Designation: C 351 – 92b (Reapproved 1999)

Standard Test Method for Mean Specific Heat of Thermal Insulation[1]

This standard is issued under the fixed designation C 351; 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 covers the determination of mean specific heat of thermal insulating materials. The materials must be essentially homogeneous and composed of matter in the solid state.

1.2 This test method employs the classical method of mixtures. This provides procedures and apparatus simpler than those generally used in scientific calorimetry, an accuracy that is adequate for most thermal insulating purposes, and a degree of precision that is reproducible by laboratory technicians of average skill. While this test method was developed for testing thermal insulations, it is easily adaptable to measuring the specific heat of other materials.

1.3 The test procedure provides for a mean temperature of approximately 60°C (100 to 20°C temperature range), using water as the calorimetric fluid. By substituting other calorimetric fluids the temperature range may be changed as desired.

1.4 The values stated in SI units are to be regarded as the 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:*

E 1 Specification for ASTM Thermometers[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *mean specific heat*—the quantity of heat required to change the temperature of a unit mass of a substance one degree, measured as the average quantity over the temperature range specified. (It is distinguished from true specific heat by being an average rather than a point value.) The unit of measurement is J/kg·K.

3.1.2 *thermal capacity*—the amount of heat necessary to change the temperature of the body one degree. For a homogeneous body it is the product of mass and specific heat. For a nonhomogeneous body it is the sum of the products of mass and specific heat of the individual constituents. Thermal capacity has the units of J/K.

3.1.3 *thermal diffusivity*—the ratio of thermal conductivity of a substance to the product of its density and specific heat. Common unit for this property is m^2/s.

3.1.4 *water equivalent*—the mass of water that requires the same amount of heat as the given body in order to change its temperature by an equal amount.

4. Summary of Test Method

4.1 The method of mixtures used in this test method consists essentially of adding a known mass of material at a known high temperature to a known mass of water at a known low temperature and determining the equilibrium temperature that results. The heat absorbed by the water and the containing vessel can be calculated and this value equated to the expression for the heat given up by the hot material. From this equation[3] the unknown specific heat can be calculated.

5. Significance and Use

5.1 Mean specific heat is an essential property of a thermal insulating material when the latter is used under conditions of unsteady or transient heat flow. It is a part of the parameter, thermal diffusivity, which governs the rate of temperature diffusion through insulation. It is a basic thermodynamic property of all substances, the value of which depends upon chemical composition and temperature.

NOTE 1—Specific heat of insulations, as measured by this test method, using small specimens of a multi-component composite or of a low-density product that has to be highly compressed, may not be directly applicable for use in calculations involving transient thermal response. The applicability of the results will depend upon a system being analyzed, the desired accuracy, and the relative amounts, and specific heats of the

[1] This test method is under the jurisdiction of ASTM Committee C-16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurements.

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

[3] Weber, R. L., *Heat and Temperature Measurement,* Prentice-Hall, New York, NY, 1950.

various solid or fluid components, or both, of the thermal insulation.

6. Apparatus

6.1 The typical apparatus is shown schematically in Fig. 1. It consists of the following:

6.1.1 *Calorimeter and Accessories*—The calorimeter shall be an unlagged Dewar flask with a maximum capacity of not less than 500 mL nor more than 750 mL. The flask shall have an insulated cover or stopper. Other accessories shall include a magnetic stirrer equipped with a speed-regulating device.

6.1.2 *Differential Temperature Sensor*—An appropriate temperature difference sensor, such as a Beckmann differential thermometer or a suitable equivalent, preferably with a magnifier, and having a range of at least 5°C and a sensitivity of no less than 0.01°C shall be used to determine the rise in temperature of the calorimetric fluid during test. Where a differential thermometer is used, it shall be set with its lowest temperature division at the approximate room temperature, and the setting point checked with a precision-type temperature sensor (such as Thermometer 632C, preferably with a magnifier, described in Specification E 1).

