Designation: D1518 – 85 (Reapproved 2003)

Standard Test Method for Thermal Transmittance of Textile Materials[1]

This standard is issued under the fixed designation D1518; 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 the overall thermal transmission coefficients due to the combined action of conduction, convection, and radiation for dry specimens of textile fabrics, battings, and other materials within the limits specified in 1.2. It measures the time rate of heat transfer from a warm, dry, constant-temperature, horizontal flat-plate up through a layer of the test material to a relatively calm, cool atmosphere.

1.2 For practical purposes, this test method is limited to determinations on specimens of fabrics, layered fabric assemblies, and battings having thermal transmittances (U_2, as defined in 3.1.2) within a range of 0.7 to 14 W/m^2·K and thicknesses not in excess of 50 mm.

1.3 The coefficients obtained apply strictly only to the particular specimens tested and for the specified thermal and environmental conditions of each test. This test method gives values that are valid for comparison under the same conditions of test, that is, with the specified air velocity, temperature difference between the warm plate and the cool air, and air gap for measuring cool air temperature.

1.4 The values stated in metric units are to be regarded as the standard. Conversion factors, for thermal conductance and conductivity and thermal resistance and resistivity, to other units in common use are given in Tables 1-5

1.5 *This standard does not purport to address the safety concerns associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles

D1777 Test Method for Thickness of Textile Materials

3. Terminology

3.1 *Definitions:*

3.1.1 *bulk density*, *n*—apparent mass per unit volume.

3.1.1.1 *Discussion*—In testing the thermal transmittance of fabrics, bulk density is calculated from the fabric weight per unit area and the thickness value used to calculate thermal conductivity.

3.1.2 *clo*, *n*—unit of thermal resistance defined as the insulation required to keep a resting man (producing heat at the rate of 58 W/m^2) comfortable in an environment at 21°C, air movement 0.1 m/s, or roughly the insulation value of typical indoor clothing.[3,4] (Syn. intrinsic clo).

3.1.2.1 *Discussion*—Numerically the clo is equal to 0.155 K·m^2/W.

3.1.3 *heat transfer coefficient*, *n*—see *thermal transmittance.*

3.1.4 *intrinsic clo*, *n*—see clo.

3.1.5 *specific clo*, *n*—the specific thermal resistance in clo units per unit thickness.

3.1.6 *thermal conductance*, *n*—see *thermal transmittance.*

3.1.7 *thermal conductivity*, *n*—time rate of unidirectional heat transfer per unit area, in the steady-state, between parallel planes separated by unit distance, per unit difference of temperature of the planes.

3.1.7.1 *Discussion*—Numerically, thermal conductivity equals the product of the heat transfer coefficient and the distance separating the planes. Thus, *k*, the thermal conductivity of the fabric only, is the product of U_2 and the fabric thickness. Units of thermal conductivity are W/m·K.

3.1.8 *thermal resistance*, *n*—reciprocal of thermal transmittance.

3.1.9 *thermal resistivity*, *n*—reciprocal of thermal conductivity.

3.1.10 *thermal transmittance*, *n*—time rate of unidirectional heat transfer per unit area, in the steady-state, between parallel planes, per unit difference of temperature of the planes (Syn. thermal conductance, heat transfer coefficient).

3.1.10.1 *Discussion*—Thermal transmittance is expressed as watts per square metre of test specimen per kelvin difference between the hot plate and the cool atmosphere (W/m^2·K).

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.51 on Chemical Conditioning and Performance.

Current edition approved July 26, 1985. Published September 1985. Originally published as D1518 – 57 T. Last previous edition D1518 – 77. DOI: 10.1520/D1518-85R03.

[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] American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[4] Gagge, A. P., Burton, A. C., Bazett, H. C., *Science,* Vol 94, Nov. 7, 1941, pp. 428–430.

