



Designation: B311 – 22

Standard Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity¹

This standard is issued under the fixed designation B311; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This test method covers the determination of density for powder metallurgy (PM) materials containing less than two percent porosity and for cemented carbides. This test method is based on the water displacement method.

NOTE 1—A test specimen that gains mass when immersed in water indicates the specimen contains surface-connected porosity. Unsealed surface porosity will absorb water and result in calculated density values higher than the true value. This test method is not applicable if this problem occurs, and Test Methods B962 should be used instead.

1.2 *Units*—With the exception of the values for density and the mass used to determine density, for which the use of the gram per cubic centimetre (g/cm^3) and gram (g) units is the long-standing industry practice, the values in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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

B243 Terminology of Powder Metallurgy

¹ This test method 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.

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

E456 Terminology Relating to Quality and Statistics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 Definitions of powder metallurgy (PM) terms can be found in Terminology B243. Additional descriptive material is available under “General Information on PM” on the ASTM B09 web page.

4. Summary of Test Method

4.1 Using an analytical balance, the test specimen is first weighed in air and then in water. The density is determined by calculation using Archimedes' principle.

5. Significance and Use

5.1 For PM materials containing less than two percent porosity, a density measurement may be used to determine if the part has been densified, either overall or in a critical region, to the degree required for the intended application. Density alone cannot be used for evaluating the degree of densification because chemical composition and heat treatment affect the pore-free density.

5.2 For cemented carbides, a density measurement is normally used to determine if there is any significant deviation in composition of the carbide grade. For straight tungsten carbide-cobalt grades, the relationship is straightforward. For complex carbide grades (for example, grades containing tantalum carbide or titanium carbide, or both, in addition to tungsten carbide-cobalt), the situation is more complicated. If the measured density is beyond the specified limits, the composition is outside of the specified limits. A measured density within the specified limits does not ensure correct composition; compensation between two or more constituents could result in the expected density with the wrong composition. Density alone cannot be used for evaluating a cemented carbide grade.

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

6. Apparatus

6.1 *Analytical Balance*—Precision single-pan analytical balance that will permit readings within 0.01% of the test specimen mass. See Table 1. The analytical balance shall be supported in a manner to eliminate mechanical vibrations and be shielded from air drafts.

6.2 *Water*—Distilled or deionized and preferably degassed water to which 0.05 to 0.1 volume percent of a wetting agent has been added to reduce the effects of surface tension. The density of distilled water changes as a function of water temperature and therefore should be accounted for when calculating the density of the specimen; see Table 2.

NOTE 2—Degassing the water by evacuation, boiling, or ultrasonic agitation helps to prevent air bubbles from collecting on the test specimen and specimen support when immersed in water.

6.3 *Water Container*—A glass beaker or other suitable transparent container should be used to contain the water.

NOTE 3—A transparent container makes it easier to see air bubbles adhering to the test specimen and specimen support when immersed in water.

NOTE 4—For the most precise density determination, the water container should be of a size that the level of the water does not rise more than 2.5 mm (0.10 in.) when the test specimen is lowered into the water.

6.4 *Test Specimen Support for Weighing in Water*—Two typical arrangements are shown in Fig. 1. The suspension wire may be twisted around the test specimen, or the test specimen may be supported in a wire basket that is attached to the suspension wire. For either arrangement, a single corrosion resistant wire—for example, austenitic stainless steel, copper, nichrome—shall be used for the basket and suspension wire. For the maximum recommended diameter of suspension wire to be used for various mass ranges, see Table 3.

NOTE 5—For the most precise density determinations, it is important that the mass and volume of all supporting wires immersed in water be minimized.

6.5 *Thermometer*—A thermometer to measure the temperature of the water to the nearest 0.5 °C (1 °F).

7. Preparation of Test Specimens

7.1 A complete part or a section of a part may be used for the test specimen. For the highest precision, the test specimen shall have a minimum mass of 5.0 g. If less precision can be tolerated, several test specimens may be used to reach the minimum mass, provided each test specimen has a mass of not less than 1.0 g.

NOTE 6—For metal injection molded (MIM) parts of less than 1.0 g, several parts may be used to reach the minimum mass.

7.2 Thoroughly clean all surfaces of the test specimen to remove any adhering foreign materials such as dirt or oxide scale. Take care with cut specimens to avoid rough surfaces to

TABLE 2 Density of Air-Free Water^A

Temperature °C	ρ_w g/cm ³	Temperature °F	ρ_w g/cm ^{3*}
15.0	0.9991	60	0.9990
15.5	0.9990	61	0.9989
16.0	0.9989	62	0.9988
16.5	0.9988	63	0.9987
17.0	0.9988	64	0.9986
17.5	0.9987	65	0.9985
18.0	0.9986	66	0.9984
18.5	0.9985	67	0.9983
19.0	0.9984	68	0.9982
19.5	0.9983	69	0.9981
20.0	0.9982	70	0.9980
20.5	0.9981	71	0.9978
21.0	0.9980	72	0.9977
21.5	0.9979	73	0.9975
22.0	0.9978	74	0.9974
22.5	0.9976	75	0.9973
23.0	0.9975	76	0.9972
23.5	0.9974	77	0.9970
24.0	0.9973	78	0.9969
24.5	0.9972	79	0.9967
25.0	0.9970	80	0.9966
25.5	0.9969	81	0.9964
26.0	0.9968	82	0.9963
26.5	0.9966	83	0.9961
27.0	0.9965	84	0.9959
27.5	0.9964	85	0.9958
28.0	0.9962	86	0.9956
28.5	0.9961		
29.0	0.9959		
29.5	0.9958		
30.0	0.9956		

*Interpolated from
°C Data

^A *Metrological Handbook 145*, "Quality Assurance for Measurements," National Institute of Standards and Technology, 1990, p. 9.10.

which an air bubble may adhere. A 100-grit sanding or abrasive grinding is recommended to remove all rough surfaces.

8. Procedure

8.1 The part or test specimen, the analytical balance and surrounding air shall be at a uniform temperature when weighing is performed.

8.2 For the most precise density determinations, duplicate weighings should be made for all mass measurements. Adjust the analytical balance to zero prior to each weighing. Average the mass determinations before calculating the density.

8.3 For improved repeatability and reproducibility, verify the analytical balance periodically with a standard mass that is approximately equal to the part or test specimen mass.

8.4 Weigh the test specimen in air using an analytical balance. This is mass A. This and all subsequent weighings shall be to the precision stated in Table 1.

8.5 Support the container of water over the pan of the balance using a suitable bridge as shown in Fig. 2. The container of water may also be supported below the balance for weighing larger specimens if the balance has a lower beam hook for this purpose. See Fig. 2b. If this arrangement is used, it is important to shield the suspension wire between the container of water and the bottom of the balance from air drafts.

8.6 Suspend the test specimen support with the test specimen from the beam hook of the balance. The water should

TABLE 1 Balance Readability

Mass, g	Balance Readable to, g
less than 10	0.0001
10 to less than 100	0.001
100 to less than 1000	0.01
1000 to less than 10 000	0.1