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Designation: E 648 – 00

An American National Standard

Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source[1]

This standard is issued under the fixed designation E 648; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This fire-test-response standard covers a procedure for measuring the critical radiant flux of horizontally mounted floor-covering systems exposed to a flaming ignition source in a graded radiant heat energy environment in a test chamber. A specimen is mounted over underlayment, a simulated concrete structural floor, bonded to a simulated structural floor, or otherwise mounted in a typical and representative way.

1.2 This fire-test-response standard measures the critical radiant flux at flame-out. It provides a basis for estimating one aspect of fire exposure behavior for floor-covering systems. The imposed radiant flux simulates the thermal radiation levels likely to impinge on the floors of a building whose upper surfaces are heated by flames or hot gases, or both, from a fully developed fire in an adjacent room or compartment. The standard was developed to simulate an important fire exposure component of fires that develop in corridors or exitways of buildings and is not intended for routine use in estimating flame spread behavior of floor covering in building areas other than corridors or exitways. See Appendix X1 for information on proper application and interpretation of experimental results from use of this test.

1.3 The values stated in SI units are to be regarded as the 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 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.* Specific hazard statements are given in Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[2]

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials[3]

E 176 Terminology of Fire Standards[4]

3. Terminology

3.1 *Definitions*—See Terminology E 176 for additional definitions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *blackbody temperature*, *n*—the temperature of a perfect radiator—a surface with an emissivity of unity and, therefore, a reflectivity of zero.

3.2.2 *corridor*, *n*—an enclosed space connecting a room or compartment with an exit. The corridor includes normal extensions, such as lobbies and other enlarged spaces, where present.

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

3.2.4 *flame-out*, *n*—the time at which the last vestige of flame or glow disappears from the surface of the test specimen, frequently accompanied by a final puff of smoke; Time 0 is the time at which the specimen is moved into the chamber and the door closed. (See 12.3.)

3.2.5 *floor covering*, *n*—an essentially planar material having a relatively small thickness in comparison to its length or width, which is laid on a floor to enhance the beauty, comfort, and utility of the floor.

3.2.6 *floor covering system*, *n*—a single material, composite or assembly comprised of the floor covering and related installation components (adhesive, cushion, etc.), if any.

[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] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 15.09.

[4] *Annual Book of ASTM Standards*, Vol 04.07.

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

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

critical radiant flux is one measure of the sensitivity to flame spread of floor-covering systems in a building corridor.

5.4 The test is applicable to floor-covering system specimens that follow or simulate accepted installation practice. Tests on the individual elements of a floor system are of limited value and not valid for evaluation of the flooring system.

FIG. 1 Flooring Radiant Panel Tester Apparatus

4. Summary of Test Method

4.1 The basic elements of the test chamber, Fig. 1, are (*1*) an air-gas fueled radiant heat energy panel inclined at 30° to and directed at (*2*) a horizontally mounted floor covering system specimen, Fig. 2. The radiant panel generates a radiant energy flux distribution ranging along the 100-cm length of the test specimen from a nominal maximum of 1.0 W/cm^2 to a minimum of 0.1 W/cm^2. The test is initiated by open-flame ignition from a pilot burner. The distance burned to flame-out is converted to watts per square centimetre from the flux profile graph, Fig. 3, and reported as critical radiant flux, W/cm^2.

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 of a floor-covering system installed in a building corridor. The test environment is intended to simulate conditions that have been observed and defined in full scale corridor 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

NOTE 1—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, it may not be possible by or from this test to predict changes in the performance characteristics measured. Therefore, the results are strictly valid only for the fire test exposure conditions described in this procedure.

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

6. Flooring Radiant Panel Test Chamber—Construction and Instrumentation

6.1 The flooring radiant panel test chamber employed for this test shall be located in a draft-protected laboratory.

6.1.1 The flooring radiant panel test chamber, Fig. 4 and Fig. 5, shall consist of an enclosure 1400 mm (55 in.) long by 500 mm (19½in.) deep by 710 mm (28 in.) above the test specimen. The sides, ends, and top shall be of 13-mm (½-in.) calcium silicate, 0.74 g/cm^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.)

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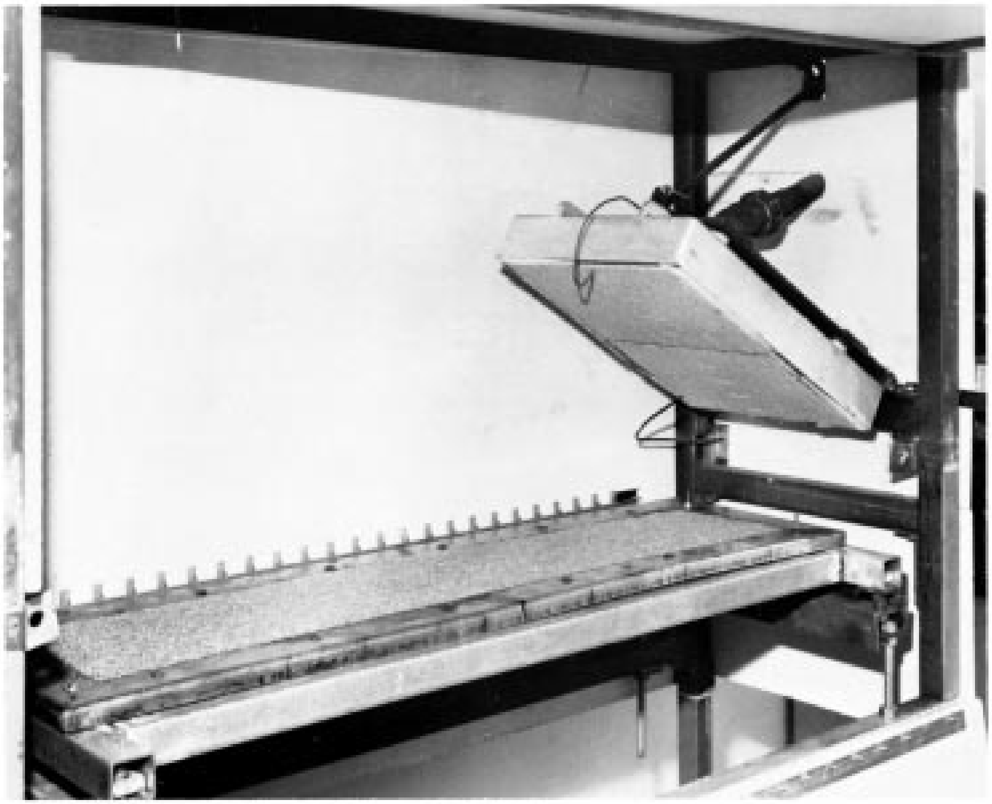

