Designation: E970 − 17

An American National Standard

Standard Test Method for Critical Radiant Flux of Exposed Attic Floor Insulation Using a Radiant Heat Energy Source[1]

This standard is issued under the fixed designation E970; 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 fire-test-response standard describes a procedure for measuring the critical radiant flux of exposed attic floor insulation subjected to a flaming ignition source in a graded radiant heat energy environment in a test chamber. The specimen is any attic floor insulation. This test method is not applicable to those insulations that melt or shrink away when exposed to the radiant heat energy environment or the pilot burner.

1.2 This fire-test-response standard measures the critical radiant flux at the point at which the flame advances the farthest. It provides a basis for estimating one aspect of fire exposure behavior for exposed attic floor insulation. The imposed radiant flux simulates the thermal radiation levels likely to impinge on the floors of attics whose upper surfaces are heated by the sun through the roof or by flames from an incidental fire in the attic. This fire-test-response standard was developed to simulate an important fire exposure component of fires that develop in attics, but is not intended for use in estimating flame spread behavior of insulation installed other than on the attic floor.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.4 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this standard.

1.5 *This standard is used to measure and describe 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.*

1.6 *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.*

1.7 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.8 *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]

C167 Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations
C665 Specification for Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing
C739 Specification for Cellulosic Fiber Loose-Fill Thermal Insulation
C764 Specification for Mineral Fiber Loose-Fill Thermal Insulation
E84 Test Method for Surface Burning Characteristics of Building Materials
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
E176 Terminology of Fire Standards
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E631 Terminology of Building Constructions
E648 Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source

[1] This test method is under the jurisdiction of ASTM Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.22 on Surface Burning.

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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.

*A Summary of Changes section appears at the end of this standard

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E2653 Practice for Conducting an Interlaboratory Study to Determine Precision Estimates for a Fire Test Method with Fewer Than Six Participating Laboratories

2.2 *Federal Specifications:*

HH-I-515 Insulation Thermal (Loose Fill for Pneumatic or Poured Application), Cellulosic or Wood Fiber[3]

HH-I-521, Insulation Blankets, Thermal (Mineral Fiber, for Ambient Temperature)[3]

HH-I-1030 Insulation, Thermal (Mineral Fiber, for Pneumatic or Poured Application)[3]

3. Terminology

3.1 For definitions of terms used in this test method and associated with fire issues refer to the terminology contained in Terminology E176.

3.2 *Definitions:*

3.2.1 *attic, n*—an accessible enclosed space in a building immediately below the roof and wholly or partly within the roof framing.

3.2.2 See Terminology E631 for additional definitions of terms used in this test method.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *critical radiant flux, n*—the level of incident radiant heat energy on the attic floor insulation system at the most distant flame-out point. It is reported as W/cm^2 (or $Btu/ft^2 \cdot s$).

3.3.2 *radiant flux profile, n*—the graph relating incident radiant heat energy on the specimen plane to distance from the point of initiation of flaming ignition, that is, 0 mm.

3.3.3 *total flux metre, n*—the instrument used to measure the level of radiant heat energy incident on the specimen plane at any point.

4. Summary of Test Method

4.1 A horizontally mounted insulation specimen is exposed to the heat from an air-gas radiant heat energy panel located above and inclined at 30 ± 5° to the specimen. After a short preheat, the hottest end of the specimen is ignited with a small calibrated flame. The distance to the farthest advance of flaming is measured, converted to kilowatts per square meter from a previously prepared radiant flux profile graph, and reported as the critical radiant flux.

5. Significance and Use

5.1 This fire-test-response standard is designed to provide a basis for estimating one aspect of the fire exposure behavior to exposed insulation installed on the floors of building attics. The test environment is intended to simulate conditions that have been observed and defined in full-scale attic experiments.

5.2 The test is intended to be suitable for regulatory statutes, specification acceptance, design purposes, or development and research.

5.3 The fundamental assumption inherent in the test is that critical radiant flux is one measure of the surface burning characteristics of exposed insulation on floors or between joists of attics.

5.4 The test is applicable to attic floor insulation specimens that follow or simulate accepted installation practice.

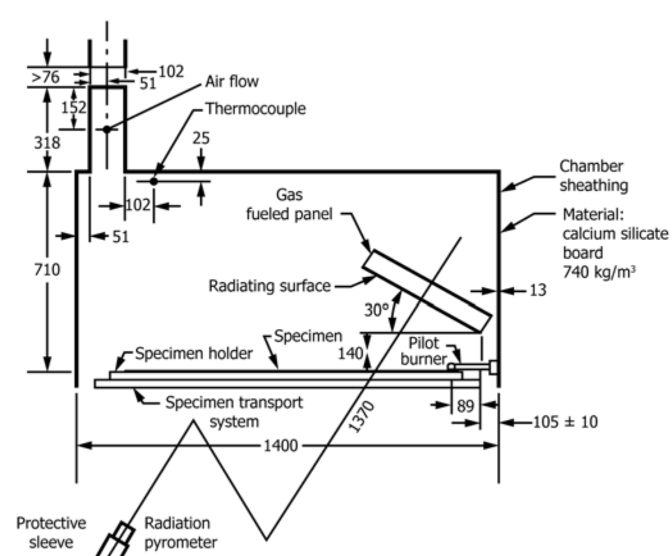
5.5 In this procedure, the specimens are subjected to one or more specific sets of laboratory fire test exposure conditions. If different test conditions are substituted or the anticipated end-use conditions are changed, caution should be used to predict changes in the performance characteristics measured by or from this test. Therefore, the results are strictly valid only for the fire test exposure conditions described in this procedure.

5.5.1 If the test results obtained by this test method are to be considered in the total assessment of fire hazard in a building structure, then all pertinent established criteria for fire hazard assessment developed by Committee E-5 must be included in the consideration.

6. Apparatus

6.1 The apparatus shall be as shown in Fig. 1, located in a draft-protected laboratory that maintains a temperature from 10.0 to 26.7°C (50 to 80°F) and a relative humidity from 30 to 70 %:

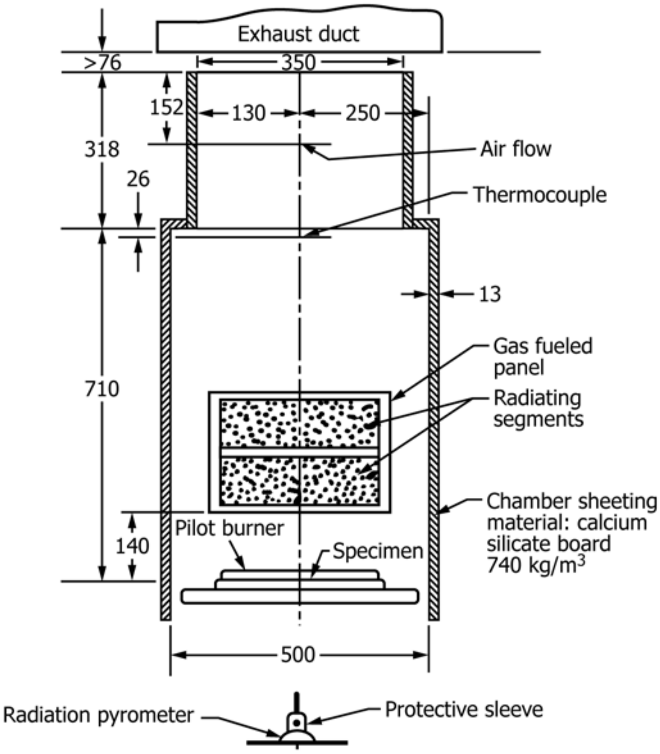
6.1.1 The radiant panel test chamber (Fig. 1 and Fig. 2) shall consist of an enclosure 1400 mm (55 in.) long by 500 mm (19½ in.) deep by 710 mm (28 in.) above the test specimen. The sides, ends, and top shall be of 13-mm (½-in.) calcium silicate, 740-kg/m^3 (46-lb/ft^3) nominal density, insulating material with a thermal conductivity at 177°C (350°F) of 0.128 W/(m·K) (0.89 Btu · in./(h·ft^2·°F)). One side shall be provided with an approximately 100 by 1100 mm (4 by 44 in.) draft-tight fire-resistant glass window so that the entire length of the test specimen is visible from outside the fire test chamber. On the same side and below the observation window is a door which, when open, allows the specimen platform to be moved out for



