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# NFPA 253
# Flooring Radiant Panel Test
## 1990 Edition

NFPA

National Fire Protection Association 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101

# NFPA 253

## Standard Method of Test for

# Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source

## 1990 Edition

This edition of NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, was prepared by the Technical Committee on Fire Tests and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 21-24, 1990 in San Antinio, TX. It was issued by the Standards Council on July 20, 1990, with an effective date of August 17, 1990, and supersedes all previous editions.

The 1990 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

## Origin and Development of NFPA 253

Experience suggests that during the early stages of a fire, floor covering systems have seldom acted as a fire spread medium. However, in a few fires involving multiple occupancy buildings, the floor covering materials in corridors were primarily responsible for fire spread over a considerable distance. This caused grave concern and pointed to the need for a realistic test to evaluate the flame spread of floor covering systems.

The Flooring Radiant Panel Test had its inception with the Armstrong Cork Company in 1966. In 1972, conceptualization of critical radiant flux (watts/cm$^2$ at extinguishment) as a measure of flame spread hazard was underway at the National Bureau of Standards. It was determined in the course of their work on model corridor fire tests that the radiant energy levels incident on the floor covering had a considerable influence on whether or not flaming combustion would propagate. Accordingly, it was natural to apply the critical radiant flux concept, and, in 1973, the National Bureau of Standards prepared a draft of the Flooring Radiant Panel Test.

In 1975, the Committee on Fire Tests began its evaluation of the proposed test methods, which culminated in the adoption of this test as an official NFPA standard in May of 1978. The standard was revised in 1984 and 1990.

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*This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.*

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

## Contents

# NFPA 253

## Standard Method of Test for

# Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source

## Chapter 1 General

### 1-1 Scope.

**1-1.1** This method of test describes a procedure for measuring critical radiant flux behavior of horizontally mounted floor covering systems exposed to a flaming ignition source in a graded radiant heat energy environment within a test chamber. The specimen can be mounted over underlayment or a simulated concrete structural floor, bonded to a simulated structural floor, or otherwise mounted in a typical and representative way.

**1-1.2** This method measures the critical radiant flux at flameout. 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 and/or hot gases from a fully developed fire in an adjacent room or compartment. The method was developed to simulate an important fire exposure component in fires that may develop in corridors or exitways of buildings and is not intended for routine use in estimating flame spread of floor covering in building areas other than corridors or exitways. Reference should be made to Appendix E for information on proper application and interpretation of experimental results from use of this test.

### 1-2 Significance.

**1-2.1** This method of test is designed primarily to provide a basis for estimating one aspect of the fire exposure behavior of a floor covering system installed in a building corridor having little or no combustible wall or ceiling finish. The test environment is intended to simulate conditions that have been observed and defined in full-scale corridor experiments.

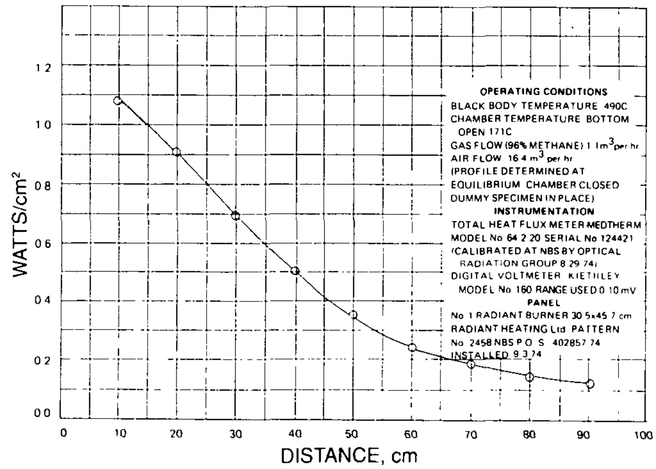
**1-2.2** The test is intended to be suitable for regulatory statutes, specification acceptance, design purposes, or development and research.

**1-2.3** The fundamental assumption inherent in the test is that "critical radiant flux" is one measure of the sensitivity to flame spread of floor covering systems located in a building corridor.

**1-2.4** 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.

### 1-3 Summary of Method.

**1-3.1** The basic elements of the test chamber are: (a) an air-gas fueled radiant heat energy panel inclined at 30 degrees to and directed at (b) a horizontally mounted floor covering system specimen. The radiant panel generates a radiant energy flux distribution ranging along the 44-in. (100-cm) length of the test specimen from a nominal maximum of 0.881 Btu/ft$^2$ sec (1.0 W/cm$^2$) to a minimum of .0881 Btu/ft$^2$ sec (0.1 W/cm$^2$). The test is initiated by open flame ignition from a pilot burner. The distance burned to flameout is converted to Btu/ft$^2$ sec (W/cm$^2$) from the flux profile graph, Figure 1-3.1, and reported as critical radiant flux Btu/ft$^2$ sec (W/cm$^2$).




Note: in. = cm × .3937; Btu/ft$^2$ sec = W/cm$^2$) × 1.135.

**Figure 1-3.1 Standard Radiant Heat Energy Flux Profile.**

### 1-4 Definitions of Terms.

**Black Body Temperature.** The temperature of a perfect radiator — a surface with an emissivity of unity and, therefore, a reflectivity of zero.

**Corridor.** An enclosed space connecting a room or compartment with an exit.

**Critical Radiant Flux.** The level of radiant heat energy incident on the floor covering system at the most distant flameout point. It is reported as Btu/ft$^2$ sec (W/cm$^2$).

**Floor Covering System.** A flooring or a combination of flooring and floor covering.

**Flooring.** Either a primary or a final floor surface.

**Floor Covering.** A separate or secondary surface applied over a flooring and including underlayment materials, carpeting, resilients, and coating systems.

**Flux Profile.** The curve relating incident radiant heat energy on the specimen plane to distance from the point of initiation of flaming ignition, i.e., 0 in. (0 cm).

**Shall.** Indicates a mandatory requirement.

**Should.** Indicates a recommendation or that which is advised but not required.

**Total Flux Meter.** The instrument used to measure the level of radiant heat energy incident on the specimen plane at any point.

## Chapter 2 Test Apparatus

**2-1** The apparatus shall be essentially as shown in Figures 2-1a and 2-1b.

**Figure 2-1a Flooring Radiant Panel Tester Apparatus.**

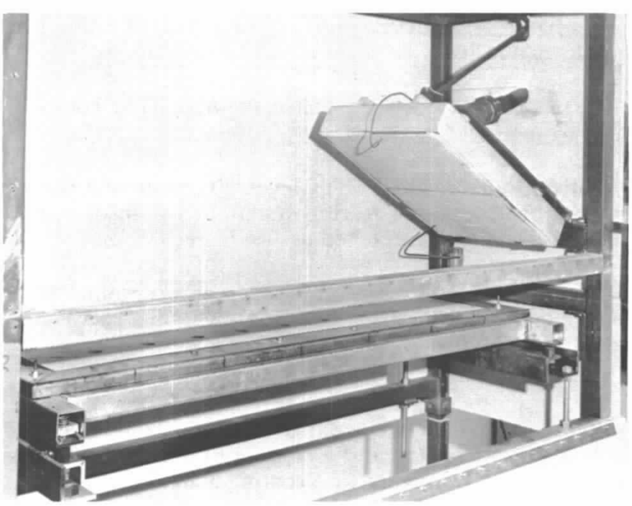
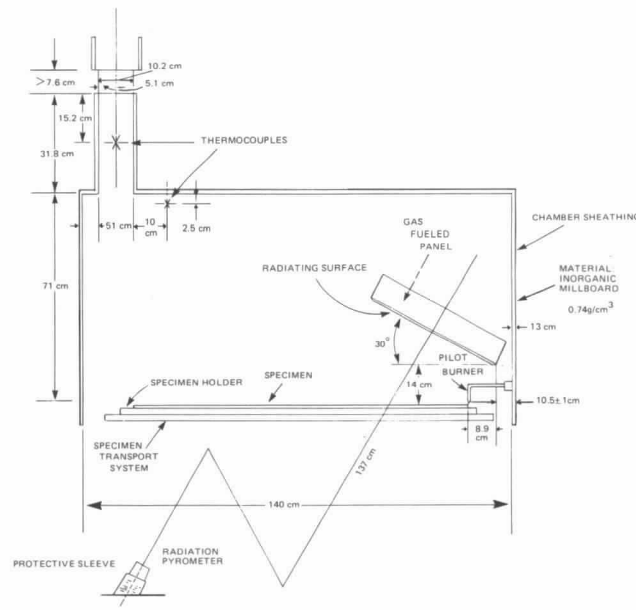


