INTERNATIONAL STANDARD

ISO 24034

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Welding consumables — Solid wire electrodes, solid wires and rods for fusion welding of titanium and titanium alloys — Classification

Produits consommables pour le soudage — Fils-électrodes pleins, fils pleins et baguettes pleines pour le soudage par fusion du titane et des alliages de titane — Classification

Reference number
ISO 24034:2010(E)

Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 24034 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 3, *Welding consumables*.

This second edition cancels and replaces the first edition (ISO 24034:2005), which has been technically revised.

Requests for official interpretations of any aspect of this International Standard should be directed to the Secretariat of ISO/TC 44/SC 3 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

Introduction

This International Standard proposes a classification in order to designate solid wire electrodes, solid wires and rods in terms of their chemical composition.

There is no unique relationship between the product form (solid wire electrodes, solid wires or rods) and the welding process used (gas-shielded metal arc welding, tungsten inert gas arc welding, plasma arc welding or laser beam welding). For this reason, solid wire electrodes, solid wires and rods may be classified in terms of their chemical composition.

In this International Standard, the symbol of the welding process is not used, because

a) different joining processes are performed with the same chemical component consumable;

b) the producer is not able to determine the process symbol before shipping.

Also, it should be noted that the mechanical properties of all-weld metal test specimens or welded joints produced by welding consumables will vary from those obtained in production joints because of differences in welding procedure and the base-metal alloy. For this reason, the mechanical properties of all-weld metal or welded joints for titanium-welding consumables are not specified in this classification.

Welding consumables — Solid wire electrodes, solid wires and rods for fusion welding of titanium and titanium alloys — Classification

1 Scope

This International Standard specifies requirements for the classification of solid wire electrodes, solid wires and rods for fusion welding of titanium and titanium alloys. The classification is based on their chemical composition.

The compositions of solid wire electrodes for metal inert gas (MIG) welding are the same as solid wire electrodes, solid wires and rods for tungsten inert gas (TIG) arc welding, plasma arc welding, laser beam welding, and other fusion welding processes.

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.

ISO 544, *Welding consumables — Technical delivery conditions for 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 classification is divided into two parts:

a) the first part gives a symbol indicating the product to be identified, see 4.1;

b) the second part gives a symbol indicating the chemical composition of the solid wire electrodes, solid wires and rods, see Table 1.

4 Symbols and requirements

4.1 Symbol for the product

The symbol for the solid wire electrodes, solid wires and rods shall be S.

4.2 Symbol for the chemical composition

The numerical symbols in Table 1 indicate the chemical composition of a solid wire or rod, determined under the conditions given in Clause 6. The first two digits indicate the alloy group. See Annex A for an explanation of the numerical symbols.

The optional additional chemical symbols in Table 1 indicate the chemical composition and include an indication of the characteristic alloying elements.

5 Mechanical properties

Mechanical properties of all-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. Any analytical technique may be used but, in cases of dispute, reference shall be made to established published methods, agreed between the contracting parties.

7 Rounding procedure

For purposes of determining compliance with the requirements of this International Standard, the actual test values obtained shall be subjected to the rounding rules of ISO 80000-1:2009, Annex B, Rule A. If the measured values are obtained by equipment calibrated in units other than those of this International Standard, the measured values shall be converted to the units of this International Standard before rounding. If an average value is to be compared to the requirements of this International Standard, rounding shall be done only after calculating the average. In the case where the testing standard cited in the normative references of this International Standard contains instructions for rounding that conflict with the instructions of this International Standard, the rounding requirements of the testing standard shall apply. The rounded-off results shall fulfil the requirements of the appropriate table for the classification under test.

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, 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.

9 Technical delivery conditions

Technical delivery conditions shall meet the requirements of ISO 544 and ISO 14344.