NOTE 1—All dimensions in millimetres. 1 in. = 25.4 mm.

FIG. 1 Flooring Radiant Tester Schematic, Side Elevation

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.



NOTE 1—All dimensions in millimetres. 1 in. = 25.4 mm.

FIG. 2 Flooring Radiant Panel Tester Schematic Low Flux End, Elevation

mounting or removal of test specimens. At the low flux end of the chamber on the 500 mm side, a draft-tight fire-resistant window is permitted for additional observations.

6.1.2 The bottom of the test chamber shall consist of a sliding steel platform which has provisions for rigidly securing the test specimen holder in fixed and level position. The free, or air access, area around the platform shall be in the range from 0.2580 to 0.3225 m^2 (400 to 500 in.^{2}).

6.1.3 When the flame front advance is to be measured, a metal scale marked with 10 mm intervals shall be installed on the back of the platform or on the back wall of the chamber.

6.1.4 The top of the chamber shall have an exhaust stack with interior dimensions of 102 ± 3 mm (4 ± 0.13 in.) wide by 380 ± 3 mm (15.00 ± 0.13 in.) deep by 318 ± 3 mm (12.50± 0.13 in.) high at the opposite end of the chamber from the radiant energy source.

6.2 *Radiant Heat Energy Source,* a panel of porous material mounted in a cast iron or steel frame, with a radiation surface of 305 by 457 mm (12 by 18 in.). It shall be capable of operating at temperatures up to 816°C (1500°F). The panel fuel system shall consist of a venturi-type aspirator for mixing gas[4] and air at approximately atmospheric pressure, a clean dry air supply capable of providing 28.3 m^3/h (1000 f^{3}t/h) at standard temperature and pressure at 76 mm (3.0 in.) of water, and suitable instrumentation for monitoring and controlling the flow of fuel to the panel.

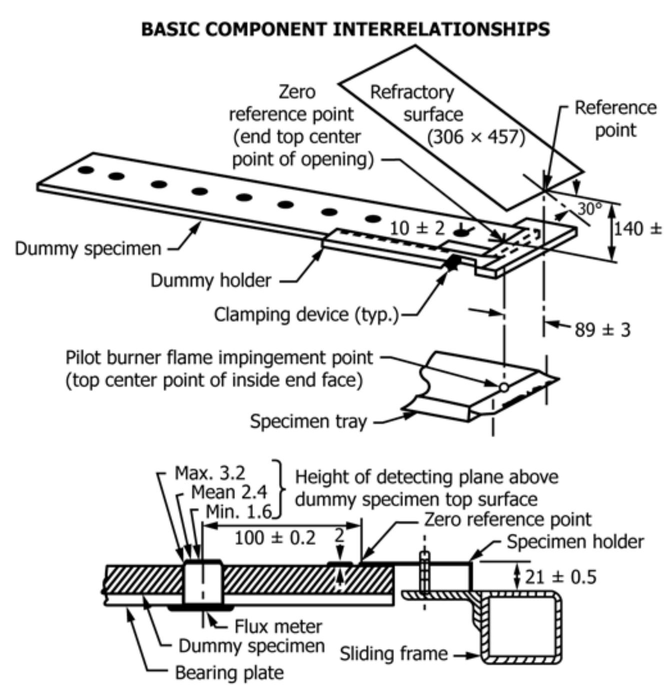
6.2.1 The radiant heat energy panel is mounted in the chamber at 30 ± 5° to the horizontal specimen plane. The radiant energy panel angle shall be adjusted to obtain the flux profile within the limits specified in accordance with 10.6. The horizontal distance from the 0 mark on the specimen fixture to the bottom edge (projected) of the radiating surface of the panel is 89 ± 3 mm (3.5 ± 0.13 in.). The panel-to-specimen vertical distance is 140 ± 3 mm (5.5 ± 0.13 in.) (Fig. 1).

6.2.2 *Radiation Pyrometer* for standardizing the thermal output of the panel, suitable for viewing a circular area 254 mm (10 in.) in diameter at a range of about 1.37 m (54 in.). It shall be calibrated over the 460 to 510°C (860 to 950°F) operating blackbody temperature range in accordance with the procedure described in Annex A1.

6.2.3 *Voltmeter,* high-impedance or potentiometric, with a suitable millivolt range shall be used to monitor the output of the radiation pyrometer described in 6.2.2.

6.3 *Dummy Specimen Holder* (Fig. 3 and Fig. 4), constructed from heat-resistant stainless steel (UNS N08330 (AISI Type 330) or equivalent) having a thickness of 1.98 mm (0.078 in.) and an overall dimension of 1140 by 320 mm (45 by 12¾ in.) with a specimen opening of 200 by 1000 mm (7.9 by 39.4 in.). Six slots shall be cut in the flange on either side of the holder to reduce warping. The holder shall be fastened to the platform with two stud bolts at each end.

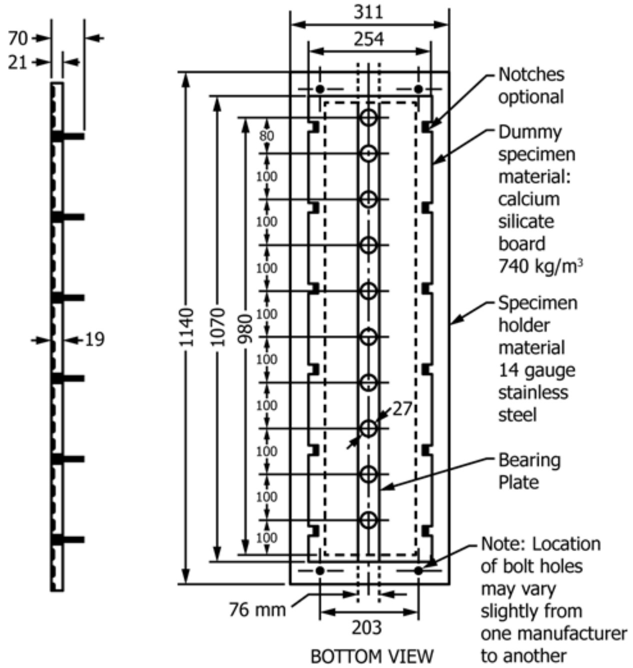
6.4 *Dummy Specimen,* used in the flux profile determination, made of 19-mm (¾-in.) inorganic 740-kg/m^3 (46-lb/ft ^{3}) nominal density calcium silicate board (Fig. 3 and Fig. 4). It is 250 mm (10 in.) wide by 1070 mm (42 in.) long with 27-mm (1¹⁄₁₆-in.) diameter holes centered on and along



NOTE 1—All dimensions in millimetres. 1 in. = 25.4 mm.