**Figure 2-1b Flooring Radiant Panel Test Showing Carpet Specimen and Gas-Fueled Panel.**

**2-2** The flooring radiant panel test chamber employed for this test shall be located in a draft-protected laboratory.

**2-3 Test Chamber.**

**2-3.1** The flooring radiant panel test chamber, Figures 2-3a and 2-3b, shall consist of an enclosure 55 in. (140 cm) long by 19 ½ in. (50 cm) deep by 28 in. (71 cm) high above the test specimen. The sides, ends, and top shall be of ½-in. (1.3-cm) calcium silicate board such as Marinite I, 46 lb/ft$^3$ (0.74 g/cm$^3$) nominal density, with a thermal conductivity at 350°F of 0.89 Btu/[(hr) (ft$^2$)(°F/in.)] (0.128 W/m• k). One side shall be provided with an approximately 4 × 44-in. (10 × 100-cm) draft-tight observation heat-resistant glass window so that the entire length of the test specimen may be observed from outside the fire test chamber. On the same side and below the observation window shall be a door that, when open, will allow the specimen platform to be moved out for mounting or removal of test specimens.



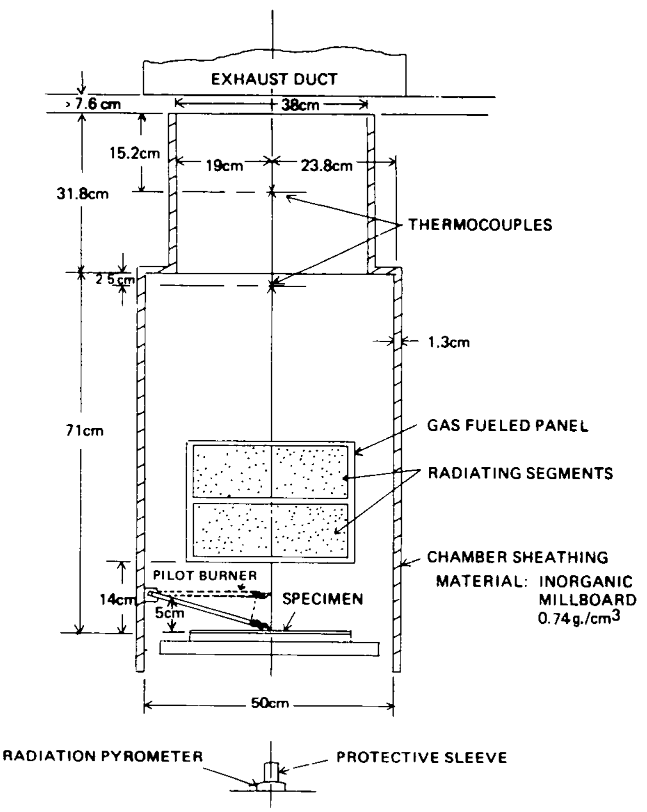

Note: in. = cm × .3937.

**Figure 2-3a Flooring Radiant Panel Tester Schematic — Side Elevation.**

**2-3.2** The bottom of the test chamber shall consist of a sliding steel platform that has provisions for rigidly securing the test specimen holder in a fixed and level position.

**2-3.2.1** The test specimen holder when in place and secured to the specimen mounting platform shall be level.

**2-3.2.2** For research and development purposes, it may be desirable to measure the rate of flame spread advance. A metal scale with ½-in. (1.3-cm) high pedestal markers at 1.57 to 1.97-in. (4 to 5-cm) intervals is mounted on the back of the platform.




Note: in. = cm × .3937.

**Figure 2-3b Flooring Radiant Panel Tester Schematic — Low Flux, Elevation.**

**2-3.2.3** The free, or air access, area around the platform shall be in the range of 300-500 in.$^2$ (1935-3225 cm$^2$).

**2-3.3** The top of the chamber shall have an exhaust stack with interior dimensions of 4 in. (10.2 cm) wide by 15 in. (38 cm) deep by 12.5 in. (31.8 cm) high at the opposite end of the chamber from the radiant panel.

## 2-4 Radiant Heat Energy Source.

**2-4.1** The radiant heat energy source shall be a panel consisting of a porous refractory material mounted in a cast-iron frame and exposing a radiation surface of 12 × 18 in. (30.5 × 45.7 cm). It shall be capable of operating at temperatures up to 1500°F (816°C).

**2-4.1.1** The panel fuel system shall consist of a venturi-type aspirator for mixing gas and air at approximately atmospheric pressure, a clean, dry air supply capable of providing 1000 Standard Cubic Feet per Hour (28.3 NTP m$^3$/h) at 3.0 in. (7.6 cm) of water column, and suitable instrumentation for monitoring and controlling the flow of fuel to the panel.

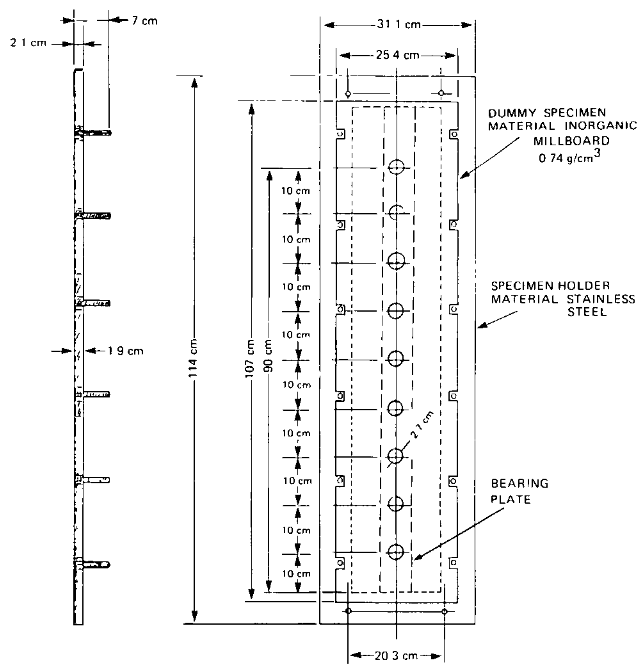
**2-4.2** The radiant heat energy panel shall be mounted at 30 degrees to the horizontal specimen plane. The horizontal distance from the zero mark on the specimen fixture to the bottom edge (projected) of the radiating surface of the panel is 3$^1/_2$ in. (8.9 cm).

The panel-to-specimen vertical distance is 5$^1/_2$ in. (14 cm) (*see Figure 2-3B*). The angle and dimensions given above are critical in order to obtain the required radiant flux profile.

**2-4.3** The radiation pyrometer for standardizing the thermal output of the panel shall be suitable for viewing a circular area 10 in. (25.4 cm) in diameter at a range of about 54 in. (137 cm). It shall be calibrated over the black body temperature range of 860-950°F (460-510°C) in accordance with the procedure described in Appendix A.

