Designation: F1939 − 15 (Reapproved 2020)

Standard Test Method for Radiant Heat Resistance of Flame Resistant Clothing Materials with Continuous Heating[1]

This standard is issued under the fixed designation F1939; 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 rates the non-steady state thermal resistance or insulating characteristics of flame resistant clothing materials subjected to a continuous, standardized radiant heat exposure.

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

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

1.1.2 This test method does not predict skin burn injury from the standardized radiant heat exposure, as it does not account for the thermal energy contained in the test specimen after the exposure has ceased.

NOTE 2—See Appendix X4 for additional information regarding this test method and predicted 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
D1776/D1776M Practice for Conditioning and Testing 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

2.2 *ASTM Special Technical Publications:*

ASTM Report ASTM Research Program on Electric Arc Test Method Developments to Evaluate Protective Clothing Fabric; ASTM F18.65.01 Testing Group Report on Arc Testing Analysis of the F1959 Standard Test Method—Phase I
ASTM Manual 12 Manual on the Use of Thermocouples in Temperature Measurement

3. Terminology

3.1 *Definitions:*

3.1.1 *break-open, 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 *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.

[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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[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.

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

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 *non-steady state thermal resistance, 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.

3.1.9 *radiant heat resistance (RHR), n—in testing of thermal protective materials*, the cumulative amount of thermal exposure 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; kJ/m^2 (cal/cm^2).

3.1.10 *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 break-open, melting, dripping, charring, embrittlement, shrinkage, sticking, and ignition.

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 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 vertically positioned test specimen is exposed to a radiant heat source with an exposure heat flux of either (*a*) 21 kW/m^2 (0.5 cal/cm^2s), or (*b*) 84 kW/m^2 (2 cal/cm^2s).

NOTE 3—Other exposure heat flux values are allowed. The test facility shall verify the stability of the exposure level over the material's exposure time interval (used to determine the radiant heat resistance value) and include this in the test results report.

4.2 The 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 delivered.

4.3 A radiant heat resistance rating of the test specimen is determined as the intersection of the time-dependent cumulative radiant heat response as measured by the calorimeter to a time-dependent, empirical performance curve identified in 10.9.

4.4 Subjective observations of the thermal response of tested specimens are optionally noted.

5. Significance and Use

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

5.2 This test method evaluates a material's heat transfer properties when exposed to a continuous and constant radiant heat source. 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 the air movement around the specimen and test apparatus will aid in the repeatability of the results.

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

5.4 This test method specifies two standard sets of exposure conditions: 21 kW/m^2 (0.5 cal/cm^2s) and 84 kW/m^2 (2.0 cal/cm^2s). Either can be used.

5.4.1 If a different set of exposure conditions is used, it is likely that different results will be obtained.

5.4.2 The optional use of other conditions representative of the expected hazard, in addition to the standard set of exposure conditions, is permitted. However, the exposure conditions used must be reported with the results along with a determination of the exposure energy level stability.

5.5 This test method does not predict skin burn injury from the standardized radiant heat exposure.

NOTE 4—See Appendix X4 for additional information regarding this test method and predicted skin burn injury.

6. Apparatus and Materials

6.1 *General Arrangement*—The apparatus consists of a vertically oriented radiant heat source, specimen holder assembly, protective shutter, sensor assembly, and data acquisition/analysis system. The general arrangement of the radiant heat source, specimen holder, and protective shutter of a suitable apparatus is shown in Fig. 1.

6.1.1 *Radiant Heat Source*—A suitable, vertically oriented radiant heat source is shown in Fig. 1. It consists of a bank of five, 500 W infrared, tubular, translucent quartz lamps having a 127-mm (5.0-in.) lighted length and a mean overall length of 222 mm (8¾ in.). The lamps are mounted on 9.5 ± 0.4-mm (⅜ ± 1⁄64-in.) centers so that the lamp surfaces are approximately 0.4 mm (1⁄64 in.) apart. The bank or array of lamps are mounted and centered behind a 63.5 by 140-mm (2½ by 5½-in.) cut-out that is positioned in the center of a 12.7 mm (½ in.) thick, 86 mm (3⅜ in.) wide by 292 mm (11½ in.) long, high-temperature insulating board as shown in Fig. 2. The quartz lamps shall be heated electrically, and the power input controlled by means of a rheostat or variable power supply having a capacity of at least 25 A.