FIG. 2 Flooring Radiant Panel Test Showing Carpet Specimen and Gas Fueled Panel

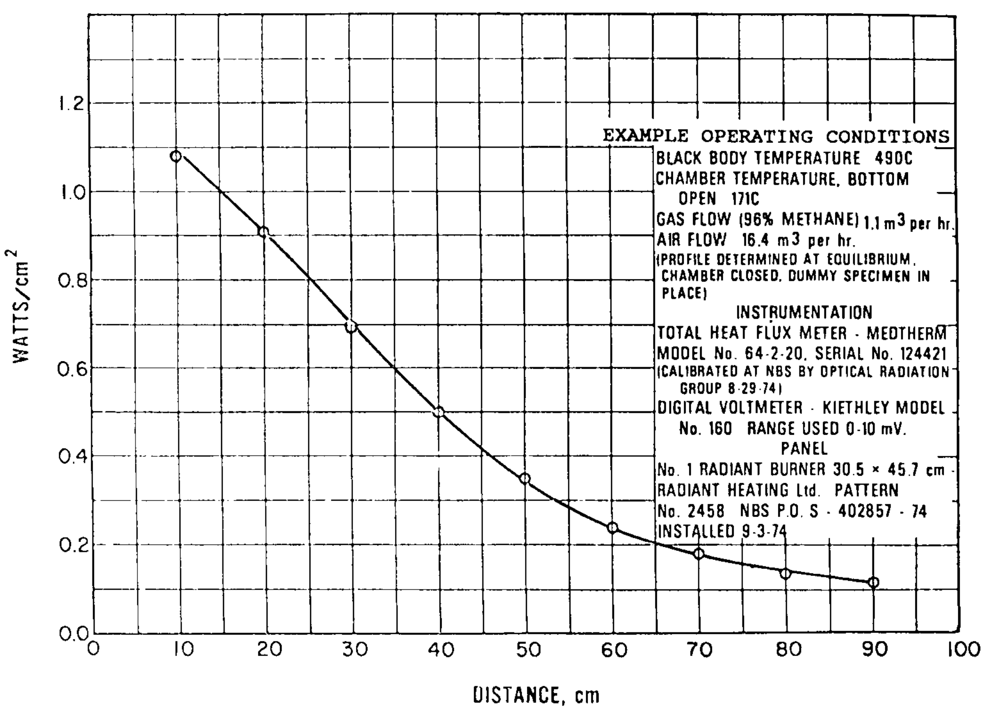

FIG. 3 Standard Radiant Heat Energy Flux Profile

draft-tight fire-resistant glass window so the entire length of the test specimen will be observable from outside the fire test chamber. On the same side and below the observation window is a door that, when open, allows the specimen platform to be moved out for mounting or removal of test specimens. When required for observation, a draft-tight fire-resistant window shall be installed at the low flux end of the chamber.

6.1.2 The bottom of the test chamber shall consist of a

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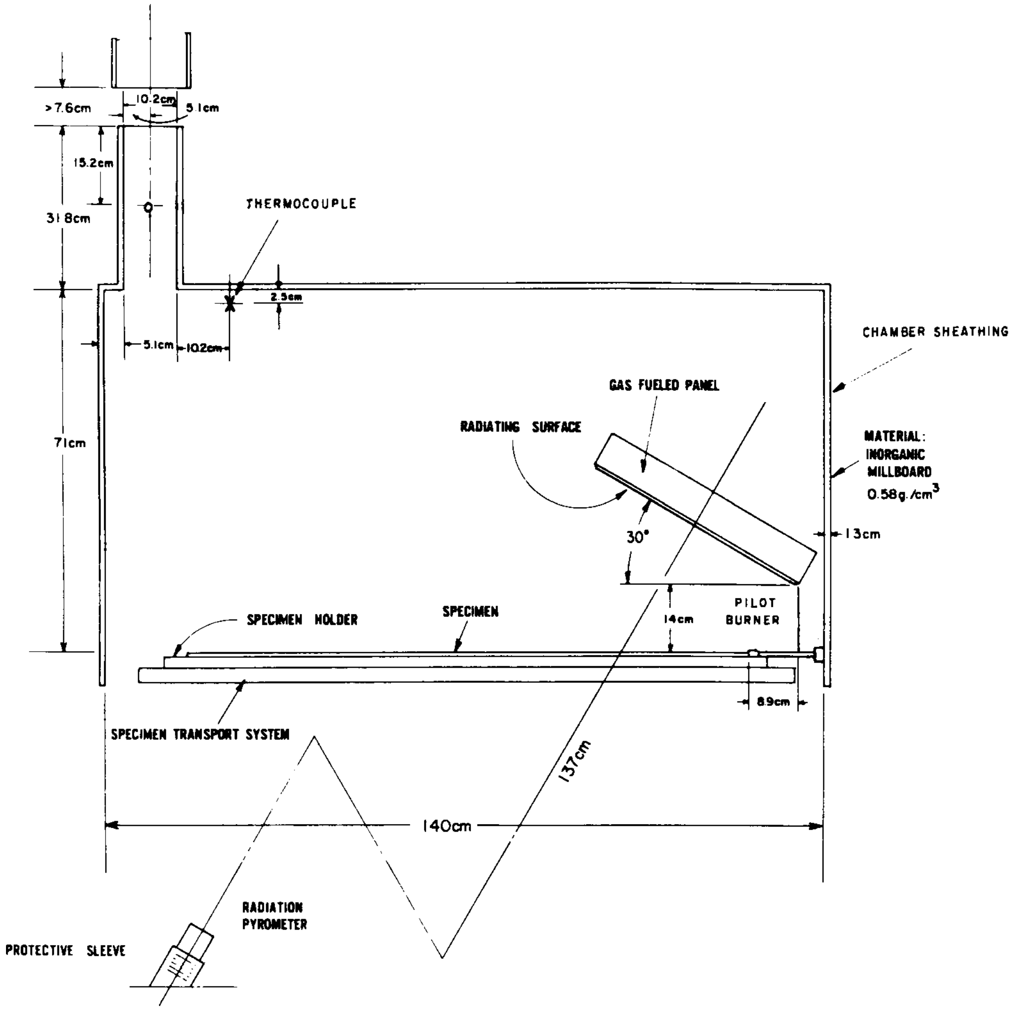

FIG. 4 Flooring Radiant Panel Tester Schematic Side Elevation

sliding steel platform that has provisions for rigidly securing the test specimen holder in a fixed and level position. The free, or air access, area around the platform shall be in the range from 2580 to 3225 cm^2 (400 to 500 $in.^2$).

