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Standard Practice for Thermal Conductivity of Leather[1]

This standard is issued under the fixed designation D7340; 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.

ε^1 NOTE—The *k* value in 5.1 was corrected editorially in April 2012.

1. Scope

1.1 This practice is intended to determine the thermal conductivity of a sheet material. This practice is not limited to leather, but may be used for any poorly conductive material such as rubber, textile and cork associated with the construction of shoes.

1.2 A constant heat source is sandwiched between two identical metal cylinders which are mounted with their axes vertical. A test specimen is placed on the top surface of the upper cylinder and a third identical metal cylinder is placed on top of the test specimen so that all the cylinders and the test specimen are concentrically aligned (see Fig. 1). The heat source is switched on and the temperatures of the three blocks allowed to reach equilibrium. The thermal conductivity of the test specimen is then determined from the steady-state temperatures of the three blocks, the exposed surface areas of the blocks and test specimen and the thickness of the test specimen.

1.3 This practice does not apply to wet blue.

1.4 *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]

D1610 Practice for Conditioning Leather and Leather Products for Testing

D1813 Test Method for Measuring Thickness of Leather Test Specimens

2.2 *Other Standard:*

SATRA TM 146 Thermal Conductivity

3. Terminology

3.1 *Definitions:*

3.2 *thermal conductivity*—the quantity of heat conducted per unit time through unit area of a slab of unit thickness having unit temperature difference between its faces.

4. Summary of Practice

4.1 A conditioned specimen of leather (see Practice D1610) is placed between two plates at different temperatures. The upper plate is at a constant temperature while the temperature of the lower plate is slowly changing. The temperature difference is measured by thermocouples. The rate of flow of heat through the specimen is proportional to the area and the temperature difference of the faces of the specimen, and inversely proportional to the thickness. Assuming no heat loss, the amount of heat flowing through the specimen per unit time is equal to the amount of heat received by the lower plate (copper block receiver) per unit time.

5. Significance and Use

5.1 Part of the function of a shoe is to assist the foot in maintaining body temperature and to guard against large heat changes. The insulating property of a material used in shoe construction is dependent on porosity or the amount of air spaces present. A good insulating material has a low thermal conductivity value, *k*. The thermal conductivity value increases with an increase in moisture content since the *k* value for water is high, 0.0014 cal/s cm · °C (0.59 W/m·K).

6. Apparatus and Materials

6.1 A "Lees' disc" apparatus, see Fig. 1, consisting of:

6.1.1 A metal, see 11.1.2, cylindrical block, which will subsequently be referred to as block B1, with:

6.1.1.1 A diameter of (D), in millimetres, which is known to an accuracy of 0.2 mm (see 11.1.1).

6.1.1.2 A height of (H), in millimetres, which is known to an accuracy of 0.2 mm (see 11.2).

6.1.1.3 A small hole of diameter 2 ± 1 mm drilled radially to its center.

6.1.1.4 A type K thermocouple inserted into the hole until its junction is at the bottom of the hole.

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[1] This practice is under the jurisdiction of ASTM Committee D31 on Leather and is the direct responsibility of Subcommittee D31.03 on Footwear.

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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.