**2-4.4** A high impedance or potentiometric voltmeter with a suitable millivolt range shall be used to monitor the output of the radiation pyrometer described in 2-4.3.

**2-5 Specimen Holder.** The specimen holder (*see Figure 2-5*) is constructed from heat-resistant stainless steel, AISI Type 300 (UNA-NO8330) or equivalent, with a thickness of 0.078 in. (0.198 cm), having overall dimensions of 45 in. × 12$^3/_4$ in. (114 cm × 32 cm) with a specimen opening of 7.9 in. × 39.4 in. (20 cm × 100 cm). Six slots are cut in the flange on either side of the holder to help reduce warping. The holder is fastened to the platform with two stud bolts at each end.




Note: in. = cm × .3937.

**Figure 2-5 Dummy Specimen in Specimen Holder.**

## 2-6 Pilot Burner.

**2-6.1** The pilot burner used to ignite the specimen is a commercial propane venturi torch, BERNZ-O-MATIC TX 101 or equivalent, with an axially symmetric burner tip having a propane supply tube with an orifice diameter of 0.003 in. (0.0076 cm). In operation, the propane flow is adjusted to give a pencil flame blue inner cone length of 1/2 in. (1.3 cm).

**2-6.1.1.** The pilot burner is positioned so that the flame generated will impinge on the centerline of the specimen at the zero distance burned point at right angles to the specimen length (*see Figures 2-3a and 2-3b*).

**2-6.1.2** The burner shall be capable of being swung out of the ignition position so that the flame is horizontal and at least 2 in. (5 cm) above the specimen plane.

**2-7 Thermocouples.**

**2-7.1** Two 1/8-in. (0.32-cm) stainless steel sheathed grounding junction chromel alumel thermocouples are located in the flooring radiant panel test chamber (*see Figures 2-3a and 2-3b*).

NOTE: Thermocouples should be kept clean to ensure accuracy of readout.

**2-7.1.1** The chamber thermocouple is located in the longitudinal central vertical plane of the chamber 1 in. (2.5 cm) down from the top and 4 in. (10.2 cm) back from the inside of the exhaust stack.

**2-7.1.2** The exhaust stack thermocouple is centrally located 6 in. (15.2 cm) from the top.

**2-7.2** An indicating potentiometer with a range of 212-932°F (100-500°C) may be used to determine the chamber temperature prior to a test.

**2-8 Exhaust Hood.** An exhaust hood with a capacity of 1000-3000 SCFM (28.3-85 NTP $m^3$/min.), decoupled from the chamber stack by at least 3 in. (7.6 cm) on all sides, and with an effective canopy area slightly larger than the plane area of the chamber when the specimen platform is in the out position, is used to remove combustion products from the chamber. With the panel turned on and the dummy specimen in place, there shall be no measurable difference in airflow through the chamber stack whether the exhaust is on or off.

**2-9 Dummy Specimen.**

**2-9.1** The dummy specimen, which is used in the flux profile determination, shall be made of 1/2- to 3/4-in. (1.3- to 1.9-cm) inorganic, 46 lb/$ft^3$ (0.74 g/$cm^3$) nominal density calcium silicate board, such as Marinite I (*see Figure 2-5*). It shall be 10 in. (25 cm) wide by 42 in. (107 cm) long with 1 1/16-in. (2.7-cm) diameter holes centered on and along the centerline at the 3.94, 7.87, 11.81...35.43 in. (10, 20, 30...90 cm) locations, starting at 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 specified above. The bearing plate shall run the length of the dummy specimen and have a minimum width of 3.0 in. (7.6 cm). The thickness of the bearing plate may vary in order to maintain the flux meter height specified.

**2-9.1.1** The total heat flux transducer used to determine the flux profile of the chamber in conjunction with the dummy specimen (*see 2-4.4*) shall be of the Schmidt-Boelter type (Medtherm 64-2-20 or equivalent) and have a range of 0 to 1.32 Btu/$ft^2$ sec (0 to 1.5 W/$cm^2$). A source of 59 to 77°F (15 to 25°C) cooling water shall be provided for this instrument. It shall be calibrated over the operating flux level range of 0.1 to 1.7 Btu/$ft^2$ sec (0.10 to 1.5 W/$cm^2$) in accordance with the procedures outlined in Appendix A.

**2-9.1.2** A high impedance or potentiometric voltmeter with a range of 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.

**2-10 Timer.** A timer shall be conveniently mounted on the chamber for measuring preheat and pilot contact time. It may also be used for measuring the distance interval times.

## Chapter 3 Test Specimens

**3-1 Sampling Procedure.**

**3-1.1** The sample selected for testing shall be representative of the product.

**3-1.2** The sampling practice outlined in ASTM E-122, *Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process*, shall be used when applicable.

**3-2 Specimen Size and Mounting.**

**3-2.1** The test specimen shall be a floor covering system 10 in. wide by 42 in. long (25 cm × 107 cm). It may be necessary to notch or punch holes in the specimen to accommodate the mounting frame bolts (*see Figure 2-5*).

**3-2.2** Insofar as possible, the floor covering system specimen should simulate actual installation practice. Typical examples follow:

(a) A hardwood floor nailed to a plywood subfloor, then sanded and finished according to standard practice.

(b) An integral foam backed carpet bonded to a high density inorganic sheet simulating a concrete subfloor.

(c) A carpet mounted over the standard cushion on the simulated or actual subfloor.

NOTE: Type II — Rubber Coated Jute and Animal Hair or Fiber DDD-C-001023 (GSA-FSS) Amendment — 1, March 10, 1972. [Minimum of 3/8-in. (.9525-cm) thick, 50 oz/$yd^2$ (1.695 kg/$m^2$).] The option of specifying the actual cushion pad to be used in the installation tested is also acceptable.

(d) A carpet mounted on a high density inorganic sheet simulating a concrete subfloor.

(e) A resilient floor bonded to a high density inorganic sheet simulating a concrete subfloor.

**3-2.3** A minimum of three specimens per sample shall be tested.

**3-3 Specimen Conditioning.** Test specimens shall be conditioned for a minimum of 48 hours at 69.8 ± 5.4°F (21 ± 3°C) and a relative humidity of 50 ± 5 percent immediately prior to testing. (*See ASTM E-171, Standard Specification for Standard Atmospheres for Conditioning and Testing Materials.*)

## Chapter 4 Radiant Heat Energy Flux Profile Standardization

**4-1 Procedure.**

**4-1.1** 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.

**4-1.2** Mount the dummy specimen in the mounting frame and attach the assembly to the sliding platform.

**4-1.3** With the sliding platform out of the chamber, ignite the radiant panel. Allow the unit to heat for one hour. Leave the pilot burner off during this determination. Adjust the fuel mixture to give an air-rich flame. Adjust fuel flow settings to bring the panel to an apparent black body temperature, as measured by the radiation pyrometer, of about 932°F (500°C), and the chamber temperature to about 356°F (180°C).

NOTE: The current use of higher density calcium silicate board for the chamber enclosure may result in lower panel black body and chamber temperatures.

**4-1.4** When equilibrium has been established, move the specimen platform into the chamber.

**4-1.5** Allow 0.5 hours for the closed chamber to equilibrate before starting the profile determination.

**4-1.6** Measure the radiant heat energy flux level at the 15.7 in. (40 cm) point with the total flux meter instrumentation. This is done by inserting the flux meter in the opening so that its detecting plane is 1/16 to 1/8 in. (0.16-0.32 cm) above and parallel to the plane of the dummy specimen and reading its output after 30 ± 10 seconds. If the level is within the limits specified in 4-1.7, the flux profile determination has begun. If it has not, make the necessary adjustments in panel fuel flow. A suggested flux profile data log format is shown in Appendix C.