6.1.3 When the rate of 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 When the extent of flame travel is to be measured after a prescribed burning period, for example, 15 min, the metal scale described in 6.1.3 shall be used.

6.1.5 The top of the chamber shall have an exhaust stack with interior dimensions of 102 ± 3 mm (4.00 ± 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 The radiant heat energy source shall be 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[5] and air at approximately atmospheric pressure, a clean, dry air supply capable of providing 28.3 NTP m^3/h (1000 standard ft^3/h) 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 a nominal angle of 30 ± 5° to the horizontal specimen plane. The radiant panel shall be adjusted to obtain the flux profile within the limits specified in 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.) (see Fig. 4).

6.2.2 The radiation pyrometer for standardizing the thermal output of the panel shall be 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 490 to 510°C (914 to 950°F) operating blackbody temperature range in accordance with the procedure described in Annex A1.

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

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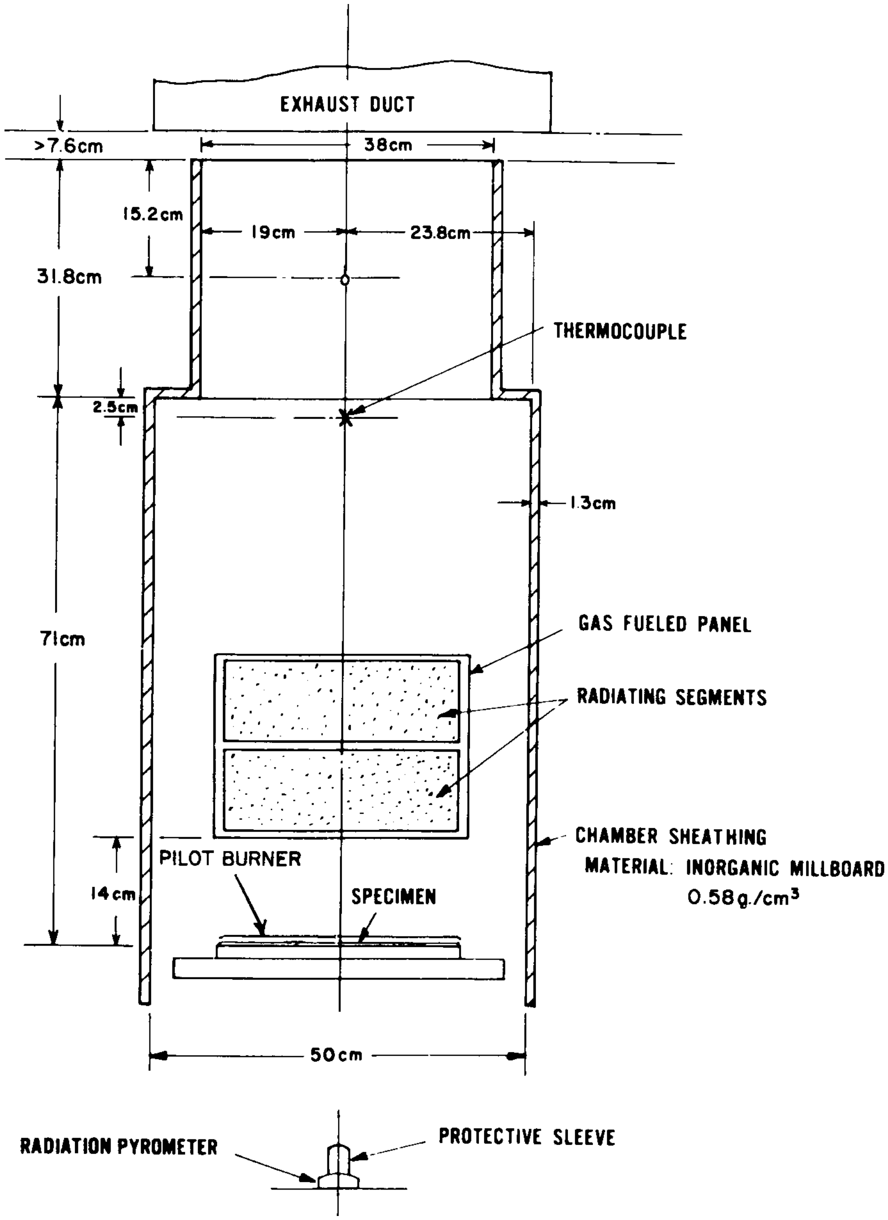

FIG. 5 Flooring Radiant Panel Tester Schematic Low Flux End, Elevation

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

6.3 The specimen holder (see Fig. 5) shall be constructed from heat-resistant stainless steel (AISI Type 300 (UNA-NO8330) or equivalent) having a thickness of 1.98 mm (0.078 in.) and an overall dimension of 1140 by 320 mm (45 by 12¾in.) 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 The 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 (#70 drill) holes drilled radially along the centerline, and 16 evenly spaced 0.7 mm (0.028 in.) diameter (#70 drill) holes drilled radially 60° below the centerline (see Fig. 6). In operation, the gas flow is adjusted to 0.085 to 0.100 m^3/h (3.0 to 3.5 SCFH) (air scale) flow rate. The pilot burner is positioned no more than 5° from the horizontal so the flame generated will impinge on the specimen at the 0 distance burned point (see Fig. 4 and Fig. 5). When the burner is not being applied to the specimen, move it away from the ignition position so it is at least 50 mm (2 in.) away from the specimen.

6.4.1 With the gas flow properly adjusted and the pilot burner in the test position, the pilot flame shall extend from approximately 63.5 mm (2.5 in.) at either end to approximately 127 mm (5 in.) at the center.

6.4.2 The holes in the pilot burner shall be kept clean. A soft wire brush has been found suitable to remove the surface contaminants. Nickel-chromium or stainless steel wire with an outside diameter of 0.5 mm (0.020 in.) is suitable for opening the holes.

