

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

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American National Standards Institute
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Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods

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

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

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.



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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	<i>Tentative Specification for Titanium-Alloy Bare Welding Rods and Electrodes</i>
ASTM B362-61T	
AWS A5.16-70	<i>Specification for Titanium and Titanium-Alloy Bare Welding Rods and Electrodes</i>
ANSI W3.16-1973	
ANSI/AWS A5.16-90	<i>Specification for Titanium and Titanium-Alloy Bare Welding Rods and Electrodes</i>
ANSI/AWS A5.16-90R	<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.

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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 .

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 standard² is referenced in the mandatory sections of this document:*

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

2.3 *The following ASTM standards³ 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 standards⁴ 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.*

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

Chemical Composition Requirements, % (by mass) ^{a, b, c, d}													
Alloy Symbols													
Numerical	AWS A5.16/A5.16M Chemical Classification												
		C	O	N	H	Fe	Al	V	Pd	Ru	Ni	Mo	Other
Ti 0100	ERTi-1	Ti99,8	0.03	0.03 to 0.10	0.012	0.005	0.08	—	—	—	—	—	—
Ti 0120	ERTi-2	Ti99,6	0.03	0.08 to 0.16	0.015	0.008	0.12	—	—	—	—	—	—
Ti 0125	ERTi-3	Ti99,5	0.03	0.13 to 0.20	0.02	0.008	0.16	—	—	—	—	—	—
Ti 0130	ERTi-4	Ti99,3	0.03	0.18 to 0.32	0.025	0.008	0.25	—	—	—	—	—	—
Ti 2251	ERTi-11	TiPd0,2	0.03	0.03 to 0.10	0.012	0.005	0.08	—	0.12 to 0.25	—	—	—	—
Ti 2253	ERTi-17	TiPd0,06	0.03	0.03 to 0.10	0.012	0.005	0.08	—	0.04 to 0.08	—	—	—	—
Ti 2255	ERTi-27	TiRu0,1	0.03	0.03 to 0.10	0.012	0.005	0.08	—	0.08 to 0.14	—	—	—	—
Ti 2401	ERTi-7	TiPd0,2A	0.03	0.08 to 0.16	0.015	0.008	0.12	—	0.12 to 0.25	—	—	—	—
Ti 2403	ERTi-16	TiPd0,06A	0.03	0.08 to 0.16	0.015	0.008	0.12	—	0.04 to 0.08	—	—	—	—
Ti 2405	ERTi-26	TiRu0,1A	0.03	0.08 to 0.16	0.015	0.008	0.12	—	0.08 to 0.14	—	—	—	—
Ti 3401	ERTi-12	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	—	—
Ti 3416	ERTi-15A	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	—	—	—
Ti 3423	ERTi-13	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	—	—	—
Ti 3424	ERTi-14	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	—	—	—
Ti 3443	ERTi-33	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
Ti 3444	ERTi-34	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
Ti 3531	ERTi-30	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
Ti 3533	ERTi-31	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
Ti 4251	ERTi-38	TiAl4V2Fe	0.05	0.20 to 0.27	0.02	0.010	1.2 to 1.8	3.5 to 4.5	0.04 to 0.08	—	—	—	—
Ti 5112	ERTi-32	TiAl5V1SmMo1Zr11	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	Sn: 0.6 to 1.4 Zr: 0.6 to 1.4 Si: 0.06 to 0.14
Ti 6321	ERTi-9 ^e	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	—	—	—	—
Ti 6324	ERTi-28	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	—	—	—	—
Ti 6326	ERTi-18	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	0.08 to 0.14	—	—
Ti 6402	ERTi-5	TiAl6V4B	0.05	0.12 to 0.20	0.030	0.015	0.22	5.50 to 6.75	3.50 to 4.50	—	—	—	—
Ti 6408	ERTi-23	TiAl6V4A	0.03	0.03 to 0.11	0.012	0.005	0.20	5.5 to 6.5	3.5 to 4.5	—	—	—	—
Ti 6413	ERTi-25	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	—
Ti 6414	ERTi-29	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	—	—
Ti 6415	ERTi-24	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	—	—	—