**4-1.7** The test shall be run under chamber operating conditions that create a flux profile as shown in Figure 1-3.1. The radiant heat energy incident on the dummy specimen shall be between:

(1) 0.7 and 0.83 Btu/ft$^2$ sec (0.87 and 0.95 W/cm$^2$) at the 7.9-in. (20-cm) point,

(2) 0.42 and 0.46 Btu/ft$^2$ sec (0.48 and 0.52 W/cm$^2$) at the 15.7-in.(40-cm) point,

(3) 0.19 and 0.23 Btu/ft$^2$ sec (0.22 and 0.26 W/cm$^2$) at the 23.6-in. (60-cm) point, and

(4) 0.10 and 0.12 Btu/ft$^2$ sec (0.11 and 0.14 W/cm$^2$) at the 35.4-in. (90-cm) point.

**4-1.8** Insert the flux meter in the 3.94-in. (10-cm) opening following the procedure outlined in 4-1.6. Read the mv output at 30 ± 10 seconds. Proceed to the 7.9-in. (20-cm) point and repeat the 3.94-in. (10-cm) procedure. The 11.8 to 35.4-in. (30 to 90-cm) flux levels are determined in the same manner. Following the 35.4-in. (90-cm) measurement, make a check reading at 15.7 in. (40 cm). If this is within the limits set forth in 4-1.7, the test chamber is in calibration and the profile determination is completed. If not, carefully adjust fuel flow, allow 0.5 hours for equilibrium, and repeat the procedure.

**4-1.9** Plot the radiant heat energy flux data as a function of distance along the specimen plane on rectangular coordinate graph paper. Carefully, draw the best smooth curve through the data points. This curve will hereafter be referred to as the flux profile curve.

**4-1.10** Determine the open chamber apparent black body and chamber temperatures that are identified with the standard flux profile by opening the door and moving the specimen platform out. Allow 0.5 hours for the chamber to equilibrate. Read the radiation pyrometer output and record the apparent black body temperature in °C. This is the temperature setting that can be used in subsequent test work in lieu of measuring the radiant flux at 7.9 in. (20 cm), 15.7 in. (40 cm), and 23.6 in. (60 cm) using the dummy specimen. The chamber temperature also shall be determined and is an added check on operating conditions.

## Chapter 5 Test Procedure

**5-1** With the sliding platform out of the chamber, ignite the gas-air mixture issuing from the panel face. Allow the unit to heat for one hour. Read the panel apparent black body temperature and the chamber temperature. If these temperatures are in agreement to within ± 9°F (± 5°C) with those determined in accordance with 4-1.9, the chamber is ready for use.

NOTE: It is recommended that a sheet of inorganic millboard 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 base and to protect the operator.

**5-2** 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 nuts firmly. Return the sample holder to its upright position, clean the test surface with a vacuum, brush, or cloth, and mount on the specimen platform. Carpet specimens shall be brushed to raise the pile to its normal position.

**5-3** Remove the millboard sheet, ignite the pilot burner, move the specimen into the chamber, and close the hinged portion of the front panel. Start the timer and the chamber temperature recorder. After 2 minutes of preheating and with the pilot burner on and set so that the flame is 1.97 in. (5 cm) above the specimen, bring the pilot burner flame into contact with the center of the specimen at the 0 in. (0 cm) mark. Leave the pilot burner flame in contact with the specimen for 10 minutes, then remove to a position 1.97 in. (5 cm) above the specimen. If the specimen does not ignite within 10 minutes following pilot burner flame application, the test is terminated by raising the pilot burner flame to a point 1.97 in. (5 cm) above the specimen plane.

**5-4** If the specimen does not ignite within 10 minutes following pilot burner flame application, the test is terminated by extinguishing the pilot burner flame. For specimens that do ignite, the test is continued until the flame goes out. Observe and record significant phenomena such as melting, blistering, penetration of flame to the substrate, etc.

**5-5** When the test is completed, the hinged portion of the front panel is opened, the specimen platform is pulled out, and the protective millboard sheet is put in place (*see Note to Section 5-1*).

**5-6** Measure the distance burned, i.e., the farthest point of advance of the flame front, to the nearest 0.04 in. (0.1 cm). From the flux profile curve, convert the distance to Btu/ft$^2$ sec (W/cm$^2$) critical radiant heat flux at flameout. Read to two significant figures. A suggested data log format is shown in Appendix C.

**5-7** Remove the specimen and its mounting frame from the movable platform.

**5-8** The succeeding test can begin as soon as the panel apparent black body temperature is verified (*see 4-1.10*). The test assembly should be at room temperature prior to start-up.

## Chapter 6 Calculations

**6-1** The mean, standard deviation, and coefficient of variation of the critical radiant flux test data on the three specimens shall be calculated in accordance with ASTM STP 15C-1951, *Manual on Quality Control of Materials*.

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

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

(*See Appendix F.*)

## Chapter 7 Report

**7-1** The report shall include the following (*see Appendix C for sample report forms*):

(a) Description of the flooring system tested including its elements.

(1) If a textile floor covering is tested, indicate whether it has been washed.

(b) Description of the procedure used to assemble the floor system specimen.

(c) Number of specimens tested.

(d) Average critical radiant flux standard deviation, and coefficient of variation.

(e) Observations of the burning characteristics of the specimen during the testing exposure, such as delamination, melting, shrinking, etc.

## Chapter 8 Referenced Publications

**8-1** The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

**8-1.1 ASTM Publications.** The American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

ASTM STP 15C-1951, *Manual on Quality Control of Materials*.

ASTM E-122-72-1979, *Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process*.

ASTM E-171-87 *Standard Specification for Standard-Atmospheres for Conditioning and Testing Materials*.

## Appendix A Procedure for Calibration of Apparatus

*This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.*

### A-1 Radiation Pyrometer.

**A-1-1** Calibrate the radiation pyrometer by means of a conventional black body enclosure placed within a furnace and maintained at uniform temperatures of 860, 878, 896, 914, 932, and 950°F (460, 470, 480, 490, 500, and 510°C). The black body enclosure may consist of a closed chromel metal cylinder with a small sight hole in one end. Sight the radiation pyrometer on the opposite end of the cylinder where a thermocouple indicates the black body temperature. Place the thermocouple within a drilled hole and in good thermal contact with the black body. When the black body enclosure has reached the appropriate temperature equilibrium, read the output of the radiation pyrometer. Repeat for each temperature.

### A-2 Total Heat Flux Meter.

**A-2-1** The total heat flux meter should be calibrated by a laboratory having suitable calibration facilities, or, alternatively, its calibration should be developed by transfer calibration methods with an NBS calibrated flux meter. This latter method of calibration should make use of the flooring radiant panel tester as the heat source. Measurements should be made at each of the nine dummy specimen positions, and the mean value of these results should constitute the final calibration.

**A-2-2** It is recommended that each laboratory maintain a dedicated calibrated reference flux meter against which one or more working flux meters can be compared as needed. The working flux meters should be calibrated according to the procedure of A-2-1 at least once per year.

## Appendix B Guide to Mounting Methods

*This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.*

**B-1 Introduction.**

**B-1-1** This guide has been compiled as an aid in selecting a method for mounting various building materials in the fire test chamber. These mountings are suggested for test method uniformity and convenience.