Table 1 — Chemical composition requirements

Alloy symbols		Chemical composition, % (by mass) [a, b, c, d]										
numerical	chemical	C	O	N	H	Fe	Al	V	Sn	Pd	Ru	Other
Ti 0100	Ti99,8	0,03	0,03 to 0,10	0,012	0,005	0,08	—	—	—	—	—	—
Ti 0120	Ti99,6	0,03	0,08 to 0,16	0,015	0,008	0,12	—	—	—	—	—	—
Ti 0125	Ti99,5	0,03	0,13 to 0,20	0,02	0,008	0,16	—	—	—	—	—	—
Ti 0130	Ti99,3	0,03	0,18 to 0,32	0,025	0,008	0,25	—	—	—	—	—	—
Ti 2251	TiPd0,2	0,03	0,03 to 0,10	0,012	0,005	0,08	—	—	—	0,12 to 0,25	—	—
Ti 2253	TiPd0,06	0,03	0,03 to 0,10	0,012	0,005	0,08	—	—	—	0,04 to 0,08	—	—
Ti 2255	TiRu0,1	0,03	0,03 to 0,10	0,012	0,005	0,08	—	—	—	—	0,08 to 0,14	—
Ti 2401	TiPd0,2A	0,03	0,08 to 0,16	0,015	0,008	0,12	—	—	—	0,12 to 0,25	—	—
Ti 2403	TiPd0,06A	0,03	0,08 to 0,16	0,015	0,008	0,12	—	—	—	0,04 to 0,08	—	—
Ti 2405	TiRu0,1A	0,03	0,08 to 0,16	0,015	0,008	0,12	—	—	—	—	0,08 to 0,14	—
Ti 3401	TiNi0,7Mo0,3	0,03	0,08 to 0,16	0,015	0,008	0,15	—	—	—	—	—	Mo: 0,2 to 0,4 Ni: 0,6 to 0,9
Ti 3416	TiRu0,05Ni0,5	0,03	0,13 to 0,20	0,02	0,008	0,16	—	—	—	—	0,04 to 0,06	Ni: 0,4 to 0,6
Ti 3423	TiNi0,5	0,03	0,03 to 0,10	0,012	0,005	0,08	—	—	—	—	0,04 to 0,06	Ni: 0,4 to 0,6
Ti 3424	TiNi0,5A	0,03	0,08 to 0,16	0,015	0,008	0,12	—	—	—	—	0,04 to 0,06	Ni: 0,4 to 0,6
Ti 3443	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	Cr: 0,1 to 0,2 Ni: 0,35 to 0,55
Ti 3444	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	Cr: 0,1 to 0,2 Ni: 0,35 to 0,55
Ti 3531	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	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	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	—	—	—	—
Ti 4621	TiAl6Zr4Mo2Sn2	0,04	0,30	0,015	0,015	0,05	5,50 to 6,50	—	1,80 to 2,20	—	—	Zr: 3,60 to 4,40 Mo: 1,80 to 2,20 Cr: 0,25 max
Ti 5112	TiAl5V1Sn1Mo1Zr1	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 1,4	—	—	Mo: 0,6 to 1,2 Zr: 0,6 to 1,4 Si: 0,06 to 0,14

Table 1 (*continued*)

Alloy symbols		Chemical composition, % (by mass) [a, b, c, d]										
numerical	chemical	C	O	N	H	Fe	Al	V	Sn	Pd	Ru	Other
Ti 6321	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	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	—
Ti 6326	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	—	—
Ti 6402	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	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	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	—	Ni: 0,3 to 0,8
Ti 6414	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	TiAl6V4Pd	0,05	0,12 to 0,20	0,030	0,015	0,22	5,5 to 6,7	3,5 to 4,5	—	—	—	Pd: 0,04 to 0,08
Ti 8211	TiMo15Al3Nb3	0,03	0,10 to 0,15	0,012	0,005	0,20 to 0,40	2,5 to 3,5	—	—	—	—	Mo14,0 to 16,0 Nb 2,2 to 3,2 Si 0,15 to 0,25
Ti 8451	TiNb45	0,03	0,06 to 0,12	0,02	0,0035	0,03	—	—	—	—	—	Nb 42,0 to 47,0
Ti 8641	TiV8Cr6Mo4Zr4Al3	0,03	0,06 to 0,10	0,015	0,015	0,20	3,0 to 4,0	7,5 to 8,5	—	—	—	Mo 3,5 to 4,5 Cr 5,5 to 6,5 Zr3,5 to 4,5
Ti 8646	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	—	Mo 3,5 to 4,5 Cr 5,5 to 6,5 Zr 3,5 to 4,5
	ZTi [e]	Any other agreed composition										

NOTE Corresponding national classifications are shown in Annex B.