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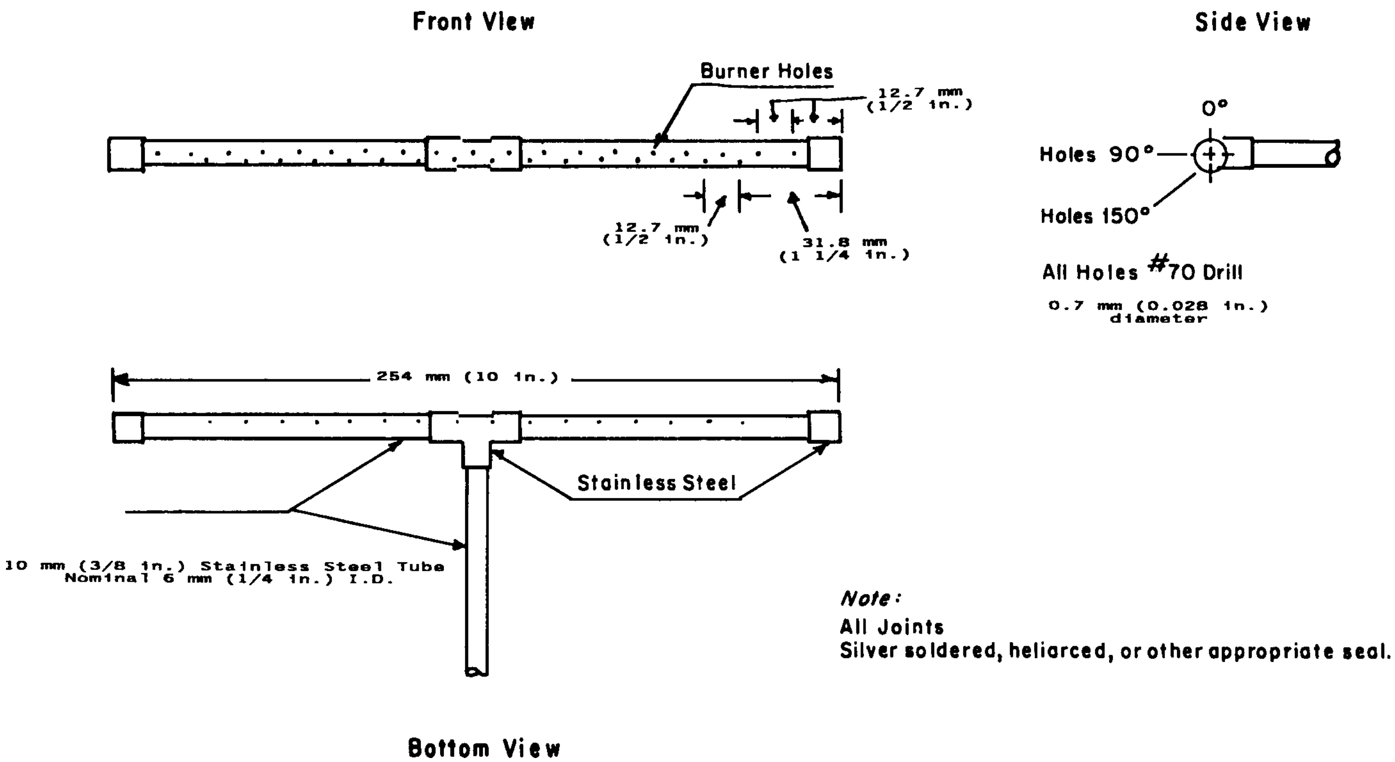

FIG. 6

6.5 A 3.2-mm (⅛-in.) stainless steel sheathed grounded junction Chromel-Alumel thermocouple shall be located in the flooring radiant panel test chamber (see Fig. 4 and Fig. 5). 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 inside the exhaust stack.

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

6.5.2 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.

6.6 An exhaust duct with a capacity of 28.3 to 85 NTP m^3/min (1000 to 3000 standard ft^3/min) 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 rate through the stack shall be 76.2 ± 15.2 m/min (250 ± 50 ft/min) when measured with a hot wire anemometer 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.

6.7 The dummy specimen that is used in the flux profile determination shall be made of 19-mm (¾-in.) inorganic 0.74 g/cm^3 (46 lb/ft^3) nominal density calcium silicate board (see Fig. 7). 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 the centerline at the 100, 200, 300, ... , 900 mm locations, measured from the maximum flux end of the specimen. To provide proper and consistent seating of the flux meter in the hole openings, a stainless or galvanized steel bearing plate shall be mounted and firmly secured to the underside of the calcium silicate board with holes corresponding to those previously specified. The bearing plate shall run the length of the dummy specimen and have a width of 76 mm (3 in.). The thickness of the bearing plate may vary in order to maintain the flux meter height specified in 10.5 up to 3.2 mm (⅛ in.) maximum.

6.7.1 The total heat flux transducer used to determine the flux profile of the chamber in conjunction with the dummy specimen shall be of the Schmidt-Boelter[6] 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 0.10 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.

6.7.2 A high impedance or potentiometric voltmeter 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.

6.8 A timing device with a minimum resolution of 0.10 min shall be used to measure preheat, pilot contact, and flame-out times.

7. Hazards

7.1 Suitable safeguards following sound engineering practices shall be installed in the panel fuel supply to guard against

