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Designation: D 2214 – 0~~0~~2

Standard Test Method for Estimating the Thermal Conductivity of Leather with the Cenco-Fitch Apparatus[1]

This standard is issued under the fixed designation D 2214; 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 quantitative determination of the thermal conductivity of leather. The measured parameters are the area, the thickness, and the temperature difference between the two sides of a leather specimen. This test method is not limited to leather, but may be used for any poorly conductive material such as rubber, textiles, and cork associated with the construction of shoes. Specimens up to 0.5 in. (13 mm) thick may be run. This test method does not apply to wet blue.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given 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.*

NOTE 1—Thermal conductivity must be measured under steady-state conditions; however, this transient test method can be used to estimate the thermal conductivity of leather.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1610 Practice for Conditioning Leather and Leather Products for Testing[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *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 Test Method

4.1 A conditioned specimen of leather 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, 14 by 10^4cal·cm/s·cm^4 · °C (0.59 W/m·K).

6. Apparatus

6.1 *Cenco-Fitch Conductivity Apparatus*— The apparatus shall consist of two parts, the source and the receiver. The source shall be a copper vessel, heat insulated on the sides. The base of the source shall be a heavy copper plate which shall be face ground and nickel plated. The receiver shall contain an insulated copper plug which shall also be face ground. A copper-constantan

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[1] This test method is under the jurisdiction of ASTM Committee D31 on Leather and is the direct responsibility of Subcommittee D31.03 on Footwear. This test method was developed in cooperation with the American Leather Chemists Assn. (Standard Method E 60 – 1965).

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[2] *Annual Book of ASTM Standards*, Vol 15.04.

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junction shall be embedded in the base of the source and leads connected to a binding post in the side of the vessel. A second copper-constantan junction shall be embedded in the copper receiver and leads connected to a binding post on the side of the receiver. The mass of the copper plug shall be stamped on the receiver.

6.2 *Galvanometer*—A galvanometer with a linear scale shall be used to record the current or deflections. If the galvanometer is so sensitive that the readings are off scale, a shunt or fixed resistor may be connected between the galvanometer and receiver.

6.3 *Immersion Heater*—A knife-shaped heater shall be used to maintain a constant temperature of the liquid water at the boiling point.

6.4 *Mass, 5-kg*—A mass of about 5 kg shall be placed around the collar of the vessel to ensure close contact between the surfaces of the apparatus and the specimen.

6.5 *Micrometer*—A micrometer shall be used to measure the diameter of the copper block and also to measure the thickness of the specimen.

6.6 *Metal Plates*—Two uniform metal plates, about 7 by 6 in. (178 by 152 mm), shall be used in measuring the thickness of the specimen. The specimen is sandwiched between the plates and the thickness measurement is made with the combination in place on the apparatus under testing conditions.

6.7 *Stop Watch*—A stop watch may be used to measure the time intervals for taking galvanometer readings.

7. Test Specimen

7.1 A conditioned specimen uniform in thickness and about 6 by 6 in. (152 by 152 mm) square or a disk about 6 in. in diameter shall be used. The specimen shall be conditioned in accordance with Practice D 1610, and the test shall be performed in the standard atmosphere described therein.

8. Procedure[3,4]

8.1 Assemble the apparatus as follows: Connect one end of a constantan wire to the constantan terminal of the source and the other end to the constantan terminal of the receiver. Join one end of a copper wire to the copper binding post of the receiver and the other end to the positive binding post of the galvanometer. Connect a second copper wire to the copper binding post of the source and the other end to the negative binding post of the galvanometer. Fill the vessel with boiling water and place it upon the leather specimen. Keep the water boiling by means of the immersion heater. Continue heating until steady deflections are obtained on the galvanometer. Place the specimen and the vessel with a 5-kg mass around its collar on the receiver, which should be at room temperature. Measure galvanometer deflections, d, at regular intervals of 1, 2, or 3 min, depending on the rate of heat conduction. Keep the water boiling with the aid of the immersion heater and replace the water evaporated by adding boiling water. Take about ten readings.

