Designation: C 356 – 03

Standard Test Method for Linear Shrinkage of Preformed High-Temperature Thermal Insulation Subjected to Soaking Heat[1]

This standard is issued under the fixed designation C 356; 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 the determination of the amount of linear shrinkage and other changes that occur when a preformed thermal insulating material is exposed to soaking heat. This test method is limited to preformed high-temperature insulation that is applicable to hot-side temperatures in excess of 200°F (93°C), with the exception of insulating fire brick which is covered by Test Method C 210.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*

C 168 Terminology Relating to Thermal Insulation[2]

C 210 Test Methods for Reheat Change of Insulating Firebrick[3]

C 411 Test Method for Hot Surface Performance of High-Temperature Thermal Insulation[2]

3. Terminology

3.1 *Definitions*—Terminology C 168 shall apply to the terms used in this test method.

4. Significance and Use

4.1 Linear shrinkage, as used in this test method, refers to the change in linear dimensions that has occurred in test specimens after they have been subjected to soaking heat for a period of 24 h and then cooled to room temperature.

4.2 Most insulating materials will begin to shrink at some definite temperature. Usually the amount of shrinkage increases as the temperature of exposure becomes higher. Eventually a temperature will be reached at which the shrinkage becomes excessive. With excessive shrinkage, the insulating material has definitely exceeded its useful temperature limit. When an insulating material is applied to a hot surface, the shrinkage will be greatest on the hot face. The differential shrinkage which results between the hotter and the cooler surfaces often introduces strains and may cause the insulation to warp. High shrinkage may cause excessive warpage and thereby may induce cracking, both of which are undesirable. High shrinkage may also open gaps at the insulation joints to an excessive extent rendering the application less efficient and more hazardous. In order to predict the limit of permissible shrinkage in service, the degree of linear shrinkage to be tolerated by specimens of an insulating material when subjected to soaking heat must be determined from experience.

4.3 It is recognized that a fixed relation between linear shrinkage under soaking heat and actual shrinkage in service cannot be established for different types of insulating materials. Generally the amount of shrinkage increases with time of exposure. The amount and rate of increase varies from one material to another. In addition, the various types of materials may have different amounts of maximum permissible shrinkage. Therefore, each product must define its own specific limits of linear shrinkage under soaking heat.

5. Apparatus

5.1 *Furnace*—A gas-fired or electrically heated muffle furnace, having a size sufficient to accommodate at least four test specimens and two dummy specimens, 6 by 2½ by 1½ in. (152.4 by 63.5 by 38.1 mm) (Note 1), spaced so as to allow a clearance of at least ½ in. (12.7 mm) on all surfaces of every test specimen. The temperature of the furnace shall be controlled throughout the volume occupied by the specimens to within ± 1 % of the desired temperature. A furnace-temperature indicator or recorder is required.

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[1] This test method is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.31 on Chemical and Physical Properties.

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

[3] *Annual Book of ASTM Standards,* Vol 15.01.

NOTE 1—If the structure is not homogeneous throughout its thickness, or if thinner materials are under test, the specimen should be tested without altering the original thickness. For smaller ovens, unable to accommodate the required number of specimens, it will be necessary to make several test batches in order to secure the minimum number of specimens required.

5.2 *Oven*—A controlled-temperature conditioning oven with range up to at least 250°F (121°C).

5.3 *Specimen-Measuring Apparatus*—An instrument suitable for measuring a gage length up to 6 in. (152.4 mm), and having an accuracy of measurement of 0.002 in. (0.05 mm) or better. Care must be taken, by the use of proper measuring techniques, to ensure reproduction of any measurement to within 0.01 in. (0.2 mm). It is particularly important to avoid crushing the ends of the specimens during measurement, especially in the case of soft materials.

