# Standard Test Method for Measuring Compressive Properties of Thermal Insulations[1]

This standard is issued under the fixed designation C 165; 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 Department of Defense.*

## 1. Scope

1.1 This test method covers two procedures for determining the compressive resistance of thermal insulations.

1.1.1 Procedure A covers thermal insulations having an approximate straight-line portion of a load-deformation curve, but that may or may not have an identifiable yield point as shown in Figs. 1 and 2. Such behavior is typical of most rigid board or block-type insulations.

1.1.2 Procedure B covers thermal insulations that become increasingly more stiff as load is increased, as shown in Fig. 3. Such behavior is typical of fibrous batt and blanket insulations that have been compressed previously to at least the same deformation by compression packaging or mechanical softening.

1.2 It is recognized that the classification of materials under Procedures A and B may not hold in all cases. For example, some batt or blanket materials that have not been compression packaged will exhibit behavior more typical of Procedure A for their first loadings. Also, some higher density fibrous insulation boards that have been precompressed will exhibit load-deformation curves more typical of Procedure B. There will also be thermal insulations with load-deformation curves that follow none of the three types shown here; that is, curves with no straight-line portion, curves with compaction areas, and curves that change from negative to positive slope.

1.3 This test method does not cover reflective or loose fill insulations.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

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:*

C 167 Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations[2]

C 168 Terminology Relating to Thermal Insulating Materials[2]

C 240 Test Methods of Testing Cellular Glass Insulation Block[2]

E 4 Practices for Force Verification of Testing Machines[3]

E 177 Practice for the Use of the Terms Precision and Bias in ASTM Test Methods[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[4]

## 3. Terminology

3.1 *Definitions:*

3.1.1 Terminology C 168 applies to the terms used in this method.

3.2 Additional terms are defined as follows:

3.3 *compressive deformation*—the decrease in specimen thickness by a compressive load.

3.4 *compressive load*—the compressive force carried by the test specimen at any given moment.

3.5 *compressive modulus of elasticity*—the ratio of the compressive load per unit of original area to the corresponding deformation per unit of original thickness below the proportional limit of a material.

3.6 *compressive resistance*—the compressive load per unit of original area at a specified deformation. For those materials where the specified deformation is regarded as indicating the start of complete failure, the compressive resistance may properly be called the compressive strength.

3.7 *proportional limit in compression*—the greatest compressive load that a material is capable of sustaining without any deviation from proportionality of load to deformation.

3.8 *yield point in compression*—the load at the first point on the load-deformation curve at which an increase in deformation occurs without an increase in load.

## 4. Significance and Use

4.1 In providing Procedures A and B, it is recognized that different types of thermal insulation may exhibit significantly different behavior under compressive load. Data must usually

[1] This test method is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.32 on Mechanical Properties.

Current edition approved Oct. 10, 2000. Published December 2000. Originally published as C 165 – 41T. Last previous edition C 165 – 95. Replaces C 203 – 45T.

[2] *Annual Book of ASTM Standards*, Vol 04.06.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

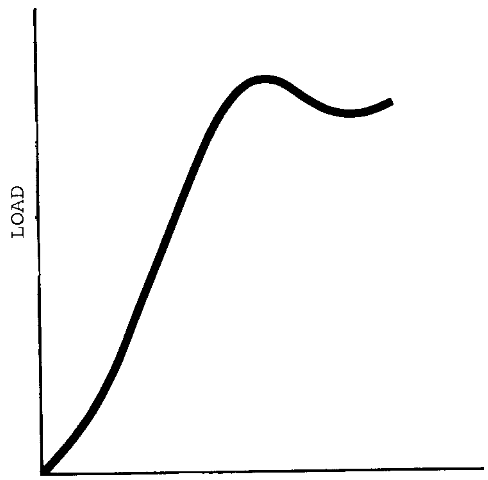


FIG. 1 Procedure A—Straight Line Portion with Definite Yield Point

be obtained from a complete load-deformation curve, and the useful working range normally corresponds to only a portion of the curve. The user is cautioned against use of the product in the range beyond which the product is permanently damaged or properties are adversely affected.

