



Standard Test Method for Green Strength of Specimens Compacted from Metal Powders¹

This standard is issued under the fixed designation B312; 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 standard covers a test method that may be used to measure the transverse rupture strength of a compacted but unsintered (green) test specimen produced from lubricated or unlubricated metal powders or powder mixtures.

1.2 Green strength is measured by a quantitative laboratory procedure in which the fracture strength is calculated from the force required to break an unsintered test specimen supported as a simple beam while subjected to a uniformly increasing three-point transverse load under controlled conditions.

1.3 This test method is a companion standard to Test Method [B528](#) that covers the measurement of the transverse rupture strength of sintered PM test specimens.

1.4 With the exception of the values for density and the mass used to determine density, for which the use of the gram per cubic centimeter (g/cm^3) and gram (g) units is the long-standing industry practice, the values in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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

[B215 Practices for Sampling Metal Powders](#)

[B243 Terminology of Powder Metallurgy](#)

[B528 Test Method for Transverse Rupture Strength of Pow-](#)

[der Metallurgy \(PM\) Specimens](#)

[B925 Practices for Production and Preparation of Powder Metallurgy \(PM\) Test Specimens](#)

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

[E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method](#)

3. Terminology

3.1 *Definitions*—the definitions of powder metallurgy (PM) terms used in this test method can be found in Terminology [B243](#). Additional descriptive PM information is available in the Related Material section of Vol 02.05 of the *Annual Book of ASTM Standards*.

4. Summary of Test Method

4.1 Three rectangular test specimens are compacted to a predetermined green density or at a specified compacting pressure from test portions of the metal powder or powder mixture that is to be tested.

4.2 Each unsintered bar is placed, in turn, in a test fixture and subjected to a uniformly increasing transverse load under controlled conditions until fracture occurs.

4.3 The green strength or maximum flexural stress of each specimen is determined by calculation using the stress equation for a simply supported beam with a concentrated mid-point load.

4.4 The green strength of the material being tested is reported as the arithmetic mean of the results of three individual tests at the measured green density or at the specified compacting pressure rounded to the nearest 100 psi (0.5 MPa).

5. Significance and Use

5.1 The green strength value determined under the conditions specified by this test method is influenced by the characteristics of the powder, how it compacts under the specified conditions (i.e., the particle to particle bonding that exists following compacting), and the lubrication system used.

5.2 Knowledge of the green strength value is useful to the production, characterization and utilization of metal powders in the manufacture of PM structural parts and bearings.

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 [B09.02](#) on Base Metal Powders.

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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.

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

5.3 The test for green strength of a compacted metal powder can be used to:

5.3.1 Relate the resistance of a pressed compact to breakage or damage due to handling.

5.3.2 Compare the quality of a metal powder or powder mixture from lot to lot.

5.3.3 Determine the effect of the addition of a lubricant or other powders to a base powder.

5.3.4 Evaluate powder mixing or blending variables.

5.4 Factors that are known to influence the green strength of a metal powder are particle shape, particle size distribution and compressibility of the metal powder.

5.5 The amount and type of lubricant or other additives and the mixing procedures have a strong effect on the green strength of specimens produced from metal powder mixtures.

6. Apparatus

6.1 *Analytical Balance*—A balance readable to 0.001 g with a minimum capacity of 100 g to be used for determining the mass of the test portion of the powder and the green test specimen to the nearest 0.01 g.

6.2 *PM Tool Set*—a compacting die and punches capable of producing the test specimens; an example of which is shown in Practices B925 as *Laboratory Tooling –Transverse Rupture Test Specimen*.

6.3 *Universal Testing Machine or PM Compacting Press*—a press with the ability to hold the PM tooling and apply the force necessary to compact the test specimens to the target green density.

6.4 *Outside Micrometers or Calipers*—instruments capable of measuring from 0.000 to 1.250 in. (0.00 to 31.75 mm) with an accuracy of 0.001 in. (0.03 mm).

