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Standard Specification for Wrought Titanium-6Aluminum-4Vanadium ELI (Extra Low Interstitial) Alloy for Surgical Implant Applications (UNS R56401)[1]

This standard is issued under the fixed designation F 136; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε^1 NOTE—Subsection 8.3.1 was editorially corrected in December 2008.

1. Scope*

1.1 This specification covers the chemical, mechanical, and metallurgical requirements for wrought annealed titanium-6aluminum-4vanadium ELI (extra low interstitial) alloy (R56401) to be used in the manufacture of surgical implants.

~~1.2The values stated in inch-pound units are to be regarded as the standard. The SI equivalents in parentheses are provided for information only.~~

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/E 8M Test Methods ~~of~~for Tension Testing of Metallic Materials

~~E120Test Methods for Chemical Analysis of Titanium and Titanium Alloys~~

~~E290Test Method for Bend Testing of Materials for Ductility~~[3]

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

~~E527Practice for Numbering Metals and Alloys (UNS)~~ 290 Test Methods for Bend Testing of Material for Ductility

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 Method~~[3] 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

F 981 Practice for Assessment of Compatibility of Biomaterials for Surgical Implants with Respect to Effect of Materials on Muscle and Bone

2.2 *ISO Standards:*[3]

ISO 6892 Metallic Materials Tensile Testing at Ambient Temperature

ISO 9001 Quality Management Systems Requirements

2.3 *ASQ Standard:*

ASQ C1 Specifications of General Requirements for a Quality Control Program

~~2.3~~ [4]

2.4 *Aerospace Material Specifications:*

AMS 2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys

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[1] This specification is under the jurisdiction of ASTM Committee F04 on Medical and Surgical Materials and Devices and is the direct responsibility of Subcommittee F04.12 on Metallurgical Materials.

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[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* ~~, Vol 03.01.~~volume information, refer to the standard's Document Summary page on the ASTM website.

~~[3] Annual Book of ASTM Standards, Vol 03.05.~~

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

~~[4] Annual Book of ASTM Standards, Vol 01.01.~~

[4] Available from American Society for Quality (ASQ), 600 N. Plankinton Ave., Milwaukee, WI 53203, http://www.asq.org.

***A Summary of Changes section appears at the end of this standard.**

~~AMS 4930Titanium Alloy Bars, Forgings, and Rings 6AL-4V Extra Low Interstitial Annealed~~
~~2.4 *Society of Automotive Engineers Standard:*~~
~~SAE J1086Practice for Numbering Metals and Alloys (UNS)~~ [5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *beta transus*, *n*—the minimum temperature at which the alpha plus beta phase can transform to 100 % beta phase.

3.1.2 *lot*, *n*—the total number of mill products produced from one heat under the same conditions at essentially the same time.

4. Product Classification

4.1 *Strip*—Any product under 0.1875 in. (~~4.75~~4.76 mm) in thickness and under 24 in. (610 mm) wide.

4.2 *Sheet*—Any product under 0.1875 in. (~~4.75~~4.76 mm) in thickness and 24 in. (610 mm) or more in width.

4.3 *Plate*—Any product 0.1875 in. (~~4.75~~4.76 mm) thick and over and 10 in. (254 mm) wide and over, with widths greater than five times thickness. Plate up to 4.00 in. (101.60 mm), thick inclusive is covered by this specification.

4.4 *Bar*—Round bars and flats from 0.1875 in. (~~4.75~~4.76 mm) to 4.00 in. (101.60 mm) in diameter or thickness (other sizes and shapes by special order).

4.5 *Forging Bar*—Bar as described in 4.4, used for production of forgings, may be furnished in the hot ~~rolled~~worked condition.

4.6 *Wire*—~~Rounds less than 0.1875 in. (4.75 mm) in diameter.~~ —Rounds, flats, or other shapes less than 0.1875 in. (4.76 mm) in diameter.