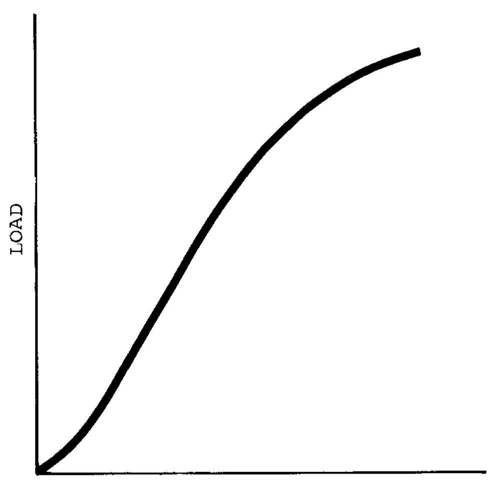


FIG. 2 Procedure A—Straight Line Portion but no Definite Yield Point

4.2 Load-deformation curves provide useful data for research and development, quality control, specification acceptance or rejection, and for other special purposes. Standard loading rates should not be used arbitrarily for all purposes; the effects of impact, creep, fatigue, and repeated cycling must be considered. All load-deformation data should be reviewed carefully for applicability prior to acceptance for use in engineering designs differing widely in load, load application rate, and material dimensions involved.

## 5. Apparatus

5.1 *Testing Machine*— Standard hydraulic or mechanical compression testing machine of suitable capacity, and capable

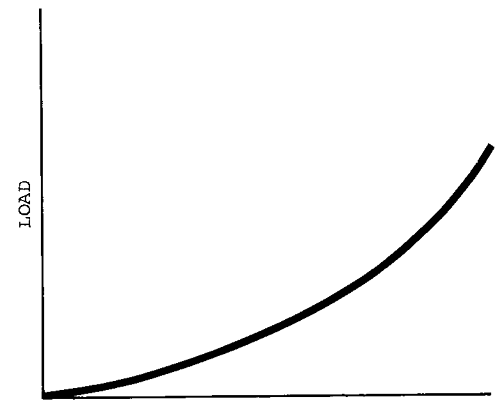


FIG. 3 Procedure B—Increasing Stiffness

of operating at the specified constant rate of motion of the movable head. Verify the accuracy of the testing machine in accordance with Practices E 4.

5.2 *Loading Surfaces*— Surfaces shall be at least 1.0 in. (25.4 mm) greater in all directions than the test specimens, and shall be designed to remain plane within ±0.003 in./ft (±0.25 mm/m) under all conditions of load.

5.2.1 *Procedure A*— A preferred size is 8.0 in. (203 mm) square. One surface plate, either the upper or lower, shall be mounted rigidly with its surface perpendicular to the testing machine axis. The other surface plate shall be self-aligning, suspended by a spherical bearing block as shown in Fig. 4.

5.2.2 *Procedure B*— A preferred size is 1.0 $ft^2$ (0.093 $m^2$) in area, either 12 in. (305 mm) square or 13.54 in. (344 mm) in diameter. Both plates shall be mounted rigidly so that the surfaces are parallel to each other and perpendicular to the testing machine axis.

5.3 *Load Indicator*— Load-indicating mechanism that will permit measurements with an accuracy of± 1 % of total load.

5.4 *Deformation Indicator*—Deformation-indicating mechanism that measures crosshead movement, or a simple jig that will permit direct measurements, with an accuracy of ±0.1 % of specimen thickness. When crosshead movement is used to measure deformation, use a calibration curve unless it has been shown that under the conditions of test the crosshead indicator gives an accurate measure of specimen deformation.

5.5 *Measuring Instruments*:

5.5.1 *Dial Gage Comparator*, with a circular foot having a minimum area of 1.00 $in.^2$ (645 $mm^2$) and capable of measuring thickness to ±0.002 in. (±0.05 mm).

5.5.2 *Steel Rule*, capable of measuring to ±0.01 in. (0.25 mm).

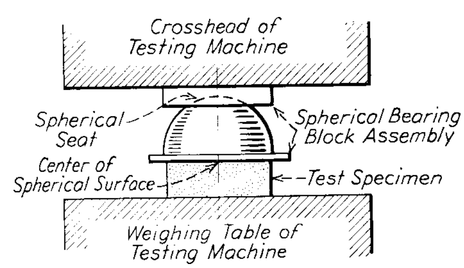


FIG. 4 Spherical Bearing Block for Compressive Strength Test

5.5.3 *Depth Gage*, pin-type, as specified in Test Methods C 167 for Procedure B only.