6.1.1.1 Setting and monitoring the voltmeter readout on a voltage-controlled variable power supply is one method to calibrate and monitor the exposure level during the testing on a system so equipped. A voltmeter, accurate to ±1 V, is typically installed with the appropriate load circuit to indicate lamp operating power.

6.1.1.2 Any covers or guards installed on the quartz lamp assembly shall be designed such that any convective energy

1	Cast Aluminum Apparatus Body
2	Toggle Switch - DPST
3	Transite - Smooth Surfaces
4	5 Quartz Lamps - 500 T 3 115-125 V
5	Screw - 10-24 ¾ in. (19 mm)
6	Legs for Horizontal Test Position
7	Tapped 10-24
8	½ in. (12.7 mm) D Imbedded Magnet Center Screw Fastening
9	Holder - 20 Gage Cold Rolled Steel
10	Bolt - 3/16 in. (4.76 mm) D ½ in. (12.7 mm) Brazed Flush
11	Test Sample
12	Holder Plate - 20 Gage Cold Rolled Steel
13	Drilled Holes - 3/8 in. (9.5 mm) D
14	Affix "DANGER - May Be Hot" labels in prominent locations on apparatus

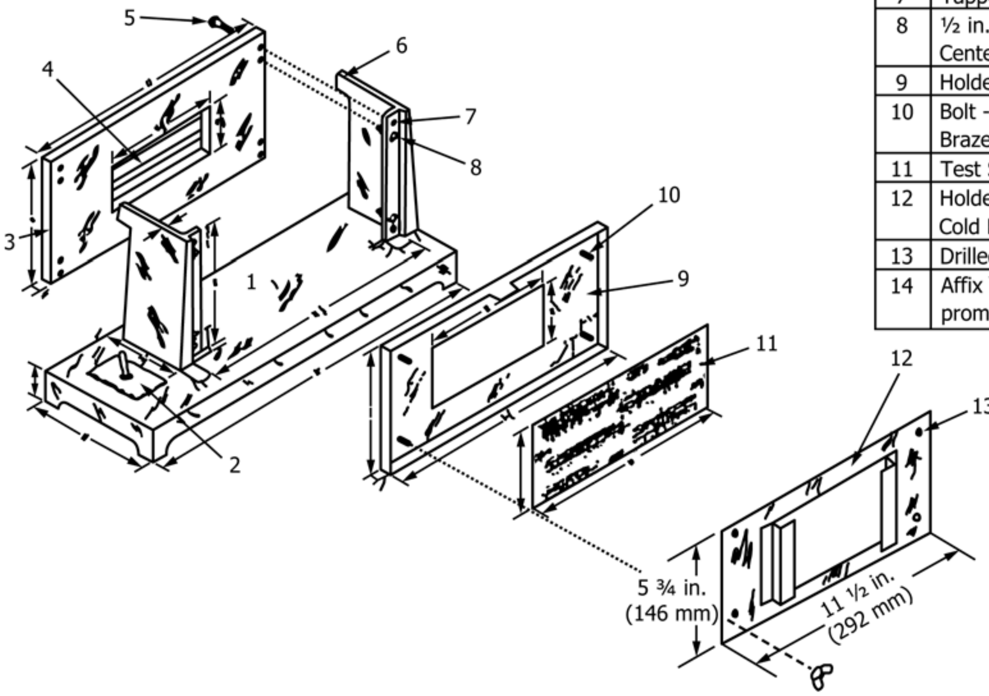

FIG. 1 General Expanded View of a Compliant Radiant Resistance Performance Test Apparatus (See Figures 2, 3, and 4 for specific item details)

