Designation: ~~F1472 – 20a~~ F1472 – 23

Standard Specification for Wrought Titanium-6Aluminum-4Vanadium Alloy for Surgical Implant Applications (UNS R56400)[1]

This standard is issued under the fixed designation F1472; 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.

1. Scope*

1.1 This specification covers the chemical, mechanical, and metallurgical requirements for wrought annealed titanium-6aluminum-4vanadium alloy (UNS R56400) to be used in the manufacture of surgical implants.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E8/E8M Test Methods for Tension Testing of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E290 Test Methods for Bend Testing of Material for Ductility
E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
E539 Test Method for Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry
E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion
E1447 Test Method for Determination of Hydrogen in Reactive Metals and Reactive Metal Alloys by Inert Gas Fusion with Detection by Thermal Conductivity or Infrared Spectrometry
E1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis
E2371 Test Method for Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)
E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals (Withdrawn 2017)[3]
E2994 Test Method for Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge Atomic Emission Spectrometry (Performance-Based Method)
F136 Specification for Wrought Titanium-6Aluminum-4Vanadium ELI (Extra Low Interstitial) Alloy for Surgical Implant Applications (UNS R56401)

[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.

Current edition approved ~~Nov. 1, 2020~~Feb. 1, 2023. Published ~~November 2020~~February 2023. Originally published in 1993. Last previous edition approved in 2020 as ~~F1472 – 20.~~F1472 – 20a. DOI: ~~10.1520/F1472-20A.~~10.1520/F1472-23.

[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] The last approved version of this historical standard is referenced on www.astm.org.

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

2.2 *Aerospace Material Specifications:*[4]
AMS 2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2631 Ultrasonic Inspection Titanium, and Titanium Alloy Bar, Billet, and Plate
AMS 4911 Titanium Alloy Sheet, Strip, and Plate 6Al-4V Annealed
AMS 4928 Titanium Alloy Bars, Wire, Forgings, Rings, and Drawn Shapes 6Al-4V Annealed
AMS 4965 Titanium Alloy, Bars, Wire, Forgings, and Rings 6.0 Al 4.0 V Solution Heat Treated and Aged

2.3 *ISO Standards:*[5]
ISO 5832–3 Implants for Surgery—Metallic Materials—Part 3, Wrought Titanium-6Aluminum-4Vanadium Alloy
ISO 6892 Metallic Materials—Tensile Testing at Ambient Temperature
ISO 9001 Quality Management Systems—Requirements

2.4 *Society of Automotive Engineers Standard:*[4,6]
SAE J1086 Practice for Numbering Metals and Alloys (UNS)

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.

3.1.3 *stress relieved*—heated to a temperature below the annealing temperature with no observable change in microstructure.

4. Product Classification

4.1 *Strip*—Any product under 4.76 mm [0.1875 in.] in thickness and under 610 mm [24 in.] wide.

4.2 *Sheet*—Any product under 4.76 mm [0.1875 in.] in thickness and 610 mm [24 in.] or more in width.

4.3 *Plate*—Any product 4.76 mm [0.1875 in.] thick and over and 254 mm [10 in.] wide and over, with widths greater than five times thickness. Plate up to 102 mm [4.00 in.] thick, inclusive, is covered by this specification.

4.4 *Bar*—Round bars and flats from 4.76 mm [0.1875 in.] to 150 mm [6.00 in.] in diameter or thickness (other sizes and shapes by special order).

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

4.6 *Wire*—Rounds, flats, or other shapes less than 4.76 mm [0.1875 in.] in diameter or thickness.

4.7 *Billet*—Solid semi-finished section hot worked from an ingot whose intended use is for additional hot or cold reduction.

4.8 *Other*—Other forms and shapes, including tubing, may be provided by agreement between purchaser and supplier.

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,

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[6] New designation established in accordance with Practice E527 and SAE J1086.

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

5.1.4 Condition (see 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 purchaser 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, stress-relieved, or cold-worked or hot-worked condition. Mechanical properties for conditions other than those listed in Table 3 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 Table 1. Ingot analysis may be used for reporting all chemical requirements, except hydrogen. Samples for hydrogen shall be taken from the finished mill product. The supplier shall not ship material with chemistry outside the requirements specified in Table 1.