5.6 *Drying or Conditioning Equipment* (see 6.5):

5.6.1 *Drying Oven*, temperatures to 250°F (121°C).

5.6.2 *Desiccator*, using dry calcium chloride or silica gel desiccant.

5.6.3 *Conditioned Space*, at temperature of 73.4 ± 3.6°F (23 ± 2°C), and relative humidity of 50 ± 5 %.

## 6. Test Specimens

6.1 *Specimen Size*:

6.1.1 Procedure A specimens shall preferably be square or circular with a minimum area of 4 in.$^2$ (2580 mm$^2$) and a preferred width or diameter of 6 in. (150 mm). The minimum thickness shall be ½ in. (12.7 mm) and the maximum thickness shall be no greater than the width or diameter.

NOTE 1—See Test Methods C 240 for preparation of cellular glass test specimens.

6.1.2 Procedure B specimens shall preferably be square or circular with a minimum width or diameter of 6.0 in. (153 mm). The minimum thickness shall be 1.0 in. (25.4 mm) and the maximum thickness shall be no greater than the width or diameter.

NOTE 2—For some materials, the specimen thickness has considerable effect on the deformation at yield, the compressive resistance, and the compressive modulus. Therefore, use the same thickness for comparisons with other test specimens. The thinner the specimen, the higher the compressive resistance and the lower the deformation at yield.

6.2 The number of specimens to be tested and the sampling plan shall conform to materials specifications where applicable. In the absence of such specifications the minimum number of specimens shall be at least four, chosen at random to represent the lot.

6.3 The specimens shall be cut from larger blocks or irregular shapes in such a manner as to preserve as many of the original surfaces as possible. The bearing faces of the test specimens shall be plane, parallel to each other, and perpendicular to the sides. Where the original surfaces of the block are substantially plane and parallel, no special preparation of the surfaces will usually be necessary. In preparing specimens from pieces of irregular shape, any means that will produce a specimen with plane and parallel faces without weakening the structure of the specimen may be used.

6.4 The specimens shall be prepared so that the direction of loading will be the same as that on the insulation in service. If the direction of loading in service is unknown and the material is suspected of being anisotropic, different sets of test specimens shall be prepared with compression axes parallel to the different directions of loading that might occur.

6.5 The specimens shall be dried and conditioned prior to test, following applicable specifications for the material. If the material is affected adversely by oven temperatures, the specimens shall be conditioned for not less than 40 h at 73.4 ± 1.8°F (23 ± 1°C), and 50 ± 5 % relative humidity before testing. In the absence of definitive drying specifications, the specimens shall be dried in an oven at 215 to 250°F (102 to 121°C) to constant mass and held in a desiccator to cool to room temperature before testing. Where circumstances or requirements preclude compliance with these conditioning procedures, exceptions agreed upon between the manufacturer and the purchaser may be made, but they shall be specifically listed in the test report.

## 7. Procedures

7.1 *Procedure A*:

7.1.1 Measure the specimen dimensions within ±1 %. Each dimension shall be the average of at least two measurements taken on each specimen face. Use the steel rule and the dial gage comparator as appropriate.

7.1.2 Place the specimen between the loading surfaces of the testing machine, taking care that the centerline of the specimen coincides with the centerline of the testing machine so that the load will be uniformly distributed. The self-aligning surface shall be approximately parallel to the fixed plate. Keep the spherical bearing seat well lubricated to ensure free movement.

7.1.3 Adjust the crosshead speed to the value specified for the material being tested. This shall not exceed the range from 0.01 to 0.5 in./min (0.25 to 12.7 mm/min) for each 1 in. (25.4 mm) of specimen thickness. In the absence of such specification, the speed shall be 0.05 in./min (1.27 mm/min) for each 1 in. of specimen thickness.

NOTE 3—The speed of crosshead travel can have considerable effect on the compressive resistance value. In general, higher crosshead speeds usually result in higher compressive resistance values. Take this into account in selecting crosshead speed other than standard when comparing different types of thermal insulation.