Table 1 (Continued)
Symbols for Chemical Composition and Composition Requirements

Alloy Symbols		Chemical Composition Requirements, % (by mass) ^{a, b, c, d}												
Numerical	AWS A5.16/A5.16M Classification	Chemical	C	O	N	H	Fe	Al	V	Pd	Ru	Ni	Mo	Other
Ti 8211	ERTi-21	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
Ti 8451	ERTi-36	TiNb45	0.03	0.06 to 0.12	0.02	0.0035	0.03	—	—	—	—	—	—	Nb: 42.0 to 47.0
Ti 8641	ERTi-19	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
Ti 8646	ERTi-20	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

^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.

^d 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.

^e 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.

^f Formerly ERTi-9 ELI

Note: Corresponding national classifications are shown in Annex B.

4.2 Symbol for the Chemical Composition

The numerical symbols or AWS Classification in Table 1 indicates 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	<i>is the numerical symbol for welding consumable (see Table 1);</i>
<i>ERTi-5</i>	<i>is the AWS Classification of the welding consumable (See Table 1);</i>
TiAl6V4B	is the optional chemical symbol for chemical composition 6402 (see Table 1).

Annex A (Informative)

Explanation of Classification Symbols for Chemical Composition

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.

A1. General

The four digit symbols for chemical composition of solid wire electrodes, solid wires and rods in this standard are taken from the last four digits of the UNS (metals and alloys in the Unified Numbering System, *SAE HS-1086/ASTM DS-56J*) designations for the alloy compositions. The first two digits indicate the general alloy group. *The UNS number for all of the titanium alloys are the ISO 24034 numerical designations preceded by a R5 (e.g. R52251, R50100, etc.)* The last two digits indicate modifications of the basic alloy within the group.

Titanium-alloys can exist at room temperature as hexagonal close-packed crystal structure (alpha alloys), body-centered cubic crystal structure (beta alloys), or a mixture of the two crystal structures. Pure titanium exists at room temperature as the alpha crystal structure. Addition of alloying elements can change the room temperature structure to traces of beta in alpha (often termed “near-alpha” alloys) *or* part beta (termed “alpha + beta” alloys), depending upon the alloy elements and amounts added. Aluminum and tin act to stabilize alpha, while vanadium, molybdenum, chromium, and copper act to stabilize beta. All beta alloys (called “metastable-beta”) are not normally produced as welding filler metals, so none are classified in this standard.

NOTE: All percentages mentioned in this annex are “by mass”.

A2. Alloy Group 01

Alloy group 01 (alloys 0100, 0120, 0125, and 0130) consists of commercially pure titanium. The alloys differ only in respect to their oxygen content. In general, higher oxygen results in higher strength, *80 ksi [550 MPA] (for alloy 0130)* instead of *62 ksi [425 MPA] (for alloy 100)*, but lower ductility. These are alpha alloys.

A3. Alloy Group 22

Alloy group 22 (alloys 2251, 2253, and 2255) consists of *low oxygen* titanium with *deliberately* small additions of palladium or ruthenium. Palladium and ruthenium enhance the corrosion resistance of titanium in reducing acid media, crevice corrosion situations, and hot oxidizing chloride brines. These are alpha alloys.

A4. Alloy Group 24

Alloy group 24 (alloys 2401, 2403, and 2405), like Group 22, has deliberately small additions of palladium and ruthenium, but consists of higher oxygen content giving higher strength. These are alpha alloys.

A5. Alloy Group 34

Alloy group 34 (alloys 3401, 3416, 3423, 3424, 3443, and 3444) contains about 0.5% Ni as a deliberate alloying element. Nickel enhances the corrosion resistance of titanium in reducing acid media, crevice corrosion situations, and hot oxidizing chloride brines. These are alpha alloys.

