless of whether it increases or decreases, and on the change in manganese, regardless of whether it increases or decreases. The Wall Neutrality Number is the absolute value (ignoring positive or negative signs) and is calculated as follows:

$$N = 100\,(|\Delta\,\%\mathrm{Si}| + |\Delta\,\%\mathrm{Mn}|)$$

where

$\Delta\%\mathrm{Si}$ = Difference in silicon content of the two pads and

$\Delta\%\mathrm{Mn}$ = Corresponding difference in manganese content.

A7. Description and Intended Use of Electrodes

A7.1 Choice of Electrodes. In choosing an electrode classification for submerged arc welding, the most important considerations are the mechanical properties expected of the weld metal, the requirements for weld metal composition, whether the weld is to be single pass or multiple pass, the cleanliness and composition of the steel to be welded, and the type of flux to be used. It is important to note that the mechanical properties obtained on a one-run or two-run weld are often quite different than those obtained on a multiple pass weld made with the same flux and electrode. For that reason, a two-run flux–electrode classification option is included in this specification to provide for an alternate classification system based upon welding conditions that more closely reflect limited pass applications. The AWS A5.23/A5.23M specification (instead of the AWS A5.17/A5.17M specification) was selected for the inclusion of a two-run classification system because, for these types of applications, it is common commercial practice to use a low-alloy electrode for the welding of carbon steel to enhance the weld metal mechanical properties. For example, an EA1 molybdenum-bearing electrode is routinely used in pipemills to improve the strength level and impact properties of the two-run welds made to manufacture pipe. In addition, the strength level requirements for two-run welds such as used for the manufacture of pipe can be significantly higher than those shown in A5.17/A5.17M and are more consistent with the strength levels included in A5.23/A5.23M.

A certain minimum weld metal manganese content is necessary to avoid centerline cracking. This minimum depends upon restraint of the joint and upon the weld metal composition. In the event that centerline cracking is encountered, especially with a low manganese electrode (see Table 4) and neutral flux, a change to a higher manganese electrode, a change to a more active flux, or both, may eliminate the problem.

Certain fluxes, generally considered to be neutral, tend to remove carbon and manganese to a limited extent and to replace these elements with silicon. With such fluxes, a silicon-killed electrode is often not necessary though it may be used. Other fluxes add no silicon and may, therefore, require the use of a silicon-killed electrode for proper wetting and freedom from porosity. The flux manufacturer should be consulted for electrode recommendations suitable for a given flux.

In welding single-pass fillet welds, especially on scaly base metal, it is important that the flux, electrode, or both, provide sufficient deoxidation to avoid unacceptable porosity. Silicon is a more powerful deoxidizer than manganese. In such applications, use of a silicon-killed electrode or of an active flux, or both, may be essential. Again, manufacturer's recommendations should be consulted.

Composite electrodes are generally designed for a specific flux. The flux identification is required (see 16.7.1) to be marked on the electrode package. Before using a composite electrode with a flux not indicated on the electrode package markings, the electrode producer should be contacted for recommendations. A composite electrode might be chosen for a higher melting rate and lower depth of fusion at a given current level than would be obtained under the same conditions with a solid electrode.

A7.2 Chemical Composition. For the welding of low-alloy steel, the chemical composition of the weld metal produced is often the primary consideration for electrode selection. Together with appropriate heat treatments, each composition can achieve a wide range of corrosion resistance and mechanical properties at various service temperatures. It is usually desirable for weld metal to match the chemical composition and the mechanical properties of the base metal as closely as possible. In fact, many of the electrodes classified to this specification have been developed for specific base-metal grades or classes. If an optimum match is not possible, engineering judgment together with weld testing may be required to select the most suitable electrodes. Table 3 provides detailed weld metal chemical composition requirements. Tables 1, 1M, and 2 list the mechanical properties of the weld metal in the as-welded condition or in the postweld heat-treated condition when the weldment is subjected to the PWHT requirements in Table 9. It should be noted that changes in welding variables or heat treatment can be expected to affect the mechanical properties. However, except for the effects of dilution, the chemical composition can be expected to remain reasonably unchanged.

The electrode classification identifies the chemical composition of the electrode. The following paragraphs highlight the differences between these electrodes and electrode groups and indicate typical applications.

A7.2.1 EL8, EL8K, EL12, EM11K, EM12, EM12K, EM13K, EM14K, EM15K, EH10K, EH11K, EH12K, and EH14 (Carbon Steel) Electrodes. These electrodes are carbon steel electrodes which vary from one another in their carbon, manganese, and silicon contents. An electrode from this group is selected for use with a particular flux to provide the best combination of these elements to meet application requirements. These requirements can include (but are not limited to) resistance to cracking and porosity, welding characteristics, welding speed, bead appearance, and weld metal mechanical properties. The EM14K electrodes also contain small additions of titanium, although they are considered carbon steel electrodes. The titanium functions to improve strength and toughness under certain conditions of high heat input welding or PWHT. The manufacturer should be consulted for specific recommendations.

A7.2.2 EA1, EA2, EA3, EA3K, and EA4 (C-Mo Steel) Electrodes. These electrodes are similar to the medium manganese and high manganese carbon steel electrodes shown above except that 0.5% molybdenum is added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance. Typical applications include the welding of C-Mo steel base metals such as ASTM A 204 plate and ASTM A335-P1 pipe. Electrodes of this type are particularly useful in developing impact strength on single-pass welds such as are used in the manufacture of line pipe.

A7.2.3 EB1, EB2, EB2H, EB3, EB5, EB6, EB6H, EB8, ***EB23***, *EB24, and EB91* (Cr-Mo Steel) Electrodes. These electrodes produce weld metal that contains between 0.5% and *10.5%* chromium and between 0.5% and 1% molybdenum. They are designed to produce weld metal for high-temperature service.

The letter "R" when added as a suffix to the EB2 or EB3 electrode classification or to the B2 or B3 weld metal designation is an optional supplemental designator indicating that the electrode will meet the reduced residual limits necessary to meet "X" factor requirements for step cooling applications.

Since all Cr-Mo weld deposits will air harden in still air, both preheat and postweld heat treatment are required for most applications.

A7.2.3.1 *EB91 (previously EB9) is a* 9% Cr–1% Mo electrode modified with niobium (columbium) and vanadium designed to provide improved creep strength, and oxidation and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.

In addition to the classification requirements of this specification, impact toughness and high-temperature creep strength properties should be determined. Due to the influence of various levels of carbon and niobium (columbium), specific values and testing must be agreed to by the purchaser and supplier.

Thermal treatment of the *B91* alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation into martensite (M_f) is relatively low; therefore, upon completion of welding and before PWHT, it is recommended that the weldment be allowed to cool below 200°F [93°C] to maximize transformation to martensite. The maximum allowable temperature for PWHT is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To aid in allowing for an adequate PWHT, the restriction of Mn + Ni has been imposed (see Table 3, Note j). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

A7.2.4 EF4, EF5, and EF6 (Cr-Ni-Mo Steel) Electrodes. These electrodes use a combination of Cr, Ni, and Mo to develop the strength levels and notch toughness required for a number of high-strength, low-alloy or microalloyed structural steels.

A7.2.5 EM2, EM3, and EM4 (High-Strength, Low-Alloy Steel) Electrodes. These electrodes may contain a combination of Cr, Ni, Mo, Ti, Zr, and Al. They are intended to produce high-strength deposits meeting 100 000 psi [690 MPa], 110 000 psi [760 MPa], or 120 000 psi [830 MPa] minimum tensile requirements to weld steels such as HY80 and HY100. They are most typically used for weldments not subject to PWHT.

A7.2.6 ENi1, ENi1K, ENi2, and ENi3 (Ni Steel) Electrodes. These electrodes have been designed to produce weld metal with increased strength without being hardenable or with increased notch toughness at temperatures as low as –100°F (–73°C) or lower. They have been specified with nickel contents which fall into three nominal levels of 1% Ni, 2.5% Ni, and 3.5% Ni. With carbon levels of up to 0.12%, strength increases and weld deposits can meet 80 000 psi [550 MPa] minimum tensile-strength requirements. However, with lower levels of carbon, low-temperature toughness improves to match the base-metal properties of nickel steels such as ASTM A 203 Gr. E, ASTM A 352 LC3 and LC4 classifications.

Many low-alloy steels require PWHT to stress relieve the weld or temper the weld metal and heat-affected zone to achieve increased ductility. It is often acceptable to exceed the PWHT holding temperatures shown in Table 9. However, for many applications, nickel steel weld metal can be used without PWHT. If PWHT is to be specified for a nickel steel weldment, the holding temperature should not exceed the maximum temperature given in Table 9 for the classification considered since nickel steels can be embrittled at higher temperatures.

A7.2.7 ENi4, ENi5, *ENi6*, EF1, EF2, and EF3 (Ni-Mo Steel) Electrodes. These electrodes contain between 0.5% and 2% nickel and between 0.25% and 0.5% molybdenum. They are typically used for the welding of high-strength, low-alloy or microalloyed structural steels where a combination of strength and good notch toughness is required.

A7.2.8 EW (Weathering Steel) Electrode. This electrode has been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels. These special properties are achieved by the addition of about 0.5% copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, some chromium and nickel additions are also made. This electrode is used to weld the typical weathering steels such as ASTM A 242 and ASTM A 588.

A7.2.9 EG (General Low-Alloy Steel) Electrodes. These electrodes are described in A2.2. These electrode classifications may be either modifications of other discrete classifications or totally new classifications. Purchaser and user should obtain from the supplier the description and intended use for any EG electrode.

A8. Mechanical Properties of Submerged Arc Welds

Tables 1, 1M, and 2 (as applicable) of this specification list the mechanical properties required of weld metal for both the multiple pass and two-run flux–electrode classifications. The mechanical properties are determined from specimens prepared according to the procedures called for in this specification. The multiple pass procedure (for multiple pass flux–electrode classifications) minimizes dilution from the base metal and provides a finer grain structure due to the reheating of the deposited metal by subsequent weld passes. Therefore, this classification procedure more accurately reflects the properties of the undiluted weld metal from each flux–electrode classification. The two-run procedure (for two-run flux–electrode classifications) more accurately reflects the properties of as-deposited weld metal made with a particular flux and electrode under conditions of high base plate dilution.

In use, the electrodes and fluxes are handled separately, and either of them may be changed without changing the other. For this reason, a classification system with standardized test methods is necessary to relate the fluxes and electrodes to the properties of their weld metal. Chemical reactions between the molten portion of the flux and electrode, and dilution by the base metal all affect the composition of the weld metal.

The specific mechanical properties of a weld are a function of its chemical composition, cooling rate, and PWHT. High-amperage, single-pass welds have a greater depth of fusion and, hence, greater dilution by the base metal than lower current, multiple pass welds. Moreover, large, single-pass welds solidify and cool more slowly than the smaller weld beads of multiple pass welds. Furthermore, the succeeding passes of a multiple pass weld subject the weld metal of previous passes to a variety of temperature and cooling cycles that alter the metallurgical structure of different portions of those beads. For these reasons, the properties of a single-pass weld may be significantly different from those of a multiple pass weld made with the same electrode and flux.

The weld metal properties in this specification are determined in either the as-welded condition or after a PWHT, or both. For multiple pass classifications tested in the postweld heat-treated condition ("P" designator, see Figure 1 or 1M, as applicable) the PWHT procedure is as indicated in Table 9 and 9.4. For two-run classifications tested in the postweld heat-treated condition ("P" designator, see Figure 2 or 2M, as applicable) the PWHT procedure is as indicated in 9.5. Most of the weld metals are suitable for service in either condition, but the specification cannot cover all of the conditions that such weld metal may encounter in fabrication or service. For this reason, the classifications in this specification require that the weld metals be produced and tested under certain specific conditions.

Procedures employed in practice may require voltage, amperage, type of current, number of welding arcs, and travel speeds that are considerably different from those required in this specification. In addition, differences encountered in electrode size, electrode composition, electrode extension, joint configuration, preheat temperature, interpass temperature, and PWHT can have a significant effect on the properties of the weld. Within a particular electrode classification, the electrode composition can vary sufficiently to produce variations in the mechanical properties of the weld deposit in both the as-welded and PWHT conditions.

For multiple pass welds, PWHT times in excess of the time used for multiple pass classification purposes in this specification (conventionally, 20 hours to 30 hours for very thick sections) may have a major influence on the strength and toughness of the weld metal. The user needs to be aware of this and of the fact that the mechanical properties of carbon steel weld metal produced with other procedures may differ from the properties required by Tables 1, 1M, and 2 of this specification, as applicable.

A9. Diffusible Hydrogen Test

A9.1 The submerged arc welding process is generally considered to be a low-hydrogen welding process. However, as the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in the root beads), and toe or underbead cracks in the heat-affected zone. It may be appropriate to evaluate the diffusible hydrogen produced during welding with the flux–electrode combination. This specification has, therefore, included the use of optional designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3.

A9.2 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values from those indicated by the designator. Moisture from the air, distinct from that in the flux or electrode, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. Some air will mix with the flux cover and add its moisture to the other sources of diffusible hydrogen. It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. The use of a reference atmospheric condition during the welding of the hydrogen test assembly is necessitated because the arc is always imperfectly shielded. The reference atmospheric condition of 10 grains of moisture per lb [1.5 grams of moisture per kilogram] of dry air is equivalent to 10% relative humidity at 68°F [20°C]. A flux–electrode combination meeting the H4 requirements under the reference atmospheric conditions may not do so under conditions of high humidity at the time of welding.

A9.3 Fluxes (and composite electrodes) can be contaminated by the condensation of moisture from the atmosphere and, in some cases, can absorb significant moisture if stored in a humid environment in damaged or open packages, or especially if unprotected for long periods of time. In the worst cases of high humidity, even overnight exposure of unprotected flux (or composite electrode) can lead to a significant increase of diffusible hydrogen. In the event the flux (or composite electrode) has been exposed, the manufacturer should be consulted regarding probable damage to low-hydrogen characteristics and possible reconditioning of the flux (or composite electrode). Solid electrodes can also be contaminated under the same conditions. In this case, the moisture contamination is on the surface. It is recommended that electrodes exhibiting visible surface rust be discarded.

A9.4 Not all classifications may be available in the H16, H8, H4, or H2 diffusible hydrogen levels. The manufacturer of a given flux (or composite electrode) should be consulted for availability of products meeting these limits.

A9.5 Aging of Tensile Specimens. Weld metals may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases toward its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. This specification permits the aging of the tensile test specimens at elevated temperatures up to 220 °F [105 °C] for up to 48 h before subjecting them to tension testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrode deposits, especially when testing high-strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds.

A10. General Safety Considerations

A10.1 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in annex Clause A5. Safety and health information is available from other sources, including, but not limited to, Safety and Health Fact Sheets listed in A10.2, ANSI Z49.1, and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3. AWS Safety and Health Fact Sheets Index (SHF)[7]

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*

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[7] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

20 *Thermal Spraying Safety*
21 *Resistance Spot Welding*
22 *Cadmium Exposure from Welding & Allied Processes*
23 *California Proposition 65*
24 *Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25 *Metal Fume Fever*
26 *Arc Viewing Distance*
27 *Thoriated Tungsten Electrodes*
28 *Oxyfuel Safety: Check Valve and Flashback Arrestors*
29 *Grounding of Portable and Vehicle Mounted Welding Generators*
30 *Cylinders: Safe Storage, Handling, and Use*
31 *Eye and Face Protection for Welding and Cutting Operations*
33 Personal Protective Equipment (PPE) for Welding & Cutting
34 Coated Steels: Welding and Cutting Safety Concerns
36 Ventilation for Welding & Cutting
37 Selecting Gloves for Welding & Cutting

SPECIFICATION FOR ZIRCONIUM AND ZIRCONIUM-ALLOY WELDING ELECTRODES AND RODS

SFA-5.24/SFA-5.24M

(Identical with AWS Specification A5.24/A5.24M:2005. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR ZIRCONIUM AND ZIRCONIUM-ALLOY WELDING ELECTRODES AND RODS

SFA-5.24/SFA-5.24M

(Identical with AWS Specification A5.24/A5.24M:2005. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of zirconium and zirconium-alloy electrodes and rods for gas tungsten arc, gas metal arc, and plasma arc welding.

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully adressed herein. Some safety and health information can be found in the nonmandatory Annex Sections A5 and A9. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each syhstem must be used independently of the other without combining in any way when referring to filler metal properties. The specification with the designation A5.24 uses U.S. Customary Units. The specification A5.24M uses SI Units. The latter are shown within brackets [ ] or in appropriate column in tables nd figures. Standard dimensions based on either system may be used for sizing of electrodes or packaging or both under the A5.24 or A5.24M specifications.

2. Normative References

2.1 The following ANSI/AWS standards[1] are referenced in the mandatory sections of this document:

(a) AWS A5.01, *Filler Metal Procurement Guidelines*

(b) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.2 The following ASTM standards[2] are referenced in the mandatory sections of this document:

(a) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(b) ASTM E 146, *Standard Methods for Chemical Analysis of Zirconium and Zirconium-Base Alloys*

2.3 The following ISO standard[3] is referenced in the mandatory sections of this document:

(a) ISO 544, *Welding consumables—Technical delivery conditions for welding filler metals—Type of product, dimensions, tolerances, and markings*

3. Classification

3.1 The welding materials covered by the A5.24/A5.24M 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 chemical composition as specified in Table 1.

3.2 Materials classified under one classification shall not be classified under any other classification of this specification. An electrode or rod may be classified undet both A5.24 and A5.24M providing it meets the requirements of both specifications.

3.3 The filler metals classified under this specification are intended for gas tungsten arc, gas metal arc, and plasma

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[1] AWS standards can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group company, 15 Inverness Way East, Englewood, CO 80112-5776.

[2] ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[3] ISO standards can be obtained from the American Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR ZIRCONIUM AND ZIRCONIUM-ALLOY ELECTRODES AND RODS

AWS Classification	UNS Number(2)	Weight Percent(1)								
		Zirconium + Hafnium	Hafnium	Iron + Chromium	Tin	Oxygen(3)	Hydrogen(3)	Nitrogen(3)	Carbon(3)	Niobium (Columbium)
ERZr2	R60702	99.0 min	4.5	0.20	. . .	0.11 to 0.15	0.005	0.015	0.03	. . .
ERZr3	R60704	97.5 min	4.5	0.20 to 0.40	1.00 to 2.00	0.11 to 0.16	0.005	0.015	0.03	. . .
ERZr4	R60705	95.5 min	4.5	0.20	. . .	0.11 to 0.16	0.005	0.015	0.03	2.0 to 3.0

NOTES:
(1) Single values are maximum, except as noted.
(2) SAE HS-1086 *Metals and Alloys in the Unified Numbering System*. Document may be obtained from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001.
(3) Analysis of the interstitial elements C, O, H and N shall be conducted on samples of filler metal taken after the filler metal has been reduced to its final diameter and all processing operations have been completed. Analysis of the other elements may be conducted on these same samples or it may have been conducted on samples taken from the ingot or the rod stock from which the filler metal is made. In case of dispute, samples from the finished filler metal shall be the referee method.

arc welding processes, but that is not to prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance[4] of the material shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*

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.[5]

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, 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 value in accordance with the rounding-off method given in ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

7. Summary of Tests

The only test required for classification of a product under this specification is full chemical analysis of the filler metal after all thermal and chemical processing or, as permitted in footnote c to Table 1, partial chemical analysis of the rod stock or orignial producer's melt being used to produce such filler metal together with partial chemical analysis of the finished filler metal when analyzing for interstitial elements C, H, O, and N.

8. Retest

If the result of any test fails to meet its requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Materials for retest may be taken from the original sample or from a new sample. 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 materials under test shall be considered as not meeting the requirements of this specification.

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 test specimens 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.

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[4] See Section A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

[5] See Section A4 (in Annex A) for further information concerning certification and the testing specified to meet this requirement.

TABLE 2
STANDARD SIZES AND LENGTHS(1)

	Diameter			Tolerances	
Standard Package Forms	in.	decimal in.(2)	mm	in.	mm
Straight Lengths(3) Coils without Support Coils with Support	1/16	0.062	1.6	±0.002	+0.01, -0.04
	. . .	0.079	2.0	±0.002	+0.01, -0.04
	3/32	0.094	2.4	±0.002	+0.01, -0.04
	. . .	0.098	2.5(4)	±0.002	+0.01, -0.04
	1/8	0.125	3.2	±0.002	+0.01, -0.07
	5/32	0.156	4.0	±0.002	+0.01, -0.07
	3/16	0.188	4.8(4)	±0.002	+0.01, -0.07
	. . .	0.197	5.0	±0.002	+0.01, -0.07
	1/4	0.25	6.4(4)	±0.002	+0.01, -0.07
Spools	. . .	0.020	0.5(4)	+0.001, -0.002	+0.01, -0.03
	. . .	0.030	0.8	+0.001, -0.002	+0.01, -0.03
	. . .	0.035	0.9	+0.001, -0.002	+0.01, -0.04
	. . .	0.039	1.0	+0.001, -0.002	+0.01, -0.04
	. . .	0.045	. . .	+0.001, -0.002	. . .
	. . .	0.047	1.2	+0.001, -0.002	+0.01, -0.04
	1/16	0.062	1.6	±0.002	+0.01, -0.04

NOTES:

(1) Dimensions, tolerances, and package forms (for round filler metal) other than those shown shall be as agreed by purchaser and supplier.

(2) Decimal inch are exact conversions with appropriate rounding.

(3) Length shall be 36 in. ± 1/4 in. [900 mm ± 5 mm].

(4) Not shown as standard metric size in ISO 544.

9. Chemical Analysis

9.1 A sample of the filler metal, or the stock from which it is made, shall be prepared for chemical analysis except as provided in Table 1, footnote c.

9.2 The sample shall be analyzed by accepted analytical methods.

9.3 The results of the analysis shall meet the requirements of Table 1, for the classification of filler metal under test.

10. Method of Manufacture

The welding electrodes and rods classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification.

11. Standard Sizes and Lengths

Standard sizes for electrodes and rods in different package forms (straight lengths, coils with support, coils without support, and spools) are shown in Table 2.

12. Finish and Uniformity

12.1 All electrodes and 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, the operation of the welding equipment, or the properties of the weld metal.

12.2 Each continuous length of filler metal shall be from a single heat 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.

13. Standard Package Forms

13.1 Standard package forms are straight lengths, coils with support, coils without support, and spools. Standard package dimensions and weights for each form are given in Table 3. Package forms, sizes, and weights other than these shall be as agreed to between purchaser and supplier.

13.2 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

13.3 Spools (Fig. 1) shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

14. Winding Requirements

14.1 Filler metal in coils and on spools shall be wound so that kinks, waves, sharp bends, overlapping, or wedging

TABLE 3
STANDARD PACKAGES, DIMENSIONS, AND WEIGHTS

Package Form			Nominal Net Weight	
			lb	kg
Straight Lengths			5	2.5
			10	5
			25	10
			50	25
Coils without Support			25	10
Coils with Support			50	25
			60	30
Spools	in.	mm		
	4	100	1	0.5
	8	200	5	2.5
	12	300	10–26	5–12
	13-½	340	30	15

GENERAL NOTES:

(a) Filler metal diameters for all forms and lengths are given in Table 2.

(b) No more than one classification or size shall be included in each package.

(c) Dimensions of coils shall be as agreed by purchaser and supplier.

(d) Dimensions of standard spools are shown in Fig. 1.

are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the electrode (the end with which welding is to begin with) shall be identified so it can be located readily and shall be fastened to avoid unwinding. The winding shall be level winding.

14.2 The cast and helix of filler metal in coils and on spools shall be such that the filler metal will feed in an uninterrupted manner in automatic and semiautomatic equipment.

14.2.1 The cast and helix of filler metal on 4 in. [100 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(a) form a circle not less than 2.5 in. [65 mm] nor more than 9 in. [230 mm] in diameter, and

(b) rise above the flat surface no more than 0.5 in. [13 mm] at any location.

14.2.2 The cast and helix of filler metal on 8 in. [200 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(a) form a circle not less than 10 in. [250 mm] nor more than 20 in. [510 mm] in diameter, and

(b) rise above the flat surface no more than 0.75 in. [19 mm] at any location.

14.2.3 The cast and helix of filler metal on 12 in. [300 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(a) form a circle not less than 15 in. [380 mm] no more than 30 in. [760 mm] in diameter, and

(b) rise above the flat surface no more than 1 in. [25 mm] at any location.

15. Filler Metal Identification

15.1 The product information and the precautionary information required in Section 17 for marking each package shall appear also on each coil and spool.

15.2 Coils without support shall have a tag containing this information securely attached to the filler metal at the inside end of the coil.

15.3 Coils with support shall have the information securely affixed in a prominent location on the support.

15.4 Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

16. Packaging

Electrodes and rods shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

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.

(a) AWS specification (year of issue may be excluded) and AWS classification numbers;

(b) Supplier's name and trade designation;

(c) Size and net weight;

(d) Lot, control, or heat number.

17.2 The appropriate precautionary information[6] as given in ANSI Z49.1, latest edition (as a minimum), shall be prominently displayed in legible print on all packages of welding material, including individual unit packages enclosed within a larger package.

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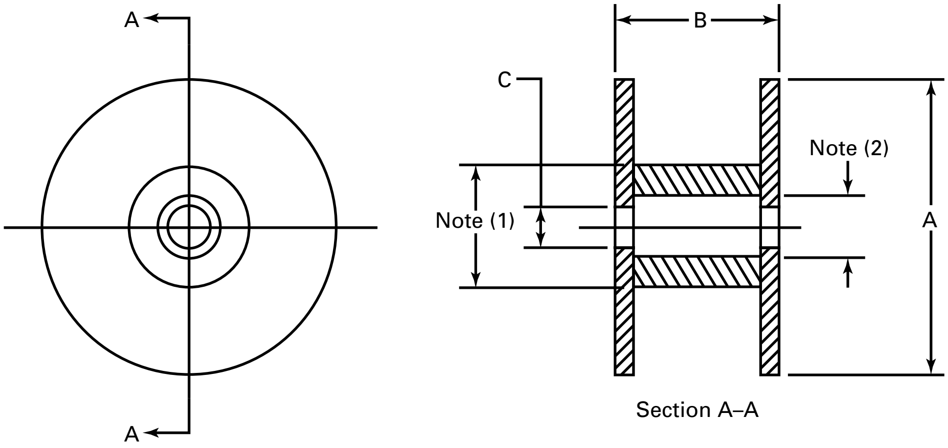
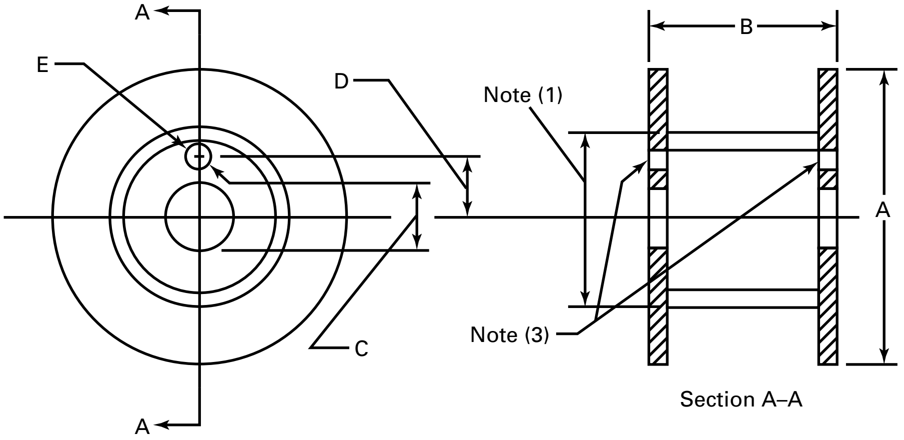
[6] Typical examples of "warning labels" are shown in figures in ANSI Z49.1, for some common or specific consumables used with certain processes.

FIG. 1 DIMENSIONS OF 4, 8, AND 12 IN. [100, 200 AND 300 MM] DIAMETER SPOOLS



Dimensions of Standard 4 in. (100 mm) Spool



Dimensions of Standard 8 and 12 in. (200 and 300 mm) Spools

		4 in. [100 mm]		8 in. [200 mm]		12 in. [300 mm]	
		in.	mm	in.	mm	in.	mm
A	Diameter, max. [Note (4)]	4.0	102	8.0	203	12	305
B	Width	1.75	45	2.16	55	4.0	16.5
	Tolerance	±0.03	+0, −2	±0.03	+0, −3	±0.06	+0, −3
C	Diameter	0.63	16	2.03	50.5	2.03	50.5
	Tolerance	+0.01, −0	+1, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0
D	Distance between axes	. . .	. . .	1.75	44.5	1.75	44.5
	Tolerance	. . .	. . .	+0.02	±0.5	±0.02	±0.5
E	Diameter [Note (3)]	. . .	. . .	0.44	10	0.44	10
	Tolerance	. . .	. . .	+0, −0.06	+1, −0	+0, −0.06	+1, −0

NOTES:

(1) Outside diameter of barrel shall be such as to permit feeding of the filler metals.

(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 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.

Annex A
Guide to AWS Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods

(This Annex is not a part of AWS A5.24/A5.24M:2005, *Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods*, but is included for informational purposes only.)

A1. Introduction

The purpose of this guide is to correlate the filler metal classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable.

A2. Classification System

A2.1 The system for identifying the filler metal classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" at the beginning of each classification designation stands for electrode, and the letter "R" stands for welding rod. Since these filler metals are used as electrodes in gas metal arc welding and as rods in gas tungsten arc welding, both letters are used.

A2.2 The chemical symbol "Zr" appears after "R" as a means of identifying the filler metals as unalloyed zirconium or a zirconium-base alloy. The numeral provides a means of identifying different variations in the composition.

A2.3 Table A1 provides a correlation of the classifications in this revision with those in earlier (1990, 1979, 1976) revisions and with other specifications for zirconium alloy filler metals. The ASTM/ASME Specifications listed are also widely used in industry as shown in Table A1.

A2.4 Request for Filler Metal Classification

A2.4.1 When a filler metal cannot be classified according to some existing classification, the manufacturer may request that a classification be established for that filler metal. They may do this by following the procedure given here.

A2.4.2 A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need.

In particular, the request needs to include:

(a) All classification requirements as given for existing classifications, such as all chemical composition ranges.

(b) Information on "Description and Intended Use," which parallels that for existing classifications, for that section of Annex A.

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.

A2.4.3 The request should be sent to the Secretary of the A5 Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will:

(a) Assign an identifying number to the request. This number shall include the date the request was received.

(b) Confirm receipt of the request and give the identification number to the person who made the request.

(c) Send a copy of the request to the Chair of the A5 Committee on Filler Metals and Allied Materials and the Chair of the particular Subcommittee involved.

(d) File the original request.

(e) Add the request to the log of outstanding requests.

A2.4.4 All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chair of the A5 Committee on Filler Metals and Allied Materials, for action.

A2.4.5 The Secretary shall include a copy of the log of all requests pending and those completed during the

TABLE A1
SPECIFICATION CROSS INDEX — INCLUDING DISCONTINUED ZIRCONIUM ELECTRODES

Filler Metal					Base Metal, ASTM/ASME Base Number	
AWS Classification				UNS Numbers	UNS Number	Grade Designations[a]
2005	1990	1979	1976			
Discontinued	Discontinued	Discontinued	ERZr1			
ERZr2	ERZr2	ERZr2	ERZr2	R60702	R60702	Unalloyed Zr
ERZr3	ERZr3	ERZr3	ERZr3	R60704	R60704	Zr-Fe-Sn-Cr
ERZr4	ERZr4	ERZr4	—	R60705	R60705	Zr-2.5%Nb

NOTE:
a. Reference: ASTM B 493, B 523, B 551, and B 653.

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.

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, needs to 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 the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of the Filler Metal Procurement Guidelines. Testing in accordance with any other Schedule in that Table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in AWS A5.01, *Filler Metal Procurement Guidelines*.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes to which welders and welding operators are exposed during welding:

(a) Dimensions of the space in which welding is done (with special regard to the height of the ceiling).

(b) Number of welders and welding operators working in that space.

(c) Rate of evolution of fumes, gases, or dust, according to the materials and processes used.

(d) The proximity of the welders or welding operators 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.

(e) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section of that document, entitled "Ventilation."

A6. Welding Considerations

A6.1 Zirconium and zirconium alloys can be welded by gas tungsten arc, gas metal arc, plasma arc, and electron beam welding processes. Zirconium is a reactive metal and is sensitive to embrittlement by oxygen, nitrogen and hydrogen at temperatures above 1100°F [590°C]. Consequently, the metal should be protected from atmospheric contamination. This can be provided by shielding the metal with high purity inert gas, or by placing in an inert gas chamber or a vacuum of 10 to the minus 4 torr [0.013 Pa] or lower. During arc welding, the zirconium should be shielded from the atmosphere until it is cooled below about 800°F [430°C]. Adequate protection by auxiliary inert gas shielding should be provided when welding in air, and for critical applications the welding should be done in a gas tight chamber thoroughly purged of air and filled with high purity inert gas.

The zirconium metal should be free of heavy oxide and chemically clean prior to welding, as contamination from oxide, water, grease, and dirt will also cause embrittlement.

Zirconium welding rods must be chemically clean and free of heavy oxide, absorbed moisture, grease, and dirt. The welding rod should be kept in the inert gas during welding and the oxide at the tip, formed upon cooling, must be removed before reusing the rod.

Zirconium can be successfully fusion welded to titanium, tantalum, niobium (columbium), and vanadium although the weld metal will be stronger and less ductile than the base metals. Zirconium cannot be welded to other common structural alloys of copper, iron, nickel, and aluminum as brittle zirconium intermetallic alloys are formed which produce extremely brittle welds.

A7. Description and Intended Use of Electrodes and Rods

A7.1 The ERZr2 classification is a "commercially pure" zirconium. It produces weld metal having good strength and ductility. The tensile strength should be at least 55 ksi [380 MPa]. These electrodes and rods are intended to be used for welding the UNS R60702 zirconium alloy.

A7.2 The ERZr3 classification contains tin as an alloying element. Tin increases the strength of the weld metal, yet allows it to retain good ductility. The strength should be at least 60 ksi [410 MPa]. These electrodes and rods are intended only for welding UNS R60704 zirconium alloy. Weld metal from ERZr3 filler metal may not resist corrosion as well as that from ERZr2 filler metal.

A7.3 The ERZr4 classification contains niobium (columbium) as an alloying element. It produces weld metal of good ductility with a tensile strength of at least 80 ksi [550 MPa]. These electrodes and rods are used only to weld UNS R60705 zirconium alloy. Weld metal from ERZr4 filler metal may not resist corrosion as well as that from ERZr2 filler metal. All welds utilizing ERZr4 filler metal should be post weld heat treated to reduce the susceptibility for delayed hydride cracking.

A8. Special Tests

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. AWS A5.01, *Filler Metal Procurement Guidelines* provides a means by which such tests can be incorporated into the purchase order. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

A8.1 Corrosion Tests. Although welds made with electrodes and rods in this specification are commonly used in corrosion applications, tests for those properties are not included in the specification. When required for a particular application, tests can be conducted on specimens taken from either a weld pad or a welded joint. Specimens from a joint are suitable for qualifying the welding procedure (for a specific application involving corrosion or oxidation resistance) but not for qualifying the electrode. Tests on specimens from a joint have the disadvantage of being a combined test of the properties of the weld metal, the heat-affected zone (HAZ), and the unaffected base metal. With them, it is more difficult to obtain reproducible data (when a difference exists in the properties of the metal in the various parts of the specimen).

Specimens taken from a joint have the advantage of being able to duplicate the joint design and the welding sequence planned for fabrication.

A8.1.1 Specimens for testing the corrosion resistance of the weld metal alone are prepared by following a procedure as agreed upon by purchaser and supplier. The pad size should be at least $\frac{3}{4}$ in. [19 mm] in height, 2-$\frac{1}{2}$ in. [65 mm] in width, and $1 + \frac{5}{8}\,n$ (in.) $[25 + 16\,n$ {mm}] in length, where n represents the number of specimens required from the pad. Specimens measuring $\frac{1}{2} \times 2 \times \frac{1}{4}$ in. [13 × 50 × 6.4 mm] are machined from the top of the pad in a manner such that the 2 in. [50 mm] dimension of the specimen is parallel with the 2-$\frac{1}{2}$ in. [65 mm] dimension of the pad and the $\frac{1}{2}$ in. [13 mm] dimension is parallel with the length of the pad.

A8.1.2 The heat treatment, 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 procedures should correspond to those of ASTM G 4, *Standard Practice for Conducting Plant Corrosion Tests*, or ASTM G 31, *Recommended Practice for Laboratory Immersion Corrosion Testing of Metals,* as the case may be.

A9. Discontinued Classifications

One classification has 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 classification that has been discontinued is listed in Table A1, along with the year in which it was last included in the specification.

A10. General Safety Considerations

NOTE: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addresses herein. Some safety and health information can be found in Annex Section A5. Safety and health information is available from other sources, including, but not limited to *Safety and Health Fact Sheets* listed in A10.2, ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*[7]*, and applicable federal and state regulations.*

A10.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.2 AWS Safety and Health Fact Sheets Index (SHF)[8]

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

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[7] This standard can be obtained from Global Engineering Documents, an Information Handling Servicews (IHS) Group company, 15 Inverness Way East, Englewood, CO 80112-5776.

[8] AWS standards can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group company, 15 Inverness Way East, Englewood, CO 80112-5776.

SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL ELECTRODES AND FLUXES FOR ELECTROSLAG WELDING

SFA-5.25/SFA-5.25M

(Identical with AWS Specification A5.25/A5.25M-97 (R2003). In case of dispute, the original AWS text applies.)

SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL ELECTRODES AND FLUXES FOR ELECTROSLAG WELDING

SFA-5.25/SFA-5.25M

(Identical to AWS Specification A5.25/A5.25M-97 (R2003). In case of dispute, the original AWS text applies.)

1. Scope

This specification prescribes requirements for the classification of electrodes (both solid and composite metal cored) and fluxes for electroslag welding of carbon and low-alloy steels.

PART A — GENERAL REQUIREMENTS

2. Classification

2.1 The solid electrodes covered by this specification are classified according to the chemical composition of the electrode, as specified in Table 1.

2.2 The composite metal cored electrodes covered by this specification are classified according to the chemical composition of the weld metal produced by use with a specific flux of a particular manufacturer and trade designation as specified in Table 2.

2.3 Fluxes covered by this specification are classified according to the mechanical properties of the weld metal as specified in Tables 3 and 4, when using an electrode of a particular classification.

2.4 Electrodes classified under one classification shall not be classified under any other classification in this specification. Fluxes may be classified under any number of classifications using a different electrode for each. Fluxes classified as FESX2-XXX may also be classified as FESX0-XXX and FESXZ-XXX, as specifically permitted by Note (a) to Table 4.

2.5 The electrodes and fluxes classified under this specification are intended for electroslag welding, but that is not to prohibit their use with any other process for which they are found suitable.

3. Acceptance

Acceptance[1] of the electrodes and fluxes shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.[2]

4. Certification

By affixing the AWS Specification and Classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[3]

5. Units of Measure and Rounding-Off Procedure

5.1 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 A5.25 uses U.S. Customary Units. The specification A5.25M uses SI units. The latter are shown in appropriate columns in tables or within brackets [] when used in the text.

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] for tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off

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[1] See Section A3 (in the Annex), Acceptance, for further information concerning acceptance, testing of the material shipped, and the ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

[2] AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] See Section A4 (in the Annex), Certification, for further information concerning certification and the testing called for to meet this requirement.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES

AWS Classification[c]	UNS Number[d]	Weight-Percent[a,b]												Other Elements, Total
		C	Mn	P	S	Si	Ni	Cr	Mo	Cu[e]	Ti	Zr	Al	
Medium-Manganese Classes														
EM5K-EW	K10726	0.07	0.90–1.40	0.025	0.030	0.40–0.70	—	—	—	0.35	0.05–0.15	0.02–0.12	0.05–0.15	0.50
EM12-EW	K01112	0.06–0.15	0.80–1.25	0.030	0.030	0.10	—	—	—	0.35	—	—	—	0.50
EM12K-EW	K01113	0.05–0.15	0.80–1.25	0.030	0.030	0.10–0.35	—	—	—	0.35	—	—	—	0.50
EM13K-EW	K01313	0.06–0.16	0.90–1.40	0.030	0.030	0.35–0.75	—	—	—	0.35	—	—	—	0.50
EM15K-EW	K01515	0.10–0.20	0.80–1.25	0.030	0.030	0.10–0.35	—	—	—	0.35	—	—	—	0.50
High-Manganese Classes														
EH14-EW	K11585	0.10–0.20	1.70–2.20	0.030	0.030	0.10	—	—	—	0.35	—	—	—	0.50
Special Classes														
EWS-EW	K11245	0.07–0.12	0.35–0.65	0.030	0.030	0.22–0.37	0.40–0.75	0.50–0.80	—	0.25–0.55	—	—	—	0.50
EA3K-EW[f]	K10945	0.07–0.12	1.60–2.10	0.025	0.025	0.50–0.80	0.15	—	0.40–0.60	0.35	—	—	—	0.50
EH10K-EW	K01010	0.07–0.14	1.40–2.00	0.025	0.030	0.15–0.30	—	—	—	—	—	—	—	0.50
EH11K-EW	K11140	0.06–0.15	1.40–1.85	0.025	0.030	0.80–1.15	—	—	—	0.35	—	—	—	0.50
ES-G-EW	—							NOT SPECIFIED[g]						

NOTES:

a. The electrode shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

b. Single values are maximums.

c. Chemical composition requirements may be similar to those in other AWS specifications; see Table A1 in the Annex.

d. SAE/ASTM Unified Numbering System for Metals and Alloys.

e. The copper limit includes copper that may be applied as a coating on the electrode.

f. Formerly classified EH10Mo-EW in ANSI/AWS A5.25-91.

g. Composition shall be reported; the requirements are those agreed to by the purchaser and the supplier.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL FROM COMPOSITE METAL CORED ELECTRODES[a]

AWS Classification	UNS Number[d]	Weight Percent[b,c] C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Other Elements, Total
EWT1	W06040	0.13	2.00	0.03	0.03	0.60	—	—	—	—	—	0.50
EWT2	W20140	0.12	0.50–1.60	0.03	0.04	0.25–0.80	0.40–0.80	0.40–0.70	—	0.25–0.75	—	0.50
EWT3	W22340	0.12	1.00–2.00	0.02	0.03	0.15–0.50	1.50–2.50	0.20	0.40–0.65	—	0.05	0.50
EWTG	—	NOT SPECIFIED[e]										

NOTES:

a. The flux used, when classifying composite electrodes shall be one with which the electrode is classified for mechanical properties (see Tables 3 or 3M and 4 or 4M).

b. The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

c. Single values are maximums.

d. SAE/ASTM Unified Numbering System for Metals and Alloys.

e. Composition shall be reported; the requirements are those agreed to by the purchaser and supplier.

TABLE 3
A5.25 TENSION TEST REQUIREMENTS (AS-WELDED)

AWS A5.25 Classification[a]	Tensile Strength psi	Yield Strength, min.[b] psi	Elongation, min.[b] percent
FES6Z-XXX FES60-XXX FES62-XXX	60 000 to 80 000	36 000	24
FES7Z-XXX FES70-XXX FES72-XXX	70 000 to 95 000	50 000	22
FES8Z-XXX FES80-XXX FES82-XXX	80 000 to 100 000	60 000	20

NOTES:

a. The letters "XXX" as used in the AWS Classification column in this table refer to the electrode classification used.

b. Yield strength at 0.2 percent offset and elongation in 2 in. (51 mm) gage length.

TABLE 3M
A5.25M TENSION TEST REQUIREMENTS (AS WELDED)

AWS A5.25M Classification(1)	Tensile Strength MPa	Yield Strength, min.(2) MPa	Elongation, min.(2) Percent
FES43Z-XXX	430		
FES432-XXX	to	250	24
FES433-XXX	550		
FES48Z-XXX	480		
FES482-XXX	to	350	22
FES483-XXX	650		
FES55Z-XXX	550		
FES552-XXX	to	410	20
FES553-XXX	700		

NOTES:

(1) The letters "XXX" as used in the AWS A5.25M Classification column in this table refer to the electrode classification used.

(2) Yield strength at 0.2 percent offset and elongation in 50 mm gage length.

TABLE 4
A5.25 IMPACT TEST REQUIREMENTS[a] (AS WELDED)

AWS A5.25 Classification[b]	Average Impact Strength, min.[c] ft·lbf
FES6Z-XXX	Not specified
FES7Z-XXX	Not specified
FES8Z-XXX	Not specified
FES60-XXX	15 @ 0°F
FES70-XXX	15 @ 0°F
FES80-XXX	15 @ 0°F
FES62-XXX	15 @ −20°F
FES72-XXX	15 @ −20°F
FES82-XXX	15 @ −20°F

NOTES:

a. A flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table. In this manner, FESX2-XXX may also be classified as FESX0-XXX and FESXZ-XXX and FESX0-XXX may be classified as FESXZ-XXX.

b. The letters "XXX" used in the AWS Classification column in this table refer to the electrode classification used.

c. Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 15 ft·lbf and one of the three remaining values may be lower than 15 ft·lbf but not lower than 10 ft·lbf. The average of the three shall not be less than the 15 ft·lbf specified.

TABLE 4M
A5.25M IMPACT TEST REQUIREMENTS (AS WELDED)(1)

AWS A5.25M Classification(2)	Average Impact Strength, min.(3) J
FES43Z-XXX	Not specified
FES48Z-XXX	Not specified
FES55Z-XXX	Not specified
FES432-XXX	20 @ −20°C
FES482-XXX	20 @ −20°C
FES552-XXX	20 @ −20°C
FES433-XXX	20 @ −30°C
FES483-XXX	20 @ −30°C
FES553-XXX	20 @ −30°C

NOTES:

(1) A flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table. In this manner, FESXX3-XXX may also be classified as FESXX2-XXX and FESXXZ-XXX and FESXX2-XXX may be classified as FESXXZ-XX.

(2) The letters "XXX" used in the AWS Classification column in this table refer to the electrode classification used.

(3) Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 20 J and one of the three remaining values may be lower than 20 J, but not lower than 14 J. The average of the three shall not be less than the 20 J specified.

method given in ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*[4]

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

6.1 Chemical analysis of solid electrodes is the only test required for classification of a solid electrode under this specification, as shown in Table 5.

6.2 Chemical analysis of undiluted weld metal from the composite electrode and a specific flux of a particular manufacturer and trade designation is the only test required for classification of a composite electrode under this specification, as shown in Table 5.

6.3 The tests required for classification of each electrode/flux combination are specified in Table 5. The purpose of these tests is to determine the mechanical properties and soundness of the weld. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 8 through 12.

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[4] ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

TABLE 5
REQUIRED TESTS

Material to be Classified	AWS Classification[a]	Chemical Analysis		Radiographic Test	Tension Test	Impact Test
		Electrode	Weld Metal			
Solid Electrodes	All	Required	Not Required	Not Required	Not Required	Not Required
Composite Electrodes[b]	All	Not Required	Required	Not Required	Not Required	Not Required
Fluxes	FES6Z-XXX FES7Z-XXX FES8Z-XXX FES43Z-XXX FES48Z-XXX FES55Z-XXX	Not Required	Not Required	Required	Required	Not Required
	FES60-XXX FES70-XXX FES80-XXX FES432-XXX FES482-XXX FES552-XXX	Not Required	Not Required	Required	Required	Required
	FES62-XXX FES72-XXX FES82-XXX FES433-XXX FES483-XXX FES553-XXX	Not Required	Not Required	Required	Required	Required

NOTES:

a. The letters "XXX" used in the AWS Classification column in this table refer to the electrode classification used.

b. The flux used when classifying composite electrodes shall be one with which the electrode is classified for mechanical properties.

7. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or from one or two new test assemblies. 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 specimens 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 prescribed procedures. In this case, the requirement for doubling of the number of test specimens does not apply.

8. Weld Test Assemblies

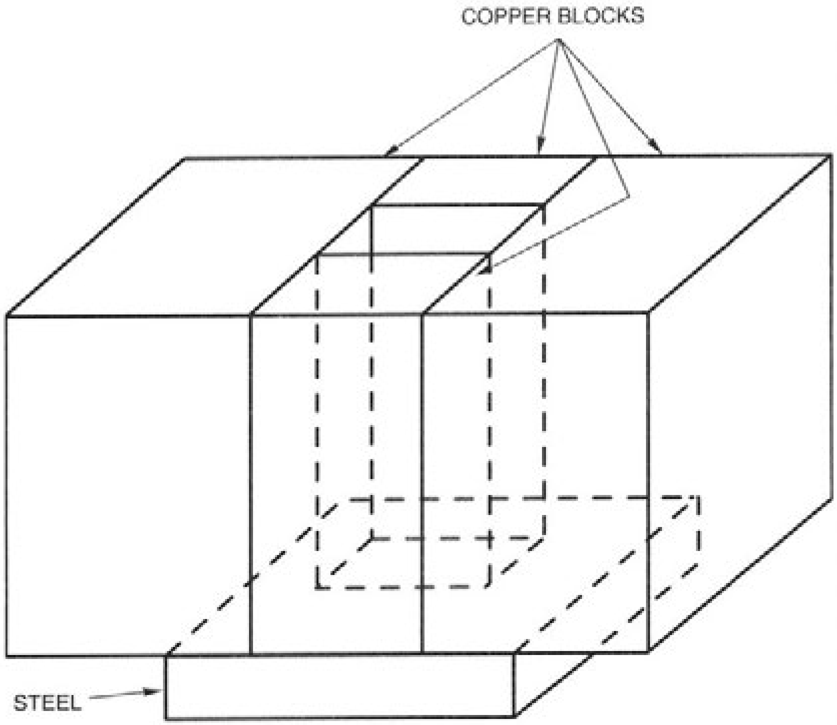
8.1 No weld test assemblies are required for classification of solid electrodes. One weld test assembly is required for classification of composite electrodes. It is the weld ingot as shown in Fig. 1, for chemical analysis of weld metal. In addition to the above, one weld test assembly is required for each classification of an electrode-flux combination. This is the groove weld in Fig. 2 for mechanical properties and soundness of the weld metal in the as-welded condition.

8.2 Preparation of each weld test assembly shall be as prescribed in 8.3, 8.4, and 9.2. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the appropriate ASTM specification shown there, or an equivalent specification. Testing of the assemblies shall be as prescribed in 9.3 and Sections 10 through 12.

8.3 Weld Ingot. An ingot shall be prepared as specified in Fig. 1.

8.4 Groove Weld for Mechanical Properties and Soundness for Flux-Electrode Combinations. A test

FIG. 1 WELD INGOT



NOTES:

(1) Weld ingot shall be deposited by arc welding in a water-cooled copper mold using welding conditions shown in Figure 2.

(2) Weld ingot shall be of any convenient shape that provides approximately 4 in.^{2} [25 cm^2] of weld metal cross-section.

(3) The weld ingot shall be started on a piece of carbon steel of sufficient size as to avoid complete fusion, and the copper mold shall be a sufficient heat sink to avoid contamination of the ingot by molten copper.

(4) The sample for chemical analysis shall be taken at least 2 in. [50 mm] above the bottom of the ingot, and at least 2 in. [50 mm] below the crater.

(5) Consumable guide tubes shall be used for preparing the weld ingot if guide tubes were used in welding the groove weld test assembly, as use of consumable guide tubes will affect chemical composition.

assembly shall be chosen and welded as specified in Fig. 2 using base metal of the appropriate type specified in Table 6. Testing of this assembly shall be as specified in Sections 10 through 12. The assembly shall be tested in the as-welded condition.

9. Chemical Analysis

9.1 For solid electrodes, a sample of the electrode shall be prepared for chemical analysis. Solid electrodes, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the electrode 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 other elements.

9.2 Composite electrodes shall be analyzed in the form of undiluted weld metal, not electrode. The sample for analysis shall be taken from weld metal obtained with the electrode and a specific flux of a particular manufacturer and trade designation with which it was classified. The sample shall come from an ingot (Fig. 1). The top surface of the ingot shall be removed and discarded, and a sample for analysis shall be obtained by any appropriate mechanical means from the underlying metal at a location at least 2 in. [50 mm] from the start of the ingot and at least 1 in. [25 mm] from the end. The sample shall be free of slag.

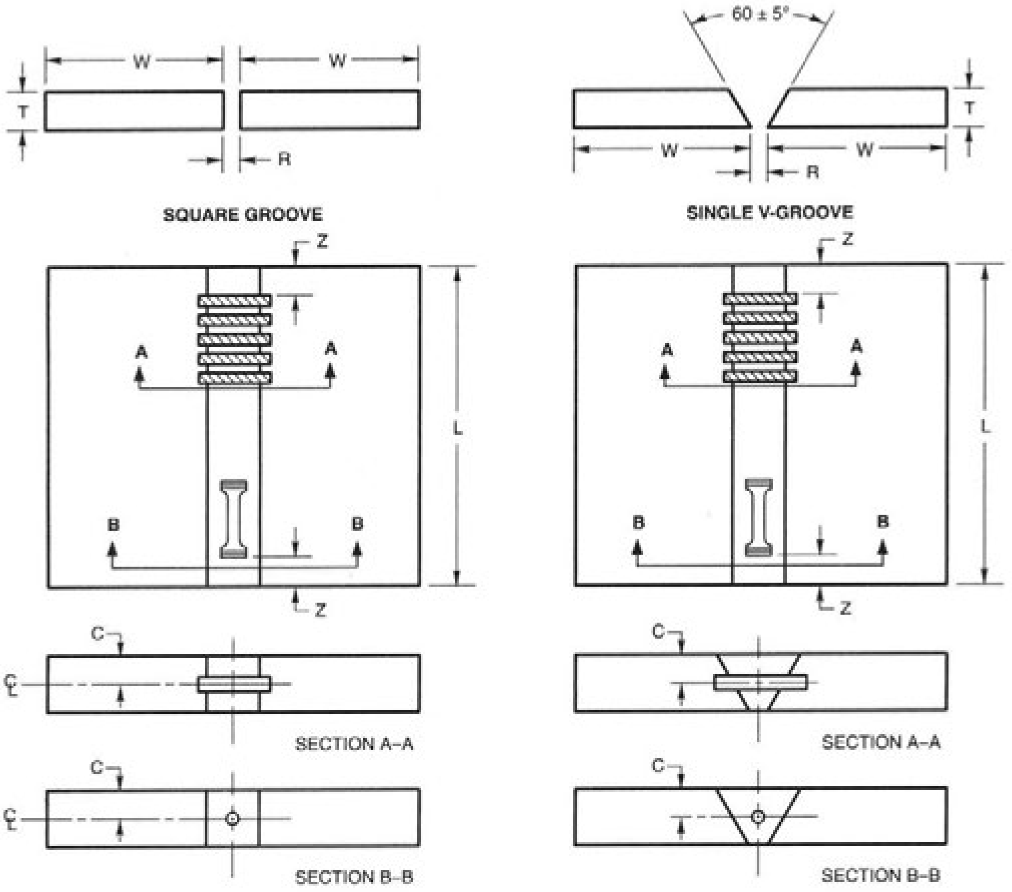
9.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM Standard Method E350, *Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron.*

9.4 The results of the analysis shall meet the requirements of Table 1 for solid electrodes or Table 2 for composite electrodes, for the classification of electrode under test.

10. Radiographic Test

10.1 The groove weld described in 8.4 and shown in Fig. 2 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, both surfaces of the weld may be machined or ground smooth and flush

FIG. 2 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS



Groove Type:	Square Groove		Square Groove		Single V-Groove	
Consumable Guide Tube:	Yes		No		No	
	in.	mm	in.	mm	in.	mm
Electrode Size:	3/32 or 1/8	2.4, 2.5, or 3.0	3/32 or 1/8	2.4, 2.5, or 3.0	3/32 or 1/8	2.4, 2.5, or 3.0
Dimensions:						
L, Length, min.	15	380	15	380	15	380
W, Width, min.	12	300	12	300	12	300
T, Thickness	2	50	2	50	2	25
Z, Discard, min.	2-1/2	65	2-1/2	65	2-1/2	65
R, Root Opening	1 to 1-1/4	25 to 32	1 to 1-1/4	25 to 32	1/4 min.	6 min.
C, Distance to the Center of Specimen	1/2	12.5	1/2	12.5	3/8	9.5
Current, dcep:						
Amperes	500 ± 50		500 ± 50		400 ± 50	
Volts	40 ± 2		40 ± 2		40 ± 2	

GENERAL NOTES:

(a) Weld test assembly shall be welded in the vertical position with upward progression.

(b) The test assembly shall be chosen and fixtured based on the manufacturer's recommendations. Water-cooled copper shoes shall be used except when using consumable guide tubes. For welding with consumable guide tubes, follow the manufacturer's recommendations regarding the use of water-cooled shoes. When using water cooling, the outgoing water temperature shall not exceed 180°F [82°C] near the exit point.

(c) If the manufacturer does not make the electrode size specified, the nearest size may be used. For sizes other than that shown, follow the manufacturer's recommended procedure.

(d) Welding shall begin with the assembly at room temperature, 65°F [18°C] minimum. No external heat shall be applied during welding. Run-on and run-off tabs are not required if the test assembly is of sufficient length to provide the required test specimens.

(e) The weld shall be completed in one pass.

(f) No thermal treatment shall be performed on the assembly subsequent to the completion of welding.

TABLE 6
BASE METALS FOR TEST ASSEMBLIES

AWS Classification		ASTM Base Metal Specification
A5.25	A5.25M	
FES6X-XXX	FES43X-XXX	ASTM A36
FES7X-XXX	FES48X-XXX	ASTM A242 Type 2 or A572 Grade 50
FES8X-XXX	FES55X-XXX	ASTM A537 Class 2, A572 Grade 60 or 65, or A633 Grade E
The following classifications are exceptions to the above general requirements:		
FESXX-EWS-EW FESXX-EWT2	FESYYY-EWS-EW FESYYY-EWT2	ASTM A588

with the original surfaces of the base metal or with a uniform reinforcement not exceeding $^3/_{32}$ in. [2.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

10.2 The weld shall be radiographed in accordance with ASTM E142, *Standard Method for Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Fig. 4.

In evaluating the radiograph, 2-$^1/_2$ in. [65 mm] of the weld on each end of the test assembly shall be disregarded.

A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be of porosity or slag. Indications whose largest dimension does not exceed $^1/_{64}$ in. [0.4 mm] shall be disregarded. Test assemblies with indications greater than the largest indications permitted in the radiographic standards do not meet the requirements of this specification.

11. Tension Test

11.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in 8.4 and shown in Fig. 2. The dimensions of the specimen shall be as shown in Fig. 3.

11.2 The specimen shall be tested in the manner described in the tension test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

11.3 The results of the tension test shall meet the requirements specified in Table 3, or Table 3M, as applicable.

12. Impact Test

12.1 Five Charpy V-notch impact test specimens (Fig. 5) shall be machined from the test assembly shown in Fig. 2, for those flux-electrode classifications for which impact testing is required in Table 5. The five specimens shall be tested in accordance with the fracture toughness test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. The test temperature and the test results shall be those specified in Table 4 or Table 4M, as applicable, for the classification under test.

12.2 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal, or exceed, the specified 15 ft·lbf [20 J] energy level. One of the three may be lower, but not lower than 10 ft·lbf [14 J], and the average of the three shall be not less than the required 15 ft·lbf [20 J] energy level.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

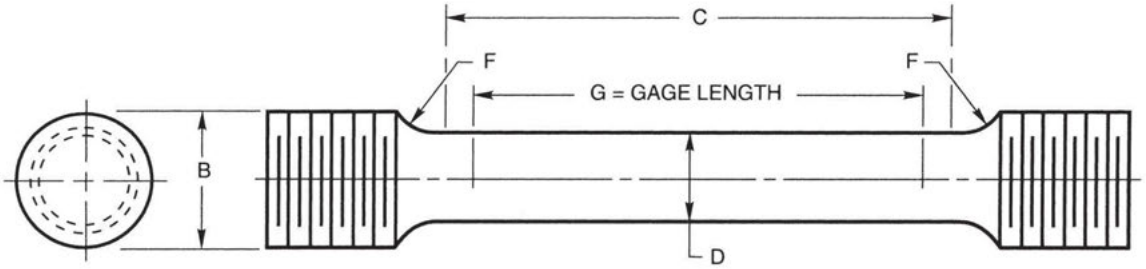
13. Method of Manufacture

The welding materials classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification.

14. Electrode Requirements

14.1 Standard Sizes. Standard sizes for electrodes in the different package forms (coils with support, coils without support, spools and drums) are shown in Table 7.

FIG. 3 TENSION TEST SPECIMEN



Dimensions of Specimen, in.					Approximate Area, in.^{2}
D	G	C	B	F, min.	
0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	0.375	0.2
Dimensions of Specimen, mm					**Approximate Area, mm^2**
D	G	C	B	F, min.	
12.5 ± 0.2	50.0 ± 0.1	55	20	10	123

GENERAL NOTES:

(1) Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.

(2) The diameter of the specimen within the gage length shall be slightly smaller at the center (controlling dimension) than at the ends. The difference shall not exceed one percent of the diameter.

(3) When the extensometer is required to determine yield strength, dimension C may be modified. However, the percent of the elongation shall be based on dimension G.

(4) The surface finish within the C dimension shall be no rougher than 63 μin. [1.6 μm].

14.2 Finish and Uniformity

14.2.1 All electrodes shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams or laps (exclusive of the longitudinal joint in cored electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment or the properties of the weld metal.

14.2.2 Each continuous length of electrode shall be from a single lot of material, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic equipment.

14.2.3 The core ingredients in composite electrodes 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.

14.2.4 A suitable protective coating may be applied to any of the electrodes in this specification.

14.3 Standard Package Forms

14.3.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 8 and Fig. 6. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.

14.3.2 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use, and shall be clean and dry enough to maintain the cleanliness of the electrode.

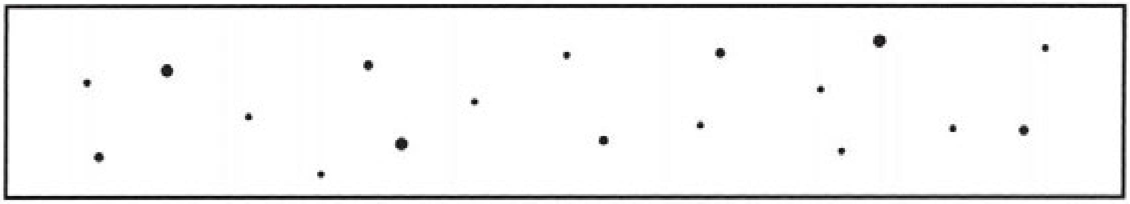
14.3.3 Spools shall be designed and constructed to prevent distortion of the electrode during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

14.4 Winding Requirements

14.4.1 Electrodes shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the electrode free to unwind without restriction. The outside end of the electrode (the end with which welding is to begin) shall be identified so it can be located readily, and shall be fastened to avoid unwinding.

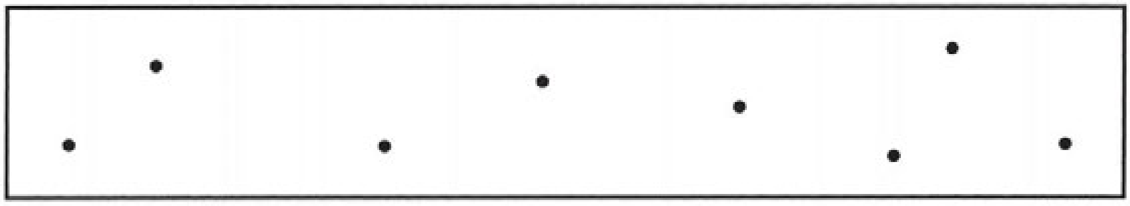
14.4.2 The cast and helix of electrode in coils, spools, and drums shall be such that the electrode will feed in an uninterrupted manner on automatic equipment.

FIG. 4 RADIOGRAPHIC ACCEPTANCE STANDARDS



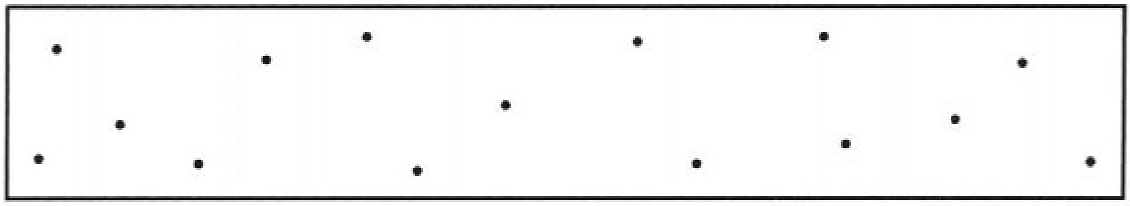
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in. TO 1/16 in. [0.4 TO 1.6 mm] 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 TO 1/16 in. [1.2 TO 1.6 mm] DIAMETER AND/OR LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 TO 3/64 in. [0.8 TO 1.2 mm] DIAMETER AND/OR LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 TO 1/32 in. [0.4 TO 0.8 mm] DIAMETER AND/OR LENGTH INDICATIONS = 10.



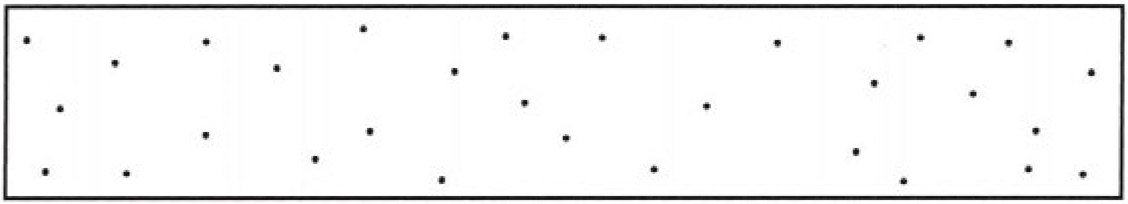
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 TO 1/16 in. [1.2 TO 1.6 mm] DIAMETER AND/OR LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 TO 3/64 in. [0.8 TO 1.2 mm] DIAMETER AND/OR LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. [150 mm] OF WELD = 15.



(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 TO 1/32 in. [0.4 TO 0.8 mm] DIAMETER AND/OR LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. [150 mm] OF WELD = 30.

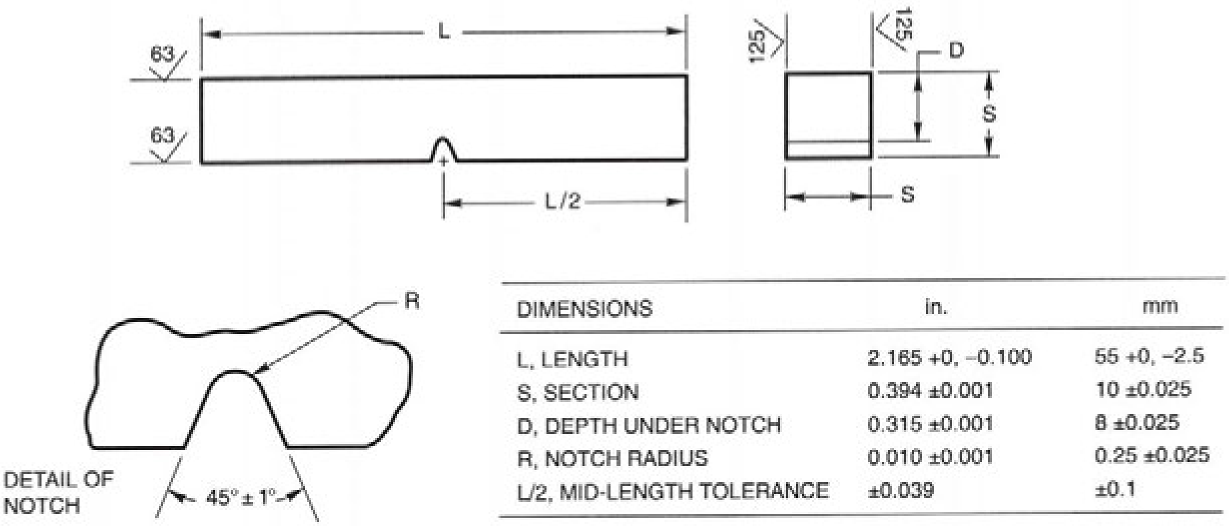
GENERAL NOTES:

(1) In using these standards the chart which is most representative of the size of the porosity and/or inclusions present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.

(2) Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.

(3) Indications smaller than $^{1}/_{64}$ in. [0.4 mm] shall be disregarded.

FIG. 5 CHARPY V-NOTCH IMPACT TEST SPECIMEN



DIMENSIONS	in.	mm
L, LENGTH	2.165 +0, −0.100	55 +0, −2.5
S, SECTION	0.394 ±0.001	10 ±0.025
D, DEPTH UNDER NOTCH	0.315 ±0.001	8 ±0.025
R, NOTCH RADIUS	0.010 ±0.001	0.25 ±0.025
L/2, MID-LENGTH TOLERANCE	±0.039	±0.1

NOTES:

(1) The notched surface and the surface to be struck shall be parallel within 0.002 in. [0.05 mm] and have at least 63 μin. [1.6 μm] finish. The other two surfaces shall be square with the notched or struck surface within ±10 minutes of a degree and have at least 125 μin. [3.2 μm] finish.

(2) The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

(3) The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at minimum 50 times magnification on either a shadowgraph or a metallograph.

(4) The correct location of the notch shall be verified by etching before or after machining.

(5) If a specimen does not break upon being struck, the value for energy absorbed shall be reported as the capacity of the impact testing machine followed by a plus sign (+).

TABLE 7
STANDARD SIZES*

	A5.25				A5.25M		
	Diameter		Tolerance		Diameter	Tolerance	
Standard Package Forms		in.	Solid in.	Cored in.	mm	Solid mm	Cored mm
Coils with support,	1/16	0.062	±0.002	±0.002	1.6	±0.05	±0.05
Coils without support,	5/64	0.078	±0.002	±0.003	2.0	±0.05	±0.08
Drums, and Spools	3/32	0.094	±0.002	±0.003	2.4	±0.05	±0.08
					2.5	±0.05	±0.08
		0.120	±0.003	±0.003	3.0	±0.08	±0.08
	1/8	0.125	±0.003	±0.003	3.2	±0.08	±0.08
	5/32	0.156	±0.003	±0.003	4.0	±0.08	±0.08

* Dimensions, tolerances, and package forms other than those shown shall be as agreed between purchaser and supplier.

TABLE 8
STANDARD PACKAGE DIMENSIONS AND WEIGHTS[a]

Type of Package	Package Size OD[d] in.	Package Size OD[d] mm	Net Weight of Electrode[b] lb	Net Weight of Electrode[b] kg
Coils without support	Not specified[c]		Not specified[c]	
Spools	12	300	25, 30, and 35	10 and 15
	14	350	50 and 60	20 and 25
	22	560	250	100
	24	610	300	150
	30	760	600, 750 and 1000	250, 350 and 450
Drums	15½	400	Not specified (c)	
	20	500	Not specified (c)	
	23	600	300 and 600	150 and 300

Coils with Support — Standard Dimensions and Weights

			Coil Dimensions			
Electrode Size	Coil Net Weight[b]		Inside Dia. of Lining		Width of Wound Electrodes	
	lb	kg	in.	mm	in., max.	mm, max.
All	50, 60, and 65	20, 25, and 30	12 ± ⅛	300 +3, −10	4⅝	120
	150 and 200	75 and 100	23½ ± ¼	600 +3, −10	5	125

NOTES:

a. Package sizes, dimensions, and net weights other than those specified shall be as agreed between supplier and purchaser.

b. Tolerance on net weight shall be ± 10 percent.

c. As agreed by supplier and purchaser.

d. OD = outside diameter.

14.5 Electrode Identification

14.5.1 The product information and the precautionary information required in 14.7 for marking each package shall also appear on each coil, spool, and drum.

14.5.2 Coils without support shall have a tag containing this information securely attached to the electrode at the inside end of the coil.

14.5.3 Coils with support shall have the information securely affixed in a prominent location on the support.

14.5.4 Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

14.5.5 Drums shall have the information securely affixed in a prominent location on the side of the drum.

14.6 Packaging. Electrodes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

14.7 Marking of Packages

14.7.1 The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package.

(a) AWS Specification and Classification (year of issue may be excluded)

(b) Supplier's name and trade designation. In the case of a composite metal cored electrode, the trade designation of the flux (or fluxes) with which it meets the requirements of Table 2.

(c) Size and net weight

(d) Lot, control, or heat number

14.7.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of electrodes including individual unit packages enclosed within a larger package.

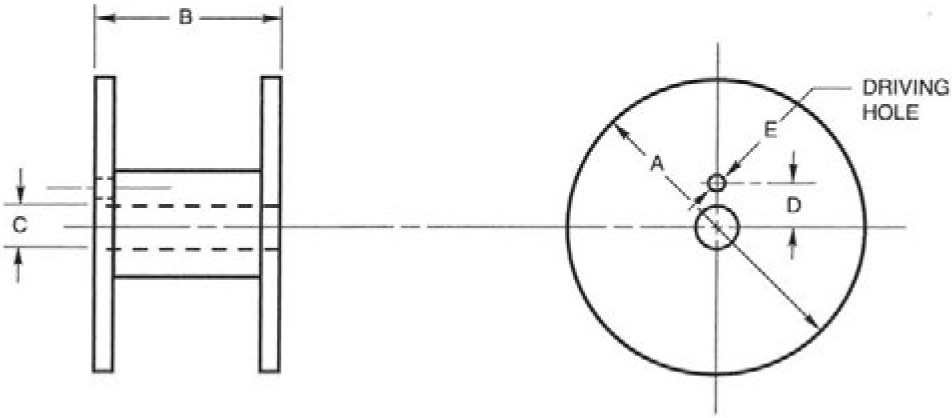
WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be hazardous to your health.

ARC RAYS can injure eyes and burn skin.

FIG. 6A DIMENSIONS OF 12 AND 14 IN. [300 AND 350 MM] STANDARD SPOOLS



DIMENSIONS

		12 in. [300 mm] Spools		14 in. [350 mm] Spools	
		in.	mm	in.	mm
A	Diameter, max.	12	300	14	350
B	Width	4.0 ± 0.06	103 −3, +0	4.0 ± 0.06	103 −3, +0
C	Diameter	2.03 −0, +0.06	50.5 −0, +2.5	2.03 −0, +0.06	50.5 −0, +2.5
D	Distance Between Axes	1.75 ± 0.02	44.5 ± 0.5	1.75 ± 0.02	44.5 ± 0.5
E	Diameter (Note 3)	0.44 ± 0.06	10 −0, +1	0.44 ± 0.06	10 −0, +1

GENERAL NOTES:

(1) Outside diameter of barrel shall be such as to permit feeding of the filler metals.

(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.

ELECTRIC SHOCK can KILL.

- Read and understand the manufacturer's instructions, the Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes,* published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and OSHA Safety and Health Standards, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402.

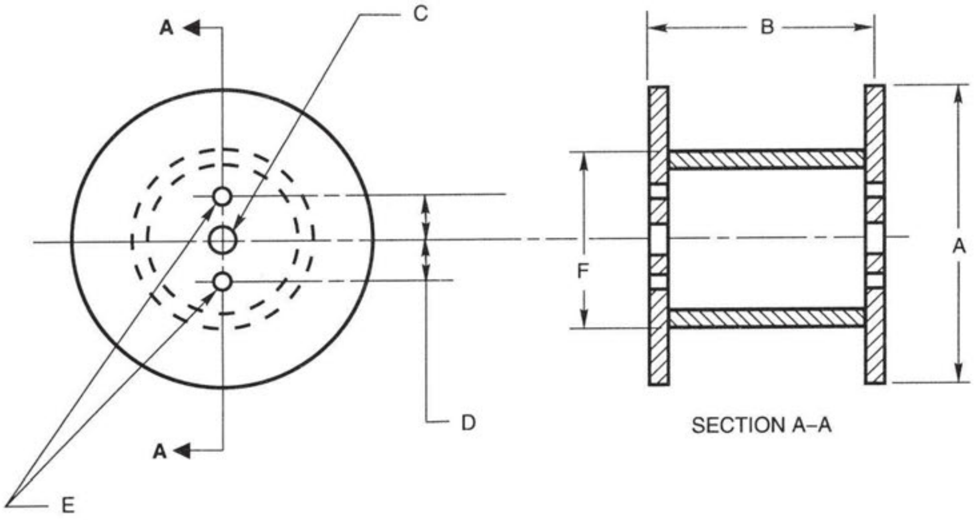
DO NOT REMOVE THIS INFORMATION

15. Flux Requirements

15.1 Form and Particle Size. Flux shall be granular in form and shall be capable of flowing freely through the flux feeding tubes, valves, and nozzles of standard electroslag welding equipment. Particle size is not specified in this specification, but, when it is addressed, it shall be a matter of agreement between the purchaser and the supplier.

15.2 Usability. The flux shall permit the production of uniform, well-shaped weld beads that merge smoothly with the base metal. The molten slag shall have electrical properties suitable for electroslag operation.

FIG. 6B DIMENSIONS OF 22, 24, AND 30 IN. [560, 610, AND 760 MM] STANDARD SPOOLS (REELS)



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.	22	560	24	610	30	760
B	Width, max.	12	305	13.5	345	13.5	345
C	Diameter	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, Ctr. to Ctr.	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)	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

GENERAL NOTES:

(1) Outside diameter of barrel, dimension F, shall be such as to permit feeding of the filler metals.

(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) Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

15.3 Packaging

15.3.1 Flux shall be suitably packaged to ensure against damage during shipment.

15.3.2 Flux, in its original unopened container, shall withstand storage under normal conditions for at least six months without damage to its welding characteristics or the properties of the weld. Heating of the flux to assure dryness may be necessary to obtain the very best operation and properties of which the materials are capable. When drying (reconditioning) is necessary, the supplier should be consulted for a recommended procedure.

15.4 Marking of Packages

15.4.1 The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package.

(a) AWS specification and classification for the appropriate flux-electrode combination (year of issue may be excluded)

(b) Supplier's name and trade designation (brand name)

(c) The trade designation of each composite electrode with which the flux manufacturer has classified the flux, if applicable

(d) Net weight

(e) Lot or control number

(f) Particle size, if more than one size is produced

15.4.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of welding material, including individual unit packages enclosed within a larger package:

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be hazardous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can KILL.

- Read and understand the manufacturer’s instructions, the Material Safety Data Sheets (MSDSs), and your employer’s safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes,* published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and OSHA Safety and Health Standards, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

Annex
Guide to AWS Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding

(This Annex is not a part of AWS A5.25/5.25M-97 (R2003), *Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*, but is included for information only.)

A1. Introduction

The purpose of this annex is to correlate the electrode and flux classifications with their intended applications so the specification can be used effectively. Reference to appropriate base-metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable.

A2. Classification System

A2.1 Classification of Electrodes. The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" at the beginning of each classification designation stands for electrode. The remainder of the designation indicates the chemical composition of the electrode, or, in the case of composite metal cored electrodes, of the weld metal obtained with a particular flux. See Fig. A1.

The letter "M" indicates that the solid electrode is of a medium manganese content, while the letter "H" would indicate a comparatively high manganese content. The one or two digits following the manganese designator indicate the nominal carbon content of the electrode. The letter "K," which appears in some designations, indicates that the electrode is made from a heat of silicon-killed steel. The designation for a solid wire is followed by the suffix "EW." Solid electrodes are classified only on the basis of their chemical composition, as specified in Table 1 of this specification. A composite electrode is indicated by the letters "WT" after the "E," and a numerical suffix. The composition of a composite electrode is meaningless, and the user is therefore referred to weld-metal composition (Table 2) with a particular flux, rather than to electrode composition.

A comparison of solid electrode classifications in this specification and those of other specifications is shown in Table A1.

A2.2 Classification of Fluxes. Fluxes are classified on the basis of the mechanical properties of the weld metal made with some particular classification of electrode, under the specific test conditions called for in this specification.

For example, consider the following flux classifications:

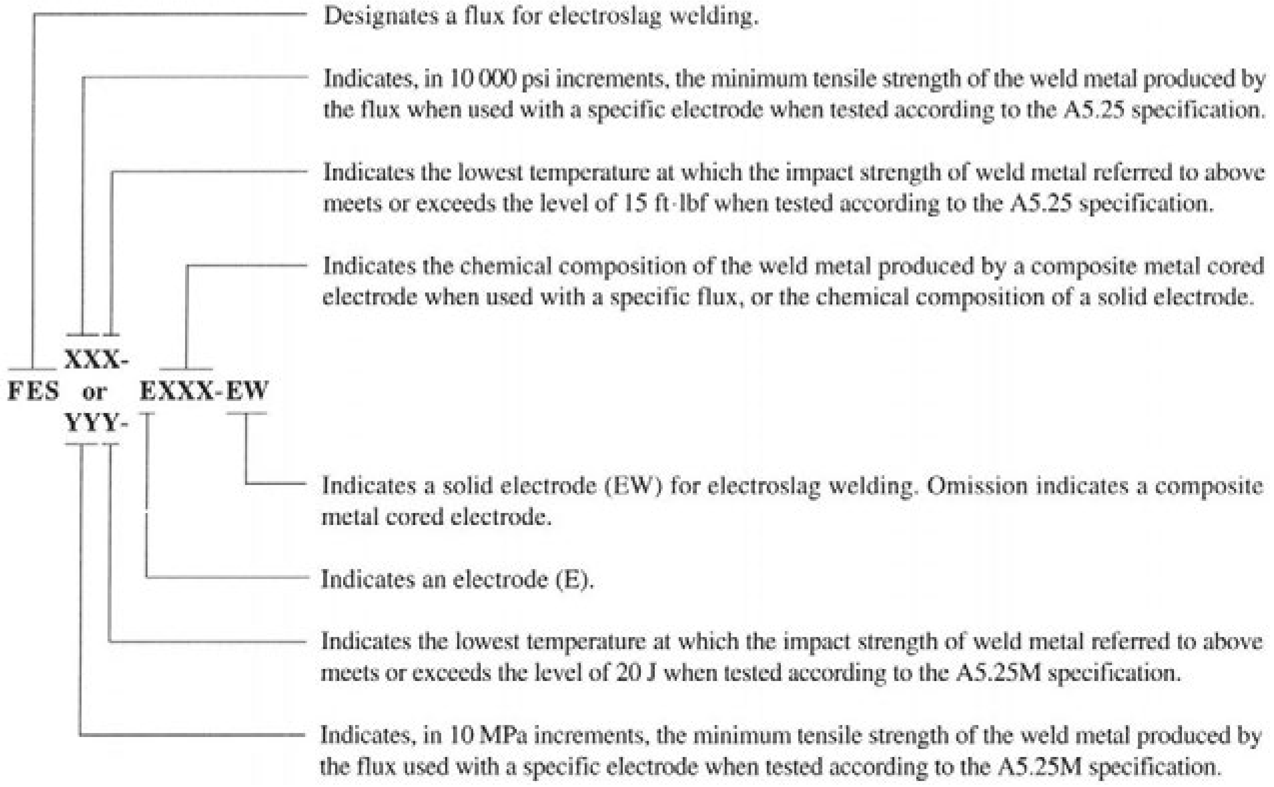
FES60-EH14-EW FES72-EWT2

The prefix "FES" designates a flux for electroslag welding. In the case of the designations for A5.25, this is followed by a single digit representing the minimum tensile strength required of the weld metal in units of 10 000 psi (see Table 3); for the designations for A5.25M, the FES is followed by two digits (43, 48, or 55), representing the minimum tensile strength in units of 10 MPa (see Table 3M).

The digit that follows is a number or the letter "Z." This digit refers to the impact strength of the weld metal. Specifically, it designates the temperature at (and above) which the weld metal meets, or exceeds, the required 15 ft·lbf [20 J] Charpy V-notch impact strength (except for the letter "Z," which indicates that no impact strength requirement is specified in Table 4). These mechanical property designators are followed by the designation of the electrode used in classifying the flux (see Tables 1 and 2). The suffix (EM12-EW, EH10K-EW, EWT2, etc.) included after the first hyphen refers to the electrode classification with which the flux will produce weld metal that meets the specified mechanical properties when tested as called for in the specification.

It should be noted that flux of any specific trade designation may have many classifications. The number is limited only by the number of different electrode classifications with which the flux can meet the classification requirements. The flux package marking lists at least one, and may list all, classifications to which the flux conforms. Solid electrodes having the same classification are interchangeable when used with a specific flux; composite metal-cored electrodes may not be. However, the specific

FIG. A1 CLASSIFICATION SYSTEM



Designates a flux for electroslag welding.

Indicates, in 10 000 psi increments, the minimum tensile strength of the weld metal produced by the flux when used with a specific electrode when tested according to the A5.25 specification.

Indicates the lowest temperature at which the impact strength of weld metal referred to above meets or exceeds the level of 15 ft·lbf when tested according to the A5.25 specification.

Indicates the chemical composition of the weld metal produced by a composite metal cored electrode when used with a specific flux, or the chemical composition of a solid electrode.

Indicates a solid electrode (EW) for electroslag welding. Omission indicates a composite metal cored electrode.

Indicates an electrode (E).

Indicates the lowest temperature at which the impact strength of weld metal referred to above meets or exceeds the level of 20 J when tested according to the A5.25M specification.

Indicates, in 10 MPa increments, the minimum tensile strength of the weld metal produced by the flux used with a specific electrode when tested according to the A5.25M specification.

TABLE A1
COMPARISON OF A5.25/A5.25M-97 CLASSIFICATIONS AND CLASSIFICATIONS IN OTHER AWS SPECIFICATIONS AND PROPOSED ISO DESIGNATIONS

	Similar Classifications[a]					
AWS A5.25/A5.25M Classification	AWS A5.17	AWS A5.18	AWS A5.23	AWS A5.26	AWS A5.28	Proposed ISO Designation[b]
EM5K-EW	—	ER70S-2	—	EGXXS-2	—	S2134
EM12-EW	EM12	—	—	—	—	S2000
EM12K-EW	EM12K	—	EM12K	—	—	S2010
EM13K-EW	EM13K	ER70S-3	—	EGXXS-3	—	S2030
EM15K-EW	EM15K	—	—	—	—	S2210
EH14-EW	EH14	—	—	—	—	S4200
EWS-EW	—	—	EW	—	—	S1000-W
EA3K-EW[c]	—	—	EA3	EGXXS-D2	ER80S-D2	S3020-A3
EH10K-EW	—	—	—	—	—	—
EH11K-EW	EH11K	ER70S-6	—	EGXXS-6	—	S3031

NOTES

a. Classifications are similar, but not necessarily identical in composition:
ANSI/AWS A5.17, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
ANSI/AWS A5.18, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*
ANSI/AWS A5.23, *Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
ANSI/AWS A5.26, *Specification for Carbon and Low Alloy Steel Electrodes for Electrogas Welding*
ANSI/AWS A5.28, *Specification for Low Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

b. IIW Doc. XII-1232-91 (also see Section A2.5)

c. Formerly classified as EH10Mo-EW in AWS A5.25-91.

usability (or operating) characteristics of various fluxes of the same classification may differ in one respect or another.

A2.3 "G" Classification

A2.3.1 This specification includes filler metals classified as ES-G-EW or EWTG. The letter "G" indicates that the filler metal is of a general classification. It is "general" because not all of the particular requirements specified for each of the other classifications are specified for this classification.

The intent, in establishing this classification, is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal — in the case of the example — does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal — one that otherwise would have to await a revision of the specification — to be classified immediately, under the existing specification. This means, then, that two filler metals — each bearing the same "G" classification — may be quite different in some certain respect (chemical composition, again, for example).

A2.3.2 Request for Filler Metal Classification

(a) When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

(b) A request to establish a new filler metal classification must be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate to satisfy the need. The request needs to state the variables and their limits for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

(c) The request should be sent to the Secretary of the Committee on Filler Metals at AWS Headquarters. Upon receipt of the request, the Secretary will do the following:

(1) Assign an identifying number to the request. This number will include the date the request was received.

(2) Confirm receipt of the request and give the identification number to the person who made the request.

(3) Send a copy of the request to the Chair of the Filler Metal Committee and the Chair of the particular Subcommittee involved.

(4) File the original request.

(5) Add the request to the log of outstanding requests.

(d) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner," and the Secretary shall report these to the Chair of the Committee on Filler Metals for action.

(e) 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 meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A2.4 Terms "Not Specified" and "Not Required." The point of difference (although not necessarily the amount of the 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 (or a welding flux). It indicates that test is not required because the requirements (results) for the test have not been specified for that particular classification.

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a filler metal to that classification. When a purchaser wants the information provided by that test, in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of that product. The purchaser and supplier also will have to establish with that supplier just what the specific testing procedure and the acceptance requirements are to be for that test. The purchaser may want to incorporate that information (via ANSI/AWS A5.01) in the purchase order.

A2.5 An international system, for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for the type of filler metal. In that system, the initial letter "S" designates a mild or low-alloy steel wire, followed by a four-digit number. If the filler metal is a metal cored wire, the initial letter is “C” if a flux-cored wire, the initial letter is “T.”

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, as the specification states.

Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing normally is conducted on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. Testing in accordance with any other Schedule in that Table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall 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 test 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 ANSI/AWS 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:

(a) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)

(b) Number of welders and welding operators working in that space

(c) Rate of evolution of fumes, gases, or dust, according to the materials and processes used

(d) The proximity of the welders or welding operators 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

(e) The ventilation provided to the space in which the welding is done

A5.2 American National Standard ANSI/ASC 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 Health Protection and Ventilation of that document.

A6. Welding Considerations

A6.1 Electroslag welding is a process producing coalescence of metals with molten slag which melts the filler metal and the surfaces of the workpiece to be welded. The process is initiated by starting an arc beneath a layer of granular welding flux. The arc is then extinguished by the conductive slag which is kept molten by its resistance to electric current passing between the electrode and the workpiece. The weld pool is shielded by this slag which covers the full cross-section of the joint as welding progresses. The joint is generally welded in a single pass.

A6.2 Heat generated by the resistance to the current through the molten slag is sufficient to fuse the edges of the workpiece and melt the welding electrode. Since no arc exists, the welding action is quiet and spatter-free. The liquid metal coming from the filler metal and the fused base metal collects in a pool beneath the slag bath and slowly solidifies to form the weld.

A6.3 Because of the necessity to contain the large volume of molten slag and weld metal produced in electroslag welding, the process is used for welding in the vertical position. Water-cooled or solid copper backing shoes are usually used on each side of the joint to retain the molten metal and slag pool and to act as a mold to cool and shape the weld faces. The copper backing shoes are normally moved upward on the plate surfaces as welding progresses.

A6.4 The entire assembly — including electrode, copper shoes, wire-feeding mechanism, controls, and oscillator — generally moves vertically during operation. The length of vertical travel is unlimited and is dependent upon the design of the equipment used.