[6] The sole source of supply of the apparatus known to the committee 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 comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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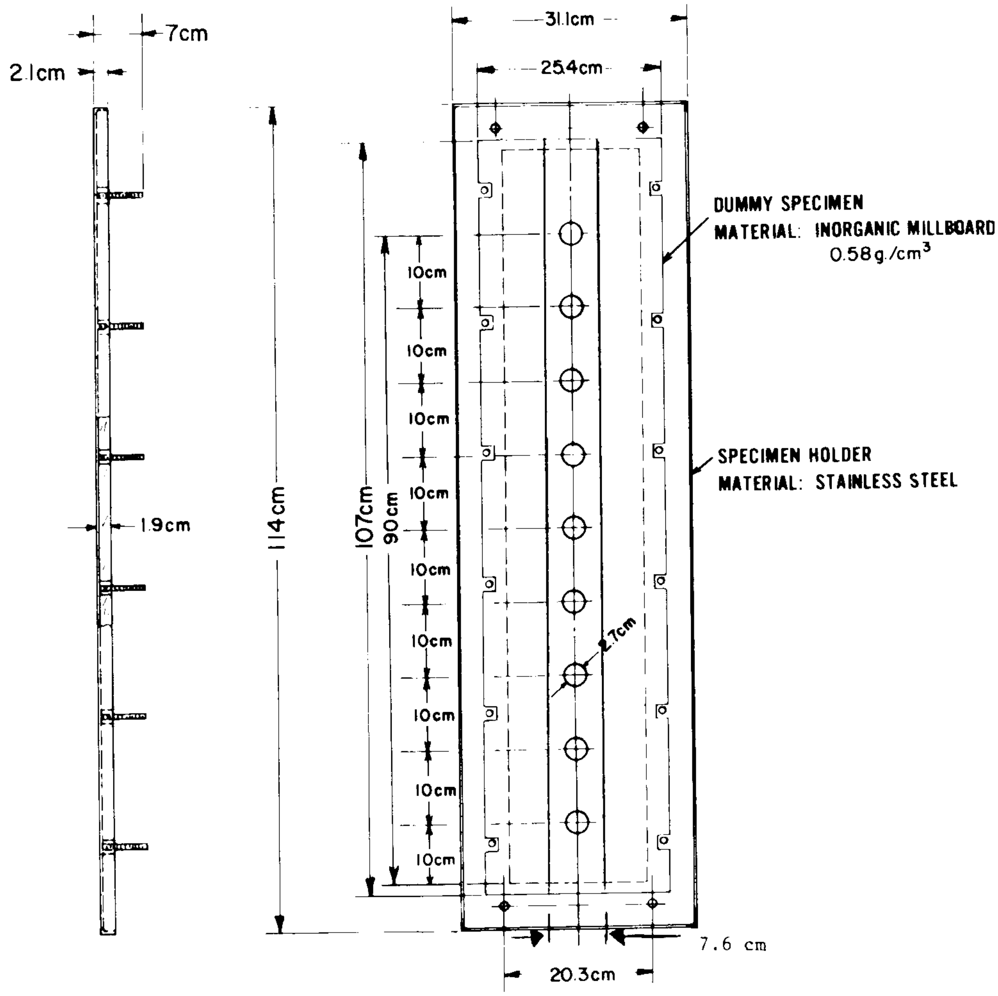

FIG. 7 Dummy Specimen in Specimen Holder

a gas-air fuel explosion in the test chamber. Consideration shall be given, but not limited to the following: (*1*) a gas feed cut-off 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, (*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 minimize the 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 E 122 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 floor-covering system sized to provide for adequate clamping in the mounting frame. Its minimum dimensions shall exceed the frame width 200 mm (7.9 in.) nominal and length 1000 mm (39.4 in.) nominal by about 50 mm (2 in.). Notch or punch holes in the specimen to accomodate the bolts when required to secure the specimen to the mounting frame (see Fig. 7).

9.2 The floor-covering system is to be specified by the test sponsor. In the absence of a specified floor-covering system, select one of the following:

9.2.1 A carpet mounted over the standard[7] cushion or the cushion proposed for use tested over the standard simulated concrete subfloor[8] (see X2.2.1).

9.2.2 A carpet with or without integral cushion pad bonded

[7] Standard is: Type II—Rubber Coated Jute and Animal Hair or Fiber Federal Specification DDD-C-001023 (GSA-FSS) Amendment-1, March 10, 1972 (minimum of ⅜ in. thick, 50 oz/yd ^{2}). The option of specifying that the actual cushion pad to be used in the installation be tested is also acceptable.

[8] Standard is: Fiber reinforced cement board with a nominal thickness of 6.3 mm (¼ in.), a density of 1762 ± 80 kg/m^3 (110 ± 5 lb/ft^3), and uncoated. The option of specifying that the actual subfloor to be used in the installation be tested is also acceptable.

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to the standard simulated concrete subfloor (see X2.2.2).

9.2.3 A resilient floor bonded to a high density inorganic sheet simulating a concrete subfloor (see X2.3.1).

9.2.4 A hardwood floor nailed to a plywood subfloor, sanded, and finished in accordance with standard practice (see X2.4.1).

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

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, ignite the radiant panel. Allow the unit to heat for 1½ 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 about 500°C (932°F) and record the chamber temperature. When equilibrium has been established, 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 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. 8.

10.6 Run the test under chamber operating conditions that give a flux profile as shown in Fig. 3. The radiant heat energy incident on the dummy specimen shall be between 0.87 and 0.95 W/cm ^{2} (0.77 and 0.83 Btu/ft^2·s) at the 200-mm point, between 0.48 and 0.52 W/cm^2 (0.42 and 0.46 Btu/ft^2·s) at the 400-mm point, and between 0.22 and 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 900-mm flux levels in the same manner. Following the 900-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 at 21 ± 3°C (69.8 ± 5.4°F) and a relative humidity of 50 ± 5 % horizontally or vertically in open racks for optimum air circulation for a minimum of 48 h; carpet specimens that have been glued down shall be conditioned for a minimum of 96 h. (See Specification E 171.)

12. Procedure

12.1 With the sliding platform out of the chamber, ignite the radiant panel. Allow the unit to heat for 1½ h (Note 2). Read the panel blackbody temperature and the chamber temperature. If these temperatures are in agreement to within ±5°C with those determined in accordance with 10.9, the chamber is ready for use.

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	______	______

Signed ____________________

FIG. 8 Flux Profile Data Log Format

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

Test Assembly: ______________
Panel Angle ______° Temperature ______°C (°F)
Flow : Gas ______NTP m³/h (SCFH) Air ______ NTP m³/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/cm² ______
Flame Front Out ______ min Flux Profile Reference ______
All Flame Out ______ min

Signed ______________

FIG. 9 Flooring Radiant Panel Test Data Log Format

NOTE 2—It is recommended that a sheet of inorganic millboard, such as calcium silicate, 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 millboard is used to prevent heating of the specimen and to protect the operator.

12.2 Invert the sample holder on a workbench and insert the flooring system. Place the steel bar clamps across the back of the assembly and tighten the nuts firmly. Return the sample holder to its upright position, clean the test surface with a vacuum, and mount it on the specimen platform. Carpet specimens shall be brushed to raise the pile to its normal position.

12.3 Ignite the pilot burner, keeping it at least 50 mm (2 in.) away from the specimen, move the specimen into the chamber, and close the door. Start the timer. After 5 min preheat, with the pilot burner on and at least 50 mm (2 in.) away from the specimen, bring the pilot burner flame into contact with the specimen at the 0 mm mark. Leave the pilot burner flame in contact with the specimen for 5 min, then remove to a position at least 50 mm (2 in.) away from the specimen and extinguish the pilot burner flame.