NOTE 2—A vernier caliper may be used. Reference points, such as pins, inserted near the ends of the specimen, serve to improve reproducibility without specimen damage; or metal strips may be inserted between the specimen ends and the jaws of the caliper. Other instruments suggested are dilatometers or comparators. One suitable type of comparator[4] is equipped with a fine adjustment. It has a long-range, continuous dial indicator. The dial is attached to a wide-face (½-in. (12.7-mm) diameter flat) button point which is held against the specimen by internal spring pressure. When the point is lifted ½ in. (12.7 mm), the pressure is about 50 g, corresponding to a bearing force of 0.6 psi (4.8 kPa), and suitable for very soft materials. For harder materials, an additional weight of 0.25 lb (0.114 kg) may be applied, making the load of the specimen, at ½ in. (12.7 mm) compression of the spring, about 1.9 psi (13.1 kPa). Directly beneath the button point is another wide-face button point tapped to the base of the comparator. The comparator is adjustable and requires a set of steel shaftings, ½ in. (12.7 mm) in diameter, having lengths at 1-in. (25.4-mm) intervals from 1 to 6 in. (25.4 to 152.4 mm), in order to zero the comparator accurately.

5.4 *Balance*—A balance, having an accuracy of 0.01 g, for weighing the specimen before and after heating.

6. Sampling and Preparation of Test Specimens

6.1 All samples that will be required to complete the tests shall be selected at one time and in such a manner as to be representative of the average of the material.

6.2 Specimens for any one test condition shall be selected from the original sample lot so as to be as representative as possible. The specimens shall be cut or sawed from full-size pieces in such a manner that they will be fully representative of the entire, full-size piece as well as of the material generally. These specimens shall be cut to size 6 by 2½ by 1½ in. (152.4 by 63.5 by 38.1 mm), in such a mannner that the length and width are cut parallel to the length and width, respectively, of the original, full-size piece. If it is impossible to faithfully represent the material by cutting to a 1½-in. (38.1-mm) thick specimen, or for thinner pieces, then the original thickness of the material should be tested. Rectangular specimens cut from pipe covering may be used if the material is homogeneous and if the sections are large enough. If the material is not homogeneous or the sections are not sufficiently large, then curved or partly curved segments of a cylinder may be used. In this case, the specimens shall preferably be cut to an over-all width of 2½ in. (63.5 mm), with the sides cut parallel rather than on a radius.

7. Procedure

7.1 Select and prepare a minimum of four test specimens as prescribed in Section 6. Weigh the specimens in the as-received condition and dry them to constant weight following applicable specifications for the material unless it has been shown that the dimensional stability is not significantly affected by moisture content. In the absence of such specifications the specimen should be dried in an oven or desiccator at a temperature of 215 to 250°F (102 to 121°C) or at a suitable lower temperature if these temperatures would be destructive. If specimens are dried, they should be allowed to cool to room temperature and if necessary held in a desiccator before testing. Other conditioning procedures may be used only where agreed upon between manufacturer and purchaser. After conditioning and before any changes in dimensions occur, determine the linear dimensions. Make at least one measurement of length and two each of width and thickness at points marked so that remeasurements can be made at the same points after soaking heat.

7.2 Place the measured and weighed specimens in the furnace, the temperature of which shall not exceed 250°F (121°C). The specimens shall rest on their 6 by 1½-in. (152.4 by 38.1-mm) edges, supported by at least three supports (such as small ceramic triangular bars, or cylindrical rods), which in turn shall be supported on a protective plate. The supporting bars or rods shall be large enough so that the specimens have a clearance of at least ½ in. (12.7 mm) above the protecting plate. Arrange the specimens face to face in a group, but separated at least ½ in. (12.7 mm) from each other. Place dummy blocks or other protective means along the sides of the two specimens at each end of the group, so as to protect the faces of these two specimens from radiation losses or gains from the inner surfaces of the furnace. This arrangement of the specimens will allow free access of the heat to all of their surfaces.

7.3 Apply the source of heat after the specimens have been arranged in the furnace. The rate of heat supply should be held constant, or reasonably so, during the heating-up period. This rate should be gaged so that the average rise to the temperature of test shall not exceed 300°F (167°C)/h (Notes 3 and 4). During the heating-up period, especially in the initial stages, make frequent observations to note any signs of combustibility, by opening the furnace door momentarily or, if possible, through observation ports. After the furnace has reached the desired test temperature, maintain soaking-heat conditions for a period of 24 h, and then cut off the supply of heat. When the furnace has cooled to 200 to 250°F (93 to 121°C), remove the specimens and place them directly into a desiccator.

NOTE 3—It is realized that the actual rate of increase in temperature will not be uniform. The temperature will rise rapidly at first, and then will continue to rise progressively slower as the final temperature is approached. By the statement, "the average rise in temperature shall not exceed 300°F (167°C)/h," it is meant, for example, that a final temperature of 600°F (316°C) should be reached in not less than 2 h, or in not less than 6 h if the test temperature is to be 1800°F (982°C).