Because of the uniform heat distribution throughout the plate thickness during welding, electroslag welds are virtually free of axial or transverse distortion; however, the joint may contract. The weld interface contour is a function of the welding voltage, current, and slag pool depth. The weld metal usually consists of approximately 30 to 50 percent of base metal.

A6.5 The standard joint preparation is a square groove in a butt joint. Joint preparations other than square grooves in butt joints can be used.

A6.6 The consumable guide method uses a metal tube extending the full length of the weld joint to guide the electrode to the welding zone. The molds and all wire-feeding equipment remain stationary, with the electrode being the only moving part. The guide tube melts into the weld pool as the pool rises, supplying additional filler metal.

In some applications, the guide tubes are covered with a flux to insulate the tube if it should contact the base metal or copper backing shoes. The coating also helps to replenish flux that solidifies on the surface of the copper shoes forming the weld-face contour. The flux coating thus helps to maintain a level of molten slag adequate to provide resistance heating and to protect the weld pool from atmospheric contamination. The manufacturer should be consulted for specific recommendations regarding consumable guide tubes.

The effect of the consumable guide tube generally is to dilute the alloy content of the weld metal. Consumable guide tubes are not classified per this specification; therefore, weld-metal strength and toughness should be tested by the user.

A6.7 The specification requires the use of certain base metals for classification purposes. This does not signify any restriction on the application of the process for joining other base metals, but rather, provides a means for obtaining reproducible results. Electroslag welding is a "high dilution" process, meaning that the base metal forms a significant portion of the weld metal. The type of base metal, especially given the wide variety of available low-alloy structural steels, will influence the mechanical and other properties of the joint. Weld procedure qualification tests, as distinguished from filler metal classification tests, should be used for assessing the properties of welds for a given application.

A6.8 Electroslag welding is a high-deposition process for thick plates. Since it usually is operated as a single-pass process, the weld metal and heat-affected zone (HAZ) are subject to no subsequent weld thermal cycles, such as is common with conventional multipass arc welding of thick materials. The weld metal is characterized by large unrefined dendrites. The relatively wide HAZ is characterized by large grains. The as-welded mechanical properties of the weld and HAZ may therefore be somewhat lower than that of the base metal.

This specification requires a minimum of 15 ft·lbf [20 J] at the specified temperature while most other AWS filler metal specifications require 20 ft·lbf [27 J]. Considerable improvement in mechanical properties can be effected by a postweld heat treatment. Subcritical stress relieving heat treatments are generally less effective for electroslag welding than for arc welding. For this reason, many code requirements require an austenitizing, or normalizing, postweld heat treatment.

All of the aforementioned postweld heat treatments (i.e., subcritical stress relief, austenitizing, normalizing) may have a pronounced effect on weld metal mechanical properties, both strength levels and Charpy V-notch toughness. The strength levels of the heat-treated weld deposit can be expected to be lower than those in the as-welded condition. For this reason, the user is cautioned to conduct actual tests to determine the effect of the heat treatment on the mechanical properties obtained.

A7. Discontinued Classifications

The following classifications have been discontinued over the life of this specification:

Discontinued Classification	Last Published
EH10Mo-EW	1991
EWT4	1991

A8. Safety Considerations

A8.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a protective head covering should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles, or the equivalent, to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flames. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection.

Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load; disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.)

The following sources provide more detailed information on personal protection:

(a) American National Standards Institute. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York: American National Standards Institute.[5]

(b) ———. ANSI/ASC Z41.1, *Safety-Toe Footwear*. New York: American National Standards Institute.

(c) American Welding Society. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, FL: American Welding Society.[6]

(d) OSHA. *Code of Federal Regulations*, Title 29 — Labor, Chapter XVII, Part 1910. Washington, DC: U.S. Government Printing Office.[7]

A8.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead; it is used only to complete the welding circuit. A separate connection is required to ground the workpiece.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform.

Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the injured area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance, if necessary.

Recognized safety standards should be followed, such as ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and NFPA No. 70, *National Electrical Code*.[8]

A8.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management, welders, and other personnel should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the electrode and base metal, welding process, current level, arc length, and other factors.

The possible effects of overexposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air and cause asphyxiation. One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from your breathing zone and the general area.

In some cases, natural air movement will provide enough ventilation. Where ventilation may be questionable, air

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[5] ANSI standards may be obtained from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

[6] AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[7] OSHA standards may be obtained from the U.S. Government Printing Office, Washington, DC 20402.

[8] NFPA documents are available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

sampling should be used to determine if corrective measures should be applied.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(a) The permissible exposure limits required by OSHA can be found in *Code of Federal Regulations*, Title 29 — Labor, Chapter XVII Part 1910.

(b) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH).[9]

(c) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*.

A8.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as x-rays), or nonionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

A8.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A8.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base-metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc welding when used properly), laser beam welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(a) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(b) Exposed skin should be protected with adequate gloves and clothing as specified ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

(c) Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. *(Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.)*

(d) Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

(e) Safety glasses with UV-protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.

A8.4.3 Ionizing radiation information sources include the following:

(a) American Welding Society F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*.

(b) Manufacturer's product information literature.

A8.4.4 Nonionizing radiation information sources include the following:

(a) American National Standards Institute. ANSI/ASC Z136.1, *Safe Use of Lasers*. New York, NY: American National Standards Institute.

(b) ———. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York, NY: American National Standards Institute.

(c) American Welding Society. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, FL: American Welding Society.

(d) Hinrichs, J. F. "Project committee on radiation — summary report." *Welding Journal* 57(1):62-s to 65-s, 1978.

(e) Marshall, W. J., Sliney, D. H., et al. "Optical radiation levels produced by air carbon arc cutting processes." *Welding Journal* 59(3):43-s to 46-s, 1980.

(f) Moss, C. E., and Murray, W. E. "Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting." *Welding Journal* 58(9):37-s to 46-s, 1979.

(g) Moss, C. E. "Optical radiation transmission levels through transparent welding curtains." *Welding Journal* 58(3):69-s to 75-s, 1979.

(h) National Technical Information Service. Nonionizing radiation protection special study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service.[10]

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[9] ACGIH documents are available from the American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1634.

[10] National Technical Information documents are available from the National Technical Information Service, Springfield, VA 22161.

(i) National Technical Information Service. Nonionizing radiation protection special study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service.

SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL ELECTRODES FOR ELECTROGAS WELDING

SFA-5.26/SFA-5.26M

(Identical with AWS Specification A5.26/A5.26M-97 (R2003). In case of dispute, the original AWS text applies.)

SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL ELECTRODES FOR ELECTROGAS WELDING

SFA-5.26/SFA-5.26M

(Identical with AWS Specification A5.26/A5.26M-97 (R2003). In case of dispute, the original AWS text applies.)

1. Scope

This specification prescribes requirements for the classification of carbon and low-alloy steel electrodes for electrogas welding. It covers solid and composite (flux cored and metal cored) electrodes used with external gas shielding, and composite (self-shielded flux cored) electrodes used without external shielding.

PART A — GENERAL REQUIREMENTS

2. Classification

2.1 The solid electrodes covered by this specification are classified according to the chemical composition of the electrode, as specified in Table 1 and the mechanical properties of the weld metal as specified in Tables 2 and 3.

2.2 The composite (flux cored and metal cored) electrodes covered by this specification are classified according to the need for external shielding gas (Table 4) and the chemical composition and mechanical properties of the weld metal, as specified in Tables 2, 3, and 4.

2.3 Electrodes classified under one classification shall not be classified under any other classification in this specification, except as specifically permitted by Note (a) to Table 3.

2.4 The electrodes classified under this specification are intended for electrogas welding, but that is not to prohibit their use with any other process for which they are found suitable.

3. Acceptance

Acceptance[1] of the electrodes shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*[2]

4. Certification

By affixing the AWS Specification and Classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[3]

5. Units of Measure and Rounding-Off Procedure

5.1 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 A5.26 uses U.S. Customary units. The specification A5.26M uses SI units. The latter are shown in appropriate columns in tables or within brackets [] when used in the text.

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] for tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.[4]

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

6.1 The tests required for each classification are specified in Table 5. The purpose of these tests is to determine

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[1] See Section A3 (in the Annex) for further information concerning acceptance, testing of the material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

[2] AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] See Section A4 (in the Annex) for further information concerning certification and the testing called for to meet this requirement.

[4] ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES

AWS Classification[c]	UNS Number[d]	Weight, Percent[a,b]											Other Elements, Total
		C	Mn	S	P	Si	Ni	Mo	Cu[e]	Ti	Zr	Al	
EGXXS-1	K01313	0.07–0.19	0.90–1.40	0.035	0.025	0.30–0.50	—	—	0.35	—	—	—	0.50
EGXXS-2	K10726	0.07	0.90–1.40	0.035	0.025	0.40–0.70	—	—	0.35	0.05–0.15	0.02–0.12	0.05–0.15	0.50
EGXXS-3	K11022	0.06–0.15	0.90–1.40	0.035	0.025	0.45–0.75	—	—	0.35	—	—	—	0.50
EGXXS-5	K11357	0.07–0.19	0.90–1.40	0.035	0.025	0.30–0.60	—	—	0.35	—	—	0.50–0.90	0.50
EGXXS-6	K11140	0.06–0.15	1.40–1.85	0.035	0.025	0.80–1.15	—	—	0.35	—	—	—	0.50
EGXXS-D2	K10945	0.07–0.12	1.60–2.10	0.035	0.025	0.50–0.80	0.15	0.40–0.60	0.35	—	—	—	0.50
EGXXS-G	—	Not Specified[f]											

NOTES:

a. The filler metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

b. Single values are maximums.

c. The letters "XX" as used in the AWS classification column of this table refer respectively to the designator for tensile strength of the weld metals (see Tables 2 and 2M) and the designator for impact strength (see Tables 3 and 3M).

d. SAE/ASTM Unified Numbering System for Metals and Alloys.

e. The copper limit includes copper that may be applied as a coating on the electrode.

f. Composition shall be reported; the requirements are those agreed to by the purchaser and the supplier.

TABLE 2
A5.26 TENSION TEST REQUIREMENTS (AS WELDED)

AWS A5.26 Classification[a]	Tensile Strength psi	Yield[b] Strength (Min.) psi	Elongation[b] Percent, Min.
EG6ZX-X	60 000		
EG60X-X	to	36 000	24
EG62X-X	80 000		
EG7ZX-X	70 000		
EG70X-X	to	50 000	22
EG72X-X	95 000		
EG8ZX-X	80 000		
EG80X-X	to	60 000	20
EG82X-X	100 000		

NOTES:

a. The letters "X-X" as they are used in the AWS A5.26 Classification column in this table refer respectively to "S" or "T" (whether the electrode is solid or composite), replacing the first "X" and "1, 2, 3, 5, 6, D2, Ni1, NM2, W, or G" (the designation for chemical composition and shielding gas requirements for composite electrodes only) replacing the second "X."

b. Yield strength at 0.2 percent offset and elongation in 2 in. gage length.

TABLE 3
A5.26 IMPACT TEST REQUIREMENTS[a] (AS WELDED)

AWS A5.26 Classification[a]	Average Impact Strength[b], min. (ft·lbf)
EG6ZX-X	
EG7ZX-X	Not specified
EG8ZX-X	
EG60X-X	
EG70X-X	20 @ 0 °F
EG80X-X	
EG62X-X	
EG72X-X	20 @ −20°F
EG82X-X	

NOTES:

a. An electrode combination that meets the impact requirements at a given temperature also meets the requirement at all higher temperatures in this table. In this manner, EGX2X-X may also be classified as EGX0X-X and EGXZX-X and EGX0X-X may be classified as EGXZX-X.

b. Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 20 ft·lb and one of the three remaining values may be lower than 20 ft·lb but not lower than 15 ft·lb. The average of the three shall not be less than the 20 ft·lb specified.

TABLE 2M
A5.26M TENSION TEST REQUIREMENTS (AS WELDED)

AWS A5.26 Classification[a]	Tensile Strength, MPa	Yield Strength, min.[b] MPa	Elongation, min.[b] percent
EG43ZX-X	430		
EG432X-X	to	250	24
EG433X-X	550		
EG48ZX-X	480		
EG482X-X	to	350	22
EG483X-X	650		
EG55ZX-X	550		
EG552X-X	to	410	20
EG553X-X	700		

NOTES:

a. The letters X-X as they are used in the AWS A5.26M Classification column in this table refer respectively to "S" or "T" (whether the electrode is solid or composite) replacing the first "X" and "1, 2, 3, 5, 6, D2, Ni1, NM2, W or G" (designation for chemical composition and shielding gas requirements) replacing the second "X."

b. Yield strength at 0.2 percent offset and elongation in 50 mm gage length.

TABLE 3M
A5.26M IMPACT TEST REQUIREMENTS (AS WELDED)[a]

AWS A5.26M Classification[a]	Average Impact Strength, min.[b] (J)
EG43ZX-X	
EG48ZX-X	Not Specified
EG55ZX-X	
EG432X-X	
EG482X-X	27 @ −20°C
EG552X-X	
EG433X-X	
EG483X-X	27 @ −30°C
EG553X-X	

NOTES:

a. An electrode combination that meets the impact requirements at a given temperature also meets the requirement at all higher temperatures in this table. In this manner, EGXX3X-X may also be classified as EGXX2X-X and EGXXZX-X and EGXX2X-X may be classified as EGXXZX-X.

b. Both the highest and the lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 27 J and one of the three remaining values may be lower than 27 J, but not lower than 20 J. The average of the three shall not be less than 27 J specified.

TABLE 4
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL FROM COMPOSITE FLUX CORED AND METAL CORED ELECTRODES

AWS Classification[c]		UNS Number[d]	Shielding Gas	Weight, Percent[a,b]										Other Elements, Total
A5.26	A5.26M			C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	
EG6XT-1	EG43XT-1	W06301	None	(e)	1.7	0.03	0.03	0.50	0.30	0.20	0.35	0.35	0.08	0.50
EG7XT-1	EG48XT-1	W07301	None	(e)	1.7	0.03	0.03	0.50	0.30	0.20	0.35	0.35	0.08	0.50
EG8XT-1	EG55XT-1	—	None	(e)	1.8	0.03	0.03	0.90	0.30	0.20	0.25–0.65	0.35	0.08	0.50
EG6XT-2	EG43XT-2	W06302	CO$_2$	(e)	2.0	0.03	0.03	0.90	0.30	0.20	0.35	0.35	0.08	0.50
EG7XT-2	EG48XT-2	W07302	CO$_2$	(e)	2.0	0.03	0.03	0.90	0.30	0.20	0.35	0.35	0.08	0.50
EGXXT-Ni1	EGXXXT-Ni1	W21033	CO$_2$	0.10	1.0–1.8	0.03	0.03	0.50	0.70–1.10	—	0.30	0.35	—	0.50
EGXXT-NM1	EGXXXT-NM1	W22334	Ar/CO$_2$ or CO$_2$	0.12	1.0–2.0	0.02	0.03	0.15–0.50	1.5–2.0	0.20	0.40–0.65	0.35	0.05	0.50
EGXXT-NM2	EGXXXT-NM2	W22333	CO$_2$	0.12	1.1–2.1	0.03	0.03	0.20–0.60	1.1–2.0	0.20	0.10–0.35	0.35	0.05	0.50
EGXXT-W	EGXXXT-W	W20131	CO$_2$	0.12	0.50–1.3	0.03	0.03	0.30–0.80	0.40–0.80	0.45–0.70	—	0.30–0.75	—	0.50
EGXXT-G	EGXXXT-G	—							Not Specified[f]					

NOTES:

a. The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed the limit specified for "Other Elements, Total" in the last column of this table.

b. Single values are maximums.

c. The letters "XX" or "XXX" as used in the AWS classification column in this table refer respectively to the designator(s) for tensile strength of the weld metal (see Tables 2 and 2M) and the designator for impact strength (see Tables 3 and 3M). The single letter "X" as used in the AWS classification column refers to the designator for impact strength (see Tables 3 and 3M).

d. SAE/ASTM Unified Numbering System for Metals and Alloys.

e. Composition range of carbon not specified for these classifications, but the amount shall be determined and reported.

f. Composition shall be reported; the requirements are those agreed to by the purchaser and supplier.

the chemical composition, the mechanical properties, and soundness of the weld. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 8 through 12.

7. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or from one or two new test assemblies. 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 specimens 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 prescribed procedures. In this case the requirement for doubling of the number of test specimens does not apply.

8. Weld Test Assemblies

8.1 At least one weld test assembly is required, and two may be required (depending on the electrode — solid as opposed to composite — and the manner in which the sample for chemical analysis is taken), as specified in Table 5. They are the following:

(a) The groove weld in Fig. 1 for mechanical properties and soundness of the weld metal for both composite and solid electrodes

(b) The weld ingot in Fig. 2 for chemical analysis of the weld metal from composite electrodes

For composite electrodes, the sample for chemical analysis may be taken from the groove weld in Fig. 1 or from the reduced section of the fractured tension test specimen, thereby avoiding the need to make the weld ingot. In case of dispute, the weld ingot shall be the referee method for chemical analysis.

TABLE 5
REQUIRED TESTS

AWS Classification*		Chemical Analysis		Radiographic Test	Tension Test	Impact Test
A5.26	A5.26M	Electrode	Weld Metal			
Solid Electrodes						
EG6ZS-X	EG43ZS-X	Required	Not Required	Required	Required	Not Required
EG60S-X	EG432S-X	Required	Not Required	Required	Required	Required
EG62S-X	EG433S-X	Required	Not Required	Required	Required	Required
EG7ZS-X	EG48ZS-X	Required	Not Required	Required	Required	Not Required
EG70S-X	EG482S-X	Required	Not Required	Required	Required	Required
EG72S-X	EG483S-X	Required	Not Required	Required	Required	Required
EG8ZS-X	EG55ZS-X	Required	Not Required	Required	Required	Not Required
EG80S-X	EG552S-X	Required	Not Required	Required	Required	Required
EG82S-X	EG553S-X	Required	Not Required	Required	Required	Required
Composite Flux Cored and Metal Cored Electrodes						
EG6ZT-X	EG43ZT-X	Not Required	Required	Required	Required	Not Required
EG60T-X	EG432T-X	Not Required	Required	Required	Required	Required
EG62T-X	EG433T-X	Not Required	Required	Required	Required	Required
EG7ZT-X	EG48ZT-X	Not Required	Required	Required	Required	Not Required
EG70T-X	EG482T-X	Not Required	Required	Required	Required	Required
EG72T-X	EG483T-X	Not Required	Required	Required	Required	Required
EG8ZT-X	EG55ZT-X	Not Required	Required	Required	Required	Not Required
EG80T-X	EG552T-X	Not Required	Required	Required	Required	Required
EG82T-X	EG553T-X	Not Required	Required	Required	Required	Required

NOTE:

* The "-X" as it is used in the AWS Classification column of this table refers to "1, 2, 3, 5, 6, D2, Ni1, NM1, NM2, W, and G" (the designation for shielding gas and chemical composition requirements.)

8.2 Preparation of each weld test assembly shall be as prescribed in 8.3 and 8.4. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the appropriate ASTM specification shown there, or an equivalent specification. Testing of the assemblies shall be as prescribed in 9.2, 9.3, and Sections 10 through 12.

8.3 Groove Weld for Mechanical Properties and Soundness. A test assembly shall be prepared and welded as specified in Fig. 1 using base metal of the appropriate type specified in Table 6. Testing of this assembly shall be as specified in Sections 10 through 12. The assembly shall be tested in the as-welded condition.

8.4 Weld Ingot. An ingot shall be prepared as specified in Fig. 2 except when the alternative in 8.1 (taking the sample from the weld metal in the groove weld or from the tension test specimen) is selected.

9. Chemical Analysis

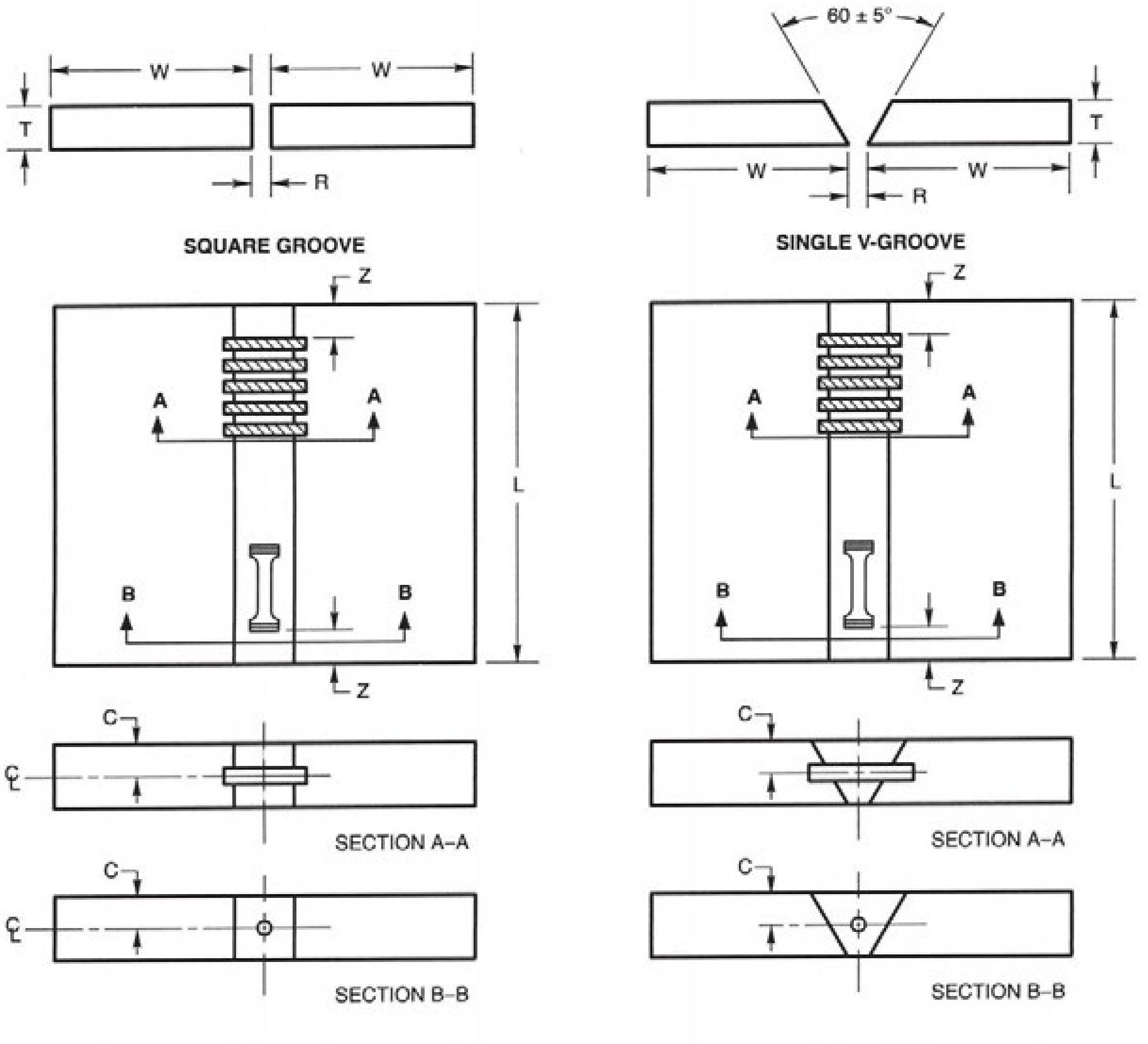
9.1 For *solid electrodes, a sample of the electrode shall be prepared for chemical analysis. Solid electrodes, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the electrode is analyzed for elements other than those in the coating, the coating must be removed if its presence affects the results of the analysis for other elements.*

9.2 *Composite electrodes* shall be analyzed in the form of weld metal, not electrode. The sample for analysis shall be taken from weld metal obtained with the electrode (and the shielding gas with which it is classified, for those classifications for which an external shielding gas is required). The sample shall come from an ingot (Fig. 2), the reduced section of the fractured tension test specimen (Fig. 3), or the groove weld in Fig. 1.

When the ingot is used, the top surface of the ingot (described in 8.4 and shown in Fig. 2) shall be removed and discarded and a sample for analysis shall be obtained from the underlying metal at a location at least 2 in. [50 mm] from both the start and crater ends of the ingot by any appropriate mechanical means. The sample shall be free of slag.

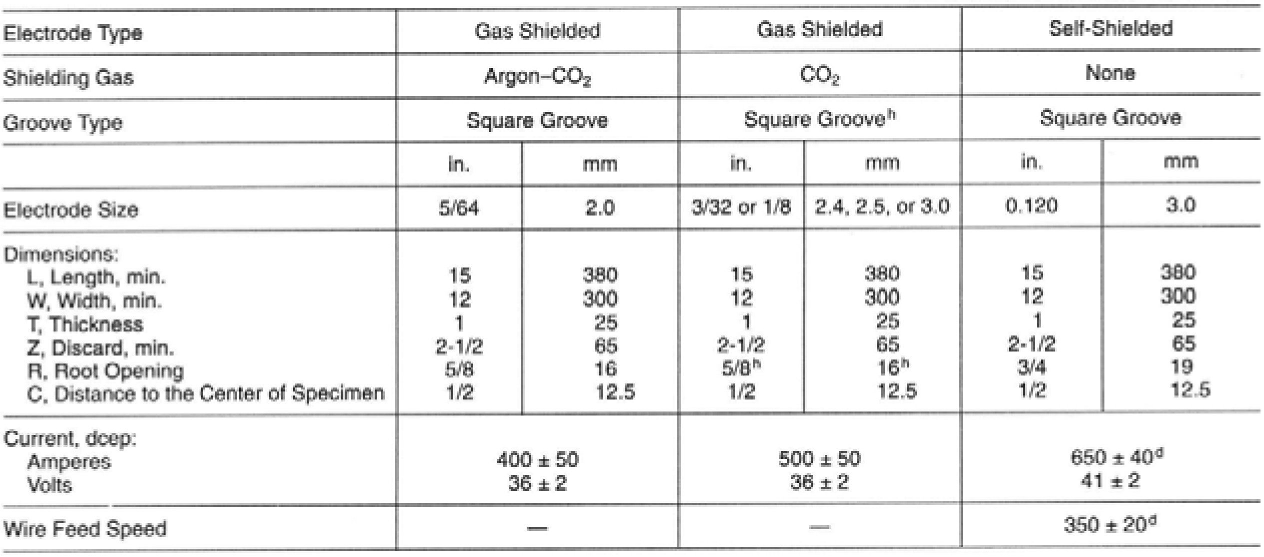
When the reduced section of the fractured tension test specimen or a sample from the groove weld in Fig. 1 is used, the sample shall be prepared by any suitable mechanical means. The sample from the groove weld shall be taken at least 2 in. [50 mm] from both the start and crater ends of the weld.

FIG. 1 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS



(SEE NOTES ON NEXT PAGE)

FIG. 1 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS (CONT'D)



Electrode Type	Gas Shielded		Gas Shielded		Self-Shielded	
Shielding Gas	Argon–CO_2		CO_2		None	
Groove Type	Square Groove		Square Groove[h]		Square Groove	
	in.	mm	in.	mm	in.	mm
Electrode Size	5/64	2.0	3/32 or 1/8	2.4, 2.5, or 3.0	0.120	3.0
Dimensions:						
L, Length, min.	15	380	15	380	15	380
W, Width, min.	12	300	12	300	12	300
T, Thickness	1	25	1	25	1	25
Z, Discard, min.	2-1/2	65	2-1/2	65	2-1/2	65
R, Root Opening	5/8	16	5/8[h]	16[h]	3/4	19
C, Distance to the Center of Specimen	1/2	12.5	1/2	12.5	1/2	12.5
Current, dcep:						
Amperes	400 ± 50		500 ± 50		650 ± 40[d]	
Volts	36 ± 2		36 ± 2		41 ± 2	
Wire Feed Speed	—		—		350 ± 20[d]	

GENERAL NOTES:

(a) Weld test assembly shall be welded in the vertical position with upward progression.

(b) Fixturing of the test assembly shall be based on the manufacturer's recommendations. Water-cooled copper shoes shall be used except when using consumable guide tubes. For welding with consumable guide tubes, follow the manufacturer's recommendations regarding the use of water-cooled shoes. When using water cooling, the outgoing water temperature shall not exceed 180°F [80°C] near the exit point.

(c) If the manufacturer does not make the electrode size specified, the nearest size may be used. For sizes other than that shown, the manufacturer's recommended procedure shall be used.

(d) Either wire feed speed or current shall be used as a control setting based on the design of the equipment.

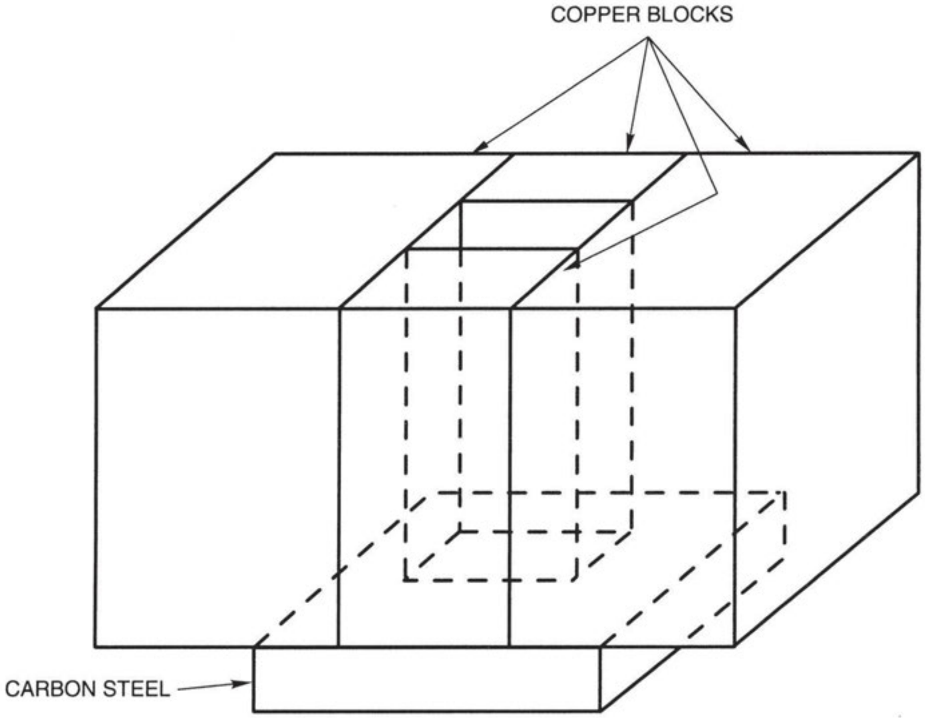
(e) Welding shall begin with the assembly at room temperature, 65°F [18°C] minimum. No external heat shall be applied during welding. Starting and run-off tabs are not required if the test assembly without weld tabs is sufficient to provide the required test specimens.

(f) The weld shall be completed in one pass.

(g) A postweld heat treatment shall not be applied to the test assembly.

(h) Single V-groove joint is optional for CO_2 gas shielded classifications only. In case of dispute, the square groove assembly is the referee method. Root opening, R, for single-V groove is $^5/_{32}$ in. [4 mm].

FIG. 2 WELD INGOT



GENERAL NOTES:

1. Weld ingot shall be deposited by arc welding in a water-cooled copper mold using welding conditions shown in Figure 1.
2. The ingot shall be of any convenient shape that provides weld metal with approximately 1 in.^{2} [625 mm^2] of cross-section.
3. The ingot shall be started on a carbon steel base of sufficient size as to avoid complete fusion, and the copper mold shall be of a size sufficient to avoid contamination of the ingot by molten copper.
4. The sample for chemical analysis shall be taken at least 2 in. [50 mm] above the bottom of the ingot, and at least 2 in. [50 mm] below the crater.

TABLE 6
BASE METALS FOR TEST ASSEMBLIES

AWS Classification		
A5.26	A5.26M	Base Metal
EG6XT-X EG6XS-X	EG43XT-X EG43XS-X	ASTM A36
EG7XT-X EG7XS-X	EF48XT-X EG48XS-X	ASTM A242 Type 2, or A572 Grade 50
EG8XT-X EG8XS-X	EG55XT-X EG55XS-X	ASTM A537 Class 2, A572 Grade 60 or 65, or A633 Grade E
The following classifications are exceptions to the above general requirements:		
EGXXT-W	EGXXXT-W	ASTM A588

9.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM Standard Method E350, *Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron.*

9.4 The results of the analysis shall meet the requirements of Table 1 for solid electrodes and Table 4 for composite electrodes, for the classification of electrode under test.

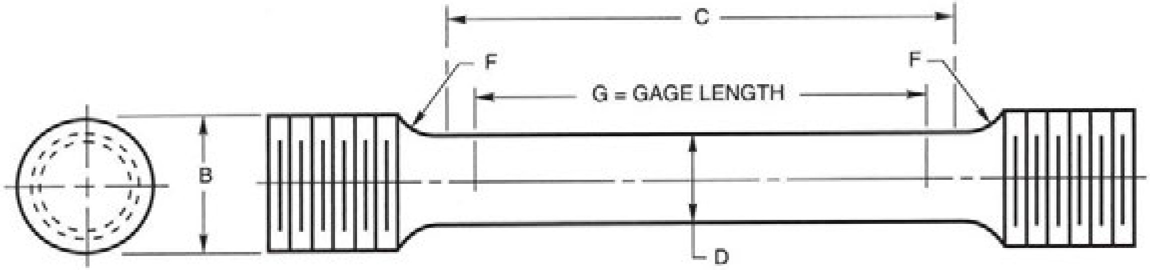
10. Radiographic Test

10.1 The groove weld described in 8.3 and shown in Fig. 1 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, both surfaces of the weld may be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding $^{3}/_{32}$ in. [2.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

10.2 The weld shall be radiographed in accordance with ASTM E142, *Standard Method for Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows the following:

FIG. 3 TENSION TEST SPECIMEN



Dimensions of Specimen, in.					Approximate Area, in.^{2}
D	G	C	B	F, min.	
0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	0.375	0.2
Dimensions of Specimen, mm					**Approximate Area, mm^2**
D	G	C	B	F, min.	
12.5 ± 0.2	50.0 ± 0.1	55	20	10	123

GENERAL NOTES:

1. Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
2. The diameter of the specimen within the gage length shall be slightly smaller at the center controlling dimension than at the ends. The difference shall not exceed one percent of the diameter.
3. When the extensometer is required to determine yield strength, dimension C may be modified. However, the percent of the elongation shall be based on dimension G.
4. The surface finish within the C dimension shall be no rougher than 63 μin. [1.6 μm].

(a) No cracks, no incomplete fusion, and

(b) No rounded indications in excess of those permitted by the radiographic standards in Fig. 4.

In evaluating the radiograph, 2-½ in. [65 mm] of the weld on each end of the test assembly shall be disregarded.

10.3.1 A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular, elliptical, conical, 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.

10.3.2 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 greater than the largest indications permitted in the radiographic standards do not meet the requirements of this specification.

11. Tension Test

11.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in 8.3 and shown in Fig. 1. The dimensions of the specimen shall be as shown in Fig. 3.

11.2 The specimen shall be tested in the manner described in the tension test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds.*

11.3 The results of the tension test shall meet the requirements specified in Table 2, or Table 2M, as applicable.

12. Impact Test

12.1 Five Charpy V-notch impact test specimens (Fig. 5) shall be machined from the test assembly shown in Fig. 1, for those classifications for which impact testing is required in Table 5. The five specimens shall be tested in accordance with the fracture toughness test section of ANSI/AWS B4.0. The test temperature and the test results shall be those specified in Table 3 or Table 3M, as applicable, for the classification under test.

12.2 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal, or exceed, the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft·lbf [20 J], and the average of the three shall be not less than the required 20 ft·lbf [27 J] energy level.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

13. Method of Manufacture

The electrodes classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification.

14. Standard Sizes

Standard sizes for electrodes in the different package forms (coils with support, coils without support, spools and drums) are shown in Table 7.

15. Finish and Uniformity

15.1 All electrodes shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams or laps (exclusive of the longitudinal joint in composite electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

15.2 Each continuous length of electrode shall be from a single lot of material, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic equipment.

15.3 The core ingredients in composite electrodes 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.

15.4 A suitable protective coating may be applied to any of the electrodes in this specification.

16. Standard Package Forms

16.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 8, and Figs. 6A and 6B provide dimensions for standard spools. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.

16.2 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

16.3 Spools shall be designed and constructed to prevent distortion of the electrode during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

17. Winding Requirements

17.1 Electrodes shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the electrode free to unwind without restriction. The outside end of the electrode (the end with which welding is to begin) shall be identified so it can be located readily, and shall be fastened to avoid unwinding.

17.2 The cast and helix of electrode in coils, spools and drums shall be such that the electrode will feed in an uninterrupted manner on automatic equipment.

18. Electrode Identification

18.1 The product information and the precautionary information required in Section 20, Marking of Packages, shall also appear on each coil, spool and drum.

18.2 Coils without support shall have a tag containing this information, securely attached to the electrode at the inside end of the coil.

18.3 Coils with support shall have the information securely affixed in a prominent location on the support.

18.4 Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

18.5 Drums shall have the information securely affixed in a prominent location on the side of the drum.

19. Packaging

Electrodes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

20. Marking of Packages

20.1 The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package.

(a) AWS specification and classification (year of issue may be excluded)

(b) Supplier's name and trade designation

(c) Size and net weight

(d) Lot, control, or heat number

20.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of electrodes including individual unit packages enclosed within a larger package.

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES can be hazardous to your health.

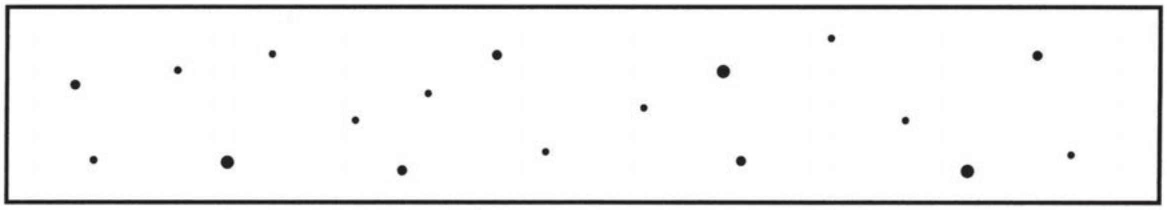
ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can KILL.

- Read and understand the manufacturer's instructions, the Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes,* published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and OSHA Safety and Health Standards, *29 CFR 1910*, available from the U.S. Government Printing Office, Washington, DC 20402.

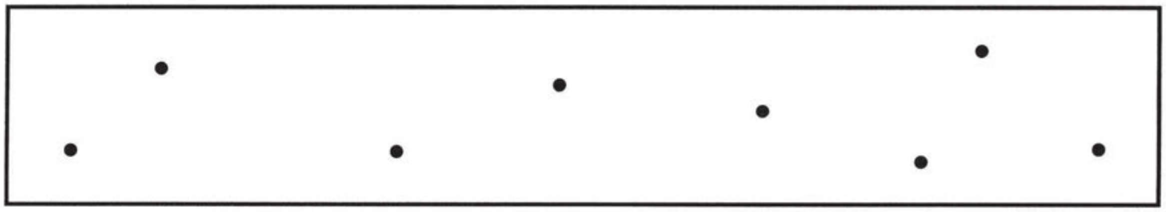
DO NOT REMOVE THIS INFORMATION

FIG. 4 RADIOGRAPHIC ACCEPTANCE STANDARDS



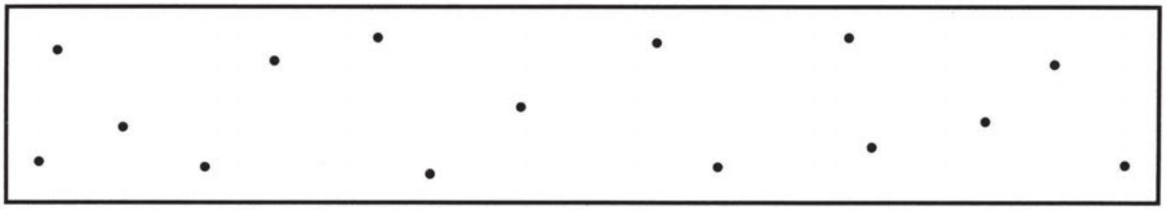
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in. TO 1/16 in. [0.4 TO 1.6 mm] 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 TO 1/16 in. [1.2 TO 1.6 mm] DIAMETER AND/OR LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 TO 3/64 in. [0.8 TO 1.2 mm] DIAMETER AND/OR LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 TO 1/32 in. [0.4 TO 0.8 mm] DIAMETER AND/OR LENGTH INDICATIONS = 10.



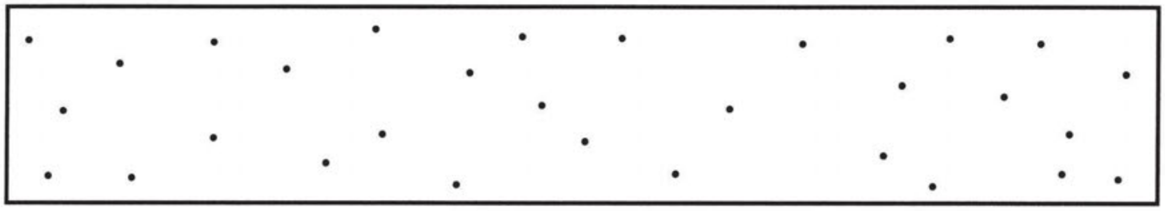
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 TO 1/16 in. [1.2 TO 1.6 mm] DIAMETER AND/OR LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 TO 3/64 in. [0.8 TO 1.2 mm] DIAMETER AND/OR LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. [150 mm] OF WELD = 15.



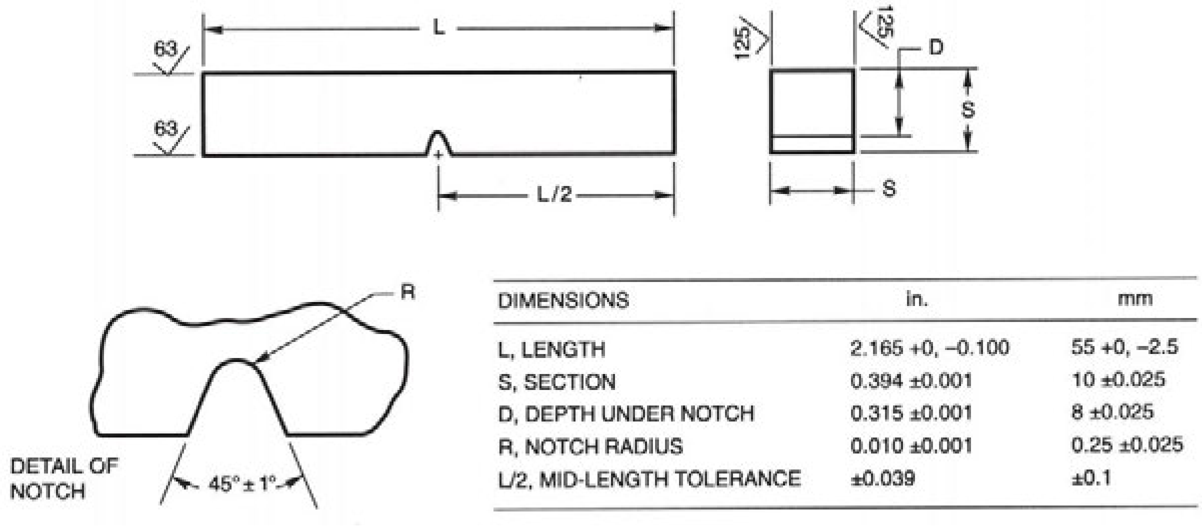
(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 TO 1/32 in. [0.4 TO 0.8 mm] DIAMETER AND/OR LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. [150 mm] OF WELD = 30.

GENERAL NOTES:

1. In using these standards the chart which is most representative of the size of the porosity and/or inclusions present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications smaller than $^1/_{64}$ in. [0.4 mm] shall be disregarded.

FIG. 5 CHARPY V-NOTCH IMPACT TEST SPECIMEN



DIMENSIONS	in.	mm
L, LENGTH	2.165 +0, −0.100	55 +0, −2.5
S, SECTION	0.394 ±0.001	10 ±0.025
D, DEPTH UNDER NOTCH	0.315 ±0.001	8 ±0.025
R, NOTCH RADIUS	0.010 ±0.001	0.25 ±0.025
L/2, MID-LENGTH TOLERANCE	±0.039	±0.1

NOTES:

1. The notched surface and the surface to be struck shall be parallel within 0.002 in. [0.05 mm] and have at least 63 μin. [1.6 μm] finish. The other two surfaces shall be square with the notched or struck surface within ±10 minutes of the degree and have at least 125 μin. [3.2 μm] finish.
2. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.
3. The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at minimum 50 times magnification on either a shadowgraph or a metallograph.
4. The correct location of the notch shall be verified by etching before or after machining.
5. If a specimen does not break upon being struck, the value for energy absorbed shall be reported as the capacity of the impact testing machine followed by a plus sign (+).

TABLE 7
STANDARD SIZES*

	A5.26			A5.26M		
		Tolerance			Tolerance	
Standard Package Forms	Diameter in.	Solid ±in.	Cored ±in.	Diameter mm	Solid ±mm	Cored ±mm
Coils with support	$\frac{1}{16}$	0.062	0.002	1.6	0.05	0.05
Coils without support	$\frac{5}{64}$	0.078	0.003	2.0	0.05	0.08
Drums, and Spools	$\frac{3}{32}$	0.094	0.003	2.4	0.05	0.08
				2.5	0.05	0.08
		0.120	0.003	3.0	0.08	0.08
	$\frac{1}{8}$	0.125	0.003	3.2	0.08	0.08
	$\frac{5}{32}$	0.156	0.003	4.0	0.08	0.08

* Dimensions, tolerances, and package forms other than those shown shall be as agreed between purchaser and supplier.

TABLE 8
STANDARD PACKAGE DIMENSIONS AND WEIGHTS[a]

Type of Package	Package Size OD[d]		Net Weight of Electrode[b]	
	in.	mm	lb	kg
Coils without support	Not specified[c]		Not specified[c]	
Spools	12	300	25, 30, and 35	10 and 15
	14	360	50 and 60	20 and 25
	22	560	250	100
	24	610	300	150
	30	760	600, 750, and 1000	250, 350, and 450
Drums	$15\frac{1}{2}$	400	Not specified[c]	
	20	500	Not specified[c]	
	23	600	300 and 600	150 and 300

Coils with Support — Standard Dimensions and Weight[a]

			Coil Dimensions			
	Coil Net Weight[b]		Inside Dia. of Lining		Width of Wound Electrodes	
Electrode Size	lb	kg	in.	mm	in., max.	mm, max.
All	60 and 75	20, 25 and 30	$12 \pm \frac{1}{8}$	300 +3, −10	$4\frac{5}{8}$	120
	150 and 200	75 and 100	$23\frac{1}{2} \pm \frac{1}{4}$	600 +3, −10	5	125

NOTES:

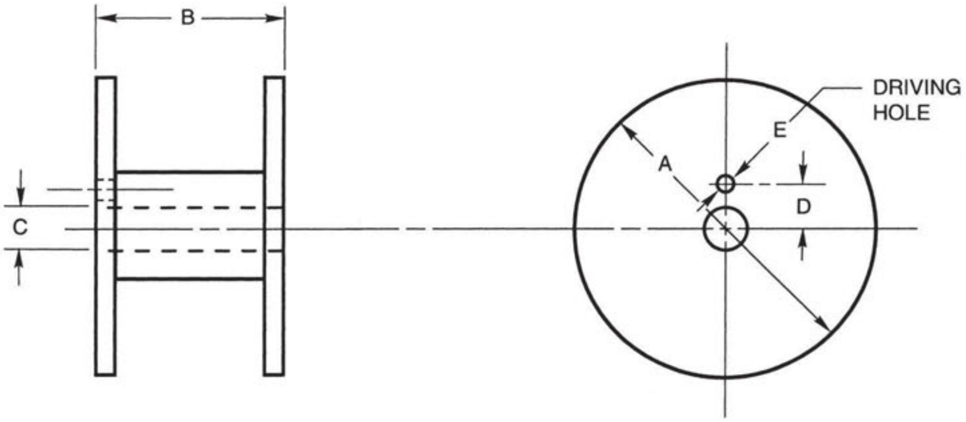
a. Sizes and net weights other than those specified shall be as agreed between supplier and purchaser.

b. Tolerance on net weight shall be ± 10 percent.

c. As agreed by supplier and purchaser.

d. OD = outside diameter.

FIG. 6A STANDARD DIMENSIONS OF 12 AND 14 IN. [300 AND 350 MM] SPOOLS



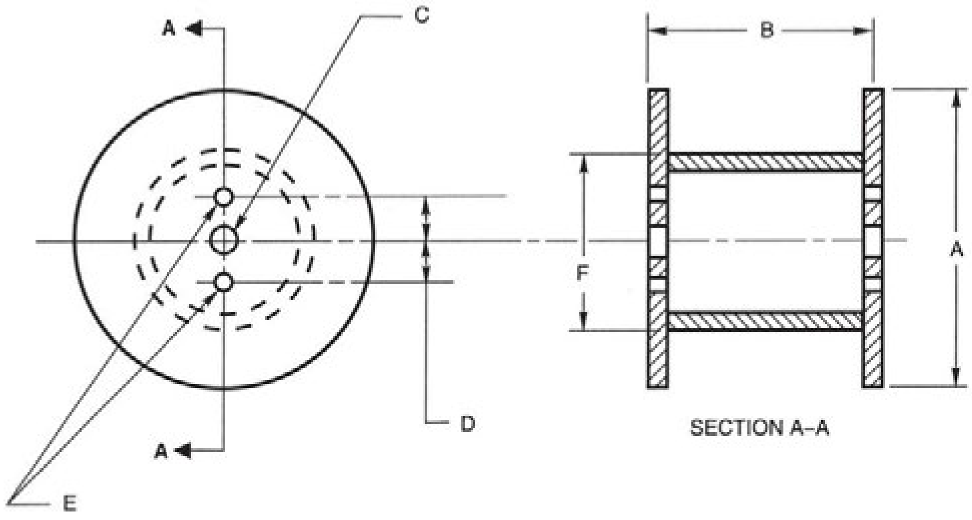
DIMENSIONS

		12 in. [300 mm] Spools		14 in. [350 mm] Spools	
		in.	mm	in.	mm
A	Diameter, max.	12	305	14	355
B	Width	4.0 ± 0.06	103 –3, +0	4.0 ± 0.6	103 –3, +0
C	Diameter	2.03 –0, +0.06	50.5 –0, +2.5	2.03 –0, +0.06	50.5 –0, +2.5
D	Distance Between Axes	1.75 ± 0.02	44.5 ± 0.5	1.75 ± 0.02	44.5 ± 0.5
E	Diameter (Note 3)	0.44 + 0, –0.06	10 –0, +1	0.44 +0, –0.06	10 –0, +1

GENERAL NOTES:

1. Outside diameter of barrel shall be such as to permit feeding of the filler metals.
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.

FIG. 6B STANDARD DIMENSIONS OF 22, 24, AND 30 IN. [560, 610, AND 760 MM] SPOOLS (REELS)



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.	22	560	24	610	30	760
B	Width, max.	12	305	13.5	345	13.5	345
C	Diameter	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, Ctr. to Ctr.	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)	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

GENERAL NOTES:

1. Outside diameter of barrel, dimension F, shall be such as to permit feeding of the filler metals.
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. Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

Annex
Guide to AWS Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding

(This Annex is not a part of AWS A5.26/A5.26M-97 (R2003), *Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*, but is included for information purposes only.)

A1. Introduction

The purpose of this annex is to correlate the electrode classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the base metals 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 (see Fig. A1). The letters "EG" at the beginning of each classification designation shows that the electrode is intended for use with the electrogas welding process.

In the case of the designations for A5.26, this is followed by a single digit (6, 7, or 8) representing the minimum tensile strength of the weld metal in units of 10 000 psi. For the designations of A5.26M, the "EG" is followed by two digits (43, 48, or 55) representing the minimum tensile strength in units of 10 MPa (see Table 2M).

The digit that follows is a number or the letter "Z." The number designates the temperature at which (and/or above which) the weld metal meets or exceeds the required 20 ft·lbf [27 J] Charpy V-notch impact strength. The letter "Z" indicates that no impact strength requirement is specified.

The next letter, either S or T, indicates that the electrode is solid (S) or composite (flux cored or metal cored) (T). The designator (digits or letters) following the hyphen in the classification indicates the chemical composition (of weld metal for the composite electrodes and of the electrode itself for solid electrodes) and the type or absence of shielding gas required in the case of composite electrodes only.

A2.2 "G" Classification

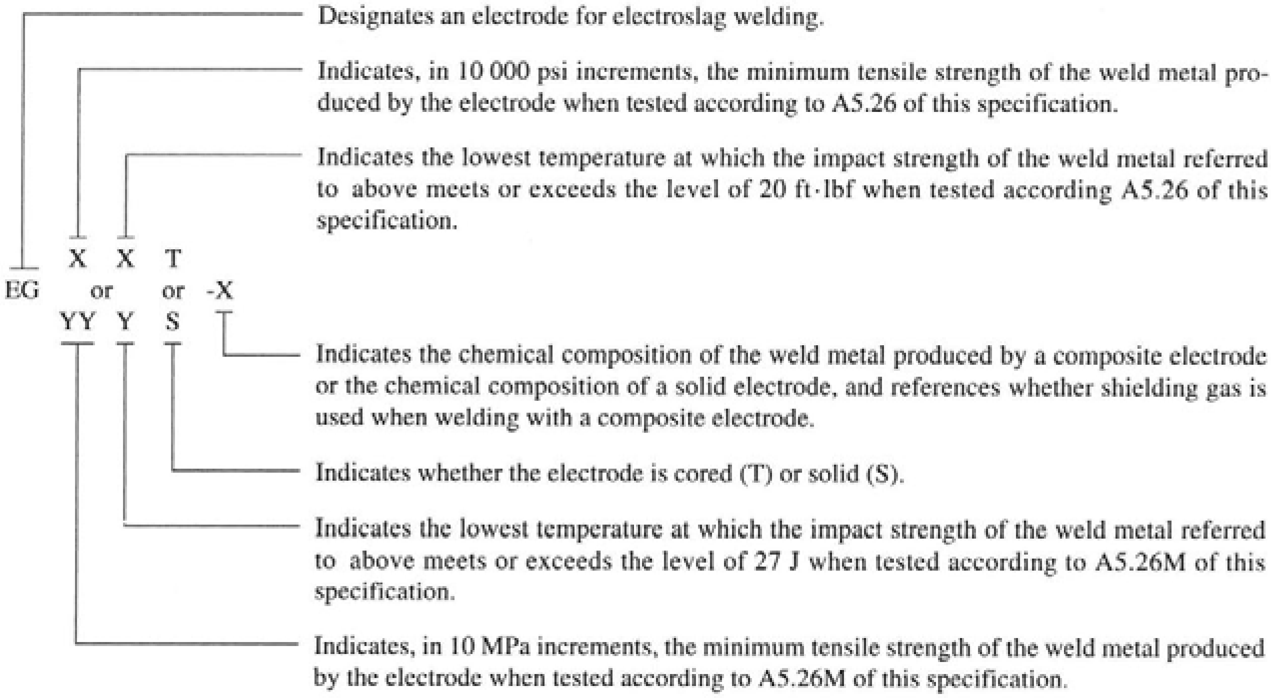
A2.2.1 This specification includes filler metals classified as EGXXT-G or EGXXS-G. The last "G" indicates that the filler metal is of a general classification. It is "general" because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing this classification is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal — one that otherwise would have to await a revision of the specification — to be classified immediately, under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some certain respect (chemical composition, again, for example).

A2.2.2 Request for Filler Metal Classification

(a) When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

(b) A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the Committee on Filler Metals or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate to satisfy the need. The request needs to state the variables and their limits for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

FIG. A1 CLASSIFICATION SYSTEM



(c) The request should be sent to the Secretary of the Committee on Filler Metals at AWS headquarters. Upon receipt of the request, the Secretary will:

(1) Assign an identifying number to the request. This number will include the date the request was received.

(2) Confirm receipt of the request and give the identification number to the person who made the request.

(3) Send a copy of the request to the Chairman of the Committee on Filler Metals and the Chairman of the particular Subcommittee involved.

(4) File the original request.

(5) Add the request to the log of outstanding requests.

(d) 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 Chairmen of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chairman of the Committee on Filler Metals for action.

(e) 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 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 Terms "Not Specified" and "Not Required." The point of difference (although not necessarily the amount of the 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 to classify a filler metal to that classification. When a purchaser wants the information provided by that test, in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of the product. The purchaser will have to establish with that supplier just what the testing procedure and the acceptance requirements are to be for that test. The purchaser may want to incorporate that information (via ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*) in the purchase order.

TABLE A1
COMPARISONS OF A5.26/A5.26M CLASSIFICATIONS AND CLASSIFICATIONS IN OTHER AWS SPECIFICATIONS AND PROPOSED ISO DESIGNATIONS

AWS A5.26/A5.26M Classification	Similar Classifications[a]					
	AWS A5.17	AWS A5.18	AWS A5.23	AWS A5.25	AWS A5.28	Proposed ISO Designations[b]
EGXXS-1	—	—	—	—	—	—
EGXXS-2	—	ER70S-2	—	EM5K-EW	—	S2134
EGXXS-3	EM13K	ER70S-3	—	EM13K-EW	—	S2030
EGXXS-5	—	ER70S-5	—	—	—	S2022
EGXXS-6	EH11K	ER70S-6	—	EH11K-EW	—	S3031
EGXXS-D2	—	—	EA3K	EH10Mo-EW	ER80S-D2	S3020-A3

NOTES:

a. Classifications are similar but not necessarily identical in composition.

ANSI/AWS A5.17	*Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
ANSI/AWS A5.18	*Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*
ANSI/AWS A5.23	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
ANSI/AWS A5.25	*Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*
ANSI/AWS A5.28	*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielding Arc Welding*

b. IIW Doc. XII-1232-91 (also see Section A2.5).

A2.4 An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for the type of filler metal. In that system the initial letter "S" designates a mild or low-alloy steel wire, followed by a four-digit number. If the filler metal is a metal cored wire, the initial letter is "C"; if a flux cored wire, the initial letter is "T."

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing is normally conducted on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*. 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 shall 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 actually has conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification.

Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above and the "Manufacturer's Quality Assurance Program," in ANSI/AWS 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:

(a) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)

(b) Number of welders and welding operators working in that space

(c) Rate of evolution of fumes, gases, or dust, according to the materials and processes used

(d) The proximity of the welders or welding operators 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

(e) The ventilation provided to the space in which the welding is done

A5.2 American National Standard ANSI/ASC 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 protection of personnel and the general area and ventilation in that document.

A6. Welding Considerations

A6.1 Electrogas welding is an arc welding process that uses solid electrodes with gas shielding, composite cored electrodes with gas shielding, or composite cored electrodes without gas shielding (self-shielded). Operating on direct current, the electrode deposits filler metal in the cavity formed by the water-cooled backing shoe(s) that bridges the groove between the joint members. The joint normally is made in a single pass, though with special fixturing multipass joints have been welded.

A6.2 Flux cored electrodes used with the electrogas welding process are designed specifically for compatibility with the process. The flux produces a thin layer of slag between the weld metal and copper backing shoes without accumulating excessive slag above the weld pool. The nonmetallic content of the flux core is lower than that of conventional gas shielded and self-shielded flux cored electrodes.

A6.3 Because of the large volume of molten weld metal produced in electrogas welding and the necessity to contain it, the process is used for welding in the essentially vertical position. Joints are readily welded in plate assemblies that are as much as 15 degrees from the vertical, or where the joint in vertical plate assemblies may be as much as 15 degrees from vertical, or both.

A6.4 The entire assembly, including electrode, copper shoes, wire-feeding mechanism, controls, and oscillator, generally moves vertically during operation. When consumable guide tubes are used, vertical movement of the equipment may not be required. The length of vertical travel is unlimited and is dependent upon the design of the equipment used.

A6.5 The standard joint geometry is a simple square groove in a butt joint. Joint geometries other than square grooves in butt joints can be used.

A6.6 Certain classifications can be used with consumable guide tubes. These guide tubes are generally AISI Grades 1008 to 1020 carbon steel tubing. In some applications, the guide tubes are covered with a flux which provides a protective slag and insulates the tube should it contact the side wall or copper backing shoes. Other applications use ceramic fusible insulators in the shape of washers affixed to the tubes. The manufacturer should be consulted for specific recommendations regarding consumable guide tubes.

The effect of the consumable guide tubes is generally to dilute the alloy content of the weld metal. Consumable guide tubes are not classified per this specification; therefore, weld metal strength and toughness should be tested by the user.

A6.7 The specification requires the use of certain base metals for classification purposes. This does not signify any restriction on the application of the process for joining other base metals, but rather to provide a means for obtaining reproducible results. Electrogas welding is a "high-dilution" process, meaning that the base metal forms a significant portion of the weld metal. The type of base metal, especially given the wide variety of available low-alloy structural steels, will influence the mechanical and other properties of the joint and weld procedure qualification tests, as distinguished from filler metal classification tests, should be used for assessing the properties of welds for a given application.

A6.8 Electrogas welding is generally a high-deposition process, especially when applied to thick plates. Since it usually is operated as a single-pass process, the weld metal and heat-affected zone are subject to no subsequent weld thermal cycles, such as is common with conventional multipass arc welding of thick materials. The relatively wide heat-affected zone (HAZ) on thick plates is often characterized by large grains. On these types of applications, the as-welded mechanical properties of the weld and HAZ may, therefore, be somewhat lower than the base metal, and should be adequately tested and evaluated for the intended application.

A7. Description and Intended Use of Electrodes

This specification contains classifications that describe three categories of electrodes: solid electrodes for use with gas shielding, composite (flux cored or metal cored) electrodes for use with gas shielding, and self-shielded composite (flux cored) electrodes which require no external gas shielding.

A7.1 Solid Electrodes. The classifications for solid electrodes contained in this specification are very similar in electrode chemical composition to, or, in many cases, identical in electrode chemical composition to classifications contained in ANSI/AWS A5.18-93, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, and ANSI/AWS A5.28-96, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*. The user should be aware that the mechanical properties obtained when using these electrodes with the electrogas welding process will differ from those obtained when using them with the gas metal or gas tungsten arc welding processes.

Weld metal mechanical properties obtained with the use of solid electrodes with the electrogas welding process are very dependent on the type of gas employed. The change from one gas type or blend to another (either more reactive or less reactive) will affect the chemical composition of the weld metal and the resulting mechanical properties. In some cases, this change in mechanical properties may be significant enough to necessitate a change in the electrode classification. For this reason, care should be taken to test the electrode with the gas or gas blend which will be used in production.

A7.2 Cored Electrodes. The classifications for composite (flux cored and metal cored) electrodes contained in this specification are based on weld metal chemical composition and the type of, or absence of, an external shielding gas, as shown in Table 4. Once again, it is important for the user to remember that the change from one gas type or blend to another (either more reactive or less reactive) will affect the chemical composition of the weld metal and the resulting mechanical properties.

It should be noted that the EGXXT-1 and EGXXT-2 classifications in this specification are totally different from the EXXT-1 and EXXT-2 classifications contained in ANSI/AWS A5.20, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, and ANSI/AWS A5.29, *Specification for Low Alloy Steel Electrodes for Flux Cored Arc Welding*.

A7.2.1 EGXXT-1 Classification. Electrodes of the EGXXT-1 (and EGXXXT-1) classifications are self-shielded electrodes which require no external shielding gas. Electrodes of these classifications are designed for the core materials to provide a slag cover, along with the appropriate alloys, deoxidizers, denitrifiers, and shielding materials. These often consist of fluorides, metallic alloys, and alkali and alkali earth oxides and carbonates. EGXXT-1 electrodes are designed for welding many structural steels such as ASTM A 36, A 572 and A 515, as well as many grades used in ship construction. Typical applications include bases for heavy equipment, storage tanks, ship hulls, structural members and pressure vessels.

A7.2.2 EGXXT-2 Classification. Electrodes of the EGXXT-2 (and EGXXXT-2) classifications are gas shielded electrodes designed for use with carbon dioxide shielding gas. Typical applications would be similar to those of EGXXT-1 electrodes, except the use of an external shielding gas would normally confine their use to a shop environment.

A7.2.3 EGXXT-Ni1 Classification. Electrodes of the EGXXT-Ni1 (and EGXXXT-Ni1) classifications are gas shielded electrodes designed for use with carbon dioxide shielding gas. These electrodes are similar to EGXXT-2 electrodes except they produce weld metal with approximately 1% nickel.

TABLE A2
DISCONTINUED CLASSIFICATIONS

Discontinued Classification	Last Published	Replaced by
EGXXS-1B	1978	EGXXS-D2 in A5.26-91
EGXXS-GB	1978	EGXXS-G in A5.26-91
EGXXT3	1978	EGXXS-Ni1 in A5.26-91
EGXXT4	1978	EGXXT-NM1 in A5.26-91
EGXXT5	1978	EGXXT-W in A5.26-91

A7.2.4 EGXXT-NM1 and -NM2 Classifications. Electrodes of the EGXXT-NM1 (EGXXXT-NM1) and EGXXT-NM2 (EGXXXT-NM2) classifications are gas shielded electrodes designed for use with carbon dioxide shielding gas (or an argon/carbon dioxide blend in the case of EGXXT-NM2). These electrodes produce weld metal alloyed with various levels of nickel and molybdenum.

A7.2.5 EGXXT-W Classification. Electrodes of the EGXXT-W (and EGXXXT-W) classifications are gas shielded electrodes designed for use with carbon dioxide shielding gas. These electrodes produce weld metal which is intended for use on bare exposed applications of weathering steels, such as ASTM A 242 and A 588.

A7.2.6 EGXXT-G Classification. Electrodes of the EGXXT-G (and EGXXXT-G) classification are those electrodes not included in the preceding classifications, and for which only mechanical property requirements are specified. The electrode supplier should be consulted for the composition, properties, characteristics, and intended use of electrodes of this classification. (See A2.2 for further information.)

A8. Discontinued Classifications

The classifications shown in Table A2 have been discontinued over the life of this specification:

A9. Safety Considerations

A9.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a protective head covering should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles, or the equivalent, to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flames. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load; disconnection under load produces arcing of the contacts and may cause burns or shock, or both. *(Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.)*

The following sources are for more detailed information on personal protection:

(a) American National Standards Institute. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York: American National Standards Institute.[5]

(b) American National Standards Institute. ANSI/ASC Z41.1, *Safety-Toe Footwear*. New York, NY: American National Standards Institute.

(c) American Welding Society. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, FL: American Welding Society.[6]

(d) OSHA. *Code of Federal Regulations*, Title 29 — Labor, Chapter XVII, Part 1910. Washington, DC: U.S. Government Printing Office.[7]

A9.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead; it is used only to complete the welding circuit. A separate connection is required to ground the workpiece.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards such as ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*; and NFPA No. 70, *National Electrical Code,*[8] should be followed.

A9.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the

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[5] ANSI standards may be obtained from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

[6] AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[7] OSHA standards may be obtained from the U.S. Government Printing Office, Washington, DC 20402.

[8] NFPA documents are available from the National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

effects of process radiation on the surrounding environment. Management, welders, and other personnel should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the electrode and base metal, welding process, current level, arc length, and other factors.

The possible effects of overexposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time.

Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air and cause asphyxiation. One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from your breathing zone and the general area.

In some cases, natural air movement will provide enough ventilation. Where ventilation may be questionable, air sampling should be used to determine if corrective measures should be applied.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(a) The permissible exposure limits required by OSHA can be found in *Code of Federal Regulations*, Title 29 — Labor, Chapter XVII Part 1910.

(b) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH).[9]

(c) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*.

A9.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as x-rays), or nonionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

A9.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A9.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser beam welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(a) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(b) Exposed skin should be protected with adequate gloves and clothing as specified ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

(c) Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. *(Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.)*

(d) Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

(e) Safety glasses with UV-protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.

A9.4.3 Ionizing radiation information sources include the following:

(a) American Welding Society. F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*.

(b) Manufacturer's product information literature.

A9.4.4 Nonionizing radiation information sources include:

(a) American National Standards Institute. ANSI/ASC Z136.1, *Safe Use of Lasers*. New York, NY: American National Standards Institute.

(b) American National Standards Institute. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York, NY: American National Standards Institute.

(c) American Welding Society. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, FL: American Welding Society.

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[9] ACGIH documents are available from the American Conference of Governmental Industrial Hygienists. 1330 Kemper Meadow Dr., Cincinnati, OH 45240-1634.

(d) Hinrichs, J. F. January 1978. Project committee on radiation — summary report. *Welding Journal* 57:62–65.

(e) Marshall, W. J., Sliney, D. H., et al. March 1980. Optical radiation levels produced by air-carbon arc cutting processes. *Welding Journal* 59:43–46.

(f) Moss, C. E., and Murray, W. E. September 1979. Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting. *Welding Journal* 58:37–46.

(g) Moss, C. E. March 1979. Optical radiation transmission levels through transparent welding curtains. *Welding Journal* 58:69-s to 75-s.

(h) National Technical Information Service. Nonionizing radiation protection special study No. 42-0053-77, *Evaluation of the Potential Retina Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service.[10]

(i) National Technical Information Service. Nonionizing radiation protection special study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*. Springfield, VA: National Technical Information Service.

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[10] National Technical Information documents are available from the National Technical Information Service, Springfield, VA 22161.

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SPECIFICATION FOR LOW-ALLOY STEEL ELECTRODES AND RODS FOR GAS SHIELDED ARC WELDING

SFA-5.28/SFA-5.28M

(Identical with AWS Specification A5.28/A5.28M:2005. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR LOW-ALLOY STEEL ELECTRODES AND RODS FOR GAS SHIELDED ARC WELDING

SFA-5.28/SFA-5.28M

(Identical with AWS Specification A5.28/A5.28M:2005. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of low-alloy steel electrodes (solid, composite stranded and composite metal cored) and rods (solid) for gas metal arc (GMAW), gas tungsten arc (GTAW), and plasma arc (PAW) welding.

1.2 Safety and health issues and concerns are beyond pthe scope of this standard and therefore are not fully addressed herein. Some safety and health information can be found in the nonmandatory Sections A5 and A10. Safety and health information is available from other sources, including but not limited to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.28 uses U.S. Customary Units. The specification A5.28M 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 electrodes or packaging or both under the A5.28 or A5.28M specifications.

PART A — GENERAL REQUIREMENTS

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard applies.

2.1 ASTM Standards[1]

(a) A 36/A 36M, *Specification for Carbon Structural Steel*

(b) A 203/A 203M, *Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

(c) A 285/A 285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

(d) A 387/A 387M, *Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

(e) A 515/A 515M, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

(f) A 516/A 516M, *Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

(g) A 537/A 537M, *Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

(h) E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(i) E 350, *Standard Test Method for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*

(j) E 1032, *Standard Test Method for Radiographic Examination of Weldments*

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[1] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

2.2 AWS Standards[2]

(a) AWS A5.01, *Filler Metal Procurement Guidelines*

(b) AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*

(c) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(d) AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

(e) AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

2.3 ANSI Standard[3]

(a) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.4 ISO Specification[4]

(a) ISO 544, *Welding consumables—Technical delivery conditions for welding filler materials—Type of product, dimensions, tolerances and markings*

2.5 Department of Defense Specification[5]

(a) MIL-S-16216, *Military Specification, Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)*

3. Classification

3.1 The solid electrodes (and rods) covered by this A5.28 specification utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition of the electrode, as specified in Table 1, and the mechanical properties of the weld metal, as specified in Tables 3 and 4. The composite stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4, and the shielding gas employed.

3.1M The solid electrodes (and rods) covered by this A5.28M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the chemical composition of the electrode, as specified in Table 1, and the mechanical properties of the weld metal, as specified in Tables 3 and 4. The composite stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon the International System of Units (SI) and are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4, and the shielding gas employed.

3.2 Electrodes and rods classified under one classification shall not be classified under any other classification in this specification, except that ER80S-D2 [ER55S-D2] may also be classified as ER90S-D2 [ER62S-D2] provided the product meets the requirements of both classifications. However, material may be classified under both A5.28 AND A5.28M specifications.

3.3 The welding electrodes and rods classified under this specification are intended for gas shielded arc welding, but that is not to prohibit their use with any other process (or any other shielding gas, or combination of shielding gases) for which they are found suitable.

4. Acceptance

Acceptance[6] of the electrodes and rods 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.[7]

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] for tensile and yield strength, and to the “nearest unit” in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E 29.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the chemical composition, the mechanical properties, and soundness of the weld metal. The base metal for the weld test assemblies, the welding and testing procedures to be

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[2] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] ANSI standards are published by the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.

[4] ISO standards are published by the International Organization for Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

[5] Department of Defense standards are published by DODSSP, Standardization Documents Order Desk, 700 Robbins Avenue, Bldg. 4D, Philadelphia, PA 19111-5094.

[6] See Section A3, Acceptance, for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

[7] See Section A4, Certification, for further information concerning certification and the testing called for to meet this requirement.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES AND RODS

AWS Classification[c]		UNS Number[d]	Weight Percent[a,b]													
A5.28	A5.28M		C	Mn	Si	P	S	Ni	Cr	Mo	V	Ti	Zr	Al	Cu[e]	Other Elements Total
Carbon-Molybdenum Steel Electrodes and Rods																
ER70S-A1	ER49S-A1	K11235	0.12	1.30	0.30–0.70	0.025	0.025	0.20	—	0.40–0.65	—	—	—	—	0.35	0.50
Chromium-Molybdenum Steel Electrodes and Rods																
ER80S-B2	ER55S-B2	K20900	0.07–0.12	0.40–0.70	0.40–0.70	0.025	0.025	0.20	1.20–1.50	0.40–0.65	—	—	—	—	0.35	0.50
ER70S-B2L	ER49S-B2L	K20500	0.05	0.40–0.70	0.40–0.70	0.025	0.025	0.20	1.20–1.50	0.40–0.65	—	—	—	—	0.35	0.50
ER90S-B3	ER62S-B3	K30960	0.07–0.12	0.40–0.70	0.40–0.70	0.025	0.025	0.20	2.30–2.70	0.90–1.20	—	—	—	—	0.35	0.50
ER80S-B3L	ER55S-B3L	K30560	0.05	0.40–0.70	0.40–0.70	0.025	0.025	0.20	2.30–2.70	0.90–1.20	—	—	—	—	0.35	0.50
ER80S-B6[f]	ER55S-B6[f]	S50280	0.10	0.40–0.70	0.50	0.025	0.025	0.60	4.50–6.00	0.45–0.65	—	—	—	—	0.35	0.50
ER80S-B8[g]	ER55S-B8[g]	S50480	0.10	0.40–0.70	0.50	0.025	0.025	0.50	8.00–10.50	0.80–1.20	—	—	—	—	0.35	0.50
ER90S-B9[h,i,j]	ER62S-B9[h,i,j]	S50482	0.07–0.13	1.20	0.15–0.50	0.010	0.010	0.80	8.00–10.50	0.85–1.20	0.15–0.30	—	—	0.04	0.20	0.50
Nickel Steel Electrodes and Rods																
ER80S-Ni1	ER55S-NI1	K11260	0.12	1.25	0.40–0.80	0.025	0.025	0.80–1.10	0.15	0.35	0.05	—	—	—	0.35	0.50
ER80S-Ni2	ER55S-NI2	K21240	0.12	1.25	0.40–0.80	0.025	0.025	2.00–2.75	—	—	—	—	—	—	0.35	0.50
ER80S-Ni3	ER55S-NI3	K31240	0.12	1.25	0.40–0.80	0.025	0.025	3.00–3.75	—	—	—	—	—	—	0.35	0.50
Manganese-Molybdenum Steel Electrodes and Rods																
ER80S-D2 ER90S-D2	ER55S-D2 ER62S-D2	K10945	0.07–0.12	1.60–2.10	0.50–0.80	0.025	0.025	0.15	—	0.40–0.60	—	—	—	—	0.50	0.50
Other Low-Alloy Steel Electrodes and Rods																
ER100S-1	ER69S-1	K10882	0.08	1.25–1.80	0.20–0.55	0.010	0.010	1.40–2.10	0.30	0.25–0.55	0.05	0.10	0.10	0.10	0.25	0.50
ER110S-1	ER76S-1	K21015	0.09	1.40–1.80	0.20–0.55	0.010	0.010	1.90–2.60	0.50	0.25–0.55	0.04	0.10	0.10	0.10	0.25	0.50
ER120S-1	ER83S-1	K21030	0.10	1.40–1.80	0.25–0.60	0.010	0.010	2.00–2.80	0.60	0.30–0.65	0.03	0.10	0.10	0.10	0.25	0.50
ERXXS-G	ERXXS-G	—	Not Specified[k]													

NOTES:

a. The filler metal shall be analyzed for the elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed the limits specified for "Other Elements, Total."

b. Single values are maximum.

c. The suffixes B2, Ni1, etc., designate the chemical composition of the electrode and rod classification.

d. SAE HS-1086/ASTM DS-56H, *Metals and Alloys in the Unified Numbering System*.

e. Copper due to any coating on the electrode or rod plus the copper content of the filler metal itself, shall not exceed the stated 0.50% max.

f. Similar to former class ER502 in AWS Specification A5.9-93.

g. Similar to former class ER505 in AWS Specification A5.9-93.

h. Niobium (Columbium) 0.02–0.10%

i. Nitrogen 0.03–0.07%

j. The sum of Mn and Ni shall be less than or equal to 1.50% max.

k. In order to meet the requirements of the "G" classification, the electrode must have a minimum of one or more of the following: 0.50% Nickel, 0.30% Chromium, or 0.20% Molybdenum. The composition shall be reported; the requirements are those agreed to by the purchaser and supplier.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL FROM COMPOSITE ELECTRODES[a]

AWS Classification[d]			Weight Percent[b,c]												
A5.28	A5.28M	UNS Number[e]	C	Mn	Si	P	S	Ni	Cr	Mo	V	Ti	Zr	Al	Cu	Other Elements Total
Chromium-Molybdenum Weld Metal																
E80C-B2	E55C-B2	W52030	0.05–0.12	0.40–1.00	0.25–0.60	0.025	0.030	0.20	1.00–1.50	0.40–0.65	0.03	—	—	—	—	0.50
E70C-B2L	E49C-B2L	W52130	0.05	0.40–1.00	0.25–0.60	0.025	0.030	0.20	1.00–1.50	0.40–0.65	0.03	—	—	—	0.35	0.50
E90C-B3	E62C-B3	W53030	0.05–0.12	0.40–1.00	0.25–0.60	0.025	0.030	0.20	2.00–2.50	0.90–1.20	0.03	—	—	—	0.35	0.50
E80C-B3L	E55C-B3L	W53130	0.05	0.40–1.00	0.25–0.60	0.025	0.030	0.20	2.00–2.50	0.90–1.20	0.03	—	—	—	0.35	0.50
E80C-B6	E55C-B6		0.10	0.40–1.00	0.25–0.60	0.025	0.025	0.60	4.50–6.00	0.45–0.65	0.03	—	—	—	0.35	0.50
E80C-B8	E55C-B8		0.10	0.40–1.00	0.25–0.60	0.025	0.025	0.20	8.00–10.50	0.80–1.20	0.03	—	—	—	0.35	0.50
E90C-B9[f]	E55C-B9		0.08–0.13	1.20[g]	0.50	0.020	0.015	0.80[g]	8.00–10.50	0.85–1.20	0.15–0.30	—	—	0.04	0.20	0.50
Nickel Steel Electrodes and Rods																
E80C-Ni1	E55C-Ni1	W21030	0.12	1.50	0.90	0.025	0.030	0.80–1.10	—	0.30	0.03	—	—	—	0.35	0.50
E70C-Ni2	E49C-Ni2	W22030	0.08	1.25	0.90	0.025	0.030	1.75–2.75	—	—	0.30	—	—	—	0.35	0.50
E80C-Ni2	E55C-Ni2	W22030	0.12	1.50	0.90	0.025	0.030	1.75–2.75	—	—	0.03	—	—	—	0.35	0.50
E80C-Ni3	E55C-Ni3	W23030	0.12	1.50	0.90	0.025	0.030	2.75–3.75	—	—	0.03	—	—	—	0.35	0.50
Manganese-Molybdenum Steel Electrodes and Rods																
E90C-D2	E62C-D2	W19230	0.12	1.00–1.90	0.90	0.025	0.030	—	—	0.40–0.60	0.03	—	—	—	0.35	0.50
Other Low-Alloy Steel Electrodes and Rods																
E90C-K3	E62C-K3		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15	0.25–0.65	0.03	—	—	—	0.35	0.50
E100C-K3	E69C-K3		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15	0.25–0.65	0.03	—	—	—	0.35	0.50
E110C-K3	E76C-K3		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15	0.25–0.65	0.03	—	—	—	0.35	0.50
E110C-K4	E76C-K4		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15–0.65	0.25–0.65	0.03	—	—	—	0.35	0.50
E120C-K4	E83C-K4		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15–0.65	0.25–0.65	0.03	—	—	—	0.35	0.50
E80C-W2	E55C-W2		0.12	0.50–1.30	0.35–0.80	0.025	0.030	0.40–0.80	0.45–0.70	—	0.03	—	—	—	0.30–0.75	0.50
EXXC-G	EXXC-G	—							Not Specified[h]							

NOTES:

a. Chemical requirements for composite electrodes are based on analysis of their weld metal in the as-welded condition using the shielding gas specified in Table 3.

b. The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed the limit specified for "Other Elements, Total."

c. Single values are maximum.

d. Solid electrodes are generally recommended for gas tungsten arc welding (GTAW) or plasma arc welding (PAW).

e. SAE/ HS-1086/ASTM DS-56H, *Metal & Alloys in the Unified Numbering System.*

f. Niobium (Columbium) 0.02–0.10%, Nitrogen 0.03–0.07%.

g. The sum of Mn and Ni shall be 1.50% max.

h. In order to meet the requirements of the "G" classification, the electrode must have a minimum of one or more of the following: 0.50% Nickel, 0.30% Chromium, or 0.20% Molybedenum. The composition shall be reported; the requirements are those agreed to by the purchaser and supplier.

TABLE 3
TENSION TEST REQUIREMENTS

AWS Classification		Shielding Gas[a]	Tensile Strength (minimuim)		Yield Strength[b] (minimum)		Elongation Percent (minimum)	Testing Condition
A5.28	A5.28M		psi	MPa	psi	MPa		
ER70S-B2L ER70C-B2L ER70S-A1	ER49S-B2L E49C-B2L ER49S-A1	Argon/1–5% O_2 (Classes SG-AO-1 thru SG-AO-5)	75,000	515	58,000	400	19	PWHT[c]
ER80S-B2 E80C-B2	ER55S-B2 E55C-B2		80,000	550	68,000	470	19	
ER80S-B3L E80C-B3L	ER55S-B3L E55C-B3L		80,000	550	68,000	470	17	
ER90S-B3 E90C-B3	ER62S-B3 E62C-B3		90,000	620	78,000	540	17	
ER80S-B6	ER55S-B6		80,000	550	68,000	470	17	
E80C-B6	E55C-B6		80,000	550	68,000	470	17	
ER80S-B8	ER55S-B8		80,000	550	68,000	470	17	
E80C-B8	E55C-B8		80,000	550	68,000	470	17	
ER90S-B9	ER62S-B9	Argon/5% CO_2 (Class SG-AC-5)	90,000	620	60,000	410	16	
E90C-B9	E62C-B9	Argon/5-25% CO_2 (Classes SG-AC-5 thru SG-AC-25)						
E70C-Ni2	E49C-Ni2	Argon/1–5% O_2 (Classes SG-AO-1 thru SG-AO-5)	70,000	480	58,000	400	24	PWHT[c]
ER80S-Ni1 E80C-Ni1	ER55S-Ni1 E55C-Ni1		80,000	550	68,000	470	24	As-Welded
ER80S-Ni2 E80C-Ni2 ER80S-Ni3 E80C-Ni3	ER55S-Ni2 E55C-Ni2 ER55S-Ni3 E55C-Ni3		80,000	550	68,000	470	24	PWHT[c]
ER80S-D2	ER55S-D2	CO_2 (Class SG-C)	80,000	550	68,000	470	17	As-Welded
ER90S-D2 E90C-D2	ER62S-D2 E62C-D2	Argon/1–5% O_2 (Classes SG-AO-1 thru SG-AO-5)	90,000	620	78,000	540	17	As-Welded
ER100S-1	ER69S-1	Argon/2% O_2 (Class SG-AO-2)	100,000	690	88,000	610	16	As-Welded
ER110S-1	ER76S-1		110,000	760	95,000	660	15	
ER120S-1	ER83S-1		120,000	830	105,000	730	14	

TABLE 3
TENSION TEST REQUIREMENTS (CONT'D)

AWS Classification		Shielding Gas^a	Tensile Strength (minimuim)		Yield Strength^b (minimum)		Elongation Percent (minimum)	Testing Condition
A5.28	A5.28M		psi	MPa	psi	MPa		
E90C-K3	E62C-K3	Argon/5-25% CO_2 (Classes SG-AC-5 thru SG-AC-25)	90,000	620	78,000	540	18	As-Welded
E100C-K3	E69C-K3		100,000	690	88,000	610	16	
E110C-K3 E110C-K4	E76C-K3 E76C-K4		110,000	760	98,000	680	15	
E120C-K4	E83C-K4		120,000	830	108,000	750	15	
E80C-W2	E55C-W2		80,000	550	68,000	470	22	
ER70S-G E70C-G		(d)	70,000	480	(e)	(e)	(e)	(e)
ER80S-G E80C-G		(d)	80,000	550	(e)	(e)	(e)	(e)
ER90S-G E90C-G		(d)	90,000	620	(e)	(e)	(e)	(e)
ER100S-G E100C-G		(d)	100,000	690	(e)	(e)	(e)	(e)
ER110S-G E110C-G		(d)	110,000	760	(e)	(e)	(e)	(e)
ER120S-G E120C-G		(d)	120,000	830	(e)	(e)	(e)	(e)

NOTES:

a. The use of a particular shielding gas for classification purposes shall not be construed to restrict the use of shielding gas mixtures. A filler metal tested with other gas blends, such as Argon/O_2 or Argon/CO_2 may result in weld metal having different strength and elongation. Classification with other gas blends shall be as agreed upon between the purchaser and supplier.

b. Yield strength at 0.2% offset and elongation in 2 in. [51 mm] gage length.

c. Postweld heat-treated condition in accordance with Table 7.

d. Shielding gas shall be as agreed to between purchaser and supplier.

e. Not specified (As agreed to between purchaser and supplier).

employed, and the results required are given in Sections 9 through 13. See Section A4.2 in the Annex for requirements for classification based on gas tungsten arc welding (GTAW) only.

7.2 The optional test for diffusible hydrogen in Section 14, Diffusible Hydrogen Test, is not required for classification. See Note (a) 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 from one or two new test assemblies. For chemical analysis, retest need be only for those specific elements that failed to meet their 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 proper specified procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 At least one weld test assembly is required, and two may be required (depending on the electrode-solid as

TABLE 4
IMPACT TEST REQUIREMENTS

AWS Classification		Average Impact Energy Absorbed[a,b](minimum)		
A5.28	A5.28M	A5.28	A5.28M	Testing Condition
ER70S-A1	ER49S-A1	Not Required	Not Required	—
ER70S-B2L	ER49S-B2L			
E70C-B2L	E49C-B2L			
ER80S-B2	ER55S-B2			
E80C-B2	E55C-B2			
ER80S-B3L	ER55S-B3L			
E80C-B3L	E55C-B3L			
ER90S-B3	ER62S-B3			
E90C-B3	E62C-B3			
ER80S-B6	ER55S-B6			
E80C-B6	E55C-B6			
ER80S-B8	ER55S-B8			
E80C-B8	E55C-B8			
ER90S-B9	ER62S-B9			
E90C-B9	E62C-B9			
ER80S-Ni1	ER55S-Nil	20 ft·lbf at −50°F	27 J at −45°C	As-Welded
E80C-Ni1	E55C-Nil			
E70C-Ni2	E49C-Ni2	20 ft·lbf at −80°F	27 J at −60°C	PWHT[b]
ER80S-Ni2	ER55S-Ni2			
E80C-Ni2	E55C-Ni2			
ER80S-Ni3	ER55S-Ni3	20 ft·lbf at −100°F	27 J at −75°C	PWHT[b]
E80C-Ni3	E55C-Ni3			
ER80S-D2	ER55S-D2	20 ft·lbf at −20°F	27 J at −30°C	As-Welded
ER90S-D2	ER62S-D2			
E90C-D2	E62C-D2			
ER100S-1	ER69S-1	50 ft·lbf at −60°F	68 J at −50°C	As-Welded
ER110S-1	ER76S-1			
ER120S-1	ER83S-1			
E90C-K3	E62C-K3	20 ft·lbf at −60°F	27 J at −50°C	As-Welded
E100C-K3	E69C-K3			
E110C-K3	E76C-K3			
E110C-K4	E76C-K4			
E120C-K4	E83C-K4			
E80C-W2	E55C-W2	20 ft·lbf at −20°F	27 J at −30°C	As-Welded
ERXXS-G	ERXXS-G	As agreed betweensupplier and purchaser	As agreed between supplier and purchaser	—
EXXC-G	EXXC-G			—

NOTES:

a. Both the highest and lowest of the five test values obtained shall be disregarded in computing the average impact energy absorbed.

For classifications requiring 20 ft·lbf [27 J]: Two of the remaining three values shall equal or exceed 20 ft·lbf [27 J]; one of the three remaining values may be lower than 20 ft·lbf [27 J], but not lower than 15 ft·lbf [20 J]. The average of the three shall not be less than the 20 ft·lbf [27 J] specified.

For classifications requiring 50 ft·lbf [68 J]: Two of the remaining three values shall equal or exceed 50 ft·lbf [68 J]; one of the three remaining values may be lower than 50 ft·lbf [68 J], but not lower than 40 ft·lbf [54 J]. The average of the three shall not be less than the 50 ft·lbf [68 J] specified.

b. Postweld heat treated in accordance with Table 7.