6.5 Either of the following sets of testing apparatus:

6.5.1 *Transverse Rupture Test Fixture and Compression Testing Machine*—a fixture (Fig. 1) for locating the test specimen and a press capable of applying a breaking load at a controlled rate of approximately 20 lbf/min (~90 N/min), and on which the force can be read to the nearest 0.1 lbf (0.5 N), or

6.5.2 *Constant Loading Beam Device, Metal Shot and Scale*— a lever-arm laboratory device (Fig. 2), designed to collect a controlled flow of metal shot that will produce a force with a loading rate of approximately 20 lbf/min (~90 N/min) on a pre-positioned test specimen until fracture occurs, and a scale with a capacity of at least 25 lb (10 kg) to determine the mass to the nearest 0.01 lb (0.005 kg) of the shot that was required.

7. Test Specimen

7.1 The recommended test specimen is an unsintered, (green), rectangular compact having dimensions of 0.500 in.

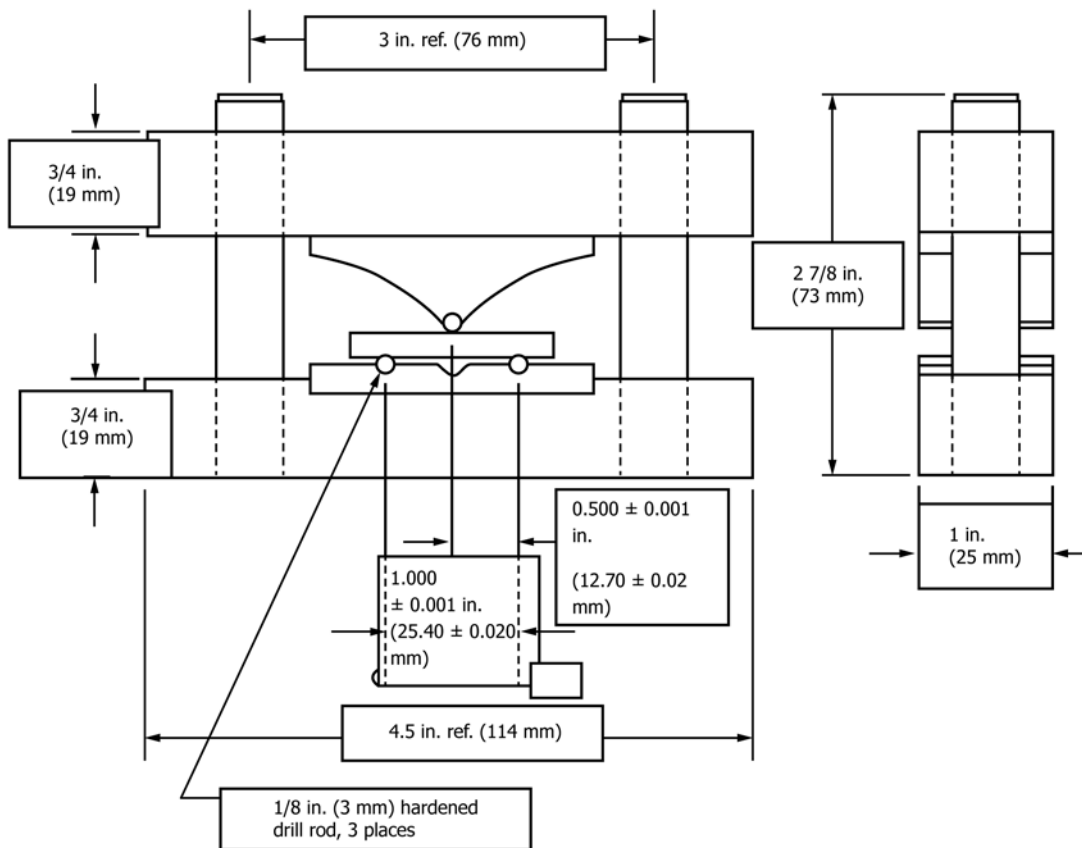


FIG. 1 Transverse Rupture Test Fixture

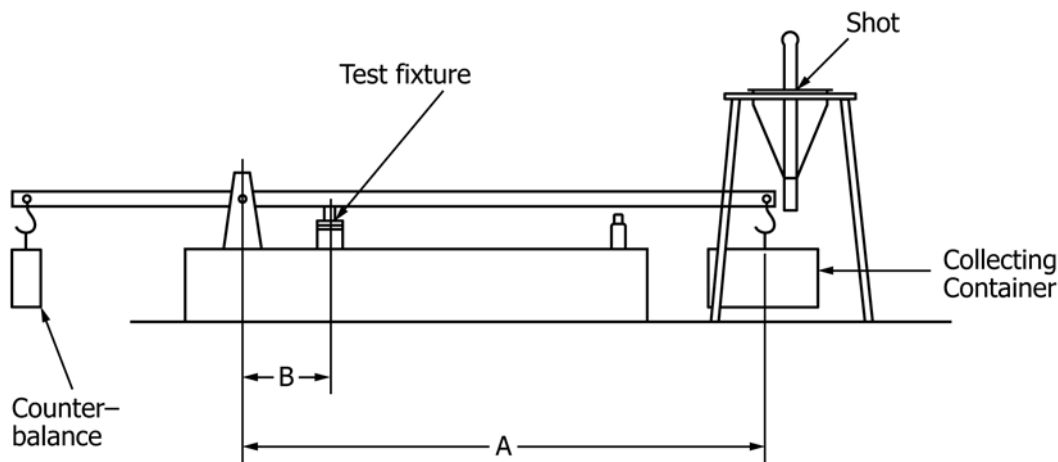


FIG. 2 Example of Constant Loading Beam Device

(12.70 mm) wide by 1.250 in. (31.75 mm) long as specified in Practices B925 as *Transverse Rupture Strength Test Specimen*.

7.2 Either the *thin* test specimen with a thickness 0.250 ± 0.005 in. (6.35 ± 0.13 mm) or the *thick* test specimen having a thickness of 0.500 ± 0.005 in. (12.70 ± 0.13 mm) may be used as agreed to by the concerned parties.

7.3 The top and bottom faces of the green compact shall be parallel within 0.001 in. (0.03 mm).

7.4 The green density shall be within ± 0.05 g/cm³ of the target green density that has been agreed to between the concerned parties.

8. Procedure

8.1 *Lubrication Method*—The lubrication system to be used when compacting the test specimen shall be a matter of agreement between the concerned parties. Compactibility and green density will vary with the method chosen as well as the care with which it is applied and affect the green strength value.

