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Standard Specification for Titanium and Titanium Alloy Wire[1]

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1. Scope

1.1 This specification covers titanium and titanium alloy wire as follows:
1.1.1 *Grade 1*—Unalloyed titanium, low oxygen,
1.1.2 *Grade 2*—Unalloyed titanium, standard oxygen,
1.1.2.1 *Grade 2H*—Unalloyed titanium (Grade 2 with 58 ksi minimum UTS),
1.1.3 *Grade 3*—Unalloyed titanium, medium oxygen,
1.1.4 *Grade 4*—Unalloyed titanium, high oxygen,
1.1.5 *Grade 5*—Titanium alloy (6 % aluminum, 4 % vanadium),
1.1.6 *Grade 6*—Titanium alloy (5 % aluminum, 2.5 % tin),
1.1.7 *Grade 7*—Unalloyed titanium plus 0.12 to 0.25 % palladium, standard oxygen,
1.1.7.1 *Grade 7H*—Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi minimum UTS),
1.1.8 *Grade 9*—Titanium alloy (3 % aluminum, 2.5 % vanadium),
1.1.9 *Grade 11*—Unalloyed titanium plus 0.12 to 0.25 % palladium, low oxygen,
1.1.10 *Grade 12*—Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
1.1.11 *Grade 13*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
1.1.12 *Grade 14*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
1.1.13 *Grade 15*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
1.1.14 *Grade 16*—Unalloyed titanium plus 0.04 to 0.08 % palladium, standard oxygen,
1.1.14.1 *Grade 16H*—Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi minimum UTS),
1.1.15 *Grade 17*—Unalloyed titanium plus 0.04 to 0.08 % palladium, low oxygen,
1.1.16 *Grade 18*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 to 0.08 % palladium,
1.1.17 *Grade 19*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),
1.1.18 *Grade 20*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 to 0.08 % palladium,
1.1.19 *Grade 21*—Titanium alloy (15 % molybdenum, 3 % aluminum, 2.7 % niobium, 0.25 % silicon),
1.1.20 *Grade 23*—Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, ELI),
1.1.21 *Grade 24*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 % to 0.08 % palladium,
1.1.22 *Grade 25*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.3 to 0.8 % nickel and 0.04 to 0.08 % palladium,
1.1.23 *Grade 26*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
1.1.23.1 *Grade 26H*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi minimum UTS),
1.1.24 *Grade 27*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
1.1.25 *Grade 28*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.08 to 0.14 % ruthenium,
1.1.26 *Grade 29*—Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, ELI) plus 0.08 to 0.14 % ruthenium,
1.1.27 *Grade 32*—Titanium alloy (5 % aluminum, 1 % tin, 1 % vanadium, 1 % zirconium, 0.8 % molybdenum),
1.1.28 *Grade 33*—Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),
1.1.29 *Grade 34*—Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),
1.1.30 *Grade 35*—Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1.6 % vanadium, 0.5 % iron, 0.3 % silicon),
1.1.31 *Grade 36*—Titanium alloy (45 % niobium),
1.1.32 *Grade 37*—Titanium alloy (1.5 % aluminum), and
1.1.33 *Grade 38*—Titanium alloy (4 % aluminum, 2.5 % vanadium, 1.5 % iron).

[1] This specification is under the jurisdiction of ASTM Committee B10 on Reactive and Refractory Metals and Alloys and is the direct responsibility of Subcommittee B10.01 on Titanium.

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NOTE 1—H grade material is identical to the corresponding numeric grade (that is, Grade 2H = Grade 2) except for the higher guaranteed minimum UTS, and may always be certified as meeting the requirements of its corresponding numeric grade. Grades 2H, 7H, 16H, and 26H are intended primarily for pressure vessel use.

The H grades were added in response to a user association request based on its study of over 5200 commercial Grade 2, 7, 16, and 26 test reports, where over 99 % met the 58 minimum UTS.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E 8 Test Methods for Tension Testing of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 539 Test Method for X-Ray Fluorescence Spectrometric Analysis of 6Al-4V Titanium Alloy

E 1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

E 1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys

E 2371 Test Method for Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma Spectrometry

E~~120Test Methods for Chemical Analysis of Titanium and Titanium Alloys~~ 2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals

2.2 *AWS Standard:*[3]

AWS A5.16/A5.16M-2007 Specification for Titanium and Titanium Alloy Welding Electrodes and Rods

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *coils*, *n*—wire in coil form with pitch and cast as described by purchaser.

3.1.2 *straight lengths*, *n*—wire in straight lengths, generally made by straightening wire from coils by the producer.