TABLE 5
REQUIRED TESTS

AWS Classification		Chemical Analysis					Diffusible Hydrogen Test
A5.28	A5.28M	Electrode	Weld Metal	Radiographic Test	Tension Test	Impact Test	
Solid Electrodes							
ER70S-A1	ER49S-A1	Required	Not Required	Required	Required	Not Required	a
ER80S-B2	ER55S-B2						
ER70S-B2L	ER49S-B2L						
ER90S-B3	ER62S-B3						
ER80S-B3L	ER55S-B3L						
ER80S-B6	ER55S-B6						
ER80S-B8	ER55S-B8						
ER90S-B9	ER62S-B9						
ER80S-Ni1	ER55S-Ni1	Required	Not Required	Required	Required	Required	a
ER80S-Ni2	ER55S-Ni2						
ER80S-Ni3	ER55S-Ni3						
ER80S-D2	ER55S-D2	Required	Not Required	Required	Required	Required	a
ER90S-D2	ER62S-D2						
ER100S-1	ER69S-1	Required	Not Required	Required	Required	Required	a
ER110S-1	ER76S-1						
ER120S-1	ER83S-1						
ERXXS-G	ERXXS-G	Required[b]	Not Required	Required	Required	Not Required	a
Composite Metal Cored Electrodes							
E80C-B2	E55C-B2	Not Required	Required	Required	Required	Not Required	a
E70C-B2L	E49C-B2L						
E90C-B3	E62C-B3						
E80C-B3L	E55C-B3L						
E80C-B6	E55C-B6						
E80C-B8	E55C-B8						
E90C-B9	E62C-B9						
E80C-Ni1	E55C-Ni1	Not Required	Required	Required	Required	Required	a
E70C-Ni2	E49C-Ni2						
E80C-Ni2	E55C-Ni2						
E80C-Ni3	E55C-Ni3						
E90C-D2	E62C-D2	Not Required	Required	Required	Required	Required	a
E90C-K3	E62C-K3	Not Required	Required	Required	Required	Required	a
E100C-K3	E69C-K3						
E110C-K3	E76C-K3						
E110C-K4	E76C-K4						
E120C-K4	E83C-K4						
E80C-W2	E55C-W2	Not Required	Required	Required	Required	Required	a
EXXC-G	EXXC-G	Not Required	Required[b]	Required	Required	Not Required	a

NOTES:

a. Optional diffusible hydrogen test is required only when specified by the puchaser or when the manufacturer puts the diffusible hydrogen designator on the label (See A2.2 and A8.2).

b. To be reported. See A7.19.

opposed to composite-and the manner in which the sample for chemical analysis is taken), as specified in Table 5. They are as follows:

(a) The groove weld in Fig. 1 for mechanical properties and soundness of the weld metal for both composite and solid electrodes (see Section A4.2 in the Annex for requirements for classification based on gas tungsten arc welding only).

(b) The weld pad in Fig. 2 for chemical analysis of the weld metal from composite stranded and composite metal cored electrodes.

The sample for chemical analysis of weld metal from composite electrodes may be taken from the reduced section of the fractured all weld metal tension test specimen or from the corresponding location (or any location above it) in the groove weld in Fig. 1, thereby avoiding the need to make a weld pad. In case of dispute, the weld pad in Fig. 2 shall be the referee method.

9.2 Preparation of each weld test assembly shall be as specified in 9.3 and 9.4. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the specification shown there, or an equivalent specification. Testing of the assembly shall be as specified in 10.2, 10.3, and Sections 11 through 13.

9.3 Groove Weld

9.3.1 For all classifications a test assembly shall be prepared and welded as specified in Fig. 1, using base metal of the appropriate type specified in Table 6, and the preheat and interpass temperature specified in Table 7. The electrode used shall be 0.045 in. or $^1/_{16}$ in. [1.2 mm or 1.6 mm] size (or the size the manufacturer produces that is closest to one of these, if these sizes are not produced). See Section A4.2 in the Annex for requirements for classification based on gas tungsten arc welding (GTAW) only.

Welding shall be in the flat position, and the assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5 degrees. An assembly that is warped more than 5 degrees out of plane shall be discarded. Test assemblies shall not be straightened. The test assembly shall be tack welded at or above room temperature and welding shall begin at the preheat temperature specified in Table 7. Welding shall continue until the assembly has reached the interpass temperature specified in Table 7, measured by temperature indicating crayons or surface thermometers at the location shown in Fig. 1.

For the remainder of the weld, the preheat temperature and interpass temperature as specified in Table 7 shall be maintained. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be preheated to the temperature specified in Table 7 before welding is resumed. When welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Section 11, Radiographic Test; Section 12, Tension Test; and Section 13, Impact Test. Testing shall be performed in the as-welded or postweld heat-treated condition, as specified in Tables 3 and 4.

9.3.2 When required, the test assembly shall be postweld heat treated before removal of mechanical test specimens. This postweld heat treatment may be done either before or after the radiographic examination.

9.3.2.1 The furnace shall be at a temperature not higher than 600°F [320°C] when the test assembly is placed in it. The heating rate, from that point to the holding temperature specified in Table 7, shall not exceed 400°F per hour [220°C per hour].

9.3.2.2 The test assembly shall be maintained at the temperature specified in Table 7 for 1 hour (-0, +15 minutes).

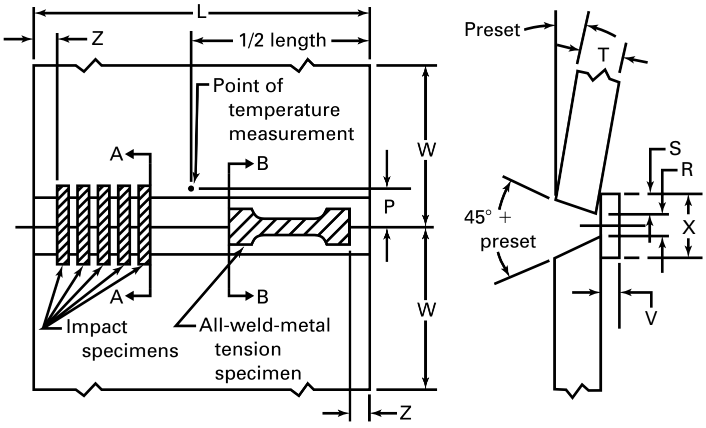
9.3.2.3 When the one hour holding time has been completed, the assembly shall be allowed to cool in the furnace to a temperature below 600°F [320°C] at a rate not exceeding 350°F per hour [190°C per hour]. The assembly may be removed from the furnace at any temperature below 600°F [320°C] and allowed to cool in still air to room temperature. Testing of the assembly shall be as specified in Sections 11 through 13.

9.4 Weld Pad. A weld pad shall be prepared using composite stranded and composite metal cored electrodes as shown in Fig. 2, except when, as permitted in 9.1, the sample for analysis is taken from the groove weld (Fig. 1) or the fractured all weld metal tension test specimen. Base metal of any convenient size which will satisfy the minimum requirements of Fig. 2, and is of a type specified in Table 6, shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal (4 layers minimum thickness). The electrode size shall be 0.045 in. or $^1/_{16}$ in. [1.2 mm or 1.6 mm] or the size that the manufacturer produces that is closest to one of these, if these sizes are not produced. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed that specified in Table 7. Any slag shall be removed after each pass. The pad may be quenched in water between passes (temperature of the water not specified). The dimensions of the completed pad shall be as shown in Fig. 2. Testing of this assembly shall be as specified in 10.2 and 10.3. The results shall meet the requirements of Table 2.

10. Chemical Analysis

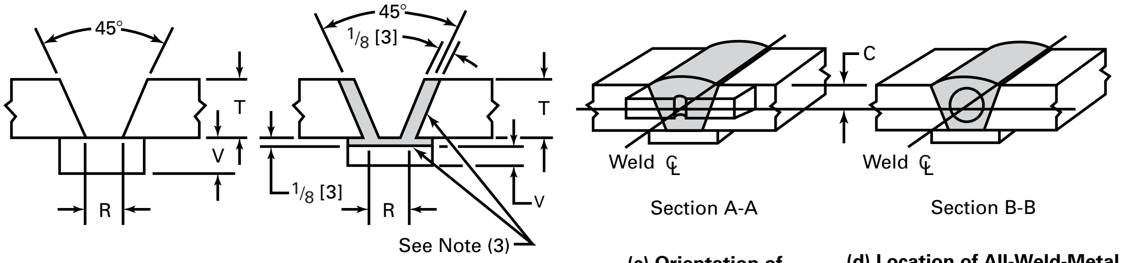
10.1 A sample of the solid electrode or rod stock from which it is made shall be prepared for chemical analysis.

FIG. 1 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS



	Dimensions	in.	mm
C	Specimen Center	3/8	9.5
L	Length, min.	10	250
P	Point of Temperature Measurement	1	25
R	Root Opening	1/2	13
S	Backup Strip Overlap, min.	1/4	6
T	Thickness	3/4	19
V	Backup Strip Thickness, min.	3/8	9
W	Width, min.	5	125
X	Backup Strip Width, min.	1	25
Z	Discard, min.	1	25

(a) Test Plate Showing Location of Test Specimens



Standard test plate

Buttered test plate (see footnote "a" of Table 6)

(c) Orientation of Impact Specimen

(d) Location of All-Weld-Metal Tension Specimen

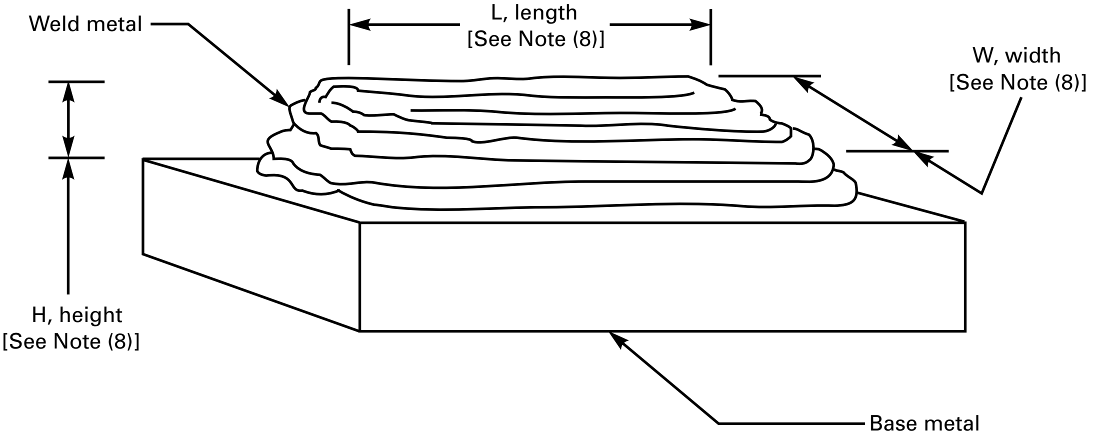
(b) Groove Preparation of Test Plate

Test Conditions for Solid Electrodes [Notes (4) and (5)]		
Standard size [Note (7)]	0.045 in. [1.2 mm]	$^1/_{16}$ in. [1.6 mm]
Shielding gas [Note (8)]	See Table 3	See Table 3
Wire feed speed	450 in./min. [190 mm/sec.] ±5%	240 in./min. [102 mm/sec.] ±5%
Nominal arc voltage	27 to 32 V	25 to 30 V
Resulting current, DCEP [Note (9)] (DCEP = electrode positive)	300 to 360 A [Note (6)]	340 to 420 A [Note (6)]
Contact-tip-to-work distance [Note (10)]	$^7/_8 \pm {}^1/_8$ in. [22 ± 3 mm]	$^7/_8 \pm {}^1/_8$ in. [22 ± 3 mm]
Travel speed	13 ± 2 in./min. [5.5 ± 1.0 mm/sec.]	13 ± 2 in./min. [5.5 ± 1.0 mm/sec.]

NOTES:

1. Base metal shall be as specified in Table 6. The surfaces to be welded shall be clean.
2. Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.
3. When required, edges of the grooves and the contacting face of the backing shall be buttered as shown. Any size of the electrode being tested may be used for buttering. See Table 6, Note a.
4. Test conditions for composite electrodes shall be as recommended by the manufacturer.
5. Preheat and interpass temperatures for both solid and composite electrodes shall be as specified in Table 7.
6. For ER80S-D2 [ER55S-D2] classification, the amperage range for 0.045 in. [1.2 mm] shall be 260 to 320 A and for $^1/_{16}$ in. [1.6 mm], 330 to 410 A.
7. If sizes other than 0.045 in. and $^1/_{16}$ in. [1.2 mm and 1.6 mm] are tested, wire feed speed (and resulting current), arc voltage, and contact-tip-to work distance shall be changed as needed. This joint configuration is not recommended for electrode sizes smaller than 0.035 in. [0.9 mm].
8. If shielding gases or blends other than those shown in Table 3 are used, the wire feed speed (and resulting current), arc voltage, and travel speed are to be as agreed to between purchaser and supplier.
9. The required combination of electrode feed rate, arc voltage, and contact-tip-to-work distance should produce welding currents in the ranges shown. Currents substantially outside these ranges suggest errors in feed rate, contact-tip-to-work distance, voltage settings, or in instrumentation.
10. Distance from the contact tip to the work, not from the shielding gas cup to the work.

FIG. 2 PAD FOR CHEMICAL ANALYSIS OF WELD METAL FROM COMPOSITE ELECTRODES



NOTES:

1. Base metal of any convenient size, of the type specified in Table 6, 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 weld metal of sufficient height
4. 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 with the amperage employed.
5. The preheat temperature shall not be less than 60°F [15°C] and the maximum interpass temperature shall not exceed that specified in Table 7
6. Any slag shall be removed after each pass.
7. The test assembly may be quenched in water between passes to control interpass temperature.
8. The minimum completed pad size shall be at least four layers in height (H). The sample for analysis shall be taken at least $^{3}/_{8}$ in. [9.5 mm] above the original base metal surface. The length (L), after allowance for start and stop areas, and width (W) shall be sufficient to perform analysis.

Solid filler metal, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the filler metal is analyzed for elements other than those in the coating, the coating shall be removed, if its presence affects the results of the analysis for the other elements.

10.2 Composite stranded or metal cored electrodes shall be analyzed in the form of weld metal, not filler metal. The sample for analysis shall be taken from weld metal obtained with the electrode and the shielding gas as specified in Table 3. The sample may be taken from the weld pad prepared in accordance with 9.4, from an area of the groove weld as specified in 9.1, or from the reduced section of the fractured tension test specimen. In case of dispute, the weld pad is the referee method.

The top surface of the pad described in 9.4 and shown in Fig. 2 shall be removed and discarded. A sample for analysis shall be obtained from the underlying metal, no closer than $^{3}/_{8}$ in. [9.5 mm] to the surface of the base metal in Fig. 2, by any appropriate mechanical means. The sample shall be free of slag. When the sample is taken from the groove weld or the reduced section of the fractured tension test specimen, that material shall be prepared for analysis by any suitable mechanical means.

10.3 The sample obtained as specified in 10.1 or 10.2 shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 350.

10.4 The results of the analysis shall meet the requirements of Table 1 for solid electrodes or Table 2 for composite electrodes for the classification of electrode under test.

11. Radiographic Test

11.1 The groove weld described in 9.3.1 and shown in Fig. 1 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. It is permitted on both sides of the test assembly to remove base metal to a depth of $^{1}/_{16}$ in. [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than $^{1}/_{16}$ in. [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 1032. The quality level of inspection shall be 2-2T.

TABLE 6
BASE METAL FOR TEST ASSEMBLIES

AWS Classification			
A5.28	A5.28M	Base Metal ASTM Standard[a]	Base Metal UNS Number[b]
ER70S-B2L E70C-B2L ER80S-B2 E80C-B2	ER49S-B2L E49C-B2L ER55S-B2 E55C-B2	A387 Grade 11	K11789
ER80S-B3L E80C-B3L ER90S-B3 E90C-B3	ER55S-B3L E55C-B3L ER62S-B3 E62C-B3	A387 Grade 22	K21590
ER80S-B6 E80C-B6	ER55S-B6 E55C-B6	A387 Grade 5	S50200
ER80S-B8 E80C-B8	ER55S-B8 E55C-B8	A387 Grade 9	S50400
ER90S-B9 E90C-B9	ER62S-B9 E62C-B9	A387 Grade 91	S50460
ER80S-Ni1 E80C-Nil	ER55S-Nil E55C-Nil	A516 Grade 60, 65, or 70	K02100, K02403, or K02700
		A537 Class 1 or 2	K12437, K21703, or K22103
		A203 Grade A or B, or HY-80 steel in accordance with MIL-S-16216	K22103, K21702, or J42015
E70C-Ni2 ER80S-Ni2 E80C-Ni2	E49C-Ni2 ER55S-Ni2 E55C-Ni2	A203 Grade A or B, or HY-80 steel in accordance with MIL-S-16216	K22103, K21703, or J42015
ER80S-Ni3 E80C-Ni3	ER55S-Ni3 E55C-Ni3	A203 Grade D or E, or HY-80 steel in accordance with MIL-S-16216	K31718, K32018, or J42015
ER70S-A1 ER80S-D2 E90C-D2 ER90S-D2	ER49S-A1 ER55S-D2 ER62S-D2 E62C-D2	ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70	K02600, K03101, K02700
ER100S-1 ER110S-1 ER120S-1	ER69S-1 ER76S-1 ER83S-1	HY-80 or HY-100 steel in accordance with MIL-S-16216	J42015 or J42240
E90C-K3 E100C-K3 E110C-K3 E110C-K4 E120C-K4	E62C-K3 E69C-K3 E76C-K3 E76C-K4 E83C-K4	A 514 or A 517, any grade, or HY-80 or HY-100 steel in accordance with MIL-S-16216	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, or K21650 or J42015 or J42240
E80C-W2	E55C-W2	A 572 or A 588, any grade in these specificaitons, or A 709 Gr 50W	K02303, K02304, K02305, K02306, K11430, K12040, K12043, or K11538
ERXXS-G EXXC-G	ERXXS-G EXXC-G	See note[a]	

TABLE 6
BASE METAL FOR TEST ASSEMBLIES (CONT'D)

NOTES:

a. For any weld metal classification in this specification, ASTM A 36, A 285 Grade C, A 515 Grade 70, or A 516 Grade 70 may be used. In that case, the groove faces and the contacting face of the backing shall be buttered, as shown in Fig. 1, using the electrode being classified or an electrode of the same weld metal composition as that specified for the electrode being tested, or using an electrode of the specified composition classified in another AWS low-alloy steel filler metal specification. Weld pads for chemical analysis meeting minimum height requirements of Fig. 2 are not subject to additional buttering requirements. Alternately, for the indicated weld metal classification, the corresponding base metals may be used for weld test assemblies without buttering. In case of dispute, buttered A 36 steel shall be the referee material.

b. SAE-HS-1086/ASTM DS-58H, *Metals & Alloys in the Unified Numbering System.*

TABLE 7
PREHEAT, INTERPASS, AND POSTWELD HEAT TREATMENT TEMPERATURES

AWS Classification		Preheat and Interpass Temperature[a]		PWHT Temperature[a]	
A5.28	A5.28M	°F	°C	°F	°C
ER70S-A1	ER49S-A1	275–325	135–165	1150 ± 25	620 ± 15
ER80S-B2	ER55S-B2				
E80C-B2	E55C-B2				
ER70S-B2L	ER49S-B2L				
E70C-B2L	E49C-B2L				
ER90S-B3	ER62S-B3	375–425	185–215	1275 ± 25	690 ± 15
E90C-B3	E62C-B3				
ER80S-B3L	ER55S-B3L				
E80C-B3L	E55C-B3L				
ER80S-B6	ER55S-B6	350–450	177–232	1375 ± 25	745 ± 15
E80C-B6	E55C-B6				
ER80S-B8	ER55S-B8	400–500	205–260	1375 ± 25	745 ± 15
E80C-B8	E55C-B8				
ER90S-B9	ER62S-B9	400–600	205–320	1400 ± 25[c]	760 ± 15[c]
E90C-B9	E62C-B9				
E70C-Ni2	E49C-Ni2	275–325	135–165	1150 ± 25	620 ± 15
ER80S-Ni2	ER55S-Ni2				
E80C-Ni2	E55C-Ni2				
ER80S-Ni3	ER55S-Ni3				
E80C-Ni3	E55C-Ni3				
ER80S-D2	ER55S-D2	275–325	135–165	None[b]	None[b]
ER90S-D2	ER62S-D2				
E90C-D2	E62C-D2				
ER80S-Ni1	ER55S-Ni1				
E80C-Ni1	E55C-Ni1				
ER100S-1	ER69S-1				
ER110S-1	ER76S-1				
ER120S-1	ER83S-1				
E90C-K3	E62C-K3				
E100C-K3	E69C-K3				
E110C-K3	E76C-K3				
E110C-K4	E76C-K4				
E120C-K4	E83C-K4				
E80C-W2	E55C-W2				
ERXXXS-G	ERXXXS-G	Conditions as agreed upon between supplier and purchaser			
EXXC-G	EXXC-G				

NOTES:

a. These temperatures are specified for testing under this specification and are not to be considered as recommendations for preheat, interpass, and postweld heat treatment in production welding. The requirements for production welding must be determined by the user. They may or may not differ from those called for here.

b. These classifications are normally used in the as-welded condition.

c. Prior to PWHT, allow the weldment to cool in still air to below 200°F [100°C]. Hold at specific temperature for two hours.

11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Fig. 3. In evaluating the radiograph, 1 in. [25 mm] of the weld on each end of the test assembly shall be disregarded.

A rounded indication is an indication (on the radiograph) whose length is no more than 3 times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be of porosity or slag. Indications whose largest dimension does not exceed $^1/_{64}$ in. [0.4 mm] shall be disregarded. Test assemblies with indications larger than the largest indications permitted in the radiographic standards (Fig. 3) do not meet the requirements of this specification.

12. Tension Test

12.1 One all-weld-metal round tension test specimen, as specified in the Tension Tests section of AWS B4.0 [AWS B4.0M], shall be machined from the groove weld described in 9.3.1, and shown in Fig. 1, as required in Table 5. The tensile specimen shall have a nominal diameter of 0.500 in. [12.5 mm] and a nominal gage length-to-diameter ratio of 4:1. Other dimensions of the tension test specimen shall be as specified in the Tension Test section of AWS B4.0 [AWS B4.0M].

12.1.1 After machining, but before testing, the specimen may be aged at 200 to 220°F [95 to 105°C] for up to 48 hours, then allowed to cool to room temperature. Refer to A8.3 for a discussion on the purpose of aging.

12.1.2 The specimen shall be tested in the manner described in the tension test section of AWS B4.0 [AWS B4.0M].

12.1.3 The results of the all-weld-metal tension test shall meet the requirements specified in Table 3. Test reports shall indicate if the specimen was tested in the aged condition.

13. Impact Test

13.1 For those classifications for which impact testing is required in Table 5, five Charpy V-notch impact test specimens, as specified in the Fracture Toughness Testing of Welds section of AWS B4.0 [AWS B4.0M], shall be machined from the test assembly shown in Fig. 1.

The Charpy V-Notch specimens shall have the notched surface and the surface to be struck parallel within 0.002 in. [0.05 mm]. The other two surfaces shall be square with the notched or struck surface within ±10 min of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50 times magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the fracture toughness test section of AWS B4.0 [AWS B4.0M]. The test temperature shall be that specified in Table 4 for the classification under test.

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal, or exceed, the specified 20 ft•lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft•lbf [20 J], and the average of the three shall be not less than the required 20 ft•lbf [27 J] energy level. For classifications requiring 50 ft•lbf [68 J], two of the remaining three values shall equal, or exceed, the specified 50 ft•lbf [68 J] energy level. One of the three may be lower, but not lower than 40 ft•lbf [54 J], and the average of the three shall be not less than the required 50 ft•lbf [68 J] energy level.

14. Diffusible Hydrogen Test

14.1 For each electrode to be designated by an optional supplemental diffusible hydrogen designator, the 0.045 in. or $^1/_{16}$ in. [1.2 mm or 1.6 mm] size, or the size that the manufacturer produces that is closest to one of these sizes if the specified sizes are not produced, shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results which satisfy the requirements of Table 8, the appropriate diffusible hydrogen designator may be added at the end of the classification.

14.2 Testing shall be done without rebaking or otherwise conditioning the electrode, unless the manufacturer recommends otherwise. If the electrode is rebaked, that fact, along with the method used for rebaking, shall be noted on the test report.

14.3 For purposes of certifying compliance with optional diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of water vapor per pound [1.43 g/kg] of dry air at the time of welding. The actual atmospheric conditions shall be reported, along with the average value for the test, according to AWS A4.3.[8]

14.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the

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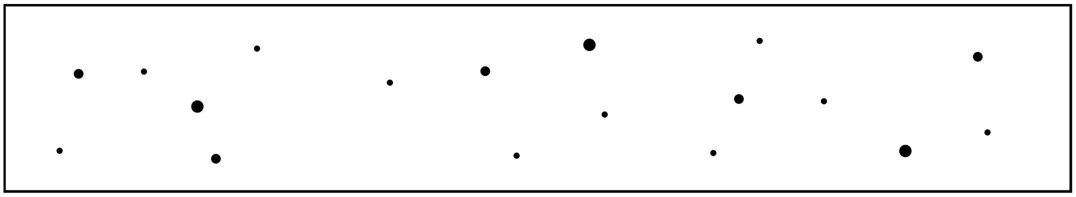
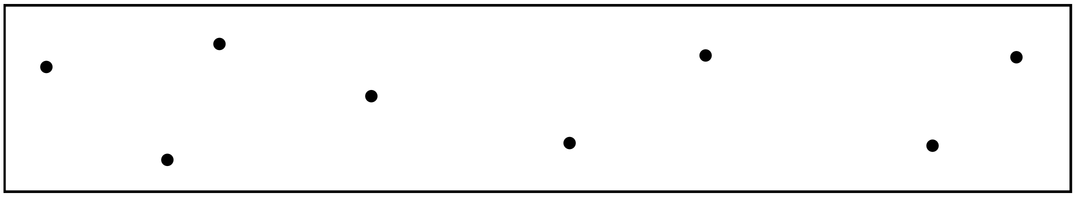
[8] See A8.2 (in Annex A).

FIG. 3 RADIOGRAPHIC ACCEPTANCE STANDARDS



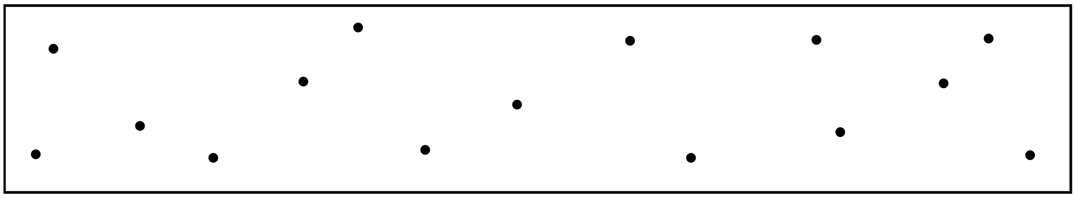
(a) Assorted Rounded Indications

Size $^{1}/_{64}$ in. (0.4 mm) to $^{1}/_{16}$ in. (1.6 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 18, with the following restrictions:
Maximum number of large $^{3}/_{64}$ in. (1.2 mm) to $^{1}/_{16}$ in. (1.6 mm) in diameter or in length indications = 3.
Maximum number of medium $^{1}/_{32}$ (0.8 mm) to $^{3}/_{64}$ in. (1.2 mm) in diameter or in length indications = 5.
Maximum number of small $^{1}/_{64}$ in. (0.4 mm) to $^{1}/_{32}$ in. (0.8 mm) in diameter or in length indications = 10.



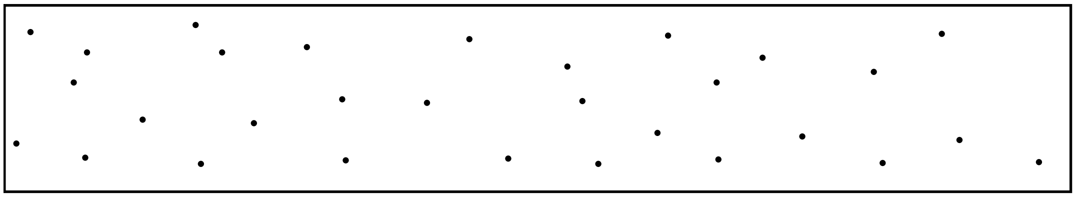
(b) Large Rounded Indications

Size $^{3}/_{64}$ in. (1.2 mm) to $^{1}/_{16}$ in. (1.6 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 8.



(c) Medium Rounded Indications

Size $^{1}/_{32}$ in. (0.8 mm) to $^{3}/_{64}$ in. (1.2 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 15.



(d) Small Rounded Indications

Size $^{1}/_{64}$ in. (0.4 mm) to $^{1}/_{32}$ in. (0.8 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 30.

NOTES:

1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed $^{1}/_{64}$ in. [0.4 mm] shall be disregarded.
4. These standards are equivalent to the Grade 1 standards of AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.*

TABLE 8
OPTIONAL DIFFUSIBLE HYDROGEN REQUIREMENTS

AWS Classifications	Optional Supplemental Diffusible Hydrogen Designator[a,b]	Average Diffusible Hydrogen, Maximum[c] (ml/100g Deposited Metal)
All	H16	16.0
All	H8	8.0
All	H4	4.0
All	H2	2.0

NOTES:

a. See Note a to Table 5.

b. This designator is added to the end of the complete electrode classification designation.

c. Some classifications may not meet the lower average diffusible hydrogen levels (H8, H4, and H2).

test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the actual test results for an electrode meet the requirements for the lower, or lowest hydrogen designator, as specified in Table 8, the electrode also meets the requirements of all higher hydrogen designators in Table 8 without need to retest.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

15. Method of Manufacture

The electrodes and rods classified according to this specification may be manufactured by any method that will produce electrodes and rods that meet the requirements of this specification.

16. Standard Sizes

Standard sizes for electrodes and rods in the different package forms [straight lengths, coils with support, coils without support, drums, and spools (see Section 18, Standard Package Forms)] are as shown in Table 9.

17. Finish and Uniformity

17.1 All electrodes and rods shall have a smooth finish which is free from slivers, depressions, scratches, scale, seams, laps (exclusive of the longitudinal joint in composite metal cored electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

17.2 Each continuous length of filler metal shall be from a single 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.

17.3 The components in composite electrodes (including the core ingredients in metal cored electrodes) 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.

17.4 A suitable protective coating may be applied to any filler metal in this specification. Copper may be used as a coating for any classification.

18. Standard Package Forms

18.1 Standard package forms are straight lengths, coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 10. Package forms, sizes, and weights other than these shall be as agreed between purchaser and supplier.

18.2 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

18.3 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal. Standard spools are shown in Figs. 4A and 4B.

19. Winding Requirements

19.1 Electrodes on spools and in coils (including drums and reels) shall be wound so that kinks, waves, sharp bends, overlapping or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

19.2 The cast and helix of electrode in coils, spools, and drums, shall be such that the electrode will feed in an uninterrupted manner in automatic and semiautomatic equipment.

19.3 The cast and helix of solid filler metal on 4 in. [100 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will

(a) Form a circle not less than 4 in. [100 mm] nor more than 9 in. [230 mm] in diameter

TABLE 9
STANDARD SIZES[a]

Standard Package Form	Diameter			Tolerance (±)			
				Solid		Composite	
	in.		mm	in.	mm	in.	mm
Straigth Lengths[b]		0.045	—	±0.001	—	±0.002	—
		—	1.2	—	+0.01, -0.04	—	+0.02, -0.05
	1/16	0.062	1.6	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	2.0	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	2.4	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	1/8	0.125	3.2	±0.002	+0.01, -0.07	±0.003	+0.02, -0.07
	5/32	0.156	4.0	±0.002	+0.01, -0.07	±0.003	+0.02, -0.07
	3/16	0.188	4.8[c]	±0.002	+0.01, -0.07	±0.003	+0.06, -0.08
Coils with and without Support	0.030		0.8	±0.001	+0.01, -0.04	±0.002	+0.02, -0.05
	0.035		0.9	±0.001	+0.01, -0.04	±0.002	+0.02, -0.05
	—		1.0	—	+0.01, -0.04	—	+0.02, -0.05
	0.045		—	±0.001	—	±0.002	—
	—		1.2	—	+0.01, -0.04	—	+0.02, -0.05
	0.052		—	±0.002	—	±0.002	—
	—		1.4	—	+0.01, -0.04	—	+0.02, -0.05
	1/16	0.062	1.6	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	2.0	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	2.4	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	7/64	0.109	2.8	±0.002	+0.01, -0.07	±0.003	+0.02, -0.06
	1/8	0.125	3.2	±0.002	+0.01, -0.07	±0.003	+0.02, -0.07
Drums	0.035		0.9	±0.001	+0.01, -0.04	±0.002	+0.02, -0.05
	—		1.0	—	+0.01, -0.04	—	+0.02, -0.05
	0.045		—	±0.001	—	±0.002	—
	—		1.2	—	+0.01, -0.04	—	+0.02, -0.05
	0.052		—	±0.002	—	±0.002	—
	—		1.4	—	+0.01, -0.04	—	+0.02, -0.05
	1/16	0.062	1.6	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	2.0	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	2.4	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	7/64	0.109	2.8	±0.002	+0.01, -0.07	±0.003	+0.02, -0.06
	1/8	0.125	3.2	±0.002	+0.01, -0.07	±0.003	+0.02, -0.07
Spools	0.020		0.5[c]	±0.001	+0.01, -0.03	±0.002	+0.02, -0.05
	0.025		0.6	±0.001	+0.01, -0.03	±0.002	+0.02, -0.05
	0.030		0.8	±0.001	+0.01, -0.04	±0.002	+0.02, -0.05
	0.035		0.9	±0.001	+0.01, -0.04	±0.002	+0.02, -0.05
	—		1.0	—	+0.01, -0.04	—	+0.02, -0.05
	0.045		—	±0.001	—	±0.002	—
	—		1.2	—	+0.01, -0.04	—	+0.02, -0.05
	0.052		—	±0.002	—	±0.002	—
	—		1.4	—	+0.01, -0.04	—	+0.02, -0.05
	1/16	0.062	1.6	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	2.0	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	2.4	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	7/64	0.109	2.8	±0.002	+0.01, -0.07	±0.003	+0.02, -0.06
	1/8	0.125	3.2	±0.002	+0.01, -0.07	±0.003	+0.02, -0.07

NOTES:

a. Dimensions, sizes, tolerances, and package forms other than those shown shall be as agreed by purchaser and supplier.

b. Length shall be 36 in. ± 1/2 in. [900 mm + 25, -0 mm].

c. Not shown as standard metric size in ISO 544.

TABLE 10
PACKAGING REQUIREMENTS[a]

Type of Package		Package Size[d]		Net Weight of Electrode[b]	
		in.	mm	lb	kg (approx.)
Coils without Support	As Specified by Purchaser[c]				
Coils with Support (See below)	ID ID	6-¾ 12	170 300	14 25, 30, 50, and 60	6 10, 15, 20, 25, and 30
Spools	OD	4	100	1-½ and 2-½	0.5 and 1.0
	OD	8	200	10, 12, and 15	4.5, 5.5, and 7
	OD	12	300	25, 30, 35, and 44	10, 15, and 20
	OD	14	360	50 and 60	20 and 25
	OD	22	560	250	100
	OD	24	610	300	150
	OD	30	760	600, 750, and 1000	250, 350, and 450
Drums	OD	15½	400	As Specified by Purchaser[c]	
	OD	20	500		
	OD	23	600	300 and 600	150 and 300
Straight Lengths		36 (long)	900 (long)	2, 5, 10, and 50	1, 2, 5, and 20

Coils with Support — Standard Dimensions and Weights

Electrode Size	Coil Net Weight[b]		Inside Diameter of Liner		Width of Wound Electrode	
	lb	kg (approx.)	in.	mm	in. max.	mm, max.
All	14	6	6-¾ ± ⅛	170 ± 3	3	75
	25 and 30	10 and 15	12 ± ⅛	300 ± 3	2-½ or 4-⅝	65 or 120
	50, 60, and 65	20, 25, and 30	12 ± ⅛	300 ± 3	4-⅝	120

NOTES:

a. Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser.

b. Tolerance on net weight shall be ± 10 percent.

c. As agreed between supplier and purchaser.

d. ID = inside diameter; OD = outside diameter.

(b) Rise above the flat surface no more than ½ in. [13 mm] at any location

19.4 The cast and helix of solid filler metal on all other package forms shall be such that a specimen long enough to produce a single loop, when cut from the package and laid unrestrained on a flat surface, will

(a) Form a circle not less than 12 in. [300 mm] for 0.030 in. [0.8 mm] and smaller sizes; or not less than 15 in. [380 mm] for 0.035 in. [0.9 mm] and larger sizes

(b) Rise above the flat surface no more than 1 in. [25 mm] at any location

Certain bulk packages may contain wire that has been elastically twisted or otherwise treated to provide straight wire feed. Wire from these packages will not form a circle when cut. Traditional cast and helix measurements may have no relevance. Wire thus treated shall conform only to the winding requirements of 19.1 and 19.2. Any method of wire form inspection shall be as agreed between purchaser and supplier.

20. Filler Metal Identification

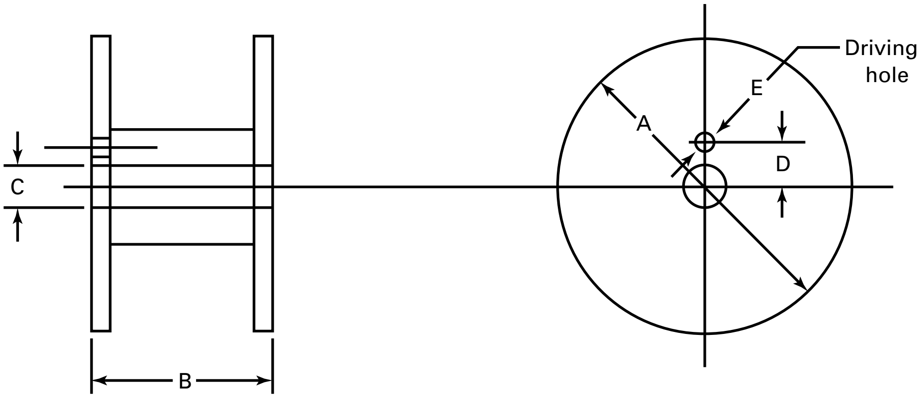
20.1 The product information and the precautionary information required in Section 22 for marking each package shall also appear on each coil, spool, and drum.

20.2 Coils without support shall have a tag containing this information securely attached to the filler metal at the inside end of the coil.

20.3 Coils with support shall have the information securely affixed in a prominent location on the support.

20.4 Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

FIG. 4A STANDARD SPOOLS — DIMENSIONS OF 4, 8, 12, AND 14 IN. [100, 200, 300, AND 350 MM] SPOOLS

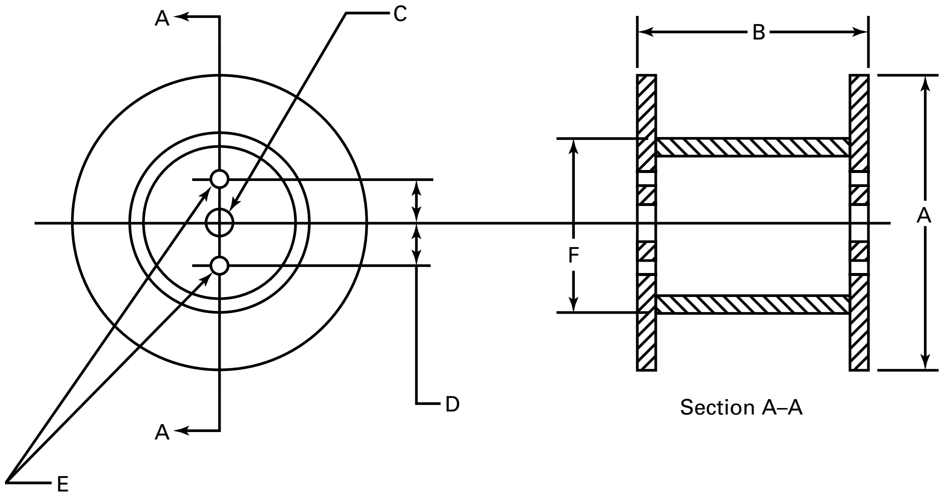


		Dimensions							
		4 in. [100 mm] Spools		8 in. [200 mm] Spools		12 in. [300 mm] Spools		14 in. [350 mm] Spools	
		in.	mm	in.	mm	in.	mm	in.	mm
A	Diameter, max. [Note (4)]	4.0	102	8.0	203	12	305	14	355
B	Width	1.75	46	2.16	56	4.0	103	4.0	103
	Tolerance	±0.03	+0, −2	±0.03	+0, −3	±0.06	+0, −3	±0.06	+0, −3
C	Diameter	0.63	16	2.03	50.5	2.03	50.5	2.03	50.5
	Tolerance	+0.01, −0	+1, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0
D	Distance between axes	—	—	1.75	44.5	1.75	44.5	1.75	44.5
	Tolerance			±0.02	±0.5	±0.02	±0.5	±0.02	±0.5
E	Diameter [Note (3)]	—	—	0.44	10	0.44	10	0.44	10
	Tolerance			+0, −0.06	+1, −0	+0, −0.06	+1, −0	+0, −0.06	+1, −0

NOTES:

1. Outside diameter of barrel shall be such as to permit feeding of the filler metals.
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 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.

FIG. 4B STANDARD SPOOLS — DIMENSIONS OF 22, 24, AND 30 IN. [560, 610, AND 760 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.	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

GENERAL 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 of the diameter of the barrel being less than the indside diameter of the flanges.
3. Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

20.5 Drums shall have the information securely affixed in a prominent location on the side of the drum.

21. Packaging

Electrodes and rods shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

22. Marking of Packages

22.1 The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package:

(a) AWS specification (year of issue may be excluded) and AWS classification numbers, along with any optional supplemental designators, if applicable

(b) Supplier's name and trade designation

(c) Size and net weight (see 1.3)

(d) Lot, control, or heat number

22.2 The appropriate precautionary information[9] given in ANSI Z49.1, latest edition (as a minimum), shall be prominently displayed in legible print on all packages, including individual unit packages within a larger package.

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[9] Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

Annex A
Guide to AWS Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding

(This Annex is not a part of AWS A5.28/A5.28M:2005, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding,* but is included for informational purposes only.)

A1. Introduction

The purpose of this guide is to correlate the electrode and rod classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable.

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 as shown in Fig. A1.

A2.2 The prefix "E" designates an electrode as in other specifications. The letters "ER" indicate that the filler metal may be used either as an electrode or a rod. For A5.28, the number 70, for example, indicates the required minimum tensile strength, as a multiple of 1000 psi, of the weld metal in a test weld made in accordance with specification A5.28. Similarly, for A5.28M, the number 49, for example, indicates the required minimum tensile strength, as a multiple of 10 MPa, of the weld metal in a test weld made in accordance with specification A5.28M.

The letter "S" designates a solid electrode or rod.

The letter "C" designates a composite electrode The suffix following the hyphen indicates the chemical composition of the filler metal itself, in the case of solid electrodes and rods, or the weld metal under certain specified test conditions, in the case of composite stranded or metal cored electrodes.

Optional designators are also used in this specification in order to identify electrodes and rods that have met mandatory classification requirements and certain supplementary requirements as agreed to between the supplier and purchaser. An optional supplemental diffusible hydrogen designator (H16, H8, H4, or H2) may follow the classification designation, indicating whether the electrode will meet a maximum hydrogen level of 16, 8, 4, or 2 mL/100g of weld metal when tested as outlined in AWS A4.3. Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 8, are also understood to be able to meet any higher hydrogen limits without necessarily being designated as such.

A2.3 "G" Classification

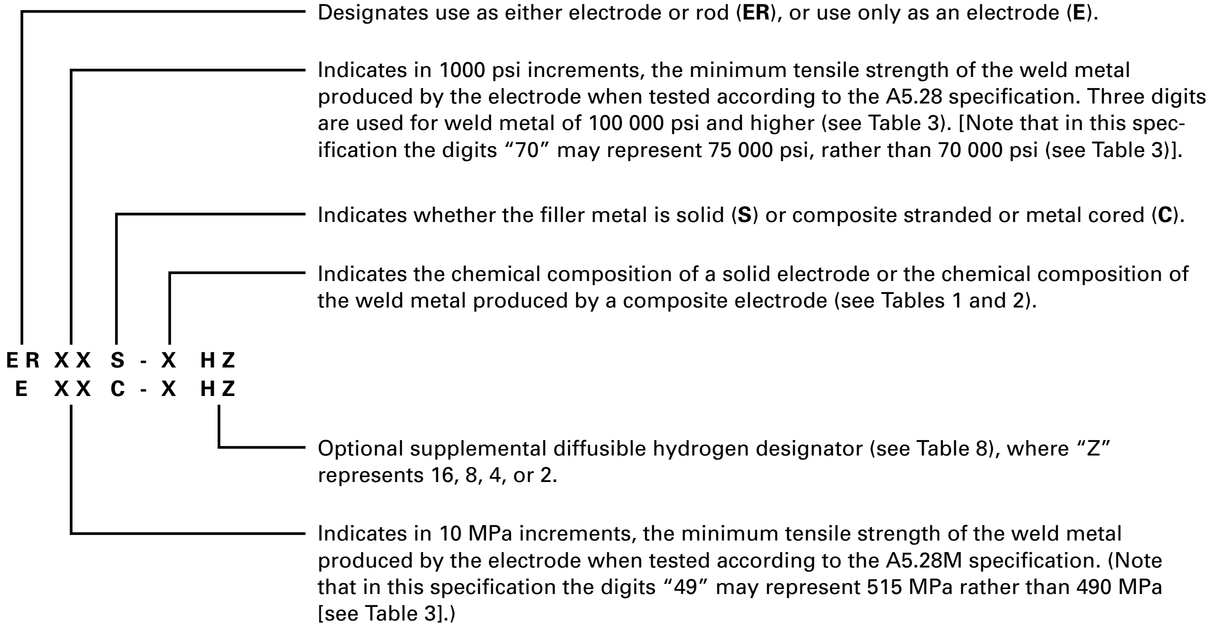
A2.3.1 These specifications include filler metals classified as ER80S-G [ER55S-G], E80C-G [E55C-G], etc. The "G" indicates that the filler metal is of a "general" classification. It is general because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing these classifications is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal-one that otherwise would have to await a revision of the specification-to be classified immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some particular respect (chemical composition, again, for example).

A2.3.2 The point of difference (although not necessarily the amount of the 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:

(a) "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.

(b) "Not Required" is used in those areas of the specification that refer to the tests that must be conducted in order to classify a filler metal. It indicates that the test is not required because the requirements (results) for the test have not been specified for that particular classification.

FIG. A1 CLASSIFICATION SYSTEM



Designates use as either electrode or rod (**ER**), or use only as an electrode (**E**).

Indicates in 1000 psi increments, the minimum tensile strength of the weld metal produced by the electrode when tested according to the A5.28 specification. Three digits are used for weld metal of 100 000 psi and higher (see Table 3). [Note that in this specification the digits "70" may represent 75 000 psi, rather than 70 000 psi (see Table 3)].

Indicates whether the filler metal is solid (**S**) or composite stranded or metal cored (**C**).

Indicates the chemical composition of a solid electrode or the chemical composition of the weld metal produced by a composite electrode (see Tables 1 and 2).

Optional supplemental diffusible hydrogen designator (see Table 8), where "Z" represents 16, 8, 4, or 2.

Indicates in 10 MPa increments, the minimum tensile strength of the weld metal produced by the electrode when tested according to the A5.28M specification. (Note that in this specification the digits "49" may represent 515 MPa rather than 490 MPa [see Table 3].)

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, they will have to arrange for that information with the supplier of the product. They will 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 A5.01, *Filler Metal Procurement Guidelines*) into the purchase order.

A2.3.3 Request for Filler Metal Classification

A2.3.3.1 When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. They may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

A2.3.3.2 A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need.

In particular, the request needs to include:

(a) All classification requirements as given for existing classifications, such as, chemical composition ranges, and mechanical property requirement.

(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 Annex A.

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.

A2.3.3.3 The request should be sent to the Secretary of the A5 Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will:

(a) Assign an identifying number to the request. This number shall 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 the Chair of the particular Subcommittee involved.

(d) File the original request.

(e) Add the request to the log of outstanding requests.

A2.3.3.4 All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chair of the Committee on Filler Metals and Allied Materials, for action.

A2.3.3.5 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.

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, shall 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

A4.1 The act of placing the AWS specification and classification designations and optional supplemental designators, if applicable, on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this "certification" is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped, and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01, *Filler Metal Procurement Guidelines*.

A4.2 (Optional) At the option and expense of the purchaser, acceptance may be based on the results of any or all of the tests required by this specification made on the GTAW test assembly described in Fig. A2.

One all-weld-metal round tension test specimen, as specified in the Tension Tests section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in Fig. A2. The tensile specimen shall have a nominal diameter of 0.350 in. [9.0 mm] and a nominal gage length-to-diameter ratio of 4:1. The specimen shall be tested as specified in Section 12.1. Other dimensions of the tension test specimen shall be as specified in the Tension Test section of AWS B4.0 [AWS B4.0M].

The Charpy V-Notch specimens shall be as specified in Section 13. Composite electrodes are normally not recommended for GTAW or PAW.

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:

(a) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)

(b) Number of welders and welding operators working in that space

(c) Rate of evolution of fumes, gases, or dust, according to the materials and processes used

(d) The proximity of the welders or welding operators 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

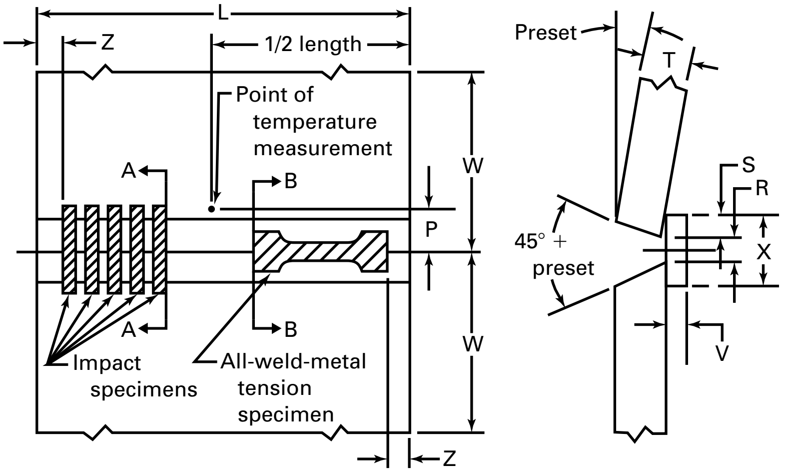
(e) The ventilation provided to the space in which the welding is done

A5.2 American National Standard Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the Section on Health Protection and Ventilation in that document.

A6. Welding Considerations

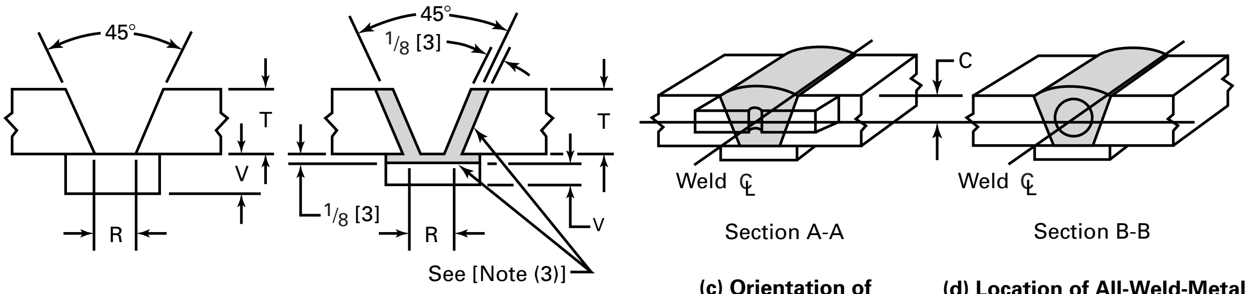
A6.1 Gas metal arc welding (GMAW) can be divided into three categories based on the mode of metal transfer. These modes are (1) spray (conventional or pulsed), (2) globular, and (3) short circuiting transfer. In the spray, pulsed spray, and globular modes, transfer occurs as distinct droplets that are detached from the electrode, transferring along the arc column into the weld pool. In the short circuiting mode, the metal is deposited during frequent short circuiting of the electrode in the molten pool.

FIG. A2 OPTIONAL GTAW GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS



Dimensions			
		in.	mm
C	Specimen Center	1/4	6.5
L	Length, min.	10	250
P	Point of Temperature Measurement	1	25
R	Root Opening	1/4	6.5
S	Backup Strip Overlap, min.	3/8	9
T	Thickness	1/2	13
V	Backup Strip Thickness, min.	1/4	6.5
W	Width, min.	5	125
X	Backup Strip Width, min.	1	25
Z	Discard, min.	1	25

(a) Test Plate Showing Location of Test Specimens



Standard test plate

Buttered test plate
(see footnote "a" of Table 6)

(c) Orientation of Impact Specimen

(d) Location of All-Weld-Metal Tension Specimen

(b) Groove Preparation of Test Plate

Test Conditions for Solid Rods [Notes (4) and (5)]		
Standard size [Note (5)]	3/32 in. [2.4 mm]	1/8 in. [3.2 mm]
Shielding gas	Argon [Note (6)]	Argon [Note (6)]
Nominal arc voltage	13 to 16 V	16 to 19 V
Nominal current, DCEN (DCEN = electrode negative)	220 to 250 A	250 to 280 A
Preheat/interpass temperature	See Table 7	See Table 7
Travel speed	4 to 6 in./min. [2.0 + 0.4 mm/sec.]	4 to 6 in./min. [2.0 + 0.4 mm/sec.]

NOTES:

1. Base metal shall be as specified in Table 6.
2. The surfaces to be welded shall be clean.
3. Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used. When required, edges of the grooves and the contacting face of the backing shall be buttered as shown. Any size of the electrode being tested may be used for buttering. See Table 6, Note a.
4. Test conditions for composite electrodes used as rods shall be as recommended by the manufacturer.
5. If sizes other than those shown above are tested, nominal current and arc voltage shall be changed as needed.
6. AWS A5.32 Class SG-A.
7. Postweld heat treatment shall be as specified in Table 7 for the classification under test.

A6.2 Spray Transfer

A6.2.1 The spray transfer mode, for carbon steel, is most commonly obtained with argon shielding gas mixtures with up to 5% of oxygen (AWS A5.32 Class SG-AO-X, where X is 1 to 5) or up to 15% carbon dioxide (AWS A5.32 Class SG-AC-Y, where Y is 5 to 15). A characteristic of these shielding gas mixtures is the smooth arc plasma through which hundreds of very fine droplets are transferred to the weld pool each second.

A6.2.2 Spray transfer with argon-oxygen (AWS A5.32 Class SG-AO-X) or argon-carbon dioxide (AWS A5.32 Class SG-AC-Y) shielding gas is, primarily, a function of current density, polarity, and resistance heating of the electrode. The high droplet rate (approximately 250 droplets per second) develops suddenly above a critical current level, commonly referred to as the transition current (for each size of electrode). Below this current, the metal is transferred in drops generally larger in diameter than the electrode and at a rate of from 10 to 20 per second (globular transfer). The transition current is also dependent, to some extent, on the chemical composition of the electrode. For $^{1}/_{16}$ in. [1.6 mm] diameter carbon steel electrodes, a transition current of 270 amperes (direct current, electrode positive [dcep]) is common. Alternating current is not recommended for this type of welding because it does not produce a stable arc.

A6.2.3 Pulsed Spray. Metal transfer in pulsed spray welding is similar to that of the spray transfer described above, but it occurs at a lower average current. The lower average current is made possible by rapid pulsing of the welding current between a high level, where metal will transfer rapidly in the spray mode, and a low level, where no transfer will take place. At a typical rate of 60 to 120 pulses per second, a melted drop is formed by the low current arc, which is then “squeezed off” by the high current pulse. This permits all-position welding.

A6.3 Globular Transfer. The mode of transfer that characterizes 100% CO_2 (AWS A5.32 Class SG-C) as a shielding gas is globular. Common practice with globular transfer is to use low arc voltage to minimize spatter. This shortens the arc length causing the arc to be “buried” and results in deeper penetration and better containment of spatter within the weld pool. Electrodes of 0.045 in. through $^{1}/_{16}$ in. [0.2 mm through 1.6 mm] diameter normally are used at welding currents in the range of 275 to 400 amperes (dcep), for this type of transfer. The rate at which droplets (globules) are transferred ranges from 20 to 70 per second, depending on the size of the electrode, the amperage, polarity, and arc voltage.

A6.4 Short Circuiting Transfer. This mode of transfer is obtained with small diameter electrodes (0.030 to 0.045 in. [0.8 to 1.2 mm]) using low arc voltages and amperages, and a power source designed for short circuiting transfer. The electrode short-circuits to the weld metal, usually at a rate of from 50 to 200 times per second. Metal is transferred with each short circuit, but not across the arc. Short circuiting gas metal arc welding of carbon steel is done most commonly with mixtures of argon and CO_2 (AWS A5.32 Class SG-AC-Y) as the shielding gas or with CO_2 (AWS A5.32 Class SG-C) alone. The penetration of such welds is greater with CO_2 than it is with argon-CO_2 mixtures. Mixtures of 50% to 80% argon with CO_2 remainder (AWS A5.32 Class SG-AC-Y, where Y is 20 to 50) can be advantageous for thin material. However shielding gas mixtures of 50% to 70% argon with CO_2 remainder (AWS A5.32 Class SG-AC-Y, where Y is 30 to 50) are unstable in the gaseous state and must be mixed from single gas components immediately prior to use. They provide low penetration, higher short circuiting rates, and lower minimum currents and voltages than CO_2 alone does. This can be an advantage in welding thin plate.

Regardless of gas used, the total heat input limits fusion and penetration. Therefore, many users limit this process to material thickness not exceeding $^{1}/_{2}$ in. [13 mm].

A7. Description and Intended Use of Electrodes and Rods

A7.1 The following is a description of the characteristics and intended use of the filler metals classified by this specification. The designations and the chemical composition requirements for all classifications are given in Tables 1 and 2 of this specification. The mechanical properties of weld metals from filler metals of the various classifications will conform to the minimum requirements stated in Tables 3 and 4 of the specification.

A7.2 It should be noted that weld properties may vary appreciably depending on filler metal size and current used, plate thickness, joint geometry, preheat and inter-pass temperatures, surface conditions, base-metal composition and extent of alloying with the filler metal, and shielding gas. For example, when filler metals having an analysis within the range of Table 1 are deposited, the weld metal chemical composition will not vary greatly from the as-manufactured composition of the filler metal when used with argon-oxygen shielding gas. However, they will show a considerable reduction in the content of manganese, silicon, and other deoxidizers when used with CO_2 as the shielding gas.

A7.3 ER70S-A1 [ER49S-A1] Classification ($^{1}/_{2}$ Mo). Filler metal of this classification is similar to many of the carbon steel filler metals classified in AWS A5.18/A5.18M, except that 0.5 percent molybdenum has been added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance; however, it will likely reduce the notch toughness of the weld metal. Typical applications include the welding of C-Mo base metals such as ASTM 204 plate and A335-P1 pipe.

A7.4 ER80S-B2 [ER55S-B2] and E80C-B2 [E55C-B2] Classification (1-$^1/_4$ Cr-$^1/_2$ Mo). Filler metals of these classifications are used to weld $^1/_2$Cr-$^1/_2$Mo, 1Cr-$^1/_2$Mo, and 1-$^1/_4$Cr-$^1/_2$Mo steels for elevated temperatures and corrosive service. They are also used for joining dissimilar combinations of Cr-Mo and carbon steels. All transfer modes of the GMAW process may be used. Careful control of preheat, interpass temperatures, and postheat is essential to avoid cracking. These electrodes are classified after postweld heat treatment. Special care must be used when using them in the as-welded condition due to higher strength levels.

A7.5 ER70S-B2L [ER49S-B2L] and E70C-B2L [E49C-B2L] Classifications (1-$^1/_4$ Cr-$^1/_2$ Mo). These filler metals are identical to the types ER80S-B2 [ER55S-B2] and E80C-B2 [E55C-B2] except for the low-carbon content (0.05 percent maximum) and thus the lower strength levels. This also reduces hardness and under some conditions improves corrosion resistance. This alloy exhibits greater resistance to cracking and is more suitable for welds to be left in the as-welded condition or when the accuracy of the postweld heat treatment operation is questionable. These classifications were previously ER80S-B2L and E80C-B2L in the A5.28-79 specification. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

A7.6 ER90S-B3 [ER62S-B3] and E90C-B3 [E62C-B3] Classifications (2-$^1/_4$Cr-1 Mo). Filler metals of these classifications are used to weld the 2-$^1/_4$Cr-1Mo steels used for high-temperature/high-pressure piping and pressure vessels. These may also be used for joining combinations of Cr-Mo and carbon steel. All GMAW modes may be used. Careful control of preheat, interpass temperatures, and postweld heat treatment is essential to avoid cracking. These electrodes are classified after postweld heat treatment. Special care must be used when using them in the as-welded condition due to higher strength levels.

A7.7 ER80S-B3L [ER55S-B3L] and E80C-B3L [E55C-B3L] Classifications (2-$^1/_4$ Cr-1 Mo). These filler metals are identical to the types ER90S-B3 [ER62S-B3] and E90C-B3 [E62C-B3] except for the low-carbon content (0.05 percent maximum) and, therefore, the lower strength levels. These alloys exhibit greater resistance to cracking and are more suitable for welds to be left in the as-welded condition. These classifications were previously ER90S-B3L and E90C-B3L in the A5.28-79 specification. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

A7.8 ER80S-Ni1 [ER55S-Ni1] and E80C-Ni1 [E55CNi1] Classifications (1.0 Ni). These filler metals deposit weld metal similar to E8018-C3 covered electrodes, and are used for welding low-alloy high-strength steels requiring good toughness at temperatures as low as −50°F [−45°C].

A7.9 ER80S-Ni2 [ER55S-Ni2], E70C-Ni2 [E49C-Ni2], and E80C-Ni2 [E55C-Ni2] Classifications (2-$^1/_4$ Ni). These filler metals deposit weld metal similar to E8018-C1 electrodes. Typically, they are used for welding 2.5 nickel steels and other materials requiring good toughness at temperatures as low as −80°F [−60°C].

A7.10 ER80S-Ni3 [ER55S-Ni3] and E80C-Ni3 [E55CNi3] Classifications (3-$^1/_4$ Ni). These filler metals deposit weld metal similar to E8018-C2 electrodes. Typically they are used for welding 3.5 nickel steels for low-temperature service.

A7.11 ER80S-D2 [ER55S-D2], ER90S-D2 [ER62SD2], and E90C-D2 [E62C-D2] Classifications ($^1/_2$ Mo). The ER80S-D2 [ER55S-D2] and ER90S-D2 [ER62S-D2] classifications have the same chemical requirements as the E70S-1B classification of AWS A5.18-69. The differences between the ER80S-D2 [ER55S-D2] and the ER90S-D2 [ER62S-D2] classifications are the change in shielding gas and the mechanical property requirements specified in Table 3. Filler metals of these classifications contain molybdenum for increased strength and a high level of deoxidizers (Mn and Si) to control porosity when welding with CO2 (AWS A5.32 Class SG-C) as the shielding gas. They will give radiographic quality welds with excellent bead appearance in both ordinary and difficult-to-weld carbon and low-alloy steels. They exhibit excellent out-of-position welding characteristics with the short circuiting and pulsed arc processes.

The combination of weld soundness and strength makes filler metals of these classifications suitable for single and multiple-pass welding of a variety of carbon and low-alloy, higher strength steels in both the as-welded and postweld heat-treated conditions. The chemical composition of these classifications differs from those of the "–D2" type electrodes in AWS A5.5.

A7.12 ER100S-1 [ER69S-1], ER110S-1 [ER76S-1], and ER120S-1 [ER83S-1] Classifications. These filler metals deposit high-strength, very tough weld metal for critical applications. Originally developed for welding HY-80 and HY-100 steels for military applications, they are also used for a variety of structural applications where tensile strength requirements exceed 100 ksi [690 MPa], and excellent toughness is required to temperatures as low as −60°F [−50°C]. Mechanical properties obtained from weld deposits made with electrodes of these classifications will vary depending on the heat input used.

A7.13 ER80S-B6 [ER55S-B6], E80C-B6 [E55C-B6] Classification (5 Cr-$^1/_2$ Mo). This classification contains about 4.5 to 6.0 percent chromium and about 0.5 percent molybdenum. It is used for welding material of similar composition, usually in the form of pipe or tubing. The alloy is an air-hardening material and, therefore, when welding with this filler metal, preheat and postweld heat treatment are required. This electrode is similar to that previously classified as ER502 in AWS A5.9-93.

A7.14 ER80S-B8 [ER55S-B8], E80C-B8 [E55C-B8] Classification (9 Cr-1 Mo). This classification contains 8.0 to 10.5 percent chromium and about 1.0 percent molybdenum. Filler metal of this classification is used for welding base metal of similar compositions, usually in the form of pipe or tubing. The alloy is an air-hardening material, and therefore, when welding with this filler metal, preheating and postweld heat treatment are required. This electrode is similar to that previously classified as ER505 in AWS A5.9-93.

A7.15 ER90S-B9 [ER62S-B9], E90C-B9 [E62C-B9] Classification [9 Cr-1 Mo-0.2V-0.07Nb(Cb)]. ER90SB9 [ER62S-B9] and E90C-B9 [E62C-B9] are 9Cr-1Mo wires modified with niobium (columbium) and vanadium designed to provide strength, toughness, fatigue life, oxidation resistance and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.

In addition to the classification requirements in this specification, either impact toughness or high-temperature creep strength properties should be determined. Due to the influence of various levels of carbon and niobium (columbium), specific values and testing must be agreed to by the supplier and purchaser.

Thermal treatment of this alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation into martensite (Mf) is relatively low; therefore, upon completion of welding and before post weld heat treatment, it is recommended to allow the weldment to cool to at least 200°F [93°C] to maximize transformation to martensite. The maximum allowable temperature for post weld heat treatment is also critical in that the lower transformation temperature (Ac1) is also comparably low. To aid in allowing for an adequate post weld heat treatment, the restriction of Mn + Ni has been imposed (see Table 1 footnote j, and Table 2 footnote g). The combination of Mn and Ni tends to lower the Ac1 temperature to the point where the PWHT temperature approaches the Ac1, possibly causing partial transformation of the micro-structure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac1 to avoid this partial transformation.

A7.16 E90C-K3 [E62C-K3], E100C-K3 [E69C-K3], E110C-K3 [E76C-K3] Classifications. Some electrodes in these classifications produce weld metal with a typical composition of 1.5 percent nickel and up to 0.35 percent molybdenum. These electrodes are used on many high-strength applications ranging from 80- 110 ksi (550-760 MPa) minimum yield strength and are primarily intended for as-welded applications. Typical applications would include the welding of ships, offshore structures, and many other structural applications where low-temperature toughness is required. Steels welded would include HY-80, HY-100, ASTM A 710, A 514, A 517, and other similar high-strength steels. Other electrodes of these types produce weld deposits with higher levels of manganese, nickel and molybdenum and usually have higher strength levels. Typical applications include the welding of HY-100, A 514, and A 517 steels.

A7.17 E110C-K4 [E76C-K4], E120C-K4 [E83C-K4] Classifications. Electrodes of these types produce weld deposits similar to that of the EXXC-K3 electrodes, with the addition of approximately 0.5 percent chromium. The additional alloy provides the higher strength necessary for many applications needing in excess of 120 000 psi [830 MPa] tensile, such as armor plate.

A7.18 E80C-W2 [E55C-W2] Classification (Weathering Steel). This classification has been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels such as A 242, A 588, and A 709 gr 50W. These special properties are achieved by the addition of about 0.5 percent copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, chromium and nickel additions are also introduced.

A7.19 ERXXS-G and EXXC-G Classifications. Electrodes and rods of the ERXXS-G and electrodes of the EXXC-G classifications are those filler metals not included in the preceding classes and for which only certain mechanical property requirements are specified. The electrodes are intended for single and multiple-pass applications. The filler metal supplier should be consulted for the composition, properties, characteristics, and intended use of these classifications (see Table 5 and Section A2.3 for further information).

A8. Special Tests

A8.1 It is recognized that supplementary tests may be required for certain applications. In such cases, additional tests to determine specific properties such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, may be required. AWS A5.01, *Filler Metal Procurement Guidelines*, contains provisions for ordering such tests. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

A8.2 Diffusible Hydrogen

A8.2.1 Hydrogen induced cracking of weld metal or the heat-affected zone (HAZ) generally is not a problem with plain carbon steels containing 0.3 percent or less carbon, nor with lower strength alloy steels. However, the electrodes classified in this specification are used to join higher carbon steels or low-alloy, high strength steels where hydrogen-induced cracking may be a serious problem.

A8.2.2 Gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) are generally considered to be low hydrogen welding processes. However, as the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. It may be appropriate to evaluate the diffusible hydrogen produced during welding with these processes. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in root beads), and toe or underbead cracks in the heat-affected zone.

A8.2.3 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 supplemental designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.

Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 8, are also understood to meet any higher electrode hydrogen limits, even though these are not necessarily designated along with the electrode classification. Therefore, for example an electrode designated as "H4" also meets the "H8" and "H16" requirements without being designated as such.

A8.2.4 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

A8.2.4.1 Surface Contamination. The welding consumable is not the only source of diffusible hydrogen in the process. For example, rust, primer coating, antispatter compounds, dirt and grease can all contribute to diffusible hydrogen levels in practice. Consequently, standard diffusible hydrogen tests for designation of welding consumables require test base material to be free from contamination. AWS A4.3 is specific as to the cleaning procedure for test base material. Surface contamination on the welding consumable being tested should always be representative of the product being delivered.

A8.2.4.2 Moisture in Shielding Gas. The shielding gas can also be a source of moisture entering the arc. Shielding gases as classified in AWS A5.32/A5.32M have a maximum dew point specified which is considered "dry" enough for welding. Utilizing shielding gases with a specified maximum dew point ensures that the shielding gas does not become a source of moisture contamination. The shielding gas delivery conduit must also be designed and maintained to prevent the ingress of moisture into the shielding gas while the gas is being transported to the arc from its source.

A8.2.5 The use of a reference atmospheric condition during welding is necessary because the arc is always imperfectly shielded. Moisture from the air, distinct from that in the electrode or gas, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining a suitable gas flow rate and as short an arc length as possible consistent with a steady arc. At times, some air will mix with the gas and add its moisture to the other sources of diffusible hydrogen. It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. For this reason, it is appropriate to specify a reference atmospheric condition. The reference atmospheric condition of 10 grains of moisture per pound [1.43 grams per kilogram] of dry air is equivalent to 10% relative humidity at 70°F [18°C] at 29.92 in. Hg [760 mm Hg] barometric pressure. Actual conditions, measured using a calibrated psychrometer, that equal or exceed this reference condition provide assurance that the conditions during welding will not diminish the final results of the test.

A8.3 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 towards its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. This specification permits the aging of the tensile test specimens at elevated temperatures for up to 48 hours before subjecting them to testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrode deposits, especially when testing high strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds. The purchaser may, by mutual agreement with the supplier, have the thermal aging of the specimens prohibited for all mechanical testing done to Schedule I or J of AWS A5.01.

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 following classifications have been discontinued over the life of this specification (along with the year in which they were last included in the specification):

Discontinued Classification	Published	Replaced With
ER100S-2	1979	None
ER80S-B2L	1979	ER70S-B2L
E80C-B2L	1979	E70C-B2L
ER90S-B3L	1979	ER80S-B3L
E90C-B3L	1979	E80C-B3L

A10. General Safety Considerations

NOTE: 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 Section A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A10.2, ANSI Z49.1, Safety in Welding, Cutting and Allied Processes,[10] and applicable federal and state regulations.

A10.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.2 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	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
27	Thoriated Tungsten Electrodes
29	Grounding of Portable and Vehicle Mounted Welding Generators

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[10] ANSI standards are published by the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.

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SPECIFICATION FOR LOW-ALLOY STEEL ELECTRODES FOR FLUX CORED ARC WELDING

SFA-5.29/SFA-5.29M

(Identical with AWS Specification A5.29/A5.29M:2010. In case of dispute, the original AWS text applies.)

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1. Scope

1.1 This specification prescribes requirements for the classification of low-alloy steel electrodes for flux cored arc welding (FCAW) either with or without shielding gas. Iron is the only element whose content exceeds 10.5 percent in undiluted weld metal deposited by these electrodes. Metal cored low-alloy steel electrodes are not classified under this specification but are classified according to AWS A5.28/A5.28M.[1]

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 A9. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1[2] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.29 uses U.S. Customary Units. The specification A5.29M uses SI Units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing of electrodes or packaging or both under the A5.29 and A5.29M specifications.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard referred to applies.

2.1 The following AWS standards are referenced in the mandatory sections of this document:

(a) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(b) AWS A5.01, *Filler Metal Procurement Guidelines*

(c) AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*

(d) AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*

2.2 The following ANSI standard is referenced in the mandatory sections of this document:

(a) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.3 The following ASTM standards[3] are referenced in the mandatory sections of this document:

(a) ASTM A 36/A 36M, *Specification for Carbon Structural Steel*

(b) ASTM A 203/A 203M, *Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

(c) ASTM A 285/A 285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low-and Intermediate-Tensile Strength*

(d) ASTM A 302/A 302M, *Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel*

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[1] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[2] ANSI standards are published by the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

[3] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

(e) ASTM A 387/A 387M, *Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

(f) ASTM A 514/A 514M, *Specification for High-Yield Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding*

(g) ASTM A 537/A 537M, *Specification for Pressure Vessel Plates, Heat Treated, Carbon-Manganese-Silicon Steel*

(h) ASTM A 588/A 588M, *Specification for High-Strength Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick*

(i) ASTM DS-56 (SAE HS-1086), *Metals & Alloys in the Unified Numbering System*

(j) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(k) ASTM E 350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

(l) ASTM E 1032, *Standard Test Method for Radiographic Examination of Weldments*

2.4 The following MIL standards[4] are referenced in the mandatory sections of this document:

(a) MIL-S-16216, *Specification for Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)*

(b) MIL-S-24645, *Specification for Steel Plate, Sheet, or Coil, Age-Hardening Alloy, Structural, High Yield Strength (HSLA-80 and HSLA-100)*

(c) NAVSEA Technical Publication T9074-BDGIB-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.

2.5 The following ISO standard[5] is referenced in the mandatory sections of this document:

(a) ISO 544, *Welding consumables—Technical delivery conditions for welding filler materials—Type of product, dimensions, tolerances, and marking.*

3. Classification

3.1 The flux cored electrodes covered by the A5.29 specification utilize a classification system based upon the U.S. Customary Units and are classified according to the following:

(a) the mechanical properties of the weld metal, as specified in Table 1U,

(b) the positions of welding for which the electrodes are suitable, as shown in Fig. 1,

(c) certain usability characteristics of the electrode (including the presence or absence of a shielding gas) as specified in Table 2 and Fig. 1, and

(d) chemical composition of the weld metal, as specified in Table 7.

3.1M The flux cored electrodes covered by the A5.29M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the following:

(a) the mechanical properties of the weld metal, as specified in Table 1M,

(b) the positions of welding for which the electrodes are suitable, as shown in Fig. 1,

(c) certain usability characteristics of the electrode (including the presence or absence of a shielding gas) as specified in Table 2 and Fig. 1, and

(d) chemical composition of the weld metal, as specified in Table 7.

3.2 Electrodes classified under one classification shall not be classified under any other classification in this specification with the exception of the following: Gas shielded electrodes may be classified with 100% CO_2 (AWS A5.32 Class SG-C) shielding gas ("C" designator) and with a 75 to 80% argon/balance CO_2 (AWS A5.32 Class SG-AC-25 or SG-AC-20) shielding gas ("M" designator).

Electrodes may be classified under A5.29 using U.S. Customary Units, and/or under A5.29M using the International System of Units (SI). Electrodes classified under either classification system must meet all requirements for classification under that system. The classification system is shown in Fig. 1.

3.3 The electrodes classified under this specification are intended for flux cored arc welding either with or without an external shielding gas. Electrodes intended for use without external shielding gas, or with the shielding gases specified in Table 2 are not prohibited from use with any other process or shielding gas for which they are found suitable.

4. Acceptance

Acceptance[6] of the welding electrodes shall be in accordance with the provisions of AWS A5.01.

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[4] For inquiries regarding MIL-S-16216 and MIL-S-24645 refer to internet website: http://assist.daps.dla.mil/online. Applications for copies of NAVSEA Technical Publication T9074-BD-GIB-010/0300 should be addressed to the Naval Inventory Control Point, 700 Robins Avenue, Philadelphia, PA 19111-5094.

[5] ISO standards are published by the International Organization for Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

[6] See Section A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

TABLE 1U
A5.29 MECHANICAL PROPERTY REQUIREMENTS

AWS Classification(s)[a, b]	Condition[c]	Tensile Strength (ksi)	Yield Strength (ksi)	% Elongation Minimum	Charpy V-Notch Impact Energy[d] Minimum
E7XT5-A1C, -A1M	PWHT	70-90	58 min.	20	20 ft·lbf @ -20°F
E8XT1-A1C, -A1M	PWHT	80-100	68 min.	19	Not Specified
E8XT1-B1C, -B1M, -B1LC, -B1LM	PWHT	80-100	68 min.	19	Not Specified
E8XT1-B2C, -B2M, -B2HC, -B2HM, -B2LC, -B2LM E8XT5-B2C, -B2M, -B2LC, -B2LM	PWHT	80-100	68 min.	19	Not Specified
E9XT1-B3C, -B3M, -B3LC, -B3LM, -B3HC, -B3HM E9XT5-B3C, -B3M	PWHT	90-110	78 min.	17	Not Specified
E10XT1-B3C, -B3M	PWHT	100-120	88 min.	16	Not Specified
E8XT1-B6C,[e]-B6M,[e]-B6LC,[e]-B6LM,[e] E8XT5-B6C,[e]-B6M,[e]-B6LC,[e]-B6LM[e]	PWHT	80-100	68 min.	19	Not Specified
E8XT1-B8C,[e]-B8M,[e]-B8LC,[e]-B8LM[e] E8XT5-B8C,[e]-B8M,[e]-B8LC,[e]-B8LM[e]	PWHT	80-100	68 min.	19	Not Specified
E9XT1-B9C, -B9M	PWHT	90-120	78 min.	16	Not Specified
E6XT1-Ni1C, -Ni1M	AW	60-80	50 min.	22	20 ft·lbf @ -20°F
E7XT6-Ni1	AW	70-90	58 min.	20	20 ft·lbf @ -20°F
E7XT8-Ni1	AW	70-90	58 min.	20	20 ft·lbf @ -20°F
E8XT1-Ni1C, -Ni1M	AW	80-100	68 min.	19	20 ft·lbf @ -20°F
E8XT5-Ni1C, -Ni1M	PWHT	80-100	68 min.	19	20 ft·lbf @ -60°F
E7XT8-Ni2	AW	70-90	58 min.	20	20 ft·lbf @ -20°F
E8XT8-Ni2	AW	80-100	68 min.	19	20 ft·lbf @ -20°F
E8XT1-Ni2C, -Ni2M	AW	80-100	68 min.	19	20 ft·lbf @ -40°F
E8XT5-Ni2C,[f]-Ni2M[f]	PWHT	80-100	68 min.	19	20 ft·lbf @ -75°F
E9XT1-Ni2C, -Ni2M	AW	90-110	78 min.	17	20 ft·lbf @ -40°F
E8XT5-Ni3C,[f]-Ni3M[f]	PWHT	80-100	68 min.	19	20 ft·lbf @ -100°F
E9XT5-Ni3C,[f]-Ni3M[f]	PWHT	90-110	78 min.	17	20 ft·lbf @ -100°F
E8XT11-Ni3	AW	80-100	68 min.	19	20 ft·lbf @ 0°F
E9XT1-D1C, -D1M	AW	90-110	78 min.	17	20 ft·lbf @ -40°F
E9XT5-D2C, -D2M	PWHT	90-110	78 min.	17	20 ft·lbf @ -60°F
E10XT5-D2C, -D2M	PWHT	100-120	88 min.	16	20 ft·lbf @ -40°F
E9XT1-D3C, -D3M	AW	90-110	78 min.	17	20 ft·lbf @ -20°F
E8XT5-K1C, -K1M	AW	80-100	68 min.	19	20 ft·lbf @ -40°F
E7XT7-K2	AW	70-90	58 min.	20	20 ft·lbf @ -20°F
E7XT4-K2	AW	70-90	58 min.	20	20 ft·lbf @ 0°F
E7XT8-K2	AW	70-90	58 min.	20	20 ft·lbf @ -20°F
E7XT11-K2	AW	70-90	58 min.	20	20 ft·lbf @ +32°F

TABLE 1U
A5.29 MECHANICAL PROPERTY REQUIREMENTS (CONT'D)

AWS Classification(s)[a, b]	Condition[c]	Tensile Strength (ksi)	Yield Strength (ksi)	% Elongation Minimum	Charpy V-Notch Impact Energy[d] Minimum
E8XT1-K2C, -K2M E8XT5-K2C, -K2M	AW	80-100	68 min.	19	20 ft·lbf @ -20°F
E9XT1-K2C, -K2M	AW	90-110	78 min.	17	20 ft·lbf @ 0°F
E9XT5-K2C, -K2M	AW	90-110	78 min.	17	20 ft·lbf @ -60°F
E10XT1-K3C, -K3M	AW	100-120	88 min.	16	20 ft·lbf @ 0°F
E10XT5-K3C, -K3M	AW	100-120	88 min.	16	20 ft·lbf @ -60°F
E11XT1-K3C, -K3M	AW	110-130	98 min.	15	20 ft·lbf @ 0°F
E11XT5-K3C, -K3M	AW	110-130	98 min.	15	20 ft·lbf @ -60°F
E11XT1-K4C, -K4M	AW	110-130	98 min.	15	20 ft·lbf @ 0°F
E11XT5-K4C, -K4M	AW	110-130	98 min.	15	20 ft·lbf @ -60°F
E12XT5-K4C, -K4M	AW	120-140	108 min.	14	20 ft·lbf @ -60°F
E12XT1-K5C, -K5M	AW	120-140	108 min.	14	Not Specified
E7XT5-K6C, -K6M	AW	70-90	58 min.	20	20 ft·lbf @ -75°F
E6XT8-K6	AW	60-80	50 min.	22	20 ft·lbf @ -20°F
E7XT8-K6	AW	70-90	58 min.	20	20 ft·lbf @ -20°F
E10XT1-K7C, -K7M	AW	100-120	88 min.	16	20 ft·lbf @ -60°F
E9XT8-K8	AW	90-110	78 min.	17	20 ft·lbf @ -20°F
E10XT1-K9C, -K9M	AW	100-120[g]	82-97	18	35 ft·lbf @ -60°F
E8XT1-W2C, -W2M	AW	80-100	68 min.	19	20 ft·lbf @ -20°F
EXXTX-G,[h]-GC,[h]-GM[h]	The weld deposit composition, condition of test (AW or PWHT) and Charpy V-Notch impact properties are as agreed upon between the supplier and purchaser. Requirements for the tension test, positionality, slag system and shielding gas, if any, conform to those indicated by the digits used.				
EXXTG-X[h]	The slag system, shielding gas, if any, condition of test (AW or PWHT) and Charpy V-Notch impact properties are as agreed upon between the supplier and purchaser. Requirements for the tension test, positionality and weld deposit composition conform to those indicated by the digits used.				
EXXTG-G[h]	The slag system, shielding gas, if any, condition of test (AW or PWHT), Charpy V-Notch impact properties and weld deposit composition are as agreed upon between the supplier and purchaser. Requirements for the tension test and positionality conform to those indicated by the digits used.				

NOTES:

a. The "Xs" in actual classification will be replaced with the appropriate designators. See Fig. 1.

b. The placement of a "G" in a designator position indicates that those properties have been agreed upon between the supplier and purchaser.

c. AW = As Welded. PWHT = Postweld heat treated in accordance with Table 6 and 9.4.1.2.

d. Electrodes with the optional supplemental designator "J" shall meet the minimum Charpy V-Notch impact energy requirement for its classification at a test temperature 20°F lower than the test temperature shown in Table 1U for its classification.

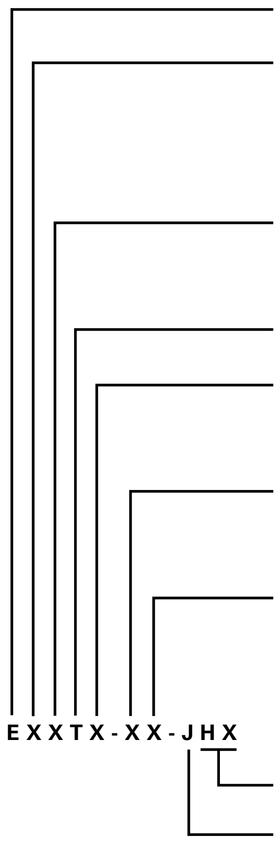
e. These electrodes are presently classified E502TX-X or E505TX-X in AWS A5.22-95. With the next revision of A5.22 they will be removed and exclusively listed in this specification.

f. PWHT temperatures in excess of 1150°F will decrease the Charpy V-Notch impact properties.

g. For this classification (E10XT1-K9C, -K9M) the tensile strength range shown is not a requirement. It is an approximation.

h. The tensile strength, yield strength, and % elongation requirements for EXXTX-G, -GC, -GM; EXXTG-X and EXXTG-G electrodes are as shown in this table for other electrode classifications (not including the E10XT1-K9C, -K9M classifications) having the same tensile strength designator.

FIG. 1 A5.29/A5.29M CLASSIFICATION SYSTEM



Mandatory Classification Designators[1]

Designates an electrode.

Tensile strength designator. For A5.29 this designator indicates the minimum tensile strength (when multiplied by 10 ksi) of the weld metal when the weld is made in the manner prescribed by this specification. Two digits are used for weld metal of 100 ksi minimum tensile strength and higher. See Table 1U. For A5.29M two digits are used to indicate the minimum tensile strength (when multiplied by 10 MPa). See Table 1M.

Positionality designator. This designator is either “0” or “1.” “0” is for flat and horizontal positions only. “1” is for all positions (flat, horizontal, vertical with downward progression and/or vertical with upward progression and overhead).

This designator identifies the electrode as a flux cored electrode.

Usability designator. This designator is the number 1, 4, 5, 6, 7, 8, or 11 or the letter “G.” The number refers to the usability of the electrode (see Section A7 in Annex A). The letter “G” indicates that the polarity and general operating characteristics are not specified.

Deposit composition designator. Two, three or four digits are used to designate the chemical composition of the deposited weld metal (see Table 7). The letter “G” indicates that the chemical composition is not specified.

Shielding gas designator.[2] Indicates the type of shielding gas used for classification. The letter “C” indicates a shielding gas of 100% CO_2. The letter “M” indicates a shielding gas of 75–80% Argon/balance CO_2. When no designator appears in this position, it indicates that the electrode being classified is self-shielded and that no external shielding gas was used.

Optional Supplemental Designators[3]

Optional supplemental diffusible hydrogen designator (see Table 9).

The letter “J” when present in this position designates that the electrode meets the requirements for improved toughness and will deposit weld metal with Charpy V-Notch properties of at least 20 ft · lbf [27J] at a test temperature of 20°F [10°C] lower than the temperature shown for that classification in Table 1U [Table 1M].

NOTES:

1. The combination of these designators constitutes the flux cored electrode classification. Note that specific chemical compositions are not always identified with specific mechanical properties in the specification. A supplier is required by the specification to include the mechanical properties appropriate for a particular electrode in the classification of the electrode. Thus, for example, a complete designation is E80T5-Ni3. EXXT5-Ni3 is not a complete classification.
2. See AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*.
3. These designators are optional and do not constitute a part of the flux cored electrode classification.

TABLE 1M
A5.29M MECHANICAL PROPERTY REQUIREMENTS

AWS Classification(s)[a, b]	Condition[c]	Tensile Strength (MPa)	Yield Strength (MPa)	% Elongation Minimum	Charpy V-Notch Impact Energy[d] Minimum
E49XT5-A1C, -A1M	PWHT	490-620	400 min.	20	27 Joules @ -30°C
E55XT1-A1C, -A1M	PWHT	550-690	470 min.	19	Not Specified
E55XT1-B1C, -B1M, -B1LC, -B1LM	PWHT	550-690	470 min.	19	Not Specified
E55XT1-B2C, -B2M, -B2HC, -B2HM, -B2LC, -B2LM E55XT5-B2C, -B2M, -B2LC, -B2LM	PWHT	550-690	470 min.	19	Not Specified
E62XT1-B3C, -B3M, -B3LC, -B3LM, -B3HC, -B3HM E62XT5-B3C, -B3M	PWHT	620-760	540 min.	17	Not Specified
E69XT1-B3C, -B3M	PWHT	690-830	610 min.	16	Not Specified
E55XT1-B6C, -B6M, -B6LC, -B6LM E55XT5-B6C, -B6M, -B6LC, -B6LM	PWHT	550-690	470 min.	19	Not Specified
E55XT1-B8C, -B8M, -B8LC, -B8LM E55XT5-B8C, -B8M, -B8LC, -B8LM	PWHT	550-690	470 min.	19	Not Specified
E62XT1-B9C, -B9M	PWHT	620-830	540 min.	16	Not Specified
E43XT1-Ni1C, -Ni1M	AW	430-550	340 min.	22	27 Joules @ -30°C
E49XT6-Ni1	AW	490-620	400 min.	20	27 Joules @ -30°C
E49XT8-Ni1	AW	490-620	400 min.	20	27 Joules @ -30°C
E55XT1-Ni1C, -Ni1M	AW	550-690	470 min.	19	27 Joules @ -30°C
E55XT5-Ni1C, -Ni1M	PWHT	550-690	470 min.	19	27 Joules @ -50°C
E49XT8-Ni2	AW	490-620	400 min.	20	27 Joules @ -30°C
E55XT8-Ni2	AW	550-690	470 min.	19	27 Joules @ -30°C
E55XT1-Ni2C, -Ni2M	AW	550-690	470 min.	19	27 Joules @ -40°C
E55XT5-Ni2C,[e]-Ni2M[e]	PWHT	550-690	470 min.	19	27 Joules @ -60°C
E62XT1-Ni2C, -Ni2M	AW	620-760	540 min.	17	27 Joules @ -40°C
E55XT5-Ni3C,[e]-Ni3M[e]	PWHT	550-690	470 min.	19	27 Joules @ -70°C
E62XT5-Ni3C,[e]-Ni3M[e]	PWHT	620-760	540 min.	17	27 Joules @ -70°C
E55XT11-Ni3	AW	550-690	470 min.	19	27 Joules @ -20°C
E62XT1-D1C, -D1M	AW	620-760	540 min.	17	27 Joules @ -40°C
E62XT5-D2C, -D2M	PWHT	620-760	540 min.	17	27 Joules @ -50°C
E69XT5-D2C, -D2M	PWHT	690-830	610 min.	16	27 Joules @ -40°C
E62XT1-D3C, -D3M	AW	620-760	540 min.	17	27 Joules @ -30°C
E55XT5-K1C, -K1M	AW	550-690	470 min.	19	27 Joules @ -40°C
E49XT7-K2	AW	490-620	400 min.	20	27 Joules @ -30°C
E49XT4-K2	AW	490-620	400 min.	20	27 Joules @ -20°C
E49XT8-K2	AW	490-620	400 min.	20	27 Joules @ -30°C
E49XT11-K2	AW	490-620	400 min.	20	27 Joules @ 0°C

TABLE 1M
A5.29M MECHANICAL PROPERTY REQUIREMENTS (CONT'D)

AWS Classification(s)[a, b]	Condition[c]	Tensile Strength (MPa)	Yield Strength (MPa)	% Elongation Minimum	Charpy V-Notch Impact Energy[d] Minimum
E55XT1-K2C, -K2M E55XT5-K2C, -K2M	AW	550-690	470 min.	19	27 Joules @ -30°C
E62XT1-K2C, -K2M	AW	620-760	540 min.	17	27 Joules @ -20°C
E62XT5-K2C, -K2M	AW	620-760	540 min.	17	27 Joules @ -50°C
E69XT1-K3C, -K3M	AW	690-830	610 min.	16	27 Joules @ -20°C
E69XT5-K3C, -K3M	AW	690-830	610 min.	16	27 Joules @ -50°C
E76XT1-K3C, -K3M	AW	760-900	680 min.	15	27 Joules @ -20°C
E76XT5-K3C, -K3M	AW	760-900	680 min.	15	27 Joules @ -50°C
E76XT1-K4C, -K4M	AW	760-900	680 min.	15	27 Joules @ -20°C
E76XT5-K4C, -K4M	AW	760-900	680 min.	15	27 Joules @ -50°C
E83XT5-K4C, -K4M	AW	830-970	745 min.	14	27 Joules @ -50°C
E83XT1-K5C, -K5M	AW	830-970	745 min.	14	Not Specified
E49XT5-K6C, -K6M	AW	490-620	400 min.	20	27 Joules @ -60°C
E43XT8-K6	AW	430-550	340 min.	22	27 Joules @ -30°C
E49XT8-K6	AW	490-620	400 min.	20	27 Joules @ -30°C
E69XT1-K7C, -K7M	AW	690-830	610 min.	16	27 Joules @ -50°C
E62XT8-K8	AW	620-760	540 min.	17	27 Joules @ -30°C
E69XT1-K9C, -K9M	AW	690-830f	560-670	18	47 Joules @ -50°C
E55XT1-W2C, -W2M	AW	550-690	470 min.	19	27 Joules @ -30°C
EXXTX-G,[g]-GC,[g]-GM[g]	The weld deposit composition, condition of test (AW or PWHT) and Charpy V-Notch impact properties are as agreed upon between the supplier and purchaser. Requirements for the tension test, positionality, slag system and shielding gas, if any, conform to those indicated by the digits used.				
EXXTG-X[g]	The slag system, shielding gas, if any, condition of test (AW or PWHT) and Charpy V-Notch impact properties are as agreed upon between the supplier and purchaser. Requirements for the tension test, positionality and weld deposit composition conform to those indicated by the digits used.				
EXXTG-G[g]	The slag system, shielding gas, if any, condition of test (AW or PWHT), Charpy V-Notch impact properties and weld deposit composition are as agreed upon between the supplier and purchaser. Requirements for the tension test and positionality conform to those indicated by the digits used.				

