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Standard Test Method for Specific Heat of Rock and Soil[1]

This standard is issued under the fixed designation D 4611; 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 instantaneous and mean specific heat of rock and soil.

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 rocks and soils, and a degree of precision that is reproducible by laboratory technicians of average skill. While this test method was developed for testing rock and soil, it is easily adaptable to measuring the specific heat of other materials.

1.3 The testing procedure provides an instantaneous specific heat over the temperature 25 to 300°C or a mean specific heat in that temperature range.

1.4 The test procedure is limited to dry samples.

1.5

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.6 *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]

C303Test Method for Density of Preformed Block-Type Thermal Insulation C 303 Test Method for Dimensions and Density of Preformed Block and BoardType Thermal Insulation

C 351 Test Method for Mean Specific Heat of Thermal Insulation

D 618Practice for Conditioning Plastics and Electrical Insulating Materials for Testing Practice for Conditioning Plastics for Testing

D 2766 Test Method for Specific Heat of Liquids and Solids

E 230Temperature-Electromotive Force (EMF) Tables for Thermocouples Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

E 344 Terminology Relating to Thermometry and Hydrometry

3. Terminology

3.1 *Definitions:*

3.1.1 *instantaneous specific heat*—the rate of change of sample enthalpy, h, per unit mass with respect to temperature, T, at constant pressure, p,

$$c_p = (\delta h/\delta T)_p \tag{1}$$

3.1.2 *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 joule per kilogram Kélvin,kelvin, J/kgK).

3.1.3 *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 joule per Kelvin,kelvin, J/K.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.
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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.

3.1.4 *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.

3.2 *Symbols:*

3.2.1 ΔH—enthalpy change (J/kg).

3.2.2 mc_p— thermal capacity (J/K).

3.2.3 T_m— final temperature of the mixture obtained by extrapolation (K).

3.2.4 T_c— temperature of the calorimeter immediately prior to drop obtained by extrapolation.

3.2.5 T_h— temperature of capsule and sample, capsule or standard in the heater prior to drop (K).

3.2.6 ΔT—temperature difference.

3.2.7 $\bar{c}_p$—mean specific heat (J/kgK).

3.2.8 c_p— instantaneous specific heat (J/kgK).

4. Summary of Test Method

4.1 The method of mixtures consists essentially of adding a known mass of material at a known temperature to a known mass of calorimetric fluid at a known lower temperature and determining the equilibrium temperature that results. The heat absorbed by the fluid and containing vessel can be calculated from calibrations and this value equated to the expression for the heat given up by the hot material. From this equation, the unknown specific heat can be calculated. If only one drop from a single temperature is performed, then only the mean specific heat can be calculated. If several drops are performed, the instantaneous specific heat can be calculated.

5. Significance and Use

5.1 Specific heat is a basic thermodynamic property of all substances. The value of specific heat depends upon chemical composition and temperature. The rate of temperature diffusion through a material, thermal diffusivity, is a function of specific heat; therefore, specific heat is an essential property of rock and soil when these materials are used under conditions of unsteady or transient heat flow.

6. Apparatus

6.1 *Calorimeter and Accessories*—The calorimeter shall be an unlagged Dewar flask. The capacity of the Dewar flask shall be such as to yield a 1 to 5 K temperature rise of the receiver fluid with average sample size used during testing (Note 1). The flask shall have an insulated cover or stopper. Other accessories shall include a magnetic stirrer equipped with a speed regulating device.

NOTE 1—Typical volumes are approximately 500 to 750 mL with rock or soil samples of 50 g in thin wall stainless steel containers.

6.2 *Calorimeter Temperature-Sensing Device*—A temperature-sensing device capable of 0.0025 K resolution and covering a minimum of 5 K range shall be used.

NOTE 2—A suitable temperature sensor is a multijunction thermopile typically referenced to an ice bath.

6.3 *Calorimeter Fluid*—The calorimeter fluid should be a high specific heat fluid, stable to 250 to 300°C and having a low vapor pressure. Silicone based fluids are frequently used.

6.4 *Heater*—The heater shall be designed to provide a uniform heating zone. A maximum variation of ±1 % of the mean heater temperature along the heater length corresponding to the sample is permitted.

NOTE 3—Typically, open-end radiation type heaters similar to the cylindrical device shown in Fig. 1 are used. Such heaters are usually heated by electricity; however, other means of heating are acceptable as long as the requirements for the heater can be met. The relative dimensions of the heater and capsule shall be such that the specimen will be heated to a uniform and constant temperature as required. The heater should be provided with an insulated removable cover designed to permit passage of sample capsule temperature sensing devices and suspension wire. The bottom should be closed with a removable insulated cover to permit free dropping of the capsule. Typically, the heater assembly is mounted so it can be swung quickly into place over the calorimeter immediately prior to drop and swung away after the sample has been dropped.

6.5 *Capsule*—The capsule shall be of the hermetically sealed type. The ~~capsule's~~capsule heat capacity should be minimized and in no instance should be greater than the heat capacity of the sample. The capsule should be made of high conductivity material. Typically, capsules are thin wall copper or stainless steel containers.

6.6 *Specimen Temperature Readout Device*—A convenient method of measuring the temperature of the sample in the heater unit shall be provided. It is desirable to measure the sample temperature inside the container; however, measuring of the outside of the container is permitted. Typically, a thermocouple calibrated to the special limits of error specified in EMF Tables E 230 is used for sample temperature readout. The temperature shall be measured to ±1 % of the test temperature.

6.7 *Test Room*—The room temperature in which the tests are conducted shall be maintained at 23 ± 2°C.

6.8 *Calibration Standards*—A minimum of three calibration standards are required. The standards must be traceable to the ~~U.S.~~ National ~~Bureau~~Institute of Standards ~~(NBS)~~ and Technology (NIST) or other ~~recognized standard.~~ National Metrology Institute.

7. Test Specimen

7.1 *Form*—In order to increase the accuracy of this test method, the sample mass should be maximized for a given capsule volume. This usually means, for dense rocks, that the sample should be machined to fit the container tightly. However, crushed