a Single values are maxima, unless otherwise noted.

b The remainder of the alloy is titanium.

c Analysis of 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 the 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 cases of dispute, samples from the finished rod/wire shall be the referee method.

d Total residual elements shall not exceed 0,20 % (by mass), with no single such element exceeding 0,05 %, except for yttrium, which shall not exceed 0,005 %. Residual elements need not be reported unless a report is specifically required by the purchaser. Residual elements are those elements other than titanium that are not listed in this table for the particular classification, but which are inherent in the raw material or the manufacturing practice. Residual elements may be present only in trace amounts and they may not be elements that have been intentionally added to the product.

e Consumables for which the chemical composition is not listed in this table shall be symbolized similarly and prefixed by the letter Z. The chemical composition ranges are not specified and it is possible that two electrodes with the same Z-classification are not interchangeable.

10 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 symbol Ti 6402 (TiAl6V4B) of Table 1 is designated as follows:

Solid wire ISO 24034 – S Ti 6402

or alternatively:

Solid wire ISO 24034 – S Ti 6402 (TiAl6V4B)

EXAMPLE 2 A solid rod (S) for fusion welding is designated as follows:

Solid rod ISO 24034 – S Ti 6402

or alternatively:

Solid rod ISO 24034 – S Ti 6402 (TiAl6V4B)

where, for the two examples

ISO 24034	is the number of this International Standard;
S	is the product form (see 4.1);
Ti 6402	is the chemical composition of welding consumable (see Table 1);
TiAl6V4B	is the optional chemical symbol for chemical composition Ti 6402 (see Table 1).

Annex A
(informative)

Explanation of classification symbols for chemical composition

A.1 General

The four-digit symbols for chemical composition of solid wire electrodes, solid wires and rods in this International Standard are taken from the last four digits of the UNS (unified numbering system for metals and alloys) designations for the alloy compositions. The first two digits indicate the general alloy group. 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-centred cubic crystal structure (beta alloys), or a mixture of the two crystal structures. Pure titanium exists at room temperature in 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. Aluminium 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 International Standard.

NOTE All percentages mentioned in this annex are "by mass".

A.2 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, 550 MPa instead of 425 MPa, but lower ductility. These are alpha alloys.

A.3 Alloy group 22

Alloy group 22 (alloys 2251, 2253, and 2255) consists of titanium with deliberately small addition of palladium or ruthenium with low oxygen. 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.

A.4 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 a higher oxygen content giving higher strength (500 MPa instead of 425 MPa). These are alpha alloys.

A.5 Alloy group 34

Alloy group 34 (alloys 3401, 3416, 3423, 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.

A.6 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.

A.7 Alloy group 42

Alloy group 42 (alloy 4251) contains about 4 % aluminium, 2,5 % vanadium, and 1,5 % iron. This is an alpha + beta alloy, having an ultimate tensile strength of around 896 MPa.

A.8 Alloy group 46

Alloy group 46 (alloy 4621) contains about 6 % aluminium and 2 % tin, and the additions of 4 % zirconium and 2 % molybdenum allow it to reach ultimate tensile strength of about 1 000 MPa. It is a near-alpha alloy.

A.9 Alloy group 48

Alloy group 48 (alloy 4810) contains about 8 % aluminium, 1 % vanadium, and 1 % molybdenum. This is a near-alpha alloy, having an ultimate tensile strength of around 950 MPa.

A.10 Alloy group 51

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

A.11 Alloy group 63

Alloy group 63 (alloys 6321, 6324, and 6326) contains about 3 % aluminium and 2,5 % vanadium. These are alpha + beta alloys, having an ultimate tensile strength of around 700 MPa.

A.12 Alloy group 64

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

A.13 Alloy group 82

Alloy group 82 (alloy 8211) contains about 15 % molybdenum, 3 % aluminium, 2,7 % niobium, and 0,25 % silicon. This is a weldable and heat-treatable beta alloy, having an ultimate tensile strength of around 793 MPa.

A.14 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 448 MPa. It has unique shape memory properties.

A.15 Alloy group 86

Alloy group 86 (alloy 8641 and 8646) contains about 3 % aluminium, 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 793 MPa. Alloy 8646 includes 0,04 % to 0,08 % palladium for improved corrosion resistance.

