Standard Test Method for Thermal Conductivity of Refractory Brick[1]

This standard is issued under the fixed designation C 202; 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 test method supplements Test Method C 201 and shall be used in conjunction with that test method to determine the thermal conductivity of refractory brick with the exception of insulating firebrick (use Test Method C 182), and carbon refractories. This test method is designed for refractories having a conductivity factor of not more than 200 Btu·in./h·ft^2·°F (28.8 W/m·K).

1.2 The values stated in inch-pound units are to be regarded as the standard. The values 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 155 Classification of Insulating Firebrick[2]

C 182 Test Method for Thermal Conductivity of Insulating Firebrick[2]

C 201 Test Method for Thermal Conductivity of Refractories[2]

E 220 Method for Calibration of Thermocouples by Comparison Techniques[3]

3. Significance and Use

3.1 The thermal conductivity of refractory brick is a property required for selecting their thermal transmission characteristics. Users select refractory brick to provide specified conditions of heat loss and cold face temperature, without exceeding the temperature limitation of the brick. This test method establishes placement of thermocouples and positioning of test specimens in the calorimeter.

3.2 This procedure must be used with Test Method C 201 and requires a large thermal gradient and steady state conditions. The results are based upon a mean temperature.

3.3 The data from this test method are suitable for specification acceptance, estimating heat loss and surface temperature, and design of multi-layer refractory construction.

3.4 The use of these data requires consideration of the actual application environment and conditions.

4. Apparatus

4.1 The apparatus shall consist of that described in Test Method C 201 with the addition of thermocouples, back-up insulation, and refractory fiber paper as described in Sections 6 and 7 of this test method.

5. Test Specimens

5.1 The test specimens shall be selected and prepared in accordance with Test Method C 201.

6. Installation of Thermocouples in Test Specimen

6.1 *Thermocouples*—Calibrated[4] thermocouples shall be embedded in the test specimen at two points for measuring temperature. Platinum-10 % rhodium/platinum thermocouples shall be used. Wire of AWG Gage 28 (0.320 mm) shall be used in making the thermocouples.

6.2 *Installation of Thermocouples*—The hot junction of the thermocouples shall be placed in the center of each 9- by 4½-in. (228- by 114-mm) face and just below the surface of the test specimen. Grooves to receive the wire shall be cut in each 9- by 4½-in. face of the brick to a depth of 1⁄32in. (0.8 mm) by means of an abrasive wheel 0.02 in. (0.5 mm) in thickness. The layout for the grooves allows all of the cold junction ends of the wires to extend from one end of the brick. A groove shall be cut in the center of each 9 by 4½-in. face along the 4½-in. dimension and ending 1 in. (25 mm) from each edge. The path of each groove is extended at an angle of 90° to one end of the brick by cutting grooves parallel to and 1.0 in. from the edge of the specimen. Before cementing[5] the thermocouple wires in place, measurements shall be taken to obtain, within ±0.01 in. (0.3 mm), the eventual distance between the center lines of the thermocouple junctions. This shall be done by measuring the 2½-in. (64-mm) dimension of the brick at the location for the hot junctions and deducting the distance between the center line of each junction in its embedded position and the surface of the brick.

[1] This test method is under the jurisdiction of ASTM Committee C-8 on Refractories and is the direct responsibility of Subcommittee C08.02 on Thermal Stress Resistance.

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

[3] *Annual Book of ASTM Standards*, Vol 14.03.

[4] Method E 220 specifies calibration procedures for thermocouples.

[5] Alundum Cement RA 562 supplied by the Norton Co., One New Bond St., Worcester, MA 01606, is satisfactory for this purpose.

7. Set-Up of Back-Up Insulation, Specimen, and Silicon Carbide Slab

7.1 The calorimeter and inner and outer guards shall be covered with a 0.50-in. (12.7-mm) thick layer of Group 20 insulating firebrick (see Classification C 155) for the purpose of obtaining a higher mean temperature in the test specimen than would result by placing the specimen directly over the calorimeter area. The back-up insulation shall be cut and ground so as to provide surfaces that are plane and do not vary from parallel by more than ±0.01 in (0.3 mm). The sides of the pieces that are to be placed in contact shall be ground plane and at right angles to the horizontal faces. The joints between the pieces shall be tight without the use of any mortar.

