Designation: D7984 – 21

Standard Test Method for Measurement of Thermal Effusivity of Fabrics Using a Modified Transient Plane Source (MTPS) Instrument[1]

This standard is issued under the fixed designation D7984; 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 provides a test method for measuring the thermal effusivity of fabrics under still air conditions. Other standards, Test Methods F1868 and D1518, measure the thermal insulation of materials under steady-state conditions; however, this test method is used to measure transient heat exchange between a fabric specimen and a heated surface. It has been established that there is a strong positive correlation between the thermal effusivity and the initial perceived coldness between human skin and different materials.[2,3]

1. Scope

1.1 This test method covers the quantitative measurement of thermal effusivity of woven, knitted, or non-woven fabrics using a guarded modified transient plane source (MTPS) instrument.[4] This test method is applicable to a wide range of thicknesses; however, the thickness of the specimen must be greater than the penetration depth of the heat flux during the measurement time.

1.2 This test method is comparative since specimens of known thermal effusivity are used to calibrate the apparatus at the factory level. Thermal effusivity of the calibration specimens are confirmed through calculations that use established properties of thermal conductivity, density, and specific heat.

1.3 This test method is intended for measuring fabrics in a dry state at ambient conditions.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[5]

D123 Terminology Relating to Textiles
D1518 Test Method for Thermal Resistance of Batting Systems Using a Hot Plate
D1776 Practice for Conditioning and Testing Textiles
D4920 Terminology Relating to Conditioning, Chemical, and Thermal Properties
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
F1868 Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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[2] Marin, E., "Teaching Thermal Physics by Touching," *Latin-American Journal of Physics Education*, Vol 2, No. 1, January 2008, pp. 15-17.

[3] Wongsriruska, S., Howes, P., Conreen, M., Miodownik, M., "The Use of Physical Property Data to Predict the Touch Perception of Materials," *Materials and Design*, Vol 42, 2012, pp. 238-244.

[4] The sole source of supply of the TCi instrument known to the committee at this time is C-Therm Technologies, Ltd., C/O RPC, 921 College Hill Rd., Fredericton, New Brunswick, Canada, E3B 6Z9. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[5] 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.

3.1.1 *modified transient plane source (MTPS), n*—an apparatus that has a one sided planar heat source and a guard, or guard ring, mounted perpendicular to the planar heat source, that is put in contact with one side of a test specimen, so that a short duration heat pulse can penetrate into the specimen.

3.1.1.1 *Discussion*—The purpose of the guard (or guard ring) is to maintain a consistent unidirectional heat flow across the test specimen.

3.1.2 *penetration depth, n*—the functional depth to which the initial radiation applied at the surface travels into the specimen.

3.1.2.1 *Discussion*—To ensure that the heat wave is contained within the test specimen, the thickness of the test specimen must be greater than the penetration depth.

3.1.3 *thermal effusivity, n*—a material property that describes its ability to exchange thermal energy with another material with which it is in contact.

$$e = \sqrt{\lambda \cdot c_p \cdot \rho} \tag{1}$$

where:

e = thermal effusivity, $W \cdot S^{½}/(m^2 \cdot K)$,
λ = thermal conductivity, $W/(m \cdot K)$,
c_p = specific heat capacity, $J/(kg \cdot K)$, and
ρ = mass density, kg/m^3.

3.1.3.1 *Discussion*—The thermal effusivity of two materials that are in contact determines the temperature at their interface as a result of heat energy exchange.

3.2 For definitions of other textile terms used in this test method refer to Terminology D123.

3.3 For definitions of other terms related to conditioning, chemical and thermal properties used in this test method, refer to Terminology D4920.

4. Summary of Test Method

4.1 A constant momentary heat pulse is applied to the surface of a test specimen. The heat pulse elevates the temperature of the surface as the heat diffuses into the test specimen in one dimensional heat flow. Thermal effusivity is determined from the temperature increase at the surface of the material with elapsed time. The temperature increase at the surface is inversely proportional to the thermal effusivity of the sample material.

5. Significance and Use

5.1 This test method measures the rate of thermal transport between a heating element and a fabric specimen. Some of the comfort properties of a garment relate to initial thermal sensations (that is, cold or warm feeling upon initial contact), where lower thermal effusivity values indicate sensations of warmth and higher values indicate sensations of coolness. The thermal effusivity of different fabrics and their initial perceived surface temperature are important to assist product developers with fabric selection.

5.2 The sensor and the test specimen being measured shall be at the same temperature for measurements at standard conditions. This test method may be applied to any fabric with a thermal effusivity in the range of 35 to 1700 $Ws^{½}/m^2 \cdot K$.

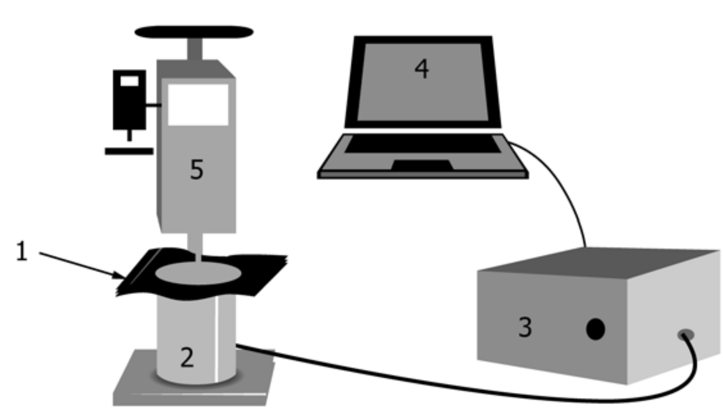
5.3 Air flow shall be kept at a minimum to ensure temperature fluctuations do not occur during the measurement.

6. Apparatus

6.1 *Modified Transient Plane Source Apparatus*—See Fig. 1. The essential instrumentation required to provide the minimum transient plane source capability for this test method includes:

6.1.1 *Heater,* to provide a heat pulse to one surface of the test specimen sufficient to cause the surface temperature of the specimen to increase 1 to 3°C.

6.1.2 *Temperature sensor,* to provide an indication of the surface temperature of the test specimen readable to within ±0.01°C.



(1) Fabric Specimen
(2) Heater and Sensor
(3) Controller
(4) Data Acquisition System
(5) Constant Pressure Applicator

FIG. 1 Basic Layout of an Effusivity Measurement Apparatus