**B-2 Mounting Procedures.**

**B-2-1 Carpet Over Concrete, Simulated.** Carpet specimens should be cut in the machine direction and mounted with the pile lay facing the gas panel. To mount the samples, invert the specimen holder on a clean, flat surface. Insert the test specimen in the holder. If the system includes an underlay, it is inserted next, followed by nominal 1/4-in. (0.64-cm) thick high density [110 ± 5 lb/ft$^3$ (1762 ± 80 kg/m$^3$)] inorganic reinforced cement board and a 1/2-in. (1.3-cm) 46-lb/ft$^3$ (0.74-g/cm$^3$) inorganic millboard which must be used with all test specimens. Finally, place the steel bar clamps across the assembly and tighten firmly.

**B-2-2 Carpet with or without Integral Cushion Pad Bonded to Concrete, Simulated.** Carpet specimens should be cut in the machine direction. The adhesive should be that recommended by the carpet manufacturer. Apply the adhesive to the smooth side of the inorganic reinforced cement board according to the directions provided by the adhesive manufacturer.[1] Apply a nominal 20-lb (9.4-kg) roller that is at least the width of the specimen, rolling across the top of the specimen to assure good contact with the substrate. Mount the specimen in the testing frame as described in B-2-1 and testing according to standard procedure.

**B-2-3 Carpet, Other.** Follow and/or simulate commercial installation practice to the extent possible.

**B-2-4 Resilient Flooring.** Follow and/or simulate commercial installation practice to the extent possible.

**B-2-5 Hardwood Flooring.** Follow and or simulate commercial installation practice. In a typical system, the substrate is a 1/2-in. (1.3-cm) plywood sheet covered with building paper. The oak flooring strips are nailed to the plywood then sanded, sealed, and waxed. The assembly should be treated with the same moisture content as the oak (7 to 8 percent).

[1] In the absence of a manufacturer's recommendation, apply adhesive with a 1/16-in. (1.6-mm) square notched trowel.

## Appendix C

*This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.*

**C-1 Radiant Flux Profile**

*(Please indicate °F/°C or US/SI units by circling where appropriate.)*

Date ______________________

Black Body Temperature ________ mv ________ °F (°C)

Gas Flow ______________________ SCFH (NTPm$^3$H)

Airflow ______________________ SCFH (NTPm$^3$H)

Room Temperature ______________________ °F (°C)

Air Pressure ________ Gas ________ in. (cm) of $H_2O$

Flux Meter Conversion Factor ________

Radiometer No. ________ From Calibration On ________

| Distance in. (cm) | MV | Btu/ft$^2$ sec (W/cm$^2$) |
|---|---|---|
| 3.94 (10) | ________ | ________ |
| 7.87 (20) | ________ | ________ |
| 11.81 (30) | ________ | ________ |
| 15.75 (40) | ________ | ________ |
| 19.69 (50) | ________ | ________ |
| 23.62 (60) | ________ | ________ |
| 27.56 (70) | ________ | ________ |
| 31.50 (80) | ________ | ________ |
| 35.43 (90) | ________ | ________ |

Signed______________________

**C-2 Flooring Radiant Panel Test Data Log Format**

*(Please indicate °F/°C or US/SI units by circling where appropriate.)*

Test Number ________ Date ________ Time ________

Laboratory ______________________

Specimen Identification/Code No. ______________________

Test Assembly ______________________

Panel: Angle ________ ° Temperature ________ °F (°C)

Flow: Gas ___ SCFH (NTPm$^3$H) Air ___ SCFH (NTPm$^3$H)

Pressure, in. (cm) $H_2O$: Initial, Air ______ Gas ________

Chamber: Temperature Initial ____ Maximum ____ °F (°C)

Room: Temperature ______________________ °F (°C)

Hood Draft ______________________ in. (cm) Water

Flame Front Advance

| Distance in. (cm) | Time min. | | | | | | |
|---|---|---|---|---|---|---|---|
| ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |

Total Burn Length____________in. (cm)

Critical Radiant Flux Btu/ft$^2$ sec (W/cm$^2$)____________________

Flame Front Out________min Flux Profile Reference________

All Flame Out________________________min

Observations

Signed____________________________________

## Appendix D Safety Precautions

*This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.*

**D-1** The possibility of an air-gas fuel explosion in the test chamber should be recognized. Suitable safeguards consistent with sound engineering practice should be installed in the panel fuel supply system. These safeguards may include one or more of the following:

(a) A gas feed cutoff activated when the air supply fails.

(b) A fire sensor directed at the panel surface that stops fuel flow when the panel flame goes out.

(c) A commercial gas water heater or gas-fired furnace pilot burner control thermostatic shutoff that is activated when the gas supply fails or other suitable and approved device.

(d) Manual reset is a requirement of any safeguard system used.

**D-2 Products of Combustion Hazard.** In view of the potential toxicity hazard from products of combustion, the exhaust system should be so designed and operated that the laboratory environment is protected from smoke and gas. Operators should be instructed to minimize their exposure to combustion products by following sound safety practices (e.g., ensuring that the exhaust system is working properly, wearing the appropriate clothing, including gloves).

## Appendix E

### Commentary on the Flooring Radiant Panel Test

*This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.*

Numbers in parentheses refer to the references in Appendix G.

**Introduction.** During the early stage of fire development in a building, experience suggests that floor covering systems have seldom served as a fire spread medium. For example, in the United Kingdom, floor covering was found to be the first material ignited in only 2 to 3 percent of all the building fires reported between 1955 and 1962 (1). However, during some recent fires, floor covering materials in corridors were involved in spreading fire over considerable distances (2, 3, 4). This has caused concern and has pointed to the need for a relevant fire test that could be used by the regulatory community to control the type of floor covering systems installed in building corridors and exitways. Attention is focused on corridors and exitways because they are often the principal path of fire spread in building fires, and therefore usually subject to more rigid code requirements for interior surface finish. Less stringent restrictions are usually applied to individual rooms, where building contents items are unrestricted.

**Nature of Fire Growth with Respect to Floor Coverings.** As a fire develops in a building compartment, flames will extend toward the ceiling of the enclosure and a hot flowing layer of combustion products will be formed beneath the ceiling. Items below this layer and outside the flame region will receive heat by means of radiation from both the flame and the hot upper region of the compartment. Thus, a floor covering in a building corridor will receive heat by radiation if it is exposed to heat flux from an adjoining room fire. As the fire grows, this irradiance level, as measured at the floor, will increase. As the irradiance level increases, both the temperature of the floor covering system and the potential for ignition increase. If ignition occurs, the probability of sustained flame spread will depend on the temperature of the floor covering located ahead of the moving flame front. This temperature distribution, resulting from the radiant flux, will determine whether the floor covering flame spread will accelerate or decelerate. The level of irradiance [or incident radiant flux, Btu/ft$^2$ sec (W/cm$^2$)] will depend on the nature and size of the room fire, the size of the room and its construction, and the extent of its open doorways, windows, and ventilation ducts. The geometry and ventilation conditions of the corridor also are significant in their affect on the level of irradiance to the corridor floor. In general the irradiance level will decrease with distance from the fire source, and the direction of airflow along the floor (induced by the fire) will be toward the fire. Thus, in the early development of a fire, a floor covering is likely to spread fire away from the igniting fire source, against the induced airflow, and in the direction of decreasing irradiance. It is in this context that the floor covering radiant panel test is applicable.

**Nature of the Floor Covering Radiant Panel Test.** Much of the early development of the present test method is credited to Zabawsky, who began work on it at Armstrong Cork Company in 1966. Further work by Hartzel (5) led to modifications in the prescribed method, which brought it nearly to its present state. The final test method is described by Benjamin and Adams (6) who also report on an extensive series of interlaboratory tests to determine the reproducibility and repeatability of the test method. A theoretical model that simulates the flame spread process in the test method was presented by Quintiere (7). In addition, a comparison of Radiant Panel Test for Floor Coverings with other fire spread test methods was made by Quintiere and Huggett (8).

