NBS CENTER FOR FIRE RESEARCH
PROGRAM FOR FIRE CONTROL - FURNISHINGS

PROPOSED PROCEDURE

STANDARD METHOD OF TEST FOR CRITICAL RADIANT FLUX OF FLOOR COVERING SYSTEMS USING A RADIANT HEAT ENERGY SOURCE

June 1975

1. Scope

1.1 This method of test describes 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. The specimen can be mounted over underlayment, a simulated concrete structural floor, bonded to a simulated structural floor or otherwise installed in the chamber in a typical and representative way.

1.2 This method measures the critical radiant flux at flame out. It provides a basis for estimating one aspect of flame spread behavior for floor covering systems in corridors or exitways of buildings. The imposed radiant flux simulates the thermal radiation levels likely to impinge on the floor of a corridor whose upper surfaces are heated by flames and/or hot gases from a fully developed fire in an adjacent room or compartment.

2. Summary of Method

2.1 The basic elements of the test chamber, Figure 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, Figure 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 watts/cm^2 to a minimum of 0.1 watt/cm^2. The test is initiated by open flame ignition from a pilot burner. The distance burned to flame out is converted to watts/cm^2 from the flux profile graph, Figure 6, and reported as critical radiant flux, watts/cm^2.

3. Significance

3.1 This method of test is designed to provide a basis for estimating one aspect of the flame spread 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.

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

3.3 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 in a building corridor.

3.4 The test is applicable to floor covering system specimens which 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.

4. Definitions of Terms

4.1 Critical Radiant Flux is the level of incident radiant heat energy on the floor covering system at the most distant flame out point. It is reported as watts/cm^2 (Btu/ft^2 sec).

4.2 Flux Profile is the curve relating incident radiant heat energy on the specimen plane to distance from the initiation of flaming ignition point i.e. 0 cm.

4.3 Total flux meter is the instrument used to measure the level of radiant heat energy incident on the specimen plane at any point.

4.4 Black Body Temperature is the temperature of a perfect radiator--a surface with an absorptivity of unity and, therefore, a reflectivity of zero.

5. Flooring Radiant Panel Test Chamber -- Construction & Instrumentation

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

5.1.1 The flooring radiant panel test chamber, Figures 3 and 4, shall consist of an enclosure 140 cm [55 in.] long by 50 cm [19-1/2 in.] deep by 71 cm [28 in.] above the test specimen. The sides, ends, and top shall be of 1.3 cm [1/2 in.] calcium silicate-asbestos fibre, 0.58 g/cm^3 [36 lbs/ft^3] nominal density, insulating material with a thermal conductivity @ 200°F of 0.96 cal. (gm)/hr. cm^2 deg C per cm [0.77 Btu/(hr.) (ft^2) (deg F per in.)]. One side shall be provided with a draft tight fire 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 is a door which when open allows the specimen platform to be moved out for mounting or removal of test specimens.

5.1.2 The bottom of the test chamber shall consist of a sliding steel platform which has provisions for rigidly securing the test specimen holder in a fixed and level position. A metal scale with 1.3 cm [1/2 in.] high pedestal markers, at 4-5 cm intervals, is mounted on the back of the platform. The free, or air access, area around the platform shall be in the range of 1950-3550 cm^2 [300-500 square inches].

5.1.3 The top of the chamber shall have an exhaust stack with interior dimensions of 12.5 cm [5 in.] wide by 38 cm [15 in.] deep by 30 cm [12 in.] high at the opposite end of the chamber from the radiant panel.

5.2 The radiant heat energy source shall be a panel of porous refractory material mounted in a cast iron frame, with a radiation surface of 30.5 x 45.7 cm [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 an aspirator for mixing gas and air at approximately atmospheric pressure, a clean dry air supply capable of providing 28.3 NTP m^3 per hr. [1000 Standard Cubic Feet per Hour] at 7.6 cm [3.0 in.] of water, and suitable instrumentation for monitoring and controlling the flow of fuel to the panel.

5.2.1 The radiant heat energy panel is mounted in the chamber at 30° to the horizontal specimen plane. The horizontal distance from the 0 mark on the specimen fixture to the bottom edge (projected) of the radiating surface of the panel is 8.9 cm [3-1/2 in.]. The panel to specimen vertical distance is 14 cm [5-1/2 in.], see Figure 3.

5.2.2 The radiation pyrometer for standardizing the thermal output of the panel shall be suitable for viewing a circular area 25.4 cm [10 in.] in diameter at a range of about 1.37 m [54 in.]. It shall be calibrated over the 490-510C (914-950F) operating black body temperature range in accordance with the procedure described in the Appendix.

5.2.3 A portable high impedance potentiometric voltmeter with a suitable millivolt range shall be used to monitor the output of the radiation pyrometer described in 5.2.2.

5.3 The specimen holder (see Figure 5), is constructed from heat resistant stainless steel* having overall dimensions of 115 cm [45 in.] by 32 cm [12-3/4 in.] with a specimen opening of 20 cm [7.9 in.] x 100 cm [40 in.]. Six slots are cut in the flange on either side of the

*Thickness 0.198 cm (0.078 in.).

holder to reduce warping. The holder is fastened to the platform with two stud bolts at each end.

5.4 The pilot burner used to ignite the specimen is a commercial propane venturi torch* with an axially symmetric burner tip having a propane supply tube with an orifice diameter of 0.0076 cm [0.003 in.]. In operation, the propane flow is adjusted to give a pencil flame blue inner cone length of 1.3 cm [1/2 in.]. The pilot burner is positioned so that the flame generated will impinge on the center line of the specimen at the 0 distance burned point at right angles to the specimen length, see Figures 3 and 4. The burner shall be capable of being swung out of the ignition position so that the flame is horizontal and at least 5 cm [2 in.] above the specimen plane.

5.5 Two 0.32 cm [1/8 in.] stainless steel sheathed grounded junction chromel alumel thermocouples[1] are located in the Flooring Radiant Panel Test Chamber, see Figures 3 & 4.

5.5.1 A recording potentiometer with a range of 100-500C (212-932F) may be used to plot the stack and chamber temperatures prior to and during a test.

5.6 An exhaust hood with a capacity of 28.3-85 NTP m^3 per minute (1000-3000 SCFM) decoupled from the chamber stack by at least 7.6 cm [3 in.] on all sides and with an effective area equivalent to the plan area of the chamber with the specimen platform in the out position is used to remove combustion products from the chamber.

5.7 The dummy specimen which is used in the flux profile determination shall be made of 1.9 cm [3/4 in.] inorganic 0.58 g/cm^3 [36 lbs/ft^3] nominal density calcium silicate asbestos fibre board (see

*BERNZ-O-MATIC TX 101 or equivalent.

[1]Thermocouples should be kept clean to insure accuracy of readout.

Figure 5). It is 25 cm [10 in.] wide by 107 cm [42 in.] long with 2.7 cm [1-1/16 in.] diameter holes centered on and along the center line at the 10, 20, 30 ---- 90 cm locations, measured from the maximum flux end of the specimen.

5.7.1 The total heat flux transducer used to determine the flux profile of the chamber in conjunction with the dummy specimen should be of the Schmidt-Boelter[2] type, have a range of 0-1.5 watts/cm^2 (0-1.32 Btu/ft^2 sec.), and shall be calibrated over the operating flux level range of 0.10 to 1.5 watts/cm^2 in accordance with the procedure outlined in the Appendix. A source of 15-25C cooling water shall be provided for this instrument.

5.7.2 A high impedance or potentiometric voltmeter with a range of 0-10 m.v. and reading to 0.01 m.v. shall be used to measure the output of the total heat flux transducer during the flux profile determination.

5.8 A 999 minute timer reading to seconds or hundredths of minutes shall be conveniently mounted on the chamber for documenting event interval observations.

