



Designation: F3538 – 22

Standard Test Method for Measuring Heat Transmission Through Flame-Resistant Materials for Clothing in Flame Exposure Using a Cylindrical Specimen Holder¹

This standard is issued under the fixed designation F3538; 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 thermal response of a material or combination of materials using a combined convective/radiant heat transmission apparatus consisting of an eccentric cylindrical test sensor. It can be used to estimate the non-steady state thermal transfer through flame-resistant materials used in clothing when subjected to a continuous, combined convective and radiant heat exposure. The average incident heat flux is 84 kW/m^2 ($2 \text{ cal/cm}^2\cdot\text{s}$), with durations up to 30 s.

1.1.1 This test method is not applicable to materials that melt, drip, or cause falling debris during the test.

NOTE 1—Because of the arrangement of the equipment, if materials melt, drip, or cause falling debris during the test, the test result is invalid.

1.2 Heat transmission through clothing is largely determined by its thickness, including any air gaps. The air gaps can vary considerably in different areas of the human body. This method provides a means of grading materials when tested under standard test conditions and an air gap exists between the fabric and the sensor. During the exposure, fabric temperatures can exceed 400°C . At these temperatures some fabrics are not dimensionally stable and can shrink or stretch. The cylindrical geometry used in this test method allows such motion to occur, which will affect the time to achieve the end point of the test. These effects are not demonstrated in planar geometry test methods such as Test Method F2700.

1.3 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.

1.4 The measurements obtained and observations noted only apply to the particular material(s) tested using the specified heat flux, flame distribution, and duration.

¹ This test method is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.80 on Flame and Thermal.

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1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units or other units commonly used for thermal testing. If appropriate, round the non-SI units for convenience.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. Fire testing is inherently hazardous. Adequate safeguards for personnel and property shall be employed in conducting these tests. 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.*

1.7 *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

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

F1494 Terminology Relating to Protective Clothing

F2700 Test Method for Unsteady-State Heat Transfer Evaluation of Flame-Resistant Materials for Clothing with Continuous Heating

2.2 *AATCC Standard:*³

AATCC LPI Laboratory Procedure for Home Laundering: Machine Washing

3. Terminology

3.1 *Definitions:*

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 Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709-2215, <http://www.aatcc.org>.

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.

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

3.1.3 *cylinder heat transfer performance value (CHTP), n*—in testing of thermal protective materials with the use of a cylindrical specimen holder, the cumulative amount of thermal energy identified by the intersection of the measured time-dependent heat transfer response through the subject material to a time-dependent, empirical performance curve, expressed as a rating or value; J/cm² (cal/cm²).

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/m² (cal/cm²·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 thermal resistance of thermal protective materials, the observable response of the material to the energy exposure as indicated by breakopen, melting, dripping, charring, embrittlement, shrinkage, sticking, and ignition.

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

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

3.1.11 *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.

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

4. Summary of Test Method

4.1 A test specimen is wrapped around an instrumented test cylinder that is horizontally positioned and exposed to a combined convective and radiant heat source with an exposure heat flux of $84 \pm 2 \text{ kW/m}^2$ ($2 \pm 0.05 \text{ cal/cm}^2\cdot\text{s}$).

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

4.1.1 The transfer of heat through the test specimen is measured using a copper slug calorimeter with a convex curvature. 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.

4.1.2 A cylinder heat transfer performance value (CHTP) of the test specimen is calculated based on measurements from the calorimeter.

4.1.3 Observations of the thermal response of the specimen resulting from the exposure are optionally noted.

5. Significance and Use

5.1 This test method is intended for the determination of the cylinder heat transfer performance value of a flame-resistant material or combination of materials when exposed to a continuous and constant heat source. This is used to compare materials used in flame-resistant clothing for workers when exposed to combined convective and radiant thermal hazards.

NOTE 3—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.

5.2 This test method maintains the specimen with and without air gaps in a static, horizontal position and does not involve movement unless the test specimen naturally changes due to the thermal exposure.

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

5.4 This test method does not predict skin burn injury from the heat exposure.

5.5 This test method is similar to Test Method **F2700** in that it uses the same energy heat source, water-cooled shutter, data acquisition, and measures the heat transfer through protective clothing materials using a copper calorimeter. This test method differs from Test Method **F2700** in the usage of an eccentric instrumented cylinder mounted horizontally that allows for the thermal shrinkage of materials when tested.

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 rotameter with range to give a flow equivalent of at least 6 L (0.21 ft³)/min air at standard conditions.

6.4 *Thermal Energy Sources:*