

**AWS A5.16/A5.16M:2013
(ISO 24034:2010 MOD)
An American National Standard**



Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods



American Welding Society®



**AWS A5.16/A5.16M: 2013 (ISO 24034:2010 MOD)
An American National Standard**

**Approved by the
American National Standards Institute
February 19, 2013**

Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods

6th Edition

Supersedes AWS A5.16/A5.16M:2007

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

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification prescribes the requirements for the classification of over 30 titanium and titanium-alloy welding electrodes and rods. Classification is based upon the chemical composition of the electrode. Major topics include general requirements, testing, packaging, and application guidelines.

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

This specification adopts the requirements of ISO 24034 and incorporates the provisions of earlier versions of A5.16/A5.16M, allowing for classifications under both specifications.



International Standard Book Number: 978-0-87171-834-1
American Welding Society
8669 Doral Blvd., Suite 130, Doral, FL 33166
© 2013 by American Welding Society
All rights reserved
Printed in the United States of America

Photocopy Rights. No portion of this standard may be reproduced, stored in a retrieval system, or transmitted in any form, including mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright owner.

Authorization to photocopy items for internal, personal, or educational classroom use only or the internal, personal, or educational classroom use only of specific clients is granted by the American Welding Society provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, tel: (978) 750-8400; Internet: <www.copyright.com>.

Statement on the Use of American Welding Society Standards

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society (AWS) are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute (ANSI). When AWS American National Standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

AWS American National Standards are developed through a consensus standards development process that brings together volunteers representing varied viewpoints and interests to achieve consensus. While AWS administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its standards.

AWS disclaims liability for any injury to persons or to property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this standard. AWS also makes no guarantee or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this standard available, AWS is neither undertaking to render professional or other services for or on behalf of any person or entity, nor is AWS undertaking to perform any duty owed by any person or entity to someone else. Anyone using these documents should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. It is assumed that the use of this standard and its provisions is entrusted to appropriately qualified and competent personnel.

This standard may be superseded by new editions. This standard may also be corrected through publication of amendments or errata, or supplemented by publication of addenda. Information on the latest editions of AWS standards including amendments, errata, and addenda is posted on the AWS web page (www.aws.org). Users should ensure that they have the latest edition, amendments, errata, and addenda.

Publication of this standard does not authorize infringement of any patent or trade name. Users of this standard accept any and all liabilities for infringement of any patent or trade name items. AWS disclaims liability for the infringement of any patent or product trade name resulting from the use of this standard.

AWS does not monitor, police, or enforce compliance with this standard, nor does it have the power to do so.

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the appropriate technical committee. Such requests should be addressed to the American Welding Society, Attention: Managing Director, Technical Services Division, 8669 Doral Blvd., Suite 130, Doral, FL 33166 (see Annex E). With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. These opinions are offered solely as a convenience to users of this standard, and they do not constitute professional advice. Such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS A5 Committee on Filler Metals and Allied Materials. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are required and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS A5 Committee on Filler Metals and Allied Materials and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS A5 Committee on Filler Metals and Allied Materials to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

This page is intentionally blank.

Personnel

AWS A5 Committee on Filler Metals and Allied Materials

H. D. Wehr, Chair	<i>Arcos Industries, LLC</i>
J. J. DeLoach Jr., 1st Vice Chair	<i>Naval Surface Warfare Center</i>
R. D. Fuchs, 2nd Vice Chair	<i>Bohler Welding Group USA, Incorporated</i>
R. K. Gupta, Secretary	<i>American Welding Society</i>
T. Anderson	<i>ITW Welding North America</i>
J. M. Blackburn	<i>Naval Sea Systems Command</i>
J. C. Bundy	<i>Hobart Brothers Company</i>
J. L. Caron	<i>Haynes International, Incorporated</i>
D. D. Crockett	<i>Consultant</i>
R. V. Decker	<i>Weldstar</i>
D. A. DelSignore	<i>Consultant</i>
H. W. Ebert	<i>Consultant</i>
D. M. Fedor	<i>The Lincoln Electric Company</i>
J. G. Feldstein	<i>Foster Wheeler North America</i>
S. E. Ferree	<i>ESAB Welding and Cutting Products</i>
D. A. Fink	<i>The Lincoln Electric Company</i>
G. L. Franke	<i>Naval Surface Warfare Center</i>
R. M. Henson	<i>Harris Products Group</i>
S. D. Kiser	<i>Special Metals</i>
P. J. Konkol	<i>Concurrent Technologies Corporation</i>
D. J. Kotecki	<i>Damian Kotecki Welding Consultants</i>
L. G. Kvidahl	<i>Ingalls Shipbuilding</i>
A. Y. Lau	<i>Canadian Welding Bureau</i>
J. S. Lee	<i>Chevron</i>
T. Melfi	<i>The Lincoln Electric Company</i>
M. T. Merlo	<i>RevWires, LLC</i>
K. M. Merlo-Joseph	<i>EWI</i>
B. Mosier	<i>Polymet Corporation</i>
A. K. Mukherjee	<i>Siemens Energy, Inc.</i>
T. C. Myers	<i>Oceaneering Intervention Engineering</i>
C. L. Null	<i>Consultant</i>
B. A. Pletcher	<i>Select-Arc</i>
K. C. Pruden	<i>BP America</i>
K. Roossinck	<i>Ingalls Shipbuilding</i>
P. K. Salvesen	<i>Det Norske Veritas (DNV)</i>
K. Sampath	<i>Consultant</i>
W. S. Severance	<i>ESAB Welding and Cutting Products</i>
M. F. Sinfield	<i>Naval Surface Warfare Center</i>
M. J. Sullivan	<i>NASSCO-National Steel and Shipbuilding</i>
R. C. Sutherlin	<i>ATI Wah Chang</i>
M. D. Tumuluru	<i>US Steel Corporation</i>
J. Zhang	<i>Indalco Alloys-Lincoln Electric</i>

