



Designation: F3302 – 18

Standard for Additive Manufacturing – Finished Part Properties – Standard Specification for Titanium Alloys via Powder Bed Fusion¹

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1. Scope

1.1 This specification covers additive manufacturing of components via full-melt powder bed fusion processing of titanium alloys. Components made using this processing method are typically used in applications that require mechanical properties similar to wrought products. Products built to this specification may require additional post-processing in the form of machining, polishing, etc., to meet necessary surface finish and dimensional requirements.

1.2 This specification is intended for the use of purchasers or producers, or both, of additively manufactured titanium 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 committee members.

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

1.5 The values stated in SI units are to be regarded as the standard. Other units are included only for informational purposes.

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.

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2. Referenced Documents

2.1 ASTM Standards:²

- B213 Test Methods for Flow Rate of Metal Powders Using the Hall Flowmeter Funnel
- B214 Test Method for Sieve Analysis of Metal Powders
- B243 Terminology of Powder Metallurgy
- B311 Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity
- B348 Specification for Titanium and Titanium Alloy Bars and Billets
- B600 Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces
- B769 Test Method for Shear Testing of Aluminum Alloys
- B822 Test Method for Particle Size Distribution of Metal Powders and Related Compounds by Light Scattering
- B855 Test Method for Volumetric Flow Rate of Metal Powders Using the Arnold Meter and Hall Flowmeter Funnel
- B964 Test Methods for Flow Rate of Metal Powders Using the Carney Funnel
- 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
- E10 Test Method for Brinell Hardness of Metallic Materials
- E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
- E18 Test Methods for Rockwell Hardness of Metallic Materials
- E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

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.

E23 Test Methods for Notched Bar Impact Testing of Metallic Materials
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
E384 Test Method for Microindentation Hardness of Materials
E399 Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials
E407 Practice for Microetching Metals and Alloys
E466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
E539 Test Method for Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry
E606 Test Method for Strain-Controlled Fatigue Testing
E647 Test Method for Measurement of Fatigue Crack Growth Rates
E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion
E1417 Practice for Liquid Penetrant Testing
E1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
E1450 Test Method for Tension Testing of Structural Alloys in Liquid Helium
E1742 Practice for Radiographic Examination
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
E2368 Practice for Strain Controlled Thermomechanical Fatigue Testing
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
F136 Specification for Wrought Titanium-6Aluminum-4Vanadium ELI (Extra Low Interstitial) Alloy for Surgical Implant Applications (UNS R56401)
F1472 Specification for Wrought Titanium-6Aluminum-4Vanadium Alloy for Surgical Implant Applications (UNS R56400)
F2971 Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing
F3049 Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes
F3122 Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes
 2.2 *ISO/ASTM Standards*:²
52900 Terminology for Additive Manufacturing – General Principles – Terminology
52901 Guide for Additive Manufacturing – General Prin-

ciples – Requirements for Purchased AM Parts
52915 Specification for Additive Manufacturing File Format (AMF) Version 1.2
52921 Terminology for Additive Manufacturing – Coordinate Systems and Methodologies
 2.3 *ASQ Standard*:⁴
ASQ C1 Specification of General Requirements for a Quality Program
 2.4 *ISO Standards*:⁵
ISO 148-1 Metallic materials – Charpy pendulum impact test – Part 1: Test method
ISO 1099 Metallic materials – Fatigue testing – Axial force-controlled method
ISO 4545-1 Metallic materials – Knoop hardness test – Part 2: Verification and calibration of testing machines
ISO 5832-3 Implants for Surgery – Metallic Materials – Part 3: Wrought Titanium 6-Aluminum 4-Vanadium Alloy Third Edition
ISO 6506-1 Metallic materials – Brinell hardness test – Part 1: Test method
ISO 6507-1 Metallic materials – Vickers hardness test – Part 1: Test method
ISO 6508 Metallic materials – Rockwell hardness test – Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)
ISO 6892-1 Metallic materials – Tensile testing at ambient temperature
ISO 6592-2 Metallic materials – Tensile testing – Part 2: Method of test at elevated temperature
ISO 9001 Quality management system – Requirements
ISO 9044 Industrial woven wire cloth – Technical requirements and testing
ISO 12108 Metallic materials – Fatigue testing – Fatigue crack growth method
ISO 12111 Metallic materials – Fatigue testing – Strain-controlled thermomechanical fatigue testing method
ISO 12135 Metallic materials – Unified method of test for the determination of quasistatic fracture toughness
ISO 12737 Metallic materials – Determination of plane-strain fracture toughness (withdrawn)
ISO 13485 Medical devices – Quality management systems – Requirements for regulatory purposes
ISO 19819 Metallic materials – Tensile testing in liquid helium
 2.5 *SAE Standards*:⁶
AMS 2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2801 Heat Treatment of Titanium Alloys
AMS H81200 Heat Treatment of Titanium and Titanium Alloys
AS1814 Terminology for Titanium Microstructures
AS 9100 Quality Management Systems – Requirements for Aviation, Space and Defense Organizations