6. Safety Precautions

6.1 The possibility of a gas-air 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 may include one or more of 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 which is activated when the gas supply fails or other suitable and

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[2]Medtherm 64-2-20 will meet this requirement.

approved device. Manual reset is a requirement of any safeguard system used.

6.2 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 should be instructed to minimize his exposure to combustion products by following sound safety practice, e.g. insure exhaust system is working properly, wear appropriate clothing including gloves, et al.

7. Sampling

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

7.2 Standard ASTM sampling practice shall be followed where applicable, see ASTM Method E-122.

8. Test Specimens

8.1 The test specimen shall be a floor covering system sized to provide for adequate clamping in the mounting frame. Its minimum dimensions shall exceed the frame width [20 cm (7.9 in.) nominal] and length [100 cm (39.4 in.) nominal] by about 5 cm (2 in.). It may be necessary to notch or punch holes in the specimen to accommodate the mounting frame bolts (see Figure 5).

8.2 Insofar as possible, the floor covering system specimen should simulate actual installation practice. Typical examples follow:

8.2.1 A carpet should be mounted over the standard[3] cushion or the standard simulated concrete subfloor[4], see Appendix A2.2.1.

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[3] Standard is: Type II - Rubber Coated Jute and Animal Hair or Fiber (3/8" thick, 55 oz/yd^2) DD-C-001023 (GSA-FSS) Amendment - 1 March 10, 1972. The option of specifying that the actual cushion pad to be used in the installation be tested is also acceptable.

[4] Standard is: Flat asbestos-cement sheet 1/4" thick, ASTM C220. The option of specifying that the actual subfloor to be used in the installation be tested is also acceptable.

8.2.2 A carpet with or without integral cushion pad should be bonded to a high density inorganic sheet simulating a concrete subfloor, see Appendix A2.2.2.

8.2.3 A resilient floor should be bonded to a high density inorganic sheet simulating a concrete subfloor, see Appendix A2.3.

8.2.4 A hardwood floor should be nailed to a plywood subfloor, then sanded and finished according to standard practice, see Appendix A2.4.

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

9. Radiant Heat Energy Flux Profile Standardization

9.1 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.

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

9.3 With the sliding platform out of the chamber, ignite the gas-air fuel mixture issuing from the panel face. Allow the unit to heat for one hour. 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 black body temperature to about 500 C (932 F), and the chamber temperature to about 180 C (356 F). When equilibrium has been established, move the specimen platform into the chamber.

9.4 Allow 0.5 hours for the closed chamber to equilibrate.

9.5 Measure the radiant heat energy flux level at the 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 0.16-0.32 cm (1/16-1/8 in.) above and parallel to the plane of the dummy specimen and reading its output after 60 seconds. If the level is within the limits specified in 9.6 the flux profile determination is started. If it is not, make the necessary adjustments in panel fuel flow. A suggested flux profile data log format is shown in Figure 7.

9.6 The test shall be run under chamber operating conditions which give a flux profile of the form shown in Figure 6. The radiant heat energy incident on the dummy specimen at the 40 cm point shall be 0.5 $\pm$ 0.02 watts/cm^2 (0.44 $\pm$ 0.017 Btu/ft^2 sec.).

9.7 The flux profile measurements begin with the 10 cm point. Insert the flux meter in the 10 cm opening following the procedure given in 9.5 above. Read the m.v. output at 60 $\pm$ 10 seconds and proceed to the 20 cm point. Repeat the 10 cm procedure. The 30 - 90 cm flux levels are determined in the same manner. Following the 90 cm measurement, make a check reading at 40 cm. If this is within the limits set forth in 9.6, 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.

9.8 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.

9.9 Determine the open chamber 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 optical pyrometer output and record 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 40 cm using the dummy specimen. The chamber temperature should also be determined and is an added check on operating conditions.

10. Conditioning

10.1 Specimens shall be conditioned according to standard practice for the floor covering being tested unless otherwise specified; see ASTM E-171-63.

11. Test Procedure

11.1 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 black body temperature and the chamber temperature. If these temperatures are in agreement to within ±5°C with those determined in accordance with 9.9 above, the chamber is ready for use.

11.2 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 and mount on the specimen platform.

11.3 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 preheat, with the pilot burner on and set so that the flame is horizontal and 5 cm above the specimen, bring the pilot burner flame into contact with the center of the specimen at the 0 cm mark. Leave the pilot burner flame in contact with the specimen for 10 minutes or until flame goes out, whichever occurs first, then remove to a position 5 cm above the specimen. If the specimen does not ignite within 10 minutes following pilot burner flame application, the test is terminated by extinguishing the pilot burner flame or raising it to a point 5 cm above and parallel to the specimen plane.

11.4 For specimens that do ignite, record the flame front advance by noting the time the front passes each 4 or 5 cm mark. Observe and record significant phenomena such as melting, blistering, penetration of flame to the substrate, etc.

11.5 The test is continued until the flame goes out.

11.6 When the test is completed, the hinged portion of the front panel is opened, the specimen platform is pulled out.

11.7 Measure the distance burned i.e. the point of farthest advance of the flame front, to the nearest 0.1 cm. From the flux profile curve, covert the distance burned to watts/cm^2 critical radiant heat flux at flame out. Read to two significant figures. A suggested data log format is shown in Figure 8.

11.8 Remove the specimen and its mounting frame from the moveable platform.

11.9 The succeeding test can begin as soon as mounting of the new specimen is complete and the panel black body temperature verified, see 11.1. It may be desirable to have the test assembly at room temperature prior to start up.

12. Calculations

12.1 The mean and standard deviation of the critical radiant flux test data on the three specimens are calculated in accordance with ASTM standard practice (ASTM Manual on Quality Control of Materials 1951 Edition STP 15C).

$$S = \sqrt{(\Sigma X^2 - n \bar{X}^2) / n - 1}$$

where S = estimated standard deviation

X = value of single observation

n = number of observations, and

$\bar{X}$ = arithmetic mean of the set of observations.

13. Report

13.1 The report shall include the following:

13.1.1 Description of the flooring system tested including its elements.

13.1.2 Description of the procedure used to assemble the flooring system specimen.

13.1.3 Number of specimens tested.

13.1.4 Average critical radiant flux and standard deviation.

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

14. Precision[4]

Defining a test result as the average of 3 replicate determinations, the repeatability (within laboratory variability) is about 20 per cent of the measured value[5] and the reproducibility (among laboratory variability) is of the order of 35 per cent of the measured value[6].

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[4]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.

[5]"Repeatability" is a quantity that will be exceeded only about 5 per cent 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. 11, No. 8, p. 8.

[6]"Reproducibility" is a quantity that will be exceeded only about 5 per cent 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 [4].

APPENDIX

A1. Procedure for Calibration of Radiation Instrumentation

A.1.1 Radiation Pyrometer

A1.1.1 Calibrate the radiation pyrometer by means of a conventional black body enclosure placed within a furnace and maintained at uniform temperatures of 490, 500, and 510 C (914, 932, 950 F). The black body enclosure may consist of a closed chromel metal cylinder with a small sight hole in one end. Sight the radiation pyrometer upon the opposite end of the cylinder where a thermocouple indicates the 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 1.2 Total Heat Flux Meter

A1.2.1 Calibrate the total flux meter against a standard quartz lamp source having a radiant energy output of approximately 0.15 $watts/cm^2$ in accordance with the procedure [NBS Report of Calibration, Test No.: 221.12/ 1B/74 Interdivision Work Order No. 490-2220, dated 10/17/74] developed by the NBS optical radiation group. The precision (3 sigma limits) of the calibration based on 25 measurements at the above single point is of the order of $\pm 1\%$. For a calibration across the operating range of the instrument, the manufacturer of the transducer should be contacted. This calibration can be good to $\pm 5\%$.