Advisors to the AWS A5 Committee on Filler Metals and Allied Materials

R. Bateman	<i>Soldaduras West Arco SAS</i>
J. E. Beckham	<i>Chrysler Group, LLC</i>
M. L. Caruso	<i>Special Metals Welding Products Company</i>
R. A. Daemen	<i>Consultant</i>

B. S. Dauble	<i>Carpenter Technology Corporation</i>
T. A. Davenport	<i>PRL Industries</i>
J. DeVito	<i>Consultant</i>
C. E. Fuerstenau	<i>Lucas-Milhaupt, Incorporated</i>
J. P. Hunt	<i>Consultant</i>
S. Imaoka	<i>KOBE Steel, Ltd.</i>
S. J. Knostman	<i>Hobart Brothers</i>
W. A. Martilla	<i>WAMcom Consulting, LLC</i>
R. Menon	<i>Stoody Company</i>
M. P. Parekh	<i>Consultant</i>
J. W. Price	<i>DMI Industries</i>
M. A. Quintana	<i>The Lincoln Electric Company</i>
E. S. Surian	<i>National University of Lomas de Zamora</i>
H. J. White	<i>Consultant</i>

AWS A5K Subcommittee on Titanium and Zirconium Filler Metals

R.C. Sutherlin, Chair	<i>ATI Wah Chang</i>
A. L. Diaz, Secretary	<i>American Welding Society</i>
S. S. Delmore	<i>CK Worldwide, Incorporated</i>
H. Kotaki	<i>Japan Titanium Society</i>
B. Krueger	<i>Consultant</i>
K. T. Tran	<i>Naval Surface Warfare Center</i>
G. E. Trepus	<i>Boeing Research and Technology</i>

Advisors to the AWS A5K Subcommittee on Titanium and Zirconium Filler Metals

J. A. McMaster	<i>MC Consulting</i>
S. D. Sparkowich	<i>SABIC Innovative Plastics</i>

Foreword

This foreword 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.

This document is the first adoption of ISO 24034:2010: *Welding consumables – Solid wires and rods for arc welding of titanium and titanium-alloys – Classification*. With its insertion of references and additional informative annexes it replaces A5.16/A5.16M: 2007. The adoption of the modified ISO 24034, designated by MOD, is in accordance with ISO/IEC Guide 21-2005, Clause 4.3. All changes are listed in Annex F. The modifications to ISO 24034:2010 are also shown in *Italic* font.

Please note that ISO uses commas (,) and AWS uses periods (.) for decimals.

Document Development

The current specification is the sixth edition of the initial AWS/ASTM document issued in 1961 as shown below:

AWS A5.16-61T ASTM B362-61T	<i>Tentative Specification for Titanium-Alloy Bare Welding Rods and Electrodes</i>
AWS A5.16-70 ANSI W3.16-1973	<i>Specification for Titanium and Titanium-Alloy Bare Welding Rods and Electrodes</i>
ANSI/AWS A5.16-90 ANSI/AWS A5.16-90R	<i>Specification for Titanium and Titanium-Alloy Bare Welding Rods and Electrodes</i> <i>Specification for Titanium and Titanium-Alloy Bare Welding Rods and Electrodes</i> , reaffirmed in 1997
AWS A5.16/A5.16M:2004	<i>Specification for Titanium and Titanium-Alloy Bare Welding Electrodes and Rods</i>
AWS A5.16/A5.16M:2007	<i>Specification for Titanium and Titanium-Alloy Bare Welding Electrodes and Rods</i>

Attention is drawn to the possibility that some of the elements of this part of ISO 24034 may be the subject of patent rights. AWS and ISO shall not be held responsible for identifying any or all such patent rights.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A5 Committee on Filler Metals and Allied Materials, American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

This page is intentionally blank.

Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	vii
<i>List of Tables</i>	x
1. General Requirements	1
1.1 Scope	1
1.2 Units of Measure	1
1.3 Safety	1
2. Normative References	1
3. Classification	2
4. Symbols and Requirements	2
4.1 Symbols for the Product Form	2
4.2 Symbol for the Chemical Composition	5
4.3 Rounding-Off Procedure	5
5. Mechanical Properties	5
6. Chemical Analysis	5
7. Retest	5
8. Technical Delivery Conditions	5
9. Designation	6
Annex A (Informative)—Explanation of Classification Symbols for Chemical Composition	7
Annex B (Informative)—Corresponding National Classifications	9
Annex C (Informative)—Informative References	11
National Annexes	13
Annex D (Informative)—Guide to AWS Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods	13
Annex E (Informative)—Guidelines for the Preparation of Technical Inquiries	17
Annex F (Informative)—List of Deviations from ISO 24034:2010	19
AWS Filler Metal Specifications by Material and Welding Process	23
AWS Filler Metal Specifications and Related Documents	25

List of Tables

Table		Page No.
1	Symbols for Chemical Composition and Composition Requirements	3
B.1	Corresponding National Classifications	9
D.1	Discontinued Titanium Filler Metal Classifications	14

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 standards¹ are referenced in the mandatory sections of this document:

¹ AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.