FIG. 3 Zero Reference Point Related to Detecting Plane

[4] Gas used in this test method shall be either commercial grade propane having a heating value of approximately 83.1 MJ/m^3 (2500 Btu/ft ^{3}), or natural gas, or commercial grade methane having a minimum purity of 96 %.



NOTE 1—All dimensions in millimetres. 1 in. = 25.4 mm.

FIG. 4 Dummy Specimen in Specimen Holder

the centerline at the 100, 200, 300, . . . , 900, and 980-mm locations measured from the maximum flux end of the specimen.

6.4.1 To provide proper and consistent seating of the flux meter in the hole openings, a stainless steel or galvanized steel bearing plate (Fig. 3 and Fig. 4) shall be mounted and firmly secured to the underside of the calcium silicate board with holes corresponding to those specified above. The bearing plate shall run the length of the dummy specimen board and have a width of 76 mm (3.0 in.). The thickness of the bearing plate shall be set in order to maintain the flux meter height specified in 10.5. The maximum thickness of the bearing plate shall not exceed 3 mm (⅛ in.).

6.5 *Total Heat Flux Transducer,* to determine the flux profile of the chamber in conjunction with the dummy specimen (Fig. 3), shall be of the Schmidt-Boelter[5] type, have a range from 0 to 1.5 W/cm^2 (0 to 1.32 $Btu/ft^2 \cdot s$) and shall be calibrated over the operating flux level range from 0.01 to 1.5 W/cm^2 in accordance with the procedure outlined in Annex A1. A source of 15 to 25°C cooling water shall be provided for this instrument.

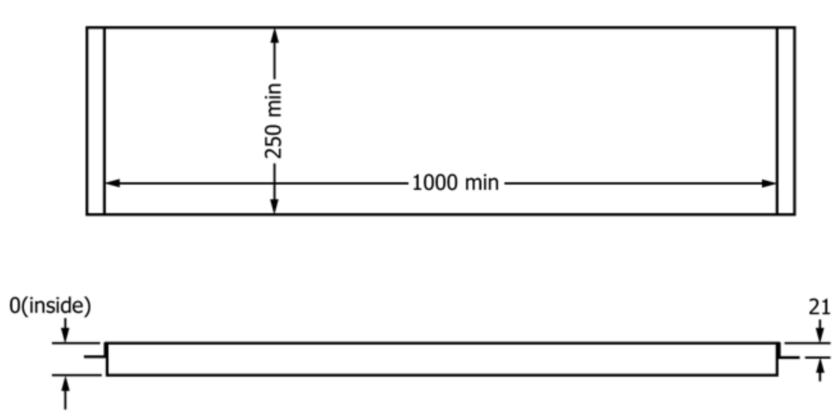
6.5.1 *Voltmeter,* high-impedance or potentiometric, with a range from 0 to 10 mV and reading to 0.01 mV shall be used to measure the output of the total heat flux transducer during the flux profile determination.

6.6 *Specimen Tray* (Fig. 5), constructed from 14-gage heat-resistant stainless steel (UNS-N08330 (AISI Type 330) or equivalent), thickness 1.98 mm (0.078 in.). The depth of the tray is 50 mm (2 in.). The flanges of the specimen tray are drilled to accommodate two stud bolts at each end; the bottom surface of the flange is 21 mm (0.83 in.) below the top edge of the specimen tray. The overall dimensions of the tray and the width of the flanges shall be such that the tray fills the open space in the sliding platform. The tray must be adequate to contain a specimen at least 1000 mm (40 in.) long and 250 mm (10 in.) wide. The zero reference point on the dummy specimen shall coincide with the pilot burner flame impingement point (Fig. 3).

6.7 *Pilot Burner,* used to ignite the specimen, is a nominal 6 mm (¼ in.) inside diameter, 10 mm (⅜ in.) outside diameter stainless steel tube line burner having 19 evenly spaced 0.7 mm (0.028 in.) diameter (No. 70 drill) holes drilled radially along the centerline and 16 evenly spaced 0.7 mm (0.028 in.) diameter (No. 70 drill) holes drilled radially 60 below the centerline (Fig. 6).

6.7.1 In operation, the gas[4] flow is adjusted to 0.85 to 0.115 m^2/h (3.0 to 4.0 SCFH) (air scale) flow rate. With the gas flow properly adjusted and the pilot burner in the test position, the pilot flame will extend from approximately 63.5 mm (2.5 in.) at the ends to approximately 127 mm (5 in.) at the center.

[5] The sole source of supply of the apparatus known to the committtee at this time is Medtherm Corp., P.O. Box 412, Huntsville, Al 35804. If you are aware of alternative suppliers, please provide this information to ASTM headquarters. Your commnents will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.



NOTE 1—All dimensions in millimetres. 1 in. = 25.4 mm.