A6. Alloy Group 35

Alloy group 35 (alloys 3531 and 3533) contains about 0.5% Co as a deliberate alloying addition. Cobalt enhances the corrosion resistance of titanium in reducing acid media, crevice corrosion situations, and hot oxidizing chloride brines. These are alpha alloys.

A7. Alloy Group 42

Alloy group 42 (alloy 4251) contains about 4% aluminum, 2.5% vanadium, and 1.5% iron. This is an alpha + beta alloy, having an ultimate tensile strength of around *130 ksi* [896 MPa].

A8. Alloy Group 51

Alloy group 51 (alloy 5112) contains about 5% aluminum, 1% vanadium, 1% tin, 1% molybdenum, and 1% zirconium. This is an alpha + beta alloy, having an ultimate tensile strength of around *123 ksi* [850 MPa].

A9. Alloy Group 63

Alloy group 63 (alloys 6321, 6324, and 6326) contains about 3% aluminum and 2.5% vanadium. These are alpha + beta alloys, having an ultimate tensile strength of around *102 ksi* [700 MPa].

A10. Alloy Group 64

Alloy group 64 (alloys 6402, 6408, 6413, 6414, and 6415) contains about 6% aluminum and 4% vanadium. These are alpha + beta alloys, having an ultimate tensile strength of around *145 ksi* [1,000 MPa].

A11. Alloy Group 82

Alloy group 82 (alloy 8211) contains about 15% molybdenum, 3% aluminum, 2.7% niobium, and 0.25% silicon. This is a weldable and heat treatable beta alloy, having an ultimate tensile strength of around *115 ksi* [793 MPa].

A12. Alloy Group 84

Alloy group 84 (alloy 8451) contains 42% to 47% niobium. This is an alpha + beta alloy, having an ultimate tensile strength of around *65 ksi* [448 MPa]. It has unique shape memory properties.

A13. Alloy Group 86

Alloys in group 86 (alloys 8641 and 8646) contain about 3% aluminum, 8% vanadium, 6% chromium, 4% zirconium, and 4% molybdenum. This is a weldable and heat treatable beta alloy, having an ultimate tensile strength of around *115 ksi* [793 MPa]. Alloy 8646 includes 0.04% to 0.08% palladium for improved corrosion resistance.

Annex B (Informative)

Corresponding National Classifications

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.

Table B.1
Corresponding National Classifications

AWS A5.16/A5.16M:2013 (ISO 24034:2010 MOD)		USA				Germany	
Numerical	Chemical	Alloy Symbols				Japan	
		AWS A5.16/A5.16M:2007	AWS A5.16/A5.16M:2004	ANSI/AWS A5.16-90	AWS A5.16-70	Aerospace Materials Specification	DIN Z3331:2011 ^a 1737-1:1984
Ti 0100	Ti99,8	ERTi-1	ERTi-1	ERTi-1	ERTi-1	—	Ti 0100 Ti 0100J 3.7026
Ti 0120	Ti99,6	ERTi-2	ERTi-2	ERTi-2	ERTi-2	—	Ti 0120 Ti 0120J —
Ti 0125	Ti99,5	ERTi-3	ERTi-3	ERTi-3	ERTi-3	AMS 4951:2003	Ti 0125 Ti 0125J —
Ti 0130	Ti99,3	ERTi-4	ERTi-4	ERTi-4	ERTi-4	—	Ti 0130 Ti 0130J 3.7036
Ti 2251	TiPd0,2	ERTi-11	ERTi-11	—	—	—	Ti 2251 Ti 2251J 3.7226
Ti 2253	TiPd0,06	ERTi-17	ERTi-17	—	—	—	Ti 2253 —
Ti 2255	TiRu0,1	ERTi-27	ERTi-27	—	—	—	Ti 2255 —
Ti 2401	TiPd0,2A	ERTi-7	ERTi-7	ERTi-7	ERTi-0.2Pd	—	Ti 2401 Ti 2401J 3.7236
Ti 2403	TiPd0,06A	ERTi-16	ERTi-16	—	—	—	Ti 2403 —
Ti 2405	TiRu0,1A	ERTi-26	ERTi-26	—	—	—	Ti 2405 —
Ti 3401	TiNi0,7Mo0,3	ERTi-12	ERTi-12	ERTi-12	—	—	Ti 3401 —
Ti 3416	TiRu0,05Ni0,05	ERTi-15A	ERTi-15A	—	—	—	Ti 3416 —
Ti 3423	TiNi0,5	ERTi-13	ERTi-13	—	—	—	Ti 3423 —
Ti 3424	TiNi0,5A	ERTi-14	ERTi-14	—	—	—	Ti 3424 —