8.1.1 Lubricated metal powder mixtures should be tested in the as-received condition.

8.1.2 Unlubricated metal powder or powder mixtures may be compacted with the aid of die-wall lubrication or an admixed powder lubricant.

8.1.2.1 If die-wall-lubrication is chosen, it shall be applied prior to the compacting of each test specimen following the procedures in Practices B925.

8.1.2.2 If an admixed lubricant is to be used; the type, grade, percentage and mixing procedure shall be agreed upon between the concerned parties or shall closely follow accepted PM practice.

8.2 *Powder Sampling*—Using Eq 1, calculate the mass of metal powder that will be needed to produce one test specimen from the nominal dimensions and desired thickness at the target green density.

$$M = \frac{D_G \times W \times T \times L}{0.061} \quad (1)$$

where:

M = mass of powder needed, g,
 D_G = target green density, g/cm³,
 W = width of test specimen, in.,
 T = thickness of test specimen, in., and
 L = length of test specimen, in., and
 0.061 = conversion factor, in³ to cm³

8.2.1 Following the recommendations in Practices B215, take a gross sample of powder from the lot that is to be tested of sufficient quantity to produce a minimum of three test specimens.

8.2.2 From this gross sample, remove three test portions of powder that can be used to produce three test specimens of the desired thickness at the target green density. Each test portion shall be within 0.02 g of the powder mass that was calculated.

8.3 *Compacting Procedure*—Set-up the PM Tooling in the compacting press or the universal testing machine. Then, using the force that is necessary to produce the desired thickness at the target green density, compact three test specimens from the three test portions of powder following the compacting procedure in Practices B925.

8.3.1 Determine the mass of each test specimen to the nearest 0.01 g, measure the specimen dimensions to the nearest 0.001 in. (0.03 mm), number and identify the top of each specimen.