The test method measures a "fire property" of the floor covering system that is expressed as a physical quantity. This is in contrast to an "index of performance," that would express the overall fire behavior of the material tested. The "property" is the minimum incident radiant heat flux necessary to sustain flame spread and has been termed the "critical radiant flux" (CRF) for flame spread. Its value is representative of a floor covering system (e.g., carpet and underlayment), and would be influenced by the aerodynamics associated with the flame. Primarily, the radiant panel in the test apparatus represents the external radiation caused by from the hot upper region of the building compartment or corridor. It can also represent the radiation caused by from an igniting fire such as a chair fire or flame plume in a doorway. Moreover, the direct heat transfer from the floor covering flame in the test apparatus is similar to the actual floor covering fire behavior as it spreads against the induced airflow. In these cases the flame heat flux decreases sharply ahead of the front after approximately 1 cm (9). This is in contrast to the less likely scenario of the early development of a floor covering fire that spreads in the direction of airflow. In order to determine, in a quantitative manner, the firesafety of a floor covering system, one must compare its CRF to the level of irradiance likely to be encountered during actual building fire conditions. The anticipated irradiance depends on many factors that are not measured by the test method, such as the initial conditions of the building and its contents. Evaluation of these factors, at least at present, is beyond the state-of-the-art of calculation.

Figure E-1 illustrates the effect of radiant flux on a typical floor covering system. If the incident flux exceeds the CRF and an ignition source initiates flame spread, then the flame will spread at a decreasing speed with decreasing flux. For each value of incident flux, the curve displayed in Figure E-1 is the maximum of steady-state flame spread speed that would result after heating the floor covering to its thermal equilibrium level for that flux. Below the CRF for the system, no flame spread is possible. At a level of incident flux to the right of point "I," the flame spread is very rapid and ill-defined. In fact, a flame would flash over the entire surface exposed to this threshold heat flux in the presence of a small pilot flame. In the test apparatus the flame front is roughly following the curve in Figure E-1, moving from high to low flux and ending in extinguishment at the flux corresponding to the CRF.

**Experimental Studies of Relevance.** The CRF was selected as a significant "property" for floor covering systems because both small and full-scale experiments in corridor configurations demonstrated the importance of radiant heating in initiating and maintaining a floor covering fire (10, 11, 12). Full-scale fire experiments designed to characterize the hazard of floor covering materials in building corridors were conducted at the National Bureau of Standards (NBS) (11, 12) and the Illinois Institute of Technology Research Institute (IITRI) (13). In both sets of experiments the corridor was exposed to a large room fire. The only combustible material in the corridor was the floor covering, and ventilation took place through an opening at one end of the corridor. A comparison of the NBS and IITRI room and corridor facilities is shown in Figure E-2.

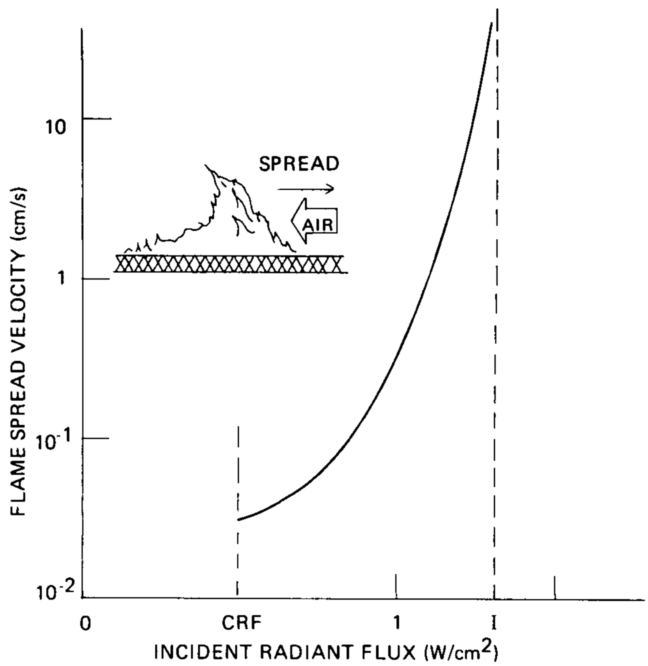



**Figure E-1 Typical Effect of Radiant Flux on Horizontal Flame Spread Speed.**

From a fire exposure condition, the "L-shaped" configuration is severe, since all of the hot fire gases must flow into the corridor in only one direction. Windows in the room, or a corridor open at two ends, would reduce the rate of hot gases flowing along the corridor. Moreover, adverse external wind conditions would dilute the fire gases as well as influence the direction of fire spread in a corridor. The NBS experiments used wood cribs as a fuel source, which could burn at a rate of 60-70 g/s[1] for about 12 minutes. The IITRI experiments used natural gas as a fuel generating a potential energy release of about 2000 kW (or roughly 130 g/s of wood fuel equivalent) for about 20 minutes.[1]

Dramatic differences in fire behavior were observed in these two sets of experiments. This is shown in Figure E-3. The IITRI experiments show a limited flame travel regardless of the CRF of the floor covering. In the IITRI series, the corridor floor covering fire spread relatively slowly; in 10 of 11 experiments it spread no farther than 4.5 m. However, in 11 of 14 NBS experiments, flameover or rapid and extensive flame travel (9.2 m, the length of the corridor) was observed, regardless of the CRF of the floor covering.

An appreciation of the reasons for these apparently conflicting results is crucial to understanding the proper application of the test method. The first point to be considered is difference in geometric and initial conditions employed in the two facilities that would cause differences in the transport of mass and heat (8) (14). Note, for example, that the heat loss to the room walls is estimated to be four times as great for the IITRI experiments as for the NBS tests. Also, the burn room and door to the corridor were both substantially larger in the IITRI work. These factors contribute to the rate of energy delivered through the door