TABLE 1 Chemical Requirements[A,B,C]

Element	Composition, % (mass/mass)
Nitrogen, max	0.05
Carbon, max	0.08
Hydrogen, max[D]	0.015
Iron, max	0.30
Oxygen, max	0.20
Aluminum	5.5–6.75
Vanadium	3.5–4.5
Yttrium, max	0.005
Titanium[E]	balance

[A] At minimum, the analysis of samples from the top and bottom of the ingot shall be completed and reported for all elements listed. Refer to AMS 4928.
[B] Other elements need not be reported unless the concentration level is greater than 0.1 % each, or 0.4 % total. Other elements may not be added intentionally. Other elements may be present in titanium or titanium alloys in small quantities and are inherent to the manufacturing process. In titanium these elements typically include aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.
[C] The purchaser may, in the written purchase order, request analysis for specific elements not listed in this specification.
[D] Final product hydrogen shall be reported. Ingot hydrogen need not be reported. Lower hydrogen may be obtained by negotiation with the manufacturer. Billets shall have a maximum of 0.01 % hydrogen content.
[E] The percentage of titanium is determined by difference and need not be determined or certified.

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

7.2 *Product Analysis:*

7.2.1 Product analysis tolerances do not broaden the specified heat analysis requirements but cover variations in the measurement of chemical content between laboratories. The product analysis tolerances shall conform to the product tolerances in Table 2.

7.2.2 The product analysis is either for the purpose of verifying the composition of a heat or manufacturing lot or for determining variations in the composition within the heat.

7.2.3 Acceptance or rejection of a heat or manufacturing lot of material may be made by the purchaser on the basis of this product analysis. Product analyses outside the tolerance limits allowed in Table 2 are cause for rejection of the product. A referee analysis may be used if agreed upon by supplier and purchaser.

7.2.4 For referee purposes, use Test Methods E539, E1409, E1447, E1941, E2371, E2626, and E2994 or other analytical methods agreed upon between the purchaser and the supplier.

7.3 Samples for chemical analysis shall be representative of the material being tested. The utmost care must be used in sampling titanium for chemical analysis because of its affinity for elements such as oxygen, nitrogen, and hydrogen. In cutting samples for analysis, therefore, the operation should be carried out insofar as possible in a dust-free atmosphere. Cutting tools should be clean and sharp. Samples for analysis should be stored in suitable containers.

8. Mechanical Requirements

8.1 The material supplied under this specification shall conform to the mechanical property requirements in Table 3.

8.2 Specimens for tension tests shall be prepared and tested in accordance with Test Methods E8/E8M or ISO 6892. Tensile properties shall be determined using a strain rate of 0.003 to 0.007 mm/mm/min [in./in./min] through yield and then the crosshead speed may be increased so as to produce fracture in approximately one additional minute.

8.3 For sheet and strip, the bend test specimen shall withstand being bent cold through an angle of 105° without fracture in the outside surface of the bent portion. Perform at least one bend test from each lot in both the longitudinal and transverse directions. Bend tests in the transverse direction need be made only on product from which a specimen not less than 200 mm [8.0 in.] can be taken. The bend shall be made over a mandrel with a diameter equal to that shown in Table 3. Test conditions shall conform to Test Method E290.

8.4 *Number of Tests:*

8.4.1 *Bar, Forging Bar, Shapes, and Wire*—Perform at least one tension test from each lot in the longitudinal direction. Should any of these test specimens not meet the specified requirements, test two additional test pieces representative of the same lot, in the same manner, for each failed test specimen. The lot will be considered in compliance only if both additional test pieces meet the specified requirements.

TABLE 2 Product Analysis Tolerance[A]

Element	Tolerance Under the Minimum or Over the Maximum Limit (Composition %)[B] % (mass/mass)
Nitrogen	0.02
Carbon	0.02
Hydrogen	0.002
Iron	0.10
Oxygen	0.02
Aluminum	0.40
Vanadium	0.15
Yttrium	0.0006

[A] See AMS 2249.
[B] Under minimum limit not applicable for elements where only a minimum percentage is indicated.