FIG. 5 Specimen Tray

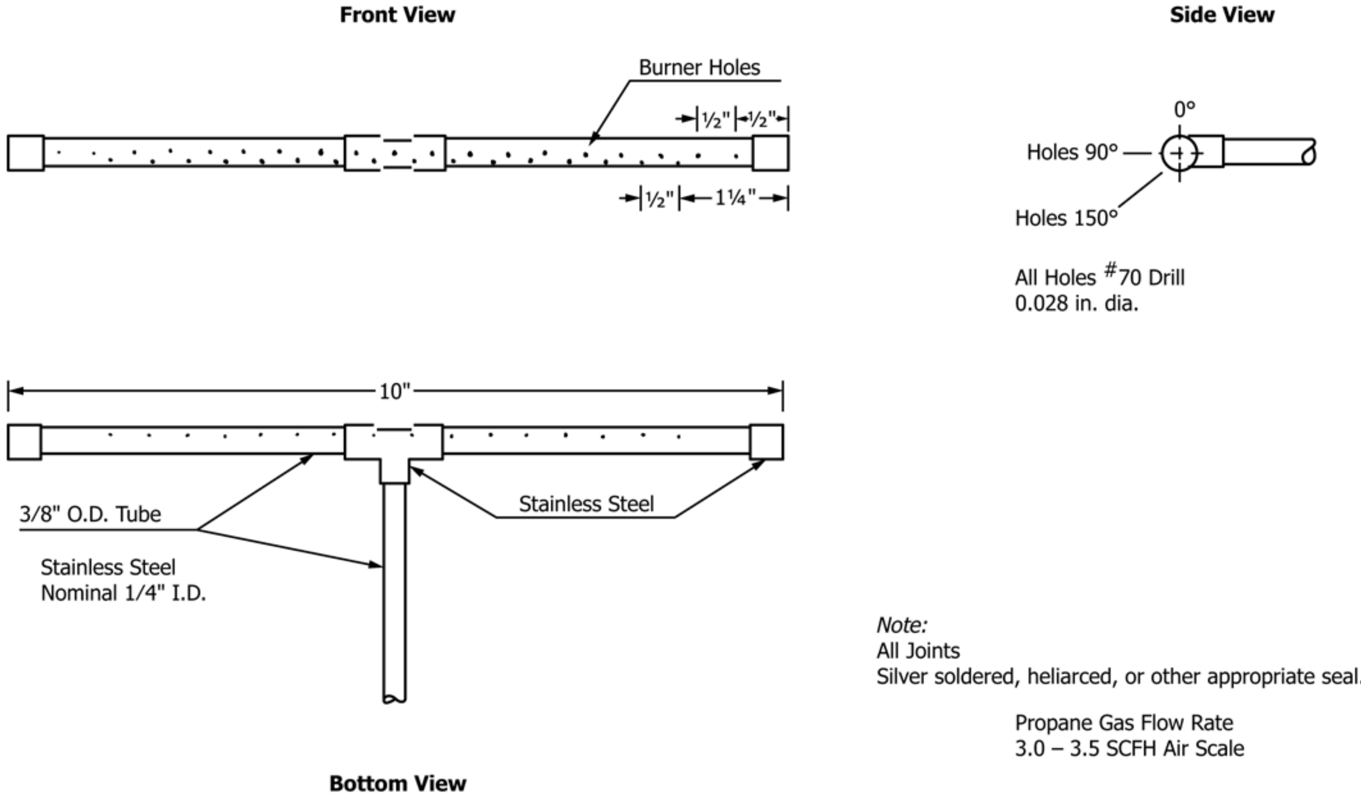


FIG. 6 Pilot Burner

6.7.2 The holes in the pilot burner shall be kept clean. One means for opening the holes in the pilot burner is to use nickel-chromium or stainless steel wire that has a diameter of 0.5 mm (0.020 in.). Surface contaminants shall be removed from the burner. One means for removing contaminants is the use of a soft wire brush.

6.7.3 The pilot burner is positioned no more than 5° from the horizontal so that the flame generated will impinge on, and reach out over the specimen from the zero distance point (see Fig. 1 and Fig. 2). The burner must have the capability of being moved at least 50 mm (2 in.) away from the specimen when not in use.

6.8 *Thermocouples*—A 3.2-mm (⅛-in.) stainless steel sheathed grounded junction Chromel-Alumel thermocouple (6.8.1) shall be located in the radiant panel test chamber (Fig. 1 and Fig. 2). The chamber thermocouple is located in the longitudinal central vertical plane of the chamber 25 mm (1 in.) down from the top and 102 mm (4 in.) back from the inside of the exhaust stack.

6.8.1 The thermocouple shall be kept clean to ensure accuracy of readout.

6.8.2 An indicating potentiometer with a range from 100 to 500°C (212 to 932°F) shall be used to determine the chamber temperature prior to a test.

6.9 *Exhaust Duct,* with a capacity of 28.3 to 85 m^3/min (1000 to 3000 ft^3/min) at standard temperature and pressure decoupled from the chamber stack by at least 76 mm (3 in.) on all sides and with an effective area of the canopy slightly larger than plane area of the chamber with the specimen platform in the OUT position, is used to remove combustion products from the chamber. With the panel turned on and the dummy specimen in place, the air flow through the stack shall be 76.2 ± 15.2 m/min. (250 ± 50 ft/min.) when measured with a calibrated hot-wire anemometer. The reading is taken about 30 s after insertion of the probe into the center of the stack opening at a distance of 152 mm (6 in.) down from the top of the stack opening (Fig. 1 and Fig. 2).

6.10 A timing device with a minimum resolution of 0.10 min shall be used to measure preheat, pilot contact, time of maximum flame travel, and when all flaming goes out.

7. Hazards

7.1 Suitable safeguards following sound engineering practices shall be installed in the panel fuel supply to guard against a gas-air explosion in the test chamber. Consideration shall be given, but not limited to the following : (*1*) a gas feed cutoff activated when the air supply fails, (*2*) a fire sensor directed at the panel surface that stops fuel flow when the panel flame goes out, and (*3*) a commercial gas water heater or gas-fired furnace pilot burner control thermostatic shut-off that is activated when the gas supply fails or other suitable and approved device. Manual reset is a requirement of any safeguard system used.

7.2 In view of the potential hazard from products of combustion, the exhaust system must be so designed and operated that the laboratory environment is protected from smoke and gas. The operator shall be instructed to mini mize his exposure to combustion products by following sound safety practice; for example, ensure that the exhaust system is working properly, wear appropriate clothing including gloves, etc.

8. Sampling

8.1 The samples selected for testing shall be representative of the product.

8.2 Standard ASTM sampling practice shall be followed where applicable; see Practice E122 for choice of sample size to estimate the average quality of a lot or process.

9. Test Specimens

9.1 The test specimen shall be attic floor insulation sized to provide for adequate filling of the specimen tray (see Fig. 5).

9.2 A minimum of three specimens per sample shall be tested.

9.3 The insulation specimen to be used for the test shall simulate actual installation practice.

9.4 The insulation specimen shall be representative of the manufacturer's recommended design density for loose-fill insulation, or the manufactured density for board and batt type insulation.

9.5 The following are specific instructions for some individual types of materials. The materials discussed under 9.5.1 through 9.5.4 represent some materials typically used with this test method. Sections 9.5.1 through 9.5.4 do not exclude other materials, which shall also be permitted to be tested in accordance with this test method.

9.5.1 *Cellulosic Fiber Loose-Fill*

9.5.1.1 The test shall be conducted at the design density per Specification C739.

9.5.1.2 If the design density is not provided by product label, determine the product design density in accordance with Section 8 procedures of Specification C739.

9.5.1.3 Determine the weight of insulation required to fill the specimen tray to achieve the design density determined above.

9.5.1.4 Specimen trays shall be prepared for testing by one of the following two methods described in 9.5.3.

9.5.2 *Mineral Fiber Loose-Fill—*

9.5.2.1 The test shall be conducted at the design density as defined in Specification C764.

9.5.2.2 If no design density is provided by the product label then the test shall be conducted at the as-blown density. The report shall indicate that the as-blown density was used for the test.

9.5.2.3 Determine the weight of insulation required to fill the specimen tray to achieve the design density determined above.

9.5.2.4 Specimen trays shall be prepared for testing by one of the following two methods described in 9.5.3.

9.5.3 *Preparing Loose-Fill Specimen Trays*

9.5.3.1 *Method A – Hand Loading*

(1) Blow the material through a commercial blower using a minimum length of 30.5 m (100 ft) length of hose, with a hose diameter as recommended per manufacturer installation requirements. Blow into a sample receiver while holding the hose horizontally at a height of 4 ft.

(2) Load the specimen tray by hand with the amount of insulation measured by weight that corresponds to the density of insulation. Gently shake the specimen to settle the insulation while loading. The top of the insulation is to be level with the top of the tray.

(3) Be careful not to compact the insulation.

9.5.3.2 *Method B*—Blowing the material into the specimen trays.

