Designation: ~~D4611 – 08~~ D4611 – 16

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

This standard is issued under the fixed designation D4611; 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~~ Scope*

1.1 This test method covers the determination of instantaneous and mean values of the specific heat of rock and soil.

1.2 This test method employs the classical method of ~~mixtures. This provides~~mixtures, which involve procedures and an apparatus that are simpler than those generally used in scientific calorimetry, but with an accuracy that is adequate for most rocks and ~~soils, and a degree of precision that is reproducible by laboratory technicians of average skill.~~ soils. While this test method was developed for testing rock and soil, it ~~is easily adaptable to measuring~~can be adapted to measure the specific heat of other materials.

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

1.4 The test procedure is limited to dry ~~samples.~~specimens of soil and rock.

1.5 *Units*—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~~ No other units of measurements are included in this standard.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.6.1 The procedure used to specify how data are collected/recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analytical methods for engineering design

1.7 *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]

~~C303 Test Method for Dimensions and Density of Preformed Block and Board–Type Thermal Insulation~~

~~C351 Test Method for Mean Specific Heat of Thermal Insulation (Withdrawn 2008)[3]~~

D618 Practice for Conditioning Plastics for Testing

D653 Terminology Relating to Soil, Rock, and Contained Fluids

~~D2766~~D3740 ~~Test Method for Specific Heat of Liquids and Solids~~Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits in Geotechnical Data

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

~~E344 Terminology Relating to Thermometry and Hydrometry~~

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[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.

***A Summary of Changes section appears at the end of this standard**

3. Terminology

3.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions:*

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

$$c_p = (\delta h/\delta T)_p \quad (1)$$

(J/kgK).

3.2.2 *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 kelvin, J/kgK).~~ specified (J/kgK).

3.2.3 *thermal capacity*—the amount of heat necessary to change the temperature of the body one ~~degree. For a homogeneous body, it is~~ degree, equal to 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, J/K.~~the mass of the body and its specific heat (J/K).

3.2.4 *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~~heat (m^2~~/s.~~/s).

3.3 *Symbols:*

3.3.1 ΔH—enthalpy change (J/kg).

3.3.2 $(\Delta H)_{cal}$—enthalpy change of the calorimeter (J/kg).

3.3.3 m—mass (kg).

3.3.4 m_{cal}—mass of calorimeter (kg).

3.3.5 m_{cap}—mass of capsule (kg).

3.3.6 m_{spec}—mass of the specimen (kg).

3.3.7 mc_p—thermal capacity (J/K).

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

3.3.9 T_c—temperature of the calorimeter immediately prior to drop ~~obtained by extrapolation.~~ (K).

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

~~3.2.6 ΔT—temperature difference.~~

3.3.11 ΔT—temperature difference (K).

3.3.12 $(\Delta T)_{cal}$—temperature change of the calorimeter (K).

3.3.13 ~~$\bar{c}$~~$(\bar{c}_p)_{spec}$—mean specific heat of the specimen (J/kgK).

3.3.14 ~~c~~$(c_p)_{spec}$—instantaneous specific heat of the specimen (J/kgK).

3.3.15 $(c_p)_{cal}$—instantaneous specific heat of the calorimeter (J/kgK).

3.3.16 $(c_p)_{cap}$—instantaneous specific heat of the capsule (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 or mineralogical 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.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etctesting. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 ~~*Calorimeter and Accessories*—~~*Calorimeter*—The calorimeter shall be an unlagged ~~Dewar~~vacuum flask. The capacity of the ~~Dewar~~vacuum 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~~2). The flask shall have an insulated cover or stopper. ~~Other accessories shall include a magnetic stirrer equipped with a speed regulating device.~~

NOTE 2—Typical volumes of vacuum flasks used for this type of measurement are approximately 500 to 750 mL ~~with~~for rock or soil samples of 50 g in ~~thin wall~~ thin-wall copper or stainless steel ~~containers.~~capsules.

6.2 Magnetic stirrer equipped with a speed regulating device.

6.3 *Calorimeter Temperature-Sensing Device*—A temperature-sensing device ~~capable~~ with a minimum resolution of 0.0025 K ~~resolution and covering a minimum of 5 K range~~ and an accuracy of ±0.5 % and capable of measuring a change in temperature of at least 5 K shall be used.

NOTE 3—A suitable temperature sensor is a multijunction thermopile typically referenced to an ice bath.

6.4 *Calorimeter Fluid*—The calorimeter fluid ~~should~~shall be a high specific heat fluid, stable to ~~250~~520 to ~~300°C~~ 570 K and having a low vapor pressure. ~~Silicone based fluids are frequently used.~~

NOTE 4—Silicone based fluids have been found to meet this requirement.

6.5 *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 5—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.

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

6.7 *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;~~capsule; however, measuring of the outside of the ~~container~~capsule is permitted. Typically, a thermocouple calibrated to the special limits of error specified in EMF Tables E230 is used for sample temperature readout. The temperature shall be measured to ±1 % of the test temperature.

6.8 *Test Room*—The room temperature in which the tests are conducted shall be maintained at ~~23~~296 ± ~~2°C.~~ 2 K.

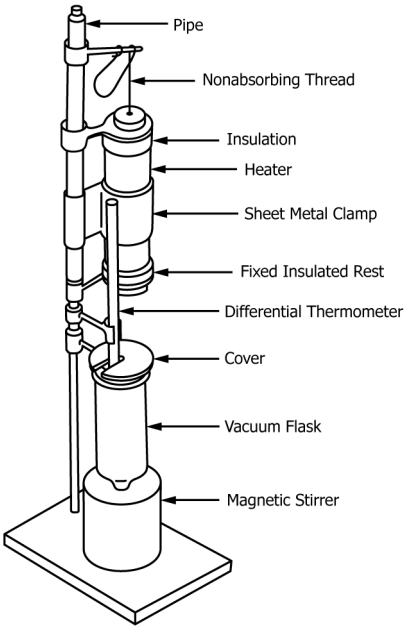

FIG. 1 Specific Ileal Calorimeter