12.4 If the specimen does not propagate flame within 5 min following pilot burner flame application, terminate the test. For specimens that do propagate flame, continue the test until the flame goes out. Observe and record significant phenomena such as melting, blistering, penetration of flame to the substrate, etc.

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

12.6 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 watts per square centimetre critical radiant heat flux at flame-out. Read to two significant figures. A suggested data log format is shown in Fig. 9.

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

12.8 Before each test, verify that the blackbody temperature and chamber temperature meet the requirements of 12.1. The test assembly shall be at room temperature prior to start up.

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 ASTM standard practice **(1)**.[9]

$$s = \sqrt{\frac{(\Sigma X^2 - n\bar{X}^2)}{n-1}} \text{ and } \nu = \frac{s}{\bar{X}} \times 100$$

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

14. Report

14.1 Report the following information:

14.1.1 Description of the flooring system tested including its elements,

14.1.2 Description of the procedure used to assemble the flooring system specimen,

14.1.3 Number of specimens tested,

14.1.4 Individual values of critical radiant flux may be reported,

14.1.5 Extent of flame travel up to the prescribed time as described in 6.1.4, where applicable. The test result shall be reported as radiant flux at (t) minutes.,

14.1.6 Average critical radiant flux, standard deviation, and coefficient of variation, and

14.1.7 Observations of the burning characteristics of the specimen during the testing exposure, such as delamination, melting, sagging, shrinking, etc.

[9] The boldface numbers in parentheses refer to the list of references at the end of this test method.

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15. Precision and Bias (Note 3)

15.1 Defining test results as the average of three replicate determinations, the repeatability (within laboratory variability) is about 20 % of the measured value (Note 4), and the reproducibility (among laboratory variability) is about 35 % of the measured value (Note 5). Based on changes that have been made in this standard, a new precision and bias statement is being prepared.

NOTE 3—This statement is based on the results of two, 13 laboratory factorially designed experiments in which a total of 18 floor covering systems were tested.

NOTE 4—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 **(2)**.

NOTE 5—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 **(2)**.

16. Keywords

16.1 critical radiant flux; fire; floor-covering systems; 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 490, 500, and 510 ± 2°C (914, 932, and 950 ± 4°F). The blackbody enclosure shall 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 calibration shall make use of the flooring radiant panel tester as the heat source. Measurements shall be made at each of the nine 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 can be compared as needed. The working flux meters shall be calibrated at least once per year.

A1.3 Potentiometer

A1.3.1 The indicating potentiometer used to measure output of the radiation pyrometer and the total heat flux meter shall be calibrated at least once per year.

A1.3.1.1 Calibrate the potentiometer using a NIST traceable calibrator with a minimun resolution of 0.01 mV.

A1.3.1.2 An acceptable alternative to the procedure described in A1.3.1 is the use of an outside agency to provide calibration traceable to NIST.

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY ON CRITICAL RADIANT FLUX TEST

X1.1 Introduction

X1.1.1 The development and behavior of fires in buildings and rooms or compartments are complex phenomena and not well understood. As a result, efforts to achieve a basis for safety requirements must, for the present, be based on the selection and use of those components of the fire system that may become involved and be regulated. These together with experienced engineering rationale must serve until a more valid technical basis for fire engineering design has been assembled.

X1.1.2 When fire develops in a building, experience suggests that the traditional floor systems have seldom served as a fire-spread medium during early stages of a fire. During several fires in the early 1970s, floor-covering materials in corridors have become involved over considerable distances. The test method described in this standard has been suggested as a means to control potential fire spread in floor covering systems.

X1.1.3 Since the quantity and nature of room furnishing items cannot at present be controlled with regard to fire

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involvement of the full room, it is necessary to assume that floor involvement can and will, on occasion, occur. It has seemed appropriate to recommend application of only floor-covering systems meeting the higher levels of resistance to fire involvement based on critical radiant flux for use in corridors. Building codes cover interior finish in general, and it appears that only in corridors do requirements for floor-covering systems need to be more restrictive than the normal regulations.

X1.1.4 This commentary is included to provide information on the technical relevance of the test method to the problem of fires. It is intended to provide both the technical and lay public with a basis for interpreting the significance and limitations of the data resulting from use of the test.

X1.2 Nature of the Test

X1.2.1 Convective heat flow cannot serve as a major feedback mechanism in most cases of fires involving floor-covering systems because of the buoyancy of the flames and hot gases. Thus these horizontal surfaces of building finishes have seldom been recognized as primary hazards in the spread of flames. However, corridor fire tests conducted at NIST **(3, 4)** together with some building fire incidents have indicated that fire spread can occur in corridors exposed to burn-out conditions in adjacent rooms. Fires were observed to propagate the full length of the corridor when little, if any, combustible other than the floor-covering system was involved in the corridor finish. Analysis of the measurements made during such tests has made clear the importance of radiant heat transfer from upper corridor surfaces, flame, smoke, and gases in serving a fire support role. Thus, the sensitivity of a floor-covering system to radiant support of combustion can be suggested **(5, 6)** as a basis of ranking floor-covering systems with respect to fire behavior. Critical radiant flux, the heat flux level below which surface flame spread will not occur, was selected as the floor-covering system fire property of controlling importance. If a room fire does not impose a radiant flux that exceeds this critical level on a corridor floor-covering system, flame spread will not occur.

X1.2.2 Critical radiant flux does not provide information on the irradiance level to which the flooring will be exposed when fires occur. This will be largely influenced by other variables that include:

X1.2.2.1 Nature, quantity, and arrangement of the fire load in the compartment where ignition occurs,

X1.2.2.2 Ventilation conditions in the portion of the building that becomes exposed to fire,

X1.2.2.3 Geometry of the compartment and ventilation passages,

X1.2.2.4 Heat release rate of the fire load and the floor-covering system, and

X1.2.2.5 Heat capacity of the enclosing walls, ceiling, and floors.

