Designation: F2703 – 21

Standard Test Method for Unsteady-State Heat Transfer Evaluation of Flame-Resistant Materials for Clothing with Burn Injury Prediction[1]

This standard is issued under the fixed designation F2703; 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 measures the non-steady state heat transfer through flame-resistant materials for clothing subjected to a combined convective and radiant heat exposure.

1.1.1 This test method is not applicable to materials that are not flame resistant.

NOTE 1—The determination of a material's flame resistance shall be made prior to testing and done in accordance with the applicable performance or specification standard, or both, for the material's end use.

1.1.2 This test method accounts for the thermal energy contained in an exposed test specimen after the standardized combined convective and radiant heat exposure has ceased and is used to estimate performance to a predicted second-degree skin burn injury.

1.2 This test method is used to measure and describe the response of materials, products, or assemblies to heat under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound or other units that are commonly used for thermal testing.

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

1.5 *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:*[2]

D123 Terminology Relating to Textiles

D1777 Test Method for Thickness of Textile Materials

D3776/D3776M Test Methods for Mass Per Unit Area (Weight) of Fabric

E457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter

F1494 Terminology Relating to Protective Clothing

3. Terminology

3.1 *Definitions:*

3.1.1 *breakopen, n*—in testing thermal protective materials, a material response evidenced by the formation of a hole in the test specimen during the thermal exposure that may result in the exposure energy in direct contact with the heat sensor.

3.1.1.1 *Discussion*—The specimen is considered to exhibit breakopen when a hole is produced as a result of the thermal exposure that is at least 3.2 cm^2 (0.5 $in.^2$) in area or at least 2.5 cm (1.0 in.) in any dimension. Single threads across the opening or hole do not reduce the size of the hole for the purposes of this test method.

3.1.2 *charring, n*—the formation of a carbonaceous residue as the result of pyrolysis or incomplete combustion.

3.1.3 *dripping, n*—a material response evidenced by flowing of the polymer.

3.1.4 *embrittlement, n*—the formation of a brittle residue as a result of pyrolysis or incomplete combustion.

3.1.5 *heat flux, n*—the thermal intensity indicated by the amount of energy transmitted divided by area and time; kW/m^2 ($cal/cm^2 \cdot s$).

3.1.6 *ignition, n*—the initiation of combustion.

3.1.7 *melting, n*—a material response evidenced by softening of the polymer.

3.1.8 *response to heat exposure, n—in testing the resistance to heat transfer of thermal protective materials*, the observable

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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.

response of the material to the energy exposure as indicated by breakopen, melting, dripping, charring, embrittlement, shrinkage, sticking, and ignition.

3.1.9 *sample test suite, n*—any number of test specimens used to derive a single thermal performance estimate value.

3.1.9.1 *Discussion*—The determination of a single thermal performance estimate value requires exposing a number of specimens under varying exposure conditions so that the thermal energy stored in the sample after the heat source is removed is considered and accounted for when determining performance against a burn injury prediction.

3.1.10 *second-degree burn injury, n—in testing of thermal protective materials*, reversible burn damage at the epidermis/dermis interface in human tissue.

3.1.11 *shrinkage, n*—a decrease in one or more dimensions of an object or material.

3.1.12 *sticking, n*—a material response evidenced by softening and adherence of the material to the surface of itself or another material.

3.1.13 *thermal performance estimate (TPE), n—in testing of thermal protective materials*, the cumulative amount of energy identified by the intersection of a measured time-dependent heat transfer response through a subject material to a time-dependent, empirical predicted second-degree skin burn injury performance curve,[3] expressed as a rating or value; J/cm^2 (cal/cm^2).

3.1.14 *unsteady state heat transfer value, n—in testing of thermal protective materials*, a quantity expressed as the time-dependent difference between the incident and exiting thermal energy values normal to and across two defined parallel surfaces of an exposed thermal insulative material.

3.1.15 For the definitions of protective clothing terms used in this method, refer to Terminology F1494, and for other textile terms used in this method, refer to Terminology D123.

4. Summary of Test Method

4.1 A horizontally positioned test specimen is exposed to a combined convective and radiant heat source with an exposure heat flux of 84 ± 2 kW/m^2 (2 ± 0.05 $cal/cm^2 \cdot s$).

NOTE 2—Other exposure heat flux values are allowed, however, different exposure conditions have the potential to produce different results. The test facility shall verify the stability of other exposure levels over the material's exposure time interval (used to determine the thermal performance estimate value) and include this in the test results report.

4.2 The unsteady-state transfer of heat through the test specimen is measured using a copper slug calorimeter. The change in temperature versus time is used, along with the known thermophysical properties of copper, to determine the respective thermal energy passed through the test specimen.

4.3 A Thermal Performance Estimate value of the test specimen is determined iteratively as the intersection of the time-dependent cumulative heat response as measured by the calorimeter to a time-dependent, empirical predicted second-degree skin burn injury performance curve identified in 10.4.1.5, Eq 1).

4.4 Observations of the thermal response of the specimen resulting from the exposure are optionally reported.

5. Significance and Use

5.1 This test method is intended for the determination of a thermal performance estimate value of a material, a combination of materials, or a comparison of different materials used in flame-resistant clothing for workers exposed to combined convective and radiant thermal hazards.

5.2 This test method evaluates a material's heat transfer properties when exposed to a heat exposure at a constant value and specific duration. Air movement at the face of the specimen and around the calorimeter can affect the measured heat transferred due to forced convective heat losses. Minimizing air movement around the specimen and test apparatus will aid in the repeatability of the results.

5.3 This test method accounts for the thermal energy stored in the exposed test specimen after the heat exposure has ceased. Higher values of thermal performance estimate ratings determined in this test associate to higher values of thermal (convective and radiative) energy protection against a predicted skin burn injury.

5.4 This test method maintains the specimen in a static, horizontal position and does not involve movement except that resulting from the exposure.

5.5 This test method specifies a standardized 84 ± 2 kW/m^2 (2 ± 0.05 $cal/cm^2 \cdot s$) exposure condition. Different exposure conditions have the potential to produce different results. Other exposure conditions representative of the expected hazard are allowed but shall be reported with the results along with a determination of the exposure energy level stability.

5.6 This test method contains optional provisions for conducting certification testing against a prescribed thermal performance estimate value.

6. Apparatus and Materials

6.1 *General Arrangement*—The measurement apparatus configuration consists of a combined convective and radiant energy heat source, a water-cooled shutter for exposure control, a specimen and sensor support structure, a specimen holder assembly, a copper calorimeter sensor assembly, and a data acquisition/analysis system. Automation of the apparatus for execution of the measurement procedure is allowed. The general arrangement of the test apparatus configuration is shown in Fig. 1.

6.2 *Gas Supply*—Propane (commercial grade or better) or methane (technical grade or better).

6.3 *Gas Flow Meter*—Any gas flow meter or rotometer with range to give a flow equivalent of at least 6 L (0.21 ft^3)/min air at standard conditions.

[3] Derived from: Stoll, A. M. and Chianta, M. A., "Method and Rating System for Evaluations of Thermal Protection," *Aerospace Medicine*, Vol 40, 1969, pp. 1232–1238 and Stoll, A. M. and Chianta, M. A., "Heat Transfer Through Fabrics as Related to Thermal Injury," *Transactions – New York Academy of Sciences*, Vol 33, No. 7, 1971, pp. 649–670.