NOTES:

a. The "Xs" in actual classification will be replaced with the appropriate designators. See Fig. 1.

b. The placement of a "G" in a designator position indicates that those properties have been agreed upon between the supplier and purchaser.

c. AW = As Welded. PWHT = Postweld heat treated in accordance with Table 6 and 9.4.1.2.

d. Electrodes with the optional supplemental designator "J" shall meet the minimum Charpy V-Notch impact energy requirement for its classification at a test temperature 10°C lower than the test temperature shown in Table 1M for its classification.

e. PWHT temperatures in excess of 620°C will decrease the Charpy V-Notch impact properties.

f. For this classification (E69XT1-K9C, -K9M) the tensile strength range shown is not a requirement. It is an approximation.

g. The tensile strength, yield strength, and % elongation requirements for EXXTX-G, -GC, -GM; EXXTG-X and EXXTG-G electrodes are as shown in this table for other electrode classifications (not including the E69XT1-K9C, -K9M classifications) having the same tensile strength designator.

TABLE 2
ELECTRODE USABILITY REQUIREMENTS

Usability Designator	AWS Classification	Position of Welding[a,b]	External Shielding[c]	Polarity[d]	Application[e]
1	EX0T1-XC	H, F	CO_2	DCEP	M
	EX0T1-XM		75-80 Ar/bal CO_2		
	EX1T1-XC	H, F, VU, OH	CO_2		
	EX1T1-XM		75-80 Ar/bal Co_2		
4	EX0T4-X	H, F	None	DCEP	M
5	EX0T5-XC	H, F	CO_2	DCEP	M
	EX0T5-XM		75-80 Ar/bal CO_2		
	EX1T5-XC	H, F, VU, OH	CO_2	DCEP or DCEN[f]	
	EX1T5-XM		75-80 Ar/bal CO_2		
6	EX0T6-X	H, F	None	DCEP	M
7	EX0T7-X	H, F	None	DCEN	M
	EX1T7-X	H, F, VU, OH			
8	EX0T8-X	H, F	None	DCEN	M
	EX1T8-X	H, F, VU, OH			
11	EX0T11-X	H, F	None	DCEN	M
	EX1T11-X	H, F, VD, OH			
G	EX0TX-G	H, F	None	(g)	M
	EX0TX-GC		CO_2	(g)	
	EX0TX-GM		75-80 Ar/bal CO_2	(g)	
	EX0TX-X		Not Specified	Not Specified	
	EX0TX-G		Not Specified	Not Specified	
	EX1TX-G	H, F, VU or VD, OH	None	(g)	M
	EX1TX-GC		CO_2	(g)	
	EX1TX-GM		75-80 Ar/bal CO_2	(g)	
	EX1TG-X		Note Specified	Not Specified	
	EX1TG-G		Note Specified	Not Specified	

NOTES:

a. H = horizontal position, F = flat position, OH = overhead position, VU = vertical position with upward progression, VD = vertical position with downward progression.

b. Electrode sizes suitable for out -of-position welding, i.e., welding positions other than flat or horizontal, are usually those sizes that are smaller than $\frac{3}{32}$ in (2.4 mm) size or the nearest one called for in 9.4.1 for the groove weld. For that reason, electrodes meeting the requirements for the groove weld tests and the fillet weld tests may be classified as EX1TX-XX (where X represents the tensile strength, usability deposit composition and shielding gas, if any, designators) regardless of their size. See Section A7 in Annex A and Figure 1 for more information.

c. Properties of weld metal from electrodes that are used with external shielding gas will vary according to the shielding gas employed. Electrodes classified with a specific shielding gas should not be used with other shielding gases without first consulting the manufacture of the electrodes.

d. The term "DCEP" refers to direct current electrode positive (dc, reverse polarity). The term "DCEN" refers to direct current electrode negative (dc, straight polarity).

e. M = suitable for use on either single or multiple pass applications.

f. Some EX1T5-XC, -XM electrodes may be recommended for use on DCEN for improved out-of-position welding. Consult the manufacturer for the recommended polarity.

g. The polarity for electrodes with usability designators for other than G is as prescribed for those designators in this table.

TABLE 3
TESTS REQUIRED FOR CLASSIFICATION

AWS Classification(s)	Chemical Analysis	Radiographic Test	Tension Test	Impact Test	Fillet Weld Test
EXXT1-XC, -XM EX0T4-X EXXT5-XC, -XM EX0T6-X EXXT7-X EXXT8-X EXXT11-X	R	R	R	(a)	R[b]
E10XTX-K9X [E69XTX-K9X]	R	R[c]	R[c]	(a), (c)	R[b]
EXXTX-G, -GC, -GM	(d)	R	R	(d)	R[b]
EXXTG-X	R	R	R	(d)	R[b]
EXXTG-G	(d)	R	R	(d)	R[b]

NOTES:
a. The Charpy V-Notch impact test is required when the classification requires minimum impact properties as specified in Table 1U (Table 1M).
b. For the fillet weld test, electrodes classified for downhand welding (EX0TX-XX electrodes) shall be tested in the horizontal position. Electrodes classified for all position welding (EX1TX-XX electrodes) shall be tested in both the vertical and overhead positions.
c. The groove weld for this classification shall be welded in the vertical position with upward progression. See A7.9.4.9 in Annex A.
d. As agreed upon between supplier and purchaser.

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification designations to the product, the manufacturer certifies that the product meets the requirements of this specification.[7]

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1,000 psi for tensile and yield strength for A5.29 [or to the nearest 10 MPa for tensile and yield strength for A5.29M] and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities in accordance with the rounding-off method given in ASTM E 29.

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 3. The purpose of these tests is to determine the mechanical properties, soundness, and chemical composition of the weld metal, and the usability of the electrode. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 14.

7.2 The optional supplemental test for diffusible hydrogen in Section 15 is not required for classification, but is included for an optional electrode designation as agreed to between the purchaser and supplier. Another optional supplemental designator (J) may be used to indicate Charpy impact testing at lower than standard temperature (see Fig. 1).

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material, specimens or samples for retest may be taken from the original test assembly or 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 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 test requirement. That test shall be repeated, following proper specified procedures. In this

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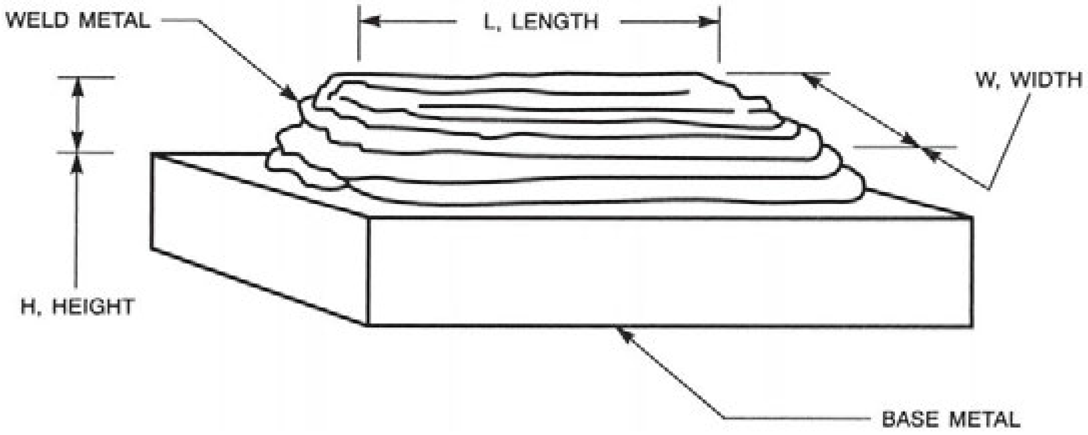
[7] See Section A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

FIG. 2 PAD FOR CHEMICAL ANALYSIS OF UNDILUTED WELD METAL



Weld Pad Size, Minimum					
Length, L		Width, W		Height, H	
in.	mm	in.	mm	in.	mm
1½	38	½	12	½	12

NOTES:

1. Base metal of any convenient size, of the type specified in Table 4, 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, using the specified shielding gas (if any), using the polarity as specified in Table 2 and following the heat input requirements specified in Table 5.
4. 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 with the amperage employed. The weave shall be limited to 6 times the electrode diameter.
5. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C].
6. The test assembly may be quenched in water (temperature unimportant) between passes to control interpass temperature.
7. The minimum completed pad size shall be that shown above. The sample to be tested in Section 10 shall be taken from weld metal that is at least ⅜ in. [10 mm] above the original base metal surface. See Table 4, Note c, for requirements when using ASTM A 36 or A 285 base steels.

case, the requirement for doubling the number of test specimens does not apply.

9. Test Assemblies

9.1 Two or three weld test assemblies are required, depending on the classification of the electrode and the manner in which the tests are conducted. They are as follows:

(a) the weld pad in Fig. 2 for chemical analysis of the weld metal,

(b) the groove weld shown in Fig. 3 for mechanical properties and soundness of the weld metal, and

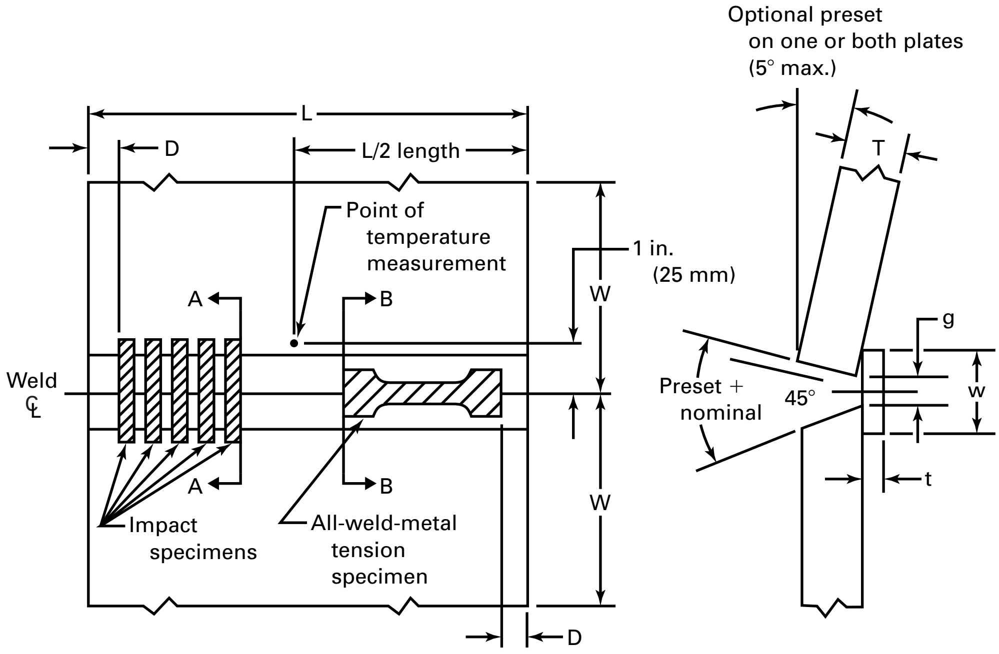
(c) the fillet weld shown in Fig. 4, for usability of the electrode.

The sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Fig. 3, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

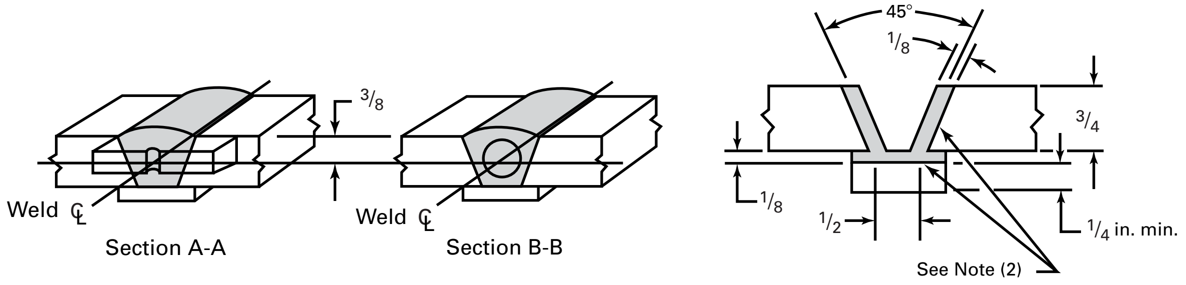
9.2 Preparation of each test assembly shall be as specified in 9.3, 9.4, and 9.5. The base metal for each assembly shall be as required in Table 4 and shall meet the requirements of any one of the appropriate ASTM specifications shown there, or an equivalent specification. Testing of the assemblies shall be as specified in Sections 10 through 14.

9.3 Weld Pad. A weld pad shall be prepared as specified in Fig. 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 — in the weld metal in the groove weld in Fig. 3) is selected. Base metal of any convenient size of the type specified in Table 4 (including note c to that table) shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal (½ in. [12 mm] minimum thickness). The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C]. The welding procedure used for the weld

FIG. 3 TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS OF WELD METAL



(a) Test Plate Showing Location of Test Specimens



(b) Orientation of Impact Specimens

(c) Location of All-Weld-Metal Tension Specimen

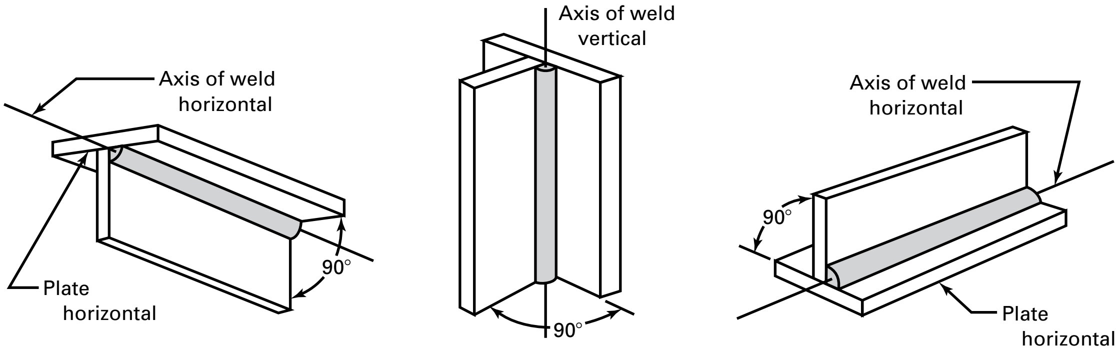
(d) Buttered Test Plate

L Test Plate Length (min.)	W Test Plate Width (min.)	T Test Plate Thickness	D Discard (min.)	l Bevel Angle	g Root Opening	w Backup Width (min.)	t Backup Thickness (min.)	M Buttered Layer (min.)
10 in. [250 mm]	6 in. [150 mm]	3/4 ± 1/32 in. [20 ± 1mm]	1 in. [25 mm]	22.5° ± 2°	1/2 − 0 in. + 1/16 in. [12 − 0 mm + 1 mm]	Approx. 2 × g	1/4 in. [6 mm]	1/8 in. [3 mm]

NOTES:

1. Test plate thickness shall be 1/2 in. [12 mm] and the maximum root opening shall be 1/4 in. −0 in., +1/16 in. [6 mm −0 mm, +1 mm] for 0.045 in. [1.2 mm] and smaller diameters of the EXXT11-X electrode classifications.
2. When required, edges of the grooves and contacting face of the backing shall be buttered as shown in (d). See Note a of Table 4.

FIG. 4 FILLET WELD TEST ASSEMBLY



(a) Overhead Fillet Welds (b) Vertical Fillet Welds (c) Horizontal Fillet Welds

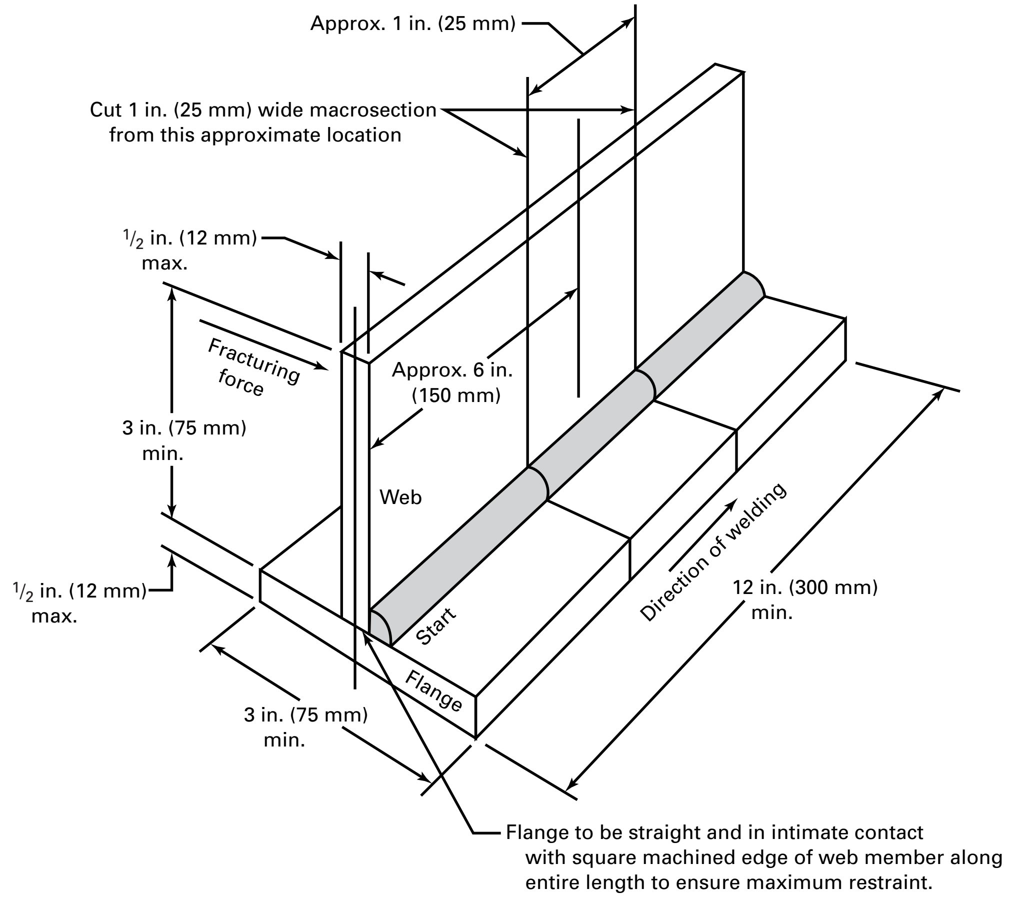


TABLE 4
BASE METAL FOR TEST ASSEMBLIES[a,b,c,d]

Weld Metal Designation	ASTM and Military Standards	UNS Number[e]
A1	A204, Grade A	K11820
	A204,Grade B	K12020
	A204, Grade C	K12320
B1, B2, B2L, B2H	A387, Grade 11	K11789
B3, B3L, B3H	A387, Grade 22	K21590
B6, B6L	A387, Grade 5	S50200
B8, B8L	A387, Grade 9	S50400
B9	A387, Grade 91	K91560
Ni1	A 537, Class 1 or 2	K12437
Ni2, Ni3	A 203, Grade E	K32018
	HY-80 (per MIL-S-16216)	K31820
	HY-100 (per MIL-S-16216)	K32045
	HSLA-80 (per MIL-S-24645)	—
	HSLA-100 (perMIL-S-24645)	—
D1,D2,D3	A 302, Grade A	K12021
	A 302, Grade B	K12022
K1,K3,K4,K5,K7,K9[f]	A 514, any grade	K11856
	HY-80[g]	K31820
	HY-100[g]	K32045
	HSLA-80[h]	—
	HSLA-100[h]	—
K2,K6,K8	A537, Class 1 or 2	K12437
W2	A588, Grade A	K11430
	A 588, Grade B	K12043
	A 588, Grade C	K11538

NOTES:

a. For the groove weld shown in Fig. 3, ASTM A 36 or A 285 base metals may be used; however, the joint surfaces shall be buttered as shown in Fig. 3 using any electrode of the same composition as the classification being tested.

b. Buttering of the groove weld in Fig. 3 is not required when using A 36 or A 285 base metals when testing EXXT4-X, EXXT6-X, EXXT7-X, EXXT8-X,and EXXT11-X electrodes with 70 ksi [490 MPa] or lower classification.

c. ASTM A 36 or A 285 base metals may be used for the weld pad shown in Fig. 2; however,the minimum weld metal height shall be increased to $\frac{5}{8}$ in. [16 mm]. The sample to be tested in Section 10 shall be taken from weld metal that is at least $\frac{1}{2}$ in. [12 mm] above the original base plate surface.

d. The use of non-buttered ASTM A 36 or A 285 base metal is permitted for the fillet weld test.

e. SAE/ASTM Unified Numbering System for Metals and Alloys.

f. Buttering is not allowed for the K9 weld metal designation.

g. According to MIL-S-16216 or NAVSEA Technical Publication T9074-BD-GIB-010/0300, Appendix B.

h. According to MIL-S-24645 or NAVSEA Technical Publication T9074-BD-GIB-010/0300, Appendix A.

TABLE 5
HEAT INPUT REQUIREMENTS AND SUGGESTED PASS AND LAYER SEQUENCE FOR MULTIPLE PASS ELECTRODE CLASSIFICATIONS

Diameter		Required Average Heat Input[a, b, c, d]		Suggested Passes per Layer		Suggested Number of Layers
in.	mm	kJ/in.	kJ/mm	Layer 1	Layer 2 to Top	
≤0.030	≤0.8	20–35	0.8–1.4	1 or 2	2 or 3	6 to 9
0.035	0.9					
—	1.0	25–50	1.0–2.0	1 or 2	2 or 3	6 to 9
0.045	—					
—	1.2					
0.052	—	25–55	1.0–2.2	1 or 2	2 or 3	5 to 8
—	1.4					
$^1/_{16}$	1.6					
0.068	—	36–65	1.4–2.6	1 or 2	2 or 3	5 to 8
—	1.8					
0.072	—					
$^5/_{64}$ (0.078)	2.0					
$^3/_{32}$ (0.094)	2.4	40–65	1.6–2.6	1 or 2	2 or 3	4 to 8
$^7/_{64}$ (0.109)	2.8	50–70	2.0–2.8	1 or 2	2 or 3	4 to 7
0.120	—	55–75	2.2–3.0	1 or 2	2	4 to 7
$^1/_8$ (0.125)	3.2					
$^5/_{32}$ (0.156)	4.0	65–85	2.6–3.3	1	2	4 to 7

NOTES:

a. The calculation to be used for heat input is:

$$(1)\ \text{Heat Input (kJ/in.)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (in./min)} \times 1000} \text{ or } \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (in.)} \times 1000}$$

$$(2)\ \text{Heat Input (kJ/mm)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (mm/min)} \times 1000} \text{ or } \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (mm)} \times 1000}$$

b. Does not apply to the first layer. The first layer shall have a maximum of two passes.

c. The average heat input is the calculated average for all passes excluding the first layer.

d. A non-pulsed, constant voltage (CV) power soruce shall be used.

pad shall satisfy the heat input requirements specified in Table 5. The slag shall be removed after each pass. The pad may be quenched in water between passes. The dimensions of the completed pad shall be as shown in Fig. 2. Testing of this assembly shall be as specified in 10.2.

9.4 Weld Test Assemblies

9.4.1 Test Assembly for Multipass Electrodes. One or two groove weld test assemblies shall be prepared and welded as specified in Fig. 3 and Table 5, using base metal of the appropriate type specified in Table 4. Preheat and interpass temperatures shall be as specified in Table 6. Testing of this assembly shall be as specified in Table 3. When ASTM A 36 or A 285 base metals are used, the groove faces and the contact face of the backing shall be buttered using an electrode of the same composition as the classification being tested except as noted in Table 4, Notes b and f. If a buttering procedure is used, the layer shall be approximately $^1/_8$ in. [3 mm] thick (see Fig. 3, Note 2). The electrode diameter for one test assembly shall be $^3/_{32}$ in. [2.4 mm] or the largest diameter manufactured. The electrode diameter for the other test assembly shall be 0.045 in. [1.2 mm] or the smallest size manufactured. If the maximum diameter manufactured is $^1/_{16}$ in. [1.6 mm] or less, only the largest diameter need be tested. The electrode polarity shall be as specified in Table 2. Testing of the assemblies shall be as required in Table 3 in the as-welded or PWHT condition as specified in Table 6.

9.4.1.1 Welding shall be in the flat position and the assembly shall be restrained (or preset as shown in Fig. 3) during welding to prevent warpage in excess of

TABLE 6
PREHEAT, INTERPASS, AND PWHT TEMPERATURES

AWS Classifications	Preheat and Interpass Temperature[a]		PWHT Temperature[a, b]	
	A5.29	A5.29M	A5.29	A5.29M
E6XT1-Ni1C, -Ni1M [E43XT1-Ni1C, -Ni1M] E7XT6-Ni1 [E49XT6-Ni1] E7XT8-Ni1 [E49XT8-Ni1] E8XT1-Ni1C, -Ni1M [E55XT1-Ni1C, -Ni1M] E7XT8-Ni2 [E49XT8-Ni2] E8XT1-Ni2C, -Ni2M [E55XT-1-Ni2C, -Ni2M] E8XT8-Ni2 [E55XT8-Ni2] E8XT11-Ni3 [E55XT11-Ni3] E9XT1-Ni2C, -Ni2M [E62XT1-Ni2C, -Ni2M]	300 ± 25°F	150 ± 15°C	None	None
E7XT5-A1C, -A1M [E49XT5-A1C, -A1M] E8XT1-A1C, -A1M [E55XT1-A1C, -A1M] E8XT5-Ni1C, -Ni1M [E55XT5-Ni1C, -Ni1M] E8XT5-Ni2C,[c] -Ni2M[c] [E55XT5-Ni2C,[c], -Ni2M[c]] E8XT5-Ni3C,[c], -Ni3M[c] [E55XT5-Ni3C,[c] -Ni3M[c]] E9XT5-Ni3C,[c] -Ni3M[c] [E62XT5-Ni3C,[c] -Ni3M[c]] E9XT5-D2C, -D2M [E62XT5-D2C, -D2M] E10XT5-D2C, -D2M [E69XT5-D2C, -D2M]	300 ± 25°F	150 ± 15°C	1150 ± 25°F	620 ± 15°C
All Classifications with B1, B1L, B2, B2L, B2H, B3, B3L, or B3H Weld Metal Designations	350 ± 25°F	175 ± 15°C	1275 ± 25°F	690 ± 15°C
All Classificaitons with B6, B6L, B8, or B8L Weld Metal Designations	400 ± 100°F	200 ± 50°C	1375 ± 25°F[d]	745± 15°C[d]
E9XT1-B9C, -B9M [E62XT1-B9C, -B9M]	500 ± 100°F	260 ± 50°C	1400 ± 25°F[d]	760 ± 15°C[d]
All Classifications with D1, D3, K1, K2, K3, K4, K5, K6, K7, K8, K9, or W2 Weld Metal Designations	300 ± 25°F	150 ± 15°C	None	None
EXXTX-G, -GC, -GM EXXTG-X EXXTG-G	Not Specified[e]			

NOTES:

a. These temperatures are specified for testing under this specificaiton and are not to be considered as recommendations for preheat and postweld heat treatment (PWHT) in production welding. The requirements for production welding must be determined by the user.

b. The PWHT schedule is as follows: Raise to required temperature at a rate not to exceed 500°F [280°C] per hour, hold at required temperature for 1 hour -0 + 15 minutes, furnace cool to 600°F [315°C] at a rate not exceeding 350°F [195°C] per hour, air cool.

c. PWHT temperature in excess of 150°F [620°C] will decrease Charpy V-Notch impact strength.

d. Held at specified temperature for two hours -0 + 15 minutes.

e. See Table 1U [Table 1M], Note b.

5 degrees. An assembly that is warped more than 5 degrees from plane shall be discarded. It shall not be straightened.

Prior to welding, the test assembly shall be heated to the preheat temperature specified in Table 6 for the electrode being tested. Welding shall continue until the assembly has reached the required interpass temperature specified in Table 6, measured by temperature indicating crayons or surface thermometers at the location shown in Fig. 3. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air. The assembly shall be heated to a temperature within the specified interpass temperature range before welding is resumed.

9.4.1.2 When postweld heat treatment is required, the heat treatment shall be applied to the test assembly before the specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination.

The temperature of the test assembly shall be raised in a suitable furnace at the rate of 150° to 500°F [85° to 280°C] per hour until the postweld heat treatment temperature specified in Table 6, for the electrode classification, is attained. This temperature shall be maintained for one hour (−0, + 15 minutes), unless otherwise noted in Table 6. The test assembly shall then be allowed to cool in the furnace at a rate not greater than 350°F [200°C] per hour. It may be removed from the furnace when the temperature of the furnace has reached 600°F [300°C] and allowed to cool in still air.

9.4.2 Fillet Weld Test Assembly. A test assembly shall be prepared and welded as specified in Table 3 and shown in Fig. 4, using base metal of the appropriate type specified in Table 4. The welding positions shall be as specified in Note b of Table 3.

Before assembly, the standing member (web) shall have one edge prepared throughout its length and the base member (flange) side shall be straight, smooth and clean. The test plates shall be assembled as shown in Fig. 4. When assembled, the faying surfaces shall be in intimate contact along the entire length of the joint. The test assembly shall be secured with tack welds deposited at each end of the weld joint.

The welding procedure and the size of the electrode to be tested shall be as selected by the manufacturer. The fillet weld shall be a single pass weld deposited in either the semiautomatic or mechanized mode as selected by the manufacturer. The fillet weld size shall not be greater than $^3/_8$ in. [10 mm]. The fillet weld shall be deposited only on one side of the joint as shown in Fig. 4. Weld cleaning shall be limited to chipping, brushing, and needle scaling. Grinding, filing, or other metal cutting of the fillet weld face is prohibited. The testing of the assembly shall be as specified in Section 14.

10. Chemical Analysis

10.1 The sample for analysis shall be taken from weld metal produced with the flux cored electrode and the shielding gas, if any, with which it is classified. The sample shall be taken from a weld pad, or the reduced section of the fractured tension test specimen, or from a corresponding location, or any location above it, in the groove weld in Fig. 3. In case of dispute, the weld pad shall be the referee method.

10.2 The top surface of the pad described in 9.3 and shown in Fig. 2 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. The sample shall be taken at least $^3/_8$ in. [10 mm] from the nearest surface of the base metal. The sample from the reduced section of the fractured tension test specimen or from a corresponding location in the groove weld in Fig. 3 shall be prepared for analysis by any suitable mechanical means.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 350.

10.4 The results of the analysis shall meet the requirements of Table 7 for the classification of electrode under test.

11. Radiographic Test

11.1 The welded test assembly described in 9.4.1 and shown in Fig. 3 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding $^3/_{32}$ in. [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of $^1/_{16}$ in. [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than $^1/_{16}$ in. [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 1032. The quality level of inspection shall be 2-2T.

11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows:

(a) no cracks, no incomplete fusion, and no incomplete penetration,

(b) no slag inclusions longer than $^1/_4$ in. [6 mm] or one-third 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

TABLE 7
WELD METAL CHEMICAL COMPOSITION REQUIREMENTS FOR CLASSIFICATION TO A5.29/A5.29M

Weld Metal Designation	UNS Number[b]	Weight Percent[a]											
		C	Mn	P	S	Si	Ni	Cr	Mo	V	Al	Cu	Other
Molybdenum Steel Electrodes													
A1	W1703X	0.12	1.25	0.030	0.030	0.80	-	-	0.40–0.65	-	-	-	-
Chromium-Molybdenum Steel Electrodes													
B1	W5103X	0.05–0.12	1.25	0.030	0.030	0.80	-	0.40–0.65	0.40–0.65	-	-	-	-
B1L	W5113X	0.05	1.25	0.030	0.030	0.80	-	0.40–0.65	0.40–0.65	-	-	-	-
B2	W5203X	0.05–0.12	1.25	0.030	0.030	0.80	-	1.00–1.50	0.40–0.65	-	-	-	-
B2L	W5213X	0.05	1.25	0.030	0.030	0.80	-	1.00–1.50	0.40–0.65	-	-	-	-
B2H	W5223X	0.10–0.15	1.25	0.030	0.030	0.80	-	1.00–1.50	0.40–0.65	-	-	-	-
B3	W5303X	0.05–0.12	1.25	0.030	0.030	0.80	-	2.00–2.50	0.90–1.20	-	-	-	-
B3L	W5313X	0.05	1.25	0.030	0.030	0.80	-	2.00–2.50	0.90–1.20	-	-	-	-
B3H	W5323X	0.10–0.15	1.25	0.030	0.030	0.80	-	2.00–2.50	0.90–1.20	-	-	-	-
B6	W50231	0.05–0.12	1.25	0.040	0.030	1.00	0.40	4.0–6.0	0.40–0.65	-	-	0.50	-
B6L	W50230	0.05	1.25	0.040	0.030	1.00	0.40	4.0–6.0	0.45–0.65	-	-	0.50	-
B8	W50431	0.05–0.12	1.25	0.040	0.030	1.00	0.40	8.0–10.5	0.85–1.20	-	-	0.50	-
B8L	W50430	0.05	1.25	0.030	0.030	1.00	0.40	8.0–10.5	0.85–1.20	-	-	0.50	-
B9	W50531	0.08–0.13	1.20[d]	0.020	0.015	0.50	0.80[d]	8.0–10.5	0.85–1.20	0.15–0.30	0.04	0.25	Nb: 0.02–0.10 N: 0.02-0.07
Nickel Steel Electrodes													
Ni1	W2103X	0.12	1.50	0.030	0.030	0.80	0.80–1.10	0.15	0.35	0.05	1.8[c]	-	-
Ni2	W2203X	0.12	1.50	0.030	0.030	0.80	1.75–2.75	-	-	-	1.8[c]	-	-
Ni3	W2303X	0.12	1.50	0.030	0.030	0.80	2.75–3.75	-	-	-	1.8[c]	-	-
Manganese-Molybdenum Steel Electrodes													
D1	W1913X	0.12	1.25–2.00	0.030	0.030	0.80	-	-	0.25–0.55	-	-	-	-
D2	W1923X	0.15	1.65–2.25	0.030	0.030	0.80	-	-	0.25–0.55	-	-	-	-
D3	W1933X	0.12	1.00–1.75	0.030	0.030	0.80	-	-	0.40–0.65	-	-	-	-

TABLE 7
WELD METAL CHEMICAL COMPOSITION REQUIREMENTS FOR CLASSIFICAITON TO A5.29/A5.29M (CONT'D)

Weld Metal Designation	UNS Number[b]	Weight Percent[a]											
		C	Mn	P	S	Si	Ni	Cr	Mo	V	Al	Cu	Other
		Other Low-Alloy Steel Electrodes											
K1	W2113X	0.15	0.80–1.40	0.030	0.030	0.80	0.80–1.10	0.15	0.20–0.65	0.05	-	-	-
K2	W2123X	0.15	0.50–1.75	0.030	0.030	0.80	1.00–2.00	0.15	0.35	0.05	1.8[c]	-	-
K3	W2133X	0.15	0.75–2.25	0.030	0.030	0.80	1.25–2.60	0.15	0.25–0.65	0.05	-	-	-
K4	W2223X	0.15	1.20–2.25	0.030	0.030	0.80	1.75–2.60	0.20–0.60	0.20–0.65	0.03	-	-	-
K5	W2162X	0.10–0.25	0.60–1.60	0.030	0.030	0.80	0.75–2.00	0.20–0.70	0.15–0.55	0.05	-	-	-
K6	W2104X	0.15	0.50–1.50	0.030	0.030	0.80	0.40–1.00	0.20	0.15	0.05	1.8[c]	-	-
K7	W2205X	0.15	1.00–1.75	0.030	0.030	0.80	2.00–2.75	-	-	-	-	-	-
K8	W2143X	0.15	1.00–2.00	0.030	0.030	0.40	0.50–1.50	0.20	0.20	0.05	1.8[c]	-	-
K9	W23230	0.07	0.50–1.50	0.015	0.015	0.60	1.30–3.75	0.20	0.50	0.05	-	0.06	-
W2	W2013X	0.12	0.50–1.30	0.030	0.030	0.35–0.80	0.40–0.80	0.45–0.70	-	-	-	0.30-0.75	-
G[e]	-	-	0.50[f]	0.030	0.030	1.00	0.50[f]	0.30[f]	0.20[f]	0.10[f]	1.8[c]	-	-

NOTES:

a. Single values are maximum unless otherwise noted.

b. ASTM DS-56 or SAE HS-1086. An "X," when present in the last position, represents the usability designator for the electrode type used to deposit the weld metal. An exception to this applies to the T11 electrode type where a "9" is used instead of an "11."

c. Applicable to self-shielded electrodes only. Electrodes intended for use with gas shielding normally do not have significant additions of aluminum.

d. Mn + Ni = 1.50% maximum. See A7.9.2 in Annex A.

e. In order to meet the alloy requirements of the G group, the undiluted weld metal shall have not less than the minimum specified for one or more of the following alloys: Mn, Ni, Cr, Mo, or V.

f. Minimum values.

length 12 times the thickness of the weld except when the distance between the successive inclusions exceeds 6 times the length of the longest inclusion in the group, and

(c) no rounded indications in excess of those permitted by the radiographic standards in Fig. 7.

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 indication may be of porosity or slag. Test assemblies with indications larger than the large indications permitted in the radiographic standard (Fig. 7) do not meet the requirements of this specification.

12. Tension Test

12.1 For multiple pass electrode classifications one all-weld-metal tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly described in 9.4.1 and shown in Fig. 3. The tension test specimen shall have a nominal diameter of 0.500 in. [12.5 mm] (0.250 in. [6.5 mm] for some electrodes as indicated in Note 1 of Fig. 3) and a nominal gage length to diameter ratio of 4:1.

12.1.1 After machining, but before testing, the tension test specimen for classifications to be tested in the as-welded condition as specified in Table 1U [Table 1M] may

TABLE 8
DIMENSIONAL REQUIREMENTS FOR FILLET WELD USABILITY TEST SPECIMENS

Measured Fillet Weld Size[a]		Maximum Convexity [a, b]		Maximum Difference Between Fillet Weld Legs[a]	
in.	mm	in.	mm	in.	mm
1/8	3.0	5/64	2.0	1/32	1.0
9/64	3.5	5/64	2.0	3/64	1.0
5/32	4.0	5/64	2.0	3/64	1.0
11/64	4.5	5/64	2.0	1/16	1.5
3/16	. . .	5/64	. . .	1/16	. . .
13/64	5.0	5/64	2.0	5/64	2.0
7/32	5.5	5/64	2.0	5/64	2.0
15/64	6.0	5/64	2.0	3/32	2.5
1/4	6.5	5/64	2.0	3/32	2.5
17/64	. . .	3/32	. . .	7/64	. . .
9/32	7.0	3/32	2.5	7/64	3.0
19/64	7.5	3/32	2.5	1/8	3.0
5/16	8.0	3/32	2.5	1/8	3.0
21/64	8.5	3/32	2.5	9/64	3.5
11/32	9.0	3/32	2.5	9/64	3.5
23/64	. . .	3/32	. . .	5/32	. . .
3/8	9.5	3/32	2.5	5/32	4.0

NOTES:

a. All measurements shall be rounded to the nearest 1/64 in. [0.5 mm].

b. Maximum convexity for EXXT5-XC, -XM electrodes may be 1/32 in. [0.8 mm] larger than the listed requirements.

TABLE 9
DIFFUSIBLE HYDROGEN LIMITS FOR WELD METAL[a]

Optional Supplemental Diffusible Hydrogen Designator[b,c,d]	Average Diffusible Hydrogen, Max.,[e] mL/100g Deposited Metal
H16	16.0
H8	8.0
H4	4.0

NOTES:

a. Limits on diffusible hydrogen when tested in accordance with AWS A4.3, as specified in Section 16.

b. See Fig. 1.

c. The lower diffusible hydrogen levels (H8 and H4) may not be available in some classifications (see A8.2.8).

d. Electrodes which satisfy the diffusible hydrogen limits for H4 category also satisfy the limits for the H8 and H16 categories. Electrodes which satisfy the diffusible hydrogen limits for the H8 category also satisfy the limits for the H16 category.

e. These hydrogen limits are based on welding in air containing a maximum of 10 grains of water per pound [1.43 g/kg] of dry air. Testing at any higher atmospheric moisture level is acceptable provided these limits are satisfied (see 15.3).

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 A8.3 for a discussion of the purpose of aging.

12.1.2 The specimen shall be tested in the manner described in the Tension Test section of AWS B4.0 or B4.0M.

12.1.3 The results of the all-weld-metal tension test shall meet the requirements specified in Table 1U or Table 1M, as applicable.

13. Impact Test

13.1 Five full-size Charpy V-Notch impact specimens, as specified in the Fracture Toughness Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly shown in Fig. 3 for those classifications for which impact testing is required in Table 3.

The Charpy V-Notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in. [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square

TABLE 10
STANDARD SIZES AND TOLERANCES OF ELECTRODES[a]

U.S. Customary Units		International System of Units (SI)	
Diameter (in.)	Tolerance (in.)	Diameter (mm)	Tolerance (mm)[b]
0.030	±0.002	0.8	+0.02/-0.05
0.035	±0.002	0.9	+0.02/-0.05
0.040	±0.002	1.0	+0.02/-0.05
0.045	±0.002	. . .	. . .
. . .	. . .	1.2	+0.02/-0.05
0.052	±0.002	. . .	. . .
. . .	. . .	1.4	+0.02/-0.05
1/16 (0.062)	±0.002	1.6	+0.02/-0.06
0.068	±0.003	. . .	. . .
. . .	. . .	1.8	+0.02/-0.06
0.072	±0.003	. . .	. . .
5/64 (0.078)	±0.003	2.0	+0.02/-0.06
3/32 (0.094)	±0.003	2.4	+0.02/-0.06
7/64 (0.109)	±0.003	2.8	+0.02/-0.06
0.120	±0.003	. . .	. . .
1/8 (0.125)	±0.003	3.2	+0.02/-0.07
5/32 (0.156)	±0.003	4.0	+0.02/-0.07

NOTES:

a. Electrodes produced in sizes other than those shown may be classified by using similar tolerances as shown.

b. The tolerances shown are as prescribed in ISO 544.

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 50X magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the Fracture Toughness Test section of AWS B4.0 or B4.0M. The test temperature shall be that specified in Table 1U [Table 1M] for the classification under test. For those electrodes to be identified by the optional supplemental impact designator "J," the test temperature shall be as specified in Note d of Table 1U [Table 1M].

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft•lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft•lbf [20 J], and the average of the three shall be not less than the required 20 ft•lbf [27 J] energy level. For the K9 classification, the average of all five values must meet the minimum requirement. One of five may be 10 ft•lbf [14 J] lower than the minimum requirement.

14. Fillet Weld Test

14.1 The fillet weld test, when required in Table 3, shall be made in accordance with the requirements of 9.4.2 and Fig. 4. The entire face of the completed fillet shall be examined visually. 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, a specimen containing approximately 1 in. [25 mm] of the weld in the lengthwise direction shall be prepared as shown in Fig. 4. The cross-sectional surface of the specimen shall be polished and etched, and then examined as required in 14.2.

14.2 Scribe lines shall be placed on the prepared surface, as shown in Fig. 5, and the leg lengths and convexity of the fillet shall be determined to the nearest $^1/_{64}$ in. [0.5 mm] by actual measurement. These measurements shall meet the requirements in Table 8 for convexity and permissible difference in the length of the legs.

14.3 The remaining two sections of the test assembly shall be broken longitudinally through the fillet weld by a force exerted as shown in Fig. 4. When necessary, to facilitate fracture through the fillet, one or more of the following procedures may be used:

(a) A reinforcing bead, as shown in Fig. 6(a), may be added to each leg of the weld.

(b) The position of the web on the flange may be changed, as shown in Fig. 6(b).

(c) The face of the fillet may be notched, as shown in Fig. 6(c).

Tests in which the weld metal pulls out of the base metal during bending are invalid. Specimens in which this occurs

TABLE 11
PACKAGING REQUIREMENTS[a]

Type of Package	Package Size[b]				Net Weight of Electrode[c]	
	in		mm		lb	kg
Coils without Support	(d)	(d)	(d)	(d)		
Coils with Support (see below)	6-¾	ID	170	ID	14	6
	12	ID	300	ID	25, 30, 50, & 60	10, 15, 25, & 30
Spools	4	OD	100	OD	1-½ & 2-½	0.5 & 1.0
	8	OD	200	OD	10, 12, & 15	4.5, 5.5, & 7
	12	OD	300	OD	25, 30, 35, & 44	10, 15, & 20
	14	OD	350	OD	50 & 60	20 & 25
	22	OD	560	OD	250	100
	24	OD	610	OD	300	150
	30	OD	760	OD	600, 750, & 1000	250, 350, & 450
Drums	15-½	OD	400	OD	(d)	(d)
	20	OD	500	OD	(d)	(d)
	23	OD	600	OD	300 & 600	150 & 300

Coils with Support-Standard Dimensions and Weights[a]

Electrode Size	Coil Net Weight[c]		Coil Dimensions			
			Inside Diameter of Liner		Width of Wound Electrode	
	lb	kg	in.	mm	in (max)	mm (max)
All	14	6	6-¾ ± ⅛	170 ± 3	3	75
	25 and 30	10 and 15	12 ± ⅛	300 +3, -10	2-½ or 4-⅝	65 or 120
	50, 60, & 65	20, 25, & 30	12 ± ⅛	300 +3, -10	4-⅝	120

NOTES:

a. Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser

b. ID = inside diameter, OD = outside diameter.

c. Tolerance on net weight shall be ± 10 percent.

d. As agreed between supplier and purchaser.

shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of the specimens required for retest in Section 8 does not apply.

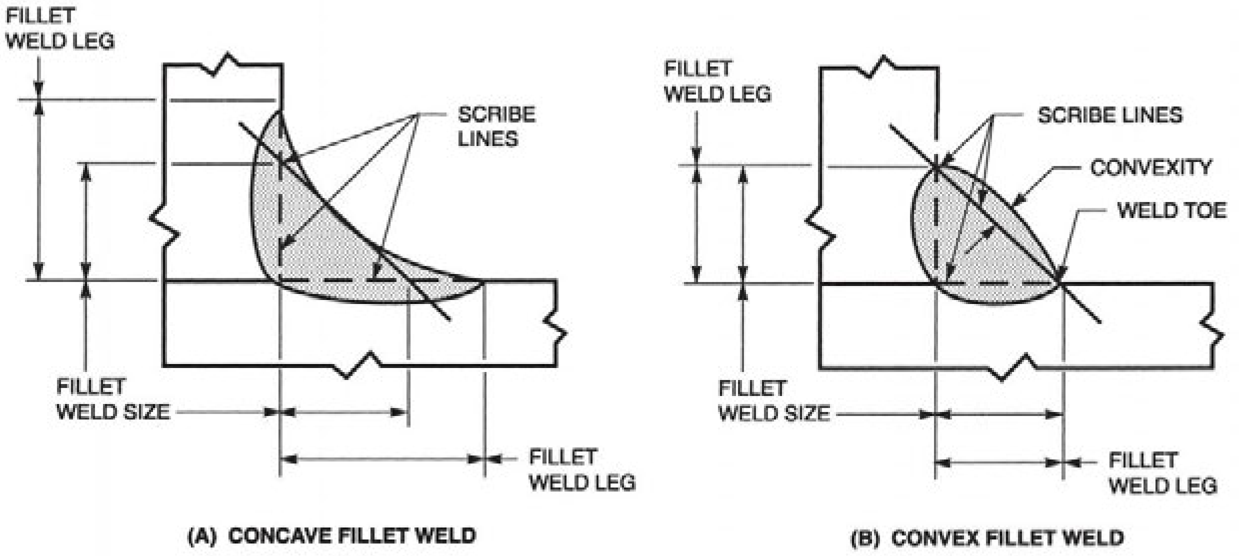
14.4 The fractured surfaces shall be examined. They shall be free of cracks and shall be reasonably free of porosity and trapped slag. Incomplete fusion at the root of the weld shall not exceed 20 percent of the total length of the weld. Slag beyond the vertex of the isosceles triangle with the hypotenuse as the face, as shown in Fig. 5, shall not be considered incomplete fusion.

15. Diffusible Hydrogen Test

15.1 The $^{3}/_{32}$ in. [2.4 mm] or the largest diameter and the 0.045 in. [1.2 mm] or the smallest diameter of an electrode to be identified by an optional supplemental diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. If the maximum diameter manufactured is $^{1}/_{16}$ in. [1.6 mm] or less, only the largest diameter need be tested. A mechanized welding system shall be used for the diffusible hydrogen test. Based upon the average value of test results which satisfy the requirements of Table 9, the appropriate diffusible hydrogen designator may be added at the end of the classification.

15.2 Testing shall be done with electrode from a previously unopened container. Conditioning of the electrode prior to testing is not permitted. Conditioning can be construed to be any special preparation or procedure, such as baking the electrode, which the user would not usually practice. The shielding gas, if any, used for classification purposes shall also be used for the diffusible hydrogen test. Welds for hydrogen determination shall be made at a wire feed rate (or welding current) which is based upon the manufacturer's recommended operating range for the electrode size and type being tested. When using wire feed rate, the minimum wire feed rate to be used for the diffusible hydrogen test is given by the equation shown below. When using welding current, the equation shown is modified by substituting 'welding current' wherever "WFR"

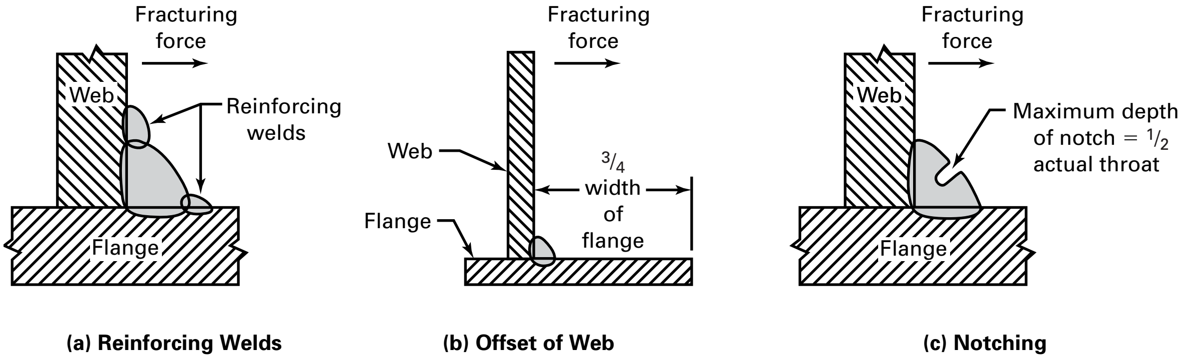
FIG. 5 DIMENSIONS OF FILLET WELDS



GENERAL NOTES:

1. Fillet weld size is the leg length of the largest isosceles right triangle which can be inscribed within the fillet weld cross section.
2. Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes.
3. Fillet weld leg is the distance from the joint root to the toe of the fillet leg.

FIG. 6 ALTERNATE METHODS FOR FACILITATING FILLET WELD FRACTURE



(a) Reinforcing Welds (b) Offset of Web (c) Notching appears. The voltage shall be as recommended by the manufacturer for the wire feed rate (or welding current) used for the test. The contact tip-to-work distance (CTWD) shall be at the minimum recommended by the manufacturer for the wire feed rate (or welding current) used for the test. The travel speed used shall be as required to establish a weld bead width that is appropriate for the specimen. See A8.2.7.

$$\mathrm{WFR}_{\mathrm{min}} = \mathrm{WFR}_{\mathrm{mfg.min}} + 0.75\ (\mathrm{WFR}_{\mathrm{mfg.max}} - \mathrm{WFR}_{\mathrm{mfg.min}})$$

where

$\mathrm{WFR}_{\mathrm{min}}$ = the minimum wire feed rate to be used for the diffusible hydrogen test

$\mathrm{WFR}_{\mathrm{mfg.min}}$ = the minimum wire feed rate recommended by the manufacturer

$\mathrm{WFR}_{\mathrm{mfg.max}}$ = the maximum wire feed rate recommended by the manufacturer

15.3 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.[8] The actual atmospheric conditions shall be reported along with the average value for the tests according to AWS A4.3.

15.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. If the actual test results for an electrode meet the requirements for the lower or lowest hydrogen designator, as specified in Table 9, the electrode also meets the requirements for all higher designators in Table 9 without need to retest.

16. 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.

17. Standard Sizes

Standard sizes for filler metal in the different package forms such as coils with support, coils without support, drums, and spools are shown in Table 10 (see Section 19, Standard Package Forms).

18. Finish and Uniformity

18.1 All electrodes shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams, laps (exclusive of the longitudinal joint), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

18.2 Each continuous length of electrode shall be from a single lot of material as defined in AWS A5.01, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic and semiautomatic equipment.

18.3 Core ingredients 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.

18.4 A suitable protective coating may be applied to any electrode in this specification.

19. Standard Package Forms

19.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 11 and Figs. 8 and 9. Package forms, sizes, and weights other than these shall be as agreed by purchaser and supplier.

19.2 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

19.3 Spools shall be designed and constructed to prevent distortion of the spool and electrode during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

20. Winding Requirements

20.1 Electrodes on spools and in coils (including drums) shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered leaving the electrode free to unwind without restriction. The outside end of the electrode (the end with which welding is to begin) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

20.2 The cast and helix of electrode in coils, spools, and drums shall be such that the electrode will feed in an uninterrupted manner in automatic and semiautomatic equipment.

21. Electrode Identification

21.1 The product information and the precautionary information required in Section 23 for marking each package shall also appear on each coil, spool, and drum.

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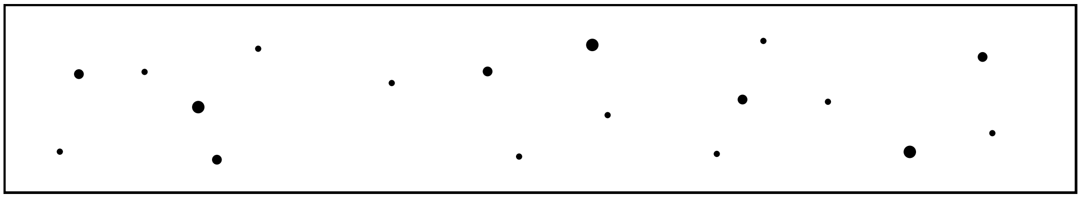
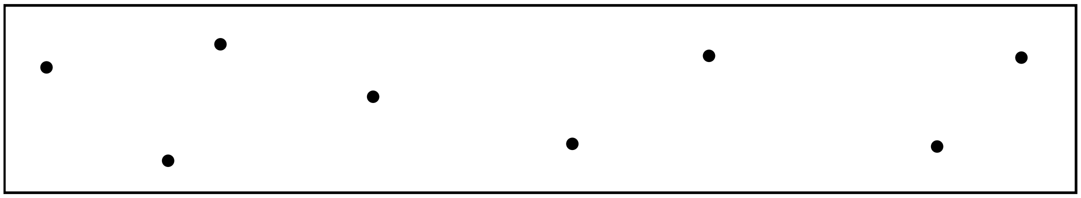
[8] See A8.2.5 in Annex A.

FIG. 7 RADIOGRAPHIC STANDARDS FOR TEST ASSEMBLY IN FIG. 3



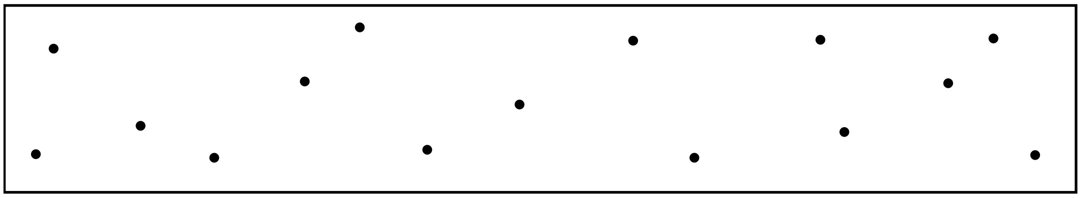
(a) Assorted Rounded Indications

Size $^{1}/_{64}$ in. (0.4 mm) to $^{1}/_{16}$ in. (1.6 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 18, with the following restrictions:
Maximum number of large $^{3}/_{64}$ in. (1.2 mm) to $^{1}/_{16}$ in. (1.6 mm) in diameter or in length indications = 3.
Maximum number of medium $^{1}/_{32}$ (0.8 mm) to $^{3}/_{64}$ in. (1.2 mm) in diameter or in length indications = 5.
Maximum number of small $^{1}/_{64}$ in. (0.4 mm) to $^{1}/_{32}$ in. (0.8 mm) in diameter or in length indications = 10.



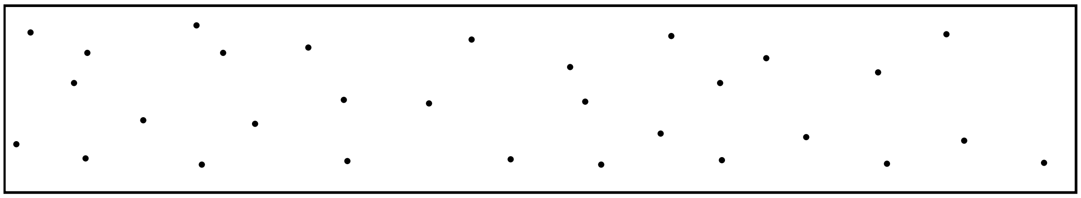
(b) Large Rounded Indications

Size $^{3}/_{64}$ in. (1.2 mm) to $^{1}/_{16}$ in. (1.6 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 8.



(c) Medium Rounded Indications

Size $^{1}/_{32}$ in. (0.8 mm) to $^{3}/_{64}$ in. (1.2 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 15.



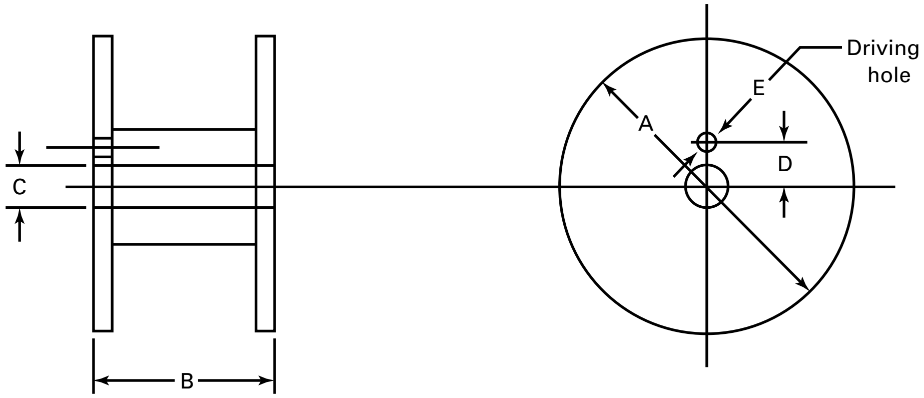
(d) Small Rounded Indications

Size $^{1}/_{64}$ in. (0.4 mm) to $^{1}/_{32}$ in. (0.8 mm) in diameter or in length.
Maximum number of indications in any 6 in. (150 mm) of weld = 30.

NOTES:

1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed $^{1}/_{64}$ in. [0.4 mm] shall be disregarded.

FIG. 8 STANDARD SPOOLS — DIMENSIONS OF 4, 8, 12, AND 14 IN. [100, 200, 300, AND 350 MM] SPOOLS



		Dimensions							
		4 in. [100 mm] Spools		8 in. [200 mm] Spools		12 in. [300 mm] Spools		14 in. [350 mm] Spools	
		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	1.75	46	2.16	56	4.0	103	4.0	103
	Tolerance	±0.03	+0, −2	±0.03	+0, −3	±0.06	+0, −3	±0.06	+0, −3
C	Diameter	0.63	16	2.03	50.5	2.03	50.5	2.03	50.5
	Tolerance	+0.01, −0	+1, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0	+0.06, −0	+2.5, −0
D	Distance between axes	—	—	1.75	44.5	1.75	44.5	1.75	44.5
	Tolerance	—	—	±0.02	±0.5	±0.02	±0.5	±0.02	±0.5
E	Diameter [Note (3)]	—	—	0.44	10	0.44	10	0.44	10
	Tolerance	—	—	+0, −0.06	+1, −0	+0, −0.06	+1, −0	+0, −0.06	+1, −0

NOTES:

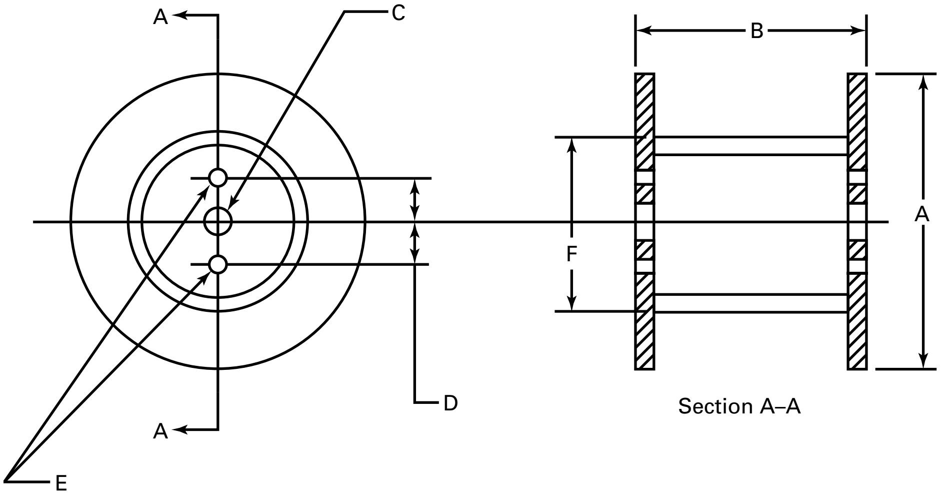
(1) Outside diameter of barrel shall be such as to permit feeding of the filler metals.

(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.

FIG. 9 STANDARD SPOOLS — DIMENSIONS OF 22, 24, AND 30 IN. [560, 610, AND 760 MM] SPOOLS



		Dimensions					
		22 in. [560 mm] Spools		24 in. [610 mm] Spools		30 in. [760 mm] Spools	
		in.in.	mm	in.	mm	in.	mm
A	Diameter, max.	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 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) Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

21.2 Coils without support shall have a tag containing this information securely attached to the electrode at the inside end of the coil.

21.3 Coils with support shall have the information securely affixed in a prominent location on the support.

21.4 Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

21.5 Drums shall have the information securely affixed in a prominent location on the outside of the drum.

22. Packaging

Electrodes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

23. Marking of Packages

23.1 The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package.

(a) AWS specification (year of issue may be excluded) and classification designators along with applicable optional designators

(b) Supplier's name and trade designation

(c) Size and net weight

(d) Lot, control, or heat number

23.2 The appropriate precautionary information[9] 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.

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[9] Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

Annex A
Guide to AWS Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding

(This Annex is not a part of AWS A5.29/A5.29M:2010, *Specification for Low-Alloy Steel Electrodes for Flux Cored 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 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 electrode is suitable.

A2. Classification System

A2.1 The system for identifying the electrode classifications in this specification follows, for the most part, the standard pattern used in other AWS filler metal specifications. An illustration of this system is given in Fig. 1.

A2.2 Some of the classifications are intended to weld only in the flat and horizontal positions (E70T5-A1C, for example). Others are intended for welding in all positions (E81T1-Ni1M, for example). As in the case of shielded metal arc electrodes, the smaller sizes of flux cored electrodes are the ones used for out-of-position work. Flux cored electrodes larger than 5/64 in. [2.0 mm] in diameter are usually used for horizontal fillets and flat position welding.

A2.3 Optional Supplemental designators are also used in this specification in order to identify electrode classifications that have met certain supplemental requirements as agreed to between supplier and purchaser. The optional supplemental designators are not part of the classification nor of its designation.

A2.3.1 Many of the classifications included in this specification have requirements for impact testing at various test temperatures as shown in Table 1U [Table 1M]. In order to include products with improved weld metal toughness at lower temperatures, an optional supplemental designator, J, has been added to identify classifications which, when tested, produce weld metal which exhibits 20 ft•lbf [27 J] at a temperature of 20°F [10°C] lower than the standard temperature shown in Table 1U [Table 1M]. The user is cautioned that although the improved weld metal toughness will be evidenced when welding is performed under conditions similar to the test assembly preparation method specified in this specification, other applications of the electrode, such as long-term postweld heat treatment or vertical up welding with high heat input, may differ markedly from the improved toughness levels given. The users should always perform their own property verification testing.

A2.3.2 This specification has included the use of optional designators for diffusible hydrogen (see Table 9 and A8.2) to indicate the maximum average value obtained under clearly defined test conditions in AWS A4.3. Electrodes that are designated as meeting the lower or lowest hydrogen limits as specified in Table 9, also are understood to be able to meet any higher hydrogen limits, when tested in accordance with Section 15. For example, see Note d of Table 9.

A2.4 "G" Classification

A2.4.1 This specification includes electrodes classified as EXXTX-G, -GC, -GM, EXXTG-X, and EXXTG-G. 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 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 electrodes–each bearing the same "G" classification–may be quite different in some certain respect (chemical composition, again, for example).

A2.4.2 The point of difference (although not necessarily the amount of that difference) between an electrode of a "G" classification and an electrode of a similar classification without the "G" (or even with it, for that matter) will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

(a) "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.

(b) "Not Required" is used in those areas of the specification that refer to the tests that must be conducted in order to classify an electrode. It indicates that the test is not required because the requirements 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 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 A5.01) in the purchase order.

A2.5 Request for Filler Metal Classification

A2.5.1 When an electrode cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that electrode as long as the filler metal is of commercial significance.

A2.5.2 A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

(a) all classification requirements as given for existing classifications such as chemical composition ranges, mechanical property requirements, and usability test requirements

(b) any conditions for conducting the tests used to demonstrate that the product meets classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)

(c) information on Descriptions and Intended Use, which parallels that for existing classifications, for that section of the Annex

(d) proposed ASME "F" Number, if appropriate

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.

A2.5.3 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 the Chair of the particular subcommittee involved

(d) file the original request

(e) add the request to the log of outstanding requests

A2.5.4 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.

A2.5.5 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.

A2.6 An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for possible adoptions as an ISO specification. The latest proposal for designating welding filler metals appears in AWS IFS:2002, *International Index of Welding Filler Metal Classifications*. Tables A1, A2, and A3 show the proposed ISO designations applicable to filler metal classifications included in this specification.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01 as the

TABLE A1
COMPARISON OF APPROXIMATE EQUIVALENT CLASSIFICATIONS[a, b] FOR ISO/DIS 17632[c]

ISO/DIS 17632A[c]	ISO/DIS 17632B	AWS A5.29	AWS A5.29M
	T493T5-XXP-2M3	E7XT5-A1X	E49XT5-A1X
T46Z Mo X X	T55ZT1-XXA-2M3	E8XT1-A1X	E55XT1-A1X
	T433T8-XNA-N1	E6XT8-K6	E43XT8-K6
	T493T8-XNA-N1	E7XT8-K6	E49XT8-K6
	T496T5-XXA-N1	E7XT5-K6X	E49XT5-K6X
T35 3 1Ni X X	T433T1-XXA-N2	E6XT1-Ni1X	E43XT1-Ni1X
T38 3 1Ni X X	E493T6-XNA-N2	E7XT6-Ni1	E49XT6-Ni1
	T493T8-XNA-N2	E7XT8-Ni1	E49XT8-Ni1
	T553T1-XXA-N2	E8XT1-Ni1X	E55XT1-Ni1X
T46 3 1Ni X X	T556T5-XXP-N2	E8XT5-Ni1X	E55XT5-Ni1X
	T493T8-XNA-N5	E7XT8-Ni2	E49XT8-Ni2
	T553T8-XNA-N5	E8XT8-Ni2	E55XT8-Ni2
T46 4 2Ni X X	T554T1-XXA-N5	E8XT1-Ni2X	E55XT1-Ni2X
T46 6 3Ni X X	T557T5-XXP-N7	E8XT5-Ni3X	E55XT5-Ni3X
T50 3 1NiMo X X	T554T5-XXA-N2M2	E8XT5-K1X	E55XT5-K1X
	T492T4-XNA-N3M1	E70T4-K2	E490T4-K2
	T493T7-XNA-N3M1	E7XT7-K2	E49XT7-K2
	T493T8-XNA-N3M1	E7XT8-K2	E49XT8-K2
	T553T1-XXA-N3M1	E8XT1-K2X	E55XT1-K2X
	T553T5-XXA-N3M1	E8XT5-K2X	E55XT5-K2X
	T553T1-XXA-NCC1	E8XT1-W2X	E55XT1-W2X

NOTES:

a. The requirements for the equivalent classifications shown are not necessarily identical in every respect.

b. An "X" in the designations indicates the type of electrode core, the positionality or the type of shielding gas used (if any). The symbols "A" and "P" in ISO 17632B designations indicate whether the mechanical properties were achieved in the as-welded (A) or post-weld heat treated (P) condition, and the symbol "N" following an "X" applies (in ISO 17632B classifications) when no shielding gas is required.

c. ISO/DIS 17632, *Welding consumables—Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels—Classification*.

TABLE A2
COMPARISON OF APPROXIMATE EQUIVALENT CLASSIFICATIONS[a, b] FOR ISO 17634[c]

ISO 17634A[c]	ISO 17634B	AWS A5.29	AWS A5.29M
T Mo X X	T55TX-XX-2M3	E8XTX-A1X	E55XTX-A1X
T MoL X X	T49TX-XX-2M3	E7XTX-A1X	E49XTX-A1X
	T55TX-XX-CM	E8XTX-B1X	E55XTX-B1X
	T55TX-XX-CML	E8XTX-B1LX	E55XTX-B1LX
T CrMo1 X X	T55TX-XX-1CM	E8XTX-B2X	E55XTX-B2X
T CrMo1L X X	T55TX-XX-1CML	E8XTX-B2LX	E55XTX-B2LX
	T55TX-XX-1CMH	E8XTX-B2HX	E55XTX-B2HX
T CrMo2 X X	T55TX-XX-2C1M	E8XTX-B3X	E55XTX-B3X
T CrMo2L X X	T55TX-XX-2C1ML	E8XTX-B3LX	E55XTX-B3LX
	T55TX-XX-2C1MH	E8XTX-B3HX	E55XTX-B3HX
T CrMo 5 X X	T55TX-XX-5CM	E8XTX-B6X	E55XTX-B6X
	T55TX-XX-5CML	E8XTX-B6LX	E55XTX-B6LX
	T55TX-XX-9C1M	E8XTX-B8X	E55XTX-B8X
	T55TX-XX-9C1ML	E8XTX-B8LX	E55XTX-B8LX
	T55TX-XX-9C1MV	E9XTX-B9X	E62XTX-B9X

NOTES:

a. The requirements for the equivalent classifications shown are not necessarily identical in every respect.

b. An "X" in the designations indicates the type of electrode core, the usability of the electrode, the positionality and the type of shielding gas used (if any), as applicable.

c. ISO 17634, *Welding consumables — Tubular cored electrodes for gas shielded metal arc welding of creep resisting steels — Classification*.

TABLE A3
COMPARISON OF APPROXIMATE EQUIVALENT CLASSIFICATIONS[a, b] FOR ISO 18276[c]

ISO/DIS 18276A[c]	ISO/DIS 18276B	AWS A5.29	AWS A5.29M
	T624T1-XXA-N4	E9XT1-Ni2X	E62XT1-Ni2X
	T627T5-XXP-N7	E9XT5-Ni3X	E62XT5-Ni3X
	T624T1-XXA-3M2	E9XT1-D1X	E62XT1-D1X
T55 4 MnMo X X	T625T5-XXP-4M2	E9XT5-D2X	E62XT5-D2X
T62 3 MnMo X X	T694T5-XXP-4M2	E10XT5-D2X	E69XT5-D2X
T55 1 MnMo X X	T622T1-XXA-3M3	E9XT1-D3X	E62XT1-D3X
	T625T5-XXA-N3M1	E9XT5-K2X	E62XT5-K2X
T55 2 MnNiMo X X	T692T1-XXA-N3M2	E10XT1-K3X	E69XT1-K3X
T55 4 MnNiMo X X	T695T5-XXA-N3M2	E10XT5-K3X	E69XT5-K3X
T62 1 Mn2NiMo X X	T762T1-XXA-N3M2	E11XT1-K3X	E76XT1-K3X
	T83ZT1-XXA-N3C1M2	E12XT1-K5X	E83XT1-K5X
T62 1 Mn2NiCrMo X X	T762T1-XXA-N4C1M2	E11XT1-K4X	E76XT1-K4X
T62 4 Mn2NiCrMo X X	T765T5-XXA-N4C1M2	E11XT5-K4X	E76XT5-K4X
T69 4 Mn2NiCrMo X X	T835T5-XXA-N4C1M2	E12XT5-K4X	E83XT5-K4X
	T695T1-XXA-N5	E10XT1-K7X	E69XT1-K7X
	T623T8-XNA-N2	E9XT8-K8	E62XT8-K8
	T695T1-XXA-N6C1M1	E10XT1-K9X	E69XT1-K9X

NOTES:

a. The requirements for the equivalent classifications shown are not necessarily identical in every respect.

b. An "X" in the designations indicates the type of electrode core, the positionality and the type of shielding gas used (if any). The symbols "A" and "P" in ISO 18276B designations indicate whether the mechanical properties were achieved in the as-welded (A) or the post-weld heat treated (P) condition, and the symbol N following an X applies when no shielding gas is required.

c. ISO/DIS 18276, *Welding consumables—Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of high strength steels—Classification*.

specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01. 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 A5.01. 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 supplemental designators, if applicable, on the packaging enclosing the products, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of that 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 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 System in AWS 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 can be exposed during welding. These are:

(a) dimensions of the space in which welding is done (with special regard to the height of the ceiling)

(b) number of welders and welding operators working in that space

(c) rate of evolution of fumes, gases, or dust according to the materials and processes used

(d) the proximity of the welders or welding operators 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

(e) the ventilation provided to the space in which the welding is done

A5.2 American National Standard 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 section on Ventilation in that document.

A6. Welding Considerations

A6.1 When examining the properties required of weld metal as a result of the tests made according to this specification, it should be recognized that in production, where the conditions and procedures may differ from those in this specification [electrode size, amperage, voltage, type and amount of shielding gas, position of welding, contact tip to work distance (CTWD), plate thickness, joint geometry, preheat and interpass temperatures, travel speed, surface condition, base metal composition and dilution, for example], the properties of the weld metal may also differ. Moreover, the difference may be large or small.

A6.2 Since it has not been possible to specify one single, detailed, welding procedure for all products classified under any given classification in this specification, details of the welding procedure used in classifying each product should be recorded by the manufacturer and made available to the user, on request. The information should include each of the items referred to in A6.1 above, as well as the actual number of passes and layers required to complete the weld test assembly.

A6.3 The toughness requirements for the different classifications in this specification can be used as a guide in the selection of electrodes for applications requiring some degree of low temperature notch toughness. For an electrode of any given classification, there can be a considerable difference between the impact test results from one assembly to another, or even from one impact specimen to another, unless particular attention is given to the manner in which the weld is made and prepared (even the location and orientation of the specimen within the weld), the temperature of testing, and the operation of the testing machine.

A6.4 Hardenability. There are inherent differences in the effect of the carbon content of the weld deposit on hardenability, depending on whether the electrode was gas shielded or self-shielded. Gas shielded electrodes generally employ a Mn-Si deoxidation system. The carbon content affects hardness in a manner which is typical of many carbon equivalent formulas published for carbon steel. Most self-shielded electrodes utilize an aluminum-based alloy system to provide for protection and deoxidation. One of the effects of the aluminum is to modify the effect of carbon on hardenability. Hardness levels obtained with self-shielded electrodes may, therefore, be lower than the carbon content would indicate (when considered on the basis of typical carbon equivalent formulas).

A7. Description and Intended Use of Flux Cored Electrodes

This specification may contain many different classifications of flux cored electrodes. The usability designator (1, 4, 5, 6, 7, 8, 11, or G) in each classification indicates a general grouping of electrodes that contain similar flux or core components and which have similar usability characteristics, except for the "G" classification where usability characteristics may differ between similarly classified electrodes.

A7.1 EXXT1-XC and EXXT1-XM Classifications. Electrodes of the EXXT1-XC group are classified with CO_2 shielding gas (AWS A5.32 Class SG-C). However, other gas mixtures (such as argon-CO_2) may be used to improve usability, especially for out-of-position applications, when recommended by the manufacturer. Increasing the amount of argon in the argon-CO_2 mixture will increase the manganese and silicon contents, along with certain other alloys, such as chromium, in the weld metal. The increase in manganese, silicon, or other alloys will increase the yield and tensile strengths and may affect impact properties.

Electrodes in the EXXT1-XM group are classified with 75–80% argon/balance CO_2 shielding gas (AWS A5.32 Class SG-AC-25 or SG-AC-20). Their use with argon-CO_2 shielding gas mixtures having reduced amounts of argon or with CO_2 shielding gas may result in some deterioration of arc characteristics and out-of-position welding characteristics. In addition, a reduction of manganese, silicon, and certain other alloy contents in the weld metal will reduce the yield and tensile strengths and may affect impact properties.

Both the EXXT1-XC and EXXT1-XM electrodes are designed for single and multiple pass welding using DCEP polarity. The larger diameters (usually $^5/_{64}$ in. [2.0 mm] and larger) are typically used for welding in the flat position and for making fillet welds in the horizontal position. The smaller diameters (usually $^1/_{16}$ in. [1.6 mm] and smaller) are typically used for welding in all positions. These electrodes are characterized by a spray transfer, low spatter loss, flat to slightly convex bead contour, and a moderate volume of slag which completely covers the weld bead. Most electrodes of this classification have rutile base slag and may produce high deposition rates.

A7.2 EXXT4-X Classification. Electrodes of this classification are self-shielded, operate on DCEP, and have a globular type transfer. The slag system is designed to make very high deposition rates possible and to produce a weld that is very low in sulfur, which makes the weld very resistant to hot cracking. These electrodes are designed for low penetration beyond the root of the weld, enabling them to be used on joints which have been poorly fit, and for single and multiple pass welding.

A7.3 EXXT5-XC and EXXT5-XM Classifications. Electrodes of the EXXT5-XC classification are designed to be used with CO_2 shielding gas (AWS A5.32 Class SG-C); however, as with EXXT1-XC classifications, argon-CO_2 mixtures may be used to reduce spatter, when recommended by the manufacturer. Increasing the amount of argon in the argon-CO_2 mixture will increase the manganese and silicon contents, along with certain other alloys, which will increase the yield and tensile strengths and may affect impact properties.

Electrodes in the EXXT5-XM group are classified with 75–80% argon/balance CO_2 shielding gas (AWS A5.32 Class SG-AC-25 or SG-AC-20). Their use with gas mixtures having reduced amounts of argon or with CO_2 shielding gas may result in some deterioration of arc characteristics, an increase in spatter, and a reduction of manganese, silicon, and certain other alloys in the weld metal. This reduction in manganese, silicon, or other alloys will decrease the yield and tensile strengths and may affect impact properties.

Electrodes of the EX0T5-XC and EX0T5-XM classifications are used primarily for single and multiple pass welds in the flat position and for making fillet welds in the horizontal position using DCEP or DCEN, depending on the manufacturer's recommendation. These electrodes are characterized by a globular transfer, slightly convex bead contour and a thin slag that may not completely cover the weld bead. These electrodes have a lime-fluoride base slag. Weld deposits produced by these electrodes typically have good to excellent impact properties and hot and cold crack resistance that are superior to those obtained with rutile base slags. Some EX1T5-XC and EX1T5-XM electrodes, using DCEN, can be used for welding in all positions. However, the operator appeal of these electrodes is not as good as those with rutile base slags.

A7.4 EXXT6-X Classification. Electrodes of this classification are self-shielded, operate on DCEP, and have a small droplet to spray type transfer. The slag system is designed to give good low temperature impact properties, good penetration into the root of the weld, and excellent slag removal, even in a deep groove. These electrodes are used for single and multipass welding in flat and horizontal positions.

A7.5 EXXT7-X Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a small droplet to spray type transfer. The slag system is designed to allow the larger sizes to be used for high deposition rates in the horizontal and flat positions, and to allow the smaller sizes to be used for all welding positions. These electrodes are used for single-pass and multiple pass welding and produce very low sulfur weld metal, which is very resistant to cracking.

A7.6 EXXT8-X Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a small droplet or spray type transfer. These electrodes are suitable for all welding positions, and the weld metal has very good low-temperature notch toughness and crack resistance. These electrodes are used for single-pass and multipass welds.

A7.7 EXXT11-X Classification. Electrodes of this classification are self-shielded, operate on DCEN and have a smooth spray-type transfer. These electrodes are intended for single-pass and multipass welding in all positions. The manufacturer should be consulted regarding any plate thickness limitations.

A7.8 EXXTX-G, EXXTG-X, and EXXTG-G Classifications. These classifications are for multiple-pass electrodes that are not covered by any presently defined classification. The mechanical properties can be anything covered by this specification. Requirements are established by the digits chosen to complete the classification. Placement of the "G" in the classification designates that the alloy requirements, shielding gas/slag system, or both are not defined and are as agreed upon between supplier and purchaser.

A7.9 Chemical Composition. The chemical composition of the weld metal produced is often the primary consideration for electrode selection. The suffixes, which are part of each alloy electrode classification, identify the chemical composition of the weld metal produced by the electrode. The following paragraphs give a brief description of the classifications, intended uses, and typical applications.

A7.9.1 EXXTX-A1X (C-Mo Steel) Electrodes. These electrodes are similar to EXXT-XX carbon steel electrodes classified in AWS A5.20, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, except that 0.5 percent molybdenum has been added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance; however, it may reduce the notch toughness of the weld metal. This type of electrode is commonly used in the fabrication and erection of boilers and pressure vessels. Typical applications include the welding of C-Mo steel base metals, such as ASTM A 161, A 204, and A 302 Gr. A plate and A335-P1 pipe.

A7.9.2 EXXTX-BXX, EXXTX-BXLX and EXXTX-BXHX (Cr-Mo Steel) Electrodes. These electrodes produce weld metal that contain between 0.5 percent and 10 percent chromium, and between 0.5 percent and 1 percent molybdenum. They are designed to produce weld metal for high temperature service and for matching properties of the typical base metals as follows:

(a) EXXTX-B1X

(1) ASTM A 335-P2 pipe

(2) ASTM A 387 Gr. 2 plate

(b) EXXTX-B2X

(1) ASTM A 335-P11 pipe

(2) ASTM A 387 Gr. 11 plate

(c) EXXTX-B2LX

(1) Thin wall A 335-P11 pipe or A 213-T11 or A 213-T22 tube, as applicable, for use in the as-welded condition or for applications where low hardness is a primary concern.

(d) EXXTX-B3X

(1) ASTM A 335-P22 pipe

(2) ASTM A 387 Gr. 22 plate

(e) EXXTX-B3LX

(1) Thin wall A 335-P22 pipe or tube for use in the as-welded condition or for applications where lower hardness is a primary concern.

(f) EXXTX-B6X

(1) ASTM A 213-T5 tube

(2) ASTM A 335-P5 pipe

(g) EXXTX-B8X

(1) ASTM A 213-T9 tube

(2) ASTM A 335-P9 pipe

(h) EXXTX-B9X

(1) ASTM A 213-T91 tube

(2) ASTM A 335-P91 pipe

For two of these Cr-Mo electrode classifications, low carbon EXXTX-BXLX classifications have been established. While regular Cr-Mo electrodes produce weld metal with 0.05 percent to 0.12 percent carbon, the "L-grades" are limited to a maximum of 0.05 percent carbon. While the lower percent carbon in the weld metals will improve ductility and lower hardness, it will also reduce the high-temperature strength and creep resistance of the weld metal.

Several of these grades also have high-carbon grades (EXXTX-BXHX) established. In these cases, the electrode produces weld metal with 0.10 percent to 0.15 percent carbon, which may be required for high temperature strength in some applications.

Since all Cr-Mo electrodes produce weld metal which will harden in still air, both preheat and postweld heat treatment (PWHT) are required for most applications.

No minimum notch toughness requirements have been established for any Cr-Mo electrode classifications. While it is possible to obtain Cr-Mo electrodes with minimum toughness values at ambient temperatures down to 32°F [0°C], specific values and testing must be agreed to by supplier and purchaser.

For the EXXTX-B9X classification, thermal treatment is critical and must be closely controlled. The temperature at which the microstructure has complete transformation into martensite (M_f) is relatively low; therefore, upon completion of welding and before postweld heat treatment, it is recommended to allow the weldment to cool to at least 200°F [93°C] to maximize transformation to martensite. The maximum allowable temperature for postweld heat treatment is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To aid in allowing for an adequate post weld heat treatment, the restriction of Mn + Ni has been imposed (see Table 7, Note d). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac1 to avoid this partial transformation.

A7.9.3 EXXTX-DXX (Mn-Mo Steel) Electrodes. These electrodes produce weld metal, which contains about 1.5 percent to 2 percent manganese and between 0.25 percent and 0.65 percent molybdenum. This weld metal provides better notch toughness than the C-0.5 percent Mo electrodes discussed in A7.9.1 and higher tensile strength than the 1 percent Ni, 0.5 percent Mo steel weld metal discussed in A7.9.4.1. However, the weld metal from these Mn-Mo steel electrodes is quite air-hardenable and usually requires preheat and PWHT. The individual electrodes under this electrode group have been designed to match the mechanical properties and corrosion resistance of the high-strength, low-alloy pressure vessel steels, such as A 302 Gr. B and HSLA steels and manganese-molybdenum castings, such as ASTM A 49, A 291, and A 735.

A7.9.4 EXXTX-KXX (Various Low-Alloy Steel Type) Electrodes. This group of electrodes produces weld metal of several different chemical compositions. These electrodes are primarily intended for as-welded applications. See Table 1U [Table 1M] for a comparison of the toughness levels required for each classification.

A7.9.4.1 EXXTX-K1X Electrodes. Electrodes of this classification produce weld metal with nominally 1 percent nickel and 0.5 percent molybdenum. These electrodes can be used for long-term stress-relieved applications for welding low-alloy, high strength steels, in particular 1 percent nickel steels.

A7.9.4.2 EXXTX-K2X Electrodes. Electrodes of this classification produce weld metal which will have a chemical composition of 1.5 percent nickel and up to 0.35 percent molybdenum. These electrodes are used on many high-strength applications ranging from 80 to 110 ksi [550 to 760 MPa] minimum yield strength steels. Typical applications would include the welding of offshore structures and many structural applications where excellent low-temperature toughness is required. Steel welded would include HY-80, HY-100, ASTM A 710, ASTM A 514, and similar high-strength steels.

A7.9.4.3 EXXTX-K3X Electrodes. Electrodes of this type produce weld deposits with higher levels of Mn, Ni and Mo than the EXXTX-K2X types. They are usually higher in strength than the -K1 and -K2 types. Typical applications include the welding of HY-100 and ASTM A 514 steels.

A7.9.4.4 EXXTX-K4X Electrodes. Electrodes of this classification deposit weld metal similar to that of the -K3 electrodes, with the addition of approximately 0.5 percent chromium. The additional alloy provides the higher strength for many applications needing in excess of 120 ksi [830 MPa] tensile strength, such as armor plate.

A7.9.4.5 EXXTX-K5X Electrodes. Electrodes of this classification produce weld metal which is designed to match the mechanical properties of the steels such as SAE 4130 and 8630 after the weldment is quenched and tempered. The classification requirements stipulate only as-welded mechanical properties, therefore, the end user is encouraged to perform qualification testing.

