



Designation: F3001 – 14 (Reapproved 2021)

Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion¹

This standard is issued under the fixed designation F3001; 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 additively manufactured titanium-6aluminum-4vanadium with extra low interstitials (Ti-6Al-4V ELI) components using full-melt powder bed fusion such as electron beam melting and laser melting. The components produced by these processes are used typically in applications that require mechanical properties similar to machined forgings and wrought products. Components manufactured to this specification are often, but not necessarily, post processed via machining, grinding, electrical discharge machining (EDM), polishing, and so forth to achieve desired surface finish and critical dimensions.

1.2 This specification is intended for the use of purchasers or producers or both of additively manufactured Ti-6Al-4V ELI components for defining the requirements and ensuring component properties.

1.3 Users are advised to use this specification as a basis for obtaining components that will meet the minimum acceptance requirements established and revised by consensus of the members of the committee.

1.4 User requirements considered more stringent may be met by the addition to the purchase order of one or more supplementary requirements, which may include, but are not limited to, those listed in S1-S4 and S1-S16 in Specification **F2924**.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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.*

¹ This specification is under the jurisdiction of ASTM Committee **F42** on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee **F42.05** on Materials and Processes.

Current edition approved Oct. 1, 2021. Published October 2021. Originally approved in 2013. Last previous edition approved in 2014 as F3001-14. DOI: 10.1520/F3001-14R21

2. Referenced Documents

2.1 ASTM Standards:²

- B214** Test Method for Sieve Analysis of Metal Powders
- B243** Terminology of Powder Metallurgy
- B600** Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces
- B769** Test Method for Shear Testing of Aluminum Alloys
- D3951** Practice for Commercial Packaging
- E3** Guide for Preparation of Metallographic Specimens
- E8/E8M** Test Methods for Tension Testing of Metallic Materials
- E9** Test Methods of Compression Testing of Metallic Materials at Room Temperature
- E11** Specification for Woven Wire Test Sieve Cloth and Test Sieves
- E29** Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E238** Test Method for Pin-Type Bearing Test of Metallic Materials
- E407** Practice for Microetching Metals and Alloys
- 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 Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
- E1820** Test Method for Measurement of Fracture Toughness
- 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)
- F136** Specification for Wrought Titanium-6Aluminum-4Vanadium ELI (Extra Low Interstitial) Alloy for Surgical

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.

Implant Applications (UNS R56401)

F2792 Terminology for Additive Manufacturing Technologies (Withdrawn 2015)³

F2924 Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion

2.2 *ISO/ASTM Standards*:²

52915 Specification for Additive Manufacturing File Format (AMF) Version 1.1

52921 Terminology for Additive Manufacturing—Coordinate Systems and Test Methodologies

2.3 *ASQ Standard*:⁴

ASQ C1 Specification of General Requirements for a Quality Program

2.4 *ISO Standards*:⁵

ISO 5832-3 Implants for Surgery—Metallic Materials—Part 3: Wrought Titanium 6-Aluminum 4-Vanadium Alloy Third Edition

ISO 6892 Metallic Materials—Tensile Testing at Ambient Temperature

ISO 9001 Quality Management System—Requirements

ISO 9044 Industrial Woven Wire Cloth – Technical Requirements and Testing

ISO 13485 Medical devices—Quality management systems—Requirements for regulatory purposes

2.5 *SAE Standards*:⁶

AMS 2249 Chemical Check Analysis Limits Titanium and Titanium Alloys

AMS 2801 Heat Treat of Titanium Alloys

AMSH81200 Heat Treatment of Titanium and Titanium Alloys

AS1814 Terminology for Titanium Microstructures

AS9100 Quality Systems—Aerospace—Model for Quality Assurance in Design, Development, Production, Installation and Servicing

3. Terminology

3.1 Terminology relating to titanium microstructure in AS1814 shall apply.

3.2 Terminology relating to additive manufacturing in Terminology **F2792** shall apply.

3.3 Terminology relating to coordinate systems in Terminology **52921** shall apply.

3.4 Terminology relating to powder metallurgy in Terminology **B243** shall apply.

3.5 Terminology relating to powder bed fusion in Specification **F2924** shall apply.

4. Classification

4.1 Unless otherwise specified herein, all classifications shall meet the requirements in each section of this standard.

³ The last approved version of this historical standard is referenced on www.astm.org.

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

⁵ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁶ Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

4.1.1 Class A components shall be stress relieved or annealed per Section **12**.

4.1.2 Class B components shall be annealed per Section **12**.

4.1.3 Class C components shall be hot isostatically pressed per Section **13**.

4.1.4 Class D components shall be solution heat treated and aged per Section **12**.

4.1.5 For Class E components all thermal post processing shall be optional.

4.1.6 Class F components shall be stress relieved or annealed per Section **12**.

5. Ordering Information

5.1 Orders for components compliant with this specification shall include the following to describe the requirements adequately:

5.1.1 This specification designation,

5.1.2 Description or part number of product desired,

5.1.3 Quantity of product desired,

5.1.4 Classification,

5.1.5 SI or SAE units,

5.1.5.1 *Discussion*—The STL file format used by many powder bed fusion machines does not contain units of measurement as metadata. When only STL files are provided by the purchaser, ordering information should specify the units of the component along with the electronic data file. More information about data files can be found in ISO/ASTM **52915**.

5.1.6 Dimensions and tolerances (Section **14**),

5.1.7 Mechanical properties (Section **11**),

5.1.8 Methods for chemical analysis (Section **9**),

5.1.9 Sampling methods (S11 in **F2924**),

5.1.10 Post-processing sequence of operations,

5.1.11 Thermal processing,

5.1.12 Allowable porosity (S8 in **F2924**),

5.1.13 Component marking such as labeling the serial or lot number in the CAD file prior to the build cycle, or product tagging,

5.1.14 Packaging,

5.1.15 Certification,

5.1.16 Disposition of rejected material (Section **15**), and

5.1.17 Supplementary requirements.

6. Manufacturing Plan

6.1 Class A, B, C, D, and F components manufactured to this specification shall have a manufacturing plan that includes, but is not limited to, the following:

6.1.1 A machine, and manufacturing control system, qualification procedure as agreed between component supplier and purchaser;

NOTE 1—Qualification procedures typically require qualification build cycles in which mechanical property test specimens are prepared and measured in accordance with Section **11** or other applicable standards. Location, orientation on the build platform, number of test specimens for each machine qualification build cycle, and relationship between specimen test results and component quality shall be agreed upon between component supplier and purchaser.

6.1.2 Feedstock that meets the requirements of Section **7**;

6.1.3 The machine identification, including machine software version, manufacturing control system version (if