A2. Guide to Mounting Methods

A.2.1 Introduction

A2.1.1 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.

A2.2.1 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 waffle side facing the carpet followed by a 0.64 cm [1/4 in.] thick cement asbestos board* and a 1.2 cm [1/2 in.] o.58 gms/cm^2 [36 lbs/ft^3] inorganic millboard. Finally, place the steel bar clamps across the assembly and tighten firmly. Turn the specimen upright and vacuum to remove any foreign particles. Brush the surface to raise the pile to its normal position. Mount the test assembly on the specimen transport frame so that the pile lay faces the panel.

A2.2.2 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. Apply the adhesive uniformly to the smooth side of the cement asbestos board using a notched trowel with 1/16" deep, 3/16" wide notches, 3/16" on center. Press the carpet specimen onto the prepared substrate within 20 minutes. Roll with a standard carpet weighted roller to insure that uniform carpet adhesive contact is achieved. Allow the adhesive to cure for 48 hours. Mount specimen in testing frame as described in A2.2.1 and test according to standard procedure.

*The cement asbestos board may spall during a test. This can be avoided by heating for 12 hours at 325°F.

A 2.3 Resilient Flooring -- Follow and/or simulate commercial installation practice. This will in most instances mean bonding to the standard cement asbestos substrate.

A 2.4 Hardwood Flooring -- Follow and/or simulate commercial installation practice. In a typical system, the substrate would be a 5/8" 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 7-8%.