TABLE 1 Conversion Factors for Thermal Conductivity[A]

To Convert Thermal Conductivity	Multiply by									
From to	W/m·K[B]	W·cm/m²·K	W/cm·K	cal/s·cm·K	kg-cal/h·m·K	kg-cal·cm/ h·m²·K	Btu/h·ft·°F	Btu·in/ h·ft²·°F	in/clo	mm/clo
W/m·K	1.	$1. \times 10^{+2}$	$1. \times 10^{-2}$	2.388×10^{-3}	8.598×10^{-1}	$8.598 \times 10^{+1}$	5.778×10^{-1}	6.934	6.093	$1.548 \times 10^{+2}$
W·cm/ m²·K	$1. \times 10^{-2}$	1.	$1. \times 10^{-4}$	2.388×10^{-5}	8.598×10^{-3}	8.598×10^{-1}	5.778×10^{-3}	6.934×10^{-2}	6.093×10^{-2}	1.548
W/cm·K	$1. \times 10^{+2}$	$1. \times 10^{+4}$	1.	2.388×10^{-1}	$8.598 \times 10^{+1}$	$8.598 \times 10^{+3}$	$5.778 \times 10^{+1}$	$6.934 \times 10^{+2}$	$6.093 \times 10^{+2}$	$1.548 \times 10^{+4}$
cal/s·cm·K	$4.187 \times 10^{+2}$	$4.187 \times 10^{+4}$	4.187	1.	$3.6 \times 10^{+2}$	$3.6 \times 10^{+4}$	$2.419 \times 10^{+2}$	$2.903 \times 10^{+3}$	$2.551 \times 10^{+3}$	$6.480 \times 10^{+4}$
kg-cal/ h·m·K	1.163	$1.163 \times 10^{+2}$	1.163×10^{-2}	2.778×10^{-3}	1.	$1. \times 10^{+2}$	6.720×10^{-1}	8.064	7.087	$1.8 \times 10^{+2}$
kg-cal·cm/ h·m²·K	1.163×10^{-2}	1.163	1.163×10^{-4}	2.778×10^{-5}	$1. \times 10^{-2}$	1.	6.720×10^{-3}	8.064×10^{-2}	7.087×10^{-2}	1.8
Btu/h·ft·°F	1.731	$1.731 \times 10^{+2}$	1.731×10^{-2}	4.134×10^{-3}	1.488	$1.488 \times 10^{+2}$	1.	$1.2 \times 10^{+1}$	$1.055 \times 10^{+1}$	$2.679 \times 10^{+2}$
Btu·in/ h·ft²·°F	1.442×10^{-1}	$1.442 \times 10^{+1}$	1.442×10^{-3}	3.445×10^{-4}	1.240×10^{-1}	$1.240 \times 10^{+1}$	8.333×10^{-2}	1.	8.788×10^{-1}	$2.232 \times 10^{+1}$
in/clo	1.641×10^{-1}	$1.641 \times 10^{+1}$	1.641×10^{-3}	3.920×10^{-4}	1.411×10^{-1}	1.411×10^{-1}	9.482×10^{-2}	1.138	1.	$2.540 \times 10^{+1}$
mm/clo	6.461×10^{-3}	6.461×10^{-1}	6.461×10^{-5}	1.543×10^{-5}	5.556×10^{-3}	5.556×10^{-1}	3.733×10^{-3}	4.480×10^{-3}	3.937×10^{-2}	1.

[A] Units are given in terms of: (1) the absolute joule per second, or watt; (2) the calorie (International Table) = 4.1868 J; (3) the British thermal unit (International Table) = 1055.06 J; and (4) the clo (unit of clothing resistance) = 0.155 K·m²/W.
[B] Recommended (SI) units.

TABLE 2 Conversion Factors for Thermal Transmittance[A]

To Convert Thermal Transmittance	Multiply by					
From to	W/m²·K[B]	W/cm²·K	cal/s·cm²·K	kg-cal/h·m²·K	Btu/h·ft²·°F	clo^{-1}
W/m²·K	1.	$1. \times 10^{-4}$	2.388×10^{-5}	8.598×10^{-1}	1.761×10^{-1}	1.548×10^{-1}
W/cm²·K	$1. \times 10^{+4}$	1.	2.388×10^{-1}	$8.598 \times 10^{+3}$	$1.761 \times 10^{+3}$	$1.548 \times 10^{+3}$
cal/s·cm²·K	$4.187 \times 10^{+4}$	4.187	1.	$3.6 \times 10^{+4}$	$7.373 \times 10^{+3}$	$6.480 \times 10^{+3}$
kg-cal/h·m²·K	1.163	1.163×10^{-4}	2.778×10^{-5}	1.	2.048×10^{-1}	1.8×10^{-1}
Btu/h·ft²·°F	5.678	5.678×10^{-4}	1.356×10^{-4}	4.882	1.	8.788×10^{-1}
clo^{-1}	6.461	6.461×10^{-4}	1.543×10^{-4}	5.556	1.138	1.

[A] Units are given in terms of: (1) the absolute joule per second, or watt; (2) the calorie (International Table) = 4.1868 J; (3) the British thermal unit (International Table) = 1055.06 J; and (4) the clo (unit of clothing resistance) = 0.155 K·m²/W.
[B] Recommended (SI) units.

TABLE 3 Conversion Factors for Thermal Resistivity[A]

To Convert Thermal Resistivity[B]	Multiply by									
From to	m·K/W[B]	m²·K/W·cm	cm·K/W	cm·K·s/cal	m·K·h/kg-cal	m²·K·h/kg-cal·cm	ft·°F·h/Btu	ft²·°F·h/ Btu·in	clo/in	clo/mm
m·K/W	1.	$1. \times 10^{-2}$	$1. \times 10^{+2}$	$4.187 \times 10^{+2}$	1.163	1.163×10^{-2}	1.731	1.442×10^{-1}	1.641×10^{-1}	6.461×10^{-3}
m²·K/W· cm	$1. \times 10^{+2}$	1.	$1. \times 10^{+4}$	$4.187 \times 10^{+4}$	$1.163 \times 10^{+2}$	1.163	$1.731 \times 10^{+2}$	$1.442 \times 10^{+1}$	1.641×10^{-1}	6.461×10^{-1}
cm·K/W	$1. \times 10^{-2}$	$1. \times 10^{-4}$	1.	4.187	1.163×10^{-2}	1.163×10^{-4}	1.731×10^{-2}	1.442×10^{-3}	1.641×10^{-3}	6.461×10^{-5}
cm·K·s/cal	2.388×10^{-3}	2.388×10^{-5}	2.388×10^{-1}	1.	2.778×10^{-3}	2.778×10^{-5}	4.134×10^{-3}	3.445×10^{-4}	3.920×10^{-4}	1.543×10^{-5}
m·K·h/kg- cal	8.598×10^{-1}	8.598×10^{-3}	$8.598 \times 10^{+1}$	$3.6 \times 10^{+2}$	1.	$1. \times 10^{-2}$	1.488	1.240×10^{-1}	1.411×10^{-1}	5.556×10^{-3}
m²·K·h/kg- cal·cm	$8.598 \times 10^{+1}$	8.598×10^{-1}	$8.598 \times 10^{+3}$	$3.6 \times 10^{+4}$	$1. \times 10^{+2}$	1.	$1.488 \times 10^{+2}$	$1.240 \times 10^{+1}$	$1.411 \times 10^{+1}$	5.556×10^{-1}
ft·°F·h/Btu	5.778×10^{-1}	5.778×10^{-3}	$5.778 \times 10^{+1}$	$2.419 \times 10^{+2}$	6.720×10^{-1}	6.720×10^{-3}	1.	8.333×10^{-2}	9.482×10^{-2}	3.733×10^{-3}
ft²·°F·h/ Btu·in	6.934	6.934×10^{-2}	$6.934 \times 10^{+2}$	$2.903 \times 10^{+3}$	8.064	8.064×10^{-2}	$1.2 \times 10^{+1}$	1.	1.138	4.480×10^{-3}
clo/in	6.093	6.093×10^{-2}	$6.093 \times 10^{+2}$	$2.551 \times 10^{+3}$	7.087	7.087×10^{-2}	$1.055 \times 10^{+1}$	8.788×10^{-1}	1.	3.937×10^{-2}
clo/mm	$1.548 \times 10^{+2}$	1.548	$1.548 \times 10^{+4}$	$6.480 \times 10^{+4}$	$1.8 \times 10^{+2}$	1.8	$2.679 \times 10^{+2}$	$2.232 \times 10^{+1}$	$2.540 \times 10^{+1}$	1.

[A] Units are given in terms of: (1) the absolute joule per second, or watt; (2) the calorie (International Table) = 4.1868 J; (3) the British thermal unit (International Table) = 1055.06 J; and (4) the clo (unit of clothing resistance) = 0.155 K·m²/W.
[B] Recommended (SI) units.

TABLE 4 Conversion Factors for Thermal Resistance[A]

To Convert Thermal Resistance	Multiply by					
From to	$m^2 \cdot K/W$[B]	$cm^2 \cdot K/W$	$cm^2 \cdot K \cdot s/cal$	$m^2 \cdot K \cdot h/kg\text{-}cal$	$ft^2 \cdot °F \cdot h/Btu$	clo
$m^2 \cdot K/W$	1.	$1. \times 10^{+4}$	$4.187 \times 10^{+4}$	1.163	5.678	6.461
$cm^2 \cdot K/W$	$1. \times 10^{-4}$	1.	4.187	1.163×10^{-4}	5.678×10^{-4}	6.461×10^{-4}
$cm^2 \cdot K \cdot s/cal$	2.388×10^{-5}	2.388×10^{-1}	1.	2.778×10^{-5}	1.356×10^{-4}	1.543×10^{-4}
$m^2 \cdot K \cdot h/kg\text{-}cal$	8.598×10^{-1}	$8.598 \times 10^{+3}$	$3.6 \times 10^{+4}$	1.	4.882	5.556
$ft^2 \cdot °F \cdot h/Btu$	1.761×10^{-1}	$1.761 \times 10^{+3}$	$7.373 \times 10^{+3}$	2.048×10^{-1}	1.	1.138
clo	1.548×10^{-1}	$1.548 \times 10^{+3}$	$6.480 \times 10^{+3}$	1.8×10^{-1}	8.788×10^{-1}	1.

[A] Units are given in terms of: (1) the absolute joule per second, or watt; (2) the calorie (International Table) = 4.1868 J; (3) the British thermal unit (International Table) = 1055.06 J; and (4) the clo (unit of clothing resistance) = 0.155 $K \cdot m^2/W$.
[B] Recommended (SI) units.

TABLE 5 Miscellaneous Conversion Factors

Properties	To Convert from a Value Expressed as	To a Value Expressed as	Multiply by
Mass per unit area	oz/yd^2	g/m^2	33.91
	mg/cm^2	g/m^2	10.0
Thickness	in.	mm	25.4
	1/1000 in. (mil)	mm	0.0254
Bulk density	lb/ft^3	kg/m^3	16.02
	$(oz/yd^2)/in$	kg/m^3	1.335
	$(g/m^2)/mm$	kg/m^3	1.0

Thermal transmittance for three different cases is determined in this method:

U_1 = combined thermal transmittance of the test specimen and air.

U_{bp} = thermal transmittance of the plate without fabric cover ("bare plate"). This property reflects the instrument constant and is used to standardize the plate, and, in conjunction with U_1, is used in the calculation of U_2.

U_2 = thermal transmittance of fabric only. This value corresponds to the C value ($W/m^2 \cdot K$) defined and used by ASTM and ASHRAE.[4] In the calculation of this value the assumption is made that the boundary layers of the bare plate and the boundary layers of the fabric are equal. Experimental results indicate that the U_2 values are valid when tested within the limits specified in Section 1.

3.1.11 *total clo*, *n*—the intrinsic clo plus the thermal resistance from the air boundary.

3.1.12 For definitions of other textile terms used in this method, refer to Terminology D123.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *effective insulation ratio*, *n*—indicates the increase in insulation afforded by the fabric in comparison to the uncovered test plate under specified conditions of test.

3.2.2 *mean temperature*, *n*—the average of the hot plate temperature and the temperature of the calm, cool air that prevailed during the test.

4. Significance and Use

4.1 The thermal transmittance of a fabric or batting is of considerable importance in determining its suitability for use in fabricating cold weather protective gear and clothing. The thermal interchange between man and his environment is, however, an extremely complicated subject which involves many factors in addition to the equilibrium insulation values of fabrics and battings. Therefore, measured thermal transmittance coefficients can only indicate relative merit of a particular material.

4.2 The measurement of heat transfer coefficients is a very difficult and highly technical field, and it is not practical in a test method of this scope to establish details sufficient to cover all contingencies. Departures from the instructions of Test Method D1518 may lead to significantly different test results. Technical knowledge concerning the theory of heat flow, temperature measurement, and testing practices is needed to evaluate which departures from the instructions are significant. Standardization of the method reduces, but does not eliminate the need for such technical knowledge. Any significant departures are to be reported with the results.

4.3 Test Method D1518 for the determination of the thermal transmittance of textile materials is considered satisfactory for acceptance testing of commercial shipments of textile materials because the test method has been used in the trade for acceptance testing. And it is the best test method known for this purpose.

4.3.1 In case of a dispute arising from differences in reported results when using Test Method D1518 for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens which are as homogeneous as possible and which are from a lot of material of the type in question. The test specimens should then be sent to each laboratory for testing. The average results from the two laboratories should be compared using Student's *t*-test for paired data and an acceptable probability level chosen by the two parties before testing is begun. If a bias is found, either its cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results with consideration to the known bias.

5. Apparatus (Fig. 1, Fig. 2, and Fig. 3)

NOTE 1—The drawings and illustrations are intended as suggested designs only. The final design of equipment, including necessary wiring,

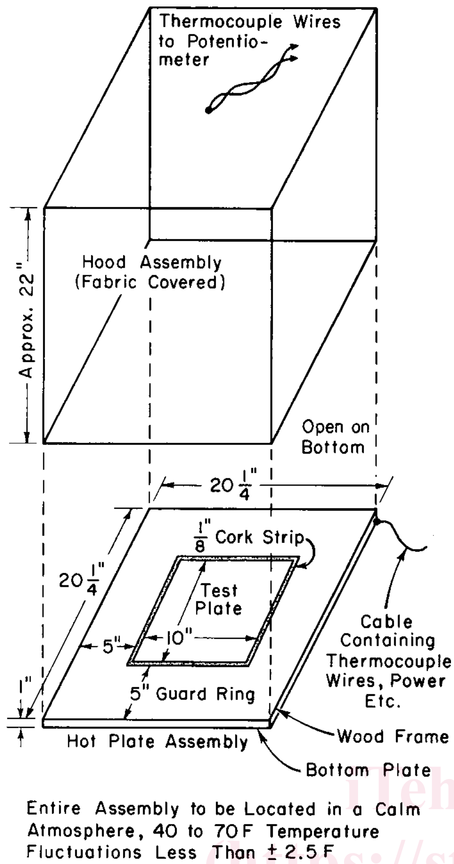

FIG. 1 Guard Ring Hot Plate For Thermal Transmittance Test

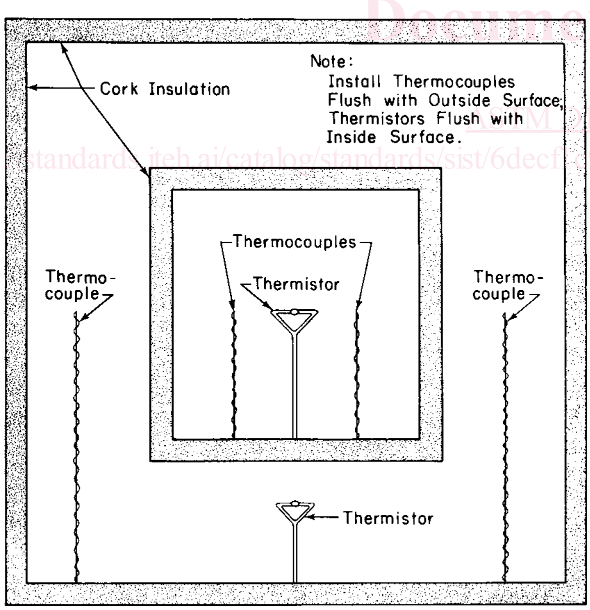

FIG. 2 Hot Plate, Top View, Showing Location of Thermistors and Thermocouples on Test Section and Guard Ring

will be dictated by the choice of the electrical measuring and control equipment.

5.1 *Hot Plate*—A guard ring flat plate composed of a test plate, guardring, and bottom plate as follows, each electrically maintained at a constant temperature in the range of human skin temperature [33 to 36°C (91.4 to 98.8°F)].

5.1.1 *Test Plate*—The test plate portion of the hot plate shall be at least 150 mm (6.0 in.) square and shall be placed at the center of the upper surface of the hot-plate assembly. It shall be made of aluminum or copper and painted a dull black to approximate the emissivity of the human skin. The heating element shall consist of parallel wires, preferably of constantan metal, insulated from, but mounted within 3 mm (0.1 in.) of the upper plate.

5.1.2 *Guard Ring*—The guard ring bordering the test plate shall be at least 63.5 mm (2.5 in.) in width and shall be of the same thickness, composition, and type of construction as the test plate. It shall be coplanar with the test plate, and shall be separated from it by means of a strip of cork or other suitable insulating material approximately 3-mm (0.1-in.) wide. The guard ring shall be designed to prevent lateral loss of heat from the test plate.

5.1.3 *Bottom Plate*—The bottom plate shall be of the same thickness, composition, and type of construction as the test plate and guard ring. The bottom plate shall be in a plane parallel to the test plate and guard ring, and at a distance of at least 25 mm (1.0 in.) but not in excess of 75 mm (3.0 in.) beneath them. It shall be separated from the test plate and guard ring by a wooden framework and the air pocket formed thereby, or by other means of causing air entrapment. The dimensions offered as suggested design specifications are shown in Fig. 3. The purpose of the bottom plate is to prevent a downward loss of heat from the test plate and guard ring.

5.2 *Temperature Control*—Separate control of the temperatures of the three sections of the hot plate (test plate, guard ring, and bottom plate) shall be established by independent adjustments of the heater currents through adjustable transformers, variable impedances, or intermittent heating cycles. Automatic regulation of temperatures is recommended. Use a constant voltage supply, controlled to ±1 % to minimize fluctuations in temperature.

5.3 *Power-Measuring Instruments*—One of any of the following instruments shall be used for measuring power:

5.3.1 Wattmeter,

5.3.2 Watt-hour meter and clock,

5.3.3 Voltmeter and ammeter, or

5.3.4 Either a voltmeter *or* an ammeter can be used if the test plate heater resistance at operating temperature is exactly known. These devices shall be operated in accordance with standard practice and shall be calibrated to measure power with an accuracy of ±2 %.

5.4 *Clocks*—When heater power is supplied on an intermittent basis, a running-time clock, energized in synchronism with the heater, shall be used to indicate the total time of heating. Another similar clock shall be used to indicate either the total time or the time during which the heater is not energized. The total limit of error of such clocks shall be less than 1 % under service conditions.

5.5 *Equipment for Measuring the Several Plate Temperatures*:

5.5.1 *Thermocouples*—The test plate, guard ring, and bottom plate shall each contain one or more thermocouples made of a junction of wires of copper and constantan, each of B & S Gage No. 30 [0.255 mm (0.01 in.)]. After calibration, these