Annex B
(informative)

Corresponding national classifications

Table B.1 — Corresponding national classifications

This International Standard		USA		Japan	Germany
Alloy symbol		AWS A5.16/ A5.16M:2007 [6]	Aerospace Materials Specification	JIS Z3331:2002 [8] a b	DIN 1737-1:1984 [7]
Numerical	Chemical				
Ti 0100	Ti99,8	ERTi-1	—	YTx270	3.7026
Ti 0120	Ti99,6	ERTi-2	—	YTx340	—
Ti 0125	Ti99,5	ERTi-3	AMS 4951:2003 [1]	YTx480	—
Ti 0130	Ti99,3	ERTi-4	—	YTx550	3.7036
Ti 2251	TiPd0,2	ERTi-11	—	YTx270Pd	3.7226
Ti 2253	TiPd0,06	ERTi-17	—	—	—
Ti 2255	TiRu0,1	ERTi-27	—	—	—
Ti 2401	TiPd0,2A	ERTi-7	—	YTx480Pd	3.7236
Ti 2403	TiPd0,06A	ERTi-16	—	YTx340Pd	—
Ti 2405	TiRu0,1A	ERTi-26	—	—	—
Ti 3401	TiNi0,7Mo0,3	ERTi-12	—	—	—
Ti 3416	TiRu0,05Ni0,05	ERTi-15A	—	—	—
Ti 3423	TiNi0,5	ERTi-13	—	—	—
Ti 3424	TiNi0,5A	ERTi-14	—	—	—
Ti 3443	TiNi0,45Cr0,15	ERTi-33	—	—	—
Ti 3444	TiNi0,45Cr0,15A	ERTi-34	—	—	—
Ti 3531	TiCo0,5	ERTi-30	—	—	—
Ti 3533	TiCo9,5A	ERTi-31	—	—	—
Ti 4251	TiAl4V2	ERTi-38	—	—	—
Ti 4621	TiAl6Zr4Mo2Sn2	—	AMS 4952:2007 [2]	—	—
Ti 4810	TiAl8V1Mo	—	AMS 4955:2008 [4]	—	—
Ti 5112	TiAl5V1Sn1Mo1Zr1	ERTi-32	—	—	—
Ti 6321	TiAl3V2,5A	ERTi-9	—	—	—
Ti 6324	TiAl3V2,5Ru	ERTi-28	—	—	—
Ti 6326	TiAl3V2,5Pd	ERTi-18	—	—	—
Ti 6402	TiAl6V4B	ERTi-5	AMS 4954:2003 [3]	—	—
Ti 6408	TiAl6V4A	ERTi-23	AMS 4956:2003 [5]	—	—
Ti 6413	TiAl6V4Ni0,5Pd	ERTi-25	—	—	—
Ti 6114	TiAl6V4Ru	ERTi-29	—	—	—
Ti 6415	TiAl6V4Pd	ERTi-24	—	—	—
Ti 8211	TiMo15Al3Nb3	ERTi-21	—	—	—

Table B.1 (*continued*)

This International Standard		USA		Japan	Germany
Alloy symbol		AWS A5.16/ A5.16M:2007 [6]	Aerospace Materials Specification	JIS Z3331:2002 [8] a b	DIN 1737-1:1984 [7]
Numerical	Chemical				
Ti 8451	TiNb45	ERTi-36	—	—	—
Ti 8641	TiV8Cr6Mo4Zr4Al3	ERTi-19	—	—	—
Ti 8646	TiV8Cr6Mo4Zr4Al3Pd	ERTi-20	—	—	—

a The filler metal form is designated by “x”, i.e. B = rods, W = wire.

b These alloys are the nearest equivalent of the relevant national standards.

Bibliography

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

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

[3] AMS 4954:2003, *Titanium alloy, welding wire, 6Al - 4V*

[4] AMS 4955:2008, *Titanium alloy, welding wire, 8Al - 1Mo - 1V*

[5] AMS 4956:2003, *Titanium alloy welding wire, 6Al - 4V, extra low interstitial environment controlled packaging*

[6] AWS A5.16/A5.16M:2007, *Specification for titanium and titanium alloy welding electrodes and rods*

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

[8] JIS Z 3331:2002, *Titanium and titanium alloy welding rods and solid wires*

1) Superseded by this International Standard.

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