INTERNATIONAL

~~Designation:F1939–99a~~ Designation: F 1939 – 07

Standard Test Method for Radiant ~~Protective Performance~~Heat Resistance of Flame Resistant Clothing Materials[1]

This standard is issued under the fixed designation F 1939; 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

~~1.1This test method covers a means of measuring the effect of radiant heat exposure at the standard levels of (*a*) 0.5 or (*b*) 2.0 cal/cm^2 ·s (21 or 84 kW/m^2) on a fabric specimen or a fabric assembly specimen.~~

~~1.2The radiant protective performance (RPP) rating is calculated.~~

~~1.2.1This value is not intended to be used as a performance specification.~~

~~1.2.2The effects of the radiant energy exposure on the specimen may be observed and reported.~~

~~1.3This test method is recommended for use with fabrics that are flame resistant and that are used in the manufacture of protective clothing.~~

~~1.4This test method is not recommended for use with fabrics or with other textile materials that are not flame resistant, and that may or may not ignite and continue to burn from exposure to the radiant heat flux.~~

~~1.5This test method measures and describes the response of materials, products, or assemblies to heat and flame 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.~~

~~1.6The values stated in customary units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units.~~

~~1.7~~

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

~~[1] This test method is under the jurisdiction of ASTM Committee F-23 on Protective Clothing and is the direct responsibility of Subcommittee F23.80 on Radiant Energy Exposure Test.~~

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[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.

D 123 Terminology Relating to Textiles
D 1776 Practice for Conditioning and Testing Textiles
D1776Practice for Conditioning Textiles for Testing 1777 Test Method for Thickness of Textile Materials
D 3776 Test Methods for Mass Per Unit Area (Weight) of Fabric
E 457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter
F 1494 Terminology Relating to Protective Clothing

2.2 *ASTM Special Technical Publication: 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 material test specimen during the thermal exposure that may result in direct contact of the heat sensorthe exposure energy in direct contact with the exposure energy. heat sensor.

3.1.2 *burn injury*, *n*—burn damage that occurs at various levels of depth within human tissue.

3.1.2.1*Discussion*—Burn injury in human tissue occurs when the tissue is heated and kept at an elevated temperature for a critical period of time. The amount of burn injury, first-, second-, or third-degree depends upon both the level of the elevated temperature and the duration of time. Material performance in this test method is related to the second-degree burn injury and is determined by the amount of thermal energy transmitted through the specimen that is sufficient to cause a second-degree burn. A second-degree burn involves irreversible damage of the epidermis/dermis interface.

3.1.3*burn time intersection*, *n— in testing of thermal protective materials*, the point where the energy transferred through the specimen and the energy required to predict a second-degree burn are equal, as indicated by the point where the sensor response curve on the recorder chart crosses the curve of the human tissue burn tolerance criteria overlay; or if the data are processed with a computer software program, a similar result achieved by comparison of the heat transferred through the specimen and the human tissue tolerance to heat.

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

3.1.5

3.1.3 *dripping*, *n*—a material response evidenced by flowing and formation of falling droplets.

3.1.6—*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.

3.1.7*flame-retardant-treated*, *adj*—having been processed with a flame retardant.

3.1.8

3.1.5 *heat flux*, *n*—the thermal intensity indicated by the amount of energy transmitted per unitdivided by area and per unit time; cal/cmkW/m ^{2}·s (kW/m[cal/cm^2]).

3.1.9*human tissue burn tolerance*, *n—in the testing of thermal protective materials*, the amount of thermal energy predicted to cause a second-degree burn injury in human tissue.

3.1.10*s].*

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

3.1.11*inherent flame-resistance*, *n—as applied to textiles*, flame resistance that derives from an essential characteristic of the fiber from which the textile is made.

3.1.12

3.1.7 *melting*, *n*—the liquefaction of material under the influence of heat.

3.1.12.1*Discussion*—Liquid in this context indicates evidence of material flow and dripping, or both. These observations may be made after conclusion of the test exposure.

3.1.13*radiant protective performance (RPP)*—a material response evidenced by softening of the polymer.

3.1.8 *non-steady state thermal resistance*, *n—in testing of thermal protective materials*, the heat transfer characteristics of the material during the test exposure.

3.1.14*radiant protective performance (RPP) rating*, 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 amount of the exposure energy resulting in heat transfer through the test material that predicts a second-degree burn injury in human tissue; cal/cm ^{2} (kJ/m 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}).