Table B.1 (Continued)
Corresponding National Classifications

AWS A5.16/A5.16M:2013 (ISO 24034:2010 MOD)		USA				Japan		Germany	
		Alloy Symbols							
Numerical	Chemical	AWS A5.16/A5.16M:2007	AWS A5.16/A5.16M:2004	ANSI/AWS A5.16-90	AWS A5.16-70	Aerospace Materials Specification	JIS Z3331:2011 ^a	DIN 1737-1:1984	
Ti 3443	TiNi0.45Cr0.15	ERTi-33	ERTi-33	-	-	-	Ti 3443	-	
Ti 3444	TiNi0.45Cr0.15A	ERTi-34	ERTi-34	-	-	-	Ti 3444	-	
Ti 3531	TiCo0.5	ERTi-30	ERTi-30	-	-	-	Ti 3531	-	
Ti 3533	TiCo9.5A	ERTi-31	ERTi-31	-	-	-	Ti 3533	-	
Ti 4251	TiAl4V2.5	ERTi-38	-	-	-	-	-	-	
Ti 5112	TiAl5V1Sn1Mo1Zr1	ERTi-32	ERTi-32	-	-	-	Ti 5112	-	
Ti 6321	TiAl3V2.5A	ERTi-9ELI	ERTi-9ELI	ERTi-9ELI	ERTi-3AL-2.5V-1	-	Ti 6321 Ti 6321J	-	
Ti 6324	TiAl3V2.5Ru	ERTi-28	ERTi-28	-	-	-	Ti 6324	-	
Ti 6326	TiAl3V2.5Pd	ERTi-18	ERTi-18	-	-	-	Ti 6326	-	
Ti 6400	TiAl6V4	-	-	-	-	-	Ti 6400 Ti 6400J	-	
Ti 6402	TiAl6V4B	ERTi-5	ERTi-5	ERTi-5	ERTi-6Al-4V	AMS 4954:2003	Ti 6402	-	
Ti 6408	TiAl6V4A	ERTi-23	ERTi-23	ERTi-5ELI	ERTi-6Al-4V-1	AMS 4956:2003	Ti 6408 Ti 6408J	-	
Ti 6413	TiAl6V4Ni0.5Pd	ERTi-25	ERTi-25	-	-	-	Ti 6413	-	
Ti 6114	TiAl6V4Ru	ERTi-29	ERTi-29	-	-	-	Ti 6114	-	
Ti 6415	TiAl6V4Pd	ERTi-24	ERTi-24	-	-	-	Ti 6415	-	
Ti 8211	TiMo15Al3Nb3	ERTi-21	-	-	-	-	-	-	
Ti 8451	TiNb45	ERTi-36	-	-	-	-	-	-	
Ti 8641	TiV8Cr6Mo4Zr4Al3	ERTi-19	-	-	-	-	-	-	
Ti 8646	TiV8Cr6Mo4Zr4Al3Pd	ERTi-20	-	-	-	-	-	-	

^a "J" designates alloys that consist of Japanese original range of chemical composition

Annex C (Informative)

Informative References

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.