7.2 Two strips of refractory fiber paper 13½ by ½ by 0.02 in. (342 by 13 by 0.5 mm) shall be placed along the 13½-in. dimension of the inner guard at the outside edges. Twelve strips of refractory fiber paper 2 by ½ by 0.02 in. (51 by 13 by 0.5 mm) shall be placed on the outer guard at intervals in the pattern shown in Fig. 1. These strips serve as spacers to prevent contact between the test material and the calorimeter assembly. The back-up insulation shall then be placed on the calorimeter assembly so as to provide a level and plane surface. Additional strips of refractory fiber paper of the same dimensions shall be placed in the same pattern upon the back-up insulation. These strips serve as spacers to prevent contact between the fireclay brick and the back-up insulation. The test specimen shall be placed centrally over the center of the calorimeter section on its 9- by 4½-in. (228- by 114-mm) face, the guard brick placed at the sides of the test specimen so as to cover completely the calorimeter and inner guard area, and the soap brick placed along the edges of the three brick so as to cover completely the calorimeter assembly. The small space between the furnace walls and the test brick assembly shall be filled with granulated insulating firebrick.

7.3 The silicon carbide slab shall be placed over the 13½- by 9-in. (342- by 228-mm) area of the three 9-in. brick specimen, and it shall be spaced 1 in. (25 mm) above the specimen by placing under each corner of the slab rectangular pieces of Group 28 insulating firebrick cut to measure ⅜-in. (10-mm) square and 1.00 in. (25.4 mm) in length.

8. Procedure

8.1 Place the heating chamber in position, start water flowing through the calorimeter assembly, and supply current to the heating unit. Above a temperature of 1470°F (800°C), the furnace atmosphere shall contain a minimum of 0.5 % oxygen with 0 % combustibles. Take the atmosphere sample from the furnace chamber proper, preferably as near the test specimen as possible. Maintain the rate of water flow through the calorimeter between 120 and 200 g/min, and determine it by weighing the quantity of water collected during a measured time period. The mass of water collected shall be not less than 200 g and shall be weighed to an accuracy of ±0.5 g. The rate of flow shall be constant within ± 1 % during the test period.

8.2 Allow the furnace to reach a condition of steady state of heat flow at a mean temperature of approximately 1400°F (760°C). A steady state shall be that condition when the measured flow of heat into the calorimeter varies less than 2 %