6.1.3 *Heater*—The heater shall be of the open-end radiation type similar to the cylindrical device shown in Fig. 1. It may be heated by electricity or steam. The relative dimensions of the heater and the capsule shall be such that the specimen will be heated to a uniform and constant temperature as required. A maximum variation of ± 1°C over the length of the heater is permitted. The heater shall be provided with an insulated removable top cover designed both to permit passage of the leads of the temperature sensor and to suspend the capsule. The bottom shall be closed with a removable insulated cover to permit free dropping of the capsule. The heater assembly shall be mounted so it can be swung quickly into place over the calorimeter.

6.1.3.1 A convenient form of electric heater can be constructed by covering a 254-mm length of 38-mm diameter brass pipe with asbestos paper, winding about 70 turns of 22-gage (0.64 mm) Nichrome wire over the paper, and insulating the assembly with 25.4-mm thick pipe insulation. It is necessary that the end turns be closer together than those over the center portion of the heater to compensate for end heat loss. The heater temperature is controlled by regulating the electric current to the heater with a variable transformer or resistor. A constant voltage source of power within ±1 % maximum voltage variation is necessary to minimize temperature fluctuations.

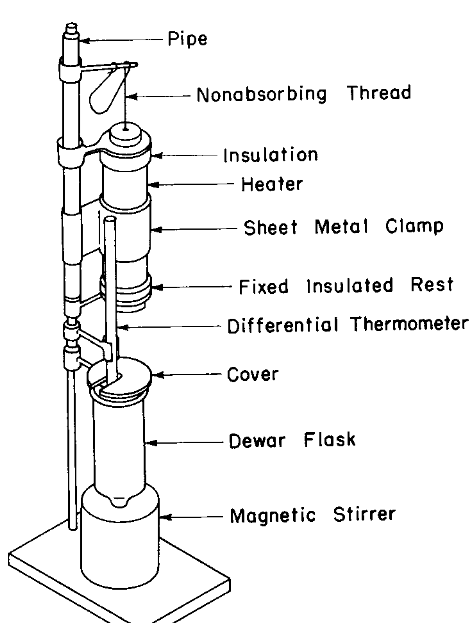

FIG. 1 Specific Heat Calorimeter

6.1.4 *Capsule*—The capsule shall comprise a hollow cylinder of brass approximately 25.4 mm in diameter by 50.8 mm long. It shall have a removable cap and a thermocouple well extending into the cavity space to accommodate the temperature sensor. It is imperative that the capsule assembly be absolutely watertight, as no leakage can be tolerated. The completed capsule, including cap, gasket, and suspension loop, shall have a thermal capacity not exceeding 10.5 J/K. A capsule design meeting the above requirements is shown in Fig. 2.

6.1.5 *Temperature Sensor*—A suitable, calibrated temperature sensor and associated read-out equipment of suitable range and precision to permit reading temperatures to an accuracy of 0.1°C shall be used. If a thermocouple is used, the wire size should be small to limit the error caused by thermal conductance losses along the length. Thermocouples can be made from any of the standard pairs registered with the National Institute of Standards and Technology.[4] A particular suitable thermocouple is chromel/constantan, fabricated from wires having a diameter no greater than No. 30 B & S gage (0.265 mm). The pair combines the attributes of reduced heat leakage and a higher emf than copper/constantan.

6.1.6 *Test Room*—The temperature of the room in which the test is conducted shall be reasonably constant during the test period. The test room temperature control is satisfactory if the time-temperature curve is a straight line (within the allowable experimental error) for a 10-min period before the dropping of the capsule and for a 10-min period just prior to the termination of the test.

6.1.7 *Specific Heat Standard*—Electrolytic copper (commercial electrical bus bar copper) shall be used as a specific heat standard. A standard specimen as shown in Fig. 3 shall be used to determine the water equivalent of the calorimeter flask and its accessories. For the temperature range covered (between 100 and 20°C) the mean specific heat of copper shall be taken as 390.0 J/(kg·K).

7. Test Specimens

7.1 Specimens shall be selected at random as required to provide test material representative of the lot sampled. The number of specimens may be determined by agreement but shall be not less than three.

7.2 The specimens shall be tested in the compressed form, since it is desirable to have as large a mass as possible. A specimen press consisting of a hollow cylinder with a close-fitting plunger used in conjunction with a bench vise or small hydraulic press has been found convenient.

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[4] "Reference Table for Thermocouples," *Circular No. 508*, National Institute of Standards and Technology, Gaithersburg, MD 20899.