7.1.4 To reduce the time for the loading head to contact the test specimen, the crosshead may be moved at a rapid until contact with the specimen is made. This may cause a slight preload to be applied to the specimen. Change the loading speed to the required value once contact is made. This preload should be as low as possible, but shall not be more than 2% of the load at the final deformation.

NOTE 4—If this test method is used in specifications or by specifiers to characterize the compressive resistance of a material, any preload value used must be specified.

7.1.5 Compress the specimen to the desired deformation. Record the loads and deformations at points that will adequately describe a load-deformation curve.

7.2 *Procedure B*:

7.2.1 Measure the specimen face dimensions within ±1 % using the steel rule. Each dimension shall be the average of at least two measurements taken on each specimen face.

7.2.2 Measure the specimen thickness to ±1 %. Use the pin-type depth gage and follow Test Methods C 167 if the material is pin-penetrable. If it is not, use the dial gage comparator. Average three measurements.

7.2.3 Place the specimen between the loading surfaces of the testing machine, taking care that the centerlines of the specimen and the testing machine coincide.

7.2.4 Adjust the crosshead speed to a maximum of 5 in./min (125 mm/min), but follow material specifications if a different speed is specified (see Note 3 above).

7.2.5 Compress the specimen to the desired deformation of either 10 or 25 % of the thickness measured in 7.2.2 or of the nominal thickness if so specified. To reduce variability in sample sets with densities greater than 3 lbs/ft$^3$ (48 kg/m$^3$), the initial deformation point on the load curve can be chosen at a fixed preload. Preload values should be less than 2 % of the load at 10 % deformation.

NOTE 5—If this test method is used in specifications or by specifiers to characterize the compressive resistance of a material, any preload value to be used must be specified.

## 8. Calculations

8.1 *Procedure A*:

8.1.1 Construct a load-deformation curve.

8.1.2 Using a straightedge, carefully extend to the zero load line the steepest straight portion of the load-deformation curve. This establishes the "zero deformation point." Measure all distances for deformation calculations from this point (Point *0* in Figs. 5 and 6).

8.1.3 Measure from Point *0* along the zero load line a distance representing 5 %, 10 %, or other specified deformation. At that point (Point *M* in Figs. 5 and 6), draw a vertical line intersecting the load deformation curve at Point *P*. If there is no yield point before Point *P* (as in Fig. 6), read the load at Point *P*. If there is a yield point before Point *P* (as Point *L* in Fig. 5), read the load and measure the percent deformation (distance *O-R*) at the yield point.

8.1.4 Calculate the compressive resistance as follows:

$$S = W/A \tag{1}$$

where:
$S$ = compressive resistance, psi (or Pa),
$W$ = load at any given deformation as determined in 8.1.3, lbf (or N), and
$A$ = average original area computed from measurements in 7.1.1, in.$^2$ (or m$^2$).

8.1.5 *Compressive Modulus of Elasticity*:

8.1.5.1 If desired, the compressive modulus of elasticity may be determined by choosing any convenient point (such as Point *S* in Fig. 6) along the straight portion of the load-deformation curve. Read the load and measure the deformation (distance *O-T*) at that point.