[1] One gram/second (g/s) is roughly equivalent to 8 lbs/hr

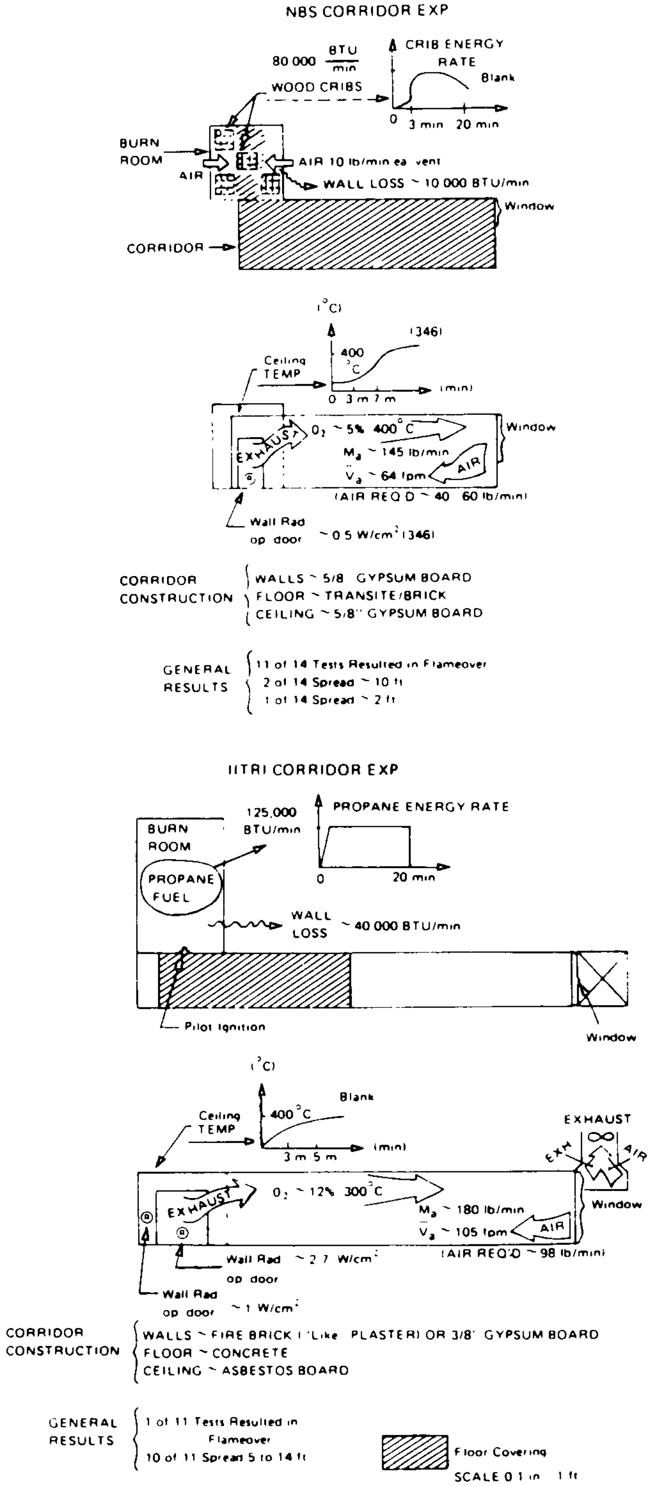



**Figure E-2 A Comparison of the NBS and IITRI Corridor Floor Covering Experiments.**

way. Another reason for the dramatic difference in fire propagation is the energy feedback process set up by energy released from the burning floor. The resulting hot gases are transported along the corridor ceiling, inducing more radiant heating of the corridor floor and hence increasing flame spread speed. (Note such a feedback mechanism is not significant in the test method.) This heat and mass transport is influenced by geometry and ventilation. There is also evidence to suggest that, in the NBS experiments, the floor covering fire affected the flow, and thus influenced the fire behavior (12). Another important contributing factor is that the NBS corridor gases vented through a window compared to a fully opened corridor window in the IITRI tests. The NBS tests approached, at times, a ventilation-limited room fire. Under low ventilation and high rates of fuel production, unburned products of combustion can accumulate and burn as they encounter sufficient air. This flameover type of burning can take place in the corridor, after the products have left the room. Such conditions can result in fire spread in corridors even without the support of any combustibles in the corridor. Shaffer and Eickner (15) report such a gas phase fire propagation in a corridor in which a large wood crib burned at an average of 150 g/s with two 1 m × 1.3 m windows capable of supplying air sufficient to burn, at most, 200 g/s of wood — a nearly ventilation-limited fire. Incidentally, the wood corridor floor in these tests ignited, but sustained only limited flame spread.

Several actual fire incidents are also plotted in Figure E-3. They demonstrate that a large ignition source can initiate extensive fire spread along corridors and stairways in which the floor covering is the only or primary combustible lining (2, 3, 4).

In all the fire incidents and experiments shown in Figure E-3, it can be shown by available data or by estimation that the irradiation to the corridor floor near the fire room doorway was greater than the CRF of the floor covering system. Hence, in all cases, given ignition, fire would begin to spread on the corridor floor covering. In these cases, the CRF values were determined by measurement in the test method, or, in the case of the IITRI values, they were estimated at an upper limit using data that had been gathered with an apparatus similar to the current test method (13).

Thus, if the irradiance level exceeds the CRF value for the floor covering, a floor fire is likely to spread, given ignition. The nature and extent of fire propagation cannot be predicted by the CRF value alone; it depends on the entire dynamic interaction of the corridor system, material properties, and resultant energy transport and feedback. Additional data are available to illustrate the merit of the test under less severe fire exposure conditions. These result from a series of experiments on crib or furniture item fires in a well-ventilated 3.4 × 2.7 m room of 2.4 m height that had been fitted with floor covering assemblies of known critical radiant flux characteristics. In these tests, the crib and floor covering assembly were the only combustibles in the room. The crib was located near one corner of the room, remote from the ventilation opening.

The results of this study by Davis (16) show some of the data developed in Figure E-4, which shows the extent of fire propagation from the crib as a function of critical radiant flux. The four floor coverings used were carpets that had all 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 illustrated by this figure, the data show that the burning ceased at positions on the floor covering system somewhat below those at which maximum flux measurement during a calibration

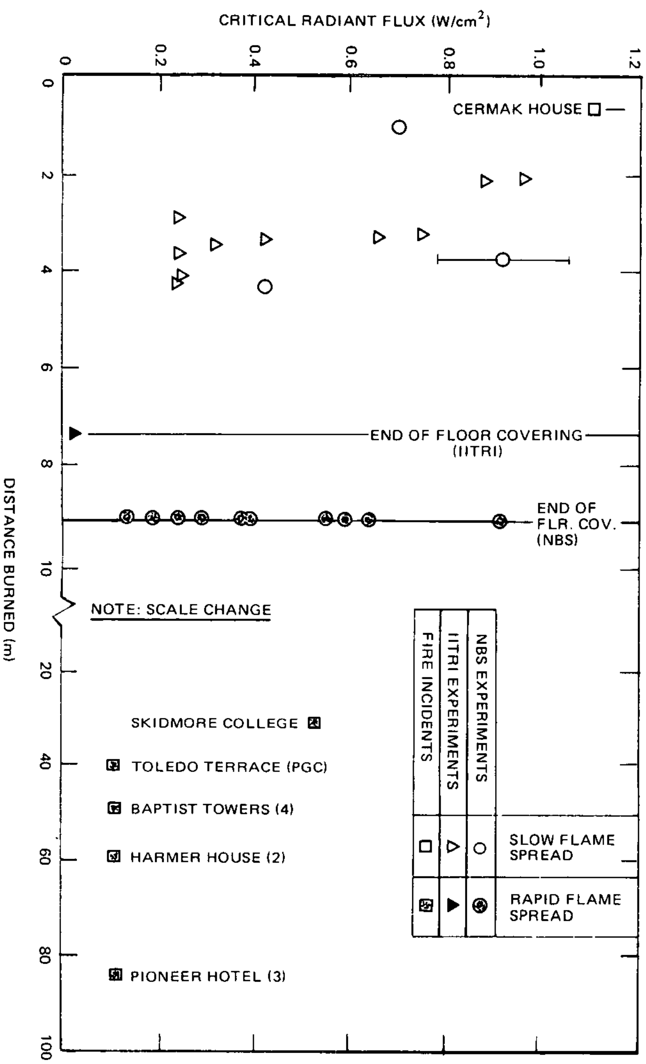



**Figure E-3 Performance of Floor Coverings in Corridor Fires Subject to Initial Irradiance Levels of Approximately 1-2 W/cm².**

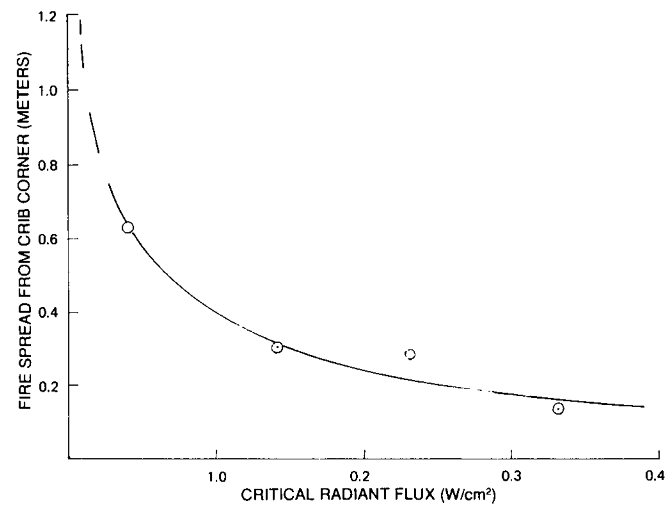



**Figure E-4 Room Burn Tests: Fire Spread from Crib Along Floor Covering; 6.4 kg (14 lb) Wood Cribs.**

test corresponded to the CRF of the flooring 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.