AWS A5.16/A5.16M:2004, *Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods*

AWS G2.4/G2.4M, *Guide for the Fusion Welding of Titanium and Titanium Alloys*

AMS 4951:2003, *Titanium welding wire commercially pure environment controlled packaging*

AMS 4952:2007, *Titanium alloy, welding wire, 6Al – 2Sn – 4Zr – 2Mo*

AMS 4954:2003, *Titanium alloy, welding wire, 6Al – 4V*

AMS 4955:2008, *Titanium alloy, welding wire, 8Al – 1Mo – 1V*

AMS 4956:2003, *Titanium alloy welding wire, 6Al – 4V, extra low interstitials environment controlled packaging*

JIS Z3331:2002, *Titanium and titanium alloy welding rods and solid wires*

DIN 1737–1:1984, *Schweißzusätze für Titan und Titan-Palladiumlegierungen — Chemische Zusammensetzung, Technische Lieferbedingungen* [Filler metals for welding titanium and titaniumpalladium alloys — Chemical composition, technical delivery conditions]⁵

GDMB e. V, *Analyse der Metalle: Band 1 Schiedsanalysen; or Analyse der Metalle: Band 2: Betriebsanalysen. Teil 1; Teil 2; Analyse der Metalle: Band 3: Probenahme.*

ASTM E120, *Standard Methods for chemical analysis of titanium and titanium-base alloys*

Thomas, R. D., Jr., 1996, *Generic System for Designation of Welding Filler Metals*, *Welding in the World*, 37 (3): 155–160

Thomas, R. D., Jr., 1998, *Generic System for Designation of Welding Filler Metals*, *Welding Journal*, 77(2): 29–32

⁵ Withdrawn (replaced by ISO 24034).

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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-6ELI	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

⁶ AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

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Annex E (Informative)

Guidelines for the Preparation of Technical Inquiries

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.

E1. 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.

E2. Procedure

All inquiries shall be directed to:

*Managing Director
Technical Services Division
American Welding Society
8669 Doral Blvd.
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.

E2.1 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.*

E2.2 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.*

E2.3 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.*

E2.4 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.*

E3. 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.

E4. Publication of Interpretations

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

E5. 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.

E6. 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 F (Informative)

List of Deviations from ISO 24034:2010

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.

Global Change

Changed “international standard” to “standard” globally

Added names and addresses of the publishers whose documents are referred to in this specification

ISO uses comma (,) for decimal, but AWS uses period (.) for decimal. Decimal commas have been changed to decimals

Clause 1

Modified Scope

Added Clause 1.2 and 1.3

Clause 2

AWS A5.01M/A5.01 (ISO 14344 MOD), A5.02/A5.02M, ANSI Z49.1, and ASTM E E29, E539, E1409, E1447, E1941, E2371 and E2626 specifications have been added

Clause 3

Modified Classification Clause

Clause 8

Added reference to AWS A5.01M/A5.01 (ISO 14344 MOD) and A5.02/A5.02M

Clause 4.1

Added information regarding numerical designation

Clause 4.2

Included AWS Classification

Clause 5

Deleted “all” from “all-weld”

Clause 9

Example 1: Changed “S Ti 6402” to “ERTi-5”, and “S Ti 6402” to “ERTi-5 (TiAl6V4B)”

Example 2: Modified to represent an AWS wire designation; changed “ISO 24034 – S Ti 6402” to “Ti-12”, and “ISO 24034 – S Ti 6402 (TiAl6V4B)” to “ERTi-12”

Modified Ti 6402’s note

Added a note for ERTi-5

Table 1

Added “AWS Classification”

Added “MO” column

Deleted Ti 4621

Modified Ti 6414

Modified Note d and e

Table B.1

Added Ti 6400

Added historical A5.16 classifications

Deleted Ti 4621 and Ti 4810

Modified Ti 6321

Modified footnotes

Updated column JIS Z3331

Annex A

Modified Clause A.1 General

Deleted alloy Group 46

Deleted alloy Group 48

Annex B

Added in accordance with ISO 24034:2005/DAM 1.