5. Ordering Information

5.1 Include with inquiries and orders for material under this specification the following information:

5.1.1 Quantity,

5.1.2 ASTM designation and date of issue,

~~5.1.3Form (sheet, strip, plate, bar, or wire),~~

~~5.1.4Condition (See~~

5.1.3 Form (sheet, strip, plate, bar, forging bar, or wire),

5.1.4 Condition (See Section 3 and 6.3),

5.1.5 Mechanical properties (if applicable, for special conditions),

5.1.6 Finish (See 6.2),

5.1.7 Applicable dimensions including size, thickness, width, length, or drawing number,

5.1.8 Special tests, if any, and

5.1.9 Other requirements.

6. Materials and Manufacture

6.1 The various titanium mill products covered in this specification normally are formed with the conventional forging and rolling equipment found in primary ferrous and nonferrous plants. The alloy is usually multiple melted in arc furnaces (including furnaces such as plasma arc and electron beam) of a type conventionally used for reactive metals.

6.2 *Finish*—~~The mill product may be furnished to the implant manufacturer as mechanically descaled or pickled, sandblasted, chemically milled, ground, machined, peeled, polished, combinations of these operations, or as specified by the purchaser.~~ —The mill product may be furnished to the implant manufacturer as mechanically descaled or pickled, abrasively blasted, chemically milled, ground, machined, peeled, polished, combinations of these operations, or as specified by the purchaser. On billets, bars, plates, and forgings, it is permissible to remove minor surface imperfections by grinding if the resultant area meets the dimensional and surface finish requirements of this specification.

6.3 *Condition*—~~Material shall be furnished in the annealed or cold-worked condition.~~ —Material shall be furnished in the annealed or cold-worked condition. Mechanical properties for conditions other than those listed in Table 1 and Table 2 may be established by agreement between the supplier and the purchaser.

7. Chemical Requirements

7.1 The heat analysis shall conform to the chemical composition ~~of~~ specified in Table ~~1~~3. Ingot analysis may be used for reporting all chemical requirements, except hydrogen. Samples for hydrogen shall be taken from the finished mill product. ~~Supplier~~ The supplier shall not ship material with chemistry outside the requirements specified in Table ~~1~~3.

7.1.1 Requirements for the major and minor elemental constituents are listed in ~~Table 1~~Table 3. Also listed are important residual elements. Analysis for elements not listed in ~~Table 1~~ Table 3 is not required to verify compliance with this specification.

7.2 *Product Analysis*—~~Product analysis tolerances do not broaden the specified heat analysis requirements but cover variations between laboratories in the measurement of chemical content. The supplier shall not ship material that is outside the limits specified~~

~~[5] Annual Book of ASTM Standards, Vol 03.06.~~

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

TABLE 3 1 Annealed Mechanical PropertiesA of Bar, Wire, and Forgings

Nominal Diameter or Distance Between Parallel Sides, in. (mm)	Tensile Strength min, psi (MPa)	Yield Strength (0.2 % offset) min, psi (MPa)	Elongation[BA] in 4D or 4W min, %			Reduction of Area[CB] min, %		
			L	LT	ST	L	LT	ST
Under 0.187 (4.75) thickness or diameter	125 000 (860)	115 000 (795)	10	...	...	...	...	...
0.187 (4.75) to under 1.75 (44.45), incl	125 000 (860)	115 000 (795)	10	...	...	25	...	...
1.75 (44.45) to under 2.50 (63.50), incl	120 000 (825)	110 000 (760)	8	...	...	20	...	...
2.50 (63.50) to 4.00 (101.60), incl	120 000 (825)	110 000 (760)	8	8[D]	8[D]	15	15[D]	15[D]
	Bend Test[E]							
Under 0.070 (1.778) in thickness	9 T							
0.070 (1.778) to 0.187 (4.75), incl	10 T							
2.50 (63.50) to 4.00 (101.60), incl	120 000 (825)	110 000 (760)	8	8[C]	8[C]	15	15[C]	15[C]

[A] MechElongation of materieal pr 0.063 in. (1.6 mm) opr greater in diameter (D) or width (W) shall be meas four coned using a gage length of 2 in. or 4 D or 4 W. The gage length must be reported with the test results. Thane methosd for determining elongatison of material under 0.063 in. (1.6 mm) in diameter or thicknes ts may be negotiated. Alte rnatively b, a gage length corresponding to ISO 6892 may blie ushed by when agreemed upont between the supplier and t purchaser. (5.65 timpes the square root of So, where So is the original cross sectional area.) Gage lengt mh shall be reported with the elonufgaetion value. L = longitudinal; LT = long transverse; ST = short transverse.

