



Standard Specification for Powder Metallurgy (PM) Titanium and Titanium Alloy Structural Components¹

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1. Scope

1.1 This specification covers powder metallurgy (PM) structural components fabricated from:

1.1.1 Commercially pure (CP) (that is, unalloyed) titanium powder,

1.1.2 Pre-alloyed powders.

1.1.3 Mixtures of elemental powders or mixtures of elemental powders and pre-alloyed powders.

1.2 This specification covers:

1.2.1 *Grade 1 PM*—Unalloyed titanium,

1.2.2 *Grade 2 PM*—Unalloyed titanium,

1.2.3 *Grade 3 PM*—Unalloyed titanium,

1.2.4 *Grade 4 PM*—Unalloyed titanium,

1.2.5 *Grade 5 PM*—Titanium alloy (6% aluminum, 4% vanadium),

1.2.6 *Grade 9 PM*—Titanium alloy (3% aluminum, 2.5% vanadium),

1.2.7 Ti-6Al-4V PM Low Interstitial (LI),

1.2.8 Ti-6Al-6V-2Sn PM.

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

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards*:²

B243 Terminology of Powder Metallurgy

B311 Test Method for Density of Powder Metallurgy (PM)

¹ This specification is under the jurisdiction of ASTM Committee B09 on Metal Powders and Metal Powder Products and is the direct responsibility of Subcommittee B09.11 on Near Full Density Powder Metallurgy 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* volume information, refer to the standard's Document Summary page on the ASTM website.

B348 Specification for Titanium and Titanium Alloy Bars and Billets

B923 Test Method for Metal Powder Skeletal Density by Helium or Nitrogen Pycnometry

B962 Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle

E8/E8M Test Methods for Tension Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E539 Test Method for Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry

E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

E1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

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 Atomic Emission Plasma Spectrometry (Withdrawn 2013)³

E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals

3. Terminology

3.1 *Definitions*—Definitions of powder metallurgy terms can be found in Terminology **B243**.

4. Ordering Information

4.1 Orders for components under this specification should include the following information, or portions of it, as agreed to between purchaser and supplier:

4.2 Grade or alloy composition (see Section 6 and **Table 1**).

4.3 Mechanical properties (see Section 8 and **Table 2**).

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

TABLE 1 Chemical Composition Requirements^A

NOTE 1—Additional compositions may be added with future revisions.

Composition, Weight %	N, max	C, max	H, max	Fe	O, max	Al	V	Sn	Cu	Cr	Nb	Residual max ea.
Grade 1 PM	0.03	0.08	0.015	0.20 max	0.18	—	—	—	—	—	—	0.1
Grade 2 PM	0.03	0.08	0.015	0.30 max	0.25	—	—	—	—	—	—	0.1
Grade 3 PM	0.05	0.08	0.015	0.30 max	0.35	—	—	—	—	—	—	0.1
Grade 4 PM	0.05	0.08	0.015	0.50 max	0.40	—	—	—	—	—	—	0.1
Grade 5 PM (Ti-6Al-4V)	0.05	0.08	0.015	0.40 max	0.30	5.50–6.75	3.50–4.50	—	—	—	—	0.1
Grade 9 PM (Ti-3Al-2.5V)	0.03	0.08	0.015	0.25 max	0.30	2.50–3.50	2.00–3.00	—	—	—	—	0.1
Ti-6Al-4V, LI ^B	0.03	0.08	0.0125	0.25 max	0.20	5.50–6.75	3.50–4.50	—	—	—	—	0.1
Ti-6Al-6V-2Sn	0.04	0.1	0.015	0.35–1.0	0.30	5.0–6.0	5.0–6.0	1.5–2.5	0.35–1.0	—	—	0.1

^A For the purpose of determining conformance with this specification, measured values shall be rounded “to the nearest unit” in the last right-hand digit used in expressing the specification limit in accordance with the rounding method of Practice E29. The specified elements of the chemical composition for the Grades in Table 1 reference the chemical compositions from Specification B348.

^B LI = low interstitial.

TABLE 2 Tensile Requirements^A

Classification (PM designation)	Yield Strength (0.2% Offset) (min) MPa	Tensile Strength (min) MPa	Elongation in 25 mm, % (min)	Reduction in Area, % (min)
Grade 1 PM100	138	240	24	30
Grade 1 PM90	124	216	22	27
Grade 2 PM100	275	345	20	30
Grade 2 PM90	248	311	18	27
Grade 3 PM100	380	450	20	30
Grade 3 PM90	342	405	18	27
Grade 4 PM100	483	550	18	30
Grade 4 PM90	435	495	16	27
Grade 5 PM100	828	895	10	25
Grade 5 PM90	745	806	9	23
Grade 9 PM100	483	620	15	25
Grade 9 PM90	435	558	14	23
Ti-6Al-4V LI PM100	759	828	10	15
Ti-6Al-4V LI PM90	683	745	9	14
Ti-6Al-6V-2Sn PM100	883	958	13	13
Ti-6Al-6V-2Sn PM90	795	862	12	12

^A PM100 denotes equivalence to Specification B348 tensile properties, and PM90 denotes 90% of Specification B348 tensile properties.

