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Standard Specification for Metal Injection Molded Unalloyed Titanium Components for Surgical Implant Applications¹

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1. Scope

1.1 This specification covers the chemical, mechanical, and metallurgical requirements for three grades of metal injection molded (MIM) unalloyed titanium components in two types to be used in the manufacture of surgical implants.

1.2 The Type 1 MIM components covered by this specification may have been densified beyond their as-sintered density by post-sinter processing.

1.3 Values in either inch-pound or SI are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore each system shall be used independent of the other. Combining values from the two systems may result in non-conformance with the specification.

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) Materials Containing Less Than Two Percent Porosity
- B923** Test Method for Metal Powder Skeletal Density by Helium or Nitrogen Pycnometry
- E3** Guide for Preparation of Metallographic Specimens
- E8/E8M** Test Methods for Tension Testing of Metallic Materials
- E29** Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E165** Practice for Liquid Penetrant Examination for General Industry

- E407** Practice for Microetching Metals and Alloys
 - 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
 - E2626** Guide for Spectrometric Analysis of Reactive and Refractory Metals
 - F67** Specification for Unalloyed Titanium, for Surgical Implant Applications (UNS R50250, UNS R50400, UNS R50550, UNS R50700)
 - F601** Practice for Fluorescent Penetrant Inspection of Metallic Surgical Implants
 - F629** Practice for Radiography of Cast Metallic Surgical Implants
 - SI 10** American National Standard for Use of the International System of Units (SI): The Modern Metric System
- ### 2.2 ISO Standards:³
- ISO 5832-3** Implants for Surgery—Metallic Materials—Part 3: Wrought Titanium 6-Aluminum 4-Vanadium Alloy
 - ISO 6892** Metallic Materials—Tensile Testing at Ambient Temperature
 - ISO 9001** Quality Management Systems—Requirements
- ### 2.3 Aerospace Material Specifications:⁴
- AMS 2249** Chemical Check Analysis Limits, Titanium and Titanium Alloys
- ### 2.4 MPIF Standards:⁵
- Standard 10** Determination of the Tensile Properties of 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.

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

⁴ Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://aerospace.sae.org>.

⁵ Available from Metal Powder Industries Federation (MPIF), 105 College Rd. East, Princeton, NJ 08540, <http://www.mpiif.org>.

Standard 42 Determination of Density of Compacted or Sintered Powder Metallurgy Product

Standard 50 Preparing and Evaluating Metal Injection Molded Sintered/Heat Treated Tension Specimens

Standard 63 Density Determinations of MIM Components (Gas Pycnometry)

Standard 64 Terms Used in Metal Injection Molding

3. Terminology

3.1 Definitions of powder metallurgy and MIM terms can be found in Terminology **B243** and MPIF Standard 64. Additional descriptive information is available in the Related Material Section of Vol. 02.05 of the *Annual Book of ASTM Standards*.

3.2 The materials produced by means of the metal injection molding process are designated by the prefix, “MIM”, followed by the appropriate designation for the alloy grade. The MIM designates that it was made by metal injection molding.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *absolute density, n*—the value of density used to characterize a powder material with a particular chemical composition as if it were a fully dense material, completely free of porosity.

3.3.1.1 *Discussion*—For the purposes of this specification, the skeletal density (also referred to as pycnometer density) measured on the raw material powders using the pycnometry method of Test Method **B923** shall be used to represent the absolute density of the particular chemical composition.

3.3.2 *debinding, v*—a step between molding and sintering where the majority of the binder used in molding is extracted by heat, solvent, a catalyst, or other techniques.

3.3.3 *feedstock, n*—in metal injection molding, a moldable mixture of metal powder and binder.

3.3.4 *feedstock batch, n*—a specified quantity of feedstock made up of the same lot of metallic powders and the same lot of binder materials mixed under the same conditions at essentially the same time.

3.3.5 *lot, n*—a specified quantity of components made up of the same batch of feedstock, debound, sintered, and post-processed under the same conditions at essentially the same time.

3.3.6 *metal injection molded component, n*—product fabricated by a metal injection molding process consisting of mixing metal powders with binders to make a feedstock, introducing this feedstock into a mold by injection or other means, debinding to remove the binders, and sintering.

3.3.7 *near net component, n*—a component that meets dimensional tolerance as built with little post processing.

3.3.8 *net component, n*—a component that meets dimensional tolerance as built with no post processing.

3.3.9 *pre-alloyed powder, n*—powder composed of two or more elements that are alloyed in the powder manufacturing process in which the particles are of the same nominal composition throughout.

3.3.10 *relative density, n*—the density ratio, often expressed as a percentage, of the density of a porous material to the absolute density of the same material, completely free of porosity.

3.3.11 *sintering, v*—the metallurgical bonding of particles in a MIM component resulting from a thermal treatment at a temperature below the melting point of the main constituent.

3.3.12 *Type 1, n*—a MIM component that may have been densified beyond its as-sintered density by post-sinter processing.

3.3.13 *Type 2, n*—a MIM component that shows the as-sintered density and was not densified after sintering.

4. Ordering Information

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

4.1.1 Quantity,

4.1.2 ASTM specification and date of issue,

4.1.3 Grade (MIM 1, MIM 2 or MIM 3),

4.1.4 Type (1 or 2),

4.1.5 Units to be certified—SI or Inch-Pounds,

4.1.6 Component configuration (engineering drawing or 3D solid model, or both) and dimensional requirements,

4.1.7 Condition (**5.2**),

4.1.8 Mechanical properties (if applicable),

4.1.9 Finish (**5.2**),

4.1.10 Special tests (**9, 10** and **11**), if any, and

4.1.11 Other requirements.

5. Materials and Manufacture

5.1 Components conforming to this specification shall be produced by the metal injection molding process using unalloyed metal powders with major elemental composition meeting the chemical requirements of **Table 1**.

5.2 Post-sintering operations may be employed to achieve the desired density, shape, size, surface finish, or other component properties. The post-sintering operations shall be agreed upon between the supplier and purchaser.

5.3 The condition and finish of the components shall be agreed upon between the supplier and purchaser.

6. Chemical Requirements

6.1 The components supplied under this specification shall conform to the chemical requirements in **Table 1**. The supplier shall not ship components with chemistry outside the requirements specified in **Table 1**.

TABLE 1 Chemical Composition

Element	Composition for both Type 1 and Type 2 Composition, % (mass/mass)		
	Grade MIM 1	Grade MIM 2	Grade MIM 3
Nitrogen, max	0.03	0.03	0.05
Carbon, max	0.08	0.08	0.08
Hydrogen, max	0.015	0.015	0.015
Iron, max	0.020	0.030	0.030
Oxygen, max	0.18	0.25	0.30
Titanium	Balance	Balance	Balance