[B] EApplongaties ton of m bateri al 0.062 in. (1.575 mm)d forgreaterin diametergs or thickness shaly. L = l be measongitured usinga gagele; LT = long th of 2 iran. osver 4 D or 4 W.se; ST = she gort trage length must bversep. Forte round wi bar, th the test resu lts. Elong ationd shof marte trial undsver 0.062se are in. (1.575 mm) indiamenter or thicknal tests may be ob, tainhed by nregfotiatire on. L=ly ongie tudinal; LT=long transverse; ST= ishо rt transvequirsed.

[C] Applies to bar, plate, and forgings only. L=longitudinal; LT=long transverse; ST=short transverse. For round bar the long and short transverse are identical tests, therefore only one transverse is required.

[D] Transverse requirements in Table 3 1 apply only to product from which a tensile specimen not less that 2.50 in. (63.5 mm) in length can be obtained.

[E] Bend test applicable to sheet and strip products; T=thickness of bend specimen in reference to diameter of bend.

TABLE 2 Annealed Mechanical Properties of Sheet, Strip, and Plate

Nominal Diameter or Distance Between Parallel Sides, in. (mm)	Tensile Strength min, psi (MPa)	Yield Strength (0.2 % offset) min, psi (MPa)	Elongation[A] in 2 in. (50 mm), min, %			Reduction of Area[B] min, %			Bend Test Mandrel Diameter[C,D]	
			L	LT	ST	L	LT	ST	Under 0.070 in. (1.78 mm) in Thickness	0.070 to 0.1875 in. (1.78 to 4.75 mm) in Thickness
Under 0.187 (4.75) thickness or diameter	125 000 (860)	115 000 (795)	10	...	...	...	...	...	9T	10T
0.187 (4.75) to under 1.75 (44.45), incl	125 000 (860)	115 000 (795)	10	...	...	25	...	...	...	...
1.75 (44.45) to under 2.50 (63.50), incl	120 000 (825)	110 000 (760)	8	...	...	20	...	...	...	...
2.50 (63.50) to 4.00 (101.60), incl	120 000 (825)	110 000 (760)	8	8[E]	8[E]	15	15[E]	15[E]	...	...

[A] Elongation of material 0.063 in. (1.6 mm) or greater width (W) shall be measured using a gage length of 2 in. or 4 W. The gage length must be reported with the test results. The method for determining elongation of material less than 0.063 in. (1.6 mm) in thickness may be negotiated. Alternatively, a gage length corresponding to ISO 6892 may be used when agreed upon between supplier and purchaser. (5.65 times the square root of So, where So is the original cross sectional area.) Gage length shall be reported with the elongation value. L = longitudinal; LT = long transverse; ST = short transverse.

[B] Applies to plate only. L = longitudinal; LT = long transverse; ST = short transverse.

[C] The bend test is applicable to sheet and strip products.

[D] T equals the thickness of the bend test specimen. Refer to Test Methods E 290. Bend tests are not applicable to material over 0.187 in. (4.75 mm) in thickness.

[E] Transverse requirements in Table 2 apply only to product from which a tensile specimen not less that 2.50 in. (63.5 mm) in length can be obtained.

TABLE 1 3 Chemical Requirements

Element	Composition, % (mass/mass)
Nitrogen, max	0.05
Carbon, max	0.08
Hydrogen, max	0.012[A]
Iron, max	0.25
Oxygen, max	0.13
Aluminum	5.5–6.50
Vanadium	3.5–4.5
Titanium[B]	balance

[A] Material 0.032 in. (0.813 mm) and under may have hydrogen content up to 0.0150 %.

[B] The percentage of titanium is determined by difference and need not be determined or certified.

in Table 1. The product analysis tolerances shall conform to the product tolerances in Table 2:

7.2.1 Product analysis tolerances do not broaden the specified heat analysis requirements but cover variations between