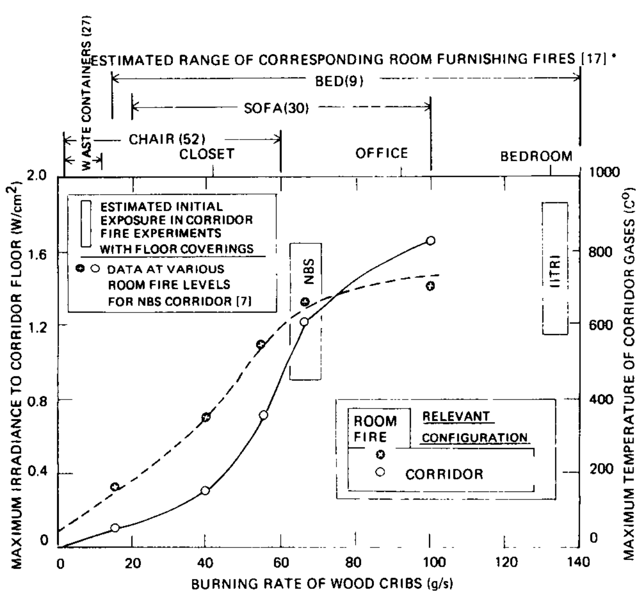
These experiments make obvious two facts:

1. The critical radiant flux concept is a useful parameter in predicting whether a floor covering system will propagate fire given ignition under radiant exposure.

2. The ability to predict the radiant flux that the flooring material will actually experience under real fire conditions depends on fuel load, room and corridor configurations, and ventilation. None of these parameters can be determined by the test method.

**Application of CRF to Building Corridors.** If the radiant flux to a floor could be predicted, then the selection of a floor covering on the basis of its CRF would be straightforward. This approach is not completely practical in view of all the variables that can influence fire growth and exposure, and in view of the limited quantitative understanding that currently exists. However, for a limited number of situations, tests can be conducted to provide a basis for gaining guidance. Data from such tests (7) are shown in Figure E-5. These tests were conducted in the NBS corridor facility described in Ref. (11). They display the maximum heat flux to the corridor floor 1.2 m from the doorway of a room in which various levels of wood crib fires were established. The maximum temperature of the combustion products entering the corridor is also shown. The range of corresponding floor heat flux preceding floor involvement is also indicated on the graph for the NBS and IITRI floor covering fire experiments. Furthermore, the range of equivalent wood burning rates of typical furnishing fires was estimated from available data (16) and superimposed on the figure. For a single corridor configuration similar in size and construction to the NBS facility (11), the figure can then be used to gain a measure of the floor irradiance associated with a particular type of room fire.

It must be emphasized that the application of critical irradiance levels of 0.25 and 0.50 W/cm² suggested by Benjamin and Adams (6) would not ensure against fire spread when floor coverings are exposed to thermal radiation levels of higher intensity. They should, however, significantly reduce the potential for flame spread on floor coverings. This is illustrated qualitatively by Figure E-6, in which the probability of extensive floor covering fire spread is plotted against CRF for a given exposure irradiance. The curve showing decreasing probability with increasing CRF was inferred from the premise that if the CRF exceeds the exposure flux, flame spread is impossible, but if the CRF is less than the exposure flux, then the chance of flame spread is likely. In fact, this probability is a function of many variables whose effect on the fire growth cannot be sufficiently quantified at this time. In principle, a firesafety design process could consider the potential fire scenario, such as a chair fire. Then the initial corridor floor irradiance due to the room fire could be determined from Figure E-5 (for, at least, that room and corridor configuration shown in the figure). This would indicate a flux of 0.15 W/cm² for an "average chair fire" but a flux as high as about 0.9 W/cm² for the extreme of "chair fires."




*Position of label indicates an average value for a number of tests indicated by (), or indicates the result of a single experiment.

**Figure E-5 Corridor Fire Exposure for Various Room Fire Levels, Applicable to a Room-Corridor Configuration Similar to that of the NBS Experiments (7).**

Of course, an increase in room or corridor ventilation for the configuration in Figure E-5 would yield lower flux levels. Judgment must then be used to select a design irradiance for the chair fire scenario; assume this is 0.5 $W/cm^2$, i.e., between 0.15 and 1 $W/cm^2$. Figure E-6 would then indicate qualitatively the consequences of selecting a given floor covering (or CRF). Thus, in this fashion, a rational design practice can be developed based on the test result of CRF, data from full-scale actual fire incidents, and experienced judgments.

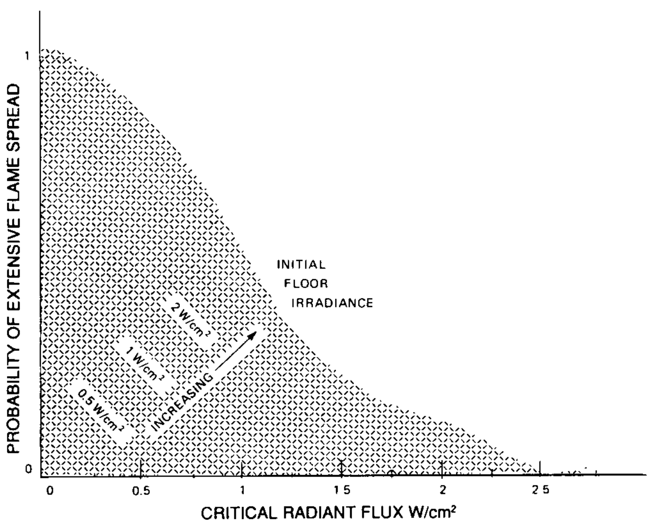



**Figure E-6 Estimated Probability of Extensive Corridor Fire Spread for a Given Initial Floor Irradiance.**

It should be emphasized that the above discussion applies to corridors with combustible floor coverings only. Corridors with combustible wall and ceiling linings would be expected to be a greater potential fire hazard. Experimental results suggest that floor coverings would contribute much less to fire spread than wall or ceiling linings in the initial growth and spread of corridor fires (18).

**Summary.** It must be recognized that the critical radiant flux test method provides a useful way of rank ordering flooring system assemblies in terms of CRF. However, this is only one of several parameters that determine the fire behavior of flooring systems. Critical radiant flux indicates the threshold above which flame spread will occur. To use this property in firesafety 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 ignition delay time, rate of flame spread and energy release, as well as corridor configuration, can be important in determining the ultimate spread of the fire.

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

## Appendix F Precision

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.

**F-1** Defining a test result as the average of three replicate determinations, the repeatability (within laboratory variability) was about 20 percent of the measured value and the reproducibility (among laboratory variability) about 35 percent of the measured value.

NOTE 1: "Repeatability" is a quantity that will be exceeded only about 5 percent of the time by the difference, taken in absolute value, of two randomly selected results obtained in the same laboratory on a given material. Reference: Mandel, John, Repeatability and Reproducibility, Materials Research and Standards, MTRSA, vol. II (8), p. 8.

NOTE 2: "Reproducibility" is a quantity that will be exceeded only about 5 percent 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. Reference: see reference in note 1 above.

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