A7.9.4.6 EXXTX-K6X Electrodes. Electrodes of this classification produce weld metal which utilizes less than 1 percent nickel to achieve excellent toughness in the 60 and 70 ksi [430 and 490 MPa] tensile strength ranges. Applications include structural, offshore construction and circumferential pipe welding.

A7.9.4.7 EXXTX-K7X Electrodes. This electrode classification produces weld metal which has similarities to that produced with EXXTX-Ni2X and EXXTX-Ni3X electrodes. This weld metal has approximately 1.5 percent manganese and 2.5 percent nickel.

A7.9.4.8 EXXTX-K8X Electrodes. This classification was designed for electrodes intended for use in circumferential girth welding of line pipe. The weld deposit contains approximately 1.5 percent manganese, 1 percent nickel, and small quantities of other alloys. It is especially intended for use on API 5L X80 pipe steels.

A7.9.4.9 EXXTX-K9X Electrodes. This electrode produces weld metal similar to that of the -K2 and -K3 type electrodes but is intended to be similar to the military requirements of MIL-101TM and MIL-101TC electrodes in MIL-E-24403/2C. The electrode is designed for welding HY-80 steel.

A7.9.5 EXXTX-NiXX (Ni-Steel) Electrodes. These electrodes have been designed to produce weld metal with increased strength (without being air-hardenable) or with increased notch toughness at temperatures as low as −100°F [−73°C]. They have been specified with nickel contents which fall into three nominal levels of 1 percent Ni, 2 percent Ni, and 3 percent Ni in steel.

With carbon levels up to 0.12 percent, the strength increases and permits some of the Ni-steel electrodes to be classified as E8XTX-NiXX and E9XTX-NiXX. However, some classifications may produce low-temperature notch toughness to match the base metal properties of nickel steels, such as ASTM A 203 Gr. A and ASTM A 352 Grades LC1 and LC2. The manufacturer should be consulted for specific Charpy V-notch impact properties. Typical base metals would also include ASTM A 302 and A 734.

Many low-alloy steels require postweld heat treatment to stress relieve the weld or temper the weld metal and heat-affected zone (HAZ) to achieve increased ductility. For most applications the holding temperature should not exceed the maximum temperature given in Table 6 for the classification considered, since nickel steels can be embrittled at higher temperatures. Higher PWHT holding temperatures may be acceptable for some applications. For many other applications, nickel steel weld metal can be used without PWHT.

Electrodes of the EXXTX-NiXX type are often used in structural applications where excellent toughness (Charpy V-Notch or CTOD) is required.

A7.9.6 EXXTX-W2X (Weathering Steel) Electrodes. These electrodes have been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels. These special properties are achieved by the addition of about 0.5 percent copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, some chromium and nickel additions are also made. These electrodes are used to weld typical weathering steel, such as ASTM A 242 and A 588.

A7.9.7 EXXTX-G, -GC, -GM (General Low-Alloy Steel) Electrodes. These electrodes are described in A2.4. These electrode classifications may be either modifications of other discrete classifications or totally new classifications. The purchaser and user should determine the description and intended use of the electrode from the supplier.

A8. Special Tests

A8.1 It is recognized that supplementary tests may need to be conducted to determine the suitability of these welding electrodes for applications involving properties such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, wear resistance, and suitability for welding combinations of dissimilar metals. Supplemental requirements as agreed between purchaser and supplier may be added to the purchase order following the guidance of AWS A5.01.

A8.2 Diffusible Hydrogen Test

A8.2.1 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, nor 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.

A8.2.2 As the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in the root beads), and toe or underbead cracks in the heat-affected zone.

A8.2.3 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.

A8.2.4 Most flux cored electrodes deposit weld metal having diffusible hydrogen levels of less than 16 mL/100 grams of deposited metal. For that reason, flux cored electrodes are generally considered to be low hydrogen. However, some commercially available products will, under certain conditions, produce weld metal with diffusible hydrogen levels in excess of 16 mL/100 grams of deposited metal. Therefore it may be appropriate for certain applications to utilize the optional supplemental designators for diffusible hydrogen when specifying the flux cored electrodes to be used.

A8.2.5 The use of a reference atmospheric condition during welding is necessitated because the arc is subject to atmospheric contamination when using either self-shielded or gas-shielded flux cored electrodes. 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.

A8.2.6 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator. The welding consumable is not the only source of diffusible hydrogen in the welding process. In actual practice, the following may contribute to the hydrogen content of the finished weldment.

(a) Surface Contamination. Rust, primer coating, anti-spatter compounds, dirt and grease can all contribute to diffusible hydrogen levels in practice. Consequently, standard diffusible hydrogen tests for classification of welding consumables require test material to be free of contamination. AWS A4.3 is specific as to the cleaning procedure for test material.

(b) Atmospheric Humidity. The welding arc is subject to atmospheric contamination when using either a self-shielded or gas shielded welding consumable. Moisture from the air, distinct from that in the welding consumable, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. AWS A4.3 has established a reference atmospheric condition at which the contribution to diffusible hydrogen from atmospheric humidity is considered to be negligible. This influence of atmospheric humidity also can be minimized by maintaining as short an arc length as possible consistent with a steady arc. For flux cored electrodes arc length is controlled primarily by arc voltage. 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.

(c) Shielding Gas. The reader is cautioned that the shielding gas itself can contribute significantly to diffusible hydrogen. Normally, welding grade shielding gases are intended to have very low dew points and very low impurity levels. This, however, is not always the case. Instances have occurred where a contaminated gas cylinder resulted in a significant increase of diffusible hydrogen in the weld metal. Further, moisture permeation through some hoses and moisture condensation in unused gas lines can become a source of diffusible hydrogen during welding. In case of doubt, a check of gas dew point is suggested. A dew point of −40°F [−40°C] or lower is considered satisfactory for most applications.

(d) Absorbed/Adsorbed Moisture. Flux cored electrodes can absorb/adsorb moisture over time which contributes to diffusible hydrogen levels. This behavior is well documented for shielded metal arc electrode coverings exposed to the atmosphere. Hydration of oxide films and lubricants on solid electrode surfaces under what may be considered "normal" storage conditions has also been reported to influence diffusible hydrogen. Moisture absorption/adsorption can be particularly significant if material is stored in a humid environment in damaged or open packages, or if unprotected for long periods of time. In the worst case of high humidity, even overnight exposure of unprotected electrodes can lead to a significant increase of diffusible hydrogen. For these reasons, indefinite periods of storage should be avoided. The storage and handling practices necessary to safeguard the condition of a welding consumable will vary from one product to another even within a given classification. Therefore, the consumable manufacturer should always be consulted for recommendations on

TABLE A4
EXAMPLE

Manufacturer ABC, an electrode manufacturer, recommends and/or publishes the following procedure range for its E81T1-K2 electrode.

Electrode Diameter	Shielding Gas	Wire Feed Rate, in./mm [cm/min]	Arc Voltage (volts)	CTWD, in. [mm]	Deposition Rate, lbs/hr [kg/hr]
0.045 in. [1.2 mm]	75 Ar/25 CO_2	175–300 [4445–760]	21–25	1/2–3/4 [12–20]	3.3–5.8 [1.5–2.6]
		300–425 [760–1 080]	24–28	5/8–7/8 [16–22]	5.8–8.1 [2.6–3.7]
		425–550 [1 080–1 400]	27–30	3/4–1 [20–25]	8.1–10.5 [3.7–4.8]
1/16 in. [1.6 mm]	75 Ar/25 CO_2	150–225 [380–570]	22–25	3/4–1 [20–25]	5.4–8.0 [2.5–3.6]
		225–300 [570–760]	24–27	7/8–1-1/8 [22–29]	8.0–10.8 [3.6–4.9]
		300–375 [760–950]	26–31	1–1-1/4 [25–32]	10.8–12.2 [4.9–5.5]

GENERAL NOTE: Based upon the manufacturer's recommended operating range, the minimum wire feed rate and the CTWD to be used for hydrogen testing are determined as follows:

1. For 0.045 in. [1.2 mm] diameter, the minimum wire feed rate (WFR_{min}) to be used for the hydrogen test, as specified in 15.2, is WFR_{min} = 175 in./min + 0.75 (550 in./min – 175 in./min) = 456 in./min [WFR_{min} = 445 cm/min + 0.75 (1 400 cm/min – 445 cm/min) = 1 160 cm/min].

   The CTWD to be used for the hydrogen test is 3/4 in. [20 mm], the minimum CTWD recommended by the manufacturer for the test wire feed rate of 456 in./min [1 160 cm/min].
2. For 1/16 in. [1.6 mm] diameter, the minimum wire feed rate (WFR_{min}) to be used for the hydrogen test, as specified in 15.2, is WFR_{min} = 150 in./min + 0.75 (375 in./min – 150 in./min) = 319 in./min [WFR_{min} = 380 cm/min + 0.75 (950 cm/min – 380 cm/min) = 808 cm/min].

   The CTWD to be used for the hydrogen test is 1 in. [25 mm], the minimum CTWD recommended by the manufacturer for the test wire feed rate of 319 in./min [808 cm/min].

storage and handling practice. In the event the electrode has been exposed, the manufacturer should be consulted regarding probable damage to its controlled hydrogen characteristics and possible reconditioning of the electrode.

(e) Effect of Welding Process Variables. Variations in welding process variables (e.g., amperage, voltage, contact tip to work distance, type of shielding gas, current type/polarity, single electrode vs. multiple electrode welding, etc.) are all reported to influence diffusible hydrogen test results in various ways. For example, with respect to contact tip to work distance, a longer CTWD will promote more preheating of the electrode, causing some removal of hydrogen-bearing compounds (e.g., moisture, lubricants, etc.) before they reach the arc. Consequently, the result of longer CTWD can be to reduce diffusible hydrogen. However, excessive CTWD with external gas shielded welding processes may cause some loss of shielding if the contact tip is not adequately recessed in the gas cup. If shielding is disturbed, more air may enter the arc and increase the diffusible hydrogen. This may also cause porosity due to nitrogen pickup.

Since welding process variables can have a significant effect on diffusible hydrogen test results, it should be noted that an electrode meeting the H4 requirements, for example, under the classification test conditions should not be expected to do so consistently under all welding conditions. Some variation should be expected and accounted for when making welding consumable selections and establishing operating ranges in practice.

A8.2.7 As indicated in A8.2.6(e), the welding procedures used with flux cored electrodes will influence the values obtained on a diffusible hydrogen test. To address this, the AWS A5M Subcommittee on Carbon and Low-Alloy Steel Electrodes for Flux Cored Arc Welding has incorporated into its specification test procedure requirements for conducting the diffusible hydrogen test when determining conformance to the hydrogen optional supplemental designator requirements shown in Table 9. See Section 15. Table A4 is provided as an example.

A8.2.8 All classifications may not be available in the H16, H8, or H4 diffusible hydrogen levels. The manufacturer of a given electrode should be consulted for availability of products meeting these limits.

A8.3 Aging of Tensile Specimens. Weld metals may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases toward its inherent value, while yield, tensile and impact strengths remain relatively unchanged. The A5.29 and A5.29M specifications permit the aging of the tensile test specimens at elevated temperatures not exceeding 220°F [105°C] for up to 48 hours before cooling them to room temperature and subjecting them to tension testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing.

Aging treatments are sometimes used for low hydrogen electrode deposits, especially when testing high strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a high 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. 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 A5.01.

A9. Changes or Obsolete Classifications

The E80T1-W classification from A5.29-80 has been changed to E8XT1-W2C, -W2M to conform to other documents.

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 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.l and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)

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
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
37	Selecting Gloves for Welding & Cutting

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SPECIFICATION FOR CONSUMABLE INSERTS

(**15**)

SFA-5.30/SFA-5.30M

(Identical with AWS Specification A5.30/A5.30M:2007. In case of dispute, the original AWS text applies.)

SPECIFICATION FOR CONSUMABLE INSERTS

SFA-5.30/SFA-5.30M

(Identical with AWS Specification A5.30/A5.30M:2007. In case of dispute, the original AWS text applies.)

1. Scope

This specification prescribes requirements for the classification of plain carbon steel, chromium-molybdenum low alloy steel, stainless steel, nickel alloy, and copper-nickel alloy consumable inserts[1] for use in conjunction with the gas tungsten arc welding process. These inserts also may be used with any other welding process for which they are found suitable. Included are packaging and testing requirements.

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in the Informative Annex Clauses A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.30 uses U.S. Customary Units. The specification A5.30M uses SI Units. The latter are shown within brackets [ ] or in appropriate columns in tables. Standard dimensions based on either system may be used for the sizing of consumable inserts under A5.30 and A5.30M.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard referred to applies.

2.1 The following ANSI and AWS standards[2] are referenced in the normative clauses of this document:

(a) AWS A5.01, *Filler Metal Procurement Guidelines*

(b) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.2 The following ASTM standards[3] are referenced in the normative clauses of this document:

(a) ASTM DS-56 (or SAE HS-1086), *Metals & Alloys in the Unified Numbering System*

(b) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(c) ASTM A 751, *Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products*

(d) ASTM E 75, *Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys*

(e) ASTM E 76, *Test Methods for Chemical Analysis of Nickel-Copper Alloys*

(f) ASTM E 1473, *Test Methods for Chemical Analysis of Nickel, Cobalt, and High Temperature Alloys*

3. Classification[4]

3.1 The consumable inserts covered by this A5.30/A5.30M specification are classified using a system that is independent of U.S. Customary Units and the International

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[1] "Consumable insert," is defined in AWS A3.0, *Standard Welding Terms and Definitions*, as: "Filler metal that is placed at the joint root before welding, and is intended to be completely fused in the joint root to become part of the weld."

[2] AWS standards and ANSI Z49.1 are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[4] See Table A1 for comparable classifications of bare wire filler metal in AWS specifications and for consumable inserts in the Military Specification.

TABLE 1
CARBON STEEL COMPOSITIONS

Group	AWS Classification	UNS Number[c]	Weight Percent[a,b]							
			C	Mn	P	S	Si	Al	Zr	Ti
A	INMs1	K10726	0.07	0.90 to 1.40	0.025	0.035	0.40 to 0.70	0.05[d] to 0.15	0.02[d] to 0.12	0.05[d] to 0.15
	INMs2	K01313	0.06 to 0.15	0.90 to 1.40	0.025	0.035	0.45 to 0.70	. . .	. . .	. . .
	INMs3	K11140	0.07 to 0.15	1.40 to 1.60	0.025	0.035	0.80 to 1.00	. . .	. . .	. . .

NOTES:

a. The consumable insert shall be analyzed for the specific elements for which values are shown in the table.

b. Single values shown are maximum.

c. SAE HS-1086/ASTM DS-561, *Metals & Alloys in the Unified Numbering System.*

d. Al + Zr + Ti = 0.15 minimum.

TABLE 2
CHROMIUM-MOLYBDENUM STEEL COMPOSITIONS

Group	AWS Classification	UNS Number[c]	Weight Percent[a,b]												Other Elements, Total
			C	Mn	P	S	Si	Al	Cr	Mo	Ni	Cu	V	Fe	
B	IN502	S50280	0.10	0.40 to 0.70	0.025	0.025	0.25 to 0.50	0.15	4.50 to 6.00	0.45 to 0.65	0.60	0.35	. . .	Balance	0.50
	IN504[d,e,f]	S50482	0.07 to 0.13	1.20[f]	0.010	0.010	0.15 to 0.50	0.04	8.00 to 10.50	0.85 to 1.20	0.80[f]	0.20	0.15 to 0.30	Balance	0.50
	IN515	K20900	0.07 to 0.12	0.40 to 0.70	0.025	0.025	0.40 to 0.70	0.15	1.20 to 1.50	0.40 to 0.65	0.20	0.35	. . .	Balance	0.50
	IN521	K30960	0.07 to 0.12	0.40 to 0.70	0.025	0.025	0.40 to 0.70	0.15	2.30 to 2.70	0.90 to 1.20	0.20	0.35	. . .	Balance	0.50

NOTE:

a. The consumable insert shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

b. Single values shown are maximum.

c. SAE HS-1086//ASTM DS-561, *Metals & Alloys in the Unified Numbering System.*

d. Niobium (Columbium) = 0.02to 0.10.

e. Nitrogen = 0.03 to 0.70.

f. Mn + Ni = 1.50 max.

System of Units (SI). Classification is according to chemical composition of the insert material as specified in Tables 1, 2, 3, and 4. Inserts are also classified by their shape as specified in 11.1 to 11.6, and in Fig. 1.

3.2 Consumable inserts classified under one classification shall not be classified under any other classification of this specification.

4. Acceptance

Acceptance[5] of the consumable inserts 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.[6]

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the "nearest unit" in the last right-hand place

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[5] See A3 (in Annex A) for further information concerning acceptance and testing of material shipped, and AWS A5.01.

[6] See A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

TABLE 3
CHROMIUM-NICKEL STAINLESS STEEL COMPOSITIONS

Group	AWS Classification	UNS Number[c]	Weight Percent[a,b]									
			C	Cr	Ni	Mo	Nb(Cb) + Ta	Mn	Si	P	S	Cu
C	IN308[d]	S30880	0.08	19.5 to 22.0	9.0 to 11.0	0.75	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN308L[d]	S30883	0.03	19.5 to 22.0	9.0 to 11.0	0.75	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN309[d]	S30980	0.12	23.0 to 25.0	12.0 to 14.0	0.75	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN309L[d]	S30983	0.03	23.0 to 25.0	12.0 to 14.0	0.75	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN310	S31080	0.08 to 0.15	25.0 to 28.0	20.0 to 22.5	0.75	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN312[d]	S31380	0.15	28.0 to 32.0	8.0 to 10.5	0.75	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN316[d]	S31680	0.08	18.0 to 20.0	11.0 to 14.0	2.0 to 3.0	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN316L[d]	S31683	0.03	18.0 to 20.0	11.0 to 14.0	2.0 to 3.0	. . .	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75
	IN348[d,e,f]	S34780	0.08	19.0 to 21.5	9.0 to 11.0	0.75	10 × C min to 1.0 max	1.0 to 2.5	0.30 to 0.65	0.03	0.03	0.75

NOTES:

a. The consumable insert shall be analyzed for the specific elements for which values are shown in this table.

b. Single values shown are maximum.

c. SAE HS-1086/ASTM DS-561, *Metlas & Alloys in the Unified Numbering System.*

d. Delta ferrite may be specified upon agreement between supplier and purchaser.

e. Tantalum content shall not exceed 0.10 percent, and cobalt shall not exceed 0.10%.

f. IN348 is suitable for welding Type 347 base metals.

TABLE 4
COPPER-NICKEL AND NICKEL ALLOY COMPOSITIONS

			Weight Percent[a,b]													
Group	AWS Classification	UNS Number[C]	C	Mn	Fe	S	P	Si	Cu	Ni[h]	Al	Ti	Cr	Mo	Nb + Ta	Other Elements, Total
E	IN52	N06052	0.04	1.0	7.0 to 11.0	0.015	0.02	0.50	0.30	Rem	1.10[g]	1.0[g]	28.0 to 31.5	0.50	0.10	0.50
	IN60	N04060	0.15	4.0	2.5	0.015	0.02	1.25	Rem	62.0 to 69.0	1.25	1.5 to 3.0	...	...	...	0.50
	IN61	N02061	0.15	1.0	1.0	0.015	0.03	0.75	0.25	93.0 min	1.5	2.0 to 3.5	...	...	...	0.50
	IN62	N06062	0.08	1.0	6.0 to 10.0	0.015	0.03	0.35	0.50	70.0 min[d]	...	...	14.0 to 17.0	...	1.5 to 3.0[e]	0.50
	IN67	C71581	...	1.0	0.4 to 0.75	0.01	0.020	0.25	Rem	29.0 to 32.0	...	0.2 to 0.5	...	...	...	0.50[f]
	IN6A	N07092	0.08	2.0 to 2.7	8.0	0.015	0.03	0.35	0.50	67.0 min[d]	...	2.5 to 3.5	14.0 to 17.0	...	...	0.50
	IN82	N06082	0.10	2.5 to 3.5	3.0	0.015	0.03	0.50	0.50	67.0 min[d]	...	0.75	18.0 to 22.0	...	2.0 to 3.0[e]	0.50

NOTES:

a. The consumable insert shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.

b. Single values shown are maximum, except where otherwise specified.

c. SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System.*

d. Cobalt = 0.12 maximum when specified.

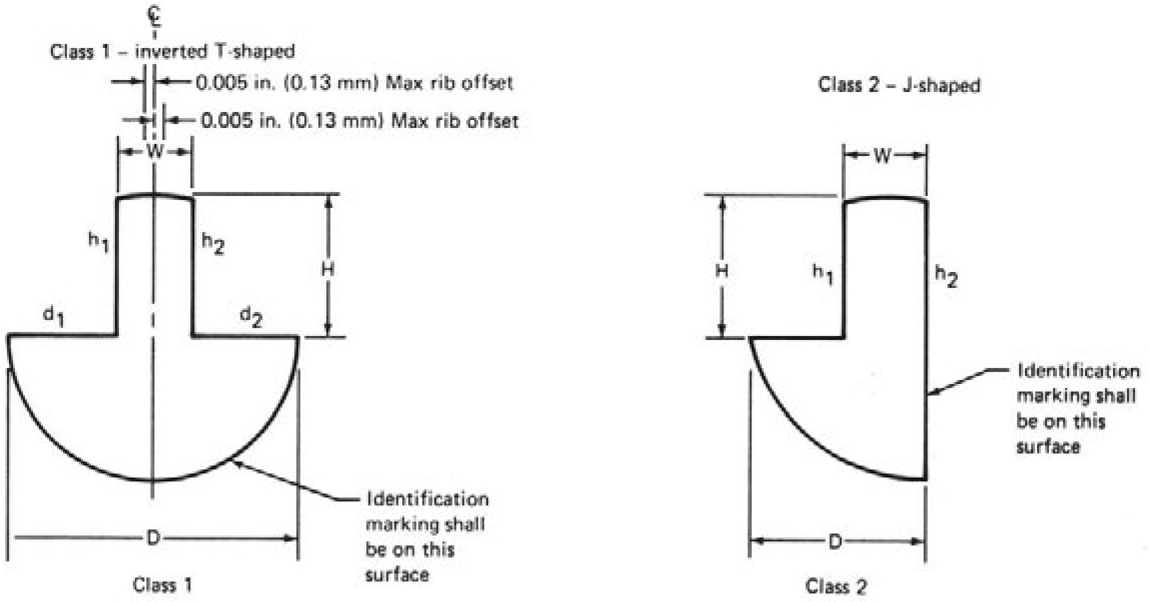
e. Tantalum = 0.30 maximum when specified (Nb is the same as Cb).

f. Lead = 0.02 maximum.

g. Al + Ti is 1.5 maximum.

h. Include incidental cobalt.

FIG. 1 STANDARD SIZES AND SHAPES OF CONSUMABLE INSERTS



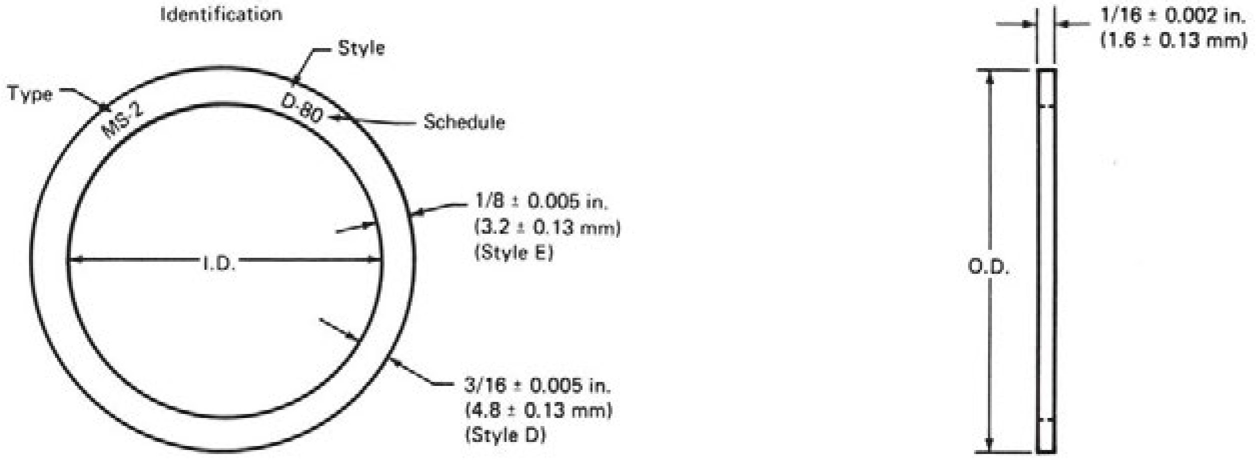
GENERAL NOTES:

(a) Lands (d_1, d_2) on either side of the rib shall be on the same plane within 0.005 in. (0.13 mm).

(b) Rib surfaces (h_1 h_2) shall be parallel within 0.002 in. (0.05 mm) and square with lands (d_1, d_2) within 0.005 in. (0.13 mm).

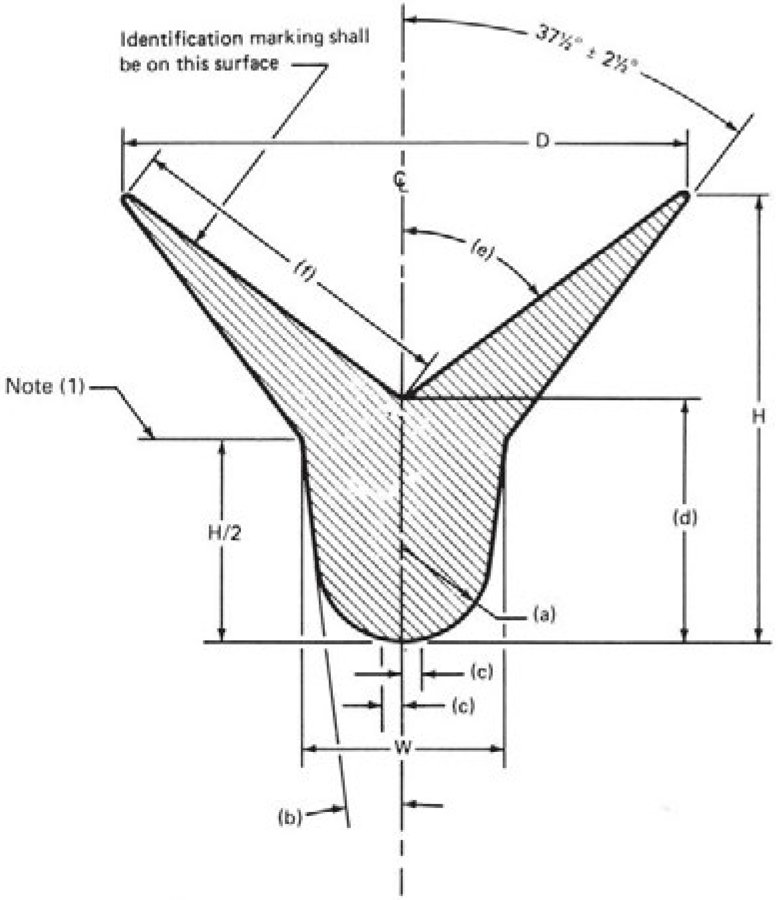
(c) Dimensions and tolerances, see Table 8.

Class 1 and Class 2 inserts – Cross-sectional configuration



Class 3 – Solid ring inserts – Plan view and cross-sectional configurations

FIG. 1 STANDARD SIZES AND SHAPES OF CONSUMABLE INSERTS (CONT'D)



GENERAL NOTES:

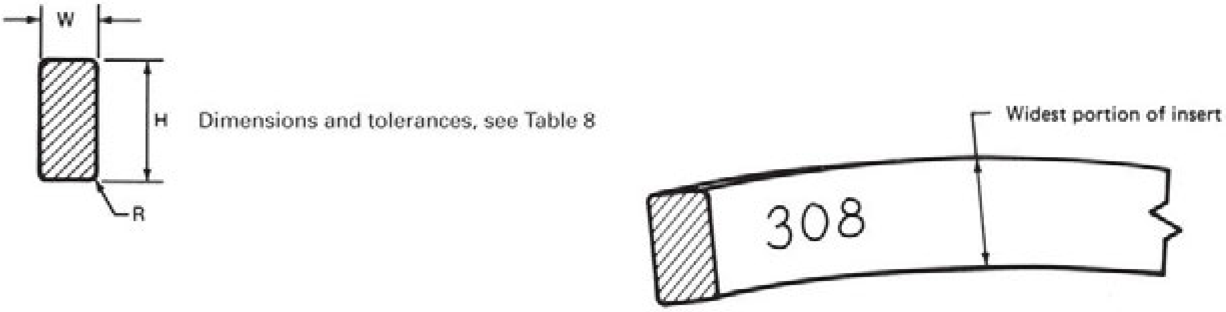
(a) Dimensions and tolerances, see Table 8.

(b) When specified, rings $1\frac{1}{2}$ to 2 in. (38.1 to 50.8 mm) in diameter shall be formed of $\frac{5}{32}$ in. (4.0 mm) material.

NOTE:

(1) Reference diameter for correlating with pipe I.D.

Class 4 inserts – cross-sectional configuration



Class 5 inserts – cross-sectional configuration of figures used in expressing the limiting value in accordance with the rounding-off method given in ASTM E 29.

7. Summary of Tests

Chemical analysis of the consumable insert material, or the stock from which it is made, is the only test required for classification of a product under this specification.

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. Samples for retest may be taken from the original test sample or from a new test sample. A 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 test specimen(s), or in conducting the tests, 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. Chemical Analysis

9.1 A sample of the consumable insert material or the stock from which it is made, sufficient for retest if necessary, shall be prepared for chemical analysis.

9.2 The sample may be analyzed by accepted analytical methods. The referee method shall be according to the appropriate techniques set forth in ASTM A 751 and ASTM E 1473 for all except IN60 and IN67, for which ASTM E 76 and ASTM E 75 shall apply, respectively.

9.3 The results of the chemical analysis shall meet the requirements of Table 1, 2, 3, or 4, for the classification of the consumable insert material under test.[7]

10. Method of Manufacture

Consumable inserts classified according to this specification may be manufactured by any method that will produce consumable inserts that meet the requirements of this specification.

TABLE 5
MINIMUM OVERLAP FOR CLASSES 1, 2, AND 5, STYLE B INSERTS

Nominal Pipe Sizes		Circumferential Overlap	
NPS	DN	in.	mm
1	25	1/4	6
1-1/4	32	1/4	6
1-1/2	40	1/4	6
2	50	1/4	6
2-1/2	65	1/4	6
3	80	3/8	10
3-1/2	90	3/8	10
4	100	3/8	10
5	125	1/2	13
6	150	1/2	13
8	200	5/8	16
10	250	3/4	20
12	300	3/4	20
14	350	3/4	20

11. Standard Shapes, Styles, and Sizes

Standard shapes, styles, and sizes shall be as listed below and shown in Fig. 1 and Tables 5, 6, 7, and 8.

11.1 Class 1, Inverted T-Shaped Cross-Section

11.1.1 Style A, coiled consumable insert

11.1.2 Style B, preformed rings, open lap joint

11.1.3 Style C, preformed rings, open butt joint

11.2 Class 2, J-Shaped Cross-Section

11.2.1 Style A, coiled consumable insert

11.2.2 Style B, preformed rings, open lap joint

11.2.3 Style C, preformed rings, open butt joint

11.3 Class 3, Solid Ring Inserts

11.3.1 Style D, 3/16 in. (4.8 mm) rim width

11.3.2 Style E, 1/8 in. (3.2 mm) rim width

11.4 Class 4, Y-Shaped Cross-Section

11.4.1 Style A, coiled consumable insert

11.4.2 Style B, preformed rings, open lap joint

11.4.3 Style C, preformed rings, open butt joint

11.5 Class 5, Rectangular-Shaped Cross Section (Contoured Edges)

11.5.1 Style A, coiled consumable insert

11.5.2 Style B, preformed rings, open lap joint

11.5.3 Style C, preformed rings, open butt joint

11.6 Other sizes and shapes may be supplied as agreed upon between supplier and purchaser. Chemical composition of other sizes and shapes shall conform to the pertinent classification requirements of this specification.

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[7] ASTM standards can be obtained from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

TABLE 6
DIMENSIONS OF CLASS 3, STYLE D INSERTS

Pipe Dimensions					Ring Diameter[a]			
Nominal Diameter			Inside Diameter		Ring OD for Nominal Pipe Diameter		Ring ID for Nominal Pipe Diameter	
NPS	DN	Schedule Number[b]	in.	mm	in.	mm	in.	mm
2	50	10S	2.157	54.78	2.43	61.7	2.06	52.3
		40, 40S	2.067	52.50	2.34	59.4	1.97	50.0
		80, 80S	1.939	49.25	2.22	56.4	1.85	47.0
2½	65	10S	2.635	66.93	2.91	73.9	2.54	64.5
		40, 40S	2.489	62.71	2.75	69.9	2.38	60.4
		80, 80S	2.323	59.00	2.60	66.0	2.23	56.6
3	80	10S	3.260	82.80	3.54	88.9	3.17	80.5
		40, 40S	3.068	77.93	3.35	85.1	2.98	75.7
		80, 80S	2.900	73.66	3.18	80.8	2.81	71.4
3½	90	10S	3.760	95.50	4.04	102.6	3.67	93.2
		40, 40S	3.548	90.12	3.82	97.0	3.45	87.6
		80, 80S	3.364	85.45	3.64	92.5	3.27	83.1
4	100	10S	4.260	108.20	4.54	115.3	4.17	105.9
		40, 40S	4.026	102.26	4.30	109.2	3.93	99.8
		80, 80S	3.826	97.18	4.10	104.1	3.73	94.7
5	125	5S	5.345	135.76	5.62	142.7	5.25	133.4
		10S	5.295	134.49	5.57	141.5	5.20	132.1
		40, 40S	5.047	128.19	5.32	135.1	4.95	125.7
		80, 80S	4.813	122.25	5.09	129.3	4.72	119.9
6	150	5S	6.407	162.74	6.68	169.7	6.31	160.3
		10S	6.357	161.47	6.63	168.4	6.26	159.0
		40, 40S	6.065	154.05	6.34	161.0	5.97	151.6
		80, 80S	5.761	146.33	6.04	153.4	5.67	144.0
8	200	5S	8.407	213.54	8.68	220.4	8.31	211.1
		10S	8.329	211.56	8.61	218.7	8.24	209.3
		40, 40S	7.981	202.72	8.26	209.8	7.89	200.4
		80, 80S	7.265	193.68	7.90	200.7	7.53	191.3
10	250	5S	10.482	266.24	10.76	273.3	10.39	263.9
		10S	10.420	264.67	10.70	271.8	10.33	262.4
		40, 40S	10.020	254.51	10.30	261.6	9.93	252.2
		80S	9.750	247.65	10.03	254.8	9.66	245.4
		80	9.564	242.93	9.84	249.9	9.47	240.5
12	250	5S	12.432	315.92	12.70	322.6	12.33	313.2
		10S	12.390	314.71	12.67	321.8	12.30	312.4
		40S	12.000	304.80	12.28	311.9	11.91	302.5
		40	11.938	303.22	12.22	310.4	11.85	301.0
		80S	11.750	298.45	12.03	305.6	11.66	296.2
		80	11.376	288.95	11.65	295.9	11.28	286.5
14	350	10S	13.624	346.05	13.78	350.0	13.41	340.6
		40, 40S	13.126	333.40	13.40	340.4	13.03	331.0
		80, 80S	12.500	317.50	12.78	324.6	12.41	315.2
16	400	10S	15.670	393.02	15.78	400.8	15.41	391.4
		40, 40S	15.000	381.00	15.28	388.1	14.91	378.7
		80, 80S	14.314	363.58	14.59	370.6	14.22	361.2

NOTES:

a. Class 3, Style D insert rings are normally furnished to match nominal internal diameter of the pipe as shown in Table 6. For Class 3 Style D insert rings required for use with specially I.D. machined pipe end joint preparation, the dimensions are determined as follows:
Ring ID = pipe ID minus 0.094 in. (2.38 mm)
Ring OD = ring ID + 0.375 in. (9.53 mm)

b. Schedule number followed by "S" applies to Group C Types.

TABLE 7
DIMENSIONS OF CLASS 3, STYLE E INSERTS

Pipe Dimensions					Ring Diameter[a]			
Nominal Diameter		Schedule Number[b]	Inside Diameter		Ring OD for Nominal Pipe Diameter		Ring ID for Nominal Pipe Diameter	
NPS	DN		in.	mm	in.	mm	in.	mm
¼	8	10S	0.410	10.41	0.57	14.5	0.32	8.1
		40, 40S	0.364	9.25	0.52	13.2	0.27	6.8
		80, 80S	0.302	7.67	0.46	11.7	0.21	5.3
⅜	10	10S	0.545	13.84	0.70	17.8	0.45	11.4
		40, 40S	0.493	12.52	0.65	16.5	0.40	10.1
		80, 80S	0.423	10.74	0.58	14.7	0.33	8.4
½	15	5S	0.710	18.03	0.87	22.1	0.62	15.7
		10S	0.674	17.12	0.83	21.1	0.58	14.7
		40, 40S	0.622	15.80	0.78	19.8	0.53	13.5
		80, 80S	0.546	13.87	0.70	17.8	0.45	11.4
¾	20	5S	0.920	23.37	1.08	27.4	0.83	21.1
		10S	0.884	22.45	1.04	26.4	0.79	20.1
		40, 40S	0.824	20.93	0.98	24.9	0.73	18.5
		80, 80S	0.742	18.85	0.90	22.9	0.65	16.5
1	25	5S	1.186	30.10	1.34	34.0	1.09	27.7
		10S	1.097	27.86	1.15	31.8	1.00	25.4
		40, 40S	1.409	26.64	1.21	30.7	0.96	24.4
		80, 80S	0.957	24.31	1.11	28.2	0.86	21.8
1-¼	32	5S	1.530	38.86	1.69	42.9	1.44	36.3
		10S	1.442	36.63	1.60	40.6	1.35	34.4
		40, 40S	1.380	35.05	1.54	39.1	1.29	32.8
		80, 80S	1.278	32.46	1.43	36.3	1.18	30.0
1-½	40	5S	1.770	44.96	1.93	49.0	1.68	42.7
		10S	1.682	42.72	1.84	46.7	1.59	40.4
		40, 40S	1.610	40.89	1.77	45.0	1.52	38.6
		80, 80S	1.500	38.10	1.65	41.9	1.41	35.8
2	50	5S	2.245	57.02	2.40	61.0	2.15	54.6
		10S	2.157	54.79	2.31	58.7	2.06	52.3
		40, 40S	2.067	52.50	2.22	56.4	1.97	50.0
		80, 80S	1.939	49.25	2.10	53.3	1.85	47.0
2-½	65	5S	2.709	68.81	2.87	72.9	2.62	66.5
3	80	5S	3.334	84.68	3.49	88.6	3.24	82.3
3-½	90	5S	3.834	97.38	3.99	101.3	3.74	95.0
4	100	5S	4.334	110.08	4.49	114.0	4.24	107.7

NOTES:

a. Class 3, Style R insert rings are normally furnished to match nominal internal diameter of the pipe as shown in Table 6. For Class 3 Style E insert rings required for use with specially I.D. machined pipe end joint preparation, the dimensions are determined as follows:
Ring ID = pipe ID minus 0.094 in. (2.38 mm)
Ring OD = ring ID + 0.250 in. (6.35 mm)

b. Schedule number followed by "S" applies to Group C Types.

TABLE 8
CROSS-SECTIONAL DIMENSIONS AND TOLERANCES FOR CLASSES 1, 2, 4, AND 5 INSERTS

Insert Size		Legend	Class One,[a] Inverted T-Shaped				Class Two,[a] J-Shaped				Class Four,[b] Y-Shaped				Class Five, Rectangular-Shaped			
in.	mm	(Fig. 1)	in.		mm		in.		mm		in.		mm		in.		mm	
3/64	1.2	D	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.165	±0.010	4.19	±0.25	. . .	. . .	. . .	. . .
		W	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.044	+0.003 −0.002	1.12	+0.08 −0.05	. . .	. . .	. . .	. . .
		H	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.155	+0.025 −0.015	3.94	+0.64 −0.38	. . .	. . .	. . .	. . .
		H/2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.078	±0.020	1.97	±0.50	. . .	. . .	. . .	. . .
		R	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
1/8	3.2	D	0.125	±0.004	3.18	±0.10	0.086	+0.011 −0.005	2.18	+0.28 −0.13	0.165	±0.010	4.19	±0.25	. . .	. . .	. . .	. . .
		W	0.047	+0.002 −0.012	1.19	+0.05 −0.30	0.047	+0.002 −0.012	1.19	+0.05 −0.30	0.078	±0.010	1.98	±0.25	0.0625	±0.010	1.59	±0.25
		H	0.055	+0.012 −0.002	1.40	+0.30 −0.05	0.055	+0.012 −0.002	1.40	+0.30 −0.05	0.140	±0.010	3.56	±0.25	0.125	±0.010	3.18	±0.25
		H/2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.072	±0.010	1.83	±0.25	. . .	. . .	. . .	. . .
		R	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.0156	±0.005	0.40	±0.13
5/32	4.0	D	0.156	±0.005	3.96	±0.13	0.110	+0.012 −0.010	2.79	+0.30 −0.25	0.205	±0.015	5.21	±0.38	. . .	. . .	. . .	. . .
		W	0.063	+0.003 −0.014	1.60	+0.08 −0.36	0.063	+0.003 −0.014	1.60	+0.08 −0.36	0.093	±0.015	2.36	±0.38	0.125	±0.015	3.18	±0.38
		H	0.063	+0.014 −0.003	1.60	+0.36 −0.08	0.063	+0.014 −0.010	1.60	+0.36 −0.25	0.175	±0.010	4.45	±0.25	0.156	±0.015	3.96	±0.38
		H/2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.093	±0.010	2.36	±0.25	. . .	. . .	. . .	. . .
		R	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.03125	±0.005	0.794	±0.13

NOTES:

a. The offset between the center of the rib (W) and center of the land (D) shall not exceed 0.005 in. (0.13 mm).

b. Additional dimensions and tolerances — Class 4, Y-shaped inserts (See Fig. 1):

	3/64 in. size (in.)	1.2 mm size (mm)	1/8 in. size (in.)	3.2 mm size (mm)	5/32 in. size (in.)	4.0 mm size (mm)
(a) Radius of rib	0.020 ± 0.003	0.5 ± 0.08	0.044 ± 0.005	1.12 ± 0.13	0.050 ± 0.005	1.27 ± 0.13
(b) Angle between side of rib and center of line	1° − 2°	1° − 2°	1° − 2°	1° − 2°	1° − 2°	1° − 2°
(c) Rib offset	±0.010	±0.25	±0.010	±0.25	±0.015	±0.38
(d) Height of rib along center line	0.093 ± 0.010	2.36 ± 0.25	0.100 ± 0.010	2.54 ± 0.25	0.115 ± 0.010	2.92 ± 0.25
(e) Angle between top surface of inclined arm and center line	50° ± 5°	50° ± 5°	50° ± 5°	50° ± 5°	50° ± 5°	50° ± 5°
(f) Length of inclined arm	0.085 ± 0.010	2.16 ± 0.25	0.085 ± 0.010	2.16 ± 0.25	0.125 ± 0.010	3.18 ± 0.25

From a practical inspection standpoint, the D, W, H, and H/2 dimensions have the most to do with the usability and weldability. The (a) through (f) dimensions are furnished to complete the description of the cross-sectional configuration.

12. Finish and Uniformity

All consumable inserts 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.

13. Standard Package Forms

Inserts shall be packaged in accordance with the manufacturer's standard practice. Solid rings or coils may be packed on mandrels, in tubes, or in boxes.

14. Insert Information

All consumable inserts shall be either tagged, steel stamped, or otherwise identified to provide the AWS classification number, and either lot, control, or heat number. The prefix letters "IN" may be omitted. Style A inserts shall be suitably marked at intervals of not less than 5 in. (125 mm).

15. Packaging

Consumable inserts shall be suitably packaged to ensure against damage during shipment or storage under normal conditions.

16. Marking of Packages

16.1 The following product information shall be legibly marked so as to be visible from the outside of each unit package:

(a) AWS specification and classification number (year of issue may be excluded)

(b) Supplier's name and trade designation

(c) Standard shape, style, size, and number of pieces

(d) Lot, control, or heat number.[8]

16.2 Marking of any overpacking of unit packages with items listed in 16.1 shall be optional with the manufacturer.

16.3 The appropriate precautionary information[9] as given in ANSI Z49.1 (as a minimum), or its equivalent, shall be prominently displayed in legible print on all packages of inserts.

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[8] For purposes of this specification, a *lot* shall be those consumable inserts having the same cross-sectional shape and produced from the same heat of metal. A *heat* is defined as that material obtained from the same melt of metal.

[9] Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumables using certain processes.

Annex
Guide to AWS Specification for Consumable Inserts

(This Annex is not a part of AWS A5.30/A5.30M:2007, *Specification for Consumable Inserts*, but is included for information purposes only.)

A1. Introduction

The purpose of this guide is to correlate the filler metal classification with their intended applications so that this specification may be used effectively.

A2. Classification System

A2.1 The classification system used in this specification follows, as closely as possible, the standard pattern used in other AWS filler metal specifications. The inherent nature of the products being classified has, however, necessitated specific changes that more precisely classify the product. As an example, consider IN308. The prefix "IN" designates a consumable insert. The numbers 308 designate the chemical composition.

A2.2 While consumable inserts are classified on the basis of their chemical composition, the cross-sectional configuration, designated by class number (Fig. 1), size (Tables 6, 7, and 8), and style (Clause 11), must also be specified when ordering.

A2.3 Request for Filler Metal Classification

A2.3.1 When a filler metal cannot be classified according to a standard classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here.

A2.3.2 A request to establish a new filler metal classification must be a written request, and it needs to provide sufficient detail to permit the A5 Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need.

In particluar, the request needs to include:

(a) all classification requirements as given for existing classifications, such as, chemical composition ranges, and available sizes, classes, and styles

(b) any conditions for conducting the tests used to demonstrate that the product meets the classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)

(c) information on Description and Intended Use, which parallels that for existing classifications, for that clause of Annex A

The request for a new classification without the above information will be considered incomplete. The Secretary will return the request for further information.

A2.3.3 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 A5 Committee on Filler Metals and Allied Materials, and the Chair of the particular Subcommittee involved

(d) file the original request

(e) add the request to the log of outstanding requests

A2.3.4 All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chair of the A5 Committee and 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 A5 Committee on Filler Metals and Allied Materials for action.

A2.3.5 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.

A2.4 An international system for designating welding filler metals developed by the International Institute of

TABLE A1
COMPARISON OF CLASSIFICATIONS

AWS Classification A5.30/A5.30M	Comparable AWS Specification		Military Designation[d]	Proposed ISO Designation[e]
	Number	Classification		
INMs1	A5.18[a]	ER70S-2	MIL-Ms-1	I-2031
INMs2		ER70S-3	MIL-Ms-2	I-2130
INMs3		ER70S-6[f]	. . .	I-3140
IN515	A5.28[b]	ER80S-B2	MIL-515	I-1130-1CM
IN521		ER90S-B3	MIL-521	I-1130-2CM
IN502		ER80S-B6	MIL-505	I-1120-6CM
IN504		ER90S-B9	. . .	I-2102-9C1MV
IN308	A5.9[c]	ER308	MIL-308	IS308
IN308L		ER308L	MIL-308L	IS308L
IN309		ER309	. . .	IS309
IN309L		ER309L	. . .	IS309L
IN310		ER310	MIL-310	IS310
IN312		ER312	MIL-312	IS312
IN316		ER316	MIL-316	IS316
IN316L		ER316L	MIL-316L	IS316lL
IN348		ER348	MIL-348Co	IS348
IN52	A5.14[c]	ERNiCrFe-7	. . .	INi 6052
IN60		ERNiCu-7	MIL-60	INi 4060
IN61		ERNi-1	MIL-61	INi 2061
IN62		ERNiCrFe-5	MIL-62	INi 6062
IN67	A5.7[c]	ERCuNi	MIL-67	ICu 7158
IN6A	A5.14[c]	ERNiCrFe-6	MIL-6A	INi 6092
IN82		ERNiCr-3	MIL-82	INi 6082

NOTES:

a. The classification ER70S-x for the corresponding metric specification, A5.18M, is ER48S-x.

b. The classification ER80S-x and ER90S-x for the corresponding metric specification, A5.28M, is ER55S-x and ER62S-x, respectively.

c. The classifications for the corresponding metric specifications are the same in both.

d. Military Specification MIL-I-23413.

e. AWS document IFS:2002.

f. INMs3 is similar to ER70S-6, but specifies more restrictive chemical composition ranges for manganese and silicon.

Welding (IIW) is being adopted in many ISO specifications. Table A1 shows the proposed designations for consumable inserts. To understand the proposed international designation system, one is referred to the tables and annex of the AWS publication document IFS:2002, *International Index of Welding Filler Metal Classifications.*

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, shall 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 requried by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that that material met the requirements of the specification. Representative material, in this case, is consumable insert material from any production run of that classification. "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.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes to which welders and welding operators are exposed during welding. They are as follows:

(1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)

(2) Number of welders and welding operators working in that space

(3) Rate of evolution of fumes, gases, or dust, according to the materials and processes involved

(4) The proximity of the welder or welding operator 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

(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 requried during welding and should be referred to for details. Attention is drawn particularly to the clause on Ventilation in that document.

A6. Description of the Process

A6.1 General. Consumable inserts are used for root pass welding from one side where consistent, high quality welds are required with minimum repairs, or rejects, and where welding conditions may be less than optimum, such as a confined space for welding or the necessity for maximum assurance against weld cracks, etc. Consumable inserts are most often used in pipe joints, and frequently used in pressure vessel and structural applications.

A6.2 Purging. To provide welded piping systems with the integrity required by some piping codes, the weld joint must be a full penetration joint with weld metal of consistently good quality. One method of obtaining this high level of quality is the use of preplaced consumable inserts in conjunction with a specific joint configuration together with a suitable protective gas back purge. The gas tungsten arc welding process, either manual or automatic, generally is used to consume or fuse the consumable insert. This method is particularly adaptable to conditions encountered in pipe welding but also may be applied to flat plate type joints. The main consideration is that a full penetration groove weld is required when the accessibility is limited to one side or when the reverse side of the joints is inaccessible for welding. In order to obtain a suitably smooth, uniform under side weld surface without crevices or oxidation, a purge must be established using a suitable protective gas. Since the second and third passes in the joint may take the previously deposited consumable insert root pass above the oxidizing temperature of the base and filler metal, it may be necessary to maintain the purge until three layers or $^{3}/_{16}$ in. (4.8 mm) root thickness is obtained.

A6.3 Ferrite Content. For austenitic stainless steel consumable inserts, the purchaser should specify in the purchase order the applicable limits of the Ferrite Number (FN) required in the consumable inserts. In general, the limits applied to the matching filler metal type being used in the joint are recommended for the consumable insert. Ferrite should be measured on a weld metal pad by means of a suitable instrument that has been calibrated in accordance with AWS A4.2, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless and Duplex Austenitic Ferritic Stainless Steel Weld Metal*. Alternately, the Ferrite Number can be estimated from the chemical composition of the insert using the constitution diagrams prepared through the efforts of the Welding Research Council, shown in Fig. A1.

A6.4 Joint Configuration. The joint end preparation configuration should be compatible with the shape of the consumable insert used in order to obtain consistent high quality, particularly under field welding conditions.

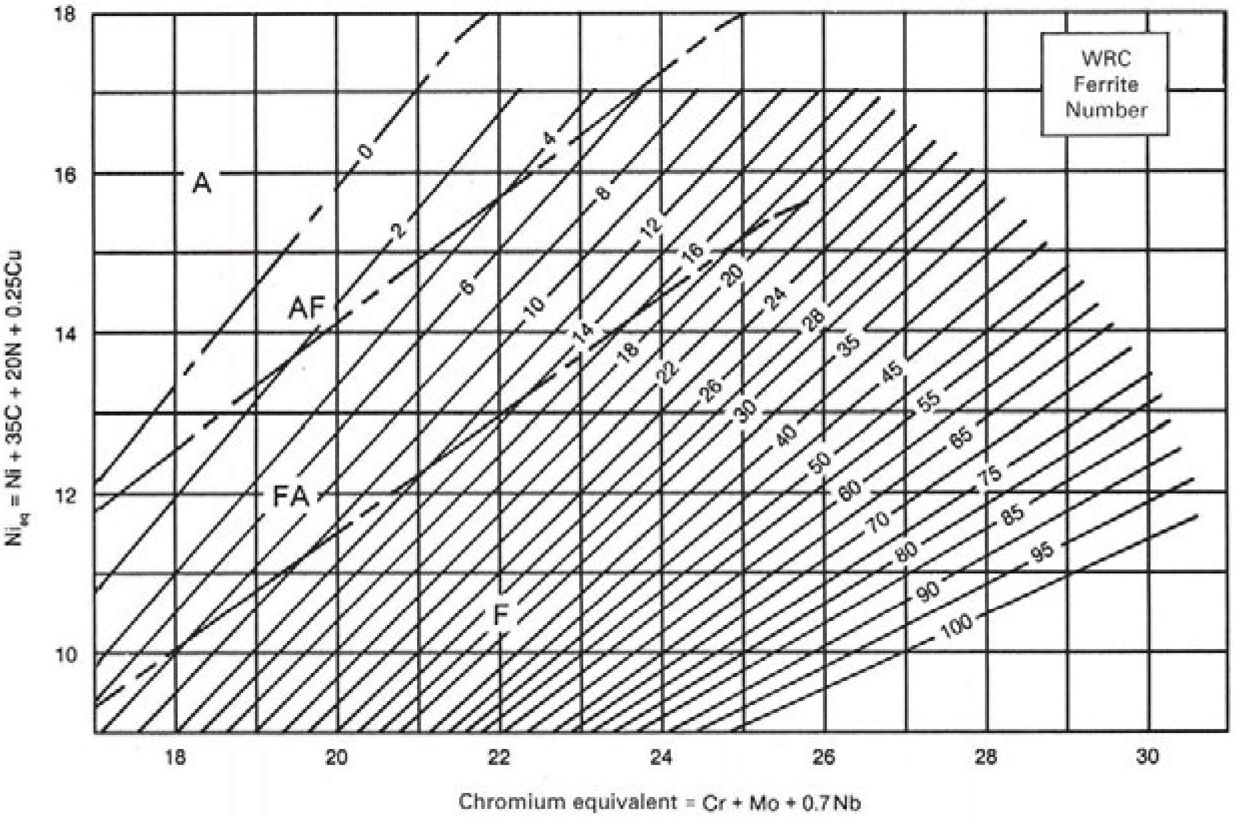
For all shape configurations, the butt gap in the insert (fitted, ready for tack welding) should not exceed $^{1}/_{16}$ in. (1.6 mm).

A6.5 Dilution. The weld metal composition will be significantly affected by the composition of the parent metal being welded. As much as 40%, or even 50%, of the weld pass may consist of metal fused from the adjacent edges at the root of a welded pipe joint. This amount of dilution may have a significant effect on the properties of the weld, as for example in estimating ferrite content in stainless steels or soundness in nickel alloy welds. The composition of the consumable insert may thus require somewhat higher levels of certain elements than for other weld filler metals to compensate for such dilution effects. An example of the dilution effect in the ferrite number of stainless steel weld pass is shown in Fig. A2.

A7. Ordering Information

When ordering inserts, the following information shall be included:

FIG. A1 WRC-1992 (FN) DIAGRAM FOR STAINLESS STEEL WELD METAL



(1) Title, number, and date of this specification

(2) Classifications, shape, style and size, including pipe schedule or pipe inside diameter

(3) Required Ferrite Number (stainless steel types)

A8. Description and Intended Use of Consumable Inserts

A8.1 Cross-Sectional Configurations. The selection of the shape of an insert (designated "class"), is largely determined by the preference of the engineer and operator for a given application. The Class 1 shape has been preferred for many highly critical weld joints especially in nuclear piping and in high temperature, high pressure piping installation. The Class 2 shape is suitable where the pipe alignment is less critical. The Class 3 shape requires compositions normally found in rod or wire forms for welding filler metals, and thus requires flattering and forming into solid rings to the required shapes and sizes. The Class 4 shape is suitable mainly for V-groove weld preparations. The Class 5 shape, like that of Class 3, is flattened from rod or wire comparable to bare welding filler metal compositions, but is not formed into solid rings, allowing the operator to size the ring to that of the pipe diameters.

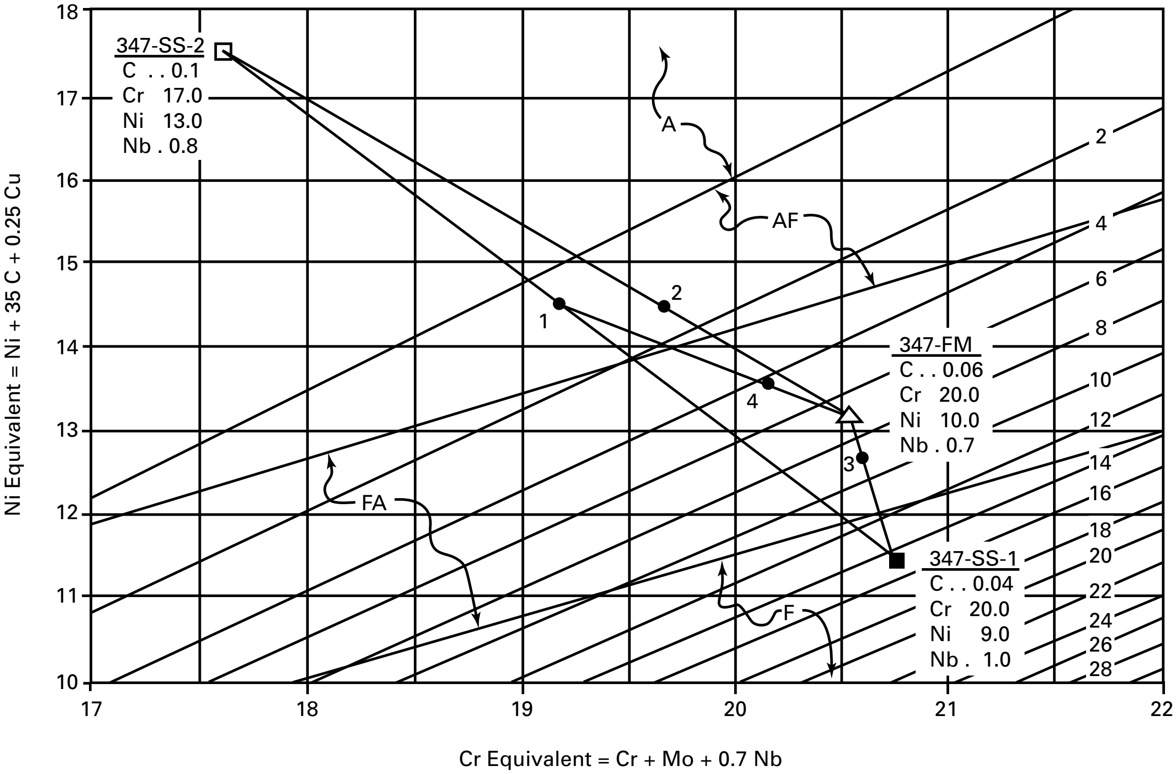
A8.2 Style. Class 1, 2, and 5 are available in continuous lengths (Style A) from which the user can fit to the desired joint configuration or to form rings to the desired size. Preformed rings can be supplied either with an overlap (Style B) to allow for contraction or expansion to the exact pipe size as needed, or for butted rings (Style C) to fit the specified pipe or tube inside diameter. Class 3 solid rings (Style D and E) are supplied to match the dimensions of standard pipe sizes as shown in Tables 6 and 7.

A8.3 Compositions. As shown in Tables 1 to 4, four groups of compositions are standardized, Group A for the three carbon steel applications, differing in carbon manganese and silicon; Group B for the types most commonly used chromium-molybdenum steel pipes and tubes, differing principally in chromium and molybdenum; Group C for the commonly employed stainless steel pipe and tube joints; and Group E for the nonferrous nickel and nickel copper alloys.

Compositions other than those shown in this specification may also be furnished by agreement between user and supplier.

FIG. A2 EFFECT OF BASE METAL DILUTION ON FERRITE CONTENT IN STAINLESS STEEL WELDS WITH CONSUMABLE INSERTS (See Note 2)

The WRC 1992 Constitution Diagram



By the use of the *FERRITEPREDICTOR*™ software (see Note 1) one can plot the compositions of base metals and filler metal to arrive at a prediction of the weld metal ferrite in various situations. This graph shows an enlarged section of the WRC-1992 Diagram. If the two Type 347 base metals at the extreme composition limits of the specifications, 347-SS-1 in the ferrite solidification mode region, and 347-SS-2 in the austenite solidification mode region, are welded with equal fusion of both base metals without filler metal, the ferrite would be predicted at position "1." If filler metal 347-FM is deposited as a bead-on-plate with 30% dilution on base metal, 347-SS-2, the ferrite prediction would be found at position "2," less than 2 FN. The same filler metal with the same dilution on base metal 347-SS-1 will produce a weld metal with 9 FN as shown at position "3." A weld joining the two base metals with equal fusion of each side and using the 347-FM filler metal with 30% dilution will have a Ferrite Number of 4, shown at position "4." This illustrates the importance of knowing not only the composition of filler metal, but also that of the base metals being welded when estimating the ferrite which may be found in the weld metal.

NOTES:

1. Copyright © 1992 The Lincoln Electric Company, Cleveland, Ohio. FERRITEPREDICTOR software is available on the web at http://software.lincolnelectric.com.
2. For an interpretive report on "Effects of Base Metal Dilution on Ferrite Content in Stainless Steel Welds with Consumable Inserts," refer to R. David Thomas, Jr. and R. W. Messler, Jr., Welding Type 347 Stainless Steel—An Interpretive Report, Welding Research Council Bulletin 421, May 1997, page 69.

A9. Special Test

A9.1 Usability. The control of chemical composition is generally sufficient to ensure usability of these classifications. However, a fusibility test may be specified. Figure A3 illustrates a typical fusibility test joint in plate. This test is applied with tungsten arc torch on the face side of a flat plate whose back is enclosed so as to retain the purging gas at atmospheric pressure. By testing in the vertical up position for half the joint and in the flat position for the second half, the test evaluates the suitability of the insert to perform suitably in a pipe welded in the 5G (horizontal fixed) position. A visual examination of the weld on both the front and back sides gives assurance that the insert will become completely fused and provide suitable weld contour in accordance with Note 5 of Fig. A3.

A9.2 Applications. A complete description of how to use consumable inserts is beyond the scope of this document. For further information, see AWS D10.4, *Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing*, and AWS D10.11, *Recommended Practices for Root Pass Welding and Gas Purging*. Standard Welding Procedures making use of consumable inserts are set forth in AWS B2.1-1-210 for carbon steel pipe joints, B2.1-8-215 and B2.1-8-216 for austenitic stainless steel pipe joints.

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 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 *Safety in Welding, Cutting, and Allied Processes,* and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[10]

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

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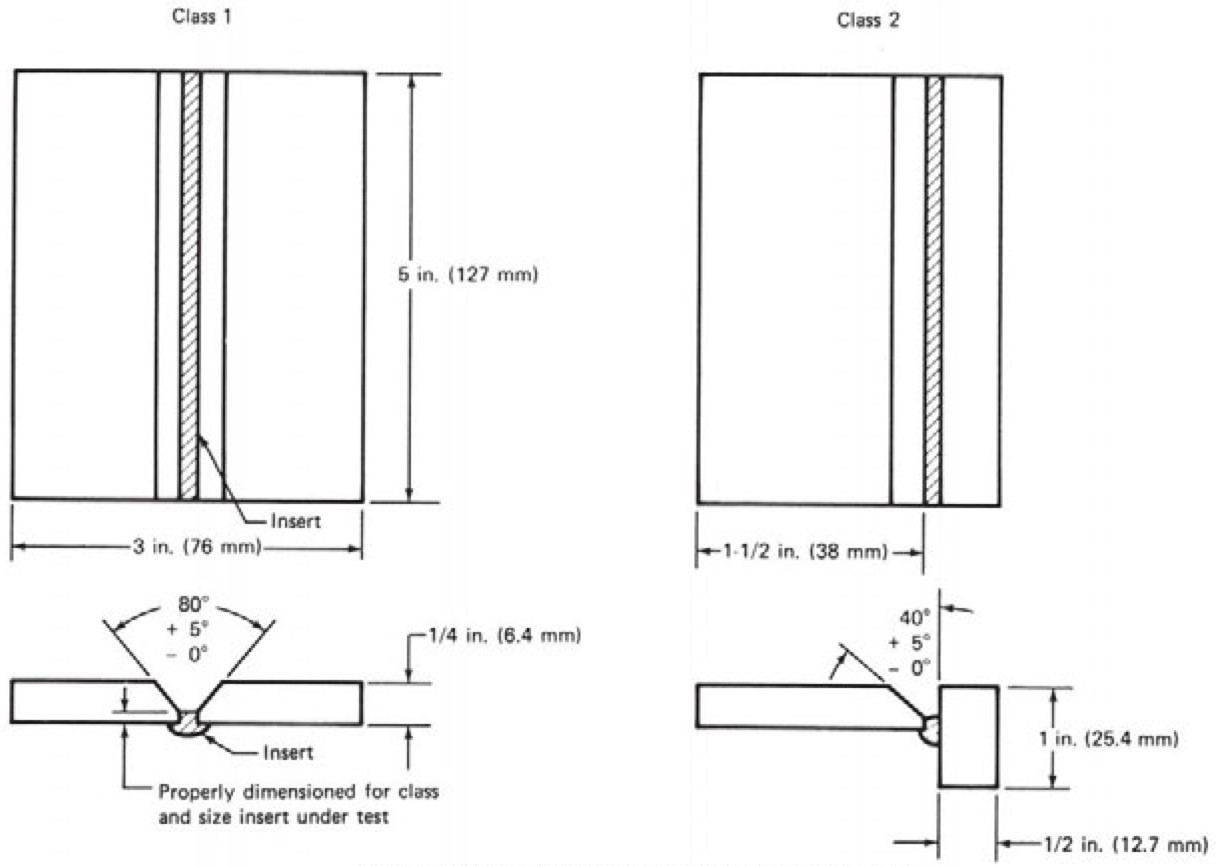
[10] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

FIG. A3 FUSIBILITY TEST JOINT



All dimensions, excluding angles, are in inches (millimeters).

GENERAL NOTES:

(a) Base plate shall be of composition similar to the insert.

(b) One-half of joint shall be welded in flat position; the remainder, in the vertical position. All welding shall be done on the groove side.

(c) Argon gas (AWS 5.32/A5.32M Class SG-A) shall be used for purging and shielding electrode and back side of weld.

(d) Standard techniques and procedures for fusing the insert shall be followed at all times.

(e) Upon completion of fusion, the joint shall be visually examined for compliance with the following:
  (1) The contour of the back side surface of fused insert.
    (a) Reinforcement shall not exceed $^3/_{32}$ in. (2.4 mm).
    (b) Concavity shall not exceed $^1/_{32}$ in. (0.8 mm).
    (c) The contour shall have a uniform radius and shall blend smoothly into the base metal.
  (2) The fused weld pass shall also be free of linear indications as revealed by liquid penetrant inspection on both weld surfaces with non-water washable penetrant.

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SPECIFICATION FOR FLUXES FOR BRAZING AND BRAZE WELDING

SFA-5.31

(Identical with AWS Specification A5.31-2012. In case of dispute, the original AWS text applies.)

Specification for Fluxes for Brazing and Braze Welding

1. General Requirements

1.1 Scope. This specification prescribes the requirements for the classification of brazing fluxes used with brazing or braze welding filler metals such as those classified in AWS A5.8M/A5.8, *Specification for Filler Metals for Brazing and Braze Welding*.

1.2 Units of Measurement. This specification makes use of both the International System of Units (SI) and U.S. Customary Units. 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 A5.31M uses SI Units. The specification A5.31 uses U.S. Customary 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 brazing fluxes or packaging or both under A5.31M or A5.31 specifications.

1.3 Safety. Safety issues and concerns are addressed in this standard, although health issues and concerns are beyond the scope of this standard. Some safety and health information can be found in non-mandatory Annex Clauses B5 and B8.

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 (see Annex Clause B8)

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Material Safety Data Sheets supplied by the 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 standards listed below contain provisions that, through reference in this text, constitute mandatory provisions of this AWS standard. 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) standards:[1]

(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 (ISO 14344 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

(3) AWS A5.02/A5.02M, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*

(4) AWS A5.8M/A5.8, *Specification for Filler Metals for Brazing and Braze Welding*

2.2 American National Standards Institute (ANSI) standard:[2]

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.3 ASTM International standards:[3]

(1) ASTM E1, *Standard Specification for Wire Cloth and Sieves for Testing Purposes*

(2) ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

2.4 International Organization for Standardization (ISO) standard:[4]

(1) ISO 544, *Welding consumables—Technical delivery conditions for welding filler materials—Type of product, dimensions, tolerances, and markings*

2.5 SAE International standard:[5]

(1) SAE HS-1086, *Metals & Alloys in the Unified Numbering System*

3. Classification

3.1 The brazing fluxes covered in this A5.31M/A5.31 specification are classified using a system that is independent of the International System of Units (SI) and U.S. Customary Units. Classification is according to the filler metal, form, and activity temperature range, as specified in Table 1.

3.2 Materials classified under one classification shall not be classified under any other classification of this specification.

4. Acceptance

Acceptance[6] of the brazing flux shall be in accordance with the tests and requirements of the appropriate clauses of this specification. Material shall be deemed acceptable to a given classification if it meets all requirements as prescribed in this specification.

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[1] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126.

[2] This ANSI standard is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] ASTM International standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959.

[4] ISO standards are published by the International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland.

[5] SAE International standards are published by SAE International, 400 Commonwealth Drive, Warrendale, PA 15096–0001.

[6] See Annex Clause B3, "Acceptance," for further information concerning acceptance of material to be shipped.

Table 1
Classification of Brazing Fluxes with Brazing or Braze Welding Filler Metals

AWS Flux Classification	Form	Filler Metal Type	Activity Temperature Range	
			°C	°F
FB1-A	Powder	BAlSi	580–615	1080–1140
FB1-B	Powder	BAlSi	560–615	1040–1140
FB1-C	Powder	BAlSi	540–615	1000–1140
FB2-A	Powder	BMg	480–620	900–1150
FB3-A	Paste	BAg and BCuP	565–870	1050–1600
FB3-C	Paste	BAg and BCuP	565–925	1050–1700
FB3-D	Paste	BAg, BCu, BNi, BAu, and RBCuZn	760–1205	1400–2200
FB3-E	Liquid	BAg and BCuP	565–870	1050–1600
FB3-F	Powder	BAg and BCuP	650–870	1200–1600
FB3-G	Slurry	BAg and BCuP	565–870	1050–1600
FB3-H	Slurry	BAg	565–925	1050–1700
FB3-I	Slurry	BAg, BCu, BNi, BAu, and RBCuZn	760–1205	1400–2200
FB3-J	Powder	BAg, BCu, BNi, BAu, and RBCuZn	760–1205	1400–2200
FB3-K	Liquid	BAg and RBCuZn	760–1205	1400–2200
FB3-L	*Dispensable paste*	*BAg and BCuP*	*565–870*	*1050–1600*
FB3-M	*Dispensable paste*	*BAg and BCuP*	*565–925*	*1050–1700*
FB3-N	*Dispensable paste*	*BAg, BCu, BNi, BAu, and RBCuZn*	*760–1205*	*1400–2200*
FB4-A	Paste	BAg and BCuP	595–870	1100–1600

Notes:
1. The selection of a flux designation for a specific type of work may be based on the form, the filler metal type, and the classification above, but the information here is generally not adequate for flux selection. Refer to Annex Clause B7 and the AWS *Brazing Handbook* for further assistance.
2. See 12.2 and 12.3 for the difference between paste flux and slurry flux.

5. Certification

By affixing the AWS specification and classification designations to the packaging or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[7]

6. Rounding-Off Procedure

For the purpose 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 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 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 unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded-off results shall fulfill the requirements for the classification under test.

7. Summary of Tests

7.1 The tests required for each flux classification are specified in Table 2. The purpose of these tests is to determine the water content, the maximum particle size, and adhesion to a test specimen. The tests are also used to determine the

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[7] See Annex Clause B4, "Certification," for further information concerning certification and the testing called for to meet this requirement.

Table 2
Required Tests

AWS Flux Classification	Form	Water Content	Particle Test	Adhesion	Fluidity	Fluxing Action	Flow	Life
FB1-A	Powder				X	X	X	
FB1-B	Powder				X	X	X	
FB1-C	Powder				X	X	X	
FB2-A	Powder				X	X	X	
FB3-A	Paste	X	X	X	X	X	X	X
FB3-C	Paste	X	X	X	X	X	X	X
FB3-D	Paste	X	X	X	X	X	X	X
FB3-E	Liquid	X	X			X	X	
FB3-F	Powder				X	X	X	X
FB3-G	Slurry	X	X	X	X	X	X	X
FB3-H	Slurry	X	X	X	X	X	X	X
FB3-I	Slurry	X	X	X	X	X	X	X
FB3-J	Powder				X	X	X	X
FB3-K	Liquid	X	X			X	X	
FB3-L	*Dispensable paste*		*X*	*X*	*X*	*X*	*X*	
FB3-M	*Dispensable paste*		*X*	*X*	*X*	*X*	*X*	*X*
FB3-N	*Dispensable paste*		*X*	*X*	*X*	*X*	*X*	*X*
FB4-A	Paste	X	X	X	X	X	X	X

fluidity at high temperature, the fluxing action, the brazing filler metal flow, and the active life of the flux at high temperature. The base metal for the test specimen, the filler metal, and the testing procedures to be employed, and the results required are given in Clauses 9 through 19 and in Table 3.

7.2 Shelf Life. When stored in its original unopened container, these materials shall meet the requirements of this specification for a minimum shelf life of 12 months from date of manufacture. Flux beyond the shelf life may be used if it continues to meet the user's requirements. The user may wish to test flux over 12 months old to ensure that it meets the requirements of this specification.

8. Retests

If the results of any test fail to meet the requirement, the test shall be repeated twice. The results of both retests shall meet the requirement. Samples for retest may be taken from the original test sample or from a new sample. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

In the event that during preparation or after the completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the test sample 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 the proper prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9. Test Specimen

9.1 The test specimen, Figure 1, shall be a rectangular sheet, 30 mm [1.25 in] wide (with a tolerance of ± 6.35 mm [± 0.25 in]), 60 mm [2.5 in] long (with a tolerance of ± 6.35 mm [± 0.25 in]), and approximately 1.6 mm [0.062 in] thick (with a tolerance of ± 0.127 mm [± 0.005 in]) of the base metal given in Table 3. When two base metals are listed, either composition is acceptable.

Table 3
Filler Metal and Base Metal for Tests, Flow and Life Test Temperature, and Flow Test Minimum Area

		Base Metal			Flow and Life Test Temperature[a]		Flow Test Area Minimum	
AWS Flux Classification	AWS Filler Metal Classification	Common Name		UNS Number[b]	°C	°F	mm^2	in^2
FB1-A	BAlSi-4	3003	Aluminum	A93003	613	1135	129	0.2
FB1-B	BAlSi-4	3003	Aluminum	A93003	613	1135	129	0.2
FB1-C	BAlSi-4	3003	Aluminum	A93003	613	1135	NR[c]	NR[c]
FB2-A	BMg-1	AZ31B	Magnesium	M11311	610	1130	NR[c]	NR[c]
FB3-A	BAg-7	1008	Carbon Steel	G10080	705	1300	161	0.25
		321	Stainless Steel	S32100				
FB3-C	BAg-24	304	Stainless Steel	S30400	760	1400	161	0.25
		321	Stainless Steel	S32100				
FB3-D	RBCuZn-D	304	Stainless Steel	S30400	955	1750	161	0.25
		1008	Carbon Steel	S32100				
	BNi-2	304	Stainless Steel	S30400	1040	1900	161	0.25
		321	Stainless Steel	S32100				
FB3-E	BAg-7	304	Stainless Steel	S30400	705	1300	NR[c]	NR[c]
		321	Stainless Steel	S32100				
FB3-F	BAg-7	1008	Carbon Steel	G10080	705	1300	161	0.25
		321	Stainless Steel	S32100				
FB3-G	BAg-7	1008	Carbon Steel	G10080	705	1300	161	0.25
		321	Stainless Steel	S32100				
FB3-H	BAg-24	1008	Carbon Steel	G10080	760	1400	161	0.25
		321	Stainless Steel	S32100				
FB3-I	RBCuZn-D	304	Stainless Steel	S30400	955	1750	161	0.25
		1008	Carbon Steel	G10080				
	BNi-2	304	Stainless Steel	S30400	1040	1900	161	0.25
		321	Stainless Steel	S32100				
FB3-J	RBCuZn-D	304	Stainless Steel	S30400	*955*	*1750*	161	0.25
		1008	Carbon Steel	G10080				
	BNi-2	304	Stainless Steel	S30400	1040	1900	161	0.25
		321	Stainless Steel	S32100				
FB3-K[d]	RBCuZn-D	1008	Carbon Steel	G10080	955	1750	NR[c]	NR[c]
		321	Stainless Steel	S32100				
FB3-L	BAg-7	1008	Carbon Steel	G10080	705	1300	161	0.25
		321	Stainless Steel	S32100				
FB3-M	BAg-24	304	Stainless Steel	S30400	760	1400	161	0.25
		321	Stainless Steel	S32100				
FB3-N	RBCuZn-D	304	Stainless Steel	S30400	955	1750	161	0.25
		321	Stainless Steel	S32100				
	BNi-2	304	Stainless Steel	S30400	1040	1900	161	0.25
		321	Stainless Steel	S32100				
FB4-A	BAg-6	C613	Aluminum Bronze	C61300	830	1525	161	0.25

[a] Temperature tolerances shall be ±8°C [±14°F].

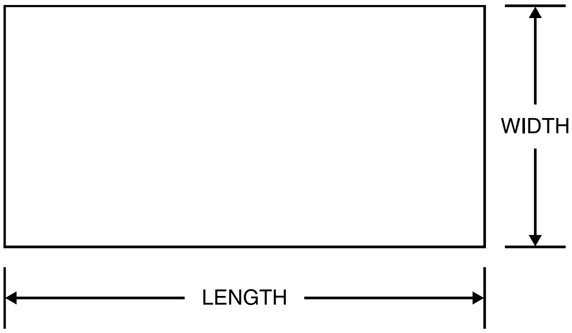
[b] *SAE HS-1086, Metals and Alloys in the Unified Numbering System.*

[c] NR = No flow requirement. The wetting of base metal by the brazing filler metal is all that is required.

[d] An AISI 1008 steel coupon shall be used for the fluxing action and flow tests.

9.2 The surface of the test specimen shall be prepared by removing all contaminants (i.e., oil, grease, lubricants, and protective coatings), polishing with a fine abrasive, rinsing with de-ionized water, and drying at a time and temperature not to exceed one hour and 80°C [176°F].

9.3 Classification required tests will be initiated within one hour of test specimen preparation.



	mm	in
Width	30	1.25
Length	60	2.5
Thickness	1.6	0.062

Figure 1—Test Specimen Approximately 1.6 mm [0.062 in] Thick

10. Flux Sample

The extraction of an unmodified flux sample shall be preceded by thorough mixing to a smooth, uniform consistency.

10.1 Test Lot. The test sample shall consist of flux of the same type, manufactured as one batch. Each lot shall be given a unique code number or designation.

10.2 Retest Requirements. Flux is produced using a specific formulation and process. Any change to the process or formulation (other than wording for clarification) shall require retesting of the flux to the classification requirements per 10.1.

11. Filler Metal

11.1 The filler metal sample shall be a 13 mm [0.5 in] length, plus/minus 1.3 mm [0.05 in], of 1.6 mm [0.062 in] diameter wire of the AWS classification given in Table 3. Exceptions are noted in 11.2.

11.2 When testing flux classifications AWS FB3-D, AWS FB3-I, AWS FB3-J, and AWS FB3-N with filler metal BNi-2, the filler metal shall be 0.2 g [0.007 oz] plus/minus 0.02 g [0.0007 oz] of powder or rod, except when otherwise noted.

11.3 Flux, when required, may be applied to the filler metal and dried prior to testing.

12. Water Content Test

Water content shall be determined using a commercial moisture analyzer or by the procedure specified in 12.1.

12.1 The following procedure may be used as an alternative method to determine water content. All weights shall be determined to the nearest 0.01 g [0.0004 oz] as follows:

(1) Determine the weight of a dry clean container;

(2) Place a 3 g [0.1 oz] minimum weight sample of the flux into the container;

(3) Determine the weight of the wet flux by weighing the flux and the container and subtracting the weight of the container;

(4) Place the container in a desiccator containing freshly activated silica gel mixed with an indicator. Use a minimum of 60 g [2 oz] of silica gel per sample;

(5) Cover the desiccator and dry for 24 hours;

(6) Determine the weight of the dry flux by weighing the flux and the container and subtracting the weight of the container; and

(7) Calculate the water content as follows:

$$\text{Water content (\%)} = \frac{(\text{Wet flux weight} - \text{Dry flux weight}) \times 100}{\text{Wet flux weight}}$$

12.2 Paste fluxes shall have a water content of 15% to 35%.

12.3 Slurry fluxes shall have a water content of 30% to 60%.

12.4 Liquid flux FB3-E shall have a water content of 82% to 90%.

13. Particle Test

13.1 The test method used to measure particle size of dispensable paste fluxes shall be as agreed upon by the manufacturer and the user.

13.2 The particle consistency of paste flux is acceptable when the entire amount of a 60 g [2 oz] sample will pass through a 425 µm [USA Standard Testing Sieve No. 40]. The screen shall conform to ASTM E11-01. Heating the flux sample at a temperature of up to a maximum of 82°C [180°F] before testing is permissible. The flux may be worked lightly with a brush.

13.3 The particle consistency of a slurry flux is acceptable when the entire amount of a 60 g [2 oz] sample will pass through a 106 µm sieve [USA Standard Testing Sieve No. 140]. Heating the flux sample at a temperature of up to a maximum of 82 °C [180 °F] before testing is permissible. The flux may be worked lightly with a brush.

13.4 Liquid fluxes shall not exhibit any visible particles when examined without magnification. Heating the flux sample at a temperature of up to a maximum of 82 °C [180 °F] before testing is permissible.

14. Adhesion Tests

The adhesion characteristics of the flux shall be determined using the following procedures:

14.1 For temperatures below the activity temperature range, the following apply:

14.1.1 Using a brush, apply a uniform layer of flux approximately 0.8 mm [0.031 in] thick to one surface of the test specimen (see Figure 1).

14.1.2 Examination No. 1: Examine the fluxed surface for areas of nonwetting.

14.1.3 With the same test specimen inclined at a 60° minimum angle, heat in an air atmosphere furnace that has been preheated to 55 °C [100 °F] below the minimum activity temperature of Table 1, hold at the furnace temperature for three minutes, and air cool to room temperature.

14.1.4 Examination No. 2: Examine the fluxed surface for areas of flux loss or retraction.

14.2 The results of the tests are acceptable when each of the two examinations (see 14.1.2 and 14.1.4) indicates that the flux coating is continuous, i.e., free from areas of nonwetting or areas of flux loss or retraction.

14.3 At the minimum activity temperature (see Table 1) the following applies:

14.3.1 Apply the flux as a uniform coating of approximately 1.4 g [0.05 oz] to one surface of the test specimen (see Figure 1) (see Table 3 for base metal).

14.3.2 With the test specimen inclined at a 60° minimum angle, heat in air in a furnace preheated to the minimum activity temperature specified in Table 1, hold at the furnace temperature for three minutes, then cool to room temperature in still air.

14.4 The result of the test is acceptable when 80% or more of the surface of the test specimen remains covered and protected from high-temperature oxidation by the flux.

15. Fluidity Test

15.1 The fluidity of the flux at high temperature shall be determined using the following procedure:

15.1.1 Place approximately 10 g [0.35 oz] of flux in a nonreactive crucible. Pure platinum, gold, and silver are acceptable crucible materials.

15.1.2 Heat the crucible in a preheated furnace with an air atmosphere to the minimum activity temperature provided in Table 1 and hold at the temperature for five minutes. The use of a furnace thermocouple as a temperature indicator is acceptable.

15.1.3 Remove the crucible and immediately observe whether the flux is in its liquid (state) condition by tilting the crucible.

15.1.4 Heat the crucible in a preheated furnace with an air atmosphere at the maximum activity temperature provided in Table 1; hold at that temperature for 10 minutes.

15.1.5 Cool as rapidly as possible by resetting the furnace controls to the minimum activity temperature or by removing the sample from the furnace.

15.1.6 When the furnace thermocouple or other external temperature indicator signifies that the flux is at the minimum activity temperature, observe whether the flux is in its liquid (state) condition at that temperature by tilting the crucible again.

15.2 The result of the test is acceptable if the fluidity at the time of the second observation is approximately the same as it was at the time of the first observation.

16. Fluxing Action Test

16.1 For all fluxes except AWS FB3-K, the fluxing action shall be determined using the following procedure:

16.1.1 Apply 1.4 g [0.05 oz] of flux as a uniform coating to one surface of the test specimen (see Figure 1) of a base metal specified in Table 3. Place the prefluxed filler metal sample (see 11.1 through 11.3 and Table 3) on the test specimen.

16.1.2 With the test specimen in a horizontal position, heat it in an air atmosphere furnace preheated to the minimum activity temperature provided in Table 1. Then, hold it at that furnace temperature for two minutes, and air cool it to room temperature.

16.1.3 Clean the test specimen by soaking it in water at 60°C [140°F] minimum until visible flux residue is removed.

16.2 For flux AWS FB3-K, the fluxing action shall be determined using the following procedure:

16.2.1 An AISI 1008 steel coupon shall be used for this test.

16.2.2 Set up an oxyacetylene liquid flux brazing station as follows:

(1) Use a No. 48 drill size torch tip;[8]

(2) Set both oxygen and acetylene pressure at 50 kPa [7 psig];

(3) Place RBCuZn-D on a test specimen that has a blue, oxidized surface; and

(4) With the torch 125 mm [5 in] above the test specimen, heat to 955°C [1750°F] by moving the flame over the entire coupon until the filler metal sample is fully melted. Air cool to room temperature.

16.3 The results of the tests are acceptable if the surface of the test specimen that was coated with the flux and the filler metal surface are free of high-temperature oxidation as indicated by a lack of discoloration of the sample.

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[8] Drill No. 48 is equivalent to 2 mm [0.076 in].

17. Flow Test

17.1 For all brazing fluxes except AWS FB3-K, the extent of filler metal flow shall be determined using the following procedure:

17.1.1 Apply 1.4 g [0.05 oz] of flux as a uniform coating to one surface of the test specimen (see Figure 1) of a base metal specified in Table 3. Place the prefluxed filler metal sample (see 11.1 through 11.3 and Table 3) on the test specimen.

17.1.2 With the test specimen in a horizontal position, heat it in an air atmosphere furnace preheated to the test temperature provided in Table 3. Then, hold it at the furnace temperature for five minutes, and air cool it to room temperature.

17.2 For flux AWS FB3-K, the extent of filler metal flow shall be determined using the following procedure:

17.2.1 An AISI 1008 steel coupon shall be used for this test.

17.2.2 Set up an oxyacetylene, liquid flux brazing station as follows:

(1) Use a No. 48 drill size torch tip;[8]

(2) Set both oxygen and acetylene pressure at 50 kPa [7 psig];

(3) Place the filler metal (as specified in Table 3) on a test specimen (see Figure 1); and

(4) With the torch tip positioned 125 mm [5 in] above the test specimen, heat to 955°C [1750°F] and air cool it to room temperature.

17.3 Clean the test specimen by soaking it in hot water.

17.4 The results of the test are acceptable if the filler metal flow area is equal to or greater than the flow area shown in Table 3. The wetting of the base metal by the filler metal is required for fluxes AWS FB1-C, AWS FB2-A, AWS FB3-E, and AWS FB3-K, but there are no specific flow area requirements.

18. Life Test

18.1 The ability of the flux to protect the surface of the base metal at high temperatures shall be determined using the following procedure:

18.1.1 Apply 1.4 g [0.05 oz] of flux as a uniform coating to one surface of the test specimen (see Figure 1) of a base metal specified in Table 3.

18.1.2 With the test specimen in a horizontal position, heat it in the furnace preheated to the test temperature provided in Table 3. Then, hold it at that furnace test temperature for 10 minutes.

18.1.3 Place the unfluxed filler metal (see 11.1 through 11.3 and Table 3) on the test specimen in the furnace.

18.1.4 Continue to heat the test specimen until the furnace returns to the test temperature. Hold the furnace for one minute at that temperature, then remove the test specimen and air cool it to room temperature.

18.1.5 Clean the test specimen by soaking in hot water.

18.2 The results of the test are acceptable if the filler metal has wet the test specimen. There is no specific flow area requirement.

19. Viscosity Test

19.1 The test method used to measure viscosity of dispensable paste fluxes shall be as agreed upon by the manufacturer and the user.

19.2 The viscosity of dispensable paste fluxes shall be as agreed upon by the manufacturer and the user.

20. Method of Manufacture

The brazing fluxes classified according to this specification may be manufactured by any method that will produce a brazing flux that meets the requirement of this specification. Chemicals of technical grade or better shall be used.[9]

21. Forms

21.1 The standard forms for brazing fluxes shall be powder, paste, slurry, dispensable paste, or liquid, as shown in Table 1.

21.2 A flux in paste form shall meet the requirements of 12.2.

21.3 A flux in slurry form shall be suitable for use with automatic flux spraying dispensing equipment and shall meet the requirements of 12.3.

21.4 A flux in liquid form shall be suitable for use with flux spraying equipment and meet the requirements of 12.4.

22. Packaging

22.1 Brazing fluxes shall be suitably packaged to protect them from damage during shipment and storage under normal conditions.

22.2 Flux containers and closures shall be made of materials that do not noticeably react with the flux during storage for a minimum period of 12 months after packaging.

22.3 Sealing shall be adequate to prevent the loss or contamination of the flux components under normal handling conditions.

22.4 Standard package weights shall be as agreed between the purchaser and the supplier.

23. Marking of Packages

23.1 Unless otherwise agreed upon by the manufacturer and the purchaser, the following product information (as a minimum) shall be legibly marked on the outside of each unit package:

(1) AWS specification and classification designation (year of issue may be excluded)

(2) Supplier’s name and trade designation

(3) Volume or net weight

(4) Lot, control, or batch number

(5) Date of manufacture

23.2 The appropriate precautionary information[10] as given in ANSI Z49.1 (as a minimum) or its equivalent shall be prominently displayed in legible print on all packages of brazing fluxes, including individual unit packages enclosed within a larger package.