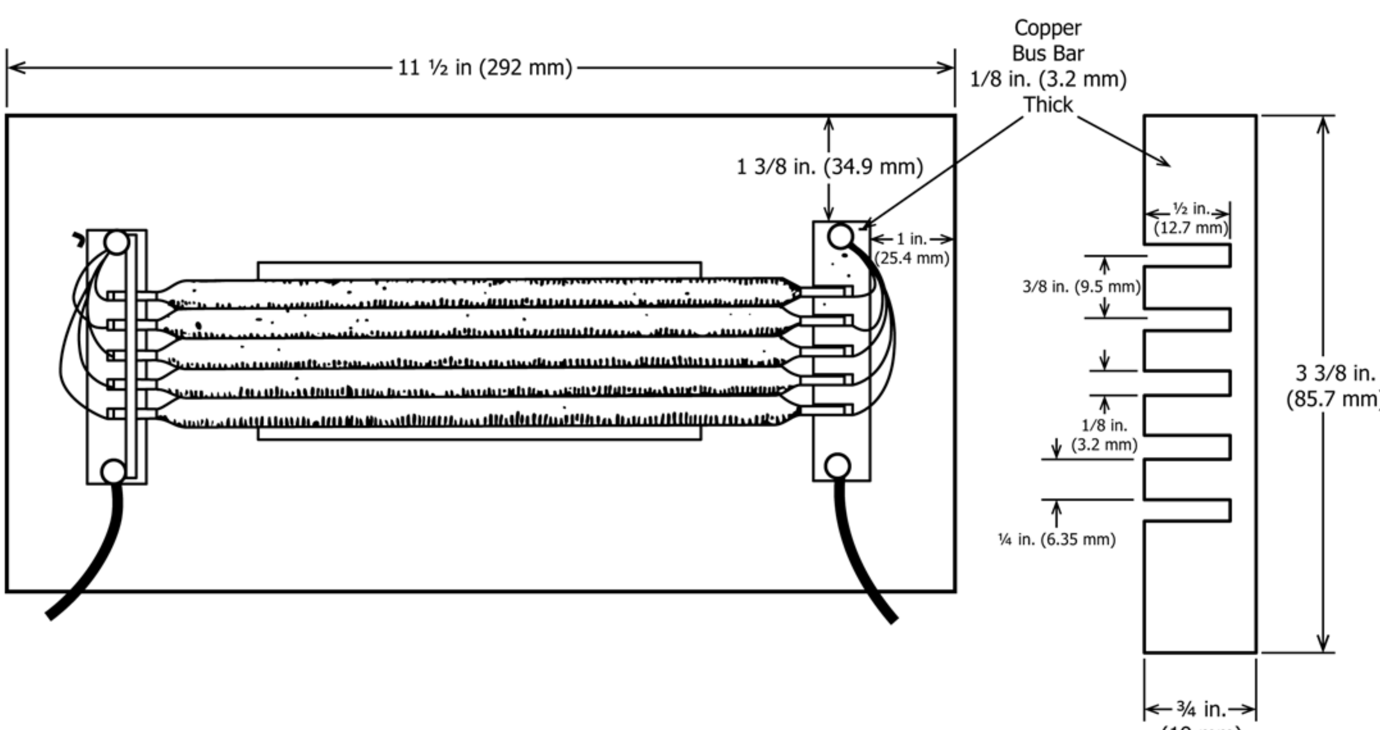

FIG. 2 Detailed View of Position of Quartz Lamps on Thermal Insulating Board

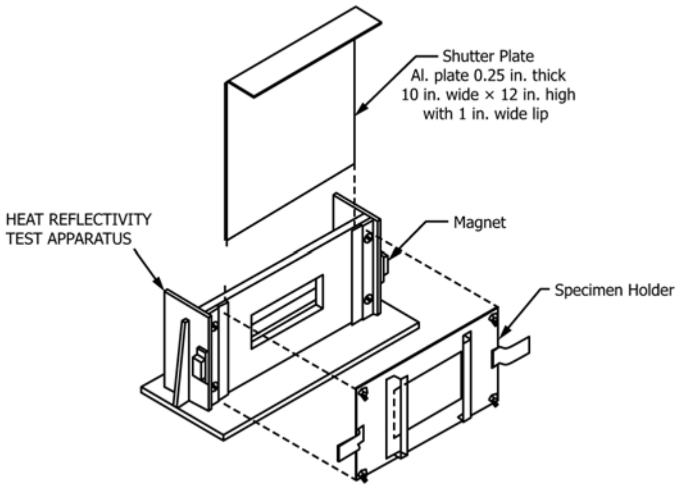

FIG. 3 Detailed View of a Compliant Radiant Protective Performance Test Apparatus Showing Holder with Window, Manual Shutter Plate, and Specimen Holder with Calorimeter Brackets (A magnet/tab arrangement is shown as an equipment design option to hold the specimen holder to the assembly)

generated is not allowed to impinge on the sample specimen (vertical, umimpeded ventilation is required).