(1) Blow the material through a commercial blower using a minimum length of 30.5 m (100 ft) length of hose, with a hose diameter as recommended per manufacture installation requirements. While holding the hose horizontally at a height of 4 ft, blow the test sample into the test specimen trays.

(2) Gently shake specimen, removing excess and overblown insulation. The specimen shall then be gently screeded with a metal straight edge in one direction so that the specimen is level across the top of the tray. Take care not to compact the insulation.

(3) As an alternative to screeding, the specimen tray may be gently dropped onto a hard level surface until the specimen is level with the sides of the specimen tray. Holding the specimen tray at a height of 1 in., drop the tray. Repeat as needed.

(4) Surface irregularities shall not exceed 4.8 mm (3⁄16 in.). Additional material may be added to fill any voids or valleys around the periphery of the specimen tray.

(5) Weigh each of the specimen trays to validate that the material is at design density.

9.5.4 *Insulation Batts or Boards*

9.5.4.1 Cut the batts or boards to a thickness of 50 mm (2 in.) and cut to fit into the specimen tray.

9.5.4.2 The test density for the batt or board specimens shall be determined in accordance with Section 8 of Test Method C167 prior to the test.

10. Radiant Heat Energy Flux Profile Standardization

10.1 In a continuing program of tests, the flux profile shall be determined not less than once a week. Where the time interval between tests is greater than one week, the flux profile shall be determined at the start of the test series.

10.2 Mount the dummy specimen in the mounting frame, and attach the assembly to the sliding platform.

10.3 With the sliding platform out of the chamber, turn on the exhaust, and ignite the radiant panel. Allow the unit to heat for 1.5 h. The pilot burner is off during this determination. Adjust the fuel mixture to give an air-rich flame. Make fuel flow settings to bring the panel blackbody temperature to 485 ± 25°C (839 ± 45°F) and record the chamber temperature. After the panel blackbody temperature has stabilized, move the specimen platform into the chamber and close the door.

10.4 Allow 0.5 h for the closed chamber to equilibrate.

10.5 Measure the radiant heat energy flux level at the 400-mm point with the total flux meter instrumentation. This is done by inserting the flux meter in the opening so that its detecting plane is 1.6 to 3.2 mm (1⁄16 to 1⁄8 in.) above and parallel to the plane of the dummy specimen and reading its output after 30 ± 10 s. If the level is within the limits specified in 10.6, start the flux profile determination. If it is not, adjust the panel fuel flow as required to bring the level within the limits specified in 10.6. A suggested flux profile data log format is shown in Fig. 7.

10.6 Run the test under chamber operating conditions that give a flux profile as shown in Fig. 8. The radiant heat energy incident on the dummy specimen shall be between 0.87 to 0.95 W/cm^2 (0.77 and 0.83 Btu/ft^2·s) at the 200-mm point, between 0.48 to 0.52 W/cm^2 (0.42 and 0.46 Btu/ft^2·s) at the 400-mm point, and between 0.22 to 0.26 W/cm^2 (0.19 and 0.23 Btu/ft^2·s) at the 600-mm point.

10.7 Insert the flux meter in the 100-mm opening following the procedure given in 10.5. Read the millivolt output at 30± 10 s and proceed to the 200-mm point. Repeat the 100-mm procedure. Determine the 300 to 980-mm flux levels in the same manner. Following the 980-mm measurement, make a check reading at 400-mm. If this is within the limits set forth in 10.6, the test chamber is in calibration, and the profile determination is completed. If not, adjust fuel flow, allow 0.5 h for equilibrium, and repeat the procedure.

10.8 Plot the radiant heat energy flux data as a function of distance along the specimen plane on rectangular coordinate graph paper. Draw a smooth curve through the data points. This curve will hereafter be referred to as the flux profile curve.

10.9 Determine the open chamber temperature and radiant panel blackbody temperature identified with the standard flux profile by opening the door and moving the specimen platform out. Allow 0.5 h for the chamber to equilibrate. Read and record, in degrees Celsius, the chamber temperature and the optical pyrometer output that gives the panel blackbody temperature. These temperature settings shall be used in subsequent test work instead of measuring the dummy specimen radiant flux at 200, 400, and 600 mm.

11. Conditioning

11.1 Condition test specimens to equilibrium or a minimum of 48 h, whichever is greater, at 21 ± 3°C (69.8 ± 5.4°F) and a relative humidity of 50 ± 5 % immediately prior to testing. A less than 1 % change in net weight of the specimen in two consecutive weighings with 2 h between each weighing constitutes equilibrium. The maximum cumulative time between removing a sample from the conditioning environment (21 ± 3°C, 50 ± 5 % relative humidity) and inserting it into the radiant chamber shall not exceed 10 min.

12. Procedure

12.1 With the sliding platform out of the chamber, turn on the exhaust fan, and ignite the radiant panel. Allow the unit to heat for 1.5 h (Note 1). Read the panel blackbody temperature and the chamber temperature. If these temperatures are in agreement to within ± 5°C (41°F) with those determined in accordance with 10.9, the chamber is ready for use.

NOTE 1—It is recommended that a sheet of calcium silicate board, be used to cover the opening when the hinged portion of the front panel is open and the specimen platform is moved out of the chamber. The mill-board is used to prevent heating of the specimen and to protect the operator.

12.2 Mount the specimen tray containing the specimen on the sliding platform.

12.3 Position the pilot burner at least 50 mm (2 in.) away from the specimen.

12.4 Ignite the pilot burner.

12.5 Move the specimen into the chamber, close the door, and start the timer.

12.6 After a 2 min ± 5 s preheat period, bring the pilot burner flame into contact with the specimen at the 0 mm mark, while the pilot burner remains on.

12.7 Time of flame front starts when the pilot burner is applied.

12.8 Leave the pilot burner flame in contact with the specimen for 2 min, then remove to a position at least 50 mm (2 in.) away from the specimen and extinguish the pilot burner flame.

12.9 If the specimen ignites before the end of the 2 min preheat period, time of flame front starts upon auto ignition.

Radiant Flux Profile

Date ______
Blackbody Temperature ______ mV. ______ °C (°F)
Gas Flow ______ NTP m^3/h (SCFH) Air Flow ______ NTP m^3/h (SCFH)
Room Temperature ______ °C (°F)
Air Pressure ______ Gas ______ mm (in.) of H_2O
Flux Meter Conversion Factor ______
Radiometer No. ______ from Calibration on ______

Distance, mm	mV	W/cm^2
100	______	______
200	______	______
300	______	______
400	______	______
500	______	______
600	______	______
700	______	______
800	______	______
900	______	______
980	______	______