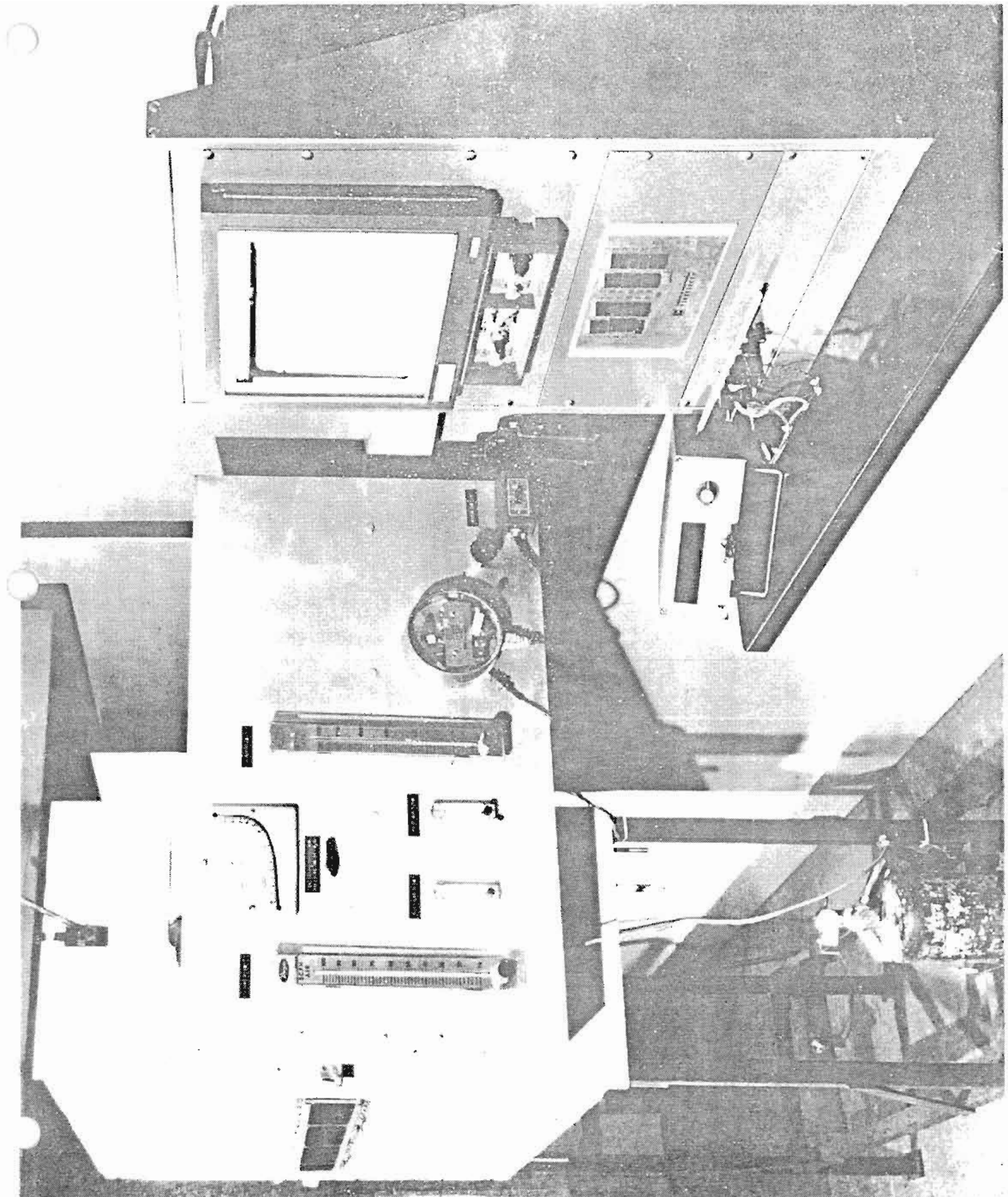

Figure 1. Flooring Radiant Panel Tester Apparatus

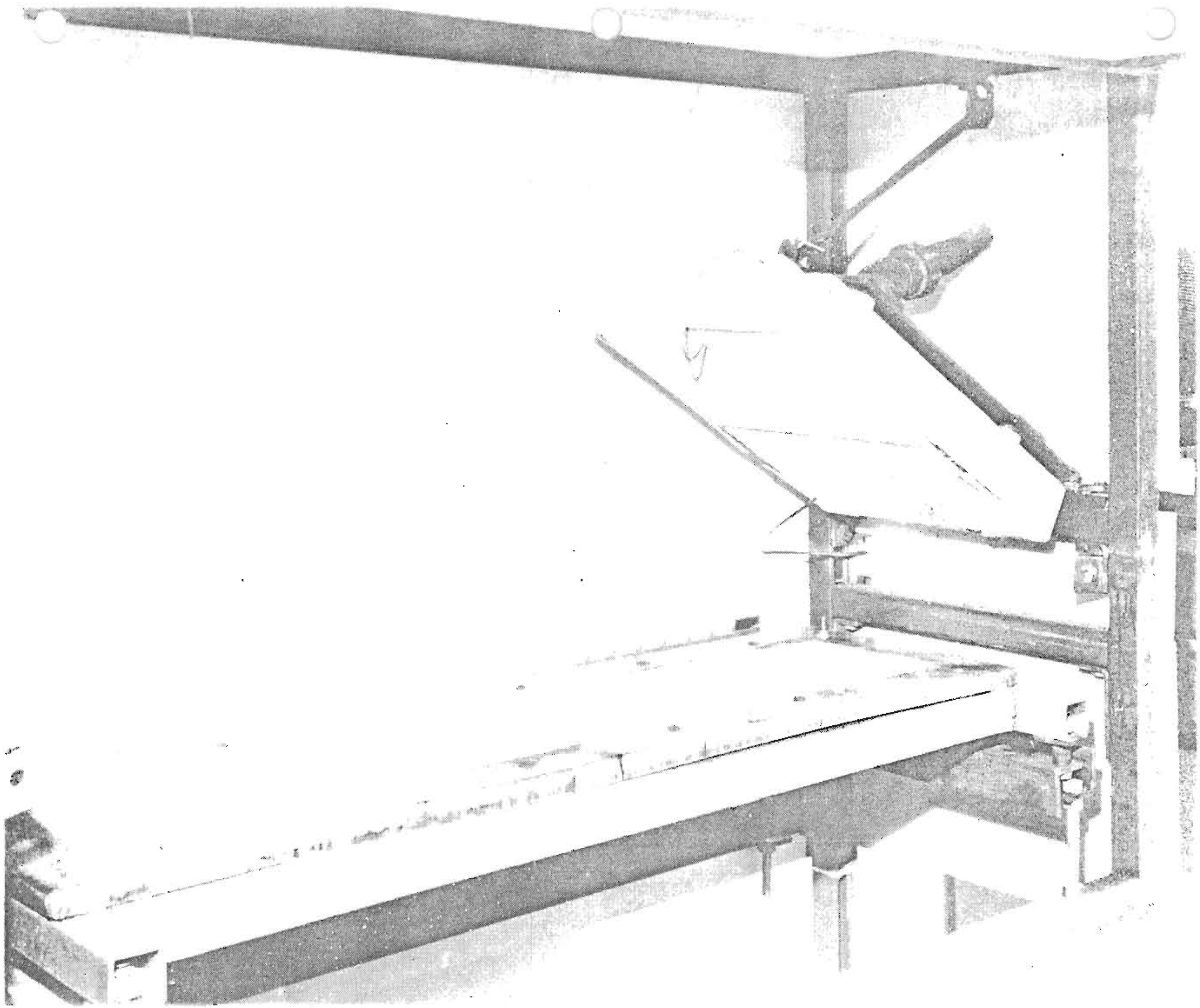

Figure 2. Flooring Radiant Panel Test Showing Carpet Specimen and Gas Fueled Panel

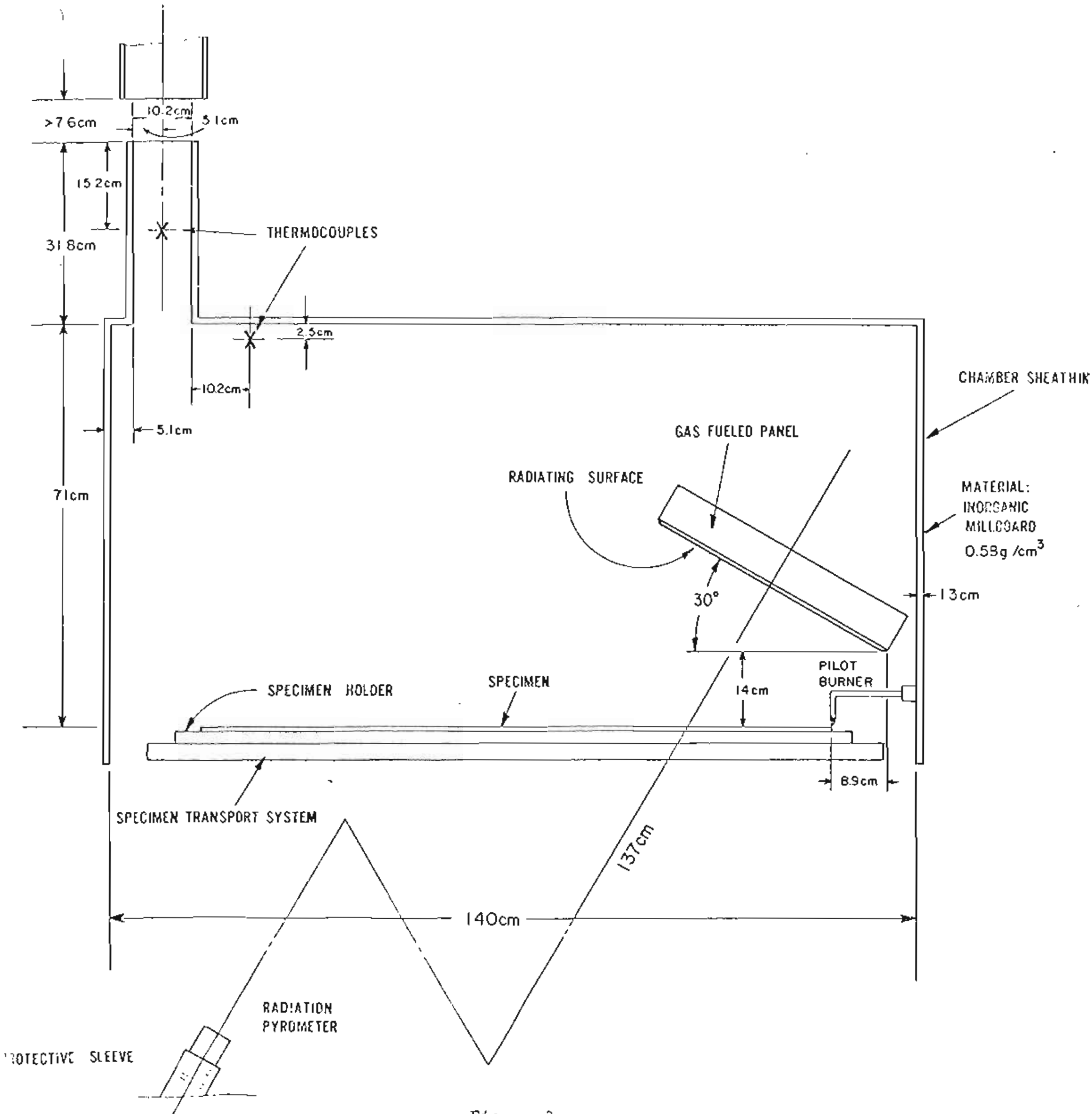

Figure 3.