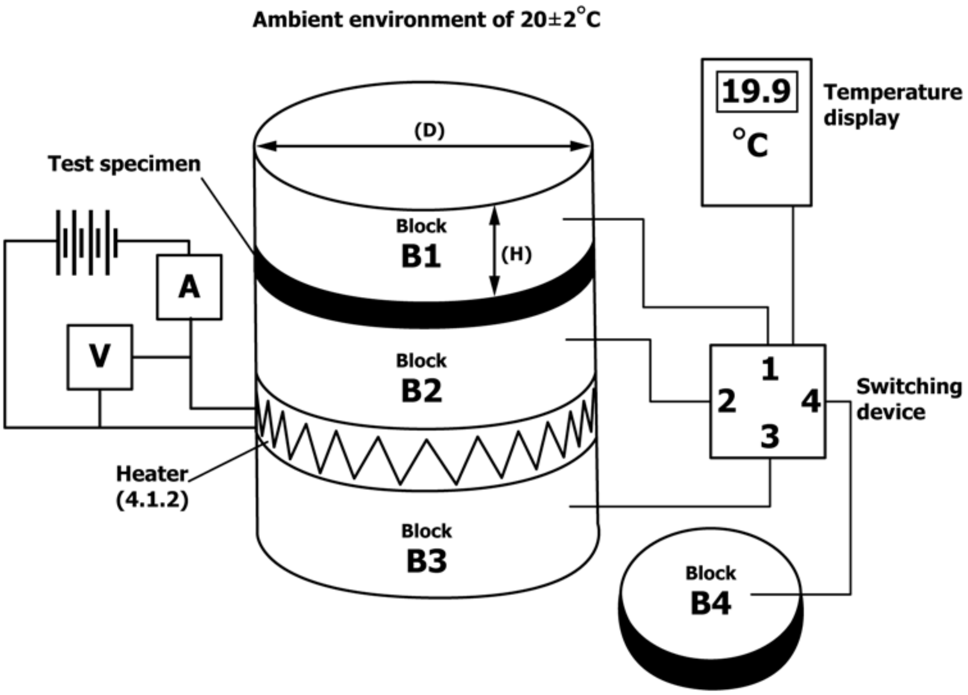

FIG. 1 SATRA Lees' Disc Thermal Conductivity Apparatus

6.1.1.5 The remaining volume of the hole filled with a high thermal conductivity compound with a thermal conductivity of better than 0.8 W/(m°C), for example a metal oxide filled paste of the type used between high power semiconductor electronic devices and heat sinks.

6.1.2 A circular electrical heater element which:

6.1.2.1 Has a diameter of (D) ± 0.5 mm.

6.1.2.2 Is capable of dissipating a minimum power density of 400 W/m^2 from each of its circular faces. See 11.1.1.

6.1.2.3 Has a cylindrical metal block, see 11.1.3, with thermocouple as block B1 (6.1.1), of diameter (D) ± 0.5 mm and of height (H) ± 0.2 mm bonded to its top and bottom faces with a high thermal conductivity adhesive compound. These two blocks will subsequently be referred to as B2 and B3. (**Warning**—Do not attempt to separate these blocks from the heater element.)

6.1.3 A fourth metal cylindrical block fitted with a thermocouple as (6.1.1) of diameter (D) ± 0.5 mm and of thickness 8 ± 2 mm. This is for measuring the ambient temperature of the surrounding atmosphere and will subsequently be referred to as block B4.

6.1.4 A power supply unit connected to the heater element (6.1.2). The unit should be capable of supplying sufficient power to enable the heater element (6.1.2) to dissipate a power density of 400 W/m^2 from each of its circular faces.

6.1.5 A means of measuring the power being supplied to the heater element (6.1.3) to an accuracy of ±4 mW. See 11.1.2.

6.1.6 A method of mounting the heater and block assembly (6.1.2) so that air can circulate freely around all the outside edges of the assembly.

6.1.7 A device capable of measuring and displaying the temperatures of the thermocouples in the four brass cylindrical blocks to an accuracy of ±0.2°C.[3]

6.2 A circular press knife of diameter (D) ± 0.5 mm.

6.3 A dial thickness gauge which applies a pressure of 13.86 ± 0.35 oz (393 ± 10 g) on the test specimen and is capable of measuring to an accuracy of 0.01 mm. This is identical to the gauge used in Test Method D1813.

7. Preparation of Test Specimens

7.1 Place the uncut sheet material in a standard controlled environment of 20 ± 2°C/65 ± 2% relative humidity or 23 ± 2°C/50 ± 2% relative humidity or for a minimum of 48 h. Include details of the conditions used in the test report.

7.2 Use the press knife (6.2) to cut two circular test specimens of diameter (D) ± 0.5 mm.

8. Procedure

8.1 Use the thickness gauge (6.3) to measure the thickness (S) at the center of each test specimen and record these two values in millimetres to the nearest 0.05 mm.

8.2 Ensure that the heater assembly (6.1.2) is mounted vertically so that block B2 is above block B3 (see Fig. 1). It should also be situated in a temperature-controlled environment of 20 ± 2°C and mounted in such a way that air can circulate freely about the assembly.

8.3 Place one of the test specimens onto the upper surface of block B2 and carefully rest the block B1 on top of the test

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[3] Suitable apparatus is available from SATRA; www.satra.co.uk.

specimen. In the case of test specimens used for footwear, the surface of the specimen which would usually be nearest the foot should be placed against block B2 so that it is closest to the heater element. Adjust the positions of the block B1 and the test specimen until they are both concentrically aligned with the heater assembly (6.1.2).

8.4 Switch on the power supply unit (6.1.4) and adjust it until it is delivering sufficient power to heat the brass cylindrical blocks B2 and B3 to a steady-state temperature of 35 ± 5°C. At an ambient temperature of 20°C a power density of 300 W/m^2 from each of the circular faces of the heater should be sufficient. See 11.1.2.

8.5 At regular intervals of approximately 30 min record the temperature of the four blocks B1, B2, B3 and B4 as [TE1], [TE2], [TE3] and [TE4] respectively in °C to the nearest 0.2°C. When three sets of successive readings taken over a total time period of not less than 60 min are found to be within ±0.2°C for each block then record these last three sets of readings in °C to the nearest 0.2°C.

8.6 Remove the test specimen and block B1 from the heater assembly (6.1.2) and repeat the procedure in 8.3 to 8.5 for the other test specimen.