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[9] For further description of the classification of grades of chemicals, refer to the American Chemistry Council, 1300 Wilson Boulevard, Arlington VA 22209, www.americanchemistry.com.

[10] Typical examples of “warning labels” for some common or specific consumables used with certain processes are shown in the figures illustrated in ANSI Z49.1. Figure B.1 illustrates an example of a cautionary label for flux.

Annex A (Informative)

Informative References

This annex is not part of AWS A5.31M/A5.31:2012, *Specification for Fluxes for Brazing and Braze Welding*, but is included for informational purposes only.

AWS A1.1, *Metric Practice Guide for the Welding Industry*, American Welding Society.

AWS A5.8M/A5.8, *Specification for Filler Metals for Brazing and Braze Welding*, American Welding Society.

AWS, 2007, *Brazing Handbook*, 5th ed., Miami: American Welding Society.

Annex B (Informative)

Guide to AWS A5.31M/A5.31:2012, *Specification for Fluxes for Brazing and Braze Welding*

This annex is not part of AWS A5.31M/A5.31:2012, *Specification for Fluxes for Brazing and Braze Welding*, but is included for informational purposes only.

B1. Introduction

The purpose of this guide is to correlate the flux classifications with their intended applications so that the specification can be used effectively. Appropriate base metals, filler metals, and brazing 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 and processes for which each brazing flux is suitable.

B2. Classification System

B2.1 The system for identifying the flux classifications in this specification is based on three factors: form, applicable filler metal, and activity temperature range. The letters "FB" at the beginning of each classification designation stand for "Flux for Brazing or Braze Welding." The third character is a number that stands for a group of applicable filler metals. The fourth character, a letter, designates a change in form and attendant composition within the broader base metal classification.

B2.2 Request for Flux Classification

(1) When a brazing flux cannot be classified according to a classification given in this specification, the manufacturer may request that a classification be established for that brazing flux. The manufacturer can do this by following the procedure below.

(2) A request to establish a new brazing flux classification must be a written request, and it must provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee on Filler Metals and Fluxes for Brazing 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. The request must state the variables and their limits for such a classification or modification. The request should contain some indication of the time by which the completion of a new classification or modification is needed. In particular, the request needs to include:

(a) All classification requirements as given for existing classifications, such as chemical composition ranges and usability test requirements;

(b) Any conditions for conducting the tests used to demonstrate that the product meets the classification requirements (it would be sufficient, for example, to state that brazing conditions are the same as for other classifications); and

(c) A description that parallels the type of information contained for the existing classifications found in Annex Clause B7 (Description and Intended Use of Brazing Fluxes).

(d) 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 the Chair of the Subcommittee on Filler Metals and Fluxes for Brazing;
(d) File the original request; and
(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 subcommittee. Requests that are still outstanding after 18 months shall be considered to not 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.

B3. Acceptance

The acceptance of all brazing fluxes classified under this specification is in accordance with the tests and requirements of this specification. Any testing a purchaser requires of the supplier, for fluxes 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 fluxes with whatever testing the supplier normally conducts on fluxes of that classification. In such cases, the acceptance of the material shipped will be in accordance with those requirements.

B4. 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 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 has met the requirements of the specification. *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 14344:2002 MOD).

B5. Ventilation During Brazing

B5.1 Five major factors govern the quantity of fumes to which brazers and brazing operators can be exposed during brazing. They are:

(1) Dimensions of the space in which brazing is performed (with special regard to the height of the ceiling);

(2) Number of brazers and brazing 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 brazer or brazing operators to the fumes, as these fumes issue from the brazing 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 brazing is performed.

B5.2 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 brazing and braze welding, and should be referred for details. Attention is drawn particularly to the Clause on Ventilation in that document. Further information concerning ventilation during brazing can be found in AWS F3.2, *Ventilation Guide for Weld Fume*.

B5.3 Local, state, and federal requirements for air quality need to be reviewed and met.

B6. Brazing Considerations

B6.1 Successful brazing requires that the surfaces of each detail part and the filler metal be free of oxide, tarnish, or other foreign matter at the time the brazing filler metal flows into the joint.

Proper prebraze cleaning is an initial step in any brazing process; however, additional protection and cleaning is required to maintain this condition throughout the brazing procedure. Fluxes are used to maintain cleanliness and protection from oxidation. Controlled atmospheres, including vacuum and active deoxidizing elements, are alternate methods of providing the necessary surface cleanliness during brazing.

B6.2 Brazing fluxes are mixtures of chemical compounds that may include inorganic salts and mild acids selected for their ability to provide chemical cleaning or protection of the faying surfaces and the filler metal during brazing. Fluxes must perform the protective, cleaning, and fluxing action with the specific filler metals being used in conjunction with the other brazing variables such as the base metal, the brazing process, the mass of the assembly, and the method of flux application. For further information, refer to the AWS *Brazing Handbook*.

B7. Description and Intended Use of Brazing Fluxes

B7.1 AWS FB1-A is a brazing flux in powder form intended for the torch and furnace brazing of aluminum and its brazeable alloys. It consists of fluorides and/or chlorides of some of the alkali metals. Water or alcohol may be used for thinning.

B7.2 AWS FB1-B is a brazing flux in powder form intended for the furnace brazing of aluminum and its brazeable alloys. The lower end of its activity temperature range is slightly lower than that of the AWS FB1-A classification. It consists primarily of fluorides and/or chlorides of some the alkali metals. Water or alcohol may be used for thinning.

B7.3 AWS FB1-C is a brazing flux in powder form intended for the salt-bath dip brazing of aluminum and its brazeable alloys. The lower end of its activity temperature range is much lower than that of the AWS FB1-A and AWS FB1-B classifications. It consists primarily of fluorides and/or chlorides of some of the alkali metals. Water should be avoided in the flux or removed prior to the immersion of the brazement in the salt bath.

B7.4 AWS FB2-A is a brazing flux in powder form intended for the salt-bath dip brazing of magnesium alloys whose designators start with "AZ." It consists primarily of fluorides and chlorides of some the alkali metals. Water should be avoided in the flux or removed prior to the immersion of the brazement in the salt bath.

B7.5 AWS FB3-A is a general purpose brazing flux in paste form intended for use with most brazing processes in the brazing of steels, copper, copper alloys, nickel, and nickel alloys. It is not suitable for aluminum bronze or other base metals containing alloying elements (e.g., aluminum) that form refractory oxides. It consists primarily of boric acid, borates, and fluorides. Water is used for thinning.

B7.6 AWS FB3-C is a brazing flux in paste form similar to AWS FB3-A, except that the activity temperature range extends to a higher temperature, and AWS FB3-C contains elemental boron. Water is used for thinning. A typical pH range is 7.0 to 10.0.

B7.7 AWS FB3-D is a brazing flux in paste form intended for the torch, furnace, and induction brazing of steels, nickel and its alloys, and carbides using high-temperature filler metals. It consists primarily of boric acid, borates, and fluorides. It may contain elemental boron. Water is used for thinning.

B7.8 AWS FB3-E is a low-activity liquid flux used in the torch brazing of jewelry or to augment borderline furnace brazing atmospheric conditions. Flux is usually applied by dipping or by the use of semi or fully automatic spray dispensing equipment. The flux constituents are similar to those in AWS FB3-D fluxes.

B7.9 AWS FB3-F is somewhat similar to the AWS FB3-A flux, except that no vehicle is added to the powder during manufacture. In application, water may be used as a thinning vehicle.

B7.10 AWS FB3-G is a brazing flux in slurry form for use with automatic spray dispensing equipment. The general areas of application are similar to those of AWS FB3-A flux. Water may be used as the thinning vehicle.

B7.11 AWS FB3-H is a brazing flux in slurry form for use with automatic spray dispensing equipment. The general areas of application are similar to those of the AWS FB3-C flux. The flux typically contains borates and fluoride compounds plus powdered boron. Water may be used as the thinning vehicle.

B7.12 AWS FB3-I is a brazing flux in slurry form for use with automatic spray dispensing equipment. The general areas of application are similar to those of the AWS FB3-D flux. The flux typically contains borates and fluoride compounds plus powdered boron. Water may be used as the thinning vehicle.

B7.13 AWS FB3-J is a brazing flux in powder form for areas of application similar to those of the AWS FB3-D flux. The flux typically contains borates and fluoride compounds plus powdered boron. Water may be used as the thinning vehicle.

B7.14 AWS FB3-K is a liquid flux used exclusively in flame brazing. The fuel gas is passed through the container of liquid flux entraining flux in the fuel gas. The flux is applied by the flame where needed on base metals such as carbon steels, low-alloy steels, cast iron, copper and copper alloys, nickel and nickel alloys, and precious metals. The flux consists primarily of liquid borates.

B7.15 *AWS FB3-L is a general purpose brazing flux in the form of a dispensable paste intended for use with automated dispensing equipment. It can be used with most brazing processes in the brazing of steels, coppers, copper alloys, nickels and nickel alloys. Viscosity requirements shall be as agreed upon by the customer and the manufacturer to meet the intended dispensing requirements. It consists primarily of borate and fluoride compounds.*

B7.16 *AWS FB3-M is similar to AWS FB3-L in composition except that the activity temperature range extends to a higher temperature due to the inclusion of elemental boron.*

B7.17 *AWS FB3-N is a brazing flux in dispensable paste form intended for the torch, furnace, and induction brazing of steels, nickel and its alloys, and carbides using high-temperature filler metals. It consists primarily of boric acid, borates, and fluorides. It may contain elemental boron. Viscosity requirements shall be as agreed upon by the customer and the manufacturer to meet the intended dispensing requirements.*

B7.18 AWS FB4-A is a brazing flux in paste form intended for the brazing of copper alloys and other base metals containing up to 9% aluminum, such as aluminum bronze. It may also be suitable for base metals containing up to 3% titanium or other metals that form refractory oxides. It consists primarily of borates, fluorides, and chlorides. Water is used for thinning. A typical pH range is 3.0 to 7.5.

B8. General Safety Considerations

B8.1 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 B5. Safety and health information is available from other sources, including, but not limited to the Safety and Health Fact Sheets listed in B8.2, ANSI Z49.1 *Safety in Welding, Cutting and Allied Processes*,[11] and applicable federal and state regulations.

B8.2 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 web site at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets are added periodically.

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 and 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*

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[11] ANSI Z49.1 is published by the American Welding Society, 550 LeJeune Road, Miami, FL 33126.

B9 General Label Information

An example of the minimum appropriate precautionary information as given in ANSI Z49.1:2005 is shown in Figure B.1.

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES AND GASES CAN BE HAZARDOUS TO YOUR HEALTH. BURNS EYES AND SKIN ON CONTACT. CAN BE FATAL IF SWALLOWED.

- Before use, read and understand the manufacturer’s instructions, Material Safety Data Sheets (MSDSs), and your employer’s safety practices.
- Keep your head out of the fume.
- Use enough ventilation or exhaust, or both, to keep fumes and gases from your breathing zone and the general area.
- Avoid contact of flux with eyes and skin.
- Do not take internally.
- Keep away from children when using.
- See American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Rd., Miami, Florida 33126; OSHA *Safety and Health Standards* are published by the U.S. Government Printing Office, 732 North Capitol Street NW, Washington DC 20401.

  First Aid: If contact in eyes, flush immediately with water for at least 15 minutes. If swallowed, induce vomiting. Never give anything by mouth to an unconscious person. Call a physician.

DO NOT REMOVE THIS INFORMATION

Source: Adapted from ANSI Z49.1:2005, *Safety in Welding, Cutting, and Allied Processes*, Figure 4, American Welding Society.

Figure B.1—Precautionary Information for Brazing and Welding Fluxes Containing Fluorides

SPECIFICATION FOR WELDING SHIELDING GASES

SFA-5.32/SFA-5.32M

(Identical with AWS Specification A5.32/A5.32M-97 (R2007). In case of dispute, the original AWS text applies.)

SPECIFICATION FOR WELDING SHIELDING GASES

SFA-5.32/SFA-5.32M

[Identical with AWS Specification A5.32/A5.32M-97 (R2007). In case of dispute, the original AWS text applies.]

1. Scope

This specification prescribes requirements for the classification of shielding gases. Gases may be supplied in either gaseous or liquid form, but when used in welding, the shielding is always in the gaseous form. Gas shielded arc welding processes include, but are not limited to: manual, semiautomatic, mechanized, and automatic gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), electrogas welding (EGW), and plasma arc welding (PAW).

PART A — GENERAL REQUIREMENTS

2. Normative References

2.1 ASTM Standards.[1] The following ASTM standards are referenced in the mandatory sections of this document.

(a) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(b) ASTM E 260, *Standard Practice for Packed Column Gas Chromatography*

2.2 CGA Publications.[2] The following CGA standards are referenced in the mandatory sections of this document.

(a) G-4.3, *Commodity Specification for Oxygen*

(b) G-5.3, *Commodity Specification for Hydrogen*

(c) G-6.2, *Commodity Specification for Carbon Dioxide*

(d) G-9.1, *Commodity Specification for Helium*

(e) G-10.1, *Commodity Specification for Nitrogen*

(f) G-11.1, *Commodity Specification for Argon*

(g) P-15, *Filling of Industrial and Medical Nonflammable Compressed Gas Cylinders*

3. Classification

3.1 The shielding gases covered by the A5.32/A5.32M 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 chemical composition of the shielding gas as specified in 13.1.

3.2 Gases classified under one classification shall not be classified under any other classification in this specification. Individual gases shall meet or exceed the requirements of Table 1.

3.3 The gases classified under this specification are intended for use with the gas shielded arc welding processes listed in the Scope. This does not prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance[3] of the gases by the user shall be in accordance with the tests and requirements of Parts B and C of this specification.

5. Certification

By affixing the AWS specification and classification designations on the packaging enclosing the product, the supplier (manufacturer) certifies that the product meets all of the requirements of the specification.[4]

6. Units of Measure and Rounding-Off Procedure

6.1 This specification uses U.S. Customary Units and the SI Units. The measurements are not exact equivalents; therefore each system must be used independently of the other without combining values in any way. The specification with the designation of A5.32 uses the U.S. Customary Units. The specification with the designation of A5.32M

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[1] ASTM standards can be obtained from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[2] CGA publications can be obtained from Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202-4102.

[3] See Section A3 (in the Annex) for more information.

[4] See Section A4 (in the Annex) for further information concerning certification and the testing called for to meet this requirement.

TABLE 1
GAS TYPE, PURITY, AND DEW POINT REQUIREMENTS FOR SHIELDING GAS COMPONENTS

Gas	AWS Classification	Product State	Minimum Purity, %	Maximum Moisture,[1] ppm	Dew Point Maximum Moisture at 1 Atmosphere		CGA Class	
					°F	°C		
Argon	SG-A	Gas	99.997	10.5	−76	−60	Type I	G-11.1 Grade C
		Liquid	99.997	10.5	−76	−60	Type II	G-11.1 Grade C
Carbon Dioxide	SG-C	Gas	99.8	32	−60	−51		G-6.2 Grade H
		Liquid	99.8	32	−60	−51		G-6.2 Grade H
Helium	SG-He	Gas	99.995	15	−71	−57	Type I	G-9.1 Grade L
		Liquid	99.995[2]	15	−71	−57	Type II	G-9.1 Grade L
Hydrogen	SG-H	Gas	99.95	32	−60	−51	Type I	G-5.3 Grade B
		Liquid	99.995[3]	32	−60	−51	Type II	G-5.3 Grade A
Nitrogen	SG-N	Gas	99.9	32	−60	−51	Type I	G-10.1 Grade F
		Liquid	99.998	4	−90	−68	Type II	G-10.1 Grade L
Oxygen	SG-O	Gas	99.5	Not Applicable	−54	−48	Type I	G-4.3 Grade B
		Liquid	99.5	Not Applicable	−82	−63	Type II	G-4.3 Grade B

NOTES:

(1) Moisture specifications are guaranteed at full cylinder pressure, at which the cylinder is analyzed.

(2) Including neon.

(3) Including helium.

uses SI Units. The latter are shown in appropriate columns in tables and in figures, and within brackets [ ] when used in the text.

6.2 For the purpose of determining conformance with this specification, values shall be rounded to the nearest unit in accordance with the rounding-off method given in ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

7. Summary of Tests

Compositional analysis of the shielding gas is the only test required for classification of a product under this specification. Tests required for each single gas are specified in Table 2. The purpose of these tests is to determine the purity and dew point of the shielding gas.

8. Retest

If any gas fails to meet its requirements, that test shall be repeated twice. The results of both retests shall meet the requirement of this specification.

If the results of one or both retests fail to meet the requirement, the gas being tested shall be considered as not meeting the requirements of this specification for that classification.

In the event that appropriate procedures were not followed in preparing the test sample(s) or in conducting the tests, 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. In this case, the requirement for two retests of the gas sample does not apply.

TABLE 2
TESTS REQUIRED FOR CLASSIFICATION

	Gas Purity	Dew Point	Mixture Composition
Single gas	Req.	Req.	Not Applicable
Multicomponent gas	Req[1]	Req.[2]	Req.[3]
Special gas mixture[4]	Req.	Req.	Not Required

NOTES:

(1) Each gas of a multicomponent mixture shall be tested for and meet the purity requirements of that specific gas (see Section 9 and Table 1).

(2) The multicomponent gas mixture shall meet the dew point requirements not greater than the highest dewpoint of the individual gases in the mixture (see Section 10 and Table 1).

(3) Individually filled cylinders or one cylinder from each filling manifold group, shall be tested for and meet the requirements of Part B, Tests, Procedures, and Requirements for the mixture composition.

(4) These gases are classified as SG-B-G.

9. Chemical Analysis

Samples of gas(es) for chemical analysis shall be drawn from an individual cylinder, vessel or from the gas outlet source. The sample shall be analyzed by acceptable methods. Results of chemical analysis of a specific gas(es) shall comply with the requirements of Table 1 for the gas being analyzed. The referee method for chemical analysis of gases shall be ASTM E 260, *Standard Practice for Packed Column Gas Chromatography*. When mixed gases are being analyzed, the volumetric percentage of minor components shall be within ±10 percent relative to the nominal percentage of the minor component of the classification. See 13.1 and 13.3 for examples.

10. Dew Point Determination

Sample gases for dew point analysis shall be drawn from the individual cylinder, vessel, or gas outlet source. Any standard dew point measurement method may be used. Dew point may be expressed in °F at one atmosphere pressure (14.7 psia), [°C at 760 mm of mercury], or in ppm. The Dew Point Conversion Chart, see Table 3, may be used to convert dew point measurements to or from °F, °C, or ppm. Results of the dew point test shall meet, or exceed, the requirements of Table 1 for the gases being analyzed.

PART C — MANUFACTURE, PACKAGING, AND IDENTIFICATION

11. Method of Manufacture

Shielding gases classified according to this specification may be manufactured by any method that will produce gas or gas mixtures that meet the requirements of this specification.

11.1 Cylinder Residual Gases. All gas containers shall either be evacuated or, if not evacuated, residual gases shall be analyzed for composition and purity prior to filling.[5]

12. Packaging

Gases and gas mixtures shall be packaged in accordance with Department of Transportation (DOT) regulations for protection during shipment and normal storage conditions.[6] Cylinder sizes shall be as agreed upon between purchaser and supplier. Cylinders shall be labeled in accordance with Sections 13 and 14.

13. Identification

13.1 Individual gas components are identified by the following codes:

A — Argon
C — Carbon Dioxide
He — Helium
H — Hydrogen
N — Nitrogen
O — Oxygen

The classification system is based on volumetric percentages. The classification designators remain the same for both U.S. Customary Units and the SI units. The shielding gas classification system is composed of the following designator and number arrangement:

(a) SG — Shielding Gas Designator. The letters SG at the beginning of each classification designation identifies the product as a shielding gas. These letters are followed by a hyphen.

(b) SG-B — Base Gas Designator. Shielding gases are classified according to chemical composition. The letter immediately to the right of SG- indicates the singular or major gas in the shielding gas or mixture (see Fig. 1).

(c) SG-B XYZ — Minor Gas Component Designators. The letter(s) immediately following the base gas indicates the minor individual gas indicators in decreasing order of percent. These letters are followed by a hyphen.

(d) SG-B XYZ-%/%/% — Percentage Designators. A slash shall be used to separate the individual minor components' percentages for two or more component mixtures. See Fig. 2 and Table 4. The percentage designator shown need not be present on the container's label.

(e) S-B-G — Special Gas Mixture. Shielding gases may be classified as special and carry the "G" designation. The base gas must be identified. Minor gases need not be identified but must be covered in 13.1 or represented by the "X" designation. The percentage of each component shall be as agreed upon between the purchaser and supplier. See Fig. 3. The "X" designation shall be used when a gas mixture component is not covered by the six base gases specified. The gas represented by the "X" must appear in parentheses after the "G." See Fig. 4.

AWS classifications for typical gas mixtures are shown in Table 4.

13.2 As stated in Section 9 of this specification, when mixed gases are classified in accordance with this specification, the percentage of the minor component(s) shall have a tolerance of ±10% relative to the minor percentage component. To compute the minor component range, multiply the minor component percentage by 0.10 to get the ± tolerance figure.

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[5] CGA P-15, *Filling of Industrial and Medical Nonflammable Compressed Gas Cylinders*, can be obtained from the Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202-4102.

[6] DOT regulations can be obtained from the Department of Transportation, NASSIF Building, 400 7th Street S.W., Washington, DC 20590.

TABLE 3
DEW POINT CONVERSION CHART

(1 Atmosphere) (70°F @ 14.7 psia/21°C @ 760 mm [Hg])

Dew Point			Dew Point			Dew Point		
°F	°C	ppm	°F	°C	ppm	°F	°C	ppm
−130	−90.0	0.1	−73	−58.3	13.3	−38	−38.9	144
−120	−84.4	0.25	−72	−57.8	14.3	−37	−38.3	153
−110	−78.9	0.63	−71	−57.2	15.4	−36	−37.8	164
−105	−76.1	1.00	−70	−56.7	16.6	−35	−37.2	174
−104	−75.6	1.08	−69	−56.1	17.9	−34	−36.7	185
−103	−75.0	1.18	−68	−55.6	19.2	−33	−36.1	196
−102	−74.4	1.29	−67	−55.0	20.6	−32	−35.6	210
−101	−73.9	1.40	−66	−54.4	22.1	−31	−35.0	222
−100	−73.3	1.53	−65	−53.9	23.6	−30	−34.4	235
−99	−72.8	1.66	−64	−53.3	25.6	−29	−33.9	250
−98	−72.2	1.81	−63	−52.8	27.5	−28	−33.3	265
−97	−71.7	1.96	−62	−52.2	29.4	−27	−32.8	283
−96	−71.1	2.15	−61	−51.7	31.7	−26	−32.2	300
−95	−70.6	2.35	−60	−51.1	34.0	−25	−31.7	317
−94	−70.0	2.54	−59	−50.6	36.5	−24	−31.1	338
−93	−69.4	2.76	−58	−50.0	39.0	−23	−30.6	358
−92	−68.9	3.00	−57	−49.4	41.8	−22	−30.0	378
−91	−68.3	3.28	−56	−48.9	44.6	−21	−24.4	400
−90	−67.8	3.53	−55	−48.3	48.0	−20	−28.9	422
−89	−67.2	3.84	−54	−47.8	51	−19	−28.3	448
−88	−66.7	4.15	−53	−47.2	55	−18	−27.8	475
−87	−66.1	4.50	−52	−46.7	59	−17	−27.2	500
−86	−65.6	4.78	−51	−46.1	62	−16	−26.7	530
−85	−65.0	5.3	−50	−45.6	67	−15	−26.1	560
−84	−64.4	5.7	−49	−45.0	72	−14	−25.6	590
−83	−63.9	6.2	−48	−44.4	76	−13	−25.0	630
−82	−63.3	6.6	−47	−43.9	82	−12	−24.4	660
−81	−62.8	7.2	−46	−43.3	87	−11	−23.9	700
−80	−62.2	7.8	−45	−42.8	92	−10	−23.3	740
−79	−61.7	8.4	−44	−42.2	98	−9	−22.8	780
−78	−61.1	9.1	−43	−41.7	105	−8	−22.2	820
−77	−60.6	9.8	−42	−41.1	113	−7	−21.7	870
−76	−60.0	10.5	−41	−40.6	119	−6	−21.1	920
−75	−59.4	11.4	−40	−40.0	128	−5	−20.6	970
−74	−58.9	12.3	−39	−39.4	136	−4	−20.0	1020

TABLE 4 AWS CLASSIFICATIONS FOR TYPICAL GAS MIXTURES

AWS Classification	Typical Gas Mixtures, %	Gas
SG-AC-25	75⁄25	Argon + Carbon Dioxide
SG-AO-2	98/2	Argon + Oxygen
SG-AHe-10	90/10	Argon + Helium
SG-AH-5	95/5	Argon + Hydrogen
SG-HeA-25	75/25	Helium + Argon
SG-HeAC-7.5/2.5	90/7.5/2.5	Helium + Argon + Carbon Dioxide
SG-ACO-8/2	90/8/2	Argon + Carbon Dioxide + Oxygen
SG-A-G	Special	Argon + Mixture

Example:

Ar – 25% CO_2 SG-AC-25

$$25 \times 0.1 = 2.5$$
$$25 - 2.5 = 22.5$$
$$25 + 2.5 = 27.5$$

Ar with 22.5 to 27.5% CO_2

Ar – 2% O_2 SG-AO-2

$$2 \times 0.1 = 0.2$$
$$2 - 0.2 = 1.8$$
$$2 + 0.2 = 2.2$$

Ar with 1.8 to 2.2% O_2

14. Marking of High-Pressure Cylinders, Liquid Containers, and Bulk Vessels

14.1 All cylinders and containers shall be marked in accordance with DOT regulations plus the following information, legibly marked on, or attached to, each cylinder:

- AWS specification and classification designation (year of issue may be excluded).
- Supplier's name and product trade designation (name of gas)
- Approved DOT warning label

14.2 The following example designates the minimum labeling requirement to comply with this specification.

This product conforms to AWS A5.32, classified as SG-AC-25.

FIG. 1 CLASSIFICATION SYSTEM FOR A SINGLE GAS

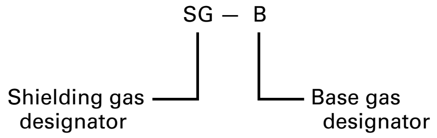


FIG. 2 CLASSIFICATION SYSTEM FOR MULTICOMPONENT SHIELDING GASES

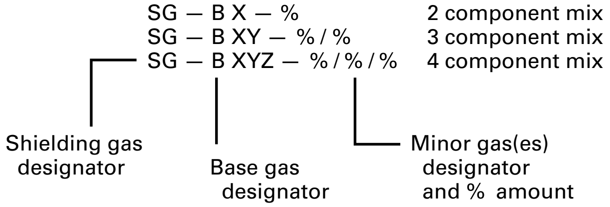


FIG. 3 CLASSIFICATION SYSTEM FOR SPECIAL MULTICOMPONENT SHIELDING GASES

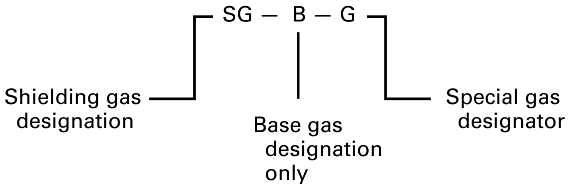
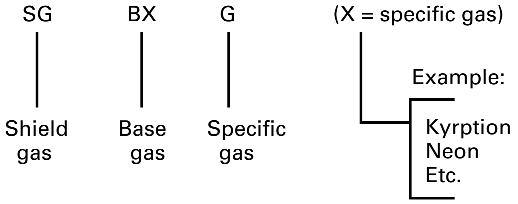


FIG. 4 CLASSIFICATION SYSTEM FOR "X" DESIGNATOR SHIELDING GASES



GENERAL NOTE:
When "X" is used in the classification, the designator gas represented by "X" must be disclosed within parentheses after the letter "G".

Annex
Guide to AWS Specification for Welding Shielding Gases

[This Annex is not a part of AWS A5.32/A5.32M-97 (R2007), *Specification for Welding Shielding Gases*, but is included for information purposes only.]

A1. Introduction

The purpose of this guide is to correlate the shielding gas classifications with their intended use so the specification can be used effectively. Appropriate 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 welding processes for which each shielding gas is suitable.

A2. Classification System

A2.1 The system for identifying the shielding gas classifications in this specification follows the standard pattern used in AWS filler metal specifications. The letter SG at the beginning of each classification designation stands for shielding gas. The letter immediately to the right of SG- indicates the singular or base gas in the shielding gas mixture.

For shielding gas mixtures, the letter designators immediately following the base gas designator indicate minor individual gas components in decreasing order of percent. These letters are followed by a hyphen and nominal whole numeric value of each minor gas volumetric percentage. If there are more than one minor gas component, each numeric value in decreasing order is separated by a virgule(/).

A2.2 "G" Classification

A2.2.1 This specification includes shielding gases classified as SG-B-G. The last "G" indicates that the shielding gas is of a "General" classification. It is "General" because not all of the particular requirements specified for each of the other classifications are met. The intent in establishing this classification is to provide a means by which shielding gases that differ, for example, chemical composition, from other classifications and do not meet the composition specified for any of the classifications in this document can still be classified. This is to allow a useful shielding gas — one that otherwise would have to await a revision of the specification — to be classified immediately under the existing document. This means that two shielding gases — each bearing the same "G" classification — may be quite different in some respect, for example, chemical composition.

A2.2.2 The point of difference (although not necessarily the amount of that difference) between shielding gas of a "G" classification and shielding gas 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:

(a) 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.

(b) Not Required is used in those areas of the specification that refer to the tests that must be conducted in order to classify a shielding gas. It indicates that that test is not required because the requirements (results) for the test have not been specified for that particular classification.

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a shielding gas 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 procedures and the acceptance requirements are to be for that test. The purchaser should specify that information in the purchase order.

A2.2.3 Request for Shielding Gas Classification

A2.2.3.1 When a shielding gas cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that shielding gas. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals recommends that the manufacturer still request that a classification be established for that shielding gas, as long as the shielding gas is of commercial significance.

A2.2.3.2 A request to establish a new shielding gas classification shall be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request needs to state the variables and their limits, for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

A2.2.3.3 The request should be sent to the Secretary of the Committee on Filler Metals at AWS Headquarters. Upon receipt of the request, the Secretary will do the following:

(a) Assign an identifying number to the request. This number shall 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 the Chair of the particular Subcommittee involved.

(d) File the original request.

(e) Add the request to the log of outstanding requests.

A2.2.3.4 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 Chairpersons of the Committee and Subcommittee. Any request outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report it to the Chair of the Committee on Filler Metals for action.

A2.2.3.5 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 meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A3. Acceptance

Acceptance of all shielding gases classified under this specification is in accordance with the tests and requirements of Part B and C of this specification. Any testing a purchaser requires of the supplier, for gases 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 gases with whatever testing the supplier normally conducts on gases of that classification. 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, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this "certification" is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped, and that that material met the requirements of the specification. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the "certification" required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.[7]

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 the following:

(a) Dimensions of the space in which the welding is done (with special regard to the height of the ceiling).

(b) Number of welders and welding operators working in that space.

(c) Rate of evolution of fumes, gases, or dust, according to the materials and processes used.

(d) 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.

(e) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard ANSI/ASC 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 sections on "Health Protection and Ventilation."

A6. Welding Considerations

The properties of gases affect the performance of all arc welding processes. The ionization potential of the shielding gas influences the ease of arc initiation and stability. Thermal conductivity of a gas determines the voltage and energy constant of the arc. Gases such as carbon dioxide can have

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[7] AWS standards can be obtained from AWS at 550 N.W. LeJeune Rd., Miami, FL 33126.

higher heat conductivity than helium at arc temperatures because of the effects of disassociation and recombination.

Reactive and oxidizing gases such as carbon dioxide (CO_2) and oxygen (O_2) can have detrimental effects on base metals such as aluminum, nickel, titanium, zirconium, and tungsten. For this reason, carbon dioxide or oxygen cannot be used as the shielding gas for gas tungsten arc welding.

Proper gas selection is crucial to efficient welding in the most cost-effective manner. Many factors must be considered. These are not limited to the following:

(a) Type and thickness of base metal being welded
(b) Arc characteristics
(c) Metal transfer
(d) Travel speed
(e) Depth and width of fusion
(f) Cost of welding
(g) Mechanical properties
(h) Root opening
(i) Cleanliness of the base material
(j) Spatter
(k) Arc cleaning action
(l) Gas purity
(m) Joint configuration
(n) Welding position
(o) Fume generation

A7. Description and Intended Use of the Shielding Gases

A7.1 Single Gases. All single gases described in this specification may be purchased either as a liquid or as a gas. If liquid, the material must be gasified prior to being supplied to the welding area.

A7.1.1 SG-A (Argon). Argon is a chemically inert gas which is used both singularly and in combination with other gases to achieve desired arc characteristics for the welding of both ferrous and nonferrous metals. Almost all arc welding processes can use argon or mixtures containing argon to achieve good weldability, mechanical properties, arc characteristics and productivity. Argon is used for welding of nonferrous materials such as aluminum, nickel, copper, magnesium alloys, and reactive metals, which include zirconium and titanium. The low-ionization potential of argon creates an excellent current path and superior arc stability. In the GMAW process, argon produces a constricted arc column at a high current density which causes the arc energy to be concentrated in a small central area of the weld pool. The result is a depth of fusion profile which may have a distinct finger-like shape. Argon is also used for single-side melt-through welding with or without consumable inserts.

A7.1.2 SG-C (Carbon Dioxide). Carbon dioxide is an active gas used primarily for GMAW and FCAW. The heat of the arc dissociates the carbon dioxide into carbon monoxide and free oxygen. This oxygen will combine with elements transferring across the arc to form oxides which are released from the weld pool in the form of slag and scale. Although carbon dioxide is an active gas and produces an oxidizing effect, sound welds and acceptable mechanical properties can be achieved in many, but not all, metals and alloys. An electrode having higher amounts of deoxidizing elements is sometimes needed to compensate for the reactive nature of the gas. Carbon dioxide can be used for solid electrode GMAW with short circuiting and globular transfer and FCAW of carbon and stainless steel. Carbon dioxide cannot be used for spray transfer with GMAW.

The popularity of carbon dioxide is due to common availability as well as its lower cost per unit volume. The lower cost per unit of gas does not automatically translate to lowest cost per foot of deposited weld and is greatly dependent on the welding application. The final weld cost with carbon dioxide shielding gas is influenced by bead contour, electrode spatter, and spatter removal. The lower deposition efficiency for carbon dioxide caused by fume and spatter loss will influence the final weld cost.

Argon is often mixed with carbon dioxide to improve the operating characteristics. If mechanical properties are to be maximized, a carbon dioxide and argon mixture is often recommended.

A7.1.3 SG-N (Nitrogen). Shielding gases containing nitrogen are not recommended for welding carbon steel. Nitrogen will combine with other elements at high temperatures which is why it is not recommended as a primary gas, but is used in combination with other gases for selected applications. Nitrogen is often used as a gas to protect the weld root from atmospheric contamination. Nitrogen root shielding of stainless steel welds may cause problems in those applications where control of the ferrite content is critical. Increased nitrogen content of the weld may reduce the ferrite level. Small additions (≤3%) of nitrogen have been combined with argon for GMA and GTA welding of duplex stainless steel.

A7.1.4 SG-He (Helium). Helium, a chemically inert gas, is used for weld applications requiring higher heat inputs. Helium may improve wetting action, depth of fusion, and travel speeds. It does not produce the stable arc provided by argon. Helium has higher thermal conductivity and a wider arc column than argon. The higher voltage gradient increases heat input compared with argon, promoting increased weld pool fluidity and better wetting action. This is an advantage when welding aluminum-based, magnesium-based, and copper-based alloys. Using GMAW, 100-percent helium will only produce globular transfer. The argon percentage must be at least 20 percent when mixed with helium to produce and maintain a stable spray transfer.

A7.1.5 SG-O (Oxygen). Oxygen is never used as a base component of a shielding gas. It can be used as a minor component.

A7.1.6 SG-H (Hydrogen). Hydrogen (H_2) is chemically active and most commonly used at low percentages (1 to 35%) as the minor component in a gas mixture (see Section A8, General Safety Considerations).

A7.2 Binary Shielding Gas Mixtures

A7.2.1 SG-AO (Argon + Oxygen Mixtures). The addition of oxygen to argon with the GMAW process improves the arc characteristics and increases weld pool fluidity by reducing the surface tension of the weld metal. Oxygen is an active gas which intensifies the arc plasma, increasing heat input, travel speed, depth of fusion, and wetting. In GMAW, the addition of small amounts (1 to 8%) of oxygen to argon stabilizes the welding arc, increases the filler metal droplet rate, lowers the spray arc transition current, and influences bead shape. The weld pool is more fluid allowing improved weld bead wetting. Oxygen is not used with GTAW because of its detrimental effect on the tungsten electrode.

A7.2.1.1 SG-AO-1 (Ar + 1% O_2). This mixture is primarily used for spray transfer on stainless steels. One-percent oxygen is usually sufficient to stabilize the arc, increase the droplet rate and provide good fluidity of the weld pool.

A7.2.1.2 SG-AO-2 (Ar + 2% O_2). This mixture is used for spray arc welding on carbon steels, low-alloy steels and stainless steels. It provides additional wetting action over SG-AO-1. Weld mechanical properties and corrosion resistance (stainless steels) of welds made using the SG-AO-2 and SG-AO-1 shielding gases are comparable.

A7.2.1.3 SG-AO-5 (Ar + 5% O_2). This mixture provides a more fluid but controllable weld pool. It is the most commonly used argon plus oxygen mixture for general carbon steel welding. The additional oxygen permits higher travel speeds on some weld applications.

A7.2.1.4 SG-AO-8 (Ar + 8% O_2). This mixture provides additional depth of fusion over SG-AO-5. Slightly lower arc voltage or increased wire feed speed should be used. The higher weld pool fluidity and lower spray transition current of this mixture are advantageous on some applications. This mixture can be used in the short circuiting and spray modes of transfer. Greater oxidation of the weld metal, with increased loss of manganese and silicon, should be expected.

A7.2.2 SG-AC (Argon + Carbon Dioxide Mixtures). The additions of carbon dioxide to argon can produce a wide range of welding characteristics from high-current spray transfer to low-current short circuiting transfer.

The dissociation of carbon dioxide in the arc provides oxygen for improved wetting and arc stabilization. The high thermal conductivity of carbon dioxide tends to increase the width of fusion as compared to SG-AO mixtures.

When using GMAW with solid carbon steel wires, SG-AC mixtures containing more than 20 percent carbon dioxide will not support spray transfer.

A7.2.2.1 SG-AC-1 through 10 (Ar + 1 to 10% CO_2). Mixtures in this range may produce all modes of metal transfer useful on a variety of steel thicknesses. Depth of fusion is improved and porosity may be reduced when using SG-AC compared to SG-AO.

In the 5 to 10 percent carbon dioxide range the arc column becomes more defined. These mixtures are effective on material with mill scale. SG-AC-5 is commonly used with GMAW for heavy-section low-alloy steel welding.

A7.2.2.2 SG-AC-11 through 20 (Ar + 11 to 20% CO_2). This mixture range has been used with various GMAW and FCAW applications. Most applications are on carbon and low-alloy steels. By mixing argon and carbon dioxide within this range, maximum productivity on thin-gauge materials can be achieved. The lower carbon dioxide percentages increase deposition efficiency by lowering spatter loss.

A7.2.2.3 SG-AC-21 through 49 (Ar + 21 to 49% CO_2). Mixtures in this range are used in the short circuiting GMAW mode and all positions of flux cored arc welding.

SG-AC-25 is widely used to replace pure carbon dioxide. These mixes operate well on light-gauge material at low currents, and at high currents on heavy materials producing good arc stability, weld pool control, bead appearance, and high productivity.

A7.2.2.4 SG-AC-50 (Ar + 50% CO_2). This mixture (not supplied at full cylinder pressure because the CO_2 would liquefy a full pressure) is used where increased heat input and depth of fusion are needed. Recommended material thickness is $^1/_8$ in. [3 mm] minimum for the globular mode of metal transfer. This mixture is satisfactory for pipe welding using the short circuiting transfer mode. Good wetting and bead shape without excessive weld pool fluidity are the main advantages for the pipe welding application. When welding at high current levels, the metal transfer is more like welding in pure carbon dioxide than other previously described argon mixtures, but some reduction in spatter loss can be realized due to the argon addition.

A7.2.3 SG-AHe Gases (Argon + Helium Mixtures). These mixtures are often recommended for GMA and GTA welding of aluminum where an increased width of fusion is required and bead appearance is of primary importance. Generally, the heavier the material the higher the percentage of helium. Small percentages of helium, as low as 10%, will affect the arc. In GMAW, as the helium percentage is increased, the arc voltage and depth of fusion will increase while minimizing porosity.

A7.2.3.1 SG-AHe-10 through 50 (Ar + 10 to 50% He). These mixtures are used for welding nonferrous base metals. Mixtures in this range provide an increase in heat input and travel speed, with improved bead appearance.

A7.2.4 SG-HeA (Helium + Argon Mixtures). Helium and argon mixtures are used primarily for GMA and GTA welding of nonferrous base metals, such as reactive metals, aluminum, copper, nickel, magnesium, and their alloys. They are also used for welding some carbon steels. These mixtures are used on thicker base metals. Argon addition to a helium base gas will decrease the heat input and improve arc starting characteristics. As argon percentages increase, the arc voltage, spatter, and weld depth-to-width ratio will decrease. In GMAW, the argon content must be at least 20 percent to produce and maintain a stable spray transfer.

A7.2.4.1 SG-HeA-10 through 25 (He + 10 to 25% Ar). These mixtures are used for welding copper over $^1\!/_2$ in. [13 mm] thick and aluminum over 3 in. [75 mm] thick. Their high heat input improves weld fusion. They may be used for short circuiting transfer with nickel filler metals.

A7.2.4.2 SG-HeA-25 through 50 (He + 25 to 50% Ar). These mixtures increase heat input and reduce porosity of welds in copper, aluminum, and magnesium. They are used for welding aluminum and magnesium greater than $^1\!/_2$ in. [13 mm] thick in the flat position.

A7.2.5 SG-AH (Argon + Hydrogen Mixtures) (see Section A8, Safety Considerations). Commercial argon-hydrogen gas mixtures produce reducing atmospheres. SG-AH-1, SG-AH-2, or SG-AH-5 are used for GTAW, GMAW, and PAW on a variety of base metals including the following:

(a) nickel and nickel alloys

(b) austenitic chromium-nickel stainless steels

(c) low-alloy steels (PAW only)

Mixtures containing up to 15 percent hydrogen (SG-AH-15) are used for GTAW of chrome-nickel stainless steels. Its high heat conductivity makes these mixtures useful in selected GTAW applications. Additions of hydrogen increase weld heat input permitting faster travel speeds, increased depth of fusion, improved bead wetting, and broader weld bead profile. Hydrogen additions to argon provide a reducing atmosphere which removes oxygen and oxides from the weld area.

A7.2.6 SG-NH (Nitrogen + Hydrogen Mixtures). This root shielding gas may be used in the fabrication of chrome-nickel stainless steels. The ferrite precaution outlined in A7.1.3 applies also to applications using SG-NH-5, or higher, as a root shielding medium.

A7.3 Ternary Shielding Gas Mixtures

A7.3.1 SG-ACO (Argon + Carbon Dioxide + Oxygen Mixtures). Mixtures containing these three components are versatile due to their ability to operate using short circuiting, globular, spray, and high-current-density spray transfer. Several ternary compositions are available, and their application will depend on the desired metal transfer.

A7.3.1.1 SG-ACO-5 through 10/1 through 6 (Ar + 5 to 10% CO_2 + 1 to 6% O_2). The advantage of these mixtures is their ability to shield carbon steel and low-alloy steel of all thicknesses using any mode of metal transfer. These mixtures produce good welding characteristics and mechanical properties on carbon and low-alloy steels. On thin-gauge base metals, the oxygen constituent improves arc stability at low current levels (30 to 60 A) permitting the arc to be kept short and controllable. This helps minimize excessive melt-through and distortion by lowering the total heat input into the weld zone.

A7.3.2 SG-AHeC and SG-HeAC (Argon + Helium + Carbon Dioxide Mixtures). Helium and carbon dioxide additions to argon increase the heat input to the weld, increasing bead wetting and fluidity. The weld bead profile becomes flatter and wider.

A7.3.2.1 SG-AHeC-10 through 40/1 through 15 (Ar + 10 to 40% He + 1 to 15% CO_2). Mixtures in this range have been developed for pulsed spray welding of carbon, low-alloy, and stainless steels. These mixtures are most often used on heavy sections, in positions other than flat. Good mechanical properties and weld pool control are characteristic of these mixtures.

A7.3.2.2 SG-HeAC-25 through 35/1 through 5 (He + 25 to 35% Ar + 1 to 5% CO_2). These mixtures are used for short circuit GMAW of high-strength steels and stainless steels, especially for welding positions other than flat. The carbon dioxide content is kept low to insure good weld metal toughness. The helium provides the heat necessary for good weld pool fluidity.

A7.3.2.3 SG-HeAC-7.5/2.5 (90% He + 7.5% Ar + 2.5% CO_2). This mixture is widely used for short circuit GMAW of stainless steel in all positions. The carbon dioxide content is kept low to minimize carbon pickup and assure good corrosion resistance, especially in multipass welds. The carbon dioxide plus argon addition provides good arc stability and depth of fusion. The high helium content provides higher heat input to overcome the high-viscosity nature of the stainless steel weld pool. Applications include welding carbon steel, stainless and alloy steels.

A7.3.3 SG-AHeO (Argon + Helium + Oxygen). Helium additions to argon plus oxygen mixtures increase arc energy with the GMAW process on ferrous base metals. Argon/helium/oxygen mixtures have been used for spray arc welding and surfacing low-alloy and stainless steels to improve the fluidity of the weld pool and the resultant bead shape as well as reduce porosity.

A7.4 Quaternary Shielding Gas Mixtures

A7.4.1 SG-AHeCO (Argon + Helium + CO_2 + O_2 Mixtures). This combination may be used for high-deposition GMAW using the high-current-density transfer mode. These mixtures produce weld metal with good mechanical properties, and can be used throughout a wide range of deposition rates. Their major application is welding low-alloy, high-strength steel base metals, and they have been used on carbon steel for high-productivity welding.

ARGON, CARBON DIOXIDE, HELIUM, AND NITROGEN HAZARD:

- Argon, carbon dioxide, helium, and nitrogen can displace oxygen in a worker's breathing zone which can result in asphyxiation, and possibly death, when released in poorly vented, confined work areas. Argon and carbon dioxide cause a special concern since they are heavier than air and may concentrate in low areas such as in the bottom of pressure vessels, tanks, pits, and ships.
- Unless adequate ventilation and breathing air are supplied, care must be taken with any of these gases when they are released in enclosed areas or confined spaces. A safety watch should be provided and in attendance anytime a worker is using any of these gases in a vessel.
- Additional information can be found in ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, CGA publications, and from suppliers of the aforementioned gases.

HYDROGEN WARNING:

- Hydrogen is a highly flammable gas. A mixture of hydrogen with oxygen or air in a confined area will explode when brought in contact with a flame or other source of ignition. Concentrations of hydrogen between 4 and 75 percent by volume in air are relatively easy to ignite by a low-energy spark and may cause an explosion. Smoking, open flames, unapproved electrical equipment, and other ignition sources must not be permitted in hydrogen areas. Store containers outdoors or in other well-ventilated areas.
- Before making any installation, become thoroughly familiar with NFPA (National Fire Protection Association) Standards No. 50-A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*; and 50-B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*; and with all local safety codes. For further safety information, refer to supplier MSDS sheets on hydrogen safety.
- Take every precaution against hydrogen leaks. Escaping hydrogen cannot be detected by sight, smell, or taste.

A8. General Safety Considerations

A8.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles or equivalent to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph.

Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load. Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.)

The following sources are for more detailed information on personal protection:

(a) ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(b) *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Part 1910, OSHA General Industry Standards available from the U.S. Government Printing Office, Washington, DC 20402.

(c) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, American National Standards Institute, 11 West 42 Street, New York, NY 10036.

(d) ANSI/ASC Z41.1, *Safety-Toe Footwear*, American National Standards Institute, 11 West 42 Street, New York, NY 10036.

A8.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity.

To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards should be followed, such as ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes; National Electrical Code;* and NFPA No. 70, available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

A8.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal, shielding gas, base metal, welding process, current level, arc length, and other factors.

The possible effects of overexposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air to cause asphyxiation.

Various gases are generated during welding. Some are a product of the decomposition of fluxes and electrode coatings. Others are formed by the action of arc heat or ultraviolet radiation emitted by the arc on atmospheric constituents and contaminants. Potentially hazardous gases include carbon monoxide, oxides of nitrogen, ozone, and decomposition products of chlorinated hydrocarbons, such as phosgene.

One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from one's breathing zone and the general area.

In some cases, natural air movement will provide enough ventilation. Where ventilation may be questionable, air sampling should be used to determine if corrective measures should be applied.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(a) The permissible exposure limits required by OSHA can be found in CFR Title 29, Chapter XVII, Part 1910. The OSHA, *General Industry Standards*, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

(b) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH), 1330

Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1634.

(c) The results of an AWS-funded study, *Fumes and Gases in the Welding Environment*, is available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

A8.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as x-rays), or nonionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

A8.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptable limits by use of suitable shielding enclosing the welding area.

A8.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base-metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser beam welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(a) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 11 West 42 Street, New York, NY 10036. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(b) Exposed skin should be protected with adequate gloves and clothing, as specified in ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society.

(c) Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. *(Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.)*

(d) Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

(e) Safety glasses with UV-protective side shields have been shown to provide some protection from ultra-violet radiation produced by welding arcs.

A8.4.3 Ionizing radiation information sources include:

(a) AWS F2.1, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society.

(b) Manufacturer's product information literature.

A8.4.4 Nonionizing radiation information sources include:

(a) Hinrichs, J. F. "Project committee on radiation-summary report." *Welding Journal*, January 1978.

(b) National Technical Information Service. Nonionizing radiation protection, Special Study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*. Springfield, VA 22161: National Technical Information Service, ADA-033768.

(c) ———. Nonionizing radiation protection, Special Study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*. Springfield, VA 22161: National Technical Information Service, ADA-043023.

(d) Moss, C. E., and Murray, W. E. "Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting." *Welding Journal*, September 1979.

(e) Marshall, W. J., Sliney, D. H., et al. "Optical radiation levels produced by air-carbon arc cutting processes." *Welding Journal*, March 1980.

(f) American National Standards Institute, ANSI/ASC Z136.1, *Safe Use of Lasers*, published by American National Standards Institute, 11 West 42 Street, New York, NY 10036.

(g) ———. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(h) ———. ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 11 West 42 Street, New York, NY 10036.

(i) Moss, C.E. "Optical radiation transmission levels through transparent welding curtains." *Welding Journal*, March 1979.

A9. Safety References

Material Safety Data Sheets (MSDS) are available from the supplier of the shielding gas. Additional safety references are shown in Table A1.

SPECIFICATION FOR NICKEL-ALLOY ELECTRODES FOR FLUX CORED ARC WELDING

(**15**)

SFA-5.34/SFA-5.34M

(Identical with AWS Specification A5.34/A5.34M:2013. In case of dispute, the original AWS text applies.)

Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of nickel-alloy electrodes for flux cored arc welding. It includes those compositions in which the nickel content exceeds that of any other element, but excludes nickel-base alloy compositions intended for the joining of cast irons.

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in the nonmandatory annex, Clauses A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI), according to the guidelines in AWS A1.1. 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 A5.34 uses U.S. Customary Units. The specification A5.34M 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 or both under the A5.34 or A5.34M specification.

2. Normative References

2.1 The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard referred to applies.

2.2 The following AWS standards[1] are referenced in the mandatory clauses of this document:

AWS A1.1, *Metric Practice Guide for the Welding Industry*

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*

AWS A5.01M/A5.01 (ISO 14344 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

AWS A5.02/A5.02M, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*

AWS A5.32/A5.32M (ISO 14175 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*

AWS B4.0 or AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

2.3 The following ANSI standard[2] is referenced in the mandatory clauses of this document:

ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*

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[1] AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166, USA.

[2] This ANSI standard is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166, USA.

2.4 The following ASTM standards[3] are referenced in the mandatory clauses of this document:

ASTM A131/A131M *Standard Specification for Structural Steel for Ships*

ASTM A240/A240M *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

ASTM A515/A515M *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate-, and Higher- Temperature Service*

ASTM A516/A516M *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

ASTM A666 *Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar*

ASTM B166 *Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire*

ASTM B168 *Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip*

ASTM B333 *Standard Specification for Nickel-Molybdenum Alloy Plate, Sheet, and Strip*

ASTM B435 Standard Specification for UNS N06002, N06230, UNS N12160, and R30556 Plate, Sheet, and Strip

ASTM B443 *Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip*

ASTM B446 *Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Rod and Bar*

ASTM B575 *Spec for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet and Strip*

ASTM E29 *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

ASTM E354 *Standard Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys*

ASTM E1019 *Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel and in Iron, Nickel, and Cobalt Alloys*

ASTM E1032 *Standard Test Methods for Radiographic Examination of Weldments*

ASTM E1473 *Standard Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys*

2.5 The following ISO standards[4] are referenced in the mandatory clauses of this document:

ISO 544, *Welding Consumables—Technical delivery conditions for welding filler materials—Type of product, dimensions, tolerances and markings*

ISO 80000-1, *Quantities and units—Part 1: General*

3. Classification

3.1 The flux cored electrodes covered by the A5.34/A5.34M specifications 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 undiluted weld metal, the shielding gas employed during welding, and the welding position usability, as specified in Tables 1 and 2.

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[3] ASTM standards are published by ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[4] ISO standards are published by the International Organization for Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

Table 1
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classifications[c]		UNS Number[d]	Wt Percent[a,b]															
ISO Format	Traditional		C	Mn	Fe	P	S	Si	Cu	Ni[e]	Co	Ti	Cr	Nb(Cb) plus Ta[g]	Mo	V	W	Other
TNi 6082-xy	ENiCr3Tx-y	W86082	0.10	2.5–3.5	3.0	0.03	0.015	0.50	0.50	67.0 min.	(f)	0.75	18.0–22.0	2.0–3.0	—	—	—	0.50
TNi 6062-xy	ENiCrFe1Tx-y	W86132	0.08	3.5	11.0	0.03	0.015	0.75	0.50	62.0 min.	—	—	13.0–17.0	1.5–4.0	—	—	—	0.50
TNi 6133-xy	ENiCrFe2Tx-y	W86133	0.10	1.0–3.5	12.0	0.03	0.02	0.75	0.50	62.0 min.	(f)	—	13.0–17.0	0.5–3.0	0.5–2.5	—	—	0.50
TNi 6182-xy	ENiCrFe3Tx-y	W86182	0.10	5.0–9.5	10.0	0.03	0.015	1.0	0.50	59.0 min.	(f)	1.0	13.0–17.0	1.0–2.5	—	—	—	0.50
TNi 1013-xy	*ENiMo13Tx-y*	*N10300*	*0.10*	*2.0–3.0*	*10.0*	*0.020*	*0.015*	*0.75*	*0.5*	*58.0 min.*	—	—	*4.0–8.0*	—	*16.0–19.0*	—	*2.0–4.0*	*0.50*
TNi 6002-xy	ENiCrMo2Tx-y	W86002	0.05–0.15	1.0	17.0–20.0	0.04	0.03	1.0	0.50	Rem.	0.50–2.50	—	20.5–23.0	—	8.0–10.0	—	0.2–1.0	0.50
TNi 6625-xy	ENiCrMo3Tx-y	W86625	0.10	0.50	5.0[h]	0.02	0.015	0.50	0.50	58.0 min.	(f)	0.40	20.0–23.0	3.15–4.15	8.0–10.0	—	—	0.50
TNi 6276-xy	ENiCrMo4Tx-y	W80276	0.02	1.0	4.0–7.0	0.03	0.03	0.2	0.50	Rem.	2.5	—	14.5–16.5	—	15.0–17.0	0.35	3.0–4.5	0.50
TNi 6022-xy	ENiCrMo10Tx-y	W86022	0.02	1.0	2.0–6.0	0.03	0.015	0.2	0.50	Rem.	2.5	—	20.0–22.5	—	12.5–14.5	0.35	2.5–3.5	0.50
TNi 6117-xy	ENiCrCoMo1Tx-y	W86117	0.05–0.15	0.3–2.5	5.0	0.03	0.015	0.75	0.50	Rem.	9.0–15.0	—	21.0–26.0	1.0	8.0–10.0	—	—	0.50

[a] The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined, the total of which shall not exceed 0.50%.

[b] Single values are maximum, except where otherwise specified. Rem. = Remainder.

[c] Both designations shall be shown as described in Clause 22.1. The letter "x" stands for the numerals 0 or 1 which denotes the welding position for which the alloy is classified, as described in Table 2. The letter "y" stands for one of the numerals 1, 3 or 4 which denotes the particular shielding gas (or none at all) required when conducting the classification tests, as described in Table 2.

[d] SAE HS-1086/ASTM DS-56 *Metals & Alloys in the Unified Numbering System*

[e] Includes residual cobalt.

[f] Cobalt is 0.10 maximum, when specified by the purchaser.

[g] Tantalum is 0.30 maximum, when specified by the purchaser.

[h] Iron is 1.0 maximum, when specified by the purchaser.

Table 2
Required Shielding Gas, Welding Current, and Welding Position

AWS Classifications[a]				
ISO Format	Traditional	External Shielding Gas Classification[b]	Current and Polarity	Welding Position[c]
TNi xxxx-01	ENiXXXXT0-1	AWS A5.32(ISO 14175)-C1-100	dcep	F & HF
TNi xxxx-11	ENiXXXXT1-1	AWS A5.32(ISO 14175)-C1-100	dcep	All
TNi xxxx-03	ENiXXXXT0-3	None	dcep	F & HF
TNi xxxx-04	ENiXXXXT0-4	AWS A5.32(ISO 14175)-M21-ArC-25	dcep	F & HF
TNi xxxx-14	ENiXXXXT1-4	or AWS A5.32(ISO 14175)-M21-ArC-20	dcep	All

[a] The letters xxxx stand for numeric designators, and XXXX stand for the chemical symbol designators for the chemical composition.

[b] See AWS A5.32M/A5.32 (ISO 14175 MOD). AWS A5.32 (ISO 14175)-C1-100 = CO_2; AWS A5.32 (ISO 14175)-M21-ArC-25 is nominally 25% CO_2, balance argon; AWS A5.32(ISO 14175)-M21-ArC-20 is nominally 20% CO_2, balance argon. The external shielding gas specified here is required when making welds for classification. This requirement is not intended to preclude the use of another shielding gas in the application of the electrode.

[c] Welding position usability is determined by the Fillet Weld Test as required by Table 3.
F = flat; HF = horizontal fillet; All = flat, horizontal, overhead and vertical with upward progression.

3.2 Electrodes classified under one classification may be classified under any other classification of this specification provided they meet all the requirements for those classifications.

4. Acceptance

Acceptance[5] of the electrodes shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

5. Certification

By affixing the AWS specification and classification designations to the packaging or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[6]

6. Rounding-Off Procedure

For the purpose 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 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 off. If an average value is to be compared to the specified limit, rounding off shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi (1 ksi) for tensile strength for A5.34 or to the nearest 10 MPa for tensile strength for A5.34M; and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded-off results shall fulfill the requirements for the classification under test.

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 3. The purpose of these tests is to determine the chemical composition, the mechanical properties, soundness of the weld metal, and the welding position usability characteristics of the electrode using the specified shielding gas.

7.2 The base metals for the weld test assemblies are as specified in Tables 4 and 5. The welding and testing procedures to be employed, and the results required are given in Clauses 9 through 14.

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[5] See Clause A3, Acceptance (in Annex A), for further information concerning acceptance, testing of the material shipped, and AWS A5.01M/A5.01 (ISO 14344 MOD).

[6] See Clause A4, Certification (in Annex A), for further information concerning certification and the testing called for to meet this requirement.

Table 3
Required Tests[a]

AWS Classifications		Chemical	Radiographic	Tension	Longitudinal	Fillet
ISO Format	Traditional	Analysis	Test	Test	Bend Test	Weld Test
TNi 6082-0y	ENiCr3T0-y	Required	Required	Required	Required	Not Required
TNi 6082-1y	ENiCr3T1-y	Required	Required	Required	Required	Required
TNi 1013-0y	*ENiMo13T0-y*	*Required*	*Required*	*Required*	*Required*	*Not Required*
TNi 1013-1y	*ENiMo13T1-y*	*Required*	*Required*	*Required*	*Required*	*Required*
TNi 6062-0y	ENiCrFe1T0-y	Required	Required	Required	Required	Not Required
TNi 6062-1y	ENiCrFe1T1-y	Required	Required	Required	Required	Required
TNi 6133-0y	ENiCrFe2T0-y	Required	Required	Required	Required	Not Required
TNi 6133-1y	ENiCrFe2T1-y	Required	Required	Required	Required	Required
TNi 6182-0y	ENiCrFe3T0-y	Required	Required	Required	Required	Not Required
TNi 6182-1y	ENiCrFe3T1-y	Required	Required	Required	Required	Required
TNi 6002-0y	ENiCrMo2T0-y	Required	Required	Required	Required	Not Required
TNi 6002-1y	ENiCrMo2T1-y	Required	Required	Required	Required	Required
TNi 6625-0y	ENiCrMo3T0-y	Required	Required	Required	Required	Not Required
TNi 6625-1y	ENiCrMo3T1-y	Required	Required	Required	Required	Required
TNi 6276-0y	ENiCrMo4T0-y	Required	Required	Required	Required	Not Required
TNi 6276-1y	ENiCrMo4T1-y	Required	Required	Required	Required	Required
TNi 6022-0y	ENiCrMo10T0-y	Required	Required	Required	Required	Not Required
TNi 6022-1y	ENiCrMo10T1-y	Required	Required	Required	Required	Required
TNi 6117-0y	ENiCrCoMo1T0-y	Required	Required	Required	Required	Not Required
TNi 6117-1y	ENiCrCoMo1T1-y	Required	Required	Required	Required	Required

[a] The tests specified are required for each size of electrode to be classified.

Table 4
Required Base Metals[a,b]

AWS Classification		Chemical	Radiographic	Tension	Bend	Fillet
ISO Format	Traditional	Analysis[c]	Test	Test	Test	Weld Test
TNi 6082-xy	ENiCr3Tx-y			Ni-Cr-Fe, Stainless, or Carbon Steels		
TNi 6062-xy	ENiCrFe1Tx-y					
TNi 6133-xy	ENiCrFe2Tx-y					
TNi 6182-xy	ENiCrFe3Tx-y					
TNi 1013-xy	*ENiMo13Tx-y*			*Ni-Mo, Stainless, or Carbon Steel*		
TNi 6002-xy	ENiCrMo2Tx-y			Ni-Cr-Mo, Stainless, or Carbon Steels		
TNi 6625-xy	ENiCrMo3Tx-y					
TNi 6276-xy	ENiCrMo4Tx-y					
TNi 6022-xy	ENiCrMo10Tx-y					
TNi 6117-xy	ENiCrCoMo1Tx-y			Ni-Cr-Co-Mo, Stainless, or Carbon Steels		

[a] See Table 5 for specifications for the required base metals.

[b] Where nickel alloy, carbon steel, or stainless steel is shown, any type or any combination of those may be used. When either or both members are carbon steel, two layers of buttering shall be applied to the face of the groove on the carbon steel member and, if the backing strip is also carbon steel, to the mating surface of that as well. The buttering shall be applied in the flat position using electrodes of the same classification as the one being tested prior to joint fit up.

[c] For chemical analysis, carbon steel, stainless steel, or nickel alloy base metals other than those specified in tables may be used in preparation of the undiluted weld metal pad provided the minimum pad height (weld metal) is 3/4 in [20 mm] and the sample for analysis is taken at least 5/8 in [16 mm] from the nearest surface of the base metal.

Table 5
Base Metal Specifications[a]

AWS Classification				
ISO Format	**Traditional**	**Base Metal**	**ASTM Specification**	**UNS Number of Base Metal**
TNi 6082-xy TNi 6062-xy TNi 6133-xy TNi 6182-xy	ENiCr3Tx-y ENiCrFe1Tx-y ENiCrFe2Tx-y ENiCrFe3Tx-y	Nickel-chromium Iron alloy	B 166, B 168	N06600
TNi 1013-xy	*ENiMo13Tx-y*	*Nickel-Molybdenum alloy*	*B333*	*N10001, N10665, and N10675*
TNi 6002-xy TNi 6625-xy	ENiCrMo2Tx-y ENiCrMo3Tx-y	Nickel-chromium-molybdenum alloy or Low carbon nickel-chromium-molybdenum alloy	B 443, B 446, B 435 B 575	N06625 N06002 N10276
TNi 6276-xy TNi 6022-xy	ENiCrMo4Tx-y ENiCrMo10Tx-y	Low carbon nickel-chromium-molybdenum alloy	B 575	N10276, N06022
TNi 6117-xy	ENiCrCoMo1Tx-y	Nickel-chromium-cobalt-Molybdenum alloy	B 166, B 168	N06617
All		Carbon steel	A 131, A 285, A515, A516	—
All		Austenitic stainless steel	A 240, A 666	S301xx, S302xx, S304xx, S316xx

[a] All base metals, except carbon steel, shall be in the annealed condition prior to welding.

8. Retest

If any test fails to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for the retest may be taken from the original test assembly or from a new test assembly. For chemical analysis, retest need be only for those specific elements that failed to meet their 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 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 prescribed procedures. In this case, the requirement for doubling of the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 Up to four weld test assemblies may be needed, depending upon the classification, as specified in Table 3. They are :

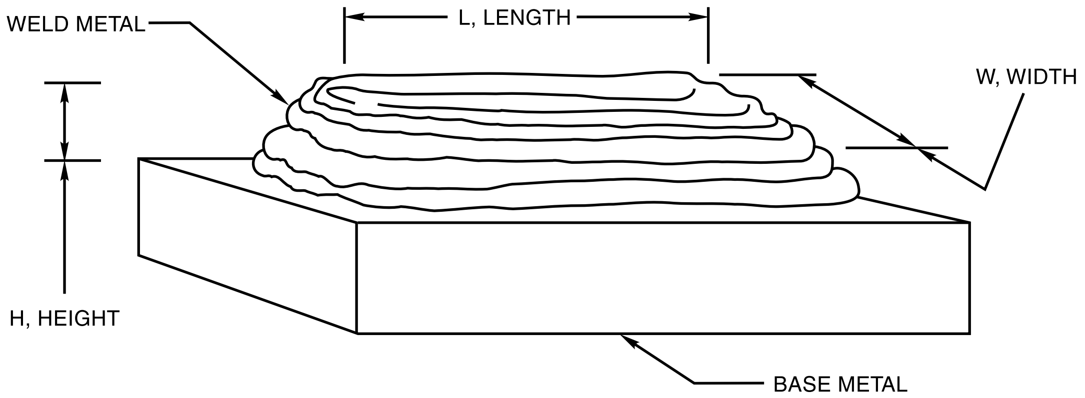
(1) the weld pad in Figure l for chemical analysis of the undiluted weld metal

(2) the groove weld in Figure 2 for mechanical properties and soundness of the weld metal

(3) the groove weld in Figure 3 for longitudinal bend testing

(4) the fillet weld in Figure 4 for welding position usability of the electrode.

The sample for chemical analysis may be taken from the reduced section of the fractured tension specimen, or from a corresponding location (or any location above it) in the weld metal of the groove weld in Figure 2, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.



Diameter		Weld Pad Size, Minimum						Minimal Distance of Sample from Surface of Base Plate[a]	
		L		W		H[a]			
in	mm	in	mm	in	mm	in	mm	in	mm
0.035 0.040 0.045 —	0.9 1.0 — 1.2	3	75	3/4	20	1/2	13	3/8	10
0.052 — 1/16 5/64	— 1.4 1.6 2.0	3	75	3/4	20	5/8	16	1/2	13
3/32 7/64	2.4 2.8	3-1/2	90	1	25	3/4	20	5/8	16

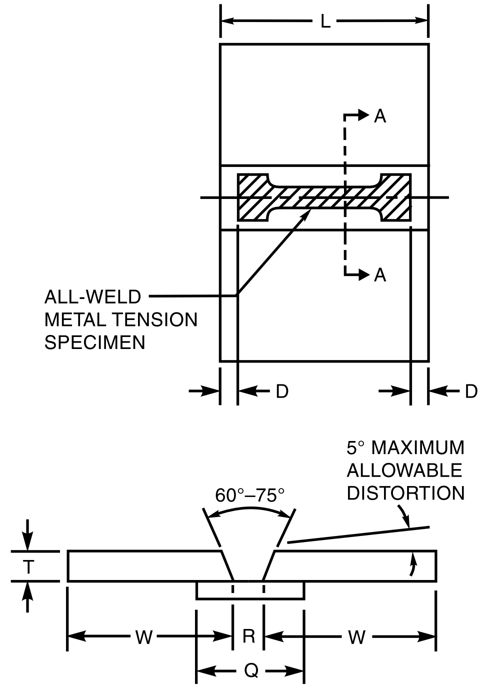
[a] Number of passes per layer is optional.

Notes:
1. Width and thickness of the base plate may be any dimensions suitable for the electrode diameter and current used.
2. The first and last inch [25 mm] of the weld length shall be disregarded. The top surface shall be removed and chemical analysis samples shall be taken from the top of the remaining deposited metal.
3. The use of copper chill bar is optional.
4. For chemical analysis, carbon steel, stainless steel, or nickel alloy base metals other than those specified in tables may be used in preparation of the undiluted weld metal pad provided the minimum pad height (weld metal) is 3/4 in [20 mm] and the sample for analysis is taken at least 5/8 in [16 mm] from the nearest surface of the base metal.

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal

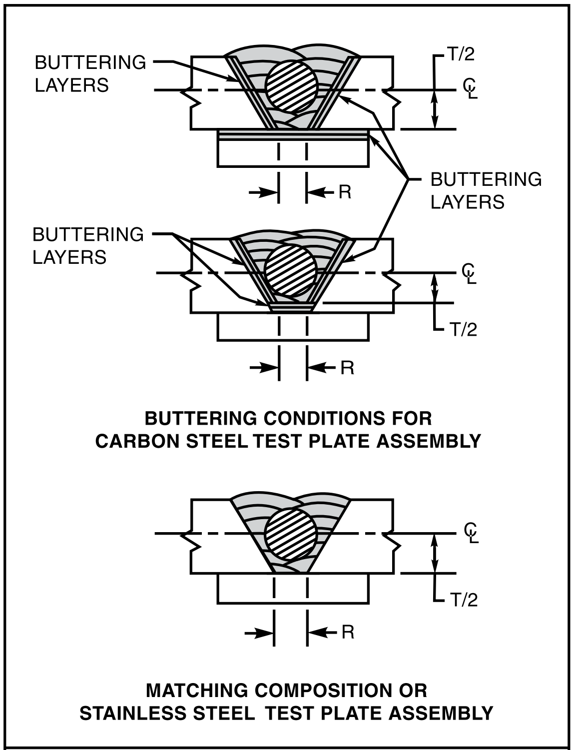
9.2 Preparation of each weld test assembly shall be as prescribed in 9.3, 9.4, 9.5, and 9.6. The base metal for each assembly shall be as required in Table 4, according to the tests to be conducted, and shall meet the requirements of the appropriate ASTM specification shown in Table 5, or an equivalent specification. Testing shall be as prescribed in Clause 10: Chemical Analysis, Clause 11: Radiographic Test, Clause 12: Tension Test, Clause 13: Bend Test, and Clause 14: Fillet Weld Test.

9.3 Weld Pad. A weld pad shall be prepared as specified in Table 3 and shown in Figure 1, except when one of the alternatives in 9.1 (taking the sample from the weld metal in the groove weld or from the tension test specimen) is selected. Base metal of any convenient size, of the type specified in Tables 4 and 5, shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position, with multiple layers to obtain undiluted weld metal using the applicable shielding gas, if any. Welding



DIMENSIONS

	in	mm
D, min.	1	25
L, min.	8	200
W, min.	5	125
Q, min.	1	25
R, min.	3/8	9.5



BUTTERING CONDITIONS FOR
CARBON STEEL TEST PLATE ASSEMBLY

MATCHING COMPOSITION OR
STAINLESS STEEL TEST PLATE ASSEMBLY

BUTTERING CONDITIONS AND
TENSION SPECIMEN LOCATION

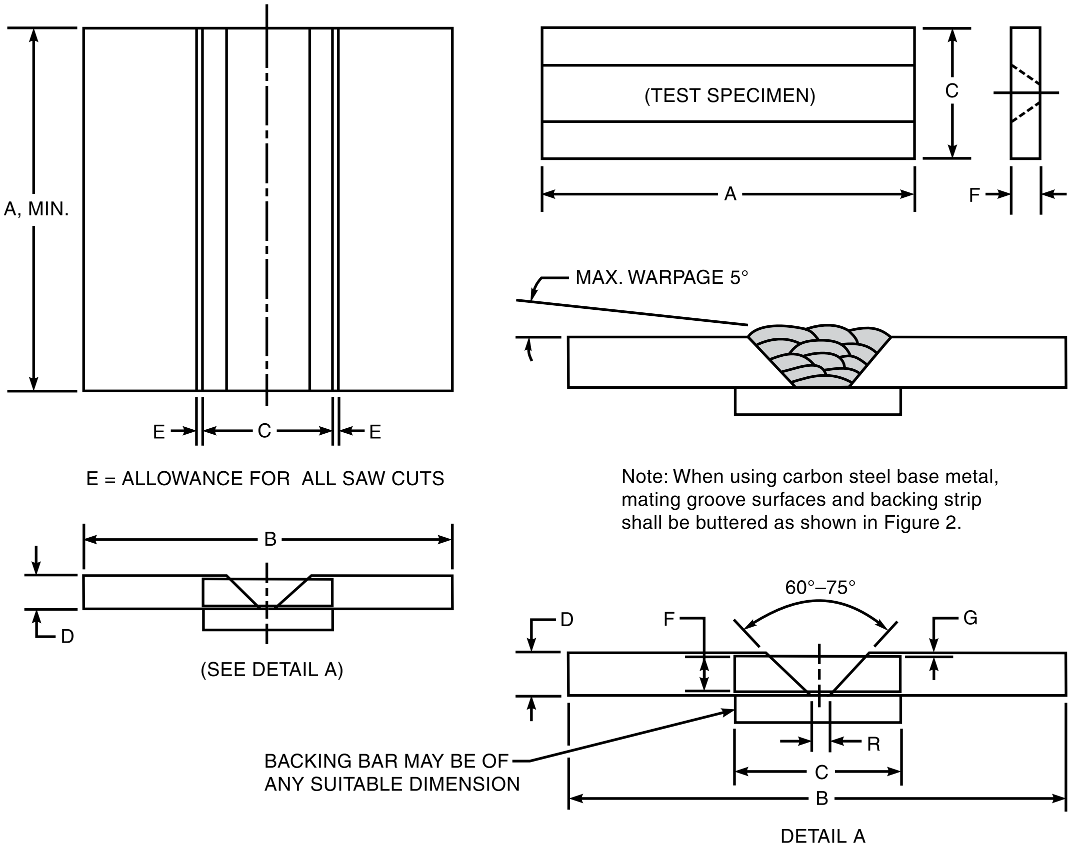
Electrode Diameter		(T) Plate Thickness		Recommended Passes per Layer		Recommended Number of Layers
in	mm	in	mm	Layer 1 and 2	Layer 3 to Top	
0.035	0.9	3/4	20	1 or 2	2, 3, or 4	8 to 12
0.040	1.0					
0.045	—					
—	1.2					
0.052		3/4	20	1 or 2	2 or 3[a]	5 to 8
—	1.4					
1/16	1.6					
5/64	2.0					
3/32	2.4					
7/64	2.8	3/4	20	1 or 2	2 or 3[a]	4 to 6

[a] Final layer may be 4 passes.

Notes:

1. The assembly shall be as long as necessary to provide the specimens needed for the number and type of tests required.
2. The root opening (R) tolerance is ± 1/16 in [1.5 mm].
3. The base metal shall be as specified in Table 4.
4. The surfaces to be welded shall be clean.
5. Prior to welding, the assembly may be preset so that the welded joint will be sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within five (5) degrees of plane. A test assembly that is more than five (5) degrees out of plane shall be discarded. Straightening of the test assembly is prohibited.
6. Welding shall be performed in the flat position, using welding parameters and technique recommended by the electrode manufacturer.
7. The preheat temperature shall be 60°F [15°C] minimum. The interpass temperature shall not exceed 300°F [150°C].
8. The tests shall be conducted without a postweld heat treatment.

Figure 2—Groove Weld Test Assembly for Tension and Radiographic Tests



Note: When using carbon steel base metal, mating groove surfaces and backing strip shall be buttered as shown in Figure 2.

Electrode Diameter		**Passes per layer**		
			Layer 2	**Number of**
in	**mm**	**Layer 1**	**to top**	**Layers**
0.035	0.9			
0.040	1.0			
0.045	—			
—	1.2			
0.052	—			
—	1.4			
1/16	1.6	1	2 to 3[a]	3 to 5
5/64	2.0			
3/32	2.4			
7/64	2.8			

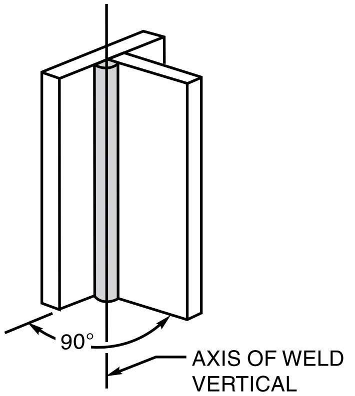
	in	**mm**
A	6 min.	150 min.
B	6	150
C	2	50
D	1/2	13
E	1/8	3
F	3/8	9.5
G	1/16	1.6
R	3/8	10

Notes:

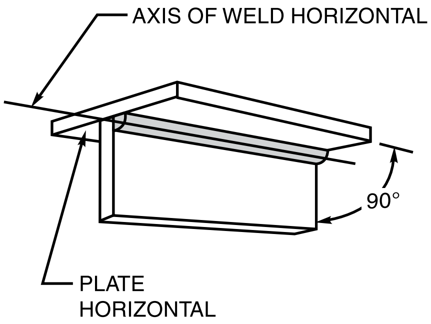
1. The assembly shall be as long as necessary to provide the specimens needed for the number and type of tests required.
2. The root opening (R) tolerance is ± 1/16 in [1.6 mm]
3. The base metal shall be as specified in Table 4.
4. The surfaces to be welded shall be clean.
5. Prior to welding, the assembly may be preset so that the welded joint will be sufficiently flat to facilitate removal of the test specimen. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within five (5) degrees of plane. A welded test assembly that is more than five (5) degrees out of plane shall be discarded. Straightening of the test assembly is prohibited.
6. Welding shall be performed in the flat position, using welding parameters and technique recommended by the electrode manufacturer.
7. The preheat temperature shall be 60°F [15°C] minimum. The interpass temperature shall not exceed 300°F [150°C].
8. The tests shall be conducted without a postweld heat treatment.

[a] Top layer must be 3.

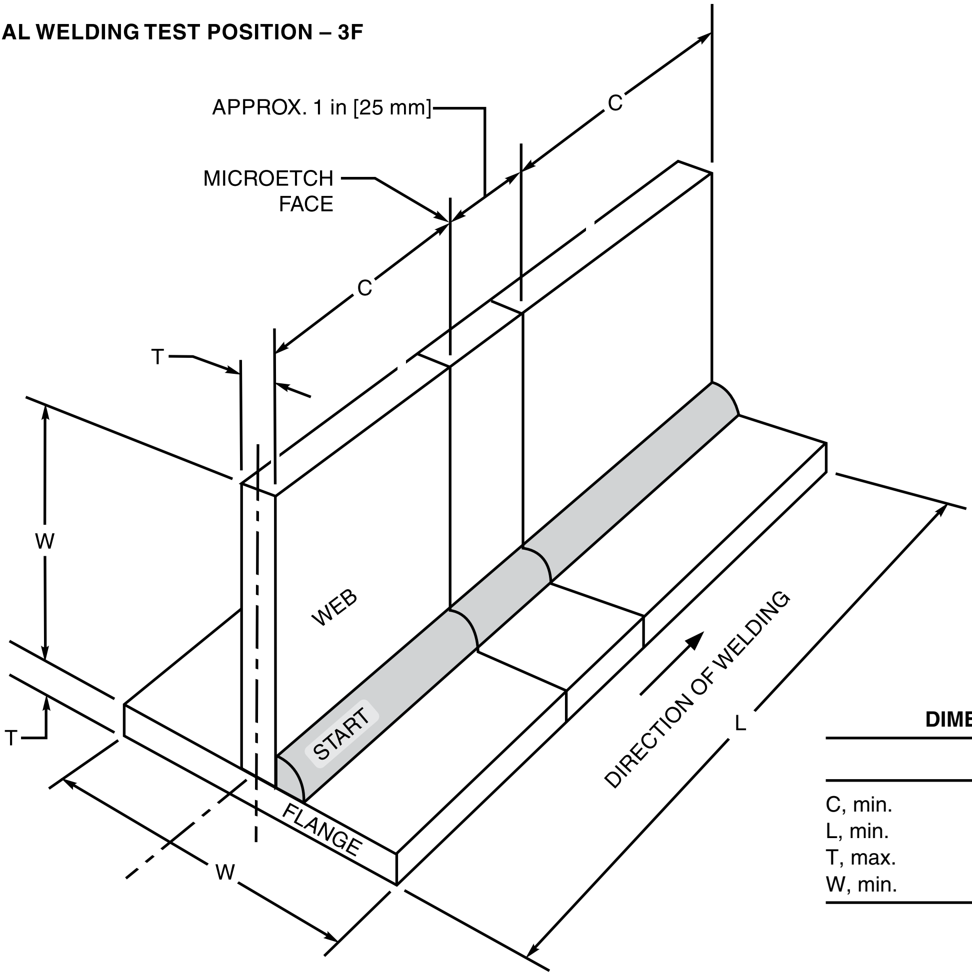
Figure 3—Groove Weld for Longitudinal Face-Bend Test



VERTICAL WELDING TEST POSITION – 3F



OVERHEAD WELDING TEST POSITION – 4F



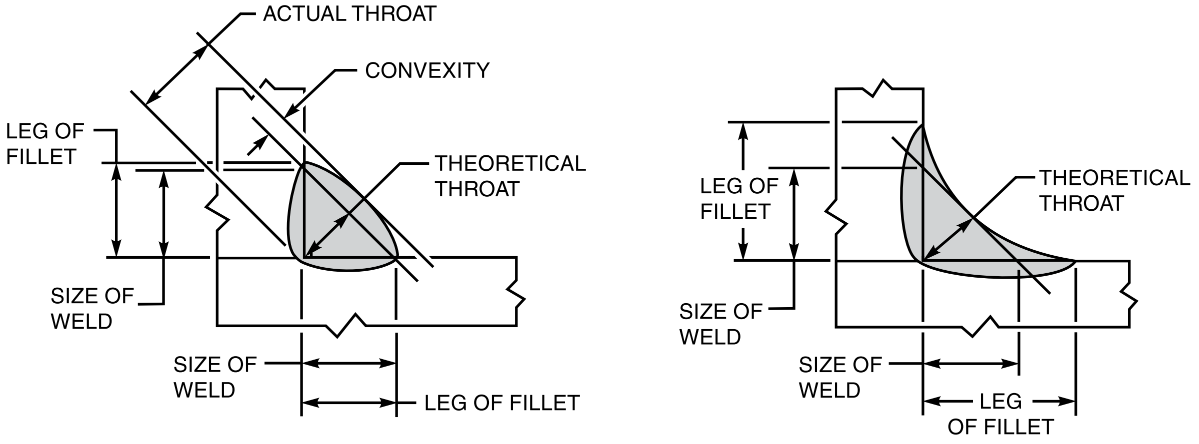
DIMENSIONS

	in	mm
C, min.	3	25
L, min.	8	200
T, max.	3/8	10
W, min.	2	50

Notes:

1. The base metal shall be as specified in Table 4.
2. The surface to be welded shall be clean.
3. The assembly shall be at room temperature at the start of the welding pass.
4. Weld cleaning shall be limited to slag chipping , brushing, and needle scaling. Grinding or filing of the weld face is prohibited.

Figure 4—Fillet Weld Test Assembly



CONVEX FILLET **CONCAVE FILLET**

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in	mm	in	mm	in	mm
1/8 or less	3.0 or less	5/64	2.0	1/32	0.8
9/64	3.5	5/64	2.0	3/64	1.2
5/32	4.0	5/64	2.0	3/64	1.2
11/64	4.5	5/64	2.0	1/16	1.6
3/16	5.0	5/64	2.0	1/16	1.6
13/64	5.2	5/64	2.0	5/64	2.0
7/32	5.5	5/64	2.0	5/64	2.0
15/64	6.0	5/64	2.0	3/32	2.4
1/4	6.5	5/64	2.0	3/32	2.4
17/64	6.7	3/32	2.4	7/64	2.8
9/32	7.0	3/32	2.4	7/64	2.8
19/64	7.5	3/32	2.4	1/8	3.2
5/16	8.0	3/32	2.4	1/8	3.2
21/64	8.5	3/32	2.4	9/64	3.6
11/32	8.7	3/32	2.4	9/64	3.6
23/64	9.0	3/32	2.4	5/32	4.0
3/8 or more	9.5 or more	3/32	2.4	5/32	4.0

Notes:

1. Size of fillet weld = leg length of largest inscribed isosceles right triangle.
2. Fillet weld size, convexity, and leg lengths of fillet welds shall be determined by actual measurement (nearest 1/64 in [0.5 mm]) on a section laid out with scribed lines shown.

Figure 5—Fillet Weld Test Specimen and Dimensional Requirements

conditions shall be those recommended by the manufacturer. The preheat temperature shall be not 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. Dimensions of the completed weld pad shall be as shown in Figure 1. Testing of this assembly shall be as specified in Clause 10, Chemical Analysis.

9.4 Groove Weld. A test assembly shall be prepared and welded as specified in Table 3 and Figure 2, using base metal of the appropriate type specified in Tables 4 and 5. Testing of this assembly shall be as specified in Clause 11, Radiographic Test, and Clause 12, Tension Test. The assembly shall be tested in the as-welded condition.

9.5 Longitudinal Face Bend

The test assembly shall be prepared and welded as specified in Table 3 and Figure 3, using base metal of the appropriate type as specified in Tables 4 and 5. Testing of this assembly shall be as specified in Clause 13, Bend Test.

9.6 Fillet Weld

9.6.1 Fillet weld tests, when required by Table 3, shall be performed in the vertical and overhead positions. A test assembly shall be prepared and welded as shown in Figure 4 using base metal of the appropriate type as specified in Tables 4 and 5, the shielding gas, current and polarity specified in Table 2, and the amperage or wire feed speed and arc voltage recommended by the manufacturer. Testing of the assembly shall be as specified in Clause 14, Fillet Weld Test.

9.6.2 In preparing the two plates forming the test assembly, the standing member (web) shall have one edge prepared so that when the web is set upon the base plate (flange), which shall be straight and smooth, there will be intimate contact along the entire length of the joint.

9.6.3 A single-pass fillet weld shall be deposited on one side of the joint. When welding in the vertical position, the welding shall progress upward.

10. Chemical Analysis

10.1 The sample for analysis shall be taken from weld metal produced with the filler metal and the shielding gas with which it is classified. The top surface of the 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. The sample shall be taken at least 3/8 in [10 mm] from the nearest surface of the base metal (see Table 4, Note c, for sample removal when base metals other than those specified are used). Samples from the reduced section of the fractured tension specimen or from a corresponding location (or any location above it) in the groove weld in Figure 2 shall be prepared for chemical analysis by any suitable mechanical means.

10.2 The sample shall be analyzed by accepted analytical methods. The primary referee method shall be ASTM Method E1473, supplemented by ASTM Method E1019 for carbon and ASTM Method E354 for phosphorus.

10.3 The results of the analysis shall meet the requirements of Table 1 for the classification of electrode under test.

11. Radiographic Test

11.1 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 metal to a depth of 1/16″ [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″ [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*. 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, and

(2) no rounded indications in excess of those permitted by the radiographic standard in Figure 6

In evaluating the radiograph one inch [25 mm] of the weld on each end of the test assembly shall be disregarded.

11.3.1 The alternative method of evaluation involves calculation of the total area of the rounded indications as they appear on the radiograph. This total area shall not exceed 1 percent of the thickness of the test assembly multiplied by the length of the weld used in evaluation (length of the weld in the test assembly minus 1 in [25 mm] on each end). The value given in Note 3 of the Figure 6 has been calculated for 6 in [150 mm] of weld (an 8 in [200 mm] long test assembly). The value for weld lengths other than this will differ on a linearly proportional basis.

11.3.2 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 indication may be of porosity or slag.

11.3.3 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 standard (Figure 6) do not meet the requirements of this specification.

12. Tension Test

12.1 One all-weld-metal tension test specimen, as specified in the Tension Test clause of AWS B4.0 or AWS B4.0M, shall be machined from the groove weld described in 9.4 and shown in Figure 2. The all-weld-metal tensile specimen shall have a nominal diameter of 0.500 in [12.5 mm] and a nominal gage length-to-diameter ratio of 4:1.

12.2 The specimen shall be tested in the manner described in the Tension Test clause 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. Bend Test

13.1 One longitudinal face bend specimen, as required in Table 3, shall be machined from the groove weld test assembly shown in Figure 3, as described in AWS B4.0 or AWS B4.0M. The dimensions of the specimen shall be as shown in Figure 3. The backing strip and weld reinforcement shall be removed by machining.

13.2 The specimen shall be tested in the manner described in the Bend Test clause of AWS B4.0 or AWS B4.0M by bending it uniformly through 180 degrees over a 3/4 in [19 mm,] radius. Any suitable jig, as specified in the Bend Test clause of AWS B4.0 or AWS B4.0M may be used.

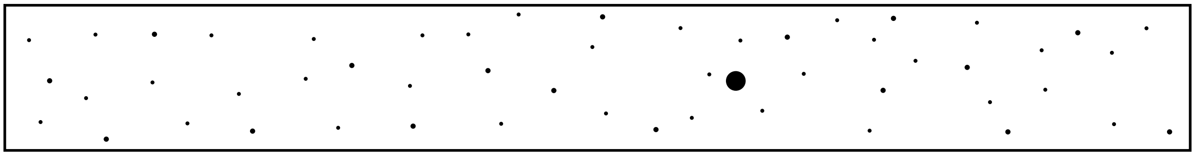
13.3 The specimen, after bending, shall conform to the 3/4 in [19 mm] radius, with appropriate allowance for spring back, and the weld metal shall show no defects on the tension face greater than 1/8 in [3 mm].