NOTE 5—Radiant measurement systems designed with closed lamp assembly covers and covers with minimal ventilation have been found to exhibit large measurement biases in round robin testing.

NOTE 6—Transite monolithic, non-asbestos fiber cement board[3,4] has been found to be effective as a high-temperature insulating board.

6.1.2 *Specimen Holder Assembly*—A specimen holder and holder plate with a 64 by 152-mm (2½ by 6-in.) center cut-out is positioned so that the distance from the nearest lamp surface to the test specimen is 25.4 ± 0.4 mm (1.0 ± 1⁄64 in.). The rear holder plate thickness is 0.9 ± 0.05 mm (0.036 ± 0.002 in.) and includes a bracket to hold the copper calorimeter sensor assembly. This rear plate holds the specimen in place so that it covers the complete cutout section (see typical designs shown in Figs. 3 and 4). Several specimen holders are recommended to facilitate testing.

NOTE 7—The copper calorimeter sensor assembly holder plate bracket is constructed such that the calorimeter assembly is in a reproducible fixed vertical position when installed and is held flush and rigidly against the rear holder plate.

6.1.3 *Protective Shutter*—A protective shutter, as shown in Fig. 3, is placed between the radiant energy source and the specimen. The protective shutter blocks the radiant energy just prior to the exposure of a specimen. Manual or mechanically operated shutter designs are allowed with and without water-cooling.

6.1.4 *Rheostat or Variable Power Supply*—A standard laboratory rheostat or appropriate power supply with a capacity of at least 25 A, which is capable of controlling the output intensity of the tubes over the range specified in 4.1.

6.1.5 *Sensor*—The radiant heat sensor is a 4 ± 0.05 cm diameter circular copper slug calorimeter constructed from electrical grade copper with a mass of 18 ± 0.05 g (prior to drilling) with a single iron-constantan (ANSI Type J) thermocouple wire bead (0.254 mm wire diameter or finer—equivalent to 30 AWG) installed as identified in 6.1.5.2 and shown in Fig. 5 (see Test Method E457 for information regarding slug calorimeters). The sensor holder shall be constructed from non-conductive, heat-resistant material with a thermal conductivity value of ≤0.15 W/m·K, high temperature stability, and resistance to thermal shock. The board shall be nominally 1.3 cm (0.5 in.) or greater in thickness and meet the specimen holder assembly requirements of 6.1.2. The sensor is held into the recess of the board using three straight pins, trimmed to a nominal length of 5 mm, by placing them equidistant around the edge of the sensor so that the heads of the pins hold the sensor flush to the surface.

[3] The sole source of supply of this type of product known to the committee at this time is BNZ Materials, Inc., 6901 South Pierce Street, Suite 260, Littleton, CO 80128, Ph: 800-999-0890.

[4] 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.

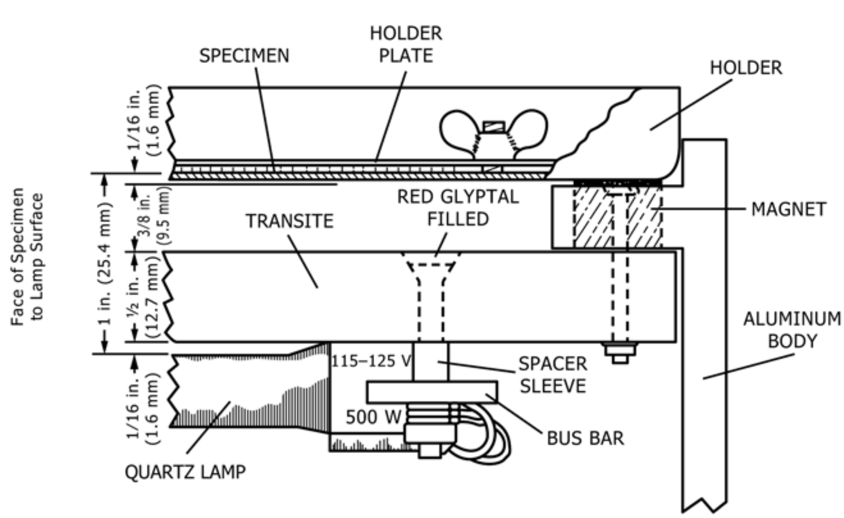

FIG. 4 Sample Position Example—Top View Enlargement