9. Calculation

9.1 Convert all length and thickness values from mm to m by dividing them by 1000.

9.2 Calculate for the apparatus. See 11.1.1.

9.2.1 1 Exposed area of block B1 = [A1] = exposed area of block B3 = [A3], where:

$$[A1] = [A3] = \pi\ x\ (D)\ x\ (0.25\ x\ [D]+[H])$$

9.2.2 Exposed area of block B2, [A2], where:

$$[A2] = [H]\ x\ \pi\ x\ [D]$$

9.3 For each test specimen calculate:

9.3.1 Exposed area of test specimen, [As], where:

$$[As] = [S]\ x\ \pi\ x\ [D]$$

9.3.2 Power supplied to heater, [P], where:

$$(P) = [V]\ x\ [I]$$

See 11.1.2.

9.4 For each set of readings calculate:

9.4.1 The temperatures of blocks B1, B2 and B3 above ambient as:

$$[T1] = [TE1] - [TE4]$$

$$[T2] = [TE2] - [TE4]$$

$$[T3] = [TE3] - [TE4]$$

9.4.2 The average temperature of test specimen [Ts] where:

$$[Ts] = 0.5\ x\ ([T1]+[T2])$$

9.4.3 The thermal conductivity of the test specimen, [K] in watts per metre per degree centigrade [W/m°C]. See 11.1. where:

$$[K] = [P]\ x\ [S]\ x\ ([As]\ x\ [Ts]+2x\ [A1]\ x\ [T1]) \div (([A1]x[T1] + [As]x[Ts]+[A2]x[T2]+[A3]x[T3])x(0.5x\pi x[D]2x([T2] - [T1])))$$

9.5 Calculate the arithmetic mean of the six values of thermal conductivity, [Ka] to three significant figures.

9.6 Calculate the average thermal resistance of the test specimens, [R] in metres squared, degree centigrade per watt (m$^{2\circ}$ C/W) to three significant figures from the arithmetic mean or the thermal conductivities using the formula:

$$R = \frac{[Sa]}{[Ka]}$$

where [Sa] is the arithmetic mean thickness of the two specimens, and [Ka] is the arithmetic mean thermal conductivity.

10. Test Report

10.1 Include in the test report:

10.1.1 Reference to this practice; ASTM D7340,

10.1.2 A full description of the material,

10.1.3 The arithmetic mean thermal conductivity as calculated in 9.5,

10.1.4 The arithmetic mean thermal resistance as calculated in 9.6,

10.1.5 The pressure on the test specimen, see 11.2, and

10.1.6 Any deviations from this practice.

11. Additional Notes

11.1 *The "Lees' Disc" Apparatus:*

11.1.1 Dimensions of cylindrical blocks B1, B2 and B3.

11.1.1.1 The blocks used have diameter 76.2 mm and height 23.1 mm. Hence:

$$[A1] = \text{exposed area of block B1} = [A3]$$
$$= \text{exposed area of block B3} = 0.0101\ \text{m}^2$$

$$[A2] = \text{exposed are of block B2} = 0.0055\ \text{m}^2$$

11.1.1.2 Pressure on test specimen = 1.93 kPa, see 11.2

11.1.2 *Heater Power:*

11.1.2.1 Power input to an electrical heater element in watts, can be measured by multiplying the voltage across the heater [V] in volts, by the current through the heater [I], in amperes.

11.1.2.2 The power input to the heater of the SATRA equipment necessary in an ambient environment of 20 ± 2°C to heat blocks B2 and B3 to a steady state temperature of 35 ± 5°C, in approximately four h, is 2.52 W; this is normally achieved by a current of 0.14 A at a voltage of 18 V.

11.1.3 *Metal Used for Blocks:*

11.1.3.1 A metal with a high thermal conductivity is recommended, such as one containing a high percentage of copper. Brass: 70/30 copper/zinc is suitable and is used in the SATRA apparatus.

11.2 *Pressure on the Test Specimen:*

11.2.1 Air is a poor conductor of heat, and the insulating properties of materials which enclose air are highly dependent on the amount of air trapped inside them. As a material is compressed the air enclosed in the material is squeezed out and the thermal conductivity of the material increases. It is therefore critical that the thermal conductivity of a material which normally contains air in its structure is always measured under the same pressure. In the vertically orientated Lees' apparatus as used by SATRA the pressure on the test specimen is determined by the weight and base surface area of block B1.

11.2.2 The pressure exerted by a cylindrical block is given by the product of the block height, density, and the acceleration due to gravity. When using brass of density 8.5 g/cm^3 (see 11.1.3), a block height of 23.2 ± 0.2 mm is required to give a pressure on the test specimen of 2.0 ± 0.2 kPa (see 6.3).

12. Keywords

12.1 conductivity; insulating; leather; thermal

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