3.1.15*].*

3.1.10 *response to heat exposure*, *n—in testing the thermal resistance of thermal protective materials* , the observable response of the textile to the energy exposure as indicated by break-open, melting, dripping, charring, embrittlement, shrinkage, sticking, and ignition.

3.1.16*second-degree burn injury*, *n*—irreversible burn damage at the epidermis/dermis interface in human tissue (Synonym–second-degree burn).

3.1.17*, 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.

3.1.18

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

3.1.19*thermal duration*, *n—in the testing of thermal protective clothing*, the total time that a material is exposed to heat energy.

3.1.20*thermal transfer threshold*, *n—in the testing of thermal protective clothing*, the point at which the heat transferred through the specimen from the thermal exposure has accumulated to the level that a burn injury is imminent.

3.1.21*thermal transfer threshold time*, *n—in the testing of thermal protective clothing*, the duration of time from the start of the exposure to the thermal transfer threshold.

3.1.22For the definitions of protective clothing terms used in this method, refer to Terminology F1494

3.1.13 For the definitions of protective clothing terms used in this method, refer to Terminology F 1494, and for other textile terms used in this method, refer to Terminology D 123.

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*) 0.5 or (*b*) 2.0 cal/cm21 kW/m^2·s (21 or 84 kW/m[0.5 cal/cm^2).

4.2The transfer of heat from the heat source through the test specimen is measured using a heat sensor. The RPP rating of the fabric is calculated from the exposure energy and the thermal transfer threshold time.

4.3The observations of the thermal response of the specimen resulting from the exposure may be noted. s] or (*b*) 84 kW/m^2[2 cal/cm^{2}s] .

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 thermo-physical 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

5.1Heat transfer is a phenomenon that is contingent upon several critical variables.

5.1.1Distance, size, and intensity of the heat source are significant in determining the exposure level and the required thermal protection. This test method specifies exposure levels of (*a*) 0.5 or (*b*) 2.0 cal/cm

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·s (21 or 84 kW/m[0.5 cal/cm^2) to cover two potential hazards.

5.1.2Air movement at the face of the specimen can affect the intensity of the exposure. Minimizing the convective air currents between the radiant source and the test specimen will aid in the repeatability of the results.

5.2This test method maintains the specimen in a static, vertical position and does not involve movement, except that resulting from the exposure.

5.3A higher radiant protective performance rating indicates a longer time to reach the thermal transfer threshold and, therefore, greater protection.

5.4This test method may be used to measure the relative performance of different materials for garments intended to provide protection from radiant energy, such as proximity fire entry suits, Method A and molten metal protective clothing, Method B.

5.5This test method is not recommended for acceptance testing of commercial shipments because its between laboratory precision has not been determined. s] and 84 kW/m^2[2.0 cal/cm^{2}s]. 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 shall consist consists of a vertically oriented radiant heat source, specimen holder assembly, protective shutter, sensor assembly, and recorder. 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*—The vertically oriented radiant heat source shall be in accordance with —A suitable, vertically oriented radiant heat source is shown in Fig. 1and shall consist of a bank of five, 500 W infrared, tubular, translucent quartz lamps having a 5.0-in. (127-mm) lighted length and a mean overall length of 8 ¾ in. (222 mm). The lamps shall be mounted on 3⁄8 ± 1⁄64-in. (9.5 ± 0.4-mm) centers so that the lamp surfaces are approximately 1⁄64-in. (0.4-mm) apart. The bank or array of lamps shall be mounted and centered behind a 2 ¼ × 5 ½-in. (63.5 × 140-mm) cut-out that is positioned in the center of a ½-in. (12.7-mm) thick, 3 3⁄8-in. (86-mm) wide, by 11-½ in. (292-mm.) long transite board as shown in . 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 [8 ¾ in.]. The lamps are mounted on 9.5 ± 0.4-mm [3⁄8 ± 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 5 ½-in.] cut-out that is positioned in the center of a 12.7-mm [½-in.] thick, 86-mm [3 3⁄8-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 having a capacity of at least 25A. A voltmeter, accurate to ± 1 V, shall be installed on the load circuit to indicate operating or load voltage to the lamps. . 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 25A.

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.