FLOORING RADIANT PANEL TESTER SCHEMATIC
SIDE ELEVATION

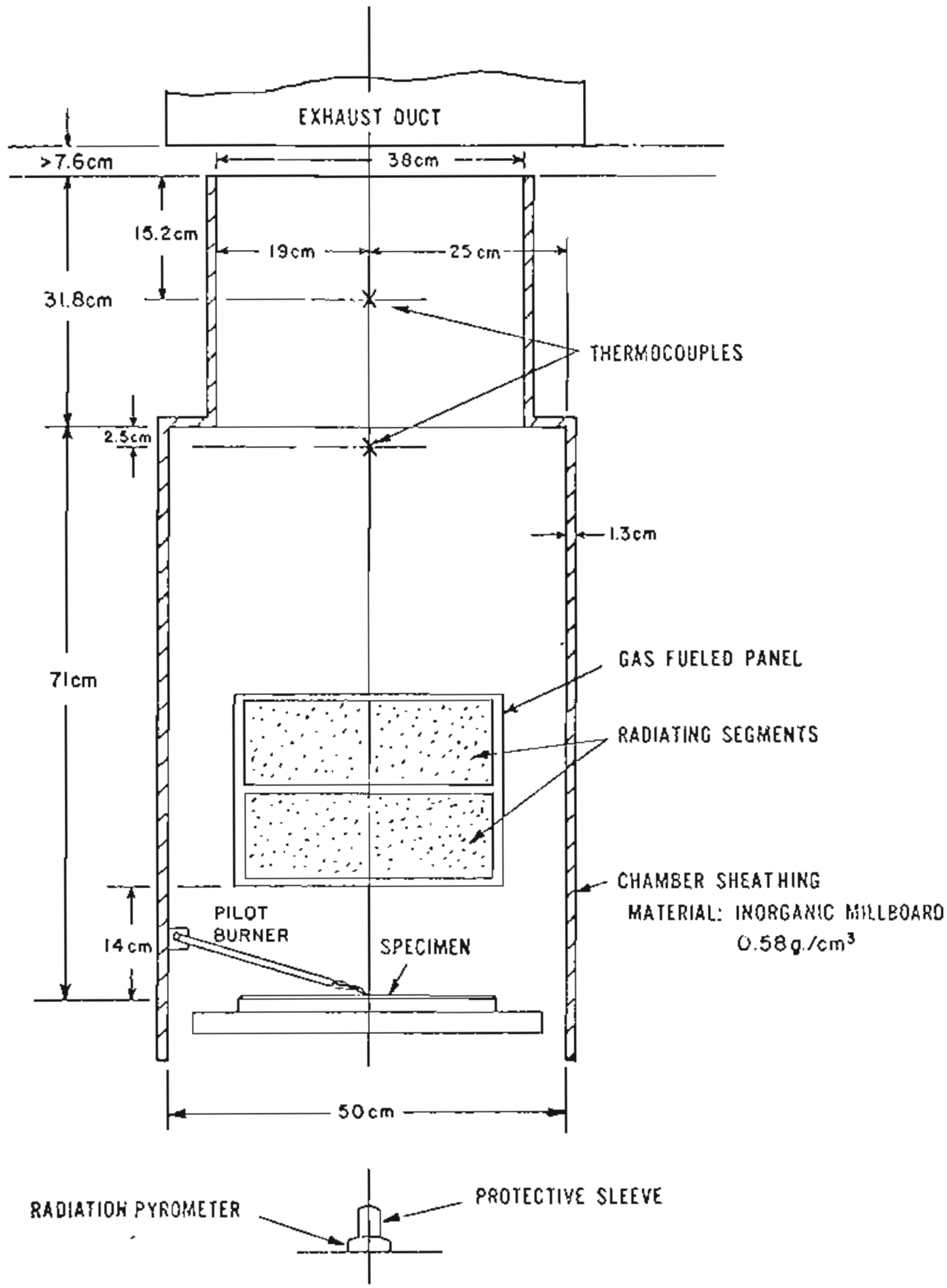

Figure 4.
FLOORING RADIANT PANEL TESTER SCHEMATIC
LOW FLUX END, ELEVATION

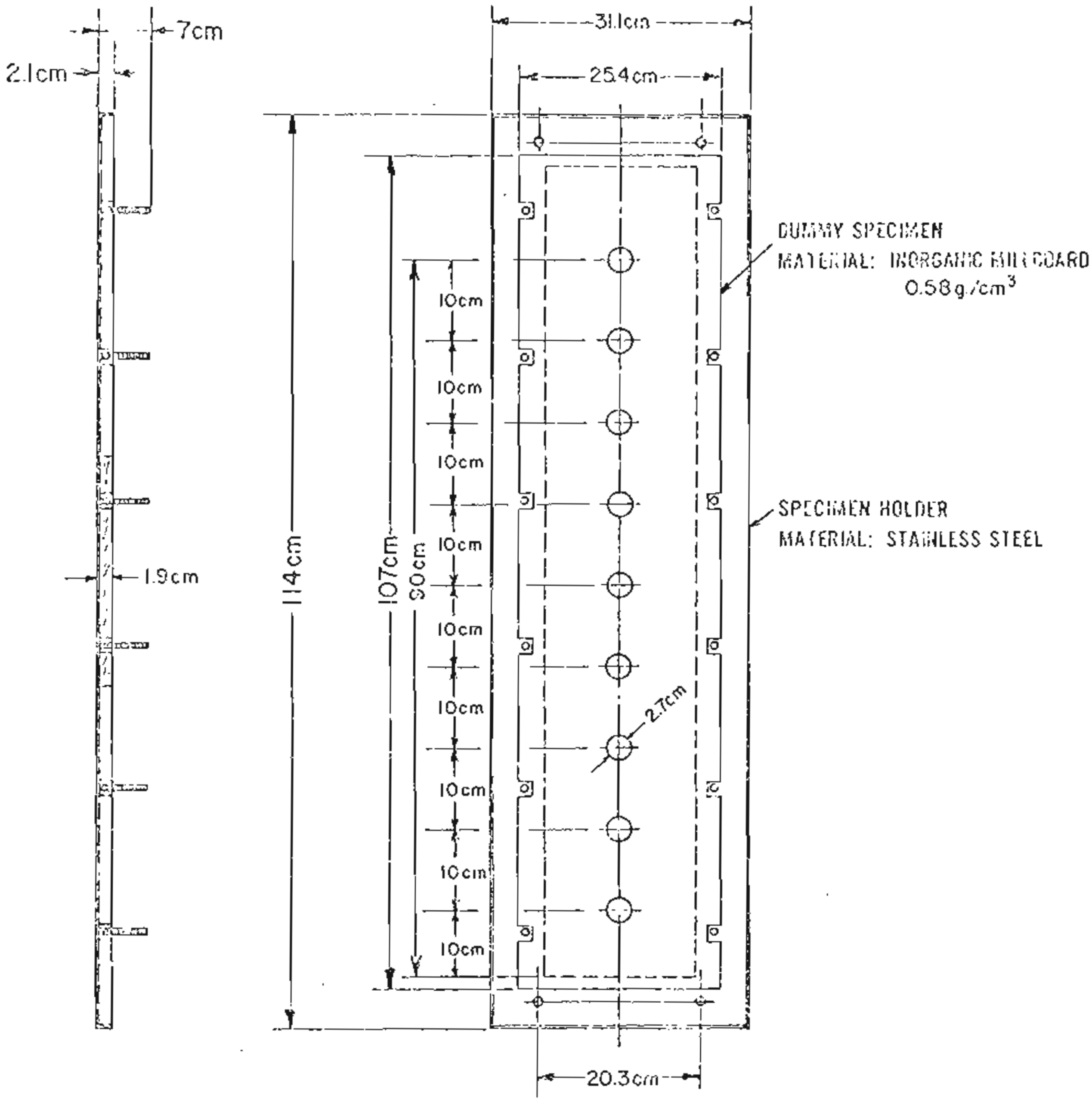

FIGURE 5 DUMMY SPECIMEN IN SPECIMEN HOLDER

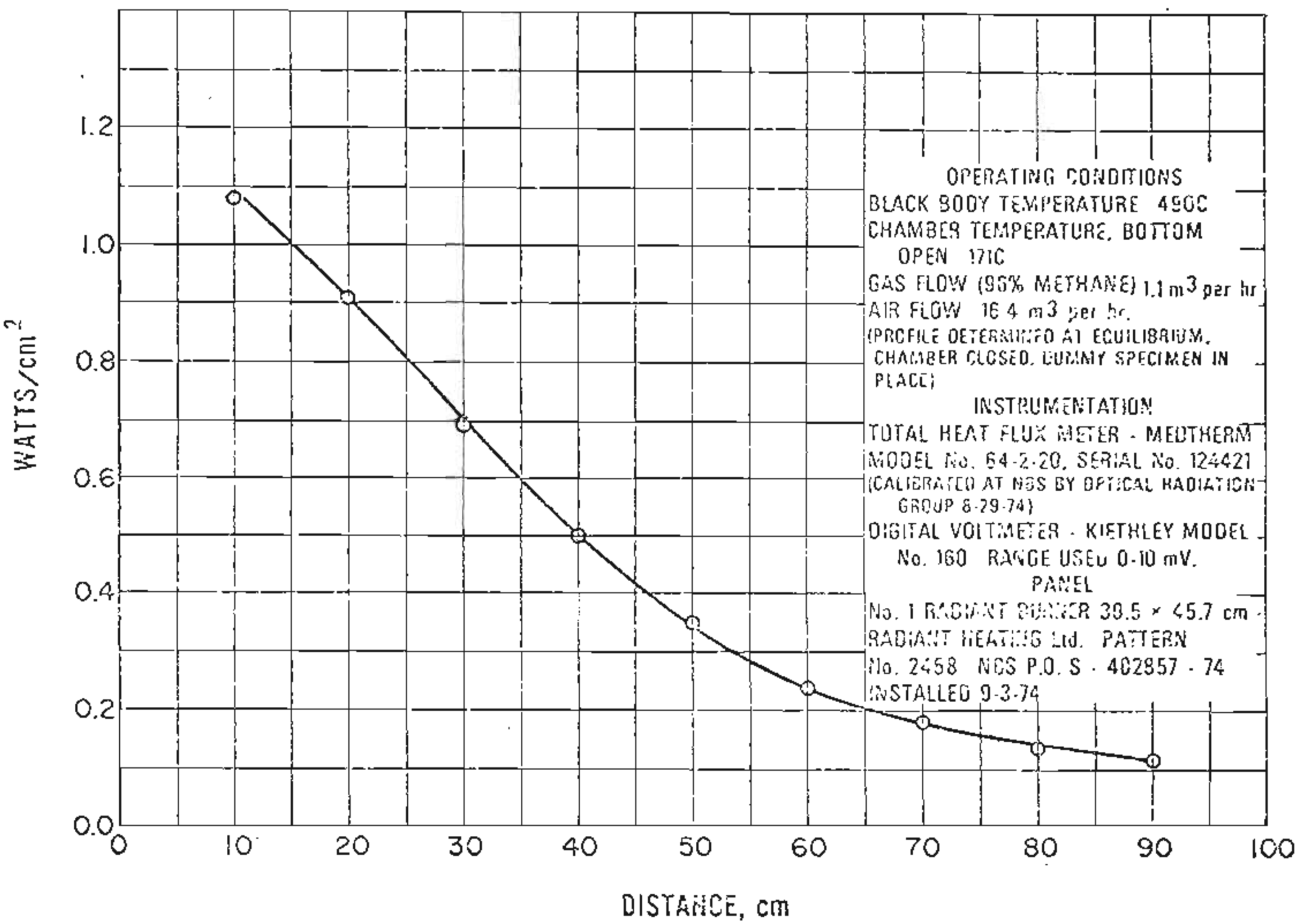

FIGURE 6 STANDARD RADIANT HEAT ENERGY FLUX PROFILE

RADIANT FLUX PROFILE

Date______________

Black Body Temperature______________m.v. ___________°C (F)

Gas Flow __________NTPm^{3}H (SCFH) Air Flow _____________NTPm^{3}H (SCFH)

Room Temperature ___________°C (F)

Air Pressure _______________ Gas _____________cm. (in.) of H_2O

Flux Meter
Radiometer No. _________________ Conversion Factor _________________
From Calibration On _______________

Distance (cm)	MV	Watts/cm^2
10	________	________
20	________	________
30	________	________
40	________	________
50	________	________
60	________	________
70	________	________
80	________	________
90	________	________

Signed ___________________________________

FIGURE 7. Flux Profile Data Log Format

FIGURE 8. FLOORING RADIANT PANEL TEST DATA LOG FORMAT

TEST NUMBER ______ DATE ______________ TIME ______________

LABORATORY ________________________________

SPECIMEN IDENTIFICATION/CODE NO. ______________________________

TEST ASSEMBLY: ____

PANEL: ANGLE __________ ° TEMPERATURE ____________________ °C (°F)

FLOW: GAS ____________ $NTPM^3H$ (SCFH) AIR ____________ $NTPM^3H$ (SCFH)

PRESSURE, CM. (IN.) H_2O: INITIAL, AIR ___________ GAS ___________;

CHAMBER: TEMPERATURE INITIAL____________, MAXIMUM__________ °C (°F)

ROOM: TEMPERATURE___________ °C (°F) HOOD DRAFT_____CM (IN.) WATER

FLAME FRONT ADVANCE

DISTANCE CM. (IN.)	TIME MIN.						

TOTAL BURN LENGTH ______________ CM (IN.) CRITICAL RADIANT FLUX WATTS/CM^2 _____

FLAME FRONT OUT______________ MIN. FLUX PROFILE REFERENCE __________________

ALL FLAME OUT ______________ MIN.

OBSERVATIONS:

SIGNED ______________________________

USCOMM-NBS-DC

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WASHINGTON, D.C. 20234

PROPOSED CRITERIA FOR USE OF THE FLOORING RADIANT PANEL TEST

(For Discussion Purposes Only)

1.0 INTRODUCTION

1.1 Problem Statement

"On December 18, 1969, there was published in the FEDERAL REGISTER (34 F.R. 19812) a notice of finding that a flammability standard was needed for carpets and rugs to protect the public against unreasonable risk of the occurrence of fire leading to death, injury or significant property damage arising from the hazards of rapid flash burning or continuous slow burning or smoldering. ---" This excerpt from the April 10, 1970, "Notice of Standard" states the need which led to the first U.S. National "Standard for the Surface Flammability of Carpets and Rugs", DOC FF 1-70, the pill test, designed to reduce the probability of carpet ignition. In January 1970, and thus before this standard went into effect, a serious corridor type fire in a Marietta, Ohio nursing home pointed to the need for a realistic flame spread test that could be used by the regulatory community to upgrade the fire safety of floor covering systems installed in building corridors and exitways.

1.2 Background