4.4 Density (see 7.1).

4.5 Component description (see Section 9).

4.6 Processing route (see Section 5).

4.7 Certification (see Section 12).

4.8 *Sampling*—Sample size for determining chemical composition will be decided by purchaser and supplier. Methods for chemical analysis are referenced in 10.1.1.

4.9 Number of tensile tests required as mutually agreed upon by purchaser and supplier.

5. Materials and Manufacture

5.1 Structural components may be fabricated from powders by processing to a near net or net shape with final machining performed if required. Powders may include titanium, pre-alloyed titanium alloys, master alloys, and other elemental powders. The consolidation method shall be sufficient to achieve the final mechanical properties specified. The processing method may include any combination of cold compaction (for example, cold isostatic pressing, uniaxial pressing), powder roll compaction, hot compaction (for example, hot isostatic pressing, powder forging, and pneumatic isostatic forging), sintering, and heat treatment.

6. Chemical Composition

6.1 Chemical composition shall conform to the requirements of Table 1. The purchaser may negotiate with the supplier for other chemical requirements.

6.2 Chemical analysis shall be made in accordance with Test Methods E2371, E1409, E1447, E1941; alternatively, Test Method E539, or any other standard method mutually agreed upon between the purchaser and supplier. Alternative techniques are discussed in Guide E2626.

7. Physical Properties

7.1 *Density*—This specification covers high-and full-density parts with no interconnected porosity.

7.2 Minimum density shall be sufficient to meet the mechanical properties of Table 2 or as specified in the purchase order or contract.

7.3 Density shall be determined in accordance with Test Methods B311, B923, or B962.

NOTE 1—Refer to Refs (1-11)⁴ for supplemental material property information.

⁴ The boldface numbers in parentheses refer to the list of references at the end of this standard.

8. Mechanical Properties

8.1 Tensile tests shall be performed using standardized test bars in accordance with Test Methods E8/E8M produced from the same lot as the components.

8.2 Alternatively, when standardized test bars are not available, or when specified by the purchaser, testing may be performed on material extracted from actual components of the same lot.

NOTE 2—Test specimens may be machined from PM parts or blanks. The test results, however, may differ from compacted test specimens.

9. Dimensions, Mass, and Permissible Variations

9.1 Dimensions and tolerances of the structural components shall be indicated on drawings accompanying the purchase order or contract.

10. Sampling

10.1 Chemical Analysis:

10.1.1 A sample from the lot shall be analyzed in accordance with Test Methods E2371, E1409, E1447 and E1941. Alternatively, Test Method E539 or any other standard method mutually agreed upon between the purchaser and supplier may be used. Definitions of powder metallurgy terms (for example, “lot”) can be found in Terminology B243.

10.1.2 Compliance to the chemical compositions identified in Table 1 is required unless otherwise specified by purchaser.

10.2 Mechanical Testing:

10.2.1 Compliance to the mechanical properties identified in Table 2 is required unless otherwise specified in purchase order or contract. Tensile testing shall be performed in confor-

mance with Test Methods E8/E8M. The purchaser and supplier should determine the number of tensile tests required.

10.2.2 Test bars shall be produced by the same processing route as the components.

10.3 Density shall be measured in accordance with Test Methods B311, B923, or B962.

11. Inspection

11.1 Products will be free of defects that are observable by visual examination and detrimental to usage, such as seams, laminations, pits, cracks, and surface inclusions.

12. Certification

12.1 The supplier shall supply at least one copy of the report certifying that the material has been manufactured, inspected, sampled and tested in accordance with the requirements of this specification, and that the results of chemical analysis, tensile, and other tests meet the requirements of this specification for the grade specified. When specified in the purchase order or contract, a report of test results shall be furnished.

12.2 Basic chemical composition as shown in Table 1 will be tested and reported. Additional elements will be measured and reported as requested by purchaser.

13. Keywords

13.1 CIP; cold isostatic pressing; compaction; HIP; hot isostatic pressing; PIF; pneumatic isostatic forging; powder forging; powder metallurgy; powder roll compaction; pre-alloyed powder; sinter; structural components; Ti Grade 1; Ti Grade 2; Ti Grade 3; Ti Grade 4; Ti-6Al4V; Ti-6Al1-6V-2Sn; Ti 3Al2.5V; titanium; titanium alloys; titanium powder

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