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

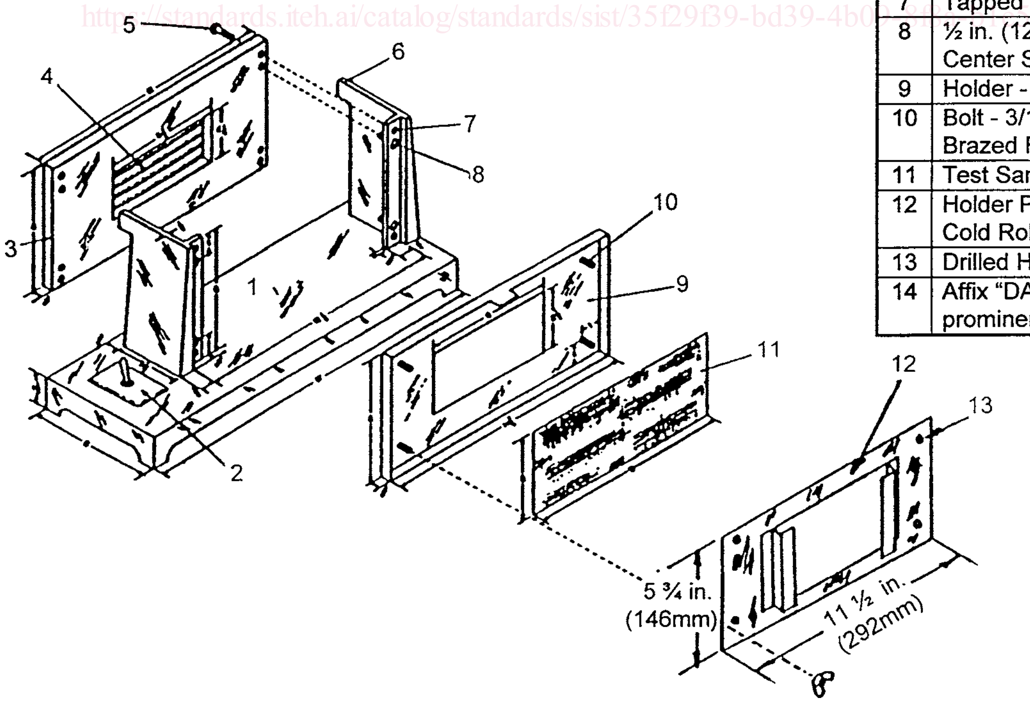

FIG. 1 General Expanded View of a Compliant Radiant Prot Reetsivstance Performance Test Apparatus (See Figures 2, 3, and 4 for specific item details.)