Signed ____________

FIG. 7 Flux Profile Data Log Format

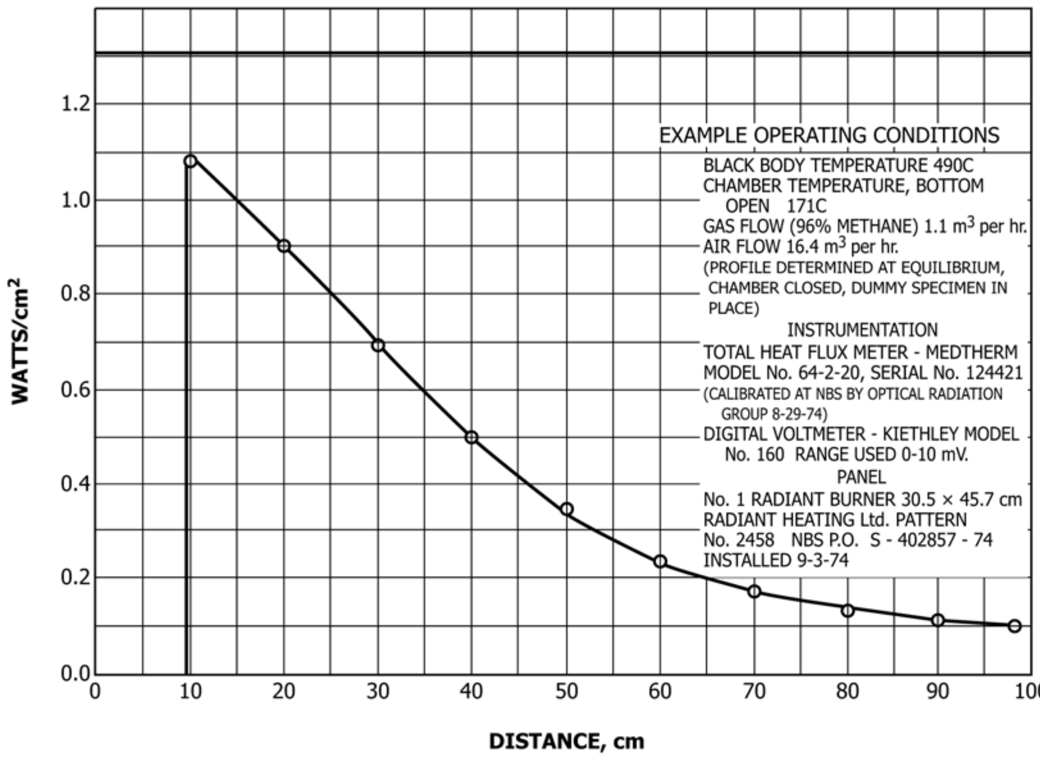


FIG. 8 Standard Radiant Heat Energy Flux Profile

Record the time to ignition but continue with the full preheat period. Then follow the procedure as described in 12.8.

12.10 If the specimen does not ignite within 2 min following pilot burner flame application, terminate the test. For specimens that do ignite, continue the test until all specimen flaming goes out.

12.11 When the test is completed, open the door and pull out the specimen platform.

12.12 Measure the distance burned, that is, the point of farthest advance of the flame front, to the nearest 1 mm. From the flux profile curve, convert the distance to kilowatts per square metre critical radiant heat flux. Read to two significant figures. A suggested data log format is shown in Fig. 9.

12.13 If the flame front does not exceed 10 cm, record the critical radiant flux as greater than 1.0 W/cm^2.

Test Number ______ Date ______ Time ______
Laboratory __________
Specimen Identification/Code No. ____________________

Test Assembly: ____________________

Panel Angle ______° Temperature __________°C (°F)
Flow: Gas ______ NTP m^3/h (SCFH) Air ______ NTP m^3/h (SCFH)
Pressure, mm (in.) H_2O: Initial, Air, __________ Gas ______;
Chamber: Temperature Initial _________ Maximum _________°C (°F)
Room: Temperature _________°C (°F) Hood Draft _________ mm (in.) water

Flame Front Advance

Distance, mm (in.)	Time, min						
___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______

Total Burn Length _________ mm (in.) Critical Radiant Flux, W/cm^2 _________
Flame Front Out _________ min Flux Profile Reference _________
All Flame Out _________ min

Signed ____________________

FIG. 9 Radiant Panel Test Data Log Format

12.14 If the critical radiant flux is lower than 0.12 W/cm^2, record the critical radiant flux as less than 0.12 W/cm^2.

12.15 Remove the specimen and its mounting frame from the movable platform.

12.16 Before each test, verify that the blackbody temperature and chamber temperature meet the requirements of Section 12.1.

13. Calculation

13.1 Calculate the mean, standard deviation, and coefficient of variation of the critical radiant flux test data on the three specimens in accordance with standard practice (**1**).[6]

$$s = \sqrt{\left(\sum X^2 - n\bar{X}^2\right)/n - 1} \text{ and } v = s/X \times 100 \quad (1)$$

where:

s = estimated standard deviation,
X = value of single observation,
n = number of observations,
$\bar{X}$ = arithmetic mean of the set of observations, and
v = coefficient of variation.

14. Report

14.1 Report the following information:

14.1.1 Description of the attic floor insulation tested,

14.1.2 Description of the procedure used to prepare the insulation specimen,

14.1.3 Density and critical radiant flux of each of the specimens tested, and

14.1.4 Average critical radiant flux, standard deviation, and coefficient of variation.

14.1.5 If the specimen prematurely ignites during the 2 min preheat period, report the time of ignition.

15. Precision and Bias

15.1 The precision estimate for this test method is based on an interlaboratory study of Test Method E970, conducted in 2005. Three laboratories analyzed four different materials under a number of test conditions by using different ways to load the samples. Every test result represents an individual determination. Each laboratory reported three replicate results for each material/condition combination in order to estimate the repeatability and reproducibility limits of the standard. Practice E2653 (Note 2) was used for the study design, and the statistical data calculations since only three laboratories were able to perform the test.[7]

NOTE 2—The study design for the round robin is identical in both Practice E2653 and Practice E691. The Precision and Bias in this standard was done per the calculation equations in Practice E2653, which are different from the calculation equations used in Practice E691.

15.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the " *r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

15.1.1.1 Repeatability limits are listed in Table 1.

15.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

15.1.2.1 Estimates of the Reproducibility limits are listed in Table 2.

15.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

15.1.4 Any judgment in accordance with statements 15.1.1 and 15.1.2 would normally have an approximate 95 % probability of being correct, however the estimated precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and laboratories reporting results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. Consider the repeatability limit and the reproducibility limit as general guides, and the associated probability of 95 % as only a rough indicator of what can be expected.

15.2 For replication of each sample material, test specimens were prepared using the three following specimen loading procedures:

(1) Using a loose-fill blowing machine to mix the test sample, each test pan blown to a set density as follows: Samples A and B to 1.6 lb/ft^3; Sample C to 1.4 lb/ft^3; Sample D to 0.71 lb/ft^3.