8.3.2 Calculate the green density of each test specimen using Eq 2. Record these values to the nearest 0.01 g/cm³.

$$D_G = 0.061 \frac{M}{W \times T \times L} \quad (2)$$

where:

D_G = green density of the test specimen, g/cm³,
 0.061 = conversion factor, in³ to cm³,
 M = mass of the test specimen, g,
 W = width of test specimen, in.,
 T = thickness of test specimen, in., and
 L = length of test specimen, in.

NOTE 1—Do not use Test Method B962 to measure the green density of

the test specimens because of the possible effect of absorbed water on the green strength value.

8.4 *Testing Procedure*—Select a set of three green test specimens that are within $\pm 0.05 \text{ g/cm}^3$ of the target green density, and break each bar in turn using either the Transverse Rupture Test Fixture, or the Constant Loading Beam Device.

USING THE TRANSVERSE RUPTURE STRENGTH TEST FIXTURE

8.4.1 Place the *Transverse Rupture Test Fixture*, Fig. 1, between the platens of the compression testing machine with the movable upper portion securely attached, (if possible), to the upper platen.

8.4.1.1 Locate each of the measured test specimens, in turn, centered lengthwise on the supporting rods of the test fixture with the top face uppermost.

8.4.1.2 Apply a uniformly increasing compressive load at a rate of approximately 20 lbf/min (~90 N/min), until fracture occurs. Record the force at fracture directly from the read-out on the testing machine for each test specimen as the breaking force, P , in lbf (or N) to the nearest 0.1 lbf (0.5 N) for use in future calculations.

8.4.1.3 If the upper portion of the test fixture is not attached to the upper press platen, then the force in lbf (N), exerted by the mass of the upper portion of the test fixture shall be determined and added to the read-out to determine the true breaking force.

USING THE CONSTANT LOADING BEAM DEVICE

8.4.2 Set up the Constant Loading Beam Device, Fig. 2, on a sturdy laboratory table or bench and balance the lever arm with the empty collecting container hanging in place on the hook.

8.4.2.1 Open the valve and adjust the flow rate of the shot to approximately 20 lb/min (~9 kg/min). Record the setting, empty and rehang the collecting container.

8.4.2.2 Locate each of the measured test specimens, in turn, centered lengthwise on the supporting rods of the test fixture with the top face uppermost.

8.4.2.3 Open the valve to the predetermined setting and allow metal shot to flow into the collecting container until fracture occurs.

8.4.2.4 Stop the flow, empty the container and determine the mass of the shot, S , to the nearest 0.01 lb (0.005 kg).

8.4.2.5 Calculate the breaking force, P , to the nearest 0.01 lbf (0.5 N) using the following equation:

$$P = \frac{A \times F}{B} \quad (3)$$

where:

- P = force required to break the test specimen, lbf (N),
- A = length of lever arm A, in. (mm) see Fig. 2,
- B = length of lever arm B, in. (mm) see Fig. 2, and
- F = force on the lever arm caused by the mass of the metal shot, lbf (N).

When using in-lb units, F in lbf = S in lb.

When using SI units, F in N = 9.8 times S in kg.

where:

S = mass of the metal shot, lb (kg)

9. Calculations

9.1 Using the breaking force values, P , obtained from the stress equation in sec. 8.4.1.2, 8.4.1.3 or 8.4.2.5, calculate the green strength values for each of the test specimens as follows:

$$GS = \frac{3 \times P \times L}{2 \times T^2 \times W} \quad (4)$$

where:

- GS = green strength, psi (MPa),
- P = Breaking force required to rupture, lbf (N)
- L = length of span between supports of test fixture, in. (mm), (see Fig. 1) to the nearest 0.001 in. (0.03 mm)

- W = width of specimen, in. (mm), and
- T = thickness of specimen, in. (mm.)

10. Report

10.1 The general reporting format shall be : *Green Strength of a (nominal thickness) test specimen at (the measured) green density or at the specified compacting pressure.*

10.1.1 The green strength shall be reported in psi (or MPa) as the arithmetic mean of three individual test results rounded to the nearest 100 psi (or 0.5 MPa).