14. Fillet Weld Test

14.1 The fillet weld test, when required by Table 3, shall be made in accordance with the requirements of 9.6 and Figure 4. The entire face of the completed fillet shall be examined visually, and shall show no cracks and be reasonably free of undercut. After the visual examination, a specimen containing approximately 1 in [25 mm] of weld (in the lengthwise direction) shall be prepared as shown in Figure 4. One cross-sectional surface of the specimen shall be polished and etched, then examined as required in 14.2.

14.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 5, and the leg lengths and convexity of the fillet shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement (see Figure 5). These dimensions shall meet the requirements in Figure 5 for fillet size, convexity, and permissible difference in the length of the legs.

14.2.1 The fillet shall have penetration to or beyond the junction of the edges of the plates.



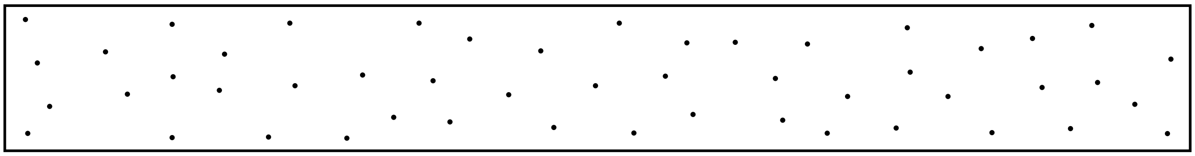
(A) ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.125 in [3.2 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 53, WITH THE FOLLOWING RESTRICTIONS:

LARGE: UP TO 0.125 in [3.2 mm] – 1 PERMITTED
MEDIUM: UP TO 0.034 in [0.9 mm] – 17 PERMITTED
SMALL: UP TO 0.024 in [0.6 mm] – 35 PERMITTED

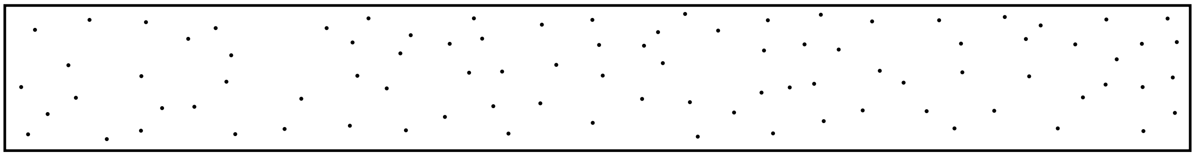
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 0.125 in [3.2 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 4.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.034 in [0.9 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 50.



(D) SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.024 in [0.6 mm] MAXIMUM.
NUMBER PERMITTED IN ANY 6 in [150 mm] OF WELD IS 90.

Notes:

1. The chart that is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used to determine conformance with this specification. Rounded indications 1/64 in [0.4 mm] and smaller shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those normally encountered in general fabrication.
3. When using the alternative method of evaluation described in 11.3.1, the total cross-sectional area of the rounded indications (calculated from measurements taken from the radiograph) shall not exceed 0.045 in^2 [29.0 mm^2] in any 6 in [150 mm] of weld.
4. The acceptance standard for slag inclusions in this assembly is the following:
   - (a) Length of each individual slag indication: 5/16 in [8 mm] maximum
   - (b) Total length of all slag indications: 15/32 in [12 mm] maximum

Figure 6—Radiographic Standards for 3/4 in [19 mm] Test Assembly in Figure 2

Table 6
Tension Test Requirements[a]

AWS Classification		Tensile Strength, min.		Elongation[b]
ISO Format	Traditional	psi	MPa	Percent, min.
TNi 6082-xy TNi 6062-xy TNi 6133-xy TNi 6182-xy	ENiCr3Tx-y ENiCrFe1Tx-y ENiCrFe2Tx-y ENiCrFe3Tx-y	80 000	550	25
TNi 6002-xy	ENiCrMo2Tx-y	90 000	620	25
TNi 1013-xy TNi 6625-xy TNi 6276-xy TNi 6022-xy	*ENiMo13Tx-y* ENiCrMo3Tx-y ENiCrMo4Tx-y ENiCrMo10Tx-y	100 000	690	25
TNi 6117-xy	ENiCrCoMo1Tx-y	90 000	620	25

[a] As-welded condition.

[b] The elongation shall be determined from gage length equal to 4 times the gage diameter.

14.2.2 The legs and convexity of the fillet weld shall be within the limits prescribed in Figure 5.

14.2.3 The fillet weld shall show no evidence of cracks.

14.2.4 The weld shall be reasonably free from undercutting, overlap, trapped slag, and porosity.

15. Method of Manufacture

The electrodes classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification.

16. Standard Sizes

Standard sizes for electrode in the different package forms (coils with support, coils without support, spools and drums) are as specified in AWS A5.02/A5.02M.

17. Finish and Uniformity

17.1 Finish and uniformity shall be as specified in 4.2 of AWS A5.02/A5.02M.

18. Standard Package Forms

18.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights and other requirements for each form shall be as specified in 4.3 of AWS A5.02/A5.02M

19. Winding Requirements

19.1 Winding requirements shall be as specified in 4.4.1 of AWS A5.02/A5.02M

19.2 The cast and helix of filler metal shall be as specified in 4.4.2 of AWS A5.02/A5.02M

20. Filler Metal Identification

20.1 Filler metal identification including product information and the precautionary information shall be as specified in 4.5 of AWS A5.02/A5.02M.

21. Packaging

Filler metal shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

22. Marking of Packages

22.1 The product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package shall be as specified in 4.6.1 of AWS A5.02/A5.02M.

22.2 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.

Annex A (Informative)

Guide to AWS Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding

This annex is not part of AWS A5.34/A5.34M: 2013, *Specification for Nickel-Alloy Electrodes for Flux Cored 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 the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the base materials for which each filler metal is suitable.

A2. Classification System

A2.1 An international system for designating filler metals (Figure A.1) is being adopted for nickel filler metals by the International Standards Organization (ISO). In order that the AWS filler metal specifications can easily conform to international standards, this specification adopts the new system along with that of the traditional designations. Both designations are to be employed for identification of the filler metal.

A2.1.1 The international, or ISO, designation system for nickel flux cored wire starts with "T" for tubular, followed by "Ni" for nickel. Four numeric digits based upon the UNS numbers are then assigned according to the composition.

A2.1.2 The composition designation is followed by two digits, marked x and y in Table 1. As defined in Table 1, the "x" stands for the welding position, and the "y" stands for the shielding gas (if any) with which the filler metal was classified by the manufacturer.

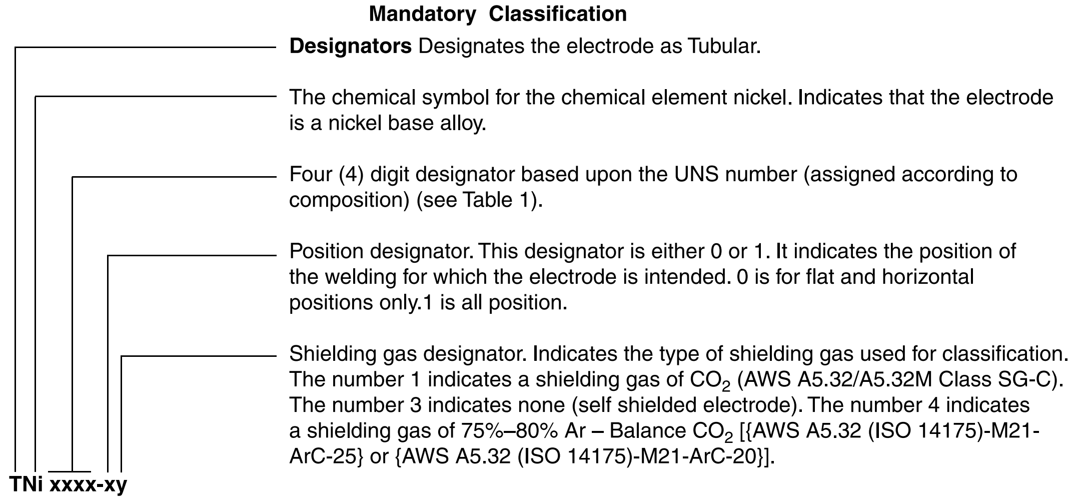
A2.2 The traditional designation system (Figure A.2) is also shown in a parallel column in Tables 1 to 6.

A2.2.1 The letter E at the beginning of each classification stands for electrode. The chemical symbol Ni appears right after the E as a means of identifying the electrodes as nickel base alloys. The other symbols (Cr, Fe, Mo, Co) in the designation are intended to group the electrodes according to their major alloying elements. The individual members of each family are designated by a numeral. These numerals are used only once in each family of compositions.

A2.2.2 Following the chemical symbols and their numeric designator comes the letter "T", which is used to designate the filler metal as a flux cored electrode. As in the ISO system, two numeric digits, marked x and y, are appended. As defined in Table 1, the "x" stands for the welding position, and the "y" stands for the shielding gas (if any) with which the filler metal was classified by the manufacturer.

A2.3 In both systems "x" in Table 1 stands for the capability of the electrode for use out of position. As shown in Table 2, "0" is for flat and horizontal fillet positions only, and "1" for all position capability.

A2.4 In both systems the symbol "y" in Table 1 stands for the external shielding gas, if any: "1" for carbon dioxide [AWS A5.32(ISO 14175)-C1-100] as the shielding gas, "3" for no external shielding gas, or "4" for 75% to 80% argon, balance carbon dioxide [{AWS A5.32(ISO 14175)-M21-ArC-25} or {AWS A5.32 (ISO 14175)-M21-ArC-20}] shielding gas.



Mandatory Classification Designators Designates the electrode as Tubular.

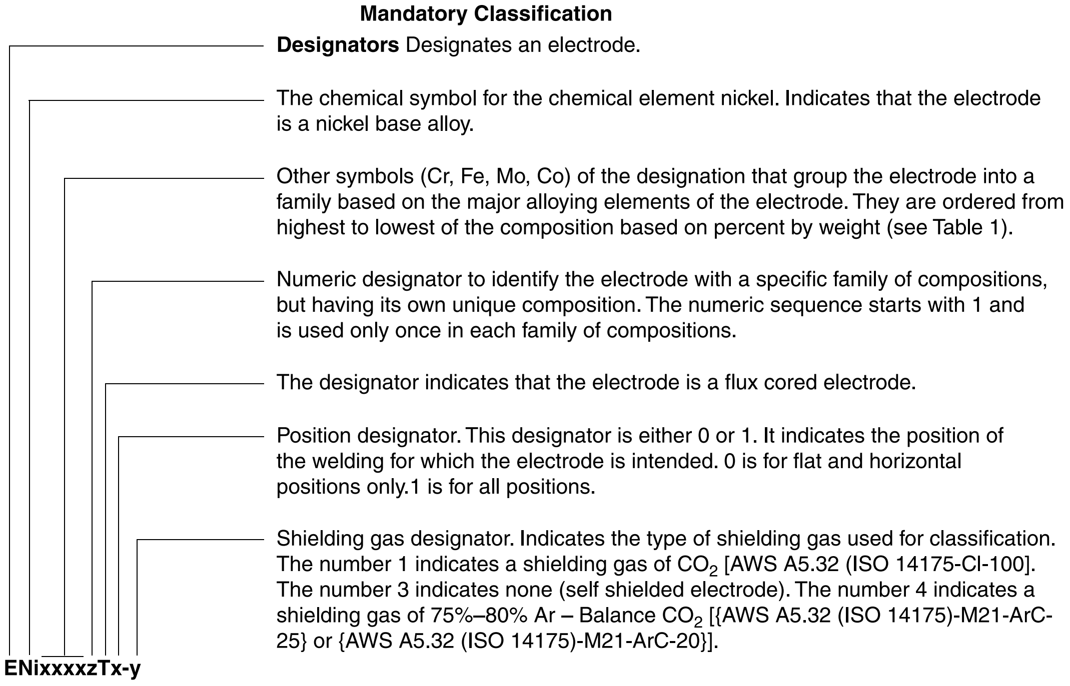
The chemical symbol for the chemical element nickel. Indicates that the electrode is a nickel base alloy.

Four (4) digit designator based upon the UNS number (assigned according to composition) (see Table 1).

Position designator. This designator is either 0 or 1. It indicates the position of the welding for which the electrode is intended. 0 is for flat and horizontal positions only.1 is all position.

Shielding gas designator. Indicates the type of shielding gas used for classification. The number 1 indicates a shielding gas of CO_2 (AWS A5.32/A5.32M Class SG-C). The number 3 indicates none (self shielded electrode). The number 4 indicates a shielding gas of 75%–80% Ar – Balance CO_2 [{AWS A5.32 (ISO 14175)-M21-ArC-25} or {AWS A5.32 (ISO 14175)-M21-ArC-20}].

Figure A.1—A5.34/A5.34M Classification System Utilizing the ISO Format



Mandatory Classification Designators Designates an electrode.

The chemical symbol for the chemical element nickel. Indicates that the electrode is a nickel base alloy.

Other symbols (Cr, Fe, Mo, Co) of the designation that group the electrode into a family based on the major alloying elements of the electrode. They are ordered from highest to lowest of the composition based on percent by weight (see Table 1).

Numeric designator to identify the electrode with a specific family of compositions, but having its own unique composition. The numeric sequence starts with 1 and is used only once in each family of compositions.

The designator indicates that the electrode is a flux cored electrode.

Position designator. This designator is either 0 or 1. It indicates the position of the welding for which the electrode is intended. 0 is for flat and horizontal positions only.1 is for all positions.

Shielding gas designator. Indicates the type of shielding gas used for classification. The number 1 indicates a shielding gas of CO_2 [AWS A5.32 (ISO 14175-Cl-100]. The number 3 indicates none (self shielded electrode). The number 4 indicates a shielding gas of 75%–80% Ar – Balance CO_2 [{AWS A5.32 (ISO 14175)-M21-ArC-25} or {AWS A5.32 (ISO 14175)-M21-ArC-20}].

Figure A.2—A5.34/A5.34M Classification System Utilizing the Traditional Format

A2.5 Many of the classifications in this specification correspond with classifications having the same composition in AWS A5.11 and A5.14. Where the composition of weld metal from the flux cored electrodes in this specification is similar to that of the covered electrodes in A5.11 and the bare wire in A5.14, an effort has been made to maintain the same composition designators for the corresponding electrode in this specification. A comparison of the classifications is given in Table A.1.

A2.6 Request for Filler Metal Classification

(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) 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) For all A5 filler metal specifications, other than A5.8M/A5.8 and A5.10/A5.10M: 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.

(f) A request for a new classification without the above information will be considered incomplete. The Secretary will return the request to the requester for further information.

Table A.1
Comparison of Classifications[a]

AWS Classification in A5.34/A5.34M		Corresponding Classification in A5.11/A5.11M	Corresponding Classification in A5.14/A5.14M
ISO Format[b]	Traditional		
TNi 6082-xy	ENiCr3Tx-y	—	ERNiCr-3
TNi 6062-xy	ENiCrFe1Tx-y	ENiCrFe-1	ERNiCrFe-5
TNi 6133-xy	ENiCrFe2Tx-y	ENiCrFe-2	ERNiCrFe-6
TNi 6182-xy	ENiCrFe3Tx-y	ENiCrFe-3	—
TNi 1013-xy	*ENiMo13Tx-y*	—	—
TNi 6002 –xy	ENiCrMo2Tx-y	ENiCrMo-2	ERNiCrMo-2
TNi 6625-xy	ENiCrMo3Tx-y	ENiCrMo-3	ERNiCrMo-3
TNi 6276-xy	ENiCrMo4Tx-y	ENiCrMo-4	ERNiCrMo-4
TNi 6022-xy	ENiCrMo10Tx-y	ENiCrMo-10	ERNiCrMo-10
TNi 6117-xy	ENiCrCoMo1Tx-y	ENiCrCoMo-1	ERNiCrCoMo-1

[a] This comparison is based on chemical composition only. Mechanical properties may not necessarily be the same.

[b] The ISO format is based on the generic designations system set forth in the annex of ISO 12153:2011: *Welding Consumables—Tubular Cored Electrodes for Gas Shielded and Non-Gas Shielded Metal Arc Welding of Nickel and Nickel Alloys—Classification*. Table 10.B of that document applies to flux-cored nickel alloys. The four-digit number is intended to relate to the designations used for the corresponding covered electrodes and solid wire filler metals designated TNi in this specification, ENi in A5.11 and ERNi in A5.14.

(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. 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:

i. No patent rights will be enforced against anyone using the patent to comply with the standard;

or

ii. The owner will make licenses available to anyone wishing to use the patent to comply with the standard, without compensation or for reasonable rates, with reasonable terms and conditions demonstrably free of any unfair competition.

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, the Committee on Filler Metals and Allied Materials, nor the relevant Subcommittee are 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.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344 MOD), as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD). In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing he 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 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 System" in AWS A5.01M/A5.01 (ISO 14344 MOD).

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding. These are as follows:

(1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)

(2) Number of welders and welding operators working in that space

(3) Rate of evolution of fumes, gases, or dust, according to the materials and processes involved

(4) The proximity of the welder or welding operator to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which they are working

(5) The ventilation provided to the space in which the welding is done

A5.2 American National Standard 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 of that document on Ventilation. Further details about ventilation can be found in AWS F3.2 Ventilation Guide for Welding Fume.

A6. Welding Considerations

A6.1 Before welding or heating any nickel-base alloy, the material must be clean. Oil, grease, paint, lubricants, marking pencils, temperature indicating materials, threading compounds, and other such materials frequently contain sulfur, lead, phosphorus, or other surface contaminants, which may cause cracking (embrittlement) of the base metal or the weld metal if present during welding or heating.

A6.2 Electrodes of some of the classifications are used for dissimilar metal welds. When making such welds it is important to obtain as little dilution as possible from the dissimilar metal member (steel, for example). This can be done by traveling slowly to deposit a thicker bead and to dissipate the energy of the arc against the molten weld metal or the nickel-base metal rather than the steel member.

A6.3 Flux cored electrodes can absorb significant moisture if stored in a humid environment in damaged or open packages, especially if unprotected for a long period of time. In the case of excessive exposure, weldability and weld integrity can be adversely affected. In the event the electrode has been exposed, the manufacturer should be consulted regarding possible reconditioning of the electrode.

A7. Description and Intended Use of Electrodes

A7.1 Nickel-Chromium Classifications

A7.1.1 TNi 6082-xy and ENiCr3Tx-y. The nominal composition (wt %) of the weld metal of this classification is 72 Ni, 20 Cr, 3 Mn, 2.5 Nb (+Ta). Electrodes of this classification are used for welding nickel-chromium-iron alloys, for dissimilar welding of nickel-based alloys, for the clad side of joints in steel clad with nickel-chromium alloy, for surfacing steel with nickel-chromium-iron weld metal, and for joining carbon and low-alloy steels to nickel-base alloys and to austenitic stainless steels. Typical specifications for the nickel-chromium-iron base metal are ASTM B163, B166, B167, and B168, all of which have UNS Number N06600.

A7.2 Nickel-Chromium-Iron Classifications

A7.2.1 TNi 6062-xy and ENiCrFe1Tx-y. The nominal composition (wt %) of the weld metal of this classification is 73 Ni, 15 Cr, 8 Fe, 2.5 Mn, 2.5 Nb (+ Ta). Electrodes of this classification are used for welding nickel-chromium-iron alloys, for the clad side of joints in steel clad with nickel-chromium-iron alloy, and for surfacing steel with nickel-chromium-iron weld metal. This electrode is also suitable for joining steel to nickel-base alloys. Typical specifications for the nickel-chromium-iron base metal are ASTM B 163, B 166, B 167, and B 168, all of which have UNS Number N06600.

A7.2.2 TNi 6133-xy and ENiCrFe2Tx-y. The nominal composition (wt %) of the weld metal of this classification is 70 Ni, 15 Cr, 8 Fe, 2 Mn, 2 Nb (+ Ta), 1.5 Mo. Electrodes of this classification are used for welding nickel-chromium-iron alloys, 9 percent nickel steel and a variety of dissimilar metal joints (involving carbon steel, low-alloy steels, stainless steel, nickel and nickel-base alloys). The base metal can be wrought or cast (welding grade), or both. Typical specifications for the nickel-chromium-iron base metal are ASTM B163, B166, B167, and B168, all of which have UNS Number N06600. Weld metal of this classification is more resistant to fissuring than weld metal of the TNi6062-xy and ENiCrFe1Tx-y classification.

A7.2.3 TNi 6182-xy and ENiCrFe3Tx-y. The nominal composition (wt %) of the weld metal of this classification is 67 Ni, 15 Cr, 7 Fe, 7.5 Mn, 2 Nb (+ Ta). Electrodes of this classification are used for welding nickel-chromium-iron and nickel-iron-chromium alloys, for welding the clad side of joints in steel clad with nickel-chromium-iron alloy and steel clad with ferritic chromium steel, and for surfacing steel with nickel-chromium-iron weld metal, when comparatively high manganese content in the weld metal is not detrimental for the intended service. This electrode is frequently used for welding carbon steel and low-alloy steels to austenitic stainless steels and nickel-base alloys. Typical specifications for nickel-chromium-iron base metal are ASTM B163, B166, B167, and B168, all of which have UNS Number 06600. Typical specifications for nickel-iron-chromium base metals are ASTM B407, B409, B512, and B564, all of which have UNS Number N08800. Weld metal of this classification is more resistant to fissuring than weld metal of the TNi6062-xy (ENiCrFelTx-y) and TNi6133-xy (ENiCrFe2Tx-y) classifications.

A7.3 Nickel-Chromium-Molybdenum Classifications

A7.3.1 TNi 6002-xy and ENiCrMo2Tx-y. The nominal composition (wt %) of weld metal produced by electrodes of this classification is 47 Ni, 22 Cr, 18 Fe, 9 Mo, 1.5 Co. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for welding the clad side of joints in steel clad with nickel-chromium-molybdenum alloy, and for welding nickel-chromium-molybdenum alloys to steel and to other nickel-base alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B435, B572, B619, B622, and B626, all of which have UNS Number N06002.

A7.3.2 TNi 6625-xy and ENiCrMo3Tx-y. The nominal composition (wt %) of the weld metal of this classification is 60 Ni, 22 Cr, 9 Mo, 3 Fe, 3.6 Nb (+ Ta). Electrodes of this classification are used for welding nickel-chromium-molybdenum and nickel-iron-chromium alloys to themselves and to steel, and for surfacing steel with nickel-chromium-molybdenum weld metal. This electrode can be used also for welding other nickel-base alloys to steel. Typical specifications for the nickel-chromium-molybdenum base metal are ASTM B443, B444, and B446, all of which have UNS Number N06625. Typical specifications for nickel-iron-chromium base metal are ASTM B407, B409, B5l4, and B564, all of which have UNS Number N08800.

A7.3.3 TNi 6276-xy and ENiCrMo4Tx-y. The nominal composition (wt %) of the weld metal of this classification is 57 Ni, 16 Mo, 15.5 Cr, 5.5 Fe, 4 W, low C. Electrodes of this classification are used for welding low carbon nickel-chromium-molybdenum alloy to steel or to other nickel-base alloys, and for clad side of joints in steel clad with low carbon NiCrMo alloys. Typical specifications for the nickel-chromium-molybdenum base metals are B574, B575, B619, B622, and B626, all of which have UNS Number N10276.

A7.3.4 TNi 6022-xy and ENiCrMo10Tx-y. The nominal composition (wt %) of weld metal produced by electrodes of this classification is 56 Ni, 22 Cr, 13 Mo, 4 Fe, 3 W. Electrodes of this classification are used for welding nickel-chromium-molybdenum alloys, for the clad side of joints in steel clad with nickel-base alloys; and for joining nickel-chromium-molybdenum alloys. Typical specifications for the nickel-chromium-molybdenum base metals are ASTM B574, B575, B619, B622, and B626, all of which have UNS Number N06022.

A7.4 Nickel-Chromium-Cobalt-Molybdenum Classifications

A7.4.1 TNi 6117-xy and ENiCrCoMo1Tx-y. The nominal composition (wt %) of weld metal produced by electrodes of this classification is 52 Ni, 23 Cr, 12 Co, 9 Mo, 2 Fe, 1.5 Mn. Electrodes of this classification are used for welding nickel-chromium-cobalt-molybdenum alloys (UNS No. N06617) to themselves and to steel and for surfacing steel with nickel-chromium-cobalt-molybdenum weld metal. The electrodes are used for applications where optimum strength and oxidation resistance are required above 1500°F [820°C] up to 2100°F [1150°C], especially when welding on base metals of nickel-iron-chromium alloys.

A7.5 Nickel-Molybdenum Classification

A7.5.1 TNi 1013-xy and ENiMo13-Tx-y. *The nominal composition (wt %) of the weld metal of this classification is 65 Ni, 17 Mo, 7 Fe, 6 Cr, 3 W. Electrodes of this classification are used for welding 9 percent nickel steel, but they can be used in other applications as well. Typical specifications for the 9 percent nickel steel base metal are ASTM A333, A334, A353, A522, and A553, all of which have UNS Number K81340.*

A8. Mechanical Tests

The mechanical tests required for classification of an electrode in this specification measure the strength and ductility of the weld metal. These properties are sometimes less important than the corrosion and heat resistance of these weld metals. The mechanical tests (tension and bend tests), as well as the radiographic test, however, do provide an indication of the weld metal defects which, if present, may cause or contribute to premature failure in service.

A9. 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, scaling resistance, or strength at elevated or cryogenic temperatures may be required. AWS A5.01M/A5.01 (ISO 14344 MOD), contains provisions for ordering such tests. This clause is included for the guidance of those who desire to specify such tests which may be conducted as agreed upon between supplier and purchaser.

A9.1 Corrosion or Scaling Tests. Although welds made with electrodes in this specification are commonly used in corrosion and heat-resisting applications, tests for those properties are not included in the specification. When required for a particular application, tests can be conducted on specimens taken from either a weld pad or a welded joint. Specimens from a joint are suitable for qualifying the welding procedure (for a specific application involving corrosion or oxidation resistance) but not for qualifying the electrode. Tests on specimens from a joint have the disadvantage of being a combined test of the properties of the weld metals, the heat-affected zone and the unaffected base metal. With them, it is more difficult to obtain reproducible data (when a difference exists in the properties of the metal in the various parts of the specimen). Specimens taken from a joint have the advantage of being able to duplicate the joint design and the welding sequence planned for fabrication.

A9.1.1 Specimens for testing corrosion or oxidation resistance of the weld metal alone are prepared by following the procedure outlined in 9.3 of the specification. The pad size should be at least 3/4 in [20 mm] in height, 2-1/2 in [65 mm] in width, and 1 + 5/8n in [25 + 16n mm] in length where n is a multiplier for the number of specimens required from the pad. Specimens measuring 1/2 × 2 × 1/4 in [13 × 50 × 6 mm] are machined from the top of the pad in a manner such that the 2 in [50 mm] dimension of the specimen is parallel to the 2-1/2 in [65 mm] dimension of the pad and the 1/2 in [13 mm] dimension is parallel with the length of the pad.

A9.1.2 The heat treatment, 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 procedures should correspond to ASTM G4, *Standard Practice for Conducting Plant Corrosion Tests*, or ASTM G31, *Recommended Practice for Laboratory Immersion Corrosion Testing of Metals*, as the case may be.

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 A.5. 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 Safety in Welding, Cutting and Allied Processes,[7] and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

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[7] ANSI Z49.1 is published by the American welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166, USA.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[8]

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 Welding 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*

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[8] AWS standards are published by the American welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166, USA.

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SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL FLUX CORED ELECTRODES FOR FLUX CORED ARC WELDING AND METAL CORED ELECTRODES FOR GAS METAL ARC WELDING

SFA-5.36/SFA-5.36M

(Identical with AWS Specification A5.36/A5.36M:2012. In case of dispute, the original AWS text applies.)

Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon and low-alloy steel flux cored electrodes for flux cored arc welding (FCAW), either with or without shielding gas, and carbon and low-alloy steel metal cored electrodes for gas metal arc welding (GMAW). This new specification replaces both AWS A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, and AWS A5.29/A5.29M, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*. It also includes provisions for the classification of carbon and low-alloy steel metal cored electrodes which previously had been classified according to AWS A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, or AWS A5.28/A5.28M, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, as applicable. Iron is the only element of the undiluted weld metal deposited by the electrodes classified under this specification whose content exceeds 10.5%.

1.2 Safety issues and concerns are addressed in this standard, although health issues and concerns are beyond the scope of this standard. Some safety and health information can be found in nonmandatory Annex A, Clauses A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1[1] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.36 uses U.S. Customary Units. The specification A5.36M uses the International System of Units (SI). The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for the sizing of electrodes or packaging or both under the A5.36 and A5.36M specifications.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard referred to applies.

2.1 The following AWS standards[2] are referenced in the mandatory sections of this document:

(1) AWS A1.1, *Metric Practice Guide for the Welding Industry*

(2) AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*

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[1] ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[2] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(3) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(4) AWS A5.01M/A5.01 (ISO 14344 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

(5) AWS A5.02/A5.02M, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*

(6) AWS A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

(7) AWS A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*

(8) AWS A5.28/A5.28M, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

(9) AWS A5.29/A5.29M, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*

(10) AWS A5.32M/A5.32 (ISO 14175 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*

(11) AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*

(12) AWS D1.8/D1.8M, *Structural Welding Code—Seismic Supplement*

2.2 The following ASME standard[3] is referenced in the mandatory sections of this document:

(1) *ASME Boiler and Pressure Vessel Code*, Section IX, Welding and Brazing Qualifications

2.3 The following ANSI standard is referenced in the mandatory sections of this document:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.4 The following ASTM standards[4] are referenced in the mandatory sections of this document:

(1) ASTM A 36/A 36M, *Standard Specification for Carbon Structural Steel*

(2) ASTM A 203/A 203M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

(3) ASTM A 285/A 285M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

(4) ASTM A 302/A 302M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel*

(5) ASTM A 387/A 387M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

(6) ASTM A 506/A 506M, *Standard Specification for Alloy and Structural Alloy Steel, Sheet and Strip, Hot-Rolled and Cold-Rolled*

(7) ASTM A 507/A 507M, *Standard Specification for Drawing Alloy Steel, Sheet and Strip, Hot-Rolled and Cold-Rolled*

(8) ASTM A 514/A 514M, *Standard Specification for High-Yield Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding*

(9) ASTM A 515/A 515M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

(10) ASTM A 516/A 516M, *Standard Specification for Pressure Vessel Plates, Carbon steel for Moderate- and Lower-Temperature Service*

(11) ASTM A 537/A 537M, *Standard Specification for Pressure Vessel Plates, Heat Treated, Carbon-Manganese-Silicon Steel*

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[3] ASME standards are available from ASME. 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300.

[4] ASTM standards are published by the ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

(12) ASTM A 572/A 572M, *Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*

(13) ASTM A 588/A 588M, *Standard Specification for High-Strength Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in [100 mm] Thick*

(14) ASTM A 830/A 830M, *Standard Specification for Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements*

(15) ASTM A 913/A 913M, *Standard Specification for High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)*

(16) ASTM A 992/A 992M, *Standard Specification for Structural Steel Shapes*

(17) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(18) ASTM E 350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*

(19) ASTM E 1032, *Standard Test Method for Radiographic Examination of Weldments*

2.5 The following FEMA standard[5] is referenced in the mandatory section of this document.

(1) FEMA 353, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications*

2.6 The following MIL standards[6] are referenced in the mandatory sections of this document.

(1) MIL-S-16216, *Specification for Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)*

(2) MIL-S-24645, *Specification for Steel Plate, Sheet, or Coil, Age-Hardening Alloy, Structural, High Yield Strength (HSLA-80 and HSLA-100)*

(3) 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*

2.7 The following ISO standard[7] is referenced in the mandatory sections of this document.

(1) ISO 80000-1, *Quantities and units — Part 1: General*

3. Classification

3.1 This new A5.36/A5.36M specification utilizes two classification systems. The first of these is a “fixed classification” system which has been carried over to this specification from AWS A5.20/A5.20M or from AWS A5.18/A5.18M, as applicable, for the classification of those carbon steel flux cored or metal cored electrodes which, with the specific mechanical properties specified for them in A5.20/A5.20M or A5.18/A5.18M, have gained wide acceptance for single pass and multiple pass applications. See Table 1 for a list of those classifications and the applicable requirements. The second classification system is an “open classification” system which is introduced with this specification for the classification of carbon and low-alloy steel flux cored electrodes and carbon and low-alloy steel metal cored electrodes. This open classification system provides the flexibility to classify an expanded number of electrode types with a variety of shielding gases (if any) to different requirements for strength, impact properties, weld metal composition, and condition of heat treatment.

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[5] FEMA documents are published for Federal Emergency Management Agency, and can be searched and downloaded for free from Internet. www.fema.gov.

[6] For inquiries regarding MIL-S-16216 and MIL-S-24645 refer to internet website: http://assist.daps.dla.mil/online. NAVSEA Technical Publication T9074-BD-GIB-010/0300 may be obtained from the Naval Inventory Control Point, 700 Robins Avenue, Philadelphia, PA 19111-5094, or may be downloaded from http://ntpdb.ddlomni.com.

[7] ISO standards are published by the International Organization for Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

Table 1
Electrode Classifications with Fixed Requirements[a]

Source Specification for Electrode Classification & Requirements	Classification Designation[b, c]	Electrode Type	Shielding Gas[d]	Weld Deposit Requirements	
				Mechanical Properties[e]	Weld Deposit[f]
AWS A5.20/A5.20M	E7XT-1C[g]	Flux Cored	C1	Tensile Strength: 70 ksi–95 ksi Minimum Yield Strength: 58 ksi[i] Min. Charpy Impact: 20 ft·lbf @ 0°F Minimum % Elongation: 22%[j]	CS1
	E7XT-1M[g]		M21		
	E7XT-5C[g]		C1	Tensile Strength: 70 ksi–95 ksi Minimum Yield Strength: 58 ksi[i] Min. Charpy Impact: 20 ft·lbf @ –20°F Minimum % Elongation: 22%[j]	CS1
	E7XT-5M[g]		M21		
	E7XT-6[g]		None		CS3
	E7XT-8[g]				
	E7XT-9C[g]		C1		CS1
	E7XT-9M[g]		M21		
	E7XT-12C[g]		C1	Tensile Strength: 70 ksi–90 ksi Minimum Yield Strength: 58 ksi[i] Min. Charpy Impact: 20 ft·lbf @ –20°F Minimum % Elongation: 22%[j]	CS2
	E7XT-12M[g]		M21		
	E70T-4[g]		None	Tensile Strength: 70 ksi–95 ksi Minimum Yield Strength: 58 ksi[i] Min. Charpy Impact: Not Specified Minimum % Elongation: 22%[j]	CS3
	E7XT-7[g]				
AWS A5.18/A5.18M	E70C-6M[h]	Metal Cored	M21	Tensile Strength: 70 ksi minimum Minimum Yield Strength: 58 ksi[i] Min. Charpy Impact: 20 ft·lbf @ –20°F Minimum % Elongation: 22%[j]	CS1

[a] These multiple pass electrodes are classified according to the fixed classification system utilized in AWS A5.20/A5.20M or A5.18/A5.18M, as applicable, which has been carried over for these specific electrodes as a part of AWS A5.36/A5.36M. The mechanical property and weld deposit requirements are as defined in this table. These same electrodes may also be classified to the same requirements or to different requirements using the open classification system introduced in this specification. In this case, the classification designations are as prescribed in Figure 1. See Table A.1 or Table A.3, as applicable, in Annex A for comparisons of the "fixed classification" designations and equivalent "open classification" designations for the above electrodes when both are classified to the requirements listed in this table.

[b] Under AWS A5.20/A5.20M, the "E" at the beginning of the classification designates an electrode. The "7" is the tensile strength designator. The "X" indicates the electrode's position of welding capability. A "0" is used to indicate flat and horizontal only. A "1" is used to indicate all position capability. The "T" identifies the electrode as a flux cored electrode The one or two digit number after the dash indicates the electrode's usability characteristics as defined in AWS A5.20/A5.20M. For the open classification system introduced in this A5.36/A5.36M specification, the "T" identifies the electrode as either a flux cored or a metal cored electrode. The "T" is combined with a one or two digit number as a part of the alpha-numeric designator for usability. See Table 4. Under AWS A5.18/A5.18M for classification E70C-6M, the "E" designates an electrode. The "70" indicates that the weld deposit will have a minimum tensile strength of 70 ksi. The "C" indicates that the electrode is a composite (metal cored) electrode. The "6" indicates the composition of the weld deposit produced with this electrode. The "M" indicates the type of shielding gas used.

[c] The electrodes shown in the shaded panels are self shielded.

[d] See Table 5.

[e] Mechanical properties are obtained by testing weld metal from the groove weld shown in Figure 2. Welding and testing shall be done as prescribed in this specification. The requirements for welding and testing are the same as those given in A5.20/A5.20M. All mechanical property testing for the classifications listed in this table shall be done in the as-welded condition.

[f] See Table 6.

[g] The "D," "Q," and "H" optional designators, which are not part of the electrode classification designation, may be added to the end of the designation as established in AWS A5.20/A5.20M, i.e., E7XT-XXD, E7XT-XXQ, E7XT-XXHX, E7XT-XXDHX, or E7XT-XXQHX, as applicable. The "J" optional, supplemental designator listed in A5.20/A5.20M is no longer required. The open classification system introduced in this A5.36/A5.36M specification eliminates the need for this designator.

[h] The "H" optional, supplemental designator, which is not part of the electrode classification designation, may be added to the end of the designation as established in AWS A5.18/A5.18M, i.e., E70C-6MHZ. Provisions for the "D" and "Q" optional, supplemental designators have not been established in A5.18/A5.18M and, as a result, may not be used with the E70C-6M designation. However, that does not preclude their use with metal core electrodes classified utilizing the open classification system under the A5.36/A5.36M specification.

[i] Yield strength at 0.2% offset.

[j] Percent elongation is in 2 in [50 mm] gage length when a 0.500 in [12 mm] nominal diameter tensile specimen and nominal gage length to diameter ratio of 4:1 is used.

The flux cored and metal cored electrodes covered by the A5.36 specification utilize a classification system based upon U.S. Customary Units. Electrodes covered by the A5.36M specification utilize a system based upon the International System of Units (SI). Under these specifications, flux cored and metal cored electrodes can be classified for multiple pass welding or for single pass welding. The groove weld test assembly shown in Figure 2 is used for the classification of multiple pass electrodes. The two-run butt weld test assembly shown in Figure 3 is used for the classification of single pass electrodes.

3.1.1 The flux cored electrodes classified utilizing the "fixed classification" system are classified for multiple pass welding based upon the following:

(1) The as-welded mechanical properties of the weld metal obtained with a particular shielding gas, if any, as specified in Table 1.

(2) The positions of welding for which the electrode is suitable, as indicated in Note b of Table 1.

(3) Certain usability characteristics of the electrode (including the presence or absence of a shielding gas). Refer to Note b of Table 1 and to Table 4.

3.1.2 The flux cored and metal cored electrodes classified utilizing the "open classification" system are classified based upon the following:

(1) The mechanical properties of the weld metal, as specified in Table 2, Table 3, and Table 7.

(2) The positions of welding for which the electrodes are suitable.

(3) Certain usability characteristics of the electrode (including the presence or absence of a shielding gas), as specified in Table 4.

(4) The nominal composition of the shielding gas used, if any, as specified in Table 5.

(5) The condition of postweld heat treatment, if any, as specified in Table 8.

(6) Chemical composition of the weld metal as specified in Table 6.

3.2 Electrodes classified under one classification shall not be classified under any other classification in this specification with the exception of the following:

(1) Electrodes may be classified utilizing the "fixed classification" system as indicated in Table 1 (if applicable), or utilizing the "open classification system," or both. Refer to Table A.1 or Table A.3, as applicable, in Annex A.

(2) Electrodes may be classified using different shielding gases. Refer to Table 5.

(3) Electrodes may be classified both in the as-welded and in the postweld heat treated (PWHT) conditions.

(4) Electrodes may be classified under A5.36 using U.S. Customary Units, or under A5.36M using the International System of Units (SI), or both. Standard dimensions based on either system may be used for sizing of electrodes or packaging, or both, under the A5.36 and A5.36M specifications. Electrodes classified under either A5.36 or A5.36M must meet all requirements for classification under that unit system. See Figure 1.

3.3 It is recognized that the documentation required by manufacturers, end users, and code bodies to transition from the classification of flux cored and metal cored electrodes from their previous classifications under AWS A5.20/A5.20M, AWS A5.29/A5.29M, AWS A5.18/A5.18M, or AWS A5.28/A2.28M, as applicable, to their new classification designations under AWS A5.36/A5.36M requires a provision for a transition period. Therefore, flux cored electrodes may be classified under AWS A5.20/A5.20M (or AWS A5.29/A5.29M, as applicable), under AWS A5.36/A5.36M, or under both. Metal cored electrodes may be classified under AWS A5.18/A5.18M (or AWS A5.28/A5.28M, as applicable), under AWS A5.36/A5.36M, or under both. Manufacturers, at their option, may list both electrode classifications on the labels and packaging. The provision for dual classification provided in this clause expires at the end of year 2015. At that time classification to AWS A5.36/A5.36M is required.

Table 2
Tension Test Requirements

Tensile Strength Designator		Single Pass Electrodes	For A5.36 Multiple Pass Electrodes U.S. Customary Units			For A5.36M Multiple Pass Electrodes International System of Units (SI)		
U.S. Customary Units	International System of Units (SI)	Minimum Tensile Strength ksi [MPa]	Tensile Strength (ksi)	Minimum Yield Strength[a] (ksi)	Minimum Percent Elongation[b]	Tensile Strength [MPa]	Minimum Yield Strength[a] [MPa]	Minimum Percent Elongation[b]
6	43	60 [430]	60–80	48	22	430–550	330	22
7	49	70 [490]	70–95	58	22	490–660	400	22
8	55	80 [550]	80–100	68	19	550–690	470	19
9	62	90 [620]	90–110	78	17	620–760	540	17
10	69	100 [690]	100–120	88	16	690–830	610	16
11	76	110 [760]	110–130	98	15[c]	760–900	680	15[c]
12	83	120 [830]	120–140	108	14[c]	830–970	740	14[c]
13	90	130 [900]	130–150	118	14[c]	900–1040	810	14[c]

[a] Yield strength at 0.2% offset.

[b] In 2 in [50 mm] gage length when a 0.500 in [12.5 mm] nominal diameter tensile specimen and nominal gage length to diameter ratio of 4:1 (as specified in the Tension Test section of AWS B4.0) is used. In 1 in [25 mm] gage length when a 0.250 in [6.5 mm] nominal tensile specimen is used as permitted for 0.045 in [1.2 mm] and smaller sizes of the E7XT11-AZ-CS3 [E49XT11-AZ-CS3].

[c] Elongation requirement may be reduced by one percentage point if the tensile strength of the weld metal is in the upper 25% of the tensile strength range.

Table 3
Charpy Impact Test Requirements

A5.36 Requirements U.S. Customary Units			A5.36M Requirements International System of Units (SI)		
Impact Designator[a, b]	Maximum Test Temperature[c, d] (°F)	Minimum Average Energy Level	Impact Designator[a, b]	Maximum Test Temperature[c, d] (°C)	Minimum Average Energy Level
Y	+68	20 ft·lbf	Y	+20	27 J
0	0		0	0	
2	–20		2	–20	
4	–40		3	–30	
5	–50		4	–40	
6	–60		5	–50	
8	–80		6	–60	
10	–100		7	–70	
15	–150		10	–100	
Z	No Impact Requirements		Z	No Impact Requirements	
G	As agreed between supplier and purchaser				

[a] Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate designator from Table 3 above, as indicated in Figure 1.

[b] When classifying an electrode to A5.36 using U.S. Customary Units, the Impact Designator indicates the maximum impact test temperature in degrees Fahrenheit. When classifying to A5.36M using the International System of Units (SI), the Impact Designator indicates the maximum impact test temperature in degrees Celsius. With the exception of the Impact Designator "4," a given Impact Designator will indicate different temperatures depending upon whether classification is according to A5.36 in U.S. Customary Units or according to A5.36M in the International System of Units (SI). For example, a "2" Impact Designator when classifying to A5.36 indicates a test temperature of –20°F. When classifying to A5.36M, the "2" Impact Designator indicates a test temperature of –20°C, which is –4°F.

[c] Weld metal from an electrode that meets the impact requirements at a given temperature also meets the requirements at all higher temperatures in this table. For example, weld metal meeting the A5.36 requirements for designator "5" also meets the requirements for designators 4, 2, 0, and Y. [Weld metal meeting the A5.36M requirements for designator "5" also meets the requirements for designators 4, 3, 2, 0, and Y.]

[d] Filler metal classification testing to demonstrate conformance to a specified minimum acceptable level for impact testing, i.e., minimum energy at specified temperature, can be met by testing and meeting the minimum energy requirement at any lower temperature. In these cases, the actual temperature used for testing shall be listed on the certification documentation when issued.

Table 4
Electrode Usability Characteristics

Electrode Usability Designator[a]	Process	General Description of Electrode Type[b, c]	Typical Positions of Welding[d, e]	Polarity[f]
T1	FCAW-G	Flux cored electrodes of this type are gas shielded and have a rutile base slag. They are characterized by a spray transfer, low spatter loss, and a moderate volume of slag which completely covers the weld bead.	H, F, VU, & OH	DCEP
T1S	FCAW-G	Flux cored electrodes of this type are similar to the "T1" type electrodes but with higher manganese or silicon, or both. They are designed primarily for single pass welding in the flat and horizontal positions. The higher levels of deoxidizers in this electrode type allow single pass welding of heavily oxidized or rimmed steel.	H, F, VU, & OH	DCEP
T3S	FCAW-S	Flux cored electrodes of this type are self shielded and are intended for single pass welding and are characterized by a spray type transfer. The titanium-based slag system is designed to make very high welding speeds possible.	H, F	DCEP
T4	FCAW-S	Flux cored electrodes of this type are self shielded and are characterized by a globular type transfer. Its fluoride-based basic slag system is designed to make very high deposition rates possible and to produce very low sulfur welds for improved resistance to hot cracking.	H, F	DCEP
T5	FCAW-G	Flux cored electrodes of this type are gas shielded and are characterized by a globular transfer, slightly convex bead contour, and a thin slag that may not completely cover the weld bead. They have a lime-fluoride slag system and develop improved impact properties and better cold cracking resistance than typically exhibited by the "T1" type electrodes.	H, F, VU, & OH	DCEP or DCEN[g]
T6	FCAW-S	Flux cored electrodes of this type are self shielded and are characterized by a spray transfer. Its oxide-based slag system is designed to produce good low temperature impacts, good penetration into the root of the weld, and excellent slag removal.	H & F	DCEP
T7	FCAW-S	Flux cored electrodes of this type are self shielded and are characterized by a small droplet to spray type transfer. The fluoride-based slag system is designed to provide high deposition rates in the downhand positions with the larger diameters and out of position capabilities with the smaller diameters.	H, F, VU, & OH	DCEN
T8	FCAW-S	Flux cored electrodes of this type are self shielded and are characterized by a small droplet to spray type transfer. The fluoride-based slag system is designed to provide improved out-of-position control. The weld metal produced typically exhibits very good low temperature notch toughness and crack resistance.	H, F, VD, VU, & OH	DCEN
T9	FCAW-G	Flux cored electrodes of this type are similar in design and application to the T1 types but with improved weld metal notch toughness capabilities.	H, F, VU, & OH	DCEP

(Continued)

Table 4 (Continued)
Electrode Usability Characteristics

Electrode Usability Designator[a]	Process	General Description of Electrode Type[b, c]	Typical Positions of Welding[d, e]	Polarity[f]
T10S	FCAW-S	Flux cored electrodes of this type are self shielded and are characterized by a small droplet transfer. The fluoride-based slag system is designed to make single pass welds at high travel speeds on steel of any thickness.	H, F	DCEN
T11	FCAW-S	Flux cored electrodes of this type are self shielded and are characterized by a smooth spray type transfer, limited slag coverage, and are generally not recommended for the welding of materials over 3/4 in [20 mm] thick.	H, F, VD, & OH	DCEN
T12	FCAW-G	Flux cored electrodes of this type are similar in design and application to the T1 types. However, they have been modified for improved impact toughness and to meet the lower manganese requirements of the A-No. 1 Analysis Group in the ASME *Boiler and Pressure Vessel Code*, Section IX.	H, F, VU, & OH	DCEP
T14S	FCAW-S	Flux cored electrodes of this type are self shielded and are characterized by a smooth spray-type transfer. The slag system is designed for single pass welds in all positions and at high travel speeds.	H, F, VD, & OH	DCEN
T15	GMAW-C	Electrodes of this type are gas shielded composite stranded or metal cored electrodes. The core ingredients are primarily metallic. The nonmetallic components in the core typically total less than 1% of the total electrode weight. These electrodes are characterized by a spray arc and excellent bead wash capabilities. Applications are similar in many ways to solid GMAW electrodes.	H, F, OH, VD, & VU	DCEP or DCEN
T16	GMAW-C	This electrode type is a gas shielded metal cored electrode specifically designed for use with AC power sources with or without modified waveforms.	H, F, VD, VU, & OH	AC[h]
T17	FCAW-S	This flux cored electrode type is a self-shielded electrode specifically designed for use with AC power sources with or without modified waveforms.	H, F, VD, VU, & OH	AC[h]
G		As agreed between supplier and purchaser	Not specified	Not specified

[a] An "S" is added to the end of the Usability Designator when the electrode being classified is recommended for single pass applications only.

[b] For more information refer to A7, Description and Intended Use, in Annex A.

[c] Properties of weld metal from electrodes that are used with external shielding gas will vary according to the shielding gas used. Electrodes classified with a specific shielding gas should not be used with other shielding gases without first consulting the manufacturer of the electrode.

[d] H = horizontal position, F = flat position, OH = overhead position, VU = vertical position with upward progression, VD = vertical position with downward progression.

[e] Electrode sizes suitable for out-of-position welding, i.e., welding positions other that flat and horizontal, are usually those sizes that are smaller than the 3/32 in [2.4 mm] size or the nearest size called for in Clause 9 for the groove weld. For that reason, electrodes meeting the requirements for the groove weld tests may be classified as EX1TX-XXX-X (where X represents the tensile strength, usability, shielding gas, if any, condition of heat treatment, impact test temperature, and weld metal composition designators) regardless of their size.

[f] The term "DCEP" refers to direct current electrode positive (dc, reverse polarity). The term "DCEN" refers to direct current electrode negative (dc, straight polarity).

[g] Some EX1T5-XXX-X electrodes may be recommended for use on DCEN for improved out-of-position welding. Consult the manufacturer for the recommended polarity.

[h] For this electrode type the welding current can be conventional sinusoidal alternating current, a modified AC waveform alternating between positive and negative, an alternating DCEP waveform, or an alternating DCEN waveform.

Table 5
Composition Requirements for Shielding Gases

AWS A5.36/A5.36M Shielding Gas Designator[a]	AWS A5.32M/A5.32 Composition Ranges for Indicated Main/Sub Group[b]		Nominal Composition of Shielding Gases to be Used for Classification of Gas Shielded Electrodes to AWS A5.36/A5.36M		
	Oxidizing Components[c]		ISO 14175 Designation[d]	Oxidizing Components[c, e]	
	% CO_2	% O_2		% CO_2	% O_2
C1	100	—	C1	100	—
M12	$0.5 \leq CO_2 \leq 5$	—	M12 – ArC – 3	3	—
M13	—	$0.5 \leq O_2 \leq 3$	M13 – ArO – 2	—	2
M14	$0.5 \leq CO_2 \leq 5$	$0.5 \leq O_2 \leq 3$	M14 – ArCO – 3/2	3	2
M20	$5 < CO_2 \leq 15$	—	M20 – ArC – 10	10	—
M21	$15 < CO_2 \leq 25$	—	M21 – ArC – 20	20	—
M22	—	$3 < O_2 \leq 10$	M22 – ArO – 7	—	7
M23	$0.5 \leq CO_2 \leq 5$	$3 < O_2 \leq 10$	M23 – ArOC – 7/3	3	7
M24	$5 < CO_2 \leq 15$	$0.5 \leq O_2 \leq 3$	M24 – ArCO – 10/2	10	2
M25	$5 < CO_2 \leq 15$	$3 < O_2 \leq 10$	M25 – ArCO – 10/7	10	7
M26	$15 < CO_2 \leq 25$	$0.5 \leq O_2 \leq 3$	M26 – ArCO – 20/2	20	2
M27	$15 < CO_2 \leq 25$	$3 < O_2 \leq 10$	M27 – ArCO – 20/7	20	7
M31	$25 < CO_2 \leq 50$	—	M31 – ArC – 38	38	—
M32	—	$10 < O_2 \leq 15$	M32 – ArO – 12.5	—	12.5
M33	$25 < CO_2 \leq 50$	$2 < O_2 \leq 10$	M33 – ArCO – 38/6	38	6
M34	$5 < CO_2 \leq 25$	$10 < O_2 \leq 15$	M34 – ArCO – 15/12.5	15	12.5
M35	$25 < CO_2 \leq 50$	$10 < O_2 \leq 15$	M35 – ArCO – 38/12.5	38	12.5
Z	The designator “Z” indicates that the shielding gas used for electrode classification is not one of the shielding gases specified in this table but is a different composition as agreed upon between the supplier and purchaser.				

[a] The Shielding Gas Designators are identical to the Main group/Sub-group designators used in AWS A5.32M/A5.32:2011 [ISO 14175:2008 MOD], *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*, for these same shielding gases.

[b] Under AWS A5.32M/A5.32:2011, the inert gas used for the balance of the gas mixture may be either argon, helium, or some mixture thereof.

[c] The mixture tolerances are as follows:
For a component gas with a nominal concentration of >5%, ±10% of nominal.
For a component gas with a nominal concentration of 1%–5%, ±0.5% absolute.
For a component gas with a nominal composition of <1%, not specified in this standard.

[d] AWS A5.32M/A5.32:2011 shielding gas designators begin with “AWS A5.32 (ISO 14175).” That part of the designation has been omitted from the Shielding Gas Designator for brevity.

[e] The inert gas to be used for the balance of the gas mixtures specified for the classification of gas shielded flux cored and metal cored electrodes shall be argon.

3.4 The electrodes classified under this specification are intended for flux cored arc welding, either with or without an external shielding gas, or for gas metal arc welding with metal cored electrodes. Electrodes intended for use without external shielding gas, or with the shielding gases specified in Table 5, are not prohibited from use with any other process or shielding gas for which they are found suitable.

4. Acceptance

Acceptance[8] of the welding electrodes shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

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[8] See Clause A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01M/A5.01 (ISO 14344 MOD).

Table 6
Weight Metal Chemical Composition Requirements[a]

Weld Metal Designation	UNS Number[b]	Weight Percent[c]											
		C	Mn	Si	S	P	Ni	Cr	Mo	V	Al	Cu	Other[d]
Carbon Steel Electrodes													
CS1[e]	—	0.12	1.75	0.90	0.030	0.030	0.50[f]	0.20[f]	0.30[f]	0.08[f]	—	0.35[f]	—
CS2[e, g]	—	0.12	1.60	0.90	0.030	0.030	0.50[f]	0.20[f]	0.30[f]	0.08[f]	—	0.35[f]	—
CS3[e]	—	0.30	1.75	0.60	0.030	0.030	0.50[f]	0.20[f]	0.30[f]	0.08[f]	1.8[f, h]	0.35[f]	—
Molybdenum Steel Electrodes													
A1	W1703X	0.12	1.25	0.80	0.030	0.030	—	—	0.40–0.65	—	—	—	—
Chromium-Molybdenum Steel Electrodes													
B1	W5103X	0.05–0.12	1.25	0.80	0.030	0.030	—	0.40–0.65	0.40–0.65	—	—	—	—
B1L	W5113X	0.05	1.25	0.80	0.030	0.030	—	0.40–0.65	0.40–0.65	—	—	—	—
B2	W5203X	0.05–0.12	1.25	0.80	0.030	0.030	—	1.00–1.50	0.40–0.65	—	—	—	—
B2L	W5213X	0.05	1.25	0.80	0.030	0.030	—	1.00–1.50	0.40–0.65	—	—	—	—
B2H	W5223X	0.10–0.15	1.25	0.80	0.030	0.030	—	1.00–1.50	0.40–0.65	—	—	—	—
B3	W5303X	0.05–0.12	1.25	0.80	0.030	0.030	—	2.00–2.50	0.90–1.20	—	—	—	—
B3L	W5313X	0.05	1.25	0.80	0.030	0.030	—	2.00–2.50	0.90–1.20	—	—	—	—
B3H	W5323X	0.10–0.15	1.25	0.80	0.030	0.030	—	2.00–2.50	0.90–1.20	—	—	—	—
B6	W50231	0.05–0.12	1.20	1.00	0.030	0.025	0.40	4.0–6.0	0.45–0.65	—	—	0.35	—
B6L	W50230	0.05	1.20	1.00	0.030	0.025	0.40	4.0–6.0	0.45–0.65	—	—	0.35	—
B8	W50431	0.05–0.12	1.20	1.00	0.030	0.040	0.40	8.0–10.5	0.85–1.20	—	—	0.50	—
B8L	W50430	0.05	1.20	1.00	0.030	0.040	0.40	8.0–10.5	0.85–1.20	—	—	0.50	—
B91[i]	W50531	0.08–0.13	1.20[j]	0.50	0.015	0.020	0.80[j]	8.0–10.5	0.85–1.20	0.15–0.30	0.04	0.25	Nb: 0.02–0.10 N: 0.02–0.07
B92	—	0.08–0.15	1.20[j]	0.50	0.015	0.020	0.80[j]	8.0–10.0	0.30–0.70	0.15–0.30	0.04	0.25	Nb: 0.02–0.08 W: 1.5–2.0 B: 0.006 N: 0.02–0.08 Co[k]
Nickel Steel Electrodes													
Ni1	W2103X	0.12	1.75	0.80	0.030	0.030	0.80–1.10	0.15	0.35	0.05	1.8[h]	—	—
Ni2	W2203X	0.12	1.50	0.80	0.030	0.030	1.75–2.75	—	—	—	1.8[h]	—	—
Ni3	W2303X	0.12	1.50	0.80	0.030	0.030	2.75–3.75	—	—	—	1.8[h]	—	—

(Continued)

Table 6 (Continued)
Weld Metal Chemical Composition Requirements[a]

Weld Metal Designation	UNS Number[b]	Weight Percent[c]											
		C	Mn	Si	S	P	Ni	Cr	Mo	V	Al	Cu	Other[d]
Manganese-Molybdenum Steel Electrodes													
D1	W1913X	0.12	1.25–2.00	0.80	0.030	0.030	—	—	0.25–0.55	—	—	—	—
D2	W1923X	0.15	1.65–2.25	0.80	0.030	0.030	—	—	0.25–0.55	—	—	—	—
D3	W1933X	0.12	1.00–1.75	0.80	0.030	0.030	—	—	0.40–0.65	—	—	—	—
Other Low-Alloy Steel Electrodes													
K1	W2113X	0.15	0.80–1.40	0.80	0.030	0.030	0.80–1.10	0.15	0.20–0.65	0.05	—	—	—
K2	W2123X	0.15	0.50–1.75	0.80	0.030	0.030	1.00–2.00	0.15	0.35	0.05	1.8[h]	—	—
K3	W2133X	0.15	0.75–2.25	0.80	0.030	0.030	1.25–2.60	0.15	0.25–0.65	0.05	—	—	—
K4	W2223X	0.15	1.20–2.25	0.80	0.030	0.030	1.75–2.60	0.20–0.60	0.20–0.65	0.03	—	—	—
K5	W2162X	0.10–0.25	0.60–1.60	0.80	0.030	0.030	0.75–2.00	0.20–0.70	0.15–0.55	0.05	—	—	—
K6	W2104X	0.15	0.50–1.50	0.80	0.030	0.030	0.40–1.00	0.20	0.15	0.05	1.8[h]	—	—
K7	W2205X	0.15	1.00–1.75	0.80	0.030	0.030	2.00–2.75	—	—	—	—	—	—
K8	W2143X	0.15	1.00–2.00	0.40	0.030	0.030	0.50–1.50	0.20	0.20	0.05	1.8[h]	—	—
K9	W23230	0.07	0.50–1.50	0.60	0.015	0.015	1.30–3.75	0.20	0.50	0.05	—	0.06	—
K10	—	0.12	1.25–2.25	0.80	0.030	0.030	1.75–2.75	0.20	0.50	—	—	0.50	—
K11	—	0.15	1.00–2.00	0.80	0.030	0.030	0.40–1.00	0.20	0.50	0.05	1.8[h]	—	—
W2	W2013X	0.12	0.50–1.30	0.35–0.80	0.030	0.030	0.40–0.80	0.45–0.70	—	—	—	0.30–0.75	—
G	—	(m)	As agreed upon between supplier and purchaser										
GS[n]	—	As agreed upon between supplier and purchaser											

[a] The weld metal shall be analyzed for the specific elements for which values are shown in this table.

[b] Refer to ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System*. An "X," when present in the last position, represents the usability designator for the electrode type used to deposit the weld metal. An exception to this applies to the "11" electrode type where a "9" is used instead of an "11."

[c] Single values are maximums.

[d] An analysis of the weld deposit for boron is required and shall be reported if this element is intentionally added or if it is known to be present at levels in excess of 0.0010%.

[e] The total of all the elements listed in this table for this classification shall not exceed 5%.

[f] fThe analysis of these elements shall be reported only if intentionally added.

[g] Meets the lower Mn requirements of the A-No. 1 Analysis Group in the ASME *Boiler and Pressure Vessel Code*, Section IX, Welding and Brazing Qualifications, QW-422.

[h] Applicable to self-shielded electrodes only. Electrodes intended for use with gas shielding normally do not have significant additions of aluminum.

[i] The "B91" designation is a new designation, replacing the "B9" designation previously used for this alloy type.

[j] Mn + Ni = 1.40% maximum. See A7.16.2 in Annex A.

[k] Analysis for Co is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.20%.

[m] The limit for gas shielded electrodes is 0.18% maximum. The limit for self-shielded electrodes is 0.30% maximum.

[n] The composition of weld metal is not particularly meaningful since electrodes in this category are intended only for single pass welds. Dilution from the base metal in such welds is usually quite high. See A7.2 in Annex A.

Table 7
Tests Required for Classification

General Electrode Category	Electrode Classification	Required Tests[a]				
		Chemical Analysis	Radiographic Test	Tension Test[b]	Impact Test	Bend Test
Multiple Pass Electrodes	EXXT1-XXX-X EXXT4-XX-X EXXT5-XXX-X EXXT6-XX-X EXXT7-XX-X EXXT8-XX-X EXXT9-XXX-X EXXT11-XX-X EXXT12-XXX-X EXXT15-XXX-X EXXT16-XXX-X EXXT17-XX-X EXXTG-XXX-X[d] EXXTX-ZXX-X[e] EXXTX-XGX-X[f] EXXTX-XXX-G[g]	R	R	R	R[c]	NR
Single Pass Electrodes	EXXT1S-X EXXT3S EXXT10S EXXT14S EXXTGS-X[d] EXXTXS-Z[e]	NR	NR	R	NR	R

[a] The letter "R" indicates the test is required. "NR" indicates the test is not required.
[b] Multiple pass classifications require an all weld metal longitudinal tension test. Single pass classifications require a transverse tension test.
[c] When the "Z" impact designator is used, the impact test is not required. See Table 3.
[d] When a "G" appears in the position shown, it indicates that the electrode type is not specified but is "as agreed upon between supplier and purchaser."
[e] When a "Z" appears in the position shown, it indicates that the type of shielding gas used is not specified but is "as agreed upon between supplier and purchaser."
[f] When a "G" appears in the position shown, it indicates that the condition of PWHT is not as specified in Table 8 but is "as agreed upon between supplier and purchaser."
[g] When a "G" appears in the position shown, it indicates that the deposited weld composition is "as agreed upon between supplier and purchaser."

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification designations to the product, the manufacturer certifies that the product meets the requirements of this specification[9].

6. Rounding-Off Procedure

For purposes of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding-off rules of ASTM E 29 or ISO 80000-1 (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 the average value is to be compared to the specified limit, rounding off shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi for tensile and yield strength for A5.36 [to the nearest 10 MPa for tensile and yield strength for A5.36M] 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.

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[9] See Clause A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

Table 8
Preheat, Interpass, and PWHT Temperatures

AWS Weld Metal Designation	Preheat and Interpass Temperature[a]		Postweld Heat Treatment (PWHT) Temperature[a, b, c]	
	For A5.36 U.S. Customary Units	For A5.36M International System of Units (SI)	For A5.36 U.S. Customary Units	For A5.36M International System of Units (SI)
CS1, CS2, CS3	60°F Preheat minimum 300°F ±25°F Interpass	15°C Preheat minimum 150°C ± 15°C Interpass	1150°F ± 25°F	620°C ± 15°C
A1, Ni1, Ni2[d], Ni3[d], D2	300°F ± 25°F	150°C ± 15°C	1150°F ± 25°F	620°C ± 15°C
B1, B1L, B2, B2L, B2H, B3, B3L, B3H	350°F ± 25°F	175°C ± 15°C	1275°F ± 25°F	690°C ± 15°C
B6, B6L, B8, B8L	400°F ± 100°F	200°C ± 50°C	1375°F ± 25°F[e]	745°C ± 15°C[e]
B91, B92	500°F ± 100°F	260°C ± 50°C	1400°F ± 25°F[e]	760°C ± 15°C[e]
D1, D3, K1, K2, K3, K4, K5, K6, K7, K8, K9, K10, K11, W2	300°F ± 25°F	150°C ± 15°C	As agreed upon between supplier and purchaser	
EXXTX-XGX-X EXXTG-XGX-X EXXTX-XGX-G	As agreed upon between supplier and purchaser		As agreed upon between supplier and purchaser	

[a] These temperatures are specified for testing under this specification and are not to be consideredas recommendations for preheat and postweld heat treatment (PWHT) in production welding. The requirements for production welding must be determined by the user.

[b] Postweld heat treatment is required only for those classifications with the "P" designator for condition of heat treatment.

[c] The PWHT schedule is as described in 9.2.1.2 of this document.

[d] PWHT temperature in excess of 1150°F [620°C] will decrease Charpy V-Notch impact strength.

[e] Held at temperature for 2 hours –0 +15 minutes.

7. Summary of Tests

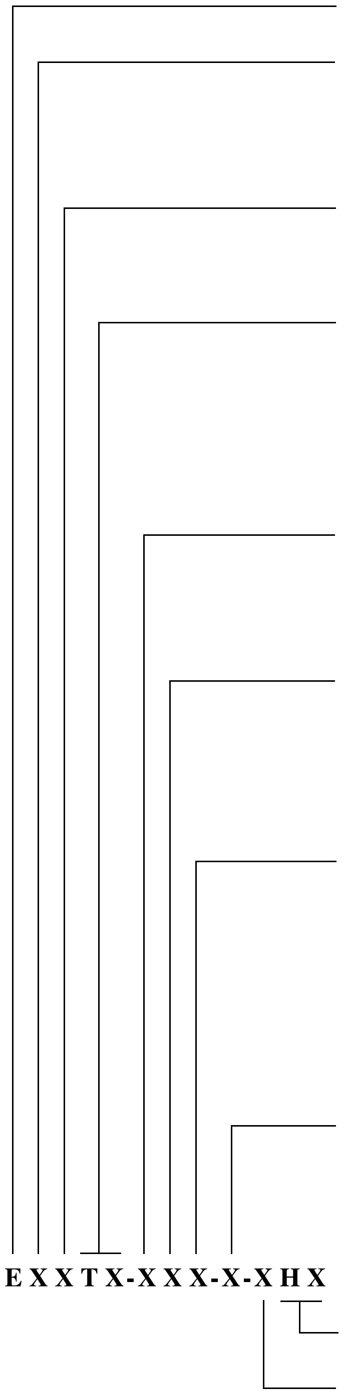
7.1 The tests required for each classification are specified in Table 7. The purpose of these tests is to determine the mechanical properties, soundness, and chemical composition of the weld metal, and the usability of the electrode. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 14.

7.2 This document provides for three supplemental tests which are not required for classification but which are included for optional supplemental designators as agreed upon between supplier and purchaser.

7.2.1 The supplemental test for diffusible hydrogen is described in Clause 15 and utilizes designators H16, H8, H4, or H2.

7.2.2 The optional supplemental designator "D" or "Q" may be used to indicate conformance to the all-weld mechanical property requirements specified in Table 9 when the weld metal is deposited (1) using the low heat input, fast cooling rate procedure and (2) using the high heat input, slow cooling rate procedure specified in Clause 16 and Table 10. The "D" designator is intended to identify those electrodes that satisfy AWS D1.8/D1.8M and FEMA 353, when the welds are made in a manner prescribed in AWS D1.8/D1.8M and FEMA 353. The "Q" designator is intended to identify those E7XTX-XXX-X [E49XTX-XXX-X] classification electrodes that meet the additional anticipated requirements of the U.S. Navy.

Mandatory Classification Designators[a]



Designates an electrode.

Tensile Strength Designator. For A5.36 one or two digits indicate the minimum tensile strength (when multiplied by 10 000 psi) of weld metal deposited with the electrode under the welding conditions specified in this specification. For A5.36M two digits are used to indicate the minimum tensile strength (when multiplied by 10 Megapascals [MPa]). See Table 2.

Position Designator. This designator is either "0" or "1." A "0" is for flat and horizontal positions only. "1" is for all positions (flat, horizontal, vertical with downward progression, and/or vertical with upward progression and overhead).

Usability Designator. This letter is the letter "T" followed by some number from 1 through 17 or the letter "G." The letter "T" identifies the electrode as a flux cored electrode or metal cored electrode. This designator refers to the usability of the electrode with requirements for polarity and general operating characteristics (see Table 4). The letter "G" indicates that the polarity and general operating characteristics are not specified. An "S" appears at the end of this designator when the electrode being classified is intended for single pass welding only.

Shielding Gas Designator. Indicates the type of shielding gas, if any, used for classification (see Table 5). The letter "Z" in this position indicates that the shielding gas composition is as agreed upon between supplier and purchaser. When no designator appears in this position, it indicates that the electrode is self shielded and that no external shielding gas is used.

Designates the condition of heat treatment in which the tests were conducted. "A" is for as-welded and "P" is for postweld heat treated. The time and temperature of the PWHT is specified in 9.2.1.2 and Table 8. The letter "G" in this position indicates that the PWHT procedure is as agreed upon between supplier and purchaser. This designator omitted when the electrode being classified is intended for single pass welding only.

Impact Designator. For A5.36 this designator indicates the temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf. For A5.36M this designator indicates the temperature in °C at or above which the impact strength of the weld metal meets or exceeds 27 J. The impact designator may be either one or two digits (see Table 3). A "Z" in this position indicates that there are no impact requirements for the electrode classification. This designator is omitted when the electrode being classified is intended for single pass welding only. A "G" in this position indicates the impact requirements are not specified but are as agreed upon between purchaser and supplier.

Deposit Composition Designator. One, two or three characters are used to designate the composition of the deposited weld metal (see Table 6). The letter "G" indicates that the chemical composition is not specified. No designator used in this position when the electrode being classified is a single pass electrode.

Optional Supplemental Designators[b]

Optional, supplemental diffusible hydrogen designator (see Table 13).

For flux cored electrodes, the letter "D" or "Q" when present in this position indicates the weld metal will meet supplemental mechanical property requirements with welding done using low heat input, fast cooling rate procedures and using high heat input, slow cooling rate procedures as prescribed in Clause 16 (see Tables 9 and 10).

[a] The combination of these designators constitutes the flux cored electrode classification.

[b] These designators are optional and do not constitute a part of the flux cored or metal cored electrode classification, as applicable.

Figure 1—A5.36/A5.36M Open Classification System

The following are examples of typical electrode classifications. The examples shown are for the A5.36 system using U.S. Customary Units. Refer to Table 4 and A7 in Annex A for additional information on electrode usability characteristics.

E71T1-C1A2-CS1-H4. The complete classification designation for this electrode is E71T1-C1A2-CS1. It refers to an all position, flux cored electrode that, when used with C1 (CO_2) shielding gas and welded under the conditions prescribed in this specification, will produce weld metal in the as welded condition having a tensile strength of 70 ksi–95 ksi and Charpy V-Notch impact strength of at least 20 ft·lbf at –20°F. The weld deposit will meet the CS1 carbon steel composition requirements. The "H4" is not part of the electrode classification designation but is an optional, supplemental designator indicating that the weld metal will have a maximum average diffusible hydrogen of 4 mL/100 g of deposited weld metal when tested under the conditions of this specification.

E80T5-M21P6-Ni2. This is a complete classification designation for a flat and horizontal flux cored electrode that, when used with M21 shielding gas (see Table 5) under the conditions prescribed in this specification, will produce weld metal in the postweld heat treated condition having a tensile strength of 80 ksi–100 ksi and Charpy V-Notch impact strength of at least 20 ft·lbf at –60°F. The weld deposit composition conforms to the Ni2 composition requirements (see Table 6).

E71T8-A4-Ni1. This is a complete classification designation for a self shielded (no Shielding Gas Designator appears), all position flux cored electrode. It refers to an electrode that will produce weld metal that, when tested under the conditions prescribed in this specification, will have a tensile strength of 70 ksi–95 ksi and Charpy V-Notch impact strength of at least 20 ft·lbf at –40°F in the as welded condition. The weld deposit composition conforms to the Ni1 composition requirements for self-shielded electrodes.

E90T15-M22A2-D2. This is a complete classification designation for a flat and horizontal metal cored electrode. It refers to a metal cored electrode that, when used with M22 shielding gas (see Table 5) under the conditions prescribed in this specification, will produce weld metal in the as welded condition with a tensile strength of 90 ksi–110 ksi and Charpy V-Notch impact strength of at least 20 ft·lbf at –20°F. The weld deposit composition conforms to the D2 composition requirements (see Table 6).

E80T15S-M20. This is a complete classification designation for a single pass (only) metal cored electrode. Under the welding and testing conditions prescribed in this specification, this metal cored electrode, when used with M20 shielding gas (see Table 5) will produce weld metal having a minimum tensile strength of 80 ksi.

Figure 1 (Continued)—A5.36/A5.36M Open Classification System

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material, specimens, or samples for retest may be taken from the original test assembly or 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 of 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 test 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.

Table 9
Mechanical Property Requirements for "D" and "Q" Optional Supplemental Designators

Optional Supplemental Designator	Tensile Test Requirements	Minimum Charpy V-Notch Requirements
D	For E7XTX-XXX-X [E49XTX-XXX-X] classifications: 58 ksi [400 MPa] min. yield strength[a] 70 ksi [490 MPa] min. tensile strength 22% min. % elongation in 2 in [50 mm]	40 ft·lbf at +70°F [54 J at +20°C] (see Notes b, c)
	For E8XTX-XXX-X [E55XTX-XXX-X] classifications: 68 ksi [470 MPa] min. yield strength[a] 80 ksi [550 MPa] min. tensile strength 19% min. % elongation in 2 in [50 mm]	
Q	58 ksi to 80 ksi [400 MPa–550 MPa] yield strength[a] for high input, slow cooling rate test. 90 ksi [620 MPa] max. yield strength[a] for low heat input, fast cooling rate test. 22% min. % elongation in 2 in [50 mm] (see Note d).	20 ft·lbf at –20°F [27 J at –30°C] (see Note e)

[a] Yield strength measured at 0.2% offset.

[b] Five specimens are to be tested. The lowest and highest values obtained from each of five specimens from a single test plate shall be disregarded. Two of the remaining three values shall equal, or exceed, the specified toughness of 40 ft·lbf [54 J] energy level at the testing temperature. One of the three may be lower, but not lower than 30 ft·lbf [41 J], and the average of the three shall not be less than the required 40 ft·lbf [54 J] energy level.

[c] The electrode shall also meet a minimum toughness requirement of 20 ft·lbf at 0°F [27 J at –18°C] when tested according to the standard A5.36/A5.36M classification test requirements.

[d] Tensile specimens shall not be aged when testing for the "Q" designator.

[e] Five specimens shall be tested. One of the five specimens may be lower than the specified 20 ft·lbf [27 J] energy level, but not lower than 15 ft·lbf [20 J], and the average of the five shall not be less than the required minimum 20 ft·lbf [27 J] energy level.

Table 10
Procedure Requirements for "D" and "Q" Optional Supplemental Designators

Optional Supplemental Designator	Procedure Heat Input (fast or slow cooling rate)	Preheat Temperature °F [°C]	Interpass Temperature °F [°C]	Heat Input Requirement for Any Single Pass[a]	Required Average Heat Input for All Passes[a]
D	Low (fast cooling rate)	120°F [50°C] maximum	250°F [120°C] maximum	For electrode diameters < 3/32 in [2.4 mm]	
				38 kJ/in [1.5 kJ/mm] maximum	24 kJ/in–36 kJ/in [0.9 kJ/mm–1.4 kJ/mm]
				For electrode diameters ≥ 3/32 in [2.4 mm]	
				44 kJ/in [1.7 kJ/mm] maximum	35 kJ/in–42 kJ/in [1.4 kJ/mm–1.6 kJ/mm]
	High (slow cooling rate)	250°F [120°C] minimum	450°F [240°C] minimum	65 kJ/in [2.6 kJ/mm] minimum	65 kJ/in-85 kJ/in [2.6 kJ/mm–3.3 kJ/mm]
Q	Low (fast cooling rate)	70°F ± 25°F [20°C ± 15°C]	150°F max. [65°C max.]	33 kJ/in [1.3 kJ/mm] maximum	25 kJ/in–32 kJ/in [1.0 kJ/mm–1.3 kJ/mm]
	High (slow cooling rate)	300°F ± 25°F [150°C ± 15°C]	300°F ± 25°F [150°C ± 15°C]	65 kJ/in [2.6 kJ/mm] minimum	68 kJ/in–75 kJ/in [2.7 kJ/mm–3.0 kJ/mm]

[a] Does not apply to first layer. The first layer may have one or two passes.

9. Test Assemblies

9.1 One or two weld test assemblies are needed, depending on the classification of the electrode and the manner in which the tests are conducted. They are as follows:

(1) For multiple pass electrodes, the groove weld test assembly showed in Figure 2 for mechanical properties, chemical analysis of the weld metal and soundness of the weld metal.

(2) For single pass electrodes, the test assembly in Figure 3 for mechanical properties.

(3) The weld pad in Figure 4 for chemical analysis of the weld metal, if required.

The sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 2, thereby avoiding the need to make the weld pad. In case of dispute, the groove weld shall be the referee method.

9.1.1 Preparation of each test assembly shall be as specified in Figure 2, 3, or 4, as applicable. The base metal for each assembly shall be as required in Table 11 and shall meet the requirements of any one of the appropriate ASTM or MIL specifications shown there, or an equivalent specification. Testing of the assemblies shall be as specified in Clauses 10 through 14.

9.2 Weld Test Assemblies

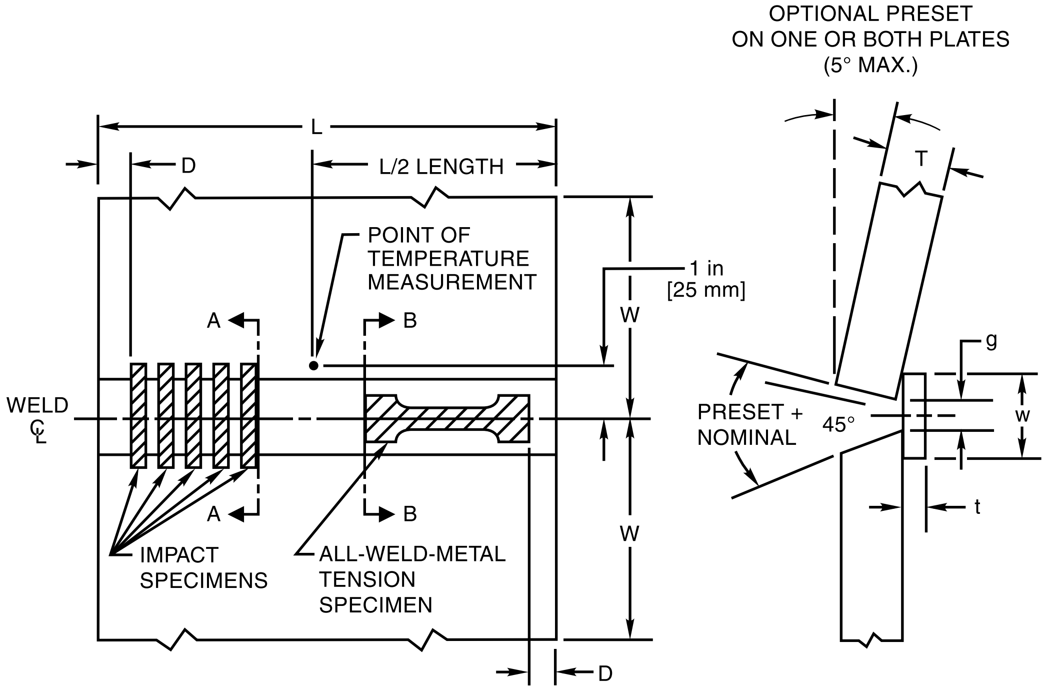
9.2.1 Test Assembly for Multipass Electrodes. One or two groove weld test assemblies shall be prepared and welded as specified in Figure 2 and Table 12, using base metal of the appropriate type specified in Table 11. Preheat and interpass temperatures shall be as specified in Table 8. Testing of this assembly shall be as specified in Table 7. When ASTM A 36 or ASTM A 285 base metals are used for low-alloy classifications (those other than CS1, CS2, and CS3), the groove faces and the contact face of the backing shall be buttered using an electrode of the same composition as the classification being tested except as noted in Table 11, Notes b and f. If a buttering procedure is used, the layer shall be approximately 1/8 in [3 mm] thick (see Figure 2, Note 3). The electrode diameter for one test assembly shall be 3/32 in [2.4 mm] or the largest diameter manufactured. The electrode diameter for the other test assembly shall be 0.045 in [1.2 mm] or the smallest size manufactured. If the maximum diameter manufactured is 1/16 in [1.6 mm] or less, only the largest diameter need be tested. The electrode polarity shall be as specified in Table 4. Testing of the assemblies shall be as required in Table 7 for electrodes classified in either the as-welded or PWHT condition, as applicable.

9.2.1.1 Welding shall be done in the flat position (except for the E10XTX-XXX-K9 [E69XTX-XXX-X] classification which shall be welded in the vertical position with upward progression), and the assembly shall be restrained (or preset as shown in Figure 2) during welding to prevent warpage in excess of 5°. An assembly that is warped more than 5° from plane shall be discarded. It shall not be straightened.

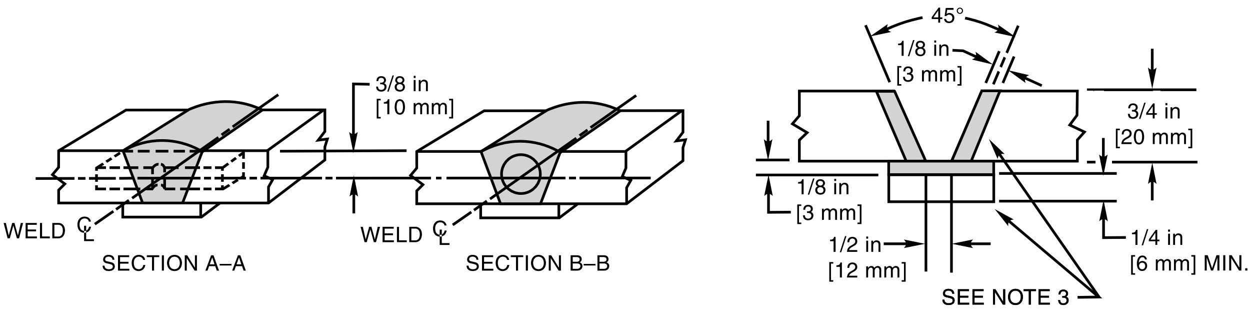
Prior to welding, the test assembly shall be heated to the preheat temperature specified in Table 8 for the electrode being tested. Welding shall continue until the assembly has reached the required interpass temperature specified in Table 8, measured by temperature indicating crayons or surface thermometers at the location shown in Figure 2. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air. The assembly shall be heated to a temperature within the specified interpass temperature range before welding is resumed.

9.2.1.2 When postweld heat treatment is required, the heat treatment shall be applied to the test assembly before the specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination. The temperature of the test assembly shall be raised in a suitable furnace at the rate of 150°F to 500°F [85°C to 280°C] per hour until the postweld heat treatment temperature specified in Table 8, for the electrode classification, is attained. This temperature shall be maintained for one hour (–0, +15 minutes), unless otherwise noted in Table 7. The test assembly shall then be allowed to cool in the furnace at a rate not greater than 350°F [200°C] per hour. It may be removed from the furnace when the temperature of the furnace has reached 600°F [300°C] and allowed to cool in still air.

9.2.2 Test Assembly for Single Pass Electrodes. For single pass electrodes a butt joint test assembly using base metal as specified in Table11 shall be prepared and welded as specified in Figure 3 and 9.2.2.1. After tack welding the plates at each end, the test assembly shall be welded in the flat position with one bead on each side.



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) ORIENTATION OF IMPACT SPECIMENS **(C) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN** **(D) BUTTERED TEST PLATE**

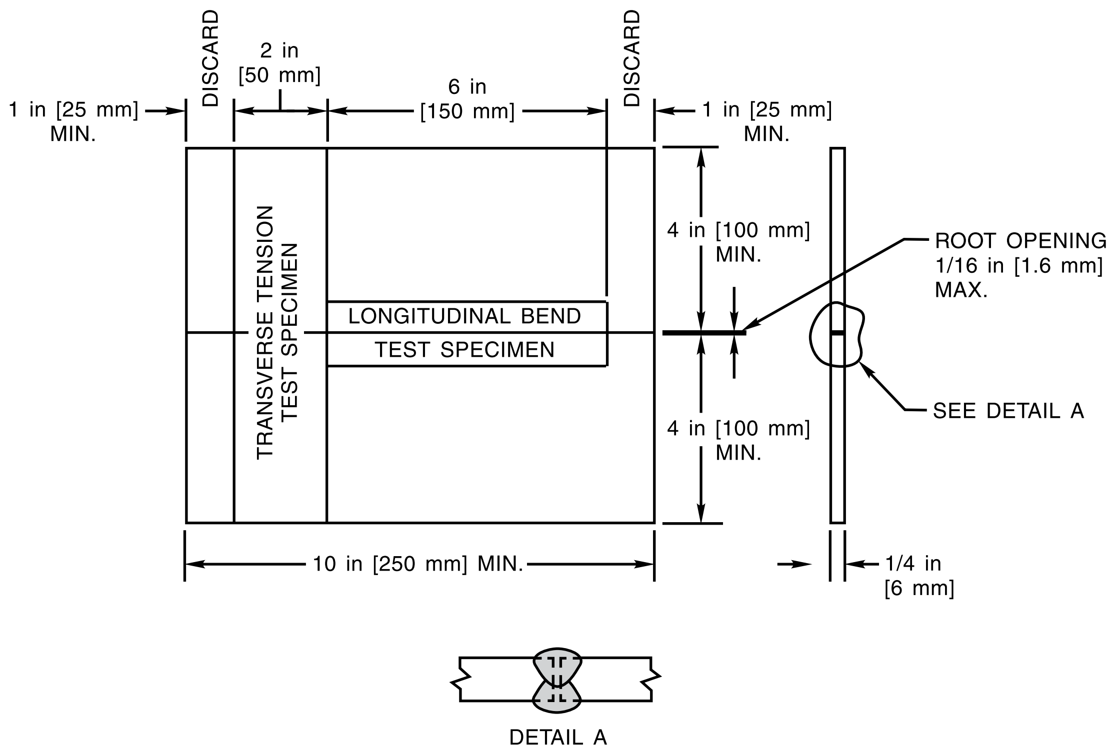
L Test Plate Length (min.)	W Test Plate Width (min.)	T Test Plate Thickness	D Discard (min.)	Bevel Angle	g Root Opening	w Backup Width (min.)	t Backup Thickness (min.)	M Buttered Layer (min.)
10 in [250 mm]	6 in [150 mm]	3/4 ± 1/32 in [20 ± 1 mm]	1 in [25 mm]	22.5° ± 2°	1/2 –0 in, +1/16 in [12 –0 mm, +1 mm]	Approx. 2 × g	1/4 in [6 mm]	1/8 in [3 mm]

Notes:

1. An acceptable alternative to the test joint shown above is the use of a bevel angle of 10°, +2.5°, –0° with a root opening of 5/8 in, +1/16, –0 in [16 mm, +1 mm, –0 mm] similar to type 1.3 per ISO 15792-1:2000.
2. Test plate thickness shall be 1/2 in [12 mm] and the maximum root opening shall be 1/4 in –0 in, +1/16 in [6 mm –0 mm, +1 mm] for 0.045 in [1.2 mm] and smaller diameters of the EXXT11-AZ-CS3 electrode classifications.
3. When required, edges of the grooves and contacting face of the backing shall be buttered as shown in (D). See Note a of Table 10.

Source: Figure 3 of AWS A5.29/A5.29M:2005 (Errata/Reprint).

Figure 2—Test Assembly for Mechanical Properties and Soundness of Weld Metal for Welds made with Multiple-Pass Electrodes



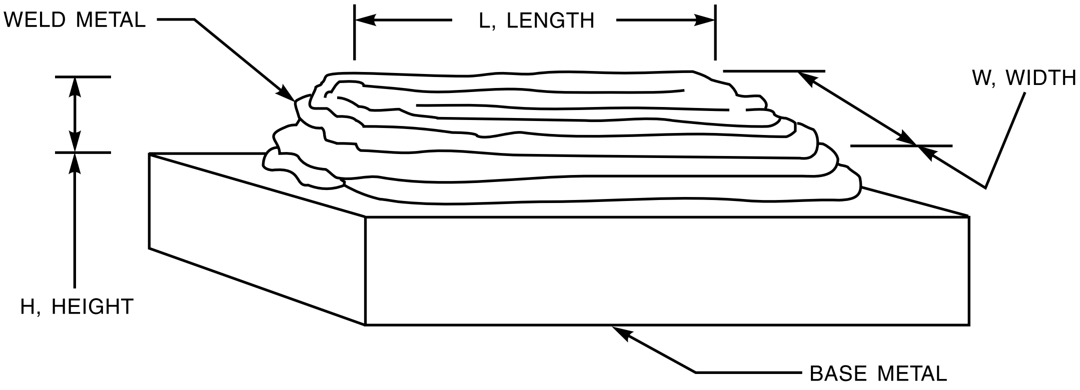
Notes:
1. Detail A shows the completed joint and approximate weld configuration.
2. Plate thickness may be reduced to 3/16 in [5 mm] for electrode of 0.068 in [1.7 mm] diameter or smaller.