TABLE 1 Within-Laboratory (Repeatability) Precision Data[A]

Material	Parameter—Critical Radiant Flux[A]	
	Mean Value	Repeatability Standard Deviation, S_r
Blown to Density of:		
Cellulose A – 1.6 lb/ft^3	0.23	0.01
Cellulose B– 1.6 lb/ft^3	0.23	0.01
Cellulose C – 1.4 lb/ft^3	0.30	0.02
Fiberglass – 0.71 lb/ft^3 [B]	>1.00	NA
Blown to Weight, density range of:		
Cellulose A – 1.29 to 1.54 lb/ft^3	0.20	0.02
Cellulose B – 1.25 to 1.44 lb/ft^3	0.21	0.03
Cellulose C – 1.24 to 1.44 lb/ft^3	0.28	0.03
Fiberglass – 0.71 lb/ft^3 [B]	>1.00	NA
Hand Loaded to Density of:		
Cellulose A – 1.6 lb/ft^3	0.23	0.02
Cellulose B– 1.6 lb/ft^3	0.23	0.01
Cellulose C – 1.4 lb/ft^3	0.27	0.03
Fiberglass – 0.71 lb/ft^3 [B]	>1.00	NA

[A] Average of laboratories' calculated averages.
[B] For all tests conducted on Fiberglass Loose-Fill Insulation, no test specimen's flame front reached the 10 cm mark, the highest recorded flux level reading of 1.00 W/cm^2. Since results exceed highest recorded test readings, data can not be used in a statistical analysis. For testing, results are recorded as >1.0 W/cm^2.

[6] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: E05-1012.

TABLE 2 Between-Laboratory (Reproducibility) Precision Data

Material	Parameter—Critical Radiant Flux[A]	
	Mean Value	Repeatability Standard Deviation, S_R
Blown to Density of:		
Cellulose A – 1.6 lb/ft^3	0.23	0.03
Cellulose B– 1.6 lb/ft^3	0.23	0.02
Cellulose C – 1.4 lb/ft^3	0.30	0.06
Fiberglass – 0.71 lb/ft^3 [B]	>1.00	NA
Blown to Weight, density range of:		
Cellulose A – 1.29 to 1.54 lb/ft^3	0.20	0.03
Cellulose B – 1.25 to 1.44 lb/ft^3	0.21	0.03
Cellulose C – 1.24 to 1.44 lb/ft^3	0.28	0.08
Fiberglass – 0.71 lb/ft^3 [B]	>1.00	NA
Hand Loaded to Density of:		
Cellulose A – 1.6 lb/ft^3	0.23	0.03
Cellulose B– 1.6 lb/ft^3	0.23	0.01
Cellulose C – 1.4 lb/ft^3	0.27	0.03
Fiberglass – 0.71 lb/ft^3 [B]	>1.00	NA

[A] Average of laboratories' calculated averages.

[B] For all tests conducted on Fiberglass Loose-Fill Insulation, no test specimen's flame front reached the 10 cm mark, the highest recorded flux level reading of 1.00 W/cm^2. Since results exceed highest recorded test readings, data can not be used in a statistical analysis. For testing, results are recorded as >1.0 W/cm^2.

(2) Using a loose-fill blowing machine to mix the test sample, each test pan was blown, then leveled off to the top of the pan as specified in 9.5.3.1(2). Each test pan was then weighted to determine the density.

(3) After using a loose-fill blowing machine to mix the test sample, each test pan was hand loaded to a set density as follows: Samples A and B to 1.6 lb/ft^3; Sample C to 1.4 lb/ft^3; Sample D to 0.71 lb/ft^3.

15.2.1 Target densities used in the testing for Blown Density (15.2 *(1)*), and Hand Loaded (15.2 *(3)*) were provided by the manufacturers or the trade associations. Cellulose samples A, B and C represent three different chemical formulations provided by two manufacturers.

15.3 *Bias*—At the time of this study, an accepted reference material specimen suitable for determining the test method bias was was not available. Therefore, no statement on bias has been provided.

15.4 The precision statement was determined through statistical examination of 99 results submitted by three laboratories, running one analysis, under varying conditions, on up to four different materials. These four materials were described as the following:

Material A: Cellulose, density 1.6 pcf
Material B: Cellulose, density 1.6 pcf
Material C: Cellulose, density 1.4 pcf
Material D: Fiberglass Loose-Fill, density 0.71 pcf

15.5 To judge the equivalency of two test results, it is recommended that the test method user choose the above material with statistics closest to the characteristics of the test material being evaluated.

16. Keywords

16.1 attic floor insulation; cellulosic fiber insulation; critical radiant flux; fire; loose fill insulation; mineral fiber insulation; radiant panel

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR CALIBRATION OF RADIATION INSTRUMENTATION

A1.1 Radiation Pyrometer

A1.1.1 Calibrate the radiation pyrometer by means of a conventional blackbody enclosure placed within a furnace and maintained at uniform temperatures of 460, 470, 480, 490, 500, and 510°C (860, 878, 896, 914, 932, and 950°F). The blackbody enclosure may consist of a closed Chromel metal cylinder with a small sight hole in one end. Sight the radiation pyrometer upon the opposite end of the cylinder where a thermocouple indicates the blackbody temperature. Place the thermocouple within a drilled hole and in good thermal contact with the blackbody. When the blackbody enclosure has reached the appropriate temperature equilibrium, read the output of the radiation pyrometer. Repeat for each temperature.

A1.1.2 An acceptable alternative to the procedure described in A1.1.1 is the use of an outside agency to provide calibration traceable to the National Institute of Standards and Technology (NIST).

A1.2 Total Heat Flux Meter

A1.2.1 The total flux meter calibration shall be developed by transfer calibration methods with an NIST-calibrated flux meter. This latter calibration shall make use of the radiant panel tester as the heat source. Measurements shall be made at each of the ten dummy specimen positions, and the mean value of these results shall constitute the final calibration.

A1.2.2 Each laboratory shall maintain a dedicated calibrated reference flux meter against which one or more working flux meters shall be compared as needed. The working flux meters shall be calibrated at least once per year.

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY OF CRITICAL RADIANT FLUX TEST FOR EXPOSED ATTIC FLOOR INSULATION

X1.1 When consideration was being given in 1977 to revision of General Services Administration (GSA) Fed. Specs. HH-I-515C, for cellulose loose-fill insulation, HH-I-521E, for insulation blankets, and HH-I-1030A, for mineral fiber loose-fill insulation, three questions were asked about the flammability requirements: (*1*) Were the existing test methods representative of configurations and exposures likely to be found in actual use?; (*2*) If not, what test methods should be introduced in their place?; and (*3*) What would be reasonable levels of acceptance in terms of fire safety of occupants? The basic premise assumed was that the addition of insulation should not increase the normal and expected level of fire risk to the occupants of typical single family dwellings. It is important to remember that the concern here is whether the insulation is the first item to ignite or is it the cause for flame spread, and not whether it becomes involved in the later stages of a fire.

X1.2 In the insulation market, in particular for residential occupancies, insulation has two major applications: (*1*) on the floors of attics in an exposed condition and (*2*) in exterior side walls. It was believed that the attic floor application was more critical because it presented an extended exposed surface and this problem should be addressed first. Past examination of the fire test methods in the Federal specifications at first suggested that Test Method E84 may be inappropriate for testing insulation installed on the floor of an attic. Loose-fill insulation is not normally installed over a metal screen nor is it likely to be exposed to flames from below.

X1.3 Attic floor insulation (loose-fill or batting) is typically applied between and over floor joist in an attic where the air is relatively still and where the temperature and humidity vary depending upon the season, the geographical location, the geometrical arrangements, the extent of free or forced attic ventilation, etc. The most severe exposure is likely to develop during periods of elevated outdoor temperatures and high solar radiation. Typical small ignition sources would be an electrical failure causing an arc or a carelessly applied propane torch.