10.1.2 The thickness of the test specimen that was used shall be included in the report as a nominal value.

10.1.3 The green density shall be reported as the average of the three test specimens to the nearest 0.01 g/cm^3 .

10.2 An alternative reporting method may be to graph the green strength as a function of green density or compacting pressure using the results obtained at a minimum of three data points.

10.3 The following information may also be reported to help interpret the test results:

10.3.1 Testing apparatus used, either the *Transverse Rupture Test Fixture* or *The Constant Loading Beam Device*.

10.3.2 Powder type, brand, grade and lot identification number.

10.3.3 Composition of the powder mixture if other than a base powder.

10.3.4 Lubrication system as well as type, brand and amount.

10.3.5 Apparent density, flow rate and sieve analysis of the powder and the test methods used to determine these properties.

10.3.6 Compacting pressure used to achieve the target green density.

11. Precision and Bias³

11.1 The precision of this test method has been determined from an interlaboratory study, (ILS) conducted on two ferrous

³ The precision for this test method was developed by the Metal Powder Industries Federation (MPIF), 105 College Road East, Princeton, NJ 08540 USA and is used herein with their permission. The ILS data and results are available in MPIF Research Report-R-15-05.

TABLE 1 Precision of Green Strength Measurements Using the Test Fixture and Compression Testing Machine

Material	Nominal thickness, in. (mm)	Number of Laboratories	Mean strength psi ^A	Repeatability, r psi	Reproducibility, R, psi
water atomized pre-alloyed powder + 0.5% wax lubricant (green density = 6.8 g/cm ³)	0.250 (6.35)	32	1301	246	452
	0.500 (12.70)	32	1685	436	540
	0.250 (6.35)	32	4979	727	1941
sponge iron + 0.5% wax lubricant (green density = 7.2 g/cm ³)	0.500 (12.70)	32	5432	648	1814

^AStrength values listed are the arithmetic averages of the test data and have not been rounded

TABLE 2 Precision of Green Strength Measurements for the Lower Green Strength Materials Using the Constant Loading Beam Device with Metal Shot

Material	Nominal thickness, in. (mm)	Number of Laboratories	Mean strength psi ^A	Repeatability, r psi	Reproducibility, R, psi
water atomized pre-alloyed powder + 0.5% wax lubricant (green density = 6.8 g/cm ³)	0.250 (6.35)	9	1274	113	201
	0.500 (12.70)	9	1703	136	518

^AStrength values listed are the arithmetic averages of the test data and have not been rounded

materials by the Metal Powder Industries Federation in 2005 in which 32 laboratories participated. Practice E691 was used to perform a statistical analysis of the data at the 95% confidence level.

11.1.1 *Repeatability Values, r*, obtained when using the test fixture and compression testing machine are listed in Table 1 and in Table 2 when using the constant loading beam device with metal shot. On the basis of test error alone, duplicate tests in the same laboratory by the same operator on the same material should not differ more than the value listed.

11.1.2 *Reproducibility Values, R*, for the two methods are also listed in Table 1 and Table 2. For tests conducted in two laboratories, and on the basis of test error alone, the results should not differ by more than the value listed.

11.2 *Bias*—The bias of the green strength test can not be established because there is no standard available for comparison.

11.3 *Measurement Uncertainty*—The precision of this test method shall be considered by those performing the test when reporting the results.

12. Keywords

12.1 constant loading beam device; green strength; PM; powder metallurgy; transverse strength; unsintered compact

SUMMARY OF CHANGES

Committee B09 has identified the location of selected changes to this standard since the last issue (B312–09) that may impact the use of this standard.

- (1) Changed the statement on units in **1.4**.
- (2) Added the option of compacting at a specified pressure in **4.1** and **4.4**.
- (3) Deleted the reference to SI 10 in Section **2**.
- (4) Changed the description of the analytical balance in **6.1**.
- (5) Corrected the captions for **Fig. 1** and **Fig. 2**.
- (6) Changed the precision for determining the mass in **8.3.1**.
- (7) Modified the reporting requirements in **10.1** and **10.2**.

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