X1.3 Experimental Studies of Relevance

X1.3.1 One important fire property of floor-covering systems has been identified that, provided effective irradiance level can be predicted when fire occurs, will provide information on the extent of fire-spread possibility. The use of this property alone, at least in some cases, is inadequate for prediction of fire spread under severe exposure conditions. For instance, Fig. X1.1 shows a plot of the maximum heat flux to the floor surface of the NIST full-scale corridor when no combustible floor-covering system or other interior finish was present in the corridor. These data were obtained with a fire load in the adjoining room of 2.2 lb/ft ^{2} (10.7 kg/m ^{2}) with a

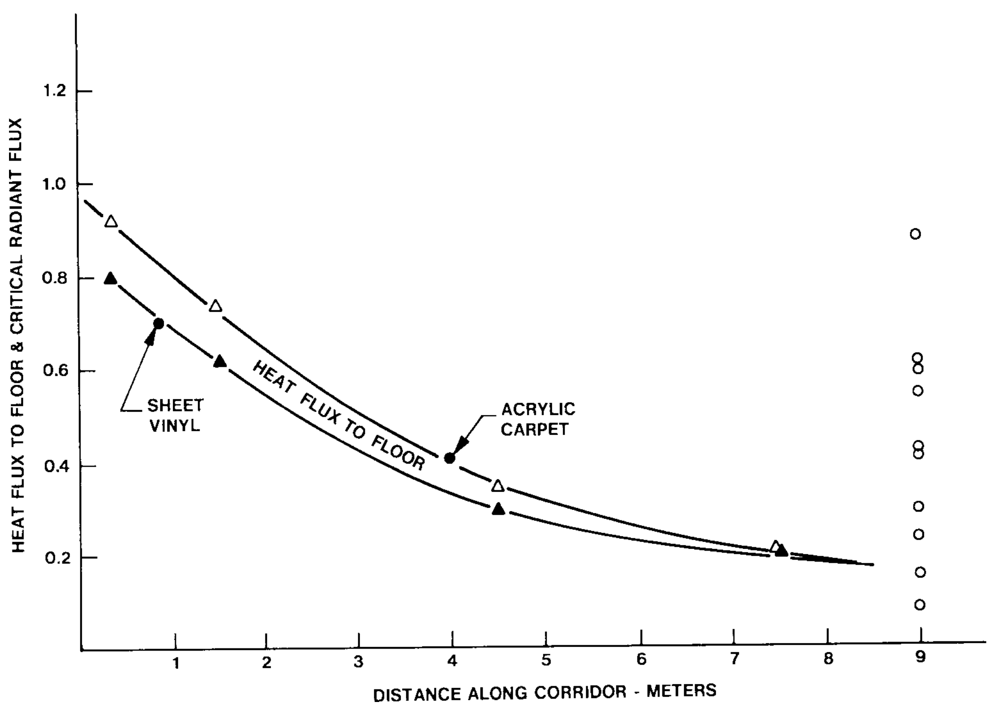

FIG. X1.1 Heat Flux to Floor with Bare Corridor versus Distance Along Corridor and Fire Propagation Distance of Various Floor Systems versus Critical Radiant Flux (NIST Corridor with Four 18-kg Cribs in Burn Room—Fuel Load 10.7 kg/m^2 (2.2 lb/ft^2))

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measured burning rate (maximum) of 10.6 lb/min (80 g/s). The two curves, designated by triangles, show the envelope resulting from two series of experiments **(7)**. The data plotted on the same figure as circles represent the critical radiant flux of twelve floor-covering systems versus the extent of flame propagation in the corridor as tested in the full-scale tests **(8)**. In all cases, the heat flux to the floor covering system at the doorway between the room and corridor was higher than the critical radiant flux for the material. Hence, flame spread should be expected to take place into the corridor, and this was observed.

X1.3.2 It is evident that only two of the twelve floor-covering systems stopped burning at distances corresponding to their critical radiant flux as shown on the flux-distance curve for the corridor without combustible linings. The reason for this difference in behavior is apparently that the flux to the floor surface has been sufficiently augmented by the heat release from the flooring itself after rapid flame spread commenced. This usually followed a period of relatively slow flame spread away from the doorway. It also seems likely that changes in ventilation of the compartment fire may have modified the location at which pyrolysis gases are burned, that is, in the corridor above the floor and influenced the flame height of the floor fire. These effects would greatly increase the radiant flux incident on the floor. To date these effects are not well understood, and no firm guidance can be provided on the way they should be introduced to predict the overall behavior of such a fire system.

X1.3.3 Other data are available to illustrate the merit of the test under less severe exposure. These result from a series of experiments on crib or furniture item fires in an open door 3.4 by 2.7-m (11 by 9-ft) room of 2.4-m (8-ft) height that had been fitted with floor-covering assemblies of known critical radiant flux characteristics. In these tests the crib or furniture and the floor covering assembly were the only combustibles in the room.

X1.3.4 The results of this study have been published and Fig. X1.2 shows some of the data developed **(9)**. This shows the extent of fire propagation from the source as a function of critical radiant flux. The four floor-covering systems used were carpets that qualified as having passed the pill test. The data are interesting since they show that under the conditions of the experiments the distance of fire propagation was inversely related to critical radiant flux. In addition, while not demonstrated by this figure, the data show that the burning ceased at positions on the floor-covering system somewhat below those at which flux measurement during the test corresponded to the critical radiant flux of the floor-covering system being studied. Thus, in this situation, which did not involve room flashover, critical radiant flux appeared to provide a method of ranking the fire spread behavior of the carpets.

X1.3.5 The current version of this test procedure is a result of a recent study conducted at NIST **(10).** The purpose of this work was twofold: to resolve a perceived problem with ignitability of and continued flame propagation across some carpet specimens and to reduce the variability of test results obtained by different laboratories. As a result, three significant changes were made in the standard: 1) specimen preparation and conditioning; 2) tighter control of the air flow through the chamber during calibration and conduct of the test; and 3) replacement of the propane torch pilot burner with a propane line burner. The ignitability (and flame propagation) question appears to have been resolved by the use of the new line