3.1.3 *weld wire*, *n*—round wire for welding.

3.1.4 *wire*, *n*—rounds, flats, or special shapes from 0.020 in. (0.5 mm) to 0.250 in. (6.4 mm) in thickness or major dimension.

4. Product Classification

4.1 *Wire*—See 3.1.4.

4.2 *Coils*—Coiled wire may be spooled on spools if required by the user.

4.3 *Straight Lengths*—After straightening, it may be necessary to perform cleaning or other finishing operations. Straight lengths are normally 10 to 12 ft long (random). Exact lengths may be specified by the purchaser when necessary.

4.4 ~~*Weld Wire*—Weld wire usually has a degree of cold work to provide sufficient stiffness to feed from spools in automatic welders. Weld wire is delivered on standard spools as described by the user, or in packages of straight lengths for manual welding operations. There are no tensile strength requirements for the weld wire; however, the chemical analysis of the wire will conform to Table 1.~~ Filler Metal or Weld Wire—Wire for welding filler metal application has special requirements for more restrictive chemistry that allows for oxygen increase inherent in most welding processes used for titanium, and has tighter limits on iron, carbon, nitrogen, and hydrogen. AWS ER Ti-XX grades are specifically designed for welding the corresponding ASTM XX wrought or cast material grades. In addition, special requirements for spooling, such as layer winding, cast, and helix, packaging to maintain cleanliness, and identification are necessary. Use AWS A5.16/A5.16M-2007 for wire for titanium and titanium alloy filler metal.

5. Ordering Information

5.1 . Orders for material under this specification shall include the following information as applicable:

5.1.1 Grade number (Section 1),

5.1.2 Product description (Sections 3 and 4),

5.1.3 Chemistry (Table 1),

5.1.4 Mechanical properties (if applicable, Table 2),

5.1.5 Marking and packaging (Section 17),

5.1.6 Finish (Section 9),

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

TABLE 1 Chemical Requirements[A]

Element	Composition, %												
	Grade 1	Grade 2	Grade 2H	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 7H	Grade 9	Grade 11	Grade 12	Grade 13
Nitrogen, max	0.03	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max	0.20	0.30	0.30	0.30	0.50	0.40	0.50	0.30	0.30	0.25	0.20	0.30	0.20
Oxygen, max	0.18	0.25	0.25	0.35	0.40	0.20	0.20	0.25	0.25	0.15	0.18	0.25	0.10
Aluminum	...	...	...	...	...	5.5–6.75	4.0–6.0	...	...	2.5–3.5	...	...	...
Vanadium	...	...	...	...	...	3.5–4.5	...	...	...	2.0–3.0	...	...	...
Tin	...	...	...	...	...	...	2.0–3.0	...	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	...	...	...	...	0.04–0.06
Palladium	...	...	...	...	...	...	...	0.12–0.25	0.12–0.25	...	0.12–0.25	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	...	...	...	...	...	0.2–0.4	...
Chromium	...	...	...	...	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	...	...	...	...	0.6–0.9	0.4–0.6
Niobium	...	...	...	...	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	...	...	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balande	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %											
	Grade 14	Grade 15	Grade 16	Grade 16H	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23	Grade 24	Grade 25
Nitrogen, max	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.05	0.05	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125	0.015	0.0125
Iron, max	0.30	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25	0.40	0.40
Oxygen, max	0.15	0.25	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13	0.20	0.20
Aluminum	...	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	5.5–6.5	5.5–6.75	5.5–6.75
Vanadium	...	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5	3.5–4.5	3.5–4.5
Tin	...	...	...	...	...	...	...	...	...	...	...	...
Ruthenium	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...	...	...	...
Palladium	...	...	0.04–0.08	0.04–0.08	0.04–0.08	0.04–0.08	...	0.04–0.08	...	...	0.04–0.08	0.04–0.08
Cobalt	...	...	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	3.5–4.5	3.5–4.5	14.0–16.0	...	...	...
Chromium	...	...	...	...	...	...	5.5–6.5	5.5–6.5	...	...	...	...
Nickel	0.4–0.6	0.4–0.6	...	...	...	...	...	...	...	...	...	0.3–0.8
Niobium	...	...	...	...	...	...	...	...	2.2–3.2	...	...	...
Zirconium	...	...	...	...	...	...	3.5–4.5	3.5–4.5	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	0.15–0.25	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %											
	Grade 26	Grade 26H	Grade 27	Grade 28	Grade 29	Grade 32	Grade 33	Grade 34	Grade 35	Grade 36	Grade 37	Grade 38
Nitrogen, max	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.03	0.03	0.03