X1.4 This scenario, insulation on the floor of an attic in still air exposed to radiation from the roof and subjected to a small ignition source, is modeled by the conditions of Test Method E648. This standard originally was developed for evaluating floor covering systems in corridors exposed to radiation from fully developed fires in rooms. The test method involves a graded radiant exposure varying from 0.1 to 1.1 W/cm^2, which corresponds approximately to differences between direct summer solar radiation and the irradiance on the floor from a preflashover fire on the ceiling. The Flooring Radiant Panel Test was adapted to accommodate insulation specimens and introduced into the GSA HH-I-515D standard as the Attic Floor Radiant Panel Test. The material under evaluation in the test is exposed to a graded irradiance and ignited with a pilot burner at the high flux end of the specimen. The flux at the farthest point where the flame extinguishes is defined as the critical radiant flux.

X1.5 Measurements were made in the attic of a private home in the Washington, DC, area during July of 1977 to define approximate attic temperatures. Daytime temperatures of 60°C were measured. A temperature of 71°C is used as a design value for attic fans by the American Ventilation Association **(2).** This temperature would correspond to the underside of the roof acting as a black body radiator imposing a flux level of 0.08 W/cm^2 onto the insulation. A50 % safety factor would bring the flux level to 0.12 W/cm^2. For comparison purposes, the solar radiation reaching the surface normal to the sun's rays on a clear summer day in Florida is 0.11 W/cm^2.

X1.6 The selected radiant flux exposure covers the range of anticipated thermal radiation levels in conventional attic spaces. The lower level (0.1 W/cm^2) corresponds approximately to that resulting from direct solar radiation. The upper level (1.1 W/cm^2) includes that which may be anticipated from an incidental fire or an overheated appliance or device. The critical radiant flux measurement is an indication of the level of external radiant heat below which surface flame propagation, in the presence of a pilot flame, would not be expected.

X1.7 In a report by Gross **(3)** there is a description of large-scale attic mock-up experiments in which several cellulosic and glass fiber products were exposed to temperatures of 71 and 82°C. These experiments supported the use of the attic floor radiant panel test and the criterion chosen for recommendation to GSA. A second series of large-scale attic fire experiments was subsequently conducted at the National Bureau of Standards **(4).** These experiments showed that materials with critical radiant flux values greater than the surface heat flux generated in the simulated summer attic conditions did not propagate flame away from a small torch ignition source. Ignition sources larger than the torch flames could raise the air temperature in the attic and the heat flux to the floor of the attic to values above those found in these experiments. Attic fire experiments carried out at Underwriters Laboratories **(5,6)**also demonstrated that, for materials having critical radiant flux values greater than 0.12 W/cm^2, flames did not propagate more than 133 mm (5.25 in.) when exposed to an open flame. On the other hand, for materials having values below 0.12 W/cm^2, flame propagation of greater than 762 mm (30 in.) was observed in at least 50 % of the experiments—on the conservative or safe side. Other attic construction methods would also influence test conditions. Flame spread over the exposed insulation surface would only be expected in cases where the incident surface heat flux exceeds the critical radiant flux of the insulation material as measured in the attic floor radiant panel test.

X1.8 As part of the development of the flammability test methods for HH-I-515D, an interlaboratory program was conducted to evaluate the repeatability and reproducibility of the methods for cellulose insulation. Details of this study are described by Lawson (**7**)**.** The results for the critical radiant flux determination showed that the pooled coefficient of variation for repeatability (within laboratory) was 12 % and the average coefficient of variation for reproducibility (between laboratory) was 25 %. These values were not significantly greater for loose-fill cellulose insulation than for other materials and compare favorably with precision estimates available from other standard fire tests. Until the adoption of the line burner in 1994, this study was the basis for the precision and bias statement. The following sections (X1.8.1 to X1.8.4) represent the precision and bias statement at that time using the small torch tip ignition burner.

X1.8.1 Defining test results as the average of three replicate determinations, the repeatability (within laboratory variability) is about 12 % of the measured value and the reproducibility (between laboratory variability) is of the order of 21 % of measured value.

X1.8.2 This statement is based on the results of one, nine-laboratory factorially designed experiment in which a total of seven cellulosic loose-fill insulations were tested.

X1.8.3 *Repeatability* is a quantity that will be exceeded only about 5 % of the time by the difference, taken in absolute value, of two randomly selected results obtained in the same laboratory on a given material (**8**).

X1.8.4 *Reproducibility* is a quantity that will be exceeded only about 5 % of the time by the difference, taken in absolute value, of two single test results made on the same material in two different randomly selected laboratories (**8**).

X1.9 The test procedure has been shown to be applicable to all insulation used on attic floors. However, certain limitations of this test are:

X1.9.1 The test does not provide an indication of the tendency of the insulation to smolder.

X1.9.2 The test does not provide information on the rate of the surface flame spread under constant heat flux exposure conditions.

X1.9.3 The test is not applicable to those insulations which melt or shrink away when exposed to the radiant heat environment or the pilot burner.

X1.9.4 The test results may not be applicable where appreciable air movement due to forced ventilation or wind is present.

X1.9.5 Current ASTM specifications that list Test Method E970 are Specifications C665, C739, and C764.

X1.10 Historic Photograph

X1.10.1 Fig. X1.1 is a photograph of typical radiant panel flame test equipment, circa mid- 1970s, and is shown for historic reference only. The appearance of the apparatus currently manufactured will, in most cases, differ from the photograph.

FIG. X1.1 Historic Photograph of Radiant Test Panel Chamber

REFERENCES

(1) *Manual on Quality Control of Materials,ASTM STP ISC*, ASTM, 1951.

(2) *The Handbook of Moving Air*, American Ventilation Association, Houston, TX, 1977.

(3) Gross, D., "A Preliminary Study of the Fire Safety of Thermal Insulation for Use in Attics or Enclosed Spaces in Residential Housing," *NBSIR 78-1497*, National Bureau of Standards, June 1978.

(4) Evans, D. D., and Davis, S., "Technical Support for the Consumer Product Safety Commission 1979 Interim Standards for Cellulose Insulation, *NBSIR 81-2213*, National Bureau of Standards," March 1981.

(5) Kleinfelder, W. A., "Investigation of the Fire Performance of Building Insulation in Full-Scale and Laboratory Fire Test," *ORNL/SUB/79-7863/1* , Oak Ridge National Laboratory, April 1984.

(6) Metes, W. S., and Kleinfelder, W. A., "Flammability of Thermal Insulation Materials in Laboratory Tests and a Simulated Attic," *Subject 861*, Underwriters Laboratories, Inc., March 1979.

(7) Lawson, J. R., "Interlaboratory Evaluation of the Attic Floor Radiant Panel Test and Smoldering Combustion Test for Cellulose Thermal Insulation," *NBSIR 79-1588*, National Bureau of Standards, February 1979.

(8) Mandel, J., "Repeatability and Reproducibility," *Materials Research and Standards*, Vol 11, No. 8, p. 8.

SUMMARY OF CHANGES

Committee E05 has identified the location of selected changes to this standard since the last issue (E970-14) that may impact the use of this standard.

(1) Units were changed from kW/m^2 to W/cm^2 for consistency throughout the standard.

(2) In X1.9.5, Specification C739 was added to those specifications that list Test Method E970.