8.1.5.2 Calculate the compressive modulus of elasticity as follows:

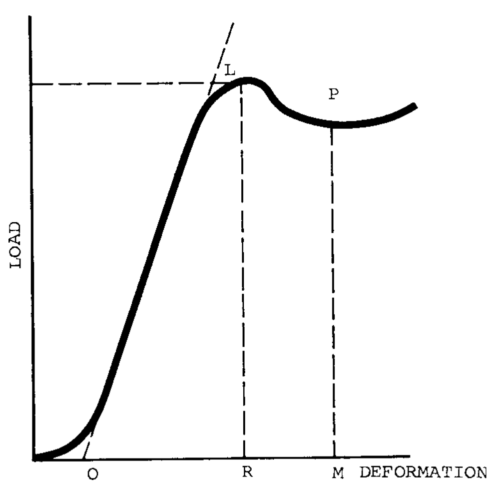


**FIG. 5 Procedure A Calculations**

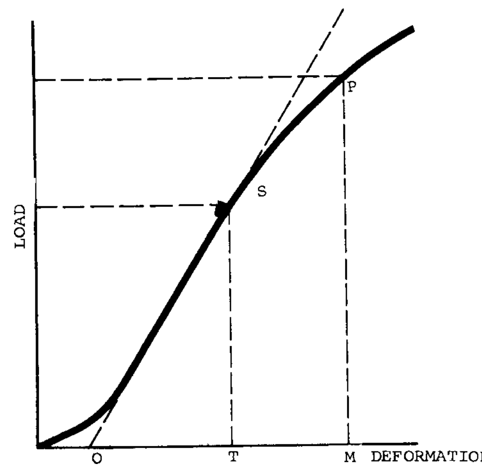


**FIG. 6 Procedure A Calculations**

$$E = \frac{\text{load/unit area}}{\text{deformation/original thickness}}$$

$$= \frac{W/A}{e/d} \tag{2}$$

where:
$E$ = compressive modulus, psi (or Pa),
$e$ = compressive deformation, in. (or mm), and
$d$ = thickness of the specimen, in. (or mm).

8.2 *Procedure B*— Calculate the compressive resistance as follows:

$$S = W/A \tag{3}$$

where:
$S$ = compressive resistance, psi (or Pa),
$W$ = load at specified deformation as determined in 7.2.5, lbf (or N), and
$A$ = average original area computed from measurements in 7.2.1, in.$^2$ (or m$^2$).

## 9. Report

9.1 Report the following information:

9.1.1 Name, type, density, original piece size, and any other pertinent identification of the insulation,

9.1.2 Dimensions of test specimens and the number of specimens tested,

9.1.3 Conditioning or drying procedures followed and the conditions during the test,

9.1.4 The compressive resistance of each specimen and the average at any stated deformation. The percent deformation and, if used, the preload shall always accompany the compressive resistance reported.

9.1.5 The compressive modulus of elasticity of each specimen and the average if determined (Procedure A only),

9.1.6 The load-deformation curve, with comments on behavior during test if appropriate. The complete load-deformation curve is desirable, particularly if the curve is not characteristic of one of the three defined in 1.1.

9.1.7 Comments on the mode of failure if other than normal compression; for example, shearing, crumbling, cracking, etc.,

9.1.8 Crosshead speed, and

9.1.9 Date of test.

**TABLE 1 Precision Information**

| Material Type | Type A | Type B | | |
|---|---|---|---|---|
| Material Composition | Calcium Silicate | High Density Mineral Fiber | Low Density Mineral Fiber | |
| Deformation | 5 % | 10 % | 10 % | 25 % |
| Number of Laboratories | 7 | 7 | 6 | 6 |
| Number of Tests | 4 | 4 | 10 | 10 |
| Preload | none | 0.06 psi (0.41 kPa) | none | none |
| Average test value | 100.0 psi (689.5 kPa) | 3.27 psi (22.5 kPa) | 0.012 psi (0.08 kPa) | 0.031 psi (0.21 kPa) |
| Repeatability limit (within laboratory), 95 % | 5.4 psi (37.2 kPa) | 0.97 psi (6.7 kPa) | 0.003 psi (0.02 kPa) | 0.007 psi (0.05 kPa) |
| Reproducibility limit (between laboratories), 95 % | 13.3 psi (91.7 kPa) | 0.97 psi (6.7 kPa) | 0.004 psi (0.03 kPa) | 0.007 psi (0.05 kPa) |

## 10. Precision and Bias

10.1 *Interlaboratory Test Program*—An interlaboratory study was run in which randomly drawn test specimens of three materials were tested for compressive resistance. Practice E 691 was followed for the design and analysis of the data. All of the test specimens were provided by a single laboratory. The details are given in ASTM Research Report No. C16-1020.[5] The data presented gives results for Type A material with no preload, Type B High Density Material with a preload and type B Low Density material without preload.

10.2 *Test Result*— The precision information given in Table 1 in units of measurement noted is for the comparison of four test results:

10.3 *Precision*—The terms (repeatability limit and reproducibility limit) in Table 1 are used as specified in Practice E 177. The respective standard deviations among the test results may be obtained by dividing the limit values in Table 1 by 2.8.

10.4 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedures in Test Method C 165 for measuring compressive strength, bias has not been determined.

## 11. Keywords

11.1 blanket-type; block-type; board-type; compression testing; compressive resistance; deformation; modulus of elasticity; thermal insulation; thermal insulation materials

[5] Available from ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428