NOTE 4— If it is desired to determine the ability of an insulation to

[4] Model NB-60, manufactured by the Federal Products Corp., 7140 Eddy St., Providence, RI.

withstand sudden, drastic changes in temperature, or thermal shock, a separate test for this condition shall be specified.

7.4 When the specimens have cooled to within 10°F (5.5°C) of room temperature, remove them from the desiccator and remeasure before any changes can occur. Weigh the specimens and measure their dimensions at the exact points which were used for determining the original lengths (see 7.1). If any warpage occurred during the soaking heat, determine the amount of warpage to the nearest 0.01 in. (0.2 mm) in accordance with Test Method C 411. If the warpage exceeds 0.04 in. (1.0 mm), the actual length of the specimen as such shall not be determined. Instead, determine the apparent length of the specimen by measuring the chord connecting the two edges of the concave surface of the warped specimen, or by measuring the chord connecting the two points of original measurement, as the case may be.

7.5 Examine the specimens, and note any visible changes that may have occurred during the heating.

8. Calculations

8.1 *Linear Shrinkage*—Calculate the percentage linear dimensional change after soaking heat as follows:

$$S = [(L_1 - L_2)/L_1] \times 100 \quad (1)$$

where:

S = percentage linear dimensional change upon soaking heat,
L_1 = average length, width, or thickness of specimen before soaking heat, in. (or mm), and
L_2 = average length, width, or thickness of specimen after soaking heat, in. (or mm).

8.2 *Apparent Linear Shrinkage*—Calculate the percentage apparent dimensional change after soaking heat when a specimen has warped excessively (more than 0.04 in. (1.0 mm)) by the same formula as for linear shrinkage, except that L_2 shall represent the *apparent* length of the specimen after soaking heat.

8.3 *Change in Weight*—Calculate the percent change in weight after soaking heat as follows:

$$C = [(W_1 - W_2)/W_1] \times 100 \quad (2)$$

where:

C = percentage change in weight after soaking heat,
W_1 = weight of specimen before soaking heat, g, and
W_2 = weight of specimen after soaking heat, g.

9. Report

9.1 Report the following information:

9.1.1 Conditioning procedure followed,

9.1.2 Temperature of test, the time to reach temperature, the time at temperature, and the time for the temperature to drop 100°F (55.5°C) after the heat is turned off,

9.1.3 Linear shrinkage,

9.1.4 Warpage, if any,

9.1.5 Apparent linear shrinkage, if the warpage is in excess of 0.04 in. (1 mm),

9.1.6 Change in weight,

9.1.7 Any visible changes in the material after soaking heat, particularly when the changes are not uniform on all faces, and

9.1.8 Any evidence of combustibility which may have occurred during the heating period or during soaking heat, such as flaming, glowing, smoking, smoldering, etc.

10. Precision and Bias [5]

10.1 *Basis*—Five laboratories tested two products five times each for linear shrinkage and weight loss under 24 h heat soak at 1200°F (649°C).

10.2 *Intralaboratory Precision*:

10.2.1 *Shrinkage*—Average within laboratory standard deviation, σ, as a percentage of the mean, $\bar{x}$, was 21.6 % for Sample I and 6.8 % for Sample II.

10.2.2 *Weight Loss*—Average within laboratory standard deviation, σ, as a percentage of the mean, $\bar{x}$, was 8.8 % for Sample I and 5.3 % for Sample II.

10.3 *Interlaboratory Precision*:

10.3.1 *Shrinkage*—Average interlaboratory standard deviation, σ, as a percentage of the mean, $\bar{x}$, was 27.0 % for Sample I and 10.0 % for Sample II.

10.3.2 *Weight Loss*—Average interlaboratory standard deviation, σ, as a percentage of the mean, $\bar{x}$, was 12.7 % for Sample I and 10.7 % for Sample II.

10.4 *Bias*—No statement of bias is possible because absolute standards are not available.

11. Keywords

11.1 high temperature insulation; linear changes; linearity; preformed thermal insulation; shrinkage; soaking heat test

[5] Supporting data are available from ASTM Headquarters. Request RR: C16–1012.