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, <http://www.sae.org>.

2.6 ASME Standard:⁷

ASME B46.1 Surface Texture

2.7 National Institute of Standards and Technology⁸

NIST 7847 Interagency/Internal Report (NISTIR)

3. Terminology

3.1 Definitions:

3.1.1 Terminology relating to additive manufacturing in ISO/ASTM 52900 shall apply.

3.1.2 Terminology relating to coordinate systems in ISO/ASTM 52921 shall apply.

3.1.3 Terminology relating to the ordering of additive manufacturing components in ISO/ASTM 52901 shall apply.

3.1.4 Terminology relating to powder metallurgy in Terminology B243 shall apply.

3.1.5 Terminology relating to titanium microstructure in AS1814 shall apply.

4. Condition

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

4.1.1 Condition SR components shall be stress relieved or annealed in accordance with Section 12.

4.1.2 Condition ANN components shall be annealed in accordance with Section 12.

4.1.3 Condition HIP components shall be hot isostatically pressed in accordance with Section 13.

4.1.4 Condition AGED components shall be solution heat treated and aged in accordance with Section 12.

4.1.5 The purchaser may specify multiple conditions on the purchase order such as Condition SR/HIP.

4.2 Table 1 provides guidance on controls by condition.

5. Ordering Information

5.1 Components shall be ordered in accordance with ISO/ASTM 52901 to a specified material condition.

5.2 Supplementary requirements such as those listed in (S1-S16) shall be stated on the purchase order.

6. Manufacturing Plan

6.1 Components manufactured to this specification shall have a manufacturing plan that includes, but is not limited to, the following:

6.1.1 A machine, manufacturing control system, and qualification procedure as agreed upon by the 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 are items commonly included as part of the qualification procedure.

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 automated), build chamber environment, machine conditioning, and calibration information of the qualified machine;

6.1.4 Predetermined process as substantiated by the qualification procedure;

6.1.5 Safeguards to ensure traceability of the digital files, including design history of the components;

6.1.6 All of the steps necessary to start the build process, including build platform selection, machine cleaning, and powder handling;

6.1.7 The requirements for approving/qualifying AM machine users;

6.1.8 Logging of machine build data files, for example, upper and lower limits of the parameters affecting component quality and other process validation controls;

6.1.9 The number of components per build cycle, their orientation and location on the build platform, and support structures, if required;

6.1.10 Process steps including, but not limited to, 8;

6.1.11 Post-processing procedure, including sequence of the post-processing steps and the specifications for each step;

6.1.12 Thermal post-processing including stress relief, furnace anneal, hot isostatic pressing, and any other heat treatment; and

6.1.13 Inspection requirements as agreed upon by the component supplier and purchaser, including any supplementary requirements.

⁷ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

⁸ Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.

TABLE 1 Guidance for Controls by Material Condition

Conditions	Thermal Post-Process	Manufacturing Plan Required	Powder Use Controlled	Powder Contamination Controlled	Post-Processing Controlled	Consolidated Material Chemistry Controlled	Microstructure Controlled	Mechanical Properties Controlled	Quality Program Required
SR	Stress Relief	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ANN	Annealed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HIP	Hot Isostatic Pressed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AGED	Aging	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes