INTERNATIONAL

~~Designation:D1518–85(Reapproved 2003)~~ Designation: D1518 – 11

Standard Test Method for ~~Thermal Transmittance of Textile Materials~~Thermal Resistance of Batting Systems Using a Hot Plate[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.

INTRODUCTION

This standard replaces D1518-85, Thermal Transmittance of Textile Materials. This standard provides a method for measuring the thermal resistance (insulation) provided by battings and batting/fabric systems under still air conditions or an air flow condition. Other hot plate standards F1868 and ISO 11092 provide a method for measuring the thermal resistance and evaporative resistance of fabrics and fabric systems. The method for measuring fabric insulation in these standards is comparable to Option 2: Air Velocity Condition in D1518. These standards can be used to compare the thermal properties of textile materials. Manikin standards F1291 and F2370 can be used to measure and compare the thermal resistance and evaporative resistance of clothing systems, respectively. Manikin standard F1720 can be used to measure the insulation provided by sleeping bag systems.

1. ~~Scope~~

~~1.1This 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~~ Scope

1.1 This test method covers the measurement of the thermal resistance, under steady-state conditions, of battings and batting/fabric systems, 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.~~ . It measures the heat transfer from a warm, dry, constant-temperature, horizontal flat-plate up through a layer of the test material to a cool atmosphere and calculates the resistance of the material. The measurements are made under still air conditions (Option #1) or with a horizontal air flow over the specimen (Option #2).

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~~For practical purposes, this test method is limited to determinations on specimens of battings and layered batting/fabric assemblies having an intrinsic thermal resistance from 0.1 to 1.5 K·m^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.~~

~~1.3The 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.~~

~~1.4The 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~~ /W and thicknesses not in excess of 50 mm.

1.3 This test method also provides a method for determining the bulk density of the material, the insulation per unit thickness, and the insulation per unit weight.

1.4 The values stated in SI units are to be regarded as standard.

1.5 *This standard does not purport to address the safety concerns associated with its use. It is the responsibility of whoever uses*

[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 D1518–57T. Last previous edition D1518–77. DOI: 10.1520/D1518-85R03.~~on Conditioning and, Chemical and Thermal Properties.

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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 3776 Test Methods for Mass Per Unit Area (Weight) of Fabric

F1291 Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin

F1494 Terminology Relating to Protective Clothing

F1720 Test Method for Measuring Thermal Insulation of Sleeping Bags Using a Heated Manikin

F1868 Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate

F2370 Test Method for Measuring the Evaporative Resistance of Clothing Using a Sweating Manikin

2.2 *ISO Standards:*[3]

ISO 11092 Textiles–Physiological Effects–Measurement of Thermal and Water-Vapour Resistance Under Steady-State Conditions (Sweating Guarded-Hotplate Test)

ISO 9073-2 Textile—Test Methods for Nonwovens—Part 2: Determination of Thickness

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. (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).

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 =thermal tra sponds to ASTM and the assump bare plate a Experiment when tested

3.1 The following terms are relevant to this standard: bulk density, clo, thermal resistance, thermal insulation.

3.2 For terminology relating to thermal resistance and insulation see Terminology F1494. U_2

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

3.3 For terminology relating to textiles see Terminology D123.

[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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

~~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

~~4.1The 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.~~

~~4.2The 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.~~

~~4.3Test 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.~~

~~4.3.1In 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.~~

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

5. Interferences

5.1 Departures from the instructions of this test method may lead to significantly different test results. Technical knowledge concerning the theory of heat transfer, 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. Report any departures from the instructions of Test Method D1518 with the results.

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

NOTE 1—The drawings, illustrations, and ~~illustrations~~captions are ~~intended~~provided as ~~suggested designs~~ possible design concepts only. The final design of equipment, including necessary wiring, will be dictated by the choice of the electrical measuring and control equipment.

~~5.1~~6.1 *Hot Plate*—A ~~guard ring~~ guarded flat plate composed of a test plate, guard ring, and bottom plate as follows, each electrically maintained at a constant temperature in the range of human skin temperature ~~[33~~(33 to ~~36°C (91.4 to 98.8°F)].~~ 38°C).

~~5.1.1~~6.1.1 *Test Plate*—The test plate portion of the hot plate shall be at least ~~150~~254 mm ~~(6.0~~(10.0 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~~ with a dull black coating to approximate the emissivity of ~~the~~ human skin. The heating element shall ~~consist of parallel wires, preferably of constantan metal, insulated from, but~~be uniformly distributed over the entire area of the test plate, mounted within 3 mm (0.1 in.) of the upper plate surface and well-thermally coupled to it.

~~5.1.2~~6.1.2 *Guard Ring*—The guard ring bordering the test plate shall be at least ~~63.5~~127 mm ~~(2.5~~(5.0 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~~6.1.3 *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.

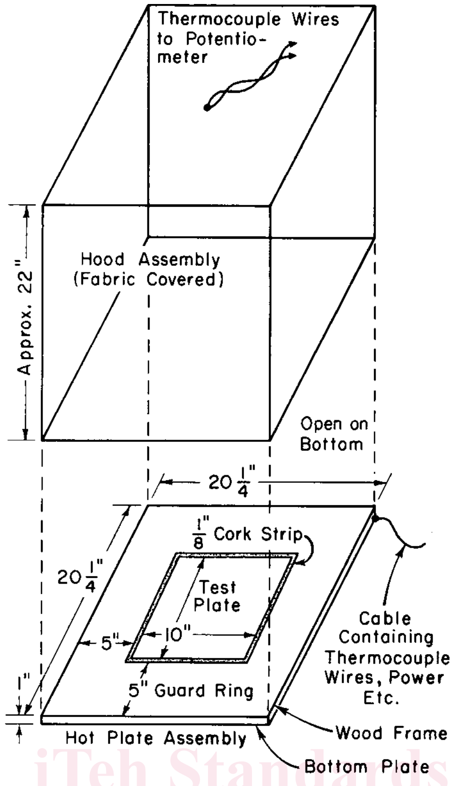

FIG. 1 Hot Plate with Guard Ring and Hot~~ Plate F~~od (No Air~~ Th~~ Vermal~~ Transmocittancy~~ Me~~ Test~~hod)

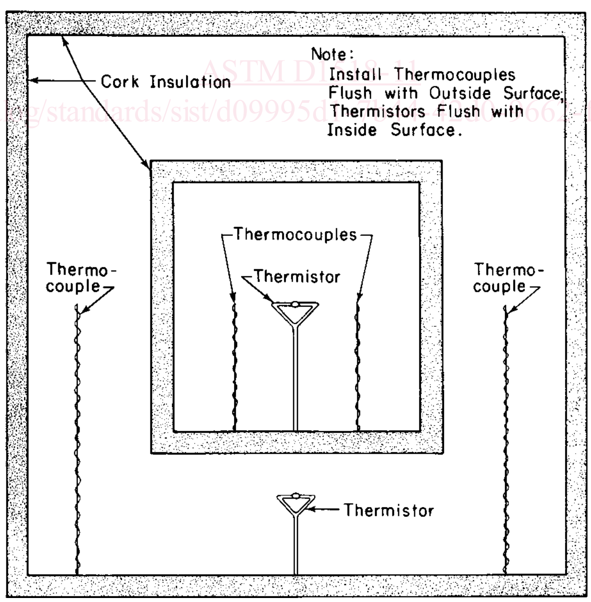

FIG. 2 Hot Plate, Top View, Showing Location of Thermistors and Thermocouples on Test Section and Guard Ring

~~5.2~~

6.2 *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.~~

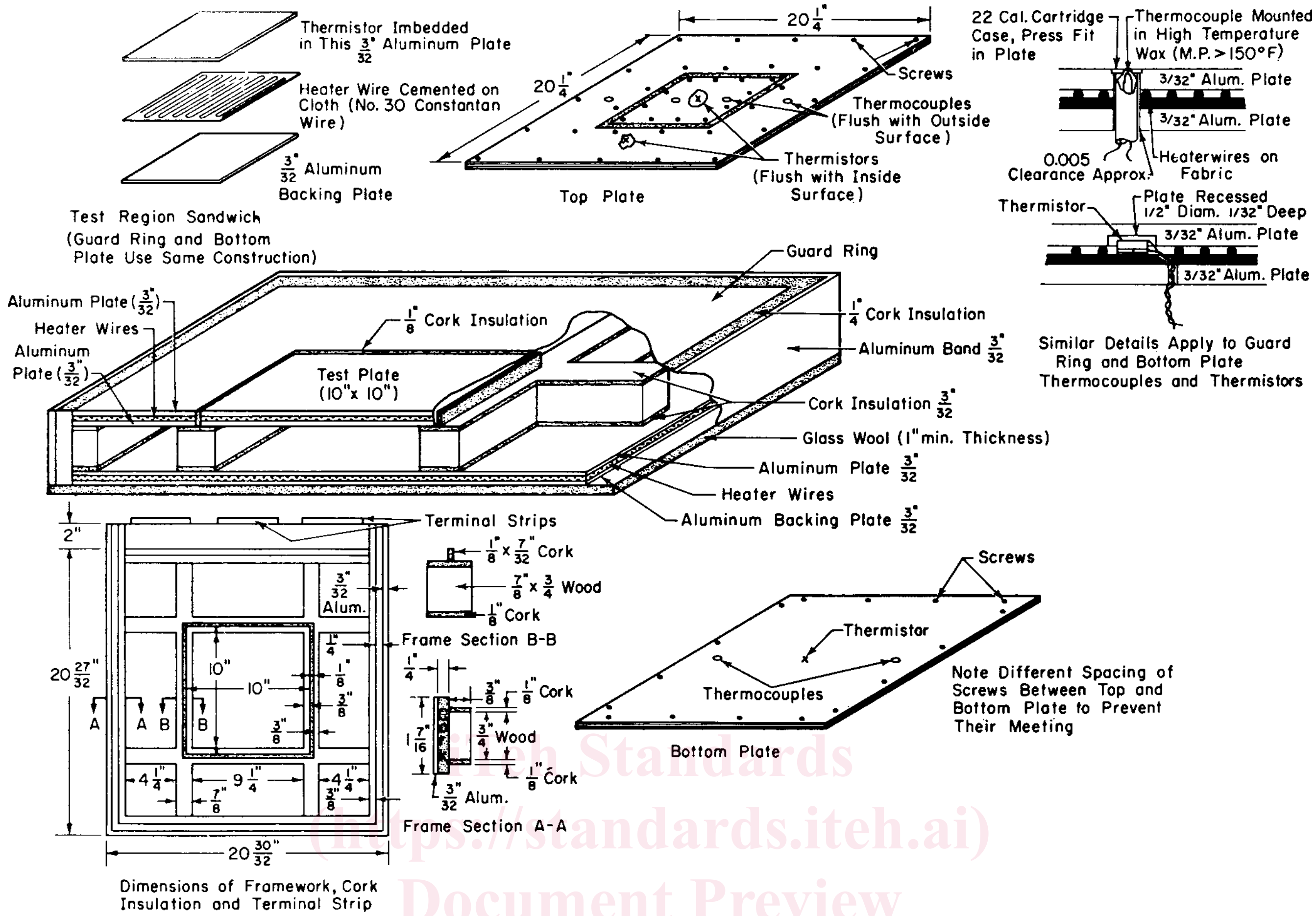

FIG. 3 **Hot Plate Apparatus ~~for Measurement of Thermal Transmittance~~, Showing Dimensions**

~~5.3~~—*Separate independent temperature control is required for the three sections of the hot plate (test plate, guard section, and bottom plate). Temperature control may be achieved by independent adjustments to the voltage or current, or both, supplied to the heaters using solid state power supplies, solid-state relays (proportional time on), adjustable transformers, variable impedances, or intermittent heating cycles. The test plate, guard, and bottom plate sections shall be controlled to measure the same temperature to within ±0.1°C of each other.*

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

~~5.3.1Wattmeter,~~

~~5.3.2Watt-hour meter and clock,~~

~~5.3.3Voltmeter and ammeter, or~~

~~5.3.4Either 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 thermocouples shall be positioned within the material of the plates as close to the external plate surfaces as physically possible [1.6 mm (0.06 in.)] to measure the temperatures of the respective surfaces.~~

~~5.5.2*Ice Bath*, as a reference junction for the thermocouples, or equivalent device.~~

~~5.5.3*Potentiometer*, accurate within ±2.5 μV, to measure the thermocouple emf's.~~

~~5.5.4*Switch*—A thermocouple selector switch for separately connecting to each set of thermocouples.~~

~~5.6*Test Chamber*—A chamber to house the hot plate that can be maintained at selected temperatures between 4.5 and 21.1°C (40 to 70°F) with a constancy of ±0.5°C (± 2.5°F). The walls of the test chamber shall not be highly reflective, and the wall~~

temperature shall be equal to that of the air in the chamber. The chamber shall be equipped with the following instruments for maintaining the relative humidity at 50± 30% for maintaining the air temperature, and for controlling the air velocity at the approximate rate of 0.1 m/s (0.33 ft/s). The hood for maintaining nearly still air conditions, shown in —Power to the hot plate test section shall be measured to provide an accurate average over the period of the test. If time proportioning or phase proportioning is used for the power control, then devices that are capable of averaging over the control cycle are required. Integrating devices (watt-hour transducers) are preferred over instantaneous devices (watt meters). Overall accuracy of the power monitoring equipment must be within ±2 % of the reading for the average power for the test period.

6.4 *Temperature Sensors*—Temperature sensors shall be thermistors, thermocouples, resistance temperature devices (RTDs), or equivalent sensors. The test plate, guard section, and bottom plate shall each contain one or more temperature sensors that are mounted flush with the hot plate surface or within 3 mm of the hot plate surface in such a manner that they measure the surface temperature within ±0.1°C.

6.5 *Controlled Atmosphere Chamber*—The hot plate shall be housed in an environmental chamber that can be maintained at selected temperatures between 1 and 20°C, or lower (see 8.1.2.1.) The test chamber wall temperature shall be ±0.5°C of the air in the chamber. The relative humidity shall be maintained between 20 and 80 %.

6.6 *Hood*—The hot plate shall be covered with a hood to control air flow.

6.6.1 *Option 1: Still Air Condition*—A box-shaped hood made of fabric on a frame with the dimensions shown in Fig. 1 , is needed.

5.6.1*is needed to cover the plate so as to maintain still air conditions over the specimen. The fabric cover must be breathable so that heat buildup is minimized inside the hood. Thin elastic knits have been successfully used to reduce air velocity in this application.*

6.6.2 *Option 2: Air Velocity Condition*—An air flow hood is needed that provides 1.0 m/s of air velocity over the batting/fabric specimen in the horizontal direction. The height of the air space above the bare plate or specimen should stay the same from test to test. Therefore, the position of the hood needs to be adjustable relative to the plate surface, or the plate surface needs to be adjustable relative to the fixed position of the hood to accommodate varying sample thicknesses and to prevent air from flowing into the edge of the sample.

6.7 *Measuring Environmental Parameters*—The air temperature, relative humidity, and air velocity shall be measured as follows:

6.7.1 *Relative Humidity Measuring Equipment*—Either a wet-and-dry bulb psychrometer or a calibrated humidity-sensitive electrical conductor.

5.6.2*Air Temperature Detector*—A thermocouple similar to those in the plates is suspended with the measuring junction exposed to the air at a point 500 mm (20.0 in.) above the center of the test plate, inside hood.

5.6.3*—Either a wet-and-dry bulb psychrometer, a dew point hygrometer, or other electronic humidity measuring device shall be used to measure the relative humidity inside the chamber. The relative humidity sensing devices shall have an overall accuracy of at least ±4 %.*

6.7.2 *Air Temperature Sensors*—Air temperature sensors with an overall accuracy of ±0.1°C shall be used. The sensors shall have a time constant not exceeding 1 min. Placement of sensors is described under test conditions for each option.

6.7.3 *Air Velocity Indicator*—Any calibrated means of measuring air velocity at the specified rate.

6.Sampling

6.1*Lot Sample*—for acceptance testing take a lot sample as directed in the applicable material specification, or as agreed upon between purchaser and supplier. In the absence of such a specification or other agreement, take a laboratory sample as directed in 6.2.

6.2Take a laboratory sample from each roll or piece of fabric in the lot sample. The laboratory sample should be full width and at least 600 mm (24 in.) long and should not be taken any closer to the end of the roll or piece of fabric than 1 m (1 yd).

6.3Sample shipments of garments or other textile materials as agreed upon between purchaser and seller.

6.4Test three specimens from each laboratory sample, unless otherwise specified in the material specification. —For Option #2, air velocity shall be measured with an accuracy of ±0.1 m/s using a hot wire anemometer. Air velocity is measured at a point 15 mm (nominal) from the plate surface or from the top of the test specimen surface to the bottom of the anemometer sensing element. The air velocity shall be measured at three positions located along a horizontal line perpendicular to the airflow, including a point at the center of the plate and at points at the centers of the guard section on both sides of the plate. Spatial variations in air velocity shall not exceed ±10 % of the mean value.

NOTE 2—The air velocity is to be measured 15 mm above the plate surface for bare plate measurements. The air velocity is to be measured 15 mm above the test specimen surface when testing fabric or systems. The 15 mm distance is to be the distance from the plate or test specimen to the anemometer sensing element (wire)—not to the bottom of the sensing element housing. If the batting system surface is uneven due to quilting, measure from the sample's highest (thickest) point.

6.7.4 *Air Temperature Variations*—Air temperature variations during testing shall not exceed ±0.1°C

6.7.5 *Relative Humidity Variations*—Relative humidity variations during testing shall not exceed ±4 %.

6.7.6 *Air Velocity Variations*—Air velocity variations shall not exceed ±5 % of the mean value for data averaged over 1 min.