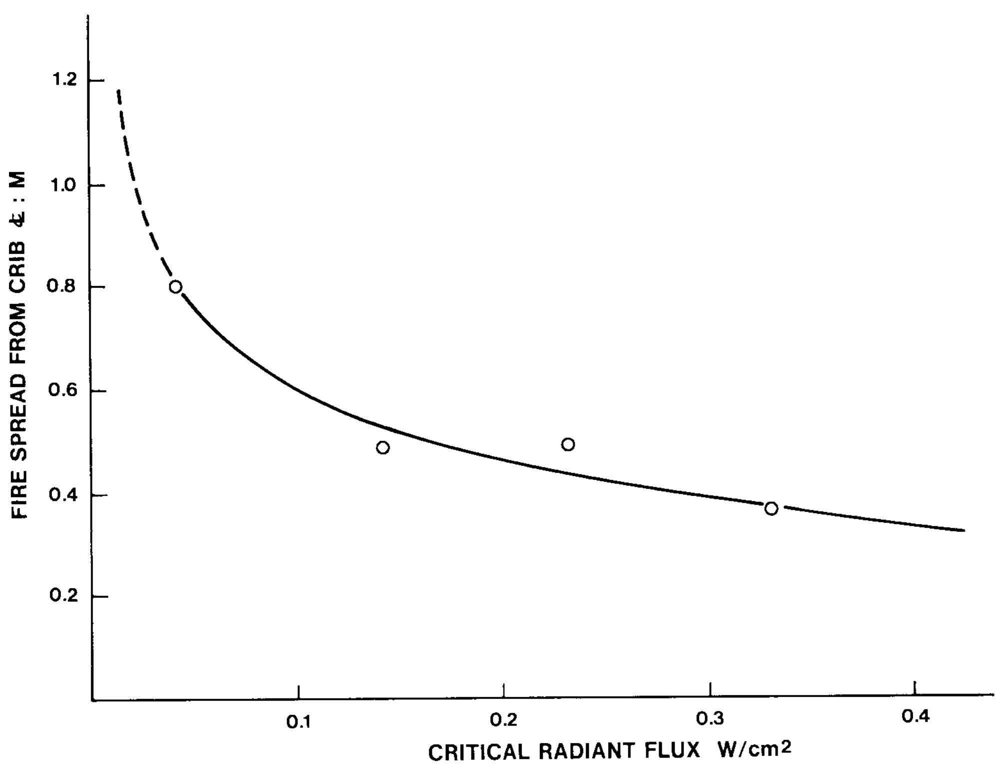

FIG. X1.2 Room Burn Tests—Fire Spread from Crib 6.4-kg (14-lb) Cribs

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burner. The variability of test results among different laboratories has been shown to be markedly improved by the aforementioned changes in the standard, at least for one carpet fabric. Previous proficiency rounds performed by NVLAP resulted in coefficients of variation ranging from 18 to 35 %; the coefficient of variation obtained using the revised standard was less than 12 %. A complete discussion of the research conducted by NIST can be found in the referenced report.

X1.4 Summary

X1.4.1 It must be recognized that the critical radiant flux test method provides a useful way of rank ordering floor-covering systems with regard to this important fire property. However, this is only one of several parameters that determine the fire behavior of floor-covering systems. Critical radiant flux indicates the threshold above which flame spread will occur. To use this property in fire safety estimates one must judge the probable heat flux exposure to the floor from the initiating fire. Such estimates must, for the present, depend on judgment or data from prototype experiments. Once a fire is initiated in a corridor, other parameters such as critical flux for ignition and rate of flame spread, as well as corridor configuration and the presence of combustibles, such as ceiling and wall linings, can be important in determining the ultimate spread of fire.

X1.4.2 Thus, establishment of criteria for critical radiant flux of floor-covering systems may be expected to reduce, but not eliminate, the incidents of extensive flame spread of floor-covering systems.

X2. GUIDELINE TO MOUNTING METHODS

X2.1 Introduction

X2.1.1 This guideline has been compiled as an aid in selecting a method of mounting various floor covering materials in the fire test chamber. The mounting methods in 9.2 are suggested for test method uniformity and convenience and are to guide the user in the evaluation of an appropriate floor-covering system.

X2.1.2 Tests of carpet/cushion systems involving other than the standard cushion are only applicable to the specific system tested. Conversely, for regulatory purposes, the results of tests for carpets over the standard cushion are normally applied to any cushion combination.

X2.2 Mounting Procedures

X2.2.1 *Carpet and Cushion Pad over Concrete, Simulated*—Carpet specimens should be cut in the machine direction. To mount a specimen, invert the holder on a clean, flat surface. Insert the test specimen in the holder. Then insert the cushion pad with the pattern side facing the carpet followed by a nominal 6.3-mm (¼-in.) thick fiber reinforced high density [1762 ± 80 kg/m^3 (110 ± 5 lb/ft ^{3})] cement board (Note X2.1) and a 13-mm (½-in.) 0.58 g/cm^2 (36 lb/ft ^{3}) inorganic millboard. Finally, place the steel bar clamps across the assembly and tighten firmly. Mount the test assembly on the specimen transport frame so that the pile lay faces the panel.

NOTE X2.1—The fiber reinforced cement board may spall during a test. This can be avoided by heating for 12 h at 163°C (325°F).

X2.2.2 *Carpet with or without Integral Cushion Pad Bonded to Concrete, Simulated*—Carpet specimens should be cut in the machine direction. The adhesive shall be that recommended by the carpet manufacturer.[10] Apply the adhesive to the smooth side of the fiber reinforced cement board in accordance with the directions provided by the adhesive manufacturer (Note X2.2). Apply a nominal 9.1 kg (20 lb) roller, having a diameter of 76 mm (3 in.) and approximately the width of the specimen, across the top of the specimen to assure good contact with the substrate. Stack the specimens under a dead load after bonding to the fiber reinforced cement board for no more than 24 h prior to conditioning. (See 11.1 for storage and conditioning requirements.) Mount the specimen in testing frame as described in X2.2.1 and test in accordance with standard procedure.

NOTE X2.2—In the absence of a manufacturer's recommendation, apply the adhesive with a 3.2 mm (⅛in.) V-notched trowel.

X2.2.3 *Carpet, Other*—Substitution of the actual subfloor for the standard fiber reinforced cement board substrate is acceptable.

X2.3 Resilient Flooring

X2.3.1 Follow or simulate, or both, commercial installation practice. This will, in most instances, mean bonding to the standard fiber reinforced cement substrate.

X2.4 Hardwood Flooring

X2.4.1 Follow or simulate, or both, commercial installation practice. In a typical system, the substrate would be a 16-mm (⅝-in.) plywood sheet covered with building paper. The oak flooring strips would be nailed to the plywood then sanded, sealed, and waxed. The assembly should be tested with the moisture content of the oak at 7 to 8 %.

[10] In the absence of the manufacturer's recommendation, a multipurpose adhesive typical of commercial installation shall be selected by the laboratory.

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