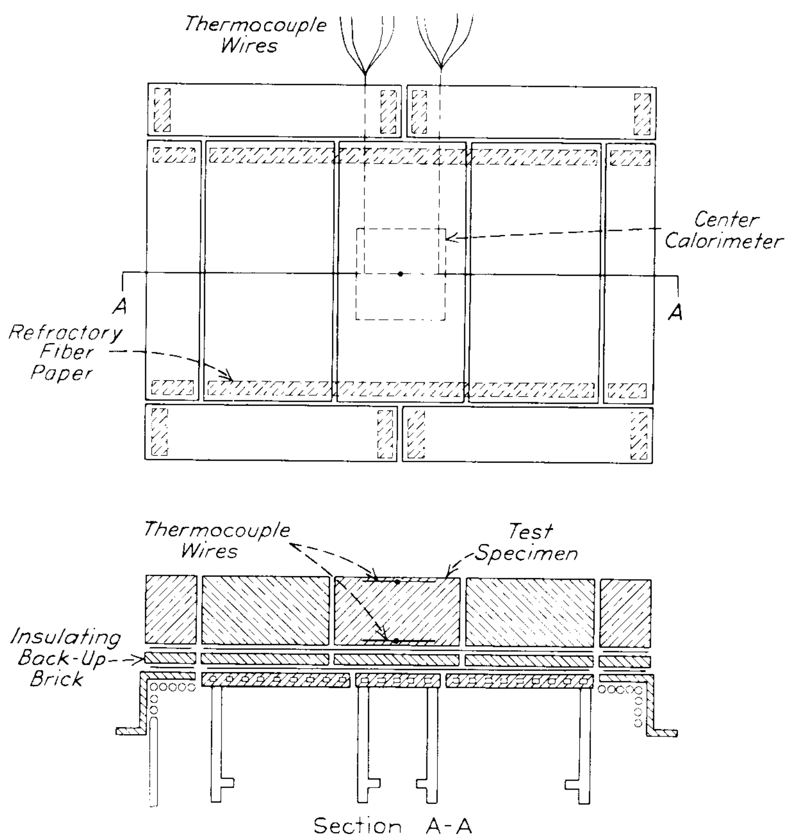

FIG. 1 Arrangement of Refractory Fiber Paper Strips in Calorimeter Assemblage

over a 2-h period, during which time the temperature difference between the calorimeter and the inner guard has not been more than 0.05°F (0.03°C), the hot face of the test specimen has not varied more than 5°F (3°C), and the temperature of the water entering the calorimeter has not varied at a rate of more than 1°F/h (0.5°C/h) (Note 1). Usually, 12 h or more are needed to obtain a balance with the apparatus after a definite change is made in the hot-face temperature.

NOTE 1—Significant errors will result if the tolerances specified are exceeded.

8.3 After the steady state of heat flow has been reached, measure the temperature of the test specimen, the rate of water flow through the calorimeter, and the temperature rise of the water flowing through the calorimeter. Take at least four sets of readings (Note 2) at approximately 30-min intervals during the 2-h holding period, and average these for the final values for that particular heating chamber temperature. Calculate the thermal conductivity.

NOTE 2—From these data a preliminary thermal conductivity calculation may be made, using estimated distances between thermocouple junctions in the test specimen.

8.4 Reheating treatment of the test specimen at a high temperature is necessary to eliminate errors arising from permanent changes in the sample which would affect the thermal conductivity value (Note 3). Carry out reheating, after obtaining the conductivity of the test specimen at the mean temperature of 1400°F (760°C) (8.2 and 8.3), by raising the temperature in the heating chamber to the highest value (Note 4) to be used in testing the sample, and maintaining that temperature for 18 ± 2 h. Although water is circulated through the calorimeter assembly during this period, no heat flow readings need be taken. After this interval, reduce the temperature in the heating chamber to obtain a mean temperature of approximately 1400°F in the specimen. After steady state has been reached at this temperature, take heat flow measurements, as previously outlined, and calculate the conductivity. Provided the conductivity value obtained at the lower mean temperature (1400°F) does not check that from the reheating operation to within ±2 %, repeat the reheating operation and the low-temperature trial until check data are obtained.

NOTE 3—Significant variation in thermal conductivity upon further heat treatment will be observed if the reheating treatment specified is neglected.

NOTE 4—The temperature to which the sample is heated depends upon the properties of the material. Changes in volume and structure resulting from high-temperature treatment may alter the conductivity value of the product.

8.5 After the specimen has been stabilized (8.4), make at least three additional conductivity determinations (Note 5), using heating chamber temperatures between the maximum and minimum used in bringing about the stable condition.

NOTE 5—When it is necessary or desirable to obtain data at mean temperatures below 1400°F (760°C), the 0.50-in. (12.7-mm) layer of back-up insulation should be removed so as to provide greater heat flow between the test material and the calorimeter.

8.6 At the conclusion of the test, examine the specimens for changes that may have taken place as a result of the heat treatment. Then remove the thermocouple wires and cut the brick in half through the 4½- by 2½-in. (114- by 64-mm) dimension and examine for voids and cracks.

9. Record of Test Data, Calculations, and Report

9.1 Make the record of test data, the calculations, and the report in accordance with Test Method C 201.

10. Precision and Bias

10.1 Refer to Text Method C 201 for a statement of precision and bias.

11. Keywords

11.1 calorimeter; refractories; refractory brick; thermal conductivity