9. Calculations

9.1 Plot a graph of the data on semilogarithmic paper (2 cycles by 70 divisions). It can be shown mathematically that:

$$t = -2.303(lMC/kA)(\log d - \log d_0) \quad (1)$$

where:
t = time, min,
l = thickness of specimen, cm,
M = mass of copper block, g,
C = specific heat of copper block = 0.093 cal/g·°C,
A = area of copper block, cm^2 = area of face of specimen,
k = thermal conductivity, and
d = deflections (d_0 = deflection at zero time).

Therefore, the graph of t as ordinate plotted against log d as abscissa should be a straight line since all the other quantities including log d_0 are constant.

9.2 The slope, m, of t plotted against log d is therefore

$$m = -2.303(lMC/kA) \quad (2)$$

9.3 Inserting the value of the slope, m, obtained by calculation and multiplied by 60 s as shown in the example in the Annex, calculate the value of k, in cal·cm/s·cm^2· °C, as follows:

$$k = -2.303(lMC/m'A) \quad (3)$$

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[3] The Thermal Conductivity *Selective Experiments Tester could be made from the apparatus description in Physics, No. H52b*, Central Scientific Co., Chicago, IL, 1940. Test Method D 2214. Similar test equipment could be purchased from Satra Footwear Technlogy Center, Satra House, Rockingham Road, Kettering Northamtonshire, NN169JH, England model STM 487. There is no known correlation between these apparatuses.

[4] Wing, Paul, and Monego, C. J., "Thermal Insulation Measurements on Textiles—A Comparison of Two Methods," *ASTM Bulletin*, No. 241, October 1959, pp. 29–33.

10. Precision and Bias

10.1 The precision is in the order of a coefficient of variation of 8 to 10 %. The precision depends on obtaining a series of points which lie on a straight line and drawing the best average line through these points to obtain a value for the slope. This may be done visually. However, the best average line and the slope are obtained more precisely and objectively by statistical calculations. An example of the method of calculation is given in Annex A1.

11. Keywords

11.1 insulating; leather; thermal conductivity

ANNEX

(Mandatory Information)

A1. EXAMPLE OF METHOD OF CALCULATION

A1.1 Following is an example of a method to calculate the slope of a straight line and two points through which the line can be drawn:

A1.1.1 *Slope*:

Time, min	Deflections, d	log d	Σt	Σ log d
0	24.0	1.380		
3	23.0	1.362		
6	22.0	1.342		
9	21.5	1.332		
			18	5.416
12	20.5	1.312		
15	19.5	1.290		
18	19.0	1.279		
			45	3.881
21	18.1	1.258		
24	17.5	1.243		
27	17.0	1.230		
30	16.5	1.218		
			102	4.949
Total			165	14.246
Avg			$\bar{t}$ = 15.00	log d = 1.2951

$$\text{Slope, } m = -(102 - 18)/(5.416 - 4.949) = -84/0.467 = -179.87 \quad \text{(A1.1)}$$

$$m' = m \times 60\ s = -179.87 \times 60 = 10\ 792.2$$

A1.1.2 *Equation of Line Passing Through $\bar{t}$ and log d*:

$$t = (\bar{t} - m \log d) + m \log d \quad \text{(A1.2)}$$

$$t = [15 - (-179.87)(1.2951) - 179.87\ (\log d)]$$

$$t = 247.95 - 179.87(\log d)$$

A1.1.3 Take two values of log d at extremes as follows:

A1.1.3.1 When log d = 1.362, t = 2.97.

A1.1.3.2 When log d = 1.218, t = 28.87.

A1.1.4 The line goes through the two points as follows:

Point	t	log d	d
1	2.97	1.362	23.0
2	28.87	1.218	16.5

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