Corrected errors in two Japanese designations, for Alloys 6400 and 6402.

Annex C

Added AWS G2.4/G2.4M and GDMB publications

Additional National Annexes

Added “Annex D (informative), Guide to AWS Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods”

Added “Annex E (informative) Guidelines for Preparation of Technical Inquiries”

Added “Annex F (informative) List of Deviations from ISO 24034:2010”

Added “AWS Filler Metal Specifications by Material and Welding Process”

Added “AWS Filler Metal Specifications and Related Documents”

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AWS Filler Metal Specifications by Material and Welding Process

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

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AWS Filler Metal Specifications and Related Documents

Designation	Title
FMC	<i>Filler Metal Comparison Charts</i>
IFS	<i>International Index of Welding Filler Metal Classifications</i>
UGFM	<i>User's Guide to Filler Metals</i>
A4.2M (ISO 8249 MOD)	<i>Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal</i>
A4.3	<i>Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding</i>
A4.4M	<i>Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings</i>
A4.5M/A4.5 (ISO 15792-3 MOD)	<i>Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld</i>
A5.01M/A5.01 (ISO 14344 MOD)	<i>Procurement guidelines for consumables – Welding and allied processes — Flux and Gas Shielded Electrical Welding Processes</i>
A5.02/A5.02M	<i>Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes</i>
A5.1/A5.1M	<i>Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding</i>
A5.2/A5.2M	<i>Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding</i>
A5.3/A5.3M	<i>Specification for Aluminum-Alloy Electrodes for Shielded Metal Arc Welding</i>
A5.4/A5.4M	<i>Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding</i>
A5.5/A5.5M	<i>Specification for Low Alloy Steel Electrodes for Shielded Metal Arc Welding</i>
A5.6/A5.6M	<i>Specification for Covered Copper and Copper-Alloy Arc Welding Electrodes</i>
A5.7/A5.7M	<i>Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes</i>
A5.8/A5.8M	<i>Specification for Filler Metals for Brazing and Braze Welding</i>
A5.9/A5.9M	<i>Specification for Bare Stainless Steel Welding Electrodes and Rods</i>
A5.10/A5.10M (ISO 18273 MOD)	<i>Welding Consumables – Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum-Alloys Classification</i>
A5.11/A5.11M	<i>Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding</i>
A5.12M/A5.12 (ISO 6848:2004 MOD)	<i>Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting</i>
A5.13/A5.13M	<i>Specification for Surfacing Electrodes for Shielded Metal Arc Welding</i>
A5.14/A5.14M	<i>Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods</i>
A5.15	<i>Specification for Welding Electrodes and Rods for Cast Iron</i>
A5.16/A5.16M (ISO 24034 MOD)	<i>Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods</i>
A5.17/A5.17M	<i>Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding</i>
A5.18/A5.18M	<i>Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding</i>
A5.19	<i>Specification for Magnesium Alloy Welding Electrodes and Rods</i>
A5.21/A5.21M	<i>Specification for Bare Electrodes and Rods for Surfacing</i>
A5.22/A5.22M	<i>Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods</i>
A5.23/A5.23M	<i>Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding</i>
A5.24/A5.24M	<i>Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods</i>
A5.25/A5.25M	<i>Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding</i>

Designation	Title
A5.26/A5.26M	<i>Specification for Carbon and Low-Alloy Steel Electrodes for Electrode Gas Welding</i>
A5.28/A5.28M	<i>Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding</i>
A5.30/A5.30M	<i>Specification for Consumable Inserts</i>
A5.31M/A5.31	<i>Specification for Fluxes for Brazing and Braze Welding</i>
A5.32/A5.32M (ISO 14175 MOD)	<i>Welding consumables – Gases and Gas mixtures for fusion welding and allied processes</i>
A5.34/A5.34M	<i>Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding</i>
A5.36/A5.36M	<i>Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding</i>

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