Source: Figure 4 of AWS A5.20/A5.20M:2005.

Figure 3—Test Assembly for Transverse Tension and Longitudinal Guided Bend Tests for Welds made with Single-Pass Electrodes

9.2.2.1 Welding shall begin with the assembly at 60°F [15°C] minimum. When the weld bead has been completed on the face side, the assembly shall be turned over and the bead deposited on the root side, as shown in Figure 3. This sequence shall not be interrupted. The electrode size shall be either 3/32 in [2.4 mm] diameter or the size the manufacturer produces that is closest to the 3/32 in [2.4 mm] diameter. The welding polarity shall be as shown in Table 4 for the classification being tested. After welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Clauses 12 and 13 in the as-welded condition (except for the aging of the bend test specimen specified in 13.2).

9.2.3 Weld Pad. As an alternative for determining weld deposit composition, a weld pad can be prepared as specified in Figure 4. Base metal of any convenient size of the type specified in Table 11 (including note c to that table) shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal (1/2 in [12 mm] minimum thickness). The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C]. The welding procedure used for the weld pad shall satisfy the heat input requirements specified in Table 12. The slag, if any, shall be removed after each pass. The pad may be quenched in water between passes. The dimensions of the completed pad shall be as shown in Figure 4. Testing of this assembly shall be as specified in Clause 10.



WELD PAD SIZE, MINIMUM					
Length, L		Width, W		Height, H	
in	mm	in	mm	in.	mm
1-1/2	38	1/2	12	1/2	12

Notes:

1. Base metal of any convenient size, of the type specified in Table 11, 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, using the specified shielding gas (if any), using the polarity as specified in Table 4 and following the heat input requirements specified in Table 12.
4. The number and size of the beads will vary according to the size of the electrode and the bead width, as well as with the amperage employed. The bead width shall be limited to 10 times the electrode diameter.
5. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C].
6. The test assembly may be quenched in water (temperature unimportant) between passes to control interpass temperature.
7. The minimum completed pad size shall be that shown above. The sample to be tested in Clause 10 shall be taken from weld metal that is at least 3/8 in [10 mm] above the original base metal surface. See Table 11, Note c, for requirements when using ASTM A 36 or A 285 base steels.

Source: Figure 2 of AWS A5.29/A5.29M:2005 (Errata/Reprint).

Figure 4—Pad for Chemical Analysis of Deposited Weld Metal

10. Chemical Analysis

10.1 The sample for analysis shall be taken from weld metal produced with the flux cored or metal cored electrode and the shielding gas, if any, with which it is classified. The sample shall be taken from the reduced section of the fractured tension test specimen, or from a corresponding location, or any location above it, in the groove weld in Figure 2. The weld pad described in 9.2.3 can also be used to produce the weld metal sample for chemical analysis. In case of dispute, the sample taken from the groove weld shall be the referee method.

10.2 The sample from the reduced section of the fractured tension test specimen or from a corresponding location, or any location above it, in the groove weld in Figure 2 shall be prepared for analysis by any suitable mechanical means.

When the weld pad is used for analysis, the top surface of the pad described in 9.2.3 and shown in Figure 4 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. The sample shall be taken at least 3/8 in [10 mm] from the nearest surface of the base metal. See note c of Table 11 for sampling requirements when ASTM A 36 or A 285 steel is used as the weld pad base metal.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E 350.

10.4 The results of the analysis shall meet the requirements of Table 6 for the classification of electrode under test.

Table 11
Base Metal for Test Assemblies[a, b, c]

Weld Metal Designation	ASTM and Military Standards[d]	UNS Number[e]
Single Pass Electrode Classifications	A 515/A 515M Grade 70 A 516/A 516M Grade 70	K03101 K02700
CS1, CS2, CS3	A 36/A 36M A 285/A 285M Grade C A 515/A 515M Grade 70 A 516/A 516M Grade 70 A 830/A 830M Grade 1015, 1018, or 1020	K02600 K02801 K03101 K02700 G10150, G10180, or G10200
A1	A 204, Grade A A 204, Grade B A 204, Grade C	K11820 K12020 K12320
B1, B2, B2L, B2H	A 387, Grade 11	K11789
B3, B3L, B3H	A 387, Grade 22	K21590
B6, B6L	A 387, Grade 5	S50200
B8, B8L	A 387, Grade 9	S50400
B91	A 387, Grade 91	K91560
B92	A 387 Grade P92	K92460
Ni1	A 537, Class 1 or 2	K12437
Ni2, Ni3	A 203, Grade E HY-80[g] HY-100[g] HSLA-80[h] HSLA-100[h]	K32018 K31820 K32045 — —
D1, D2, D3	A 302 Grade A or B A506 A507	K12021, K12022 G41300 G41300
K1, K2, K3, K4, K5, K7, K9[f], K10	A 514, any Grade HY-80[g] HY-100[g] HSLA-80[h] HSLA-100[h]	K11856 K31820 K32045 — —
K2, K6, K8, K11	A 537, Class 1 or 2	K12437
W2	A 588, Grade A A 588, Grade B A 588, Grade C	K11430 K12043 K11538
G	See Note a	—

[a] For the groove weld shown in Figure 2, ASTM A 36, A 285, or A 516 Grade 70 base metals may be used for low-alloy steel classifications however, the joint surfaces shall be buttered as shown in Figure 2 using any electrode of the same composition as the classification being tested. Buttering is not required for carbon steel classifications (CS1, CS2, and CS3). For the "G" weld metal designation the base metal may also be as agreed upon between supplier and purchaser.

[b] Buttering of the groove weld in Figure 2 is not required when using A 36 or A 285 base metals when testing the T4, T6, T7, T8, or T11 self-shielded multiple pass electrode types with 70 ksi [490 MPa] or lower classification.

[c] ASTM A 36 or A 285 base metals may be used for the weld pad referenced in 9.2.3. The minimum weld metal height shall be 5/8 in [16 mm]. The sample for analysis shall be taken from weld metal that is at least 1/2 in [12 mm] above the original plate surface.

[d] Chemically equivalent steels in other U.S. Customary grades or in any metric grades (in SI units) may also be used.

[e] As classified in ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System*.

[f] Buttering is not allowed for the K9 weld metal designation.

[g] According to MIL-S-16216 or NAVSEA Technical Publication T9074-BD-GIB-010/0300, Appendix B.

[h] According to MIL-S-24645 or NAVSEA Technical Publication T9074-BD-GIB-010/0300, Appendix A.

Table 12
Heat Input Requirements and Suggested Pass and Layer Sequence for Multiple Pass Electrode Classifications

Diameter		Required Average Heat Input[a, b]		Suggested Passes per Layer		Suggested Number of Layers
in	mm	kJ/in	kJ/mm	Layer 1	Layer 2 to Top	
≤0.030 0.035	≤0.8 0.9	20–35	0.8–1.4	1 or 2	2 or 3	6 to 9
— 0.045 —	1.0 — 1.2	25–50	1.0–2.0	1 or 2	2 or 3	6 to 9
0.052 — 1/16	— 1.4 1.6	25–55	1.0–2.2	1 or 2	2 or 3	5 to 8
0.068 — 0.072 5/64 (0.078)	— 1.8 — 2.0	35–65	1.4–2.6	1 or 2	2 or 3	5 to 8
3/32 (0.094)	2.4	40–65	1.6–2.6	1 or 2	2 or 3	4 to 8
7/64 (0.109)	2.8	50–70	2.0–2.8	1 or 2	2 or 3	4 to 7
0.120 1/8 (0.125)	— 3.2	55–75	2.2–3.0	1 or 2	2	4 to 7
5/32 (0.156)	4.0	65–85	2.6–3.3	1	2	4 to 7

[a] For all electrode types, except those with the T16 or T17 Usability Designator, the calculation to be used for heat input is:

$$(1)\ \text{Heat Input (kJ/in)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (in/min)} \times 1000} \text{ or } \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (in)} \times 1000}$$

or

$$(2)\ \text{Heat Input (kJ/mm)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (mm/min)} \times 1000} \text{ or } \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (mm)} \times 1000}$$

These restrictions on heat input do not apply to the first layer. The first layer shall have a maximum of two passes. The average heat input is the calculated average for all passes excluding the first layer. A non-pulsed, constant voltage (CV) power source shall be used.

[b] For electrode types having the T16 or T17 Usability Designator, the welding procedure shall be as recommended by the manufacturer. The welding current shall be an alternating current with or without a modified waveform. The welding procedure used shall be consistent with procedures recommended by the manufacturer for commercial applications.

11. Radiographic Test

11.1 The groove weld described in 9.2.1 and shown in Figure 2 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 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] maximum 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] so that the thickness of the prepared radiographic test specimen equals at least the thickness of the base metal minus 1/16 in [1.5 mm]. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 1032. The quality level of inspection shall be 2-2T.

11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows:

(1) no cracks, no incomplete fusion, and no incomplete penetration;

(2) no slag inclusions longer than 1/4 in [6 mm] or 1/3 of the thickness of the weld, whichever is greater, or no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld except when the distance between the successive inclusions exceeds 6 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 5. 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 indication may be of porosity or slag. Test assemblies with indications larger than the large indications permitted in the radiographic standard (Figure 5) do not meet the requirements of this specification.

12. Tension Test

12.1 For multiple pass electrode classifications one all-weld-metal tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly described in 9.2.1 and shown in Figure 2. The tension test specimen shall have a nominal diameter of 0.500 in [12.5 mm] (0.250 in [6.5 mm] for some electrodes as indicated in Note 2 of Figure 2) and a nominal gage length to diameter ratio of 4:1.

12.1.1 After machining, but before testing, the tension test specimen for classifications to be tested in the as-welded condition 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 A8.3 for a discussion of the purpose of aging.

12.1.2 The specimen shall be tested in the manner described in the Tension Test section of AWS B4.0 or B4.0M.

12.1.3 The results of the all-weld-metal tension test shall meet the requirements specified in Table 2.

12.2 For single pass electrode classifications, one transverse tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly described in 9.2.2 and shown in Figure 3. The transverse rectangular tension specimen shall be a full thickness specimen machined transverse to the weld with a nominal reduced section width of 1.50 in [38 mm].

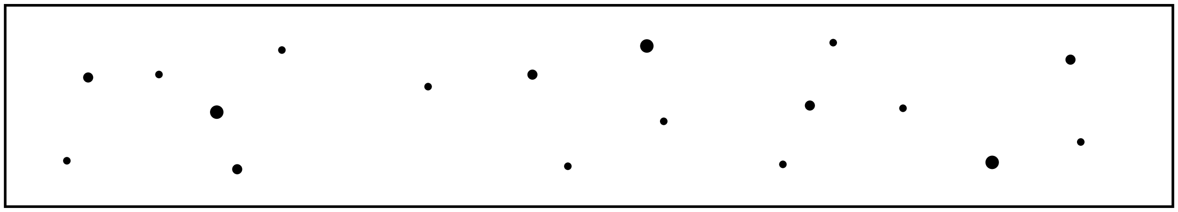
12.2.1 The specimen shall be tested in the manner described in the Tension Test section of AWS B4.0 or B4.0M.

12.2.2 The results of the tension test shall meet the requirements specified in Table 2.

13. Bend Test

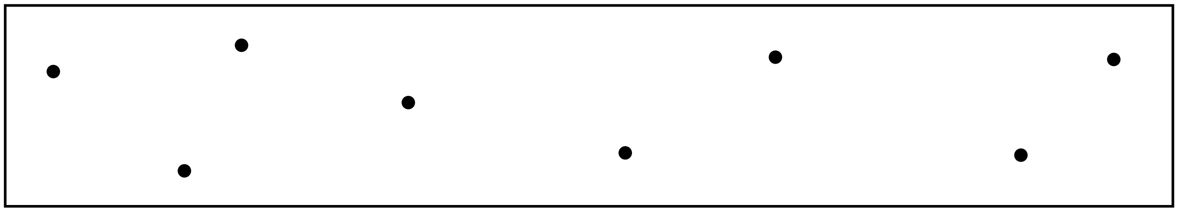
13.1 One longitudinal face bend test specimen, as required in Table 7, shall be machined from the welded test assembly described in 9.2.2 and shown in Figure 3. The dimensions of the specimen shall be as shown in Figure 3. Other dimensions of the bend specimen shall be as specified in the Bend Test section of AWS B4.0 or B4.0M.

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 A8.3 for a discussion on the purpose of aging.



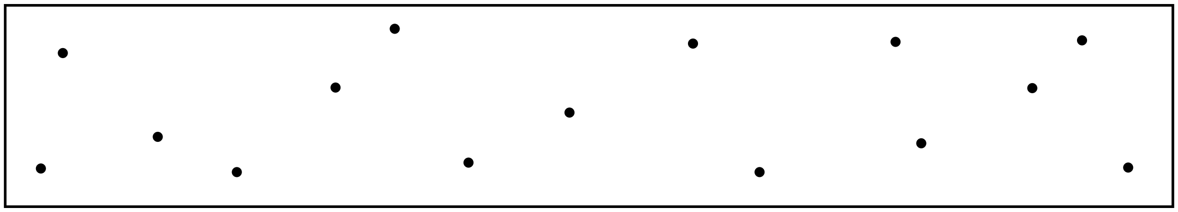
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:
MAXIMUM NUMBER OF LARGE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 10.



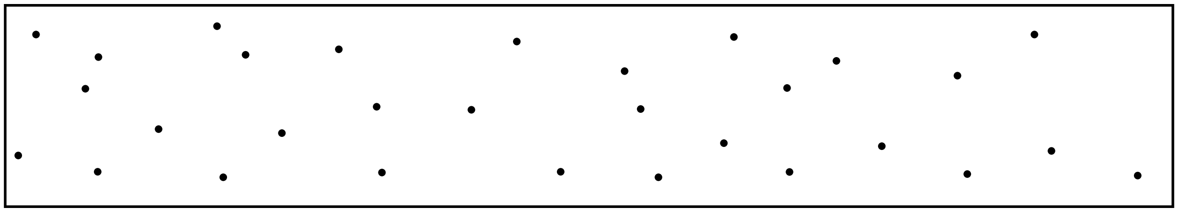
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 15.



(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 30.

Notes:

1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded.

Source: Figure 7 of AWS A5.29/A5.29M:2005 (Errata/Reprint).

Figure 5—Radiographic Standard for Test Assembly in Figure 2

13.3 The specimen shall be tested in the manner described in the Bend Test section of AWS B4.0 or B4.0M by bending it uniformly through 180° over a 3/4 in [19 mm] radius using any suitable jig as specified in the Bend Test section of B4.0 or B4.0M. Positioning of the longitudinal face bend specimen shall be such that the weld face of the last side welded is in tension.

13.4 The 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 show any crack or other open defect exceeding 1/8 in [3.2 mm] in any direction when examined with the unaided eye. Cracks in the base metal shall be disregarded, as long as they do not enter the weld metal. When base metal openings or cracks enter the weld metal, the test shall be considered invalid. Specimens in which this occurs shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of specimens required in Clause 8 does not apply.

14. Impact Test

14.1 Five full-size Charpy V-Notch impact specimens, as specified in the Fracture Toughness Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly shown in Figure 2 for those classifications for which impact testing is required (see Figure 1).

The Charpy V-Notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50X magnification on either a shadowgraph or metallograph. 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 section of AWS B4.0 or B4.0M. The test temperature shall be that specified in Table 3 for the classification under test.

14.3 In evaluating the test results for all classifications except the K9 low-alloy electrode classification, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft·lbf [20 J], and the average of the three shall be not less than the required 20 ft·lbf [27 J] energy level, except as noted in 14.4.

14.4 In evaluating the results for a K9 low-alloy electrode classification, all five impact values shall be included. At least four of the five shall be not less than the energy level specified for the classification. One of the five may be lower than that, but not lower than the minimum requirement by more than 10 ft·lbf [14 J]. The average of all five values must meet the minimum requirement.

15. Diffusible Hydrogen Test

15.1 The 3/32 in [2.4 mm] or the largest diameter and the 0.045 in [1.2 mm] or the smallest diameter of an electrode to be identified by an optional supplemental diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. If the maximum diameter manufactured is 1/16 in [1.6 mm] or less, only the largest diameter need be tested. A mechanized welding system shall be used for the diffusible hydrogen test. Based upon the average value of test results which satisfy the requirements of Table 13, the appropriate diffusible hydrogen designator may be added at the end of the classification.

15.2 Testing shall be done with electrode from a previously unopened container. Conditioning of the electrode prior to testing is not permitted. Conditioning can be construed to be any special preparation or procedure, such as baking the electrode, which the user would not usually practice. The shielding gas, if any, used for classification purposes shall also be used for the diffusible hydrogen test. Welds for hydrogen determination shall be made at a wire feed rate (or welding current) which is based upon the manufacturer's recommended operating range for the electrode size and type being tested. When using wire feed rate, the minimum wire feed rate to be used for the diffusible hydrogen test is given by the equation shown below. When using welding current, the equation shown is modified by substituting "welding current"

Table 13
Diffusible Hydrogen Limits for Weld Metal[a]

Optional Supplemental Diffusible Hydrogen Designator[b, c, d]	Average Diffusible Hydrogen, Maximum[e] mL/100 g Deposited Metal
H16	16
H8	8
H4	4
H2	2

[a] Limits on diffusible hydrogen when tested in accordance with AWS A4.3, as specified in Clause 15.
[b] See Figure 1.
[c] The lower diffusible hydrogen levels (H8, H4, and H2) may not be available in some classifications (see A8.2 in Annex A).
[d] Electrodes which satisfy the diffusible hydrogen limits for H2 category also satisfy the limits for the H4, H8, and H16 categories. Electrodes which satisfy the diffusible hydrogen limits for the H4 category also satisfy the limits for the H8 and H16 categories. Electrodes which satisfy the diffusible hydrogen limits for H8 category also satisfy the limits for the H16 category.
[e] These hydrogen limits are based on welding in air containing a maximum of 10 grains of water per pound [1.43 g/kg] of dry air. Testing at any higher atmospheric moisture level is acceptable provided these limits are satisfied (see A8.2 in Annex A).

wherever "WFR" appears. The voltage shall be as recommended by the manufacturer for the wire feed rate (or welding current) used for the test. The contact tip-to-work distance (CTWD) shall be at the minimum recommended by the manufacturer for the wire feed rate (or welding current) used for the test. The travel speed used shall be as required to establish a weld bead width that is appropriate for the specimen. See A8.2 in Annex A.

$$\mathbf{WFR_{min} = WFR_{mfg.min} + 0.75\ (WFR_{mfg.max} - WFR_{mfg.min})}$$

where:

WFR_{min} is the minimum wire feed rate to be used for the diffusible hydrogen test

$WFR_{mfg.min}$ is the minimum wire feed rate recommended by the manufacturer

$WFR_{mfg.max}$ is the maximum wire feed rate recommended by the manufacturer

15.3 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.[10] The actual atmospheric conditions shall be reported along with the average value for the tests according to AWS A4.3.

15.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. If the actual test results for an electrode meet the requirements for the lower or lowest hydrogen designator, as specified in Table 13, the electrode also meets the requirements for all higher designators in Table 13 without need to retest.

16. "D" and "Q" Optional Supplemental Designator Tests

16.1 Each diameter of an electrode to be identified with either the "D" or "Q" optional supplemental designator (see Figure 1) shall be tested using both (1) a low heat input, fast cooling rate procedure and (2) a high heat input, slow cooling rate procedure as outlined in 16.2, 16.3, 16.4, 16.5, and Table 10.

16.1.1 Two test assemblies shall be prepared as shown in Figure 2. The base metals for the qualification of 70 ksi [490 MPa] minimum tensile strength filler metals shall conform to ASTM A 36, A 572 Grade 50, or A 992. Base metals for the qualification of 80 ksi [550 MPa] minimum tensile strength filler metals shall conform to ASTM A 36, A 572 Grade 50 or 65, or A 913 Grade 65, as agreed upon between the supplier and purchaser. Steel backing shall be of one of the five

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[10] See A8.2.5 in Annex A.

specifications and grades listed above, but need not be the same as the base material used for the qualification test assemblies. The assemblies shall be restrained (or preset) during welding to prevent warpage in excess of 5°. An assembly that is warped more than 5° from plane shall be discarded. It shall not be straightened.

16.1.2 The low heat input, fast cooling rate groove weld for both the "D" and "Q" designators shall be welded in the 1G position.

16.1.3 The high heat input, slow cooling rate groove weld for both the "D" and "Q" designators shall be welded in the 1G position for electrodes classified for flat and horizontal welding (position designator "0").

For electrodes classified for all-position welding (position designator "1") the high heat input, slow cooling rate groove weld shall be made in the 3G position with upward progression.

16.2 When testing for the "D" designator, the welding of the low heat input, fast cooling rate groove weld shall begin with the test assembly at 120ºF [50ºC] maximum. Welding shall continue until the assembly has reached the interpass temperature of 250ºF [120ºC] maximum. This maximum interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt the welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to between 120ºF [50ºC] and 250ºF [120ºC] before welding is resumed.

For electrode diameters less than 3/32 in [2.4 mm] the average heat input for all passes, exclusive of the first layer, shall be 24 kJ/in – 36 kJ/in [0.9 kJ/mm – 1.4 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 38 kJ/in [1.5 kJ/mm] heat input. See Table 10.

For electrode diameters 3/32 in [2.4 mm] or larger the average heat input for all passes, exclusive of the first layer, shall be 35 kJ/in – 42 kJ/in [1.4 kJ/mm – 1.6 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 44 kJ/in [1.7 kJ/mm] heat input. See Table 10.

16.3 When testing for the "D" designator, the welding of the high heat input, slow cooling rate groove weld shall begin with the test assembly preheated to 250°F [120°C] minimum. Welding shall continue until the test assembly has reached the interpass temperature of 450°F [240°C] minimum. See Table 10. This minimum interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature above the minimum interpass temperature before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 65 kJ/in – 85 kJ/in [2.6 kJ/mm – 3.3 kJ/mm]. No individual pass, exclusive of the first layer, shall be made at less than 65 kJ/in [2.6 kJ/mm] heat input. See Table 10.

16.4 When testing for the "Q" designator, the welding of the low heat input, fast cooling rate groove weld shall begin with the test assembly at 70°F ± 25°F [20°C ± 15°C]. Welding shall continue until the test assembly has reached the maximum interpass temperature of 150°F [65°C] which shall not be exceeded. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to 150°F [65°C] maximum before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 25 kJ/in – 32 kJ/in [1.0 kJ/mm – 1.3 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 33 kJ/in [1.3 kJ/mm] heat input. See Table 10.

16.5 When testing for the "Q" designator, the welding of the high heat input, slow cooling rate groove weld shall begin with the test assembly preheated to 300°F ± 25°F [150°C ± 15°C] prior to welding. An interpass temperature of 300°F ± 25°F [150°C ± 15°C] shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature of 300°F ± 25°F [150°C ± 15°C] before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 68 kJ/in – 75 kJ/in [2.7 kJ/mm – 3.0 kJ/mm]. No individual pass, exclusive of the first layer, shall be made at less than 65 kJ/in [2.6 kJ/mm] heat input. See Table 10.

16.6 After welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as shown in Figure 2 and as specified in Clauses 11, 12, and 14. The tension and impact tests shall meet the requirements specified in Table 9 for the "D" or "Q" designator, as applicable.

16.7 When certifying an electrode for the "D" or "Q" optional supplemental designator the actual average heat input used, exclusive of the first layer, for both the low heat input, fast cooling rate and high heat input, slow cooling rate groove welds shall be clearly stated on the test report(s).

17. 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.

18. Standard Sizes

18.1 Standard sizes for filler metal in the different package forms such as coils with support, coils without support, drums, and spools are as specified in AWS A5.02/A5.02M.

19. Finish and Uniformity

19.1 Finish and uniformity shall be as specified in 4.2 of AWS A5.02/A5.02M.

20. Standard Package Forms

20.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form shall be as specified in 4.3 of AWS A5.02/A5.02M:2007.

21. Winding Requirements

21.1 Winding requirements shall be as specified in 4.4.1 of AWS A5.02/A5.02M. The outermost layer of electrode on spools shall be at least 1/8 in [3 mm] from the rim (the OD) of the flanges of the spool.

21.2 The cast and helix of electrode in coils, spools, and drums shall be as specified in 4.4.2 of AWS A5.02/A5.02M.

22. Electrode Identification

22.1 Electrode identification, product information and the precautionary information shall be as specified in 4.5 of AWS A5.02/A5.02M.

23. Packaging

Electrodes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

24. Marking of Packages

24.1 The product information (as a minimum) that shall be legibly marked so as to be visible from the outside of each unit package shall be as specified in 4.6.1 of AWS A5.02/A5.02M:2007.

24.2 The appropriate precautionary information[11] 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.

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[11] Typical examples of "warning labels" 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 Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding*

This annex is not part of AWS A5.36/A5.36M:2012, *Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas 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 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 electrode is suitable.

A2. Classification System

A2.1 This AWS A5.36/A5.36M specification utilizes two different classification systems. The first of these is a "fixed classification system" which is carried over from A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, or from A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, as applicable, for the classification those carbon steel flux cored or metal cored electrodes which, with the specific requirements already established, have enjoyed wide acceptance for single and multiple pass applications. These specific electrode classifications and their requirements are given in Table 1. The second classification system utilized in this specification is an "open classification system" for the classification of flux cored and metal cored carbon and low-alloy steel electrodes. The system for identifying the electrode classifications in this specification follows, for the most part; the standard pattern used in other AWS filler metal specifications (see Figure 1). It contains provisions for both multiple pass and single pass classifications. Classifications include designators for (1) tensile strength, (2) position of welding, (3) electrode usability characteristics, (4) shielding gas, if any, (5) condition of heat treatment, (6) impact toughness, and (7) weld deposit composition. This A5.36/A5.36M specification is used to classify flux cored electrodes previously classified under AWS A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding,* and AWS A5.29/A5.29M, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding,* and metal cored electrodes previously classified under AWS A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, and AWS A5.28/A5.28M, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*.

A2.1.1 Some of the classifications are intended to weld only in the flat and horizontal positions. Others are intended for welding in all positions. As in the case of shielded metal arc electrodes, the smaller sizes of flux cored electrodes are the ones used for out-of-position work. Cored electrodes larger than 5/64 in [2.0 mm] in diameter are usually used for horizontal fillets and flat position welding.

A2.1.2 Optional supplemental designators are also used in this specification in order to identify electrode classifications that have met certain supplemental requirements as agreed to between supplier and purchaser. The optional supplemental designators are not part of the classification nor of its designation. See 7.2.

A2.3 "G" Classification

A2.3.1 This specification includes electrodes classified as EXXTG-XXX-X, EXXTX-GXX-X, EXXTX-XGX-X, EXXTX-XXG-X, and EXXTX-XXX-G. 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 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 electrodes—each bearing the same "G" classification—may be quite different in some certain respect (chemical composition, again, for example).

A2.3.2 The point of difference (although not necessarily the amount of that difference) between an electrode of a "G" classification and an electrode of a similar classification without the "G" (or even with it, for that matter) will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

(1) "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.

(2) "Not Required" is used in those areas of the specification that refer to the tests that must be conducted in order to classify an electrode. It indicates that the test is not required because the requirements 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 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 (ISO 14344 MOD)] in the purchase order.

A2.3.3 Request for Filler Metal Classification

(1) When an electrode cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that electrode. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a classification be established for that electrode as long as the electrode is of commercial significance.

(2) A request to establish a new electrode classification must be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

(a) All classification requirements as given for existing classifications such as chemical composition ranges *and* mechanical property requirements.

(b) Any conditions for conducting the tests used to demonstrate that the product meets classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)

(c) Information on Descriptions and Intended Use, which parallels that for existing classifications, for that section of Annex A.

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 the Chair of the particular Subcommittee involved.

(d) File the original request.

(e) Add the request to the log of outstanding requests.

(4) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and 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.

A2.4 The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies. ISO provides for the classification of tubular cored products for carbon and low-alloy steels under their ISO 17632, *Welding consumables — Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels — Classification,* ISO 17634, *Welding consumables — Tubular cored electrodes for gas shielded metal arc welding of creep-resisting steels — Classification* and ISO 18276, *Welding consumables — Tubular cored electrodes for gas-shielded and non-gas shielded metal arc welding of high strength steels — Classification standards*.

A3. Acceptance

Acceptance of all cored welding electrodes classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344 MOD) as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD). In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of AWS A5.01M/A5.01 (ISO 14344 MOD). Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations and optional supplemental designators, if applicable, on the packaging enclosing the products, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of that 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 material from any production run of that classification using the same formulation. *Certification* is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the *certification* required by the specification is the classification test of representative material cited above, and the Manufacturer's Quality Assurance Program in AWS A5.01M/A5.01 (ISO 14344 MOD).

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators can be exposed during welding. These 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 or welding operators 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.

(5) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard 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 section on Ventilation in that document. Refer also to AWS F3.2M/F3.2, *Ventilation Guide for Weld Fume*.

A6. Welding Considerations

A6.1 When examining the properties required of weld metal as a result of the tests made according to this specification, it should be recognized that in production, where the conditions and procedures may differ from those in this specification (electrode size, amperage, voltage, type and amount of shielding gas, position of welding, contact tip to work distance (CTWD), plate thickness, joint geometry, preheat and interpass temperatures, travel speed, surface condition, base metal composition and dilution, for example), the properties of the weld metal may also differ. Moreover, the difference may be large or small.

A6.2 Since it has not been possible to specify one single, detailed, welding procedure for all products classified under any given classification in this specification, details of the welding procedure used in classifying each product should be recorded by the manufacturer and made available to the user, on request. The information should include each of the items referred to in A6.1 above, as well as the actual number of passes and layers required to complete the weld test assembly.

A6.3 The toughness requirements for the different classifications in this specification can be used as a guide in the selection of electrodes for applications requiring some degree of low temperature notch toughness. For an electrode of any given classification, there can be a considerable difference between the impact test results from one assembly to another, or even from one impact specimen to another, unless particular attention is given to the manner in which the weld is made and prepared (even the location and orientation of the specimen within the weld), the temperature of testing, and the operation of the testing machine.

A6.4 Hardenability. There are inherent differences in the effect of the carbon content of the weld deposit on hardenability, depending on whether the carbon steel electrode was gas shielded or self-shielded. Gas shielded carbon steel electrodes generally employ a Mn-Si deoxidation system. The carbon content affects hardness in a manner which is typical of many carbon equivalent formulas published for carbon steel. Most self-shielded electrodes utilize an aluminum-based deoxidation system to provide for protection and deoxidation. One of the effects of the aluminum is to modify the effect of carbon on hardenability. Hardness levels obtained with self-shielded carbon steel electrodes may, therefore, be lower than the carbon content would indicate (when considered on the basis of typical carbon equivalent formulas).

A7. Description and Intended Use of Flux Cored and Metal Cored Electrodes

This specification may contain many different classifications of flux cored and metal cored electrodes. The usability designator (1, 3, 4, 5, 6, 7, 8, 10, 11, 14, 15, 16, 17, or G) in each classification indicates a general grouping of electrodes that contain similar flux or core components and which have similar usability characteristics, except for the “G” classification where usability characteristics may differ between similarly classified electrodes.

A7.1 Flux Cored Electrode Classifications with the T1 Usability Designator. Electrodes with EXXT1-XXX-X designations (or E7XT-1C, E7XT-1M) have similar type slags and are designed for single and multiple pass welding using DCEP. The EX0T1-XXX-X electrodes are typically used for welding in the flat position and for welding fillet welds in the horizontal position. The EX1T1-XXX-X electrodes are classified for welding in all positions. Typically these electrodes are manufactured in smaller diameters (1/16 in [1.6 mm] and smaller) to facilitate out of position capability. However, some EX1T1-XXX-X electrodes may also be manufactured in larger diameters (5/64 in [2.0 mm] and larger). EXXT1-XXX-X electrodes are characterized by a spray transfer, low spatter loss, flat to slightly convex bead contour, and a moderate volume of slag, which completely covers the weld bead. Electrodes of this classification have a rutile base slag and have the ability to produce high deposition rates.

Electrodes with EXXT1-C1XX-X designations are classified with CO_2 shielding gas (Shielding Gas Designator C1 in Table 5). When recommended by the manufacturer, these electrodes may be used with argon mixes that contain CO_2, O_2, or both. This is typically done to improve usability, especially for out-of-position welding. This specification provides for classifying T1 type electrodes with different argon blends (see Table 5), when appropriate, as determined by the manufacturer. Increasing the amount of argon in the gas blend beyond that recommended by the manufacturer may adversely affect weld metal performance (for example, penetration, chemical composition, strength, toughness, and crack resistance).

A7.2 Flux Cored Electrode Classifications with the T1S Usability Designator. Electrodes with the EXXT1S-X classification are essentially the EXXT1-XXX-X types with higher manganese or silicon, or both, and are designed primarily for single pass welding in the flat position and for welding fillet welds in the horizontal position. The higher levels of deoxidizers in these classifications allow single pass welding of heavily oxidized or rimmed steel. Weld metal composition requirements are not specified for single pass electrodes, since checking the composition of undiluted weld metal will not provide an indication of the composition of a single pass weld. Note that the EXXT1S-X classification included in this specification is new and is a direct substitute for the EXXT-2X classification listed in A5.20/A5.20M:2005.

The manganese content and the tensile strength of the weld metal of multiple-pass welds made with EXXT1S-X electrodes will be high. These electrodes can be used for welding base metals which have heavier mill scale, rust, or other foreign matter that cannot be tolerated by some electrodes of the EXXT1-XXX-X classifications. The arc transfer, welding characteristics, and deposition rates of these electrodes, however, are similar.

A7.3 Flux Cored Electrode Classifications with the T3S Usability Designator. Electrodes with EXXT3S classifications are self-shielded, used with DCEP and have a spray-type transfer. The slag system is designed to make very high welding speeds possible. The electrodes are used for single-pass welds in the flat, horizontal, and vertical (up to 20° incline) positions (downward progression) on sheet metal. Since these electrodes are sensitive to the effects of base metal quenching, they are not generally recommended for the following:

(1) T- or lap joints in materials thicker than 3/16 in [5 mm]

(2) Groove, edge, or corner joints in materials thicker than 1/4 in [6 mm]

The electrode manufacturer should be consulted for specific recommendations.

A7.4 Flux Cored Electrode Classifications with the T4 Usability Designator. Electrodes having EXXT4-XX-X classifications are self-shielded, operate on DCEP, and have a globular type transfer. The basic slag system is designed to make very high deposition rates possible and to produce a weld that is very low in sulfur for improved resistance to hot cracking. These electrodes produce welds with low penetration enabling them to be used on joints with varying gaps and for single and multiple pass welding.

A7.5 Flux Cored Electrode Classifications with the T5 Usability Designator. Electrodes of the EXXT5-C1XX-X (or E7XT-5C) classification are designed to be used with CO_2 shielding gas. However, when recommended by the manufacturer, these same electrodes may be classified and used with a blend of CO_2 with argon to reduce spatter and improve welding characteristics. This specification provides for the classifying T5 type electrodes for use with different shielding gases (see Table 5), when appropriate. Increasing the amount of argon in the shielding gas mixture will increase the manganese and silicon contents, along with certain other alloys, which will increase the yield and tensile strengths and may affect impact properties. T5 type electrodes may also be classified with a shielding gas which is a blend of argon with CO_2, O_2, or both (refer to Table 5). Their use with gas mixtures having reduced amounts of argon (with corresponding increases is CO_2 and/or O_2) may result in some deterioration of arc characteristics, an increase in spatter, and a reduction of manganese, silicon, and certain other alloys in the weld metal. This reduction in manganese, silicon, or other alloys will decrease the yield and tensile strengths and may affect impact properties.

Electrodes of the EXXT5-XXX-X classifications are used primarily for single and multiple pass welds in the flat position and for making fillet welds in the horizontal position using DCEP or DCEN, depending on the manufacturer's recommendation. These electrodes are characterized by a globular transfer, slightly convex bead contour and a thin slag that may not completely cover the weld bead. These electrodes have a lime-fluoride base slag. Weld deposits produced by these electrodes typically have good to excellent impact properties and hot and cold crack resistance that are superior to those obtained with rutile base slags. Some EXXT5-XXX-X electrodes, using DCEN, can be used for welding in all positions. However, the operator appeal of these electrodes is not as good as those with rutile base slags.

A7.6 Flux Cored Electrode Classifications with the T6 Usability Designator. Electrodes having an EXXT6-XX-X (or E7XT-6) classification are self-shielded, operate on DCEP, and have a spray-type transfer. The slag system is designed to give good low temperature impact properties, good penetration into the root of the weld, and excellent slag removal, even in a deep groove. These electrodes are used for single and multiple pass welding in flat and horizontal positions.

A7.7 Flux Cored Electrode Classifications with the T7 Usability Designator. Electrodes having EXXT7-XX-X (or E7XT-7) classifications are self-shielded, operate on DCEN, and have a small droplet to spray type transfer. The slag system is designed to allow the larger sizes to be used for high deposition rates in the horizontal and flat positions, and to allow the smaller sizes to be used for all welding positions. These electrodes are used for single-pass and multiple pass welding and produce very low sulfur weld metal, which is very resistant to hot cracking.

A7.8 Flux Cored Electrode Classifications with the T8 Usability Designator. Electrodes classified as EXXT8-XX-X (or E7XT-8) are self-shielded, operate on DCEN, and have a small droplet or spray type transfer. These electrodes are suitable for all welding positions, and the weld metal has very good low-temperature notch toughness and crack resistance. These electrodes are used for single-pass and multipass welds.

A7.9 Flux Cored Electrode Classifications with the T10S Usability Designator. Electrodes with EXXT10S classifications are self-shielded, operate on DCEN, and have a small droplet transfer. The electrodes are used for single-pass welds at high travel speeds on material of any thickness in the flat, horizontal, and vertical (up to 20° incline) positions.

A7.10 Flux Cored Electrode Classifications with the T11 Usability Designator. Electrodes with EXXT11-XX-X classifications are self-shielded, operate on DCEN, and have a smooth spray-type transfer. They are general purpose electrodes for single- and multiple-pass welding in all positions. Their use is generally not recommended on thicknesses greater than 3/4 in [19 mm]. The electrode manufacturer should be consulted for specific recommendations.

A7.11 Flux Cored Electrode Classifications with the T14S Usability Designator. Electrodes with EXXT14S classifications are self-shielded, operate on DCEN, and have a smooth spray-type transfer. They are intended for single-pass welding. The slag system is designed with characteristics so that these electrodes can be used to weld in all positions and also to make welds at high speed. They are used to make welds on sheet metal up to 3/16 in [5 mm] thick, and often are specifically designed for galvanized, aluminized, or other coated steels. Since these welding electrodes are sensitive to the effects of base metal quenching, they are not generally recommended for the following:

(1) T- or lap joints in materials thicker than 3/16 in [5 mm]

(2) Groove, edge, or corner joints in materials thicker than 1/4 in [6 mm]

The electrode manufacturer should be consulted for specific recommendations.

A7.12 Metal Cored Electrode Classifications with the T15 Usability Designator. Electrodes classified as E70C-3C [E48C-3C], E70C-3M [E48C-3M], E70C-6C [E48C-6C], E70C-6M [E48C-6M] in AWS A5.18/A5.18M:2005, EXXC-X in AWS A5.28/A5.28M:2005, and EXXT15-XXX-X (or E70C-6M) in this specification are composite stranded or metal cored electrodes intended for both single and multiple pass applications. They are characterized by a spray arc and excellent bead wash characteristics. They are used for gas metal arc welding (GMAW). Metal cored electrodes are similar in many ways to solid GMAW electrodes.

A7.13 Metal Cored Electrode Classifications with the T16 Usability Designator. Electrodes classified as EXXT16-XXX-X are gas shielded metal cored electrodes specifically designed for use with AC power source with or without modified waveforms. The manufacturer should be consulted for application and welding procedure recommendations.

A7.14 Flux Cored Electrode Classifications with the T17 Usability Designator. Electrodes classified as EXXT17-XX-X are self shielded flux cored electrodes specifically designed for use with AC power sources with or without modified waveforms. The manufacturer should be consulted for application and welding procedure recommendations.

A7.15 EXXTG-XXX-X, EXXTX-XGX-X, EXXTX-XXG-X, EXXTX-XXX-G and EXXTG-ZXX-X Classifications. These classifications and combinations thereof are for multiple-pass electrodes that are not covered by any presently defined classification. The mechanical properties can be anything covered by this specification. Requirements are established by the digits chosen to complete the classification. Placement of the “G” (“Z” for shielding gas) in the classification designates that the electrode usability characteristics, shielding gas used for classification, condition of heat treatment, Charpy impact requirements or weld metal composition requirements, as applicable, are not defined in this specification and are as agreed upon between supplier and purchaser.

A7.16 Chemical Composition. The chemical composition of the weld metal produced is often the primary consideration for electrode selection. The suffixes, which are part of each alloy electrode classification, identify the chemical composition of the weld metal produced by the electrode. The following paragraphs give a brief description of the classifications, intended uses, and typical applications.

A7.16.1 EXXTX-XXX-A1 (C-Mo Steel) Electrodes. These electrodes are similar to EXXTX-XXX carbon steel electrodes classified under this specification, except that 0.5% Mo has been added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance; it may, however, reduce the notch toughness of the weld metal. This type of electrode is commonly used in the fabrication and erection of boilers and pressure vessels. Typical applications include the welding of C-Mo steel base metals, such as ASTM A 161, A 204, and A 302 Gr. A plate and A 335-P1 pipe.

A7.16.2 EXXTX-XXX-BX, EXXTX-XXX-BXL, and EXXTX-XXX-BXH (Cr-Mo Steel) Electrodes. These electrodes produce weld metal that contain between 0.5% and 10% Cr, and between 0.5% and 1% Mo. They are designed to produce weld metal for high temperature service and for matching properties of the typical base metals as follows:

EXXTX-XXX-B1	ASTM A 335-P2 pipe ASTM A 387 Gr. 2 plate
EXXTX-XXX-B2	ASTM A 335-P11 pipe ASTM A 387 Gr. 11 plate
EXXTX-XXX-B2L	Thin wall ASTM A 335-P11 pipe or ASTM A 213-T11tube, as applicable, for use in the as-welded condition or for applications where low hardness is a primary concern.
EXXTX-XXX-B3	ASTM A 335-P22 pipe ASTM A 387 Gr. 22 plate
EXXTX-XXX-B3L	Thin wall ASTM A 335-P22 pipe or ASTM A 213-T22 tube for use in the as-welded condition or for applications where lower hardness is a primary concern.
EXXTX-XXX-B6	ASTM A 213-T5 tube ASTM A 335-P5 pipe
EXXTX-XXX-B8	ASTM A 213-T9 tube ASTM A 335-P9 pipe
EXXTX-XXX-B91	ASTM A 213-T91 tube ASTM A 335-P91 pipe
EXXTX-XXX-B92	ASTM A 213-T92 tube ASTM A 335-P92 pipe

For two of these Cr-Mo electrode classifications, low carbon EXXTX-XXX-BXL classifications have been established. While regular Cr-Mo electrodes produce weld metal with 0.05% to 0.12% carbon, the “L-grades” are limited to a maximum of 0.05% C. While the lower percent carbon in the weld metals will improve ductility and reduce hardness, it will also reduce the high-temperature strength and creep resistance of the weld metal.

Several of these grades also have high-carbon grades (EXXTX-XXX-BXH) established. In these cases, the electrode produces weld metal with 0.10% to 0.15% carbon, which may be required for high temperature strength in some applications.

Since all Cr-Mo electrodes produce weld metal which will harden in still air, both preheat and postweld heat treatment (PWHT) are required for most applications.

No minimum notch toughness requirements have been established for any Cr-Mo electrode classifications. While it is possible to obtain Cr-Mo electrodes with minimum toughness values at ambient temperatures down to 32°F [0°C], specific values and testing must be agreed to by supplier and purchaser.

For the EXXTX-XXX-B91 and EXXTX-XXX-B92 classifications thermal treatment is critical and must be closely controlled. The temperature at which the microstructure has complete transformation into martensite (M_f) is relatively low; therefore, upon completion of welding and before post weld heat treatment, it is recommended to allow the weldment to cool to 200°F [93°C] or lower to maximize transformation to martensite. The maximum allowable temperature for post weld heat treatment is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To aid in allowing for an adequate post weld heat treatment, the restriction of Mn + Ni has been imposed (see Table 6, footnote j). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

A7.16.3 EXXTX-XXX-DX (Mn-Mo Steel) Electrodes. These electrodes produce weld metal which contains about 1.5% to 2% Mn and between 0.25% and 0.65% Mo. This weld metal provides better notch toughness than the C-0.5% Mo electrodes discussed in A7.16.1 and higher tensile strength than the 1% nickel 0.5% Mo steel weld metal discussed in A7.16.4.1. However, the weld metal from these Mn-Mo steel electrodes is quite air-hardenable and usually requires preheat and PWHT. The individual electrodes under this electrode group have been designed to match the mechanical properties and corrosion resistance of the high-strength, low-alloy pressure vessel steels, such as ASTM A 302 Gr. B and HSLA steels and Mn-Mo castings, such as ASTM A 49, A 291, and A 735.

A7.16.4 EXXTX-XXX-KX (Various Low-Alloy Steel Type) Electrodes. This group of electrodes produces weld metal of several different chemical compositions. These electrodes are primarily intended for as-welded applications.

A7.16.4.1 EXXTX-XXX-K1 Electrodes. Electrodes of this classification produce weld metal with nominally 1% Ni and 0.5% Mo. These electrodes may also be used for long-term stress-relieved applications for welding low-alloy, high strength steels, in particular 1% nickel steels.

A7.16.4.2 EXXTX-XXX-K2 Electrodes. Electrodes of this classification produce weld metal which will have a chemical composition of 1.5% nickel and up to 0.35% Mo. These electrodes are used on many high-strength applications ranging from 80 ksi to 110 ksi [550 MPa to 760 MPa] minimum yield strength steels. Typical applications would include the welding of offshore structures and many structural applications where excellent low-temperature toughness is required. Steel welded would include HY-80, HY-100, ASTM A 710, ASTM A 514, and similar high-strength steels.

A7.16.4.3 EXXTX-XXX-K3 Electrodes. Electrodes of this type produce weld deposits with higher levels of Mn, nickel and Mo than the EXXTX-XXX-K2 types. They are usually higher in strength than the -K1 and -K2 types. Typical applications include the welding of HY-100 and ASTM A 514 steels.

A7.16.4.4 EXXTX-XXX-K4 Electrodes. Electrodes of this classification deposit weld metal similar to that of the -K3 electrodes, with the addition of approximately 0.5% Cr. The additional alloy provides the higher strength for many applications needing in excess of 120 ksi [830 MPa] tensile strength, such as armor plate.

A7.16.4.5 EXXTX-XXX-K5 Electrodes. Electrodes of this classification produce weld metal which is designed to match the mechanical properties of the steels such as SAE 4130 and 8630 after the weldment is quenched and tempered. The classification requirements stipulate only as-welded mechanical properties, therefore, the end user is encouraged to perform qualification testing.

A7.16.4.6 EXXTX-XXX-K6 Electrodes. Electrodes of this classification produce weld metal which utilizes less than 1% nickel to achieve excellent toughness in the 60 ksi and 70 ksi [430 MPa and 490 MPa] tensile strength ranges. Applications include structural, offshore construction, and circumferential pipe welding.

A7.16.4.7 EXXTX-XXX-K7 Electrodes. This electrode classification produces weld metal which has similarities to that produced with EXXTX-XXX-Ni2 and EXXTX-XXX-Ni3 electrodes. This weld metal has approximately 1.5% manganese and 2.5% Ni. The weld metal for K7 allows for a higher alloying content of % Mn compared to the weld metal for Ni2/Ni3, which is useful for higher strength applications.

A7.16.4.8 EXXTX-XXX-K8 Electrodes. This classification was designed for electrodes intended for use in circumferential girth welding of line pipe. The weld deposit contains approximately 1.5% Mn, 1% Ni, and small quantities of other alloys. It is especially intended for use on API 5L X80 pipe steels.

A7.16.4.9 EXXTX-XXX-K9 Electrodes. These electrodes produce weld metal similar to that of the -K2 and -K3 type electrodes, but are intended to be similar to the military requirements of MIL-101TM and MIL-101TC electrodes in MIL-E-24403/2C. Theses electrodes are designed for welding HY-80 steel.

A7.16.4.10 EXXTX-XXX-K10 Electrodes. Electrodes of this classification produce weld metal which has similarities to that produced with EXXTX-XXX-Ni2 and EXXTX-XXX-Ni3 electrodes. The K10 weld metal has approximately 1.8% Mn, 2.0% Ni, up to 0.5% Mo, and up to 0.2% Cr. These electrodes are used on high-strength steel applications with minimum yield strength requirements of 80 ksi to 120 ksi [550 MPa to 830 MPa].

A7.16.4.11 EXXTX-XXX-K11 Electrodes. Electrodes of this classification produce weld metal similar to that of the -K6 type electrodes, but are intended for higher strength applications. Applications include structural, offshore construction and sour gas circumferential pipe welding where controlling Ni contents to 1% maximum is important.

A7.16.5 EXXTX-XXX-NiX (Ni-steel) Electrodes. These electrodes have been designed to produce weld metal with increased strength (without being air-hardenable) or with increased notch toughness at temperatures as low as –100°F [–73°C]. They have been specified with nickel contents which fall into three nominal levels of 1% nickel, 2% nickel, and 3% nickel in steel.

With carbon levels up to 0.12%, the strength increases and permits some of the Ni-steel electrodes to be classified as E8XTX-XXX-NiX [E55XTX-XXX-NiX] and E9XTX-XXX-NiX [E62XTX-XXX-NiX]. However, some classifications may produce low-temperature notch toughness to match the base metal properties of nickel steels, such as ASTM A 203 Gr. A and ASTM A 352 Grades LC1 and LC2. The manufacturer should be consulted for specific Charpy V-Notch impact properties. Typical base metals would also include ASTM A 302 and A 734.

Many low-alloy steels require postweld heat treatment to stress relieve the weld or temper the weld metal and heat-affected zone (HAZ) to achieve increased ductility. For most applications the holding temperature should not exceed the maximum temperature given in Table 7 for the classification considered, since nickel steels can be embrittled at higher temperatures. Higher PWHT holding temperatures may be acceptable for some applications. For many other applications, nickel steel weld metal can be used without PWHT.

Electrodes of the EXXTX-NiXX type are often used in structural applications where excellent toughness (Charpy V-Notch or CTOD) is required.

A7.16.6 EXXTX-XXX-W2 (Weathering Steel) Electrodes. These electrodes have been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels. These special properties are achieved by the addition of about 0.5% Cu to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, some Cr and Ni additions are also made. These electrodes are used to weld typical weathering steel, such as ASTM A 242, ASTM A 588, and ASTM A 709 Grade 50W.

A7.16.7 EXXTX-XXX-G (General Low-Alloy Steel) Electrodes. These electrodes are described in A2.3. These electrode classifications may be either modifications of other discrete classifications or totally new classifications. The purchaser and user should determine the description and intended use of the electrode from the supplier.

A8. Special Tests

A8.1 It is recognized that supplementary tests may need to be conducted to determine the suitability of these welding electrodes for applications involving properties such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, wear resistance, and suitability for welding combinations of dissimilar metals, or for evaluating an electrode's positional usability characteristics. Supplemental requirements as agreed upon between purchaser and supplier may be added to the purchase order following the guidance of AWS A5.01M/A5.01 (ISO 14344 MOD).

A8.1.1 The fillet weld test is not required for the classification of an electrode under this specification. However, the fillet weld test can be used, as agreed upon between the purchaser and supplier, to assess the ability of an electrode to meet application requirements for positional usability and root penetration. Refer to AWS A4.5 (ISO 15792-3), *Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld.*

A8.2 Diffusible Hydrogen Test

A8.2.1 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, nor 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.

A8.2.2 As the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in the root beads), and toe or underbead cracks in the heat-affected zone.

A8.2.3 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.

A8.2.4 Most flux cored and metal cored electrodes deposit weld metal having diffusible hydrogen levels of less than 16 mL/100 g of deposited metal. For that reason, flux cored and metal cored electrodes are generally considered to be low hydrogen. However, some commercially available products will, under certain conditions, produce weld metal with diffusible hydrogen levels in excess of 16 mL/100 g of deposited metal. Therefore, it may be appropriate for certain applications to utilize the optional supplemental designators for diffusible hydrogen when specifying the flux cored or metal cored electrodes to be used.

A8.2.5 The use of a reference atmospheric condition during welding is necessitated because the arc is subject to atmospheric contamination when using either a self-shielded flux cored electrode or a gas-shielded flux cored or metal cored electrode. 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 and H2 levels. An electrode meeting the H4 or H2 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.

A8.2.6 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator. The welding consumable is not the only source of diffusible hydrogen in the welding process. In actual practice, the following may contribute to the hydrogen content of the finished weldment.

(1) *Surface Contamination.* Rust, primer coating, anti-spatter compounds, dirt and grease can all contribute to diffusible hydrogen levels in practice. Consequently, standard diffusible hydrogen tests for classification of welding consumables require test material to be free of contamination. AWS A4.3 is specific as to the cleaning procedure for test material.

(2) *Atmospheric Humidity.* The welding arc is subject to atmospheric contamination when using either a self-shielded or gas shielded welding consumable. Moisture from the air, distinct from that in the welding consumable, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. AWS A4.3 has established a reference atmospheric condition at which the contribution to diffusible hydrogen from atmospheric humidity is considered to be negligible. This influence of atmospheric humidity also can be minimized by maintaining as short an arc length as possible consistent with a steady arc. For flux cored electrodes, arc length is controlled primarily by arc voltage. Experience has shown that the effect of arc length is minor at the H16 level, but can be very significant at the H4 level.

(3) *Shielding Gas.* The reader is cautioned that the shielding gas itself can contribute significantly to diffusible hydrogen. Normally, welding grade shielding gases are intended to have very low dew points and very low impurity levels. This, however, is not always the case. Instances have occurred where a contaminated gas cylinder resulted in a significant increase of diffusible hydrogen in the weld metal. Further, moisture permeation through some hoses and moisture condensation in unused gas lines can become a source of diffusible hydrogen during welding. In case of doubt, a check of gas dew point is suggested. A dew point of –40°F [–40°C] or lower is considered satisfactory for most applications.

(4) *Absorbed/Adsorbed Moisture.* Flux cored and metal cored electrodes can absorb/adsorb moisture over time which contributes to diffusible hydrogen levels. This behavior is well documented for shielded metal arc electrode coverings exposed to the atmosphere. Hydration of oxide films and lubricants on solid electrode surfaces under what may be con-

sidered “normal” storage conditions has also been reported to influence diffusible hydrogen. Moisture absorption/adsorption can be particularly significant if material is stored in a humid environment in damaged or open packages, or if unprotected for long periods of time. In the worst case of high humidity, even overnight exposure of unprotected electrodes can lead to a significant increase of diffusible hydrogen. For these reasons, indefinite periods of storage should be avoided. The storage and handling practices necessary to safeguard the condition of a welding consumable will vary from one product to another even within a given classification. Therefore, the consumable manufacturer should always be consulted for recommendations on storage and handling practice. In the event the electrode has been exposed, the manufacturer should be consulted regarding probable damage to its controlled hydrogen characteristics and possible reconditioning of the electrode.

(5) *Effect of Welding Process Variables.* Variations in welding process variables (e.g., amperage, voltage, contact tip to work distance, type of shielding gas, current type/polarity, single electrode vs. multiple electrode welding, etc.) are all reported to influence diffusible hydrogen test results in various ways. For example, with respect to contact tip to work distance, a longer CTWD will promote more preheating of the electrode, causing some removal of hydrogen-bearing compounds (e.g., moisture, lubricants, etc.) before they reach the arc. Consequently, the result of longer CTWD can be to reduce diffusible hydrogen. However, excessive CTWD with external gas shielded welding processes may cause some loss of shielding if the contact tip is not adequately recessed in the gas cup. If shielding is disturbed, more air may enter the arc and increase the diffusible hydrogen. This may also cause porosity due to nitrogen pickup.

Since welding process variables can have a significant effect on diffusible hydrogen test results, it should be noted that an electrode meeting the H4 requirements, for example, under the classification test conditions should not be expected to do so consistently under all welding conditions. Some variation should be expected and accounted for when making welding consumable selections and establishing operating ranges in practice.

A8.2.7 As indicated in A8.2.6(5), the welding procedures used with flux cored and metal cored electrodes will influence the values obtained on a diffusible hydrogen test. To address this, the AWS A5M Subcommittee has incorporated into its specification test procedure requirements for conducting the diffusible hydrogen test when determining conformance to the hydrogen optional supplemental designator requirements shown in Table 13. See Clause 15. The following is provided as an example.

EXAMPLE: Manufacturer ABC, an electrode manufacturer, recommends and/or publishes the following procedure range for its E81T1-M21XX-K2 electrode.

Electrode Diameter	Shielding Gas	Wire Feed Rate in/min [cm/min]	Arc Voltage (volts)	CTWD in [mm]	Deposition Rate lbs/hr [kg/hr]
0.045 in [1.2 mm]	80 Ar/20 CO_2	175–300 [445–760]	21–25	1/2–3/4 [12–20]	3.3–5.8 [1.5–2.6]
		300–425 [760–1080]	24–28	5/8–7/8 [16–22]	5.8–8.1 [2.6–3.7]
		425–550 [1080–1400]	27–30	3/4–1 [20–25]	8.1–10.5 [3.7-4.8]
1/16 in [1.6 mm]	80 Ar/20 CO_2	150–225 [380–570]	22–25	3/4–1 [20–25]	5.4–8.0 [2.5–3.6]
		225–300 [570–760]	24–27	7/8–1-1/8 [22–29]	8.0–10.8 [3.6–4.9]
		300–375 [760–950]	26–31	1–1-1/4 [25–32]	10.8–12.2 [4.9–5.5]

Based upon the manufacturer’s recommended operating range, the minimum wire feed rate and the CTWD to be used for hydrogen testing are as follows:

1. For 0.045 in [1.2 mm] diameter the minimum wire feed rate (WFR_{min}) to be used for the hydrogen test, as specified in 15.2, is WFR_{min} = 175 in/min + 0.75 (550 in/min – 175 in/min) = 456 in/min. [WFR_{min}= 445 cm/min + 0.75 (1400 cm/min – 445 cm/min) = 1160 cm/min].

   The CTWD to be used for the hydrogen test is 3/4 in [20 mm], the minimum CTWD recommended by the manufacturer for the test wire feed rate of 456 in/min [1160 cm/min].

2. For 1/16 in [1.6mm] diameter the minimum wire feed rate (WFR_{min}) to be used for the hydrogen test, as specified in 15.2, is WFR_{min} = 150 in/min +0.75 (375 in/min – 150 in/min) = 319 in/min [WFR_{min} = 380 cm/min + 0.75 (950 cm/min – 380 cm/min) = 808 cm/min].

   The CTWD to be used for the hydrogen test is 1 in [25 mm], the minimum CTWD recommended by the manufacturer for the test wire feed rate of 319 in/min [808 cm/min].

A8.2.8 All classifications may not be available in the H16, H8, H4, or H2 diffusible hydrogen levels. The manufacturer of a given electrode should be consulted for availability of products meeting these limits.

A8.3 Aging of Tensile Specimens. Weld metals may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases toward its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. The A5.36/A5.36M specifications permit the aging of the tensile test specimens at elevated temperatures not exceeding 220°F [105°C] for up to 48 hours before cooling them to room temperature and subjecting them to tension testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing.

Aging treatments are sometimes used for low hydrogen electrode deposits, especially when testing high strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a high 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. 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 (ISO 14344 MOD).

A9. Discontinued Classifications

The EXXT-2X classification has been discontinued. Flux cored electrodes previously utilizing the "2" Usability Designator to indicate a single pass electrode can now be classified utilizing the open classification system introduced in this specification. The EXXT-13 electrode classification has been discontinued due to lack of commercial significance. With the exception of the classifications shown in Table 1, the classifications listed in the left hand columns of Tables A.1, A.2, and A.3 will be discontinued.

The equivalent classifications for these electrodes utilizing the open classification system in this specification are also noted in these tables. The classification systems used in A5.20/A5.20M, A5.29/A5.29M, A5.18/A5.18M, and A5.28/A5.28M are given below for comparison purposes.

A9.1 The classification system for AWS A5.20/A5.20M:2005, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, is as follows:

$$\mathbf{E^1X^2X^3T^4 - X^5X^6 - J^7X^8HX^9}$$

where:

1. "E" designates an electrode.
2. Tensile strength designator (one or two digits are used).
3. Position designator.
4. "T" identifies the electrode as a flux cored electrode.
5. Usability designator.
6. Shielding gas designator. No designator is used for self-shielded electrodes.
7. "J" is an optional supplemental designator indicating improved toughness.
8. "D" or "Q" is an optional supplemental designator indicating conformance to supplemental mechanical property requirements under slow cooling and fast cooling welding parameters.
9. "HX" is an optional supplemental diffusible hydrogen designator.

Table A.1
Existing A5.20/A5.20M[a] Classifications and Equivalent A5.36/A5.36M Classifications Utilizing the Open Classification System

	A5.20/A5.20M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]		A5.20/A5.20M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]
1	E7XT-1C [E49XT-1C]	E7XT1-C1A0-CS1 [E49XT1-C1A2-CS1]	12	E7XT-8-J [E49XT-8-J]	E7XT8-A4-CS3 [E49XT8-A4-CS3]
2	E7XT-1M [E49XT-1M]	E7XT1-M21A0-CS1 [E49XT1-M21A2-CS1]	13	E7XT-9C [E49XT-9C]	E7XT1-C1A2-CS1[c] [E49XT1-C1A3-CS1][c]
3	E7XT-2C [E49XT-2C]	E7XT1S-C1 [E49XT1S-C1]	14	E7XT-9M [E49XT-9M]	E7XT1-M21A2-CS1[c] [E49XT1-M21A3-CS1][c]
4	E7XT-2M [E49XT-2M]	E7XT1S-M21 [E49XT1S-M21]	15	E7XT-10 [E49XT-10]	E7XT10S [E49XT10S]
5	E7XT-3 [E49XT-3]	E7XT3S [E49XT3S]	16	E7XT-11 [E49XT-11]	E7XT11-AZ-CS3 [E49XT11-AZ-CS3]
6	E7XT-4 [E49XT-4]	E7XT4-AZ-CS3 [E49XT4-AZ-CS3]	17	E7XT-12C [E49XT-12C]	E7XT1-C1A2-CS2 [E49XT1-C1A3-CS2]
7	E7XT-5C [E49XT-5C]	E7XT5-C1A2-CS1 [E49XT5-C1A3-CS1]	18	E7XT-12M [E49XT-12M]	E7XT1-M21A2-CS2 [E49XT1-M21A3-CS2]
8	E7XT-5M [E49XT-5M]	E7XT5-M21A2-CS1 [E49XT5-M21A3-CS1]	19	E7XT-12M-J [49XT-12M-J]	E7XT1-M21A4-CS2[d] [E49XT1-M21A4-CS2][d]
9	E7XT-6 [E49XT-6]	E7XT6-A2-CS3 [E49XT6-A3-CS3]	20	E6XT-13 [E43XT-13]	The EXXT-13 electrode type is obsolete
10	E7XT-7 [E49XT-7]	E7XT7-AZ-CS3 [E49XT7-AZ-CS3]	21	E7XT-13 [E49XT-13]	
11	E7XT-8 [E49XT-8]	E7XT8-A2-CS3 [E49XT8-A3-CS3]	22	E7XT-14 [E49XT-14]	E7XT14S [E49XT14S]

[a] *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*.

[b] The "X" which appears as part of the electrode designations in this table represents the Position Designator. A "1" in this position indicates that the electrode has all position capabilities. A "0" indicates that the electrode is intended for flat and horizontal positions only. See Figure 1.

[c] The new open classification system utilized in this document eliminates the need for a "T9" electrode type. The "T9" is essentially a "T1" type electrode with Charpy impact requirements at –20°F [–30°C] instead of at 0°F [–20°C]. Under the new classification system this difference is indicated by the use of different Impact Designators.

[d] The new classification system utilized in this document eliminates the need for the "J" optional supplemental designator. The "J" designator in A5.20/A5.20M:2005 required the test temperature for impact toughness to be –40°F [–40°C]. Under the new classification System the impact designator "4" is used to indicate the –40°F [–40°C] test temperature.

Table A.2
Existing A5.29/A5.29M[a] Classifications and Equivalent A5.36/A5.36M Classifications Utilizing the Open Classification System

	A5.29/A5.29M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]		A5.29/A5.29M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]
1	E7XT5-A1C [E49XT5-A1C]	E7XT5-C1P2-A1 [E49XT5-C1P3-A1]	23	E9XT1-B3HC [E62XT1-B3HC]	E9XT1-C1PZ-B3H [E62XT1-C1PZ-B3H]
2	E7XT5-A1M [E49XT5-A1M]	E7XT5-M21P2-A1 [E49XT5-M21P3-A1]	24	E9XT1-B3HM [E62XT1-B3HM]	E9XT1-M21PZ-B3H [E62XT1-M21PZ-B3H]
3	E8XT1-A1C [E55XT1-A1C]	E8XT1-C1PZ-A1 [E55XT1-C1PZ-A1]	25	E9XT5-B3C [E62XT5-B3C]	E9XT5-C1PZ-B3 [E62XT5-C1PZ-B3]
4	E8XT1-A1M [E55XT1-A1M]	E8XT1-M21PZ-A1 [E55XT1-M21PZ-A1]	26	E9XT5-B3M [E62XT5-B3M]	E9XT5-M21PZ-B3 [E62XT5-M21PZ-B3]
5	E8XT1-B1C [E55XT1-B1C]	E8XT1-C1PZ-B1 [E55XT1-C1PZ-B1]	27	E10XT1-B3C [E69XT1-B3C]	E10XT1-C1PZ-B3 [E69XT1-C1PZ-B3]
6	E8XT1-B1M [E55XT1-B1M]	E8XT1-M21PZ-B1 [E55XT1-M21PZ-B1]	28	E10XT1-B3M [E69XT1-B3M]	E10XT1-M21PZ-B3 [E69XT1-M21PZ-B3]
7	E8XT1-B1LC [E55XT1-B1LC]	E8XT1-C1PZ-B1L [E55XT1-C1PZ-B1L]	29	E8XT1-B6C [E55XT1-B6C]	E8XT1-C1PZ-B6 [E55XT1-C1PZ-B6]
8	E8XT1-B1LM [E55XT1-B1LM]	E8XT1-M21PZ-B1L [E55XT1-M21PZ-B1L]	30	E8XT1-B6M [E55XT1-B6M]	E8XT1-M21PZ-B6 [E55XT1-M21PZ-B6]
9	E8XT1-B2C [E55XT1-B2C]	E8XT1-C1PZ-B2 [E55XT1-C1PZ-B2]	31	E8XT1-B6LC [E55XT1-B6LC]	E8XT1-C1PZ-B6L [E55XT1-C1PZ-B6L]
10	E8XT1-B2M [E55XT1-B2M]	E8XT1-M21PZ-B2 [E55XT1-M21PZ-B2]	32	E8XT1-B6LM [E55XT1-B6LM]	E8XT1-M21PZ-B6L [E55XT1-M21PZ-B6L]
11	E8XT1-B2HC [E55XT1-B2HC]	E8XT1-C1PZ-B2H [E55XT1-C1PZ-B2H]	33	E8XT5-B6C [E55XT5-B6C]	E8XT5-C1PZ-B6 [E55XT5-C1PZ-B6]
12	E8XT1-B2HM [E55XT1-B2HM]	E8XT1-M21PZ-B2H [E55XT1-M21PZ-B2H]	34	E8XT5-B6M [E55XT5-B6M]	E8XT5-M21PZ-B6 [E55XT5-M21PZ-B6]
13	E8XT1-B2LC [E55XT1-B2LC]	E8XT1-C1PZ-B2L [E55XT1-C1PZ-B2L]	35	E8XT5-B6LC [E55XT5-B6LC]	E8XT5-C1PZ-B6L [E55XT5-C1PZ-B6L]
14	E8XT1-B2LM [E55XT1-B2LM]	E8XT1-M21PZ-B2L [E55XT1-M21PZ-B2L]	36	E8XT5-B6LM [E55XT5-B6LM]	E8XT5-M21PZ-B6L [E55XT5-M21PZ-B6L]
15	E8XT5-B2C [E55XT5-B2C]	E8XT5-C1PZ-B2 [E55XT5-C1PZ-B2]	37	E8XT1-B8C [E55XT1-B8C]	E8XT1-C1PZ-B8 [E55XT1-C1PZ-B8]
16	E8XT5-B2M [E55XT5-B2M]	E8XT5-M21PZ-B2 [E55XT5-M21PZ-B2]	38	E8XT1-B8M [E55XT1-B8M]	E8XT1-M21PZ-B8 [E55XT1-M21PZ-B8]
17	E8XT5-B2LC [E55XT5-B2LC]	E8XT5-C1PZ-B2L [E55XT5-C1PZ-B2L]	39	E8XT1-B8LC [E55XT1-B8LC]	E8XT1-C1PZ-B8L [E55XT1-C1PZ-B8L]
18	E8XT5-B2LM [E55XT5-B2LM]	E8XT5-M21PZ-B2L [E55XT5-M21PZ-B2L]	40	E8XT1-B8LM [E55XT1-B8LM]	E8XT1-M21PZ-B8L [E55XT1-M21PZ-B8L]
19	E9XT1-B3C [E62XT1-B3C]	E9XT1-C1PZ-B3 [E62XT1-C1PZ-B3]	41	E8XT5-B8C [E55XT5-B8C]	E8XT5-C1PZ-B8 [E55XT5-C1PZ-B8]
20	E9XT1-B3M [E62XT1-B3M]	E9XT1-M21PZ-B3 [E62XT1-M21PZ-B3]	42	E8XT5-B8M [E55XT5-B8M]	E8XT5-M21PZ-B8 [E55XT5-M21PZ-B8]
21	E9XT1-B3LC [E62XT1-B3LC]	E9XT1-C1PZ-B3L [E62XT1-C1PZ-B3L]	43	E8XT5-B8LC [E55XT5-B8LC]	E8XT5-C1PZ-B8L [E55XT5-C1PZ-B8L]
22	E9XT1-B3LM [E62XT1-B3LM]	E9XT1-M21PZ-B3L [E62XT1-M21PZ-B3L]	44	E8XT5-B8LM [E55XT5-B8LM]	E8XT5-M21PZ-B8L [E55XT5-M21PZ-B8L]

(Continued)

Table A.2 (Continued)
Existing A5.29/A5.29M[a] Classifications and Equivalent A5.36/A5.36M Classifications Utilizing the Open Classification System

	A5.29/A5.29M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]		A5.29/A5.29M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]
45	E9XT1-B9C[c] [E62XT1-B9C][c]	E9XT1-C1PZ-B91 [E62XT1-C1PZ-B91] or E10XT1-C1PZ-B91 [E69XT1-C1PZ-B91]	65	E8XT5-Ni3M [E55XT5-Ni3M]	E8XT5-M21P10-Ni3 [E55XT5-M21P7-Ni3]
46	E9XT1-B9M[c] [E62XT1-B9M][c]	E9XT1-M21PZ-B91 [E62XT1-M21PZ-B91] or E10XT1-M21PZ-B91 [E69XT1-M21PZ-B91]	66	E9XT5-Ni3C [E62XT5-Ni3C]	E9XT5-C1P10-Ni3 [E62XT5-C1P7-Ni3]
47	E6XT1-Ni1C [E43XT1-Ni1C]	E6XT1-C1A2-Ni1 [E43XT1-C1A3-Ni1]	67	E9XT5-Ni3M [E62XT5-Ni3M]	E9XT5-M21P10-Ni3 [E62XT5-M21P7-Ni3]
48	E6XT1-Ni1M [E43XT1-Ni1M]	E6XT1-M21A2-Ni1 [E43XT1-M21A3-Ni1]	68	E8XT11-Ni3 [E55XT11-Ni3]	E8XT11-A0-Ni3 [E55XT11-A2-Ni3]
49	E7XT6-Ni1 [E49XT6-Ni1]	E7XT6-A2-Ni1 [E49XT6-A3-Ni1]	69	E9XT1-D1C [E62XT1-D1C]	E9XT1-C1A4-D1 [E62XT1-C1A4-D1]
50	E7XT8-Ni1 [E49XT8-Ni1]	E7XT8-A2-Ni1 [E49XT8-A3-Ni1]	70	E9XT1-D1M [E62XT1-D1M]	E9XT1-M21A4-D1 [E62XT1-M21A4-D1]
51	E8XT1-Ni1C [E55XT1-Ni1C]	E8XT1-C1A2-Ni1 [E55XT1-C1A3-Ni1]	71	E9XT5-D2C [E62XT5-D2C]	E9XT5-C1P6-D2 [E62XT5-C1P5-D2]
52	E8XT1-Ni1M-J [E55XT1-Ni1M-J]	E8XT1-M21A4-Ni1[d] [E55XT1-M21A4-Ni1][d]	72	E9XT5-D2M [E62XT5-D2M]	E9XT5-M21P6-D2 [E62XT5-M21P5-D2]
53	E8XT1-Ni1M [E55XT1-Ni1M]	E8XT1-M21A2-Ni1 [E55XT1-M21A3-Ni1]	73	E10XT5-D2C [E69XT5-D2C]	E10XT5-C1P4-D2 [E69XT5-C1P4-D2]
54	E8XT5-Ni1C [E55XT5-Ni1C]	E8XT5-C1P6-Ni1 [E55XT5-C1P5-Ni1]	74	E10XT5-D2M [E69XT5-D2M]	E10XT5-M21P4-D2 [E69XT5-M21P4-D2]
55	E8XT5-Ni1M [E55XT5-Ni1M]	E8XT5-M21P6-Ni1 [E55XT5-M21P5-Ni1]	75	E9XT1-D3C [E62XT1-D3C]	E9XT1-C1A2-D3 [E62XT1-C1A3-D3]
56	E7XT8-Ni2 [E49XT8-Ni2]	E7XT8-A2-Ni2 [E49XT8-A3-Ni2]	76	E9XT1-D3M [E62XT1-D3M]	E9XT1-M21A2-D3 [E62XT1-M21A3-D3]
57	E8XT8-Ni2 [E55XT8-Ni2]	E8XT8-A2-Ni2 [E55XT8-A3-Ni2]	77	E8XT5-K1C [E55XT5-K1C]	E8XT5-C1A4-K1 [E55XT5-C1A4-K1]
58	E8XT1-Ni2C [E55XT1-Ni2C]	E8XT1-C1A4-Ni2 [E55XT1-C1A4-Ni2]	78	E8XT5-K1M [E55XT5-K1M]	E8XT5-M21A4-K1 [E55XT5-M21A4-K1]
59	E8XT1-Ni2M [E55XT1-Ni2M]	E8XT1-M21A4-Ni2 [E55XT1-M21A4-Ni2]	79	E7XT7-K2 [E49XT7-K2]	E7XT7-A2-K2 [E49XT7-A3-K2]
60	E8XT5-Ni2C [E55XT5-Ni2C]	E8XT5-C1P8-Ni2 [E55XT5-C1P6-Ni2]	80	E7XT4-K2 [E49XT4-K2]	E7XT4-A0-K2 [E49XT4-A2-K2]
61	E8XT5-Ni2M [E55XT5-Ni2M]	E8XT5-M21P8-Ni2 [E55XT5-M21P6-Ni2]	81	E7XT8-K2 [E49XT8-K2]	E7XT8-A2-K2 [E49XT8-A3-K2]
62	E9XT1-Ni2C [E62XT1-Ni2C]	E9XT1-C1A4-Ni2 [E62XT1-C1A4-Ni2]	82	E7XT11-K2 [E49XT11-K2]	(e) [E49XT11-A0-K2]
63	E9XT1-Ni2M [E62XT1-Ni2M]	E9XT1-M21A4-Ni2 [E62XT1-M21A4-Ni2]	83	E8XT1-K2C [E55XT1-K2C]	E8XT1-C1A2-K2 [E55XT1-C1A3-K2]
64	E8XT5-Ni3C [E55XT5-Ni3C]	E8XT5-C1P10-Ni3 [E55XT5-C1P7-Ni3]	84	E8XT1-K2M [E55XT1-K2M]	E8XT1-M21A2-K2 [E55XT1-M21A3-K2]

(Continued)

Table A.2 (Continued)
Existing A5.29/A5.29M[a] Classifications and Equivalent A5.36/A5.36M Classifications Utilizing the Open Classification System

	A5.29/A5.29M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]		A5.29/A5.29M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]
85	E8XT5-K2C [E55XT5-K2C]	E8XT5-C1A2-K2] [E55XT5-C1A3-K2]	102	E11XT5-K4M [E76XT5-K4M]	E11XT5-M21A6-K4 [E76XT5-M21A5-K4]
86	E8XT5-K2M [E55XT5-K2M]	E8XT5-M21A2-K2 [E55XT5-M21A3-K2]	103	E12XT5-K4C [E83XT5-K4C]	E12XT5-C1A6-K4 [E83XT5-C1A5-K4]
87	E9XT1-K2C [E62XT1-K2C]	E9XT1-C1A0-K2 [E62XT1-C1A2-K2]	104	E12XT5-K4M [E83XT5-K4M]	E12XT5-M21A6-K4 [E83XT5-M21A5-K4]
88	E9XT1-K2M [E62XT1-K2M]	E9XT1-M21A0-K2 [E62XT1-M21A2-K2]	105	E12XT1-K5C [E83XT1-K5C]	E12XT1-C1AZ-K5 [E83XT1-C1AZ-K5]
89	E9XT5-K2C [E62XT5-K2C]	E9XT5-C1A6-K2 [E62XT5-C1A5-K2]	106	E12XT1-K5M [E83XT1-K5M]	E12XT1-M21AZ-K5 [E83XT1-M21AZ-K5]
90	E9XT5-K2M [E62XT5-K2M]	E9XT5-M21A6-K2 [E62XT5-M21A5-K2]	107	E7XT5-K6C [E49XT5-K6C]	E7XT5-C1A8-K6 [E49XT5-C1A6-K6]
91	E10XT1-K3C [E69XT1-K3C]	E10XT1-C1A0-K3 [E69XT1-C1A2-K3]	108	E7XT5-K6M [E49XT5-K6M]	E7XT5-M21A8-K6 [E49XT5-M21A6-K6]
92	E10XT1-K3M [E69XT1-K3M]	E10XT1-M21A0-K3 [E69XT1-M21A2-K3]	109	E6XT8-K6 [E43XT8-K6]	E6XT8-A2-K6 [E43XT8-A3-K6]
93	E10XT5-K3C [E69XT5-K3C]	E10XT5-C1A6-K3 [E69XT5-C1A5-K3]	110	E7XT8-K6 [E49XT8-K6]	E7XT8-A2-K6 [E49XT8-A3-K6]
94	E10XT5-K3M [E69XT5-K3M]	E10XT5-M21A6-K3 [E69XT5-M21A5-K3]	111	E10XT1-K7C [E69XT1-K7C]	E10XT1-C1A6-K7 [E69XT1-C1A5-K7]
95	E11XT1-K3C [E76XT1-K3C]	E11XT1-C1A0-K3 [E76XT1-C1A2-K3]	112	E10XT1-K7M [E69XT1-K7M]	E10XT1-M21A6-K7 [E69XT1-M21A5-K7]
96	E11XT1-K3M [E76XT1-K3M]	E11XT1-M21A0-K3 [E76XT1-M21A2-K3]	113	E9XT8-K8 [E62XT8-K8]	E9XT8-A2-K8 [E62XT8-A3-K8]
97	E11XT5-K3C [E76XT5-K3C]	E11XT5-C1A6-K3 [E76XT5-C1A5-K3]	114	E10XT1-K9C [E69XT1-K9C]	(f)
98	E11XT5-K3M [E76XT5-K3M]	E11XT5-M21A6-K3 [E76XT5-M21A5-K3]	115	E10XT1-K9M [E69XT1-K9M]	(f)
99	E11XT1-K4C [E76XT1-K4C]	E11XT1-C1A0-K4 [E76XT1-C1A2-K4]	116	E8XT1-W2C [E55XT1-W2C]	E8XT1-C1A2-W2 [E55XT1-C1A3-W2]
100	E11XT1-K4M [E76XT1-K4M]	E11XT1-M21A0-K4 [E76XT1-M21A2-K4]	117	E8XT1-W2M [E55XT1-W2M]	E8XT1-M21A2-W2 [E55XT1-M21A3-W2]
101	E11XT5-K4C [E76XT5-K4C]	E11XT5-C1A6-K4 [E76XT5-C1A5-K4]			

[a] *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*.

[b] The "X" which appears as part of the electrode designations in this table represents the Position Designator. A "1" in this position indicates that the electrode has all position capabilities. A "0" indicates that the electrode is intended for flat and horizontal positions only. See Figure 1.

[c] Under AWS A5.29/A5.29M, the tensile strength requirement for this classification is 90 ksi–120 ksi [620 MPa–830 MPa]

[d] The new classification system utilized in this document eliminates the need for "J" optional supplemental designator. The "J" designator in A5.29/A5.29M required the test temperature for impact toughness to be 20°F [10°C] lower than the –20°F [–30°C] normally required for this alloy. Under the new classification system an impact designator (in this example, "4" is used to indicate the –40°F [–40°C] toughness requirement).

[e] Under AWS A5.29/A5.29M:2005, the E7XT11-K2 electrode has an impact requirement of 20 ft·lbf @ +32°F. This document does not include a Charpy impact designator for that test temperature. As a result, there is no direct equivalent for the E7XT11-K2 electrode classification in Customary Units under this specification.

[f] Under AWS A5.29/A5.29M:2005, the E10XT1-K9C, -K9M [E69XT1-K9C, -K9M] electrode has an impact requirement of 35 ft·lbf @ –60°F [47 J @ –50°C]. This document does not include a provision for a 35 ft·lbf [47 J] impact strength level. As a result, there is no direct equivalent for this electrode under this specification.

Table A.3
Existing A5.18/A5.18M[a] and A5.28/A5.28M[b] Classifications and Equivalent A5.36/A5.36M Classifications Utilizing the Open Classification System

	A5.18/A5.18M Classifications	Equivalent Classifications Under A5.36 [A5.36M][c]		A5.28/A5.28M Classifications	Equivalent Classifications Under A5.36 [A5.36M][b]
1	E70C-3X [E48C-3X]	E7XT15-C1A0-CS1 or E7XT15-M21A0-CS1 [E49XT15-C1A2-CS1 or [E49XT15-M21A2-CS1]	9	E80C-Ni1 [E55C-Ni1]	E8XT15-M13A5-Ni1 or E8XT15-M22A5-Ni1[e]
2	E70C-6X [E48C-6X]	E7XT15-C1A2-CS1 or E7XT15-M21A2-CS1 [E49XT15-C1A3-CS1 or [E49XT15-M21A3-CS1]	10	E80C-Ni2 [E55C-Ni2]	E8XT15-M13P8-Ni2 or E8XT15-M22P8-Ni2 [E55XT15-M13P6-Ni2 or E55XT15-M22P6-Ni2]
	A5.28/A5.28M Classifications	Equivalent Classifications Under A5.36 [A5.36M][c]	11	E80C-Ni3 [E55C-Ni3]	E8XT15-M13P10-Ni3 or E8XT15-M22P10-Ni3[f]
1	E70C-B2Ld [E49C-B2Ld]	E7XT15-M13PZ-B2L or E7XT15-M22PZ-B2L [E49XT15-M13PZ-B2L or E49XT15-M22PZ-B2L]	12	E90C-D2 [E62C-D2]	E9XT15-M13A2-D2 or E9XT15-M22A2-D2 [E62XT15-M13A3-D2 or E62XT15-M22A3-D2]
2	E80C-B2 [E55C-B2]	E8XT15-M13PZ-B2 or E8XT15-M22PZ-B2 [E55XT15-M13PZ-B2 or E55XT15-M22PZ-B2]	13	E90C-K3 [E62C-K3]	E9XT15-M20A6-K3[h] [E62XT15-M20A5-K3][h]
3	E80C-B3L [E55C-B3L]	E8XT15-M13PZ-B3L or E8XT15-M22PZ-B3L [E55XT15-M13PZ-B3L or E55XT15-M22PZ-B3L]	14	E100C-K3 [E69C-K3]	E10XT15-M20A6-K3[h] [E69XT15-M20A5-K3][h]
4	E90C-B3 [E62C-B3]	E9XT15-M13PZ-B3 or E9XT15-M22PZ-B3 [E62XT15-M13PZ-B3 or E62XT15-M22PZ-B3]	15	E110C-K3 [E76C-K3]	E11XT15-M20A6-K3[h] [E76XT15-M20A5-K3][h]
5	E80C-B6 [E55C-B6]	E8XT15-M13PZ-B6 or E8XT15-M22PZ-B6 [E55XT15-M13PZ-B6 or E55XT15-M22PZ-B6]	16	E110C-K4 [E76C-K4]	E11XT15-M20A6-K4[h] [E76XT15-M20A5-K4][h]
6	E80C-B8 [E55C-B8]	E8XT15-M13PZ-B8 or E8XT15-M22PZ-B8 [E55XT15-M13PZ-B8 or E55XT15-M22PZ-B8]	17	E120C-K4 [E83C-K4]	E12XT15-M20A6-K4[h] [E83XT15-M20A5-K4][h]
7	E90C-B9g [E62C-B9] g	E9XT15-M20PZ-B91[h] [E62XT15-M20PZ-B91][h] or E10XT15-M20PZ-B91[h] [E69XT15-M20PZ-B91][h]	18	E80C-W2 [E55C-W2]	E8XT15-M20A2-W2[h] [E55XT15-M20A3-W2][h]
8	E70C-Ni2 [E49C-Ni2]	E7XT15-M13P8-Ni2 or E7XT15-M22P8-Ni2 [E49XT15-M13P6-Ni2 or E49XT15-M22P6-Ni2]			

[a] *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding.*

[b] *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding.*

[c] The “X” which appears as part of the electrode designations in this table represents the Position Designator. A “1” in this position indicates that the electrode has all position capabilities. A “0” indicates that the electrode is intended for flat and horizontal positions only. See Figure 1.

[d] The minimum tensile requirement for this electrode classification specified in AWS A5.28/A5.28M is 75 000 psi [515 MPa]. The replacement classification listed for this electrode requires a minimum tensile of 70 000 psi [490 MPa].

[e] Under the International System of Units (SI) the Charpy impact requirement for this electrode type is 27 J @ –45°C. This document does not include an Impact Designator for that specific test temperature.

[f] In A5.28/A5.28M the Charpy impact requirement for this electrode in the International System of Units (SI) is 27 J @ –75°C. This document does not include an Impact Designator for that specific test temperature.

[g] Under AWS A5.28/A5.28M, the tensile strength requirement for this classification is 90 ksi [620 MPa] minimum.

[h] Under AWS A5.28/A5.28M, this electrode type was classified with an Argon/5%–25% CO_2 shielding gas (AWS A5.32/A5.32M types SG-AC-5 through SG-AC-25). Therefore, the replacement classification may be either this classification or one with M21 shielding gas substituted for the M20 shielding gas.

A9.2 The classification system for AWS A5.29/A5.29M:2005, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*, is as follows:

$\mathbf{E^1X^2X^3T^4X^5 – X^6X^7 – J^8HX^9}$

where:

1. "E" designates an electrode.
2. Tensile strength designator (one or two digits are used).
3. Position designator.
4. "T" identifies the electrode as a flux cored electrode.
5. Usability designator.
6. Deposit composition designator.
7. Shielding gas designator.
8. "J" is an optional supplemental designator indicating improved toughness.
9. "HX" is an optional supplemental diffusible hydrogen designator.

A9.3 The classification system for AWS A5.18/A5.18M:2005, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, is as follows:

$\mathbf{E^1X^2C^3 – X^4Y^5HZ^6}$

where:

1. "E" designates an electrode.
2. Tensile strength designator (two digits).
3. "C" indicates a composite (metal cored) electrode.
4. Indicates composition of weld metal produced by the composite electrode.
5. Shielding gas designator. "C" in this position indicates a 100% CO_2 shielding gas. An "M" in this position indicates a 75–80% Argon/balance CO_2 shielding gas.
6. "HZ" is an optional supplemental diffusible hydrogen designator.

A9.4 The classification system for AWS A5.28/A5.28M:2005, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, is as follows:

$\mathbf{E^1X^2C^3 – X^4HZ^5}$

where:

1. "E" designates an electrode.
2. Tensile strength designator (two digits).
3. "C" indicates a composite (metal cored) electrode.
4. Indicates composition of weld metal produced by the composite electrode.
5. "HZ" is an optional supplemental diffusible hydrogen designator.

NOTE: There is no designator for shielding gas in A5.28/A5.28M. The shielding gas to be used for classification is specified in Table 3 of this specification.

A10. General Safety Considerations

A10.1 Safety issues and concerns are addressed in this standard, although health issues and concerns are beyond the scope of this standard. Some safety and health information can be found in Annex 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.l, and applicable federal and state regulations.

A10.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)[12]

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 Welding 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*

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[12] AWS standards are published by American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

MANDATORY APPENDIX I
STANDARD UNITS FOR USE IN EQUATIONS

Table I-1
Standard Units for Use in Equations

Quantity	U.S. Customary Units	SI Units
Linear dimensions (e.g., length, height, thickness, radius, diameter)	inches (in.)	millimeters (mm)
Area	square inches (in.^{2})	square millimeters (mm^{2})
Volume	cubic inches (in.^{3})	cubic millimeters (mm^{3})
Section modulus	cubic inches (in.^{3})	cubic millimeters (mm^{3})
Moment of inertia of section	inches^{4} (in.^{4})	millimeters^{4} (mm^{4})
Mass (weight)	pounds mass (lbm)	kilograms (kg)
Force (load)	pounds force (lbf)	newtons (N)
Bending moment	inch-pounds (in.-lb)	newton-millimeters (N·mm)
Pressure, stress, stress intensity, and modulus of elasticity	pounds per square inch (psi)	megapascals (MPa)
Energy (e.g., Charpy impact values)	foot-pounds (ft-lb)	joules (J)
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)
Absolute temperature	Rankine (°R)	kelvin (K)
Fracture toughness	ksi square root inches (ksi $\sqrt{\text{in.}}$)	MPa square root meters (MPa $\text{MPa}\sqrt{\text{m}}$)
Angle	degrees or radians	degrees or radians
Boiler capacity	Btu/hr	watts (W)

INTENTIONALLY LEFT BLANK

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