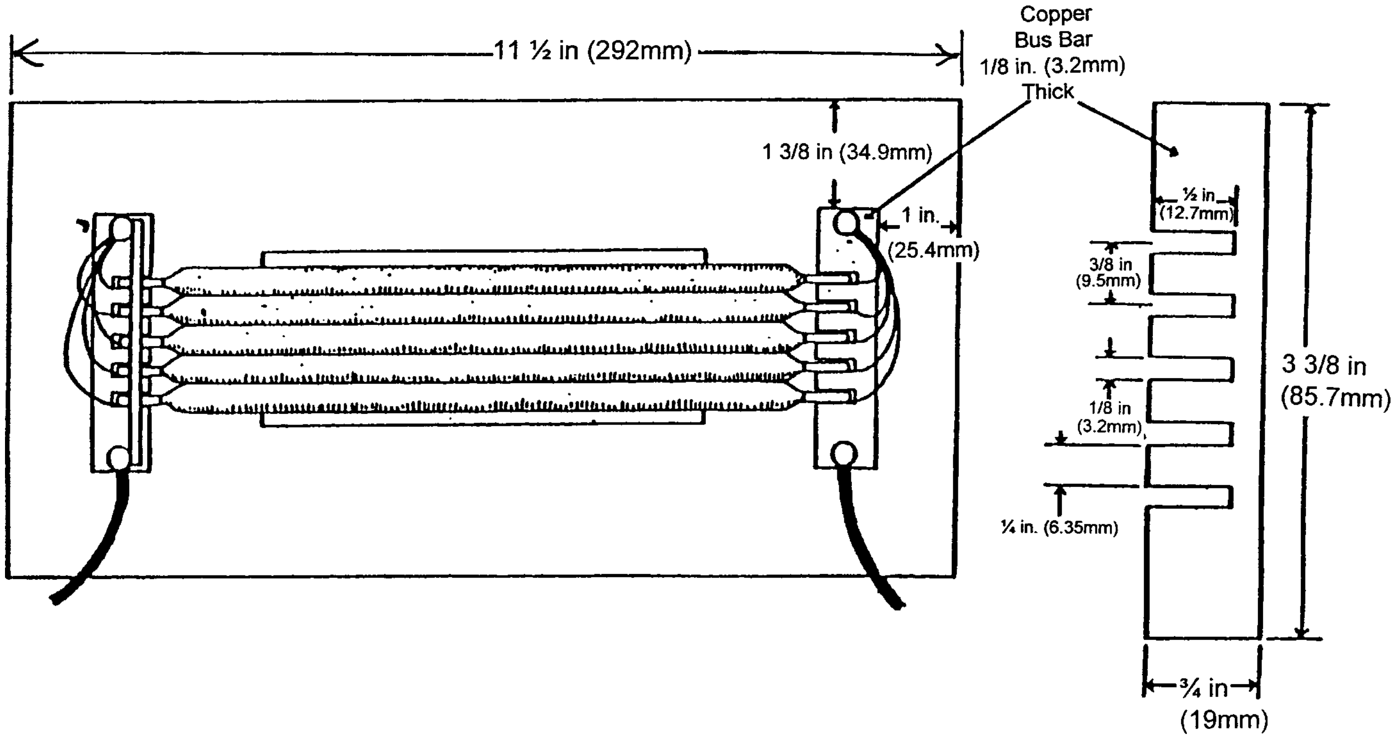

FIG. 2 Detailed View of Position of Quartz Lamps on Thermal Insiulateing Board

6.1.1.2 Any covers or guards installed on the quartz lamp assembly shall be designed such that any convective energy generated is not allowed to impinge on the sample specimen (vertical, umimpeded ventilation is required.)

NOTE ~~1—The voltage used to achieve a given level of radiant heat energy may be used to set the exposure level for calibration and monitored during the testing to ensure consistent exposure levels.~~

~~6.1.2~~ *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 2 ½ × 6-in. (64 × 152-mm) center cut-out shall be positioned so that the distance from the nearest lamp surface to the test specimen is 1.0 ± 1⁄64 in. (25.4 ± 0.4 mm). The holder plate, as shown in Fig. 3, shall include a bracket to hold the copper calorimeter sensor assembly and shall cover the complete cut-out section (see~~ —A specimen holder and holder plate with a 64 by 152-mm [2 ½ 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.~~). 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~~, shall be placed between the radiant energy source and the specimen. The protective shutter shall be capable of blocking the radiant load during the period before exposure of the specimen. The shutter may be manually or mechanically operated.~~ , 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*, a standard laboratory rheostat with a capacity of at least 25A to control the power input to the radiant tubes for use at standard current levels.~~ 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*~~—A sensor shall consist of a copper calorimeter that has the surface painted with a thin layer of flat black paint and mounted in an insulating block (see~~ —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 ~~). The calorimeter shall consist of a 1.57-in. (40-mm) diameter, 1⁄16-in. (1.6-mm) thick electrical grade copper disc, weighing 18 ± 0.1 g before thermocouples are attached, with four 30 gage iron/constantan thermocouples connected and mechanically secured, as indicated in~~ (see Test Method E 457 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, which you may attend.

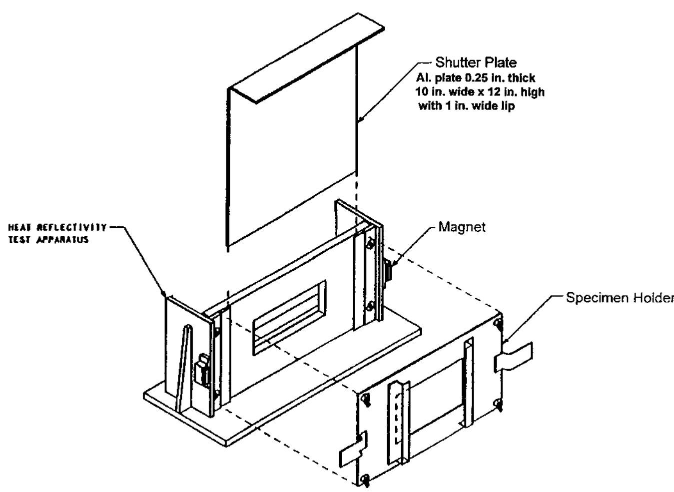

FIG. 3 MoDetailed View of a Complieant Radioant Pro Heat Reflective Performance Testi Apparatus Showing Hof Ralder with Window, Manual Shut Ptero Plate, and Spectivme Pn Holderf with Calorimeter Brancke Tests. (App magnet/tab arrangement is shown as an equipment design option to hold the specimen holder to the assembly.)