One of the early flame spread tests for carpets that is still widely used is the UL Steiner Tunnel Test (ASTM E-84); the test called for in the standards for the Hill-Burton program. The E-84 test was considered an interim measure when the directive regulating the "Use of Carpeting in (Hill-Burton funded) hospitals" was issued in March 1965. For this reason, HEW in 1969 sponsored the development at Underwriters' Laboratories of a test specifically directed at evaluating flooring and floor covering materials. The UL 992 chamber was the product of this contract with the Health Services and Mental Health Administration.

The UL 992 chamber test is conducted with the specimen mounted on the floor whereas in the E-84 tunnel the specimen is on the ceiling. However, the chamber generates an index which has undetermined fire hazard relevance. Finally, in the test environment the draft spreading the flame is in the opposite direction to that observed in full scale corridors. In recent months under MMFPA/CRI sponsorship, a new chamber has been built at UL's Northbrook, Illinois laboratories. This is patterned after the NBS Model Corridor.[1]

During the 1968-1974 period, another small scale test the Flooring Radiant Panel was under development at the Research and Development Laboratories of Armstrong Cork Company. Concurrently in these years,

[1] NBSIR 73-199 "Experimental and Analytical Studies of Floor Covering Flammability with a Model Corridor" by Wells Denyes and James Quintiere, May 1973.

full scale corridor programs designed to gain a better understanding of the mechanisms controlling the spread of fire along a carpeted corridor were being carried out. The National Bureau of Standards and the Illinois Institute of Technology Research Institute built corridor test facilities which simulated a corridor with an adjoining fire source room. The results of these test programs shed some important light on the mechanism of corridor flame spread.

The Flooring Radiant Panel Test development program has benefited from the work on the UL 992 chamber, the NBS Model Corridor and the full scale corridor projects. The test is now ready for use as a standard test for floor covering systems offering these advantages over ASTM E-84, UL 992 and the NBS Model Corridor:

1. Test conditions have full scale corridor relevance
2. Total flooring system is tested as used in horizontal plane
3. Reproducibility and repeatability are good
4. Apparatus is simple and compact and the test specimen is small
5. The test procedure is simple and of laboratory size
6. Test data provide basic physical measurements
7. The test provides a continuous scale of floor covering performance

2.0 OBJECTIVE

The objective of this discussion is to present background and other technical data that will help in suggesting criteria to be used in conjunction with the Flooring Radiant Panel Test to determine the potential contribution to fire growth of floor covering systems for use in corridors and exitways.

3.0 A PERSPECTIVE

Reduced to its basics, the floor covering system fire question must deal with these two issues:

1. the ease of ignition in a "first-to-ignite" situation, i.e., under zero incident radiant energy flux

2. the degree to which the floor covering system presents a fire propagation link in a corridor and/or exitway given a fire in an adjoining room: the ability of a radiant energy load on the floor covering system to produce sustained flame spread after ignition.

The test method described in the "Standard for the Surface Flammability of Carpets and Rugs" DOC FF 1-70 (the pill test) is felt to be an appropriate and valid measure of ignition ease and flame spread hazard under zero incident radiant energy conditions. Floor coverings which pass the pill test would be expected to provide adequate "first-to-ignite" protection in all occupancies.

The Flooring Radiant Panel Test is designed to deal with the fire propagation potential of floor covering systems in corridors and exitways before the corridor is otherwise involved in the fire. The test exposure spans the range of moderately high flux levels from a room fire source and therefore imposes a relatively high radiant energy load on the corridor flooring and a flaming ignition input.

4.0 THE FLOORING RADIANT PANEL TEST

4.1 Historical

The Flooring Radiant Panel Test had its beginnings in the Research and Development Laboratories of the Armstrong Cork Company in 1966. Zabawsky originated the design and did the preliminary test development work. At this stage, the E-84 concept of a red oak standard was the basis for reporting results. Other approaches to data treatment and reporting were under study at Armstrong in 1970, e.g., 1) rate of burn and 2) distance burned to extinguishment of the flame. The latter is a complement to the measure of hazard that is used today, i.e., critical radiant flux.

Conceptualization in early 1972 of Critical Radiant Flux (watts/cm^2 at extinguishment) as the measure of flame spread hazard is credited to work at NBS by Quintiere and Denyes*.[1] They determined in the course of work on a model corridor that the radiant energy level incident on the floor covering test specimen had considerable influence on whether flaming combustion would propagate or terminate. In the model the radiant energy level was a function of the energy input from a gas diffusion ignition burner. Several runs at different levels were required to establish a Critical Radiant Flux for a given specimen - the minimum burner energy below which flame spread ceased to propagate. The concept of a governing radiant flux also reflected the energy approach to the full scale corridor test, reported by Fung, Suchomel and Oglesby[2], where it was shown that the energy required to produce "flame over" in the corridor was a function of the given floor covering.

It was natural to apply the Quintiere/Denyes "Critical Radiant Flux" concept to the distance burned to extinguishment, and to then study a broad range of floor covering systems. This was the assignment given to Hartzell** in mid 1972. His report[3] covering the further development of the Flooring Radiant Panel Test during 1972-1973 has been, by and large, the basis for the current development and standardization program.

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[2] NBS Technical Note 794, "NBS Corridor Fire Tests; Energy and Radiation Models" by Francis C. W. Fung, Miles R. Suchomel and Philip L. Oglesby, October 1973.

[3] NBSIR 74-495, "Development of a Radiant Panel Test for Flooring Materials" by L. G. Hartzell, May 1974.

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**NBS Research Associate, Armstrong Cork Company.

In 1973, C. Howard Adams* was assigned the task of finalizing the test procedure and preparing a draft of the Flooring Radiant Panel Test, which would be suitable for use as a Standard Technique for Measuring the Critical Radiant Flux of Floor Covering Systems. This report covers some of the highlights of this final phase of the test development. This aspect of the program has, in effect, been a joint effort with the floor covering system industry. Thus, the laboratories of the Man Made Fiber Producer's Association and the Carpet and Rug Institute members have installed testers and participated in the Interlaboratory Programs discussed below. Their people have contributed much time and effort to technical and procedural issues. Without this important help and motivation, the program could not have met its target dates.

4.2 The Test Procedure

The May 15, 1975, Draft Procedure of the Method for determining "Surface Flammability of Floor Covering Systems Using a Radiant Heat Energy Source" is Appendix I of this report. The reader is referred thereto for test specifics and apparatus details. This test procedure is the result of multiple comments and corrections suggested by the many individuals who are currently operating the test apparatus--approximately 20.

The basic elements of the test hardware are shown in Figure 1. The horizontally mounted 100 cm floor covering test specimen receives radiant energy from an air-gas fueled radiant panel mounted above the specimen and inclined at an angle of 30°. A pilot burner is used to initiate the test by open flame ignition of the specimen. The gas panel generates a flux profile along the length of the specimen ranging from a maximum of 1.1 watts/cm^2 to 0.1 watts/cm^2 minimum.

As the first step in carrying out a test, the floor covering system specimen is carefully mounted in the holding frame. With the chamber at equilibrium conditions, the specimen is moved into the test position and the chamber is closed. Following the 2 minute preheat, the pilot burner flame is applied. The test continues until the specimen flaming goes out (extinguishment). The distance burned to extinguishment is converted to watts/cm^2 from the calibrated flux profile graph and the result is reported as a critical radiant flux, watts/cm^2. This value represents the minimum flux necessary to sustain flame propagation on the flooring surface.

4.3 Interlaboratory Programs

4.3.1 ASTM E-5.04.08

A pilot interlaboratory program under the aegis of the ASTM E-5.04.08 Task Group involved NBS and Armstrong Cork Company. From this test program and previous data developed by Hartzell it was decided to

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standardize on a panel temperature of 490°C. Although the Armstrong test equipment was smaller, exposed specimen length was approximately 80 centimeters compared to the now standard 100 centimeters, yet the ranking of materials was consistent when the critical radiant flux levels were within the range of both the panels. The floor coverings included in this program were wool, acrylic, and nylon carpets, red oak and vinyl tile.

4.3.2 Phase I NBS/MMFPA

The Phase I NBS/MMFPA Interlaboratory program was the first major study of the reproducibility and repeatability of the Flooring Radiant Panel Test. In this project, thirteen laboratories tested eight carpet systems in a classic factorial design with replication at the three level. The carpets in this program were primarily for residential use. The experimental results are given in Table I. The procedure used was that of the January 7, 1975, NBS draft, i.e., no preheat. During this program, it was confirmed that total fluxmeters are the preferred instruments for the flux profile determination. All flux profile instrumentation was field calibrated by NBS against an NBS working standard.

The statistical analysis of the data was done by Dr. Mandel at NBS using the proposed ASTM E-11 procedure for interlaboratory evaluation studies. This showed the test to be suitable for use as a standard. Defining a test result as the average of 3 replicate determinations, the repeatability (within laboratory variability) was about 20 per cent of the measured value[4] and the reproducibility (among laboratory variability) was of the order of 35 per cent of the measured value[5].

This program pointed up a minor potential problem in the conduct of the test--the ignition procedure. Two laboratories had some trouble here. The difficulties were resolved by the use of a propane pencil flame torch.

4.3.3 Phase II NBS/MMFPA/CRI

The Phase II NBS/MMFPA/CRI Interlaboratory program expanded on Phase I. The procedure used was that of the March 13, 1975, draft, i.e., a 2 minute

[4] "Repeatability" is a quantity that will be exceeded only about 5 per cent 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. 11, No. 8, p. 8.

[5] "Reproducibility" is a quantity that will be exceeded only about 5 per cent 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 [4].

preheat. The test included only carpets that are sold to what is identified as the contract market. Carpets in this category are used in regulated public occupancy buildings, e.g., hospitals, nursing homes, hotels, office buildings and apartment corridors. The Phase II program was divided into two parts. Part A was a classic 12 laboratory 10 carpet systems interlaboratory factorial design experiment with replication at the three level. The test data repeatability and reproducibility for this set of fabrics was comparable to that demonstrated in Phase I. The data are shown in Table II. The carpet system selection process was to have picked products that differed by uniform increments on the flux profile scale. Though this objective was not fully realized, the distribution of specimens did cover the range in reasonably good order.

4.3.3.1 Part B Phase II, Economic Impact Studies

The purpose of Part B of Phase II was to determine the commerical impact on current contract carpet products for a given recommended critical flux threshold. This is part of a Carpet and Rug Institute economic impact assessment study. Part B included approximately 60 carpet systems selected to be representative of the 800+ carpet products that comprise the contract market. In this segment of the Phase II work, each carpet system was tested once in each of 6 laboratories. The laboratory selection process was done by reference to a random number table.

Table III shows the distribution of this group of contract carpets as a function of Critical Flux level. The effect of the inclusion of a non-integral cushion pad in the system is clearly evident in Figure 2. It may be appropriate at this point to emphasize that the Flooring Radiant Panel Test is designed to deal only with corridor and exitway floor coverings. The extent to which non-integral cushion pads are used in these areas of a regulated building may not be significant.

4.4 Other Laboratory Programs

In parallel with its participation in the interlaboratory programs cited, the Center for Fire Research has conducted cooperative projects with the Wool Bureau, the Resilient Tile Institute and several manufacturers of floor covering systems. The purpose of this work was to extend the applicability of the Flooring Radiant Panel Test and the knowledge base to include all commercially significant floor covering systems. The data obtained are plotted on the critical radiant flux property map, see Figure 3.

5.0 CRITICAL RADIANT FLUX THRESHOLD CRITERIA

The rationale underlying the selection of recommended critical radiant flux threshold levels is built on a combination of:

1. past record of fires involving floor coverings,
2. what full scale corridor burns have contributed to fire hazard knowledge,
3. what judgements are indicated to reflect occupancy and occupant levels,
4. critical flux threshold levels for the commercially used range of floor covering systems.

5.1 The Record of Past Fires

In 1973, Dr. A. F. Robertson reported on a study of fire incidents in which carpets were reported to have been significantly involved in the spread of flame along a corridor. From a total of 142 reports of carpet related fire accidents, he concluded that there were seven instances in which the floor covering material seemed likely to pass the pill test and yet appeared to have been a factor in the spread of fire. Samples of carpet from three of these fire cases were obtained from the FFACTS[6] file repository and run in the Flooring Radiant Panel Tester. The results are shown in Figure 3. In each instance, the data show that critical radiant flux was very low. Therefore, from these data we concluded that a floor covering system with a critical radiant flux of less than 0.1 watts/cm^2, as determined in the Flooring Radiant Panel Test, could present a flame spread hazard in a corridor or exitway. It is of interest to note that data from the United Kingdom for the 1961-1970 period show that floors and stairs of wood construction are involved in the initial spread of fires as frequency as floor coverings, such as carpet and tile[7].

5.2 Full Scale Corridor Experiments

The full scale corridor experiments are of value for their contribution to a better understanding of the mechanisms at work during a fire in this type of space. This research also provides some definition of the environment that floor covering systems may be exposed to in a real fire incident. Thus, the NBS and IITRI investigations[7] shed light on radiant flux levels incident on the floor covering system, temperature distributions in the corridor and air velocities. However, the results for corridor flame spread in the two test programs differed in the occurrence of flashover. The reasons for this lack of agreement are not completely understood, but it is surmised that in addition to corridor configuration, air flow patterns and fuel differences, certain key variables may have been uncontrolled, e.g. moisture, air temperature, carpet installation technique, air velocity et al. In a special series of tests, subsequent to the earlier NBS work already discussed, Quintiere studied the effect of burn room fire loadings on the corridor environment.

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[6] FFACTS - "Flammable Fabrics Accident Case and Testing System."

[7] NBS Special Publication 411 - "Fire Safety Research," M. J. Butler and J. A. Slater, Editors Nov. 1974. "An Evaluation of Flame Spread Test Methods for Floor Covering Materials," by J. Quintiere and C. Huggett, pp. 59-104.

The instrumented corridor was free of organic combustibles, i.e. no carpet, no wall covering, no furnishings. Figure 4 shows the total heat flux generated as a function of the wood crib fuel loading (lbs/ft^2) in the burn room and the distance from the burn room door along the corridor[8].

5.3 Occupancies

We noted that critical radiant flux levels of less than 0.1 $watts/cm^2$ were observed on carpets from the three classic fire cases; this level in unacceptable for corridors. Therefore, what might an acceptable level or levels be? Consideration will be given to two categories as follows:

1. Institutional - Hospitals, nursing homes, and other health care facilities where the patients are generally only partially or completely non-ambulatory.

2. Residential and Commercial - Hotels, motels, officer and apartments whose occupants are generally ambulatory.

The general fuel loadings, particularly in the institutional category, would be under 2 lbs/sq.ft. Another input to the critical radiant flux level judgements is the assumption that a typical distance from one door to another in an institutional occupancy would be about 10 feet (3.0m). Combining this assumption with the information given in Figure 4 for 2 lbs/sq.ft. fuel load in the room of origin, one arrives at an average threshold level of 0.5 $watts/cm^2$. Assuming a room burnout with this fuel load, the door left open, and the windows not blowing out - all maximum assumptions, floor covering systems which will resist this critical radiant flux level would be expected to limit the fire spread in most cases to a point not over 10 ft. down the corridor from the room of origin. This criterion is suggested as reasonable for institutional facilities.

For the less critical No. 2 category occupancies, (people are ambulatory), a lower critical radiant flux level of 0.25 $watts/cm^2$ is being suggested. This level would resist in most cases about a 2 lbs/sq.ft. total burn out with a maximum fire spread of 25 ft. (7.5m) down the corridor. This position is supported by field experience with wood floor and wood floor coverings which have historically been considered acceptable for these occupancies and have critical radiant flux levels as low as 0.35 $watts/cm^2$.

The above values are suggested for use in corridors only and not for rooms or compartments. For this discussion a corridor is taken to be an enclosed public space linking a room or compartment to an exit. The values are suggested for buildings which do not have automatic extinguishment systems in the corridor. Where such systems are present the above criteria are not required.

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[8] J. Quintiere, Unpublished Paper.

5.4 The Institutional Marketplace

A final consideration in dealing with the critical radiant flux threshold question is the Flooring Radiant Panel performance of floor covering materials in the commercial market place. Data on products selected by CRI are presented in Table III and Figures 2 and 3. Of particular importance are the data in Table III. The carpets represent a total of 64 systems selected for this group of tests and are representative of the 800 + carpets currently identified with the contract market -- the institutional market.

About 80% of the carpets tested and 2/3 of the existing contract market production volume meet the 0.25 watts/cm^2 criterion. Wood flooring and all sheet and tile flooring systems tested meet the criterion.

At the suggested health care facility criterion of 0.5 watts/cm^{-2} the choice of products is limited to about the upper 50% of the current contract carpet market, including some carpets with integral foam backing. Also vinyl asbestos tile and most resilient vinyl flooring materials meet the criterion.

6.0 CURRENT LIFE SAFETY CODE REQUIREMENTS

The criteria proposed in Section 5.3 for institutional occupancies would also address the problem which has been posed by the interpretation of Section 10-1352 of the 1973 Life Safety Code. The code mandates the use of the E-84 tunnel test, and states that "floor finish materials shall be Class A or B throughout all hospitals, nursing homes and residential--custodial care facilities." An equivalent level of safety to that stipulated in Section 10-1352 can be achieved by:

- Limiting the critical radiant flux, as measured by the Flooring Radiant Panel Test, in the corridors and exitways;

- and having all carpeting in the rooms and compartments meet the requirements of DOC FF 1-70.

This equivalence in requirements reflects a change in test evaluation technology and will in our opinion provide equivalent safety to that intended by the Life Safety committee.

7.0 SUMMARY

This discussion covers the background and history of the flooring radiant panel test method: from hazard analysis, to full scale test, to qualitative models, to the development of the test in its final form. For flooring in corridors and exitways an average acceptance criterion of 0.25 w/cm^2 for residential and commercial occupancies and an average acceptance criterion of 0.5 w/cm^2 critical radiant flux for institutional occupancies is suggested. These values are derived from experience with floor coverings above and below these values, analysis of measured flux values in the corridor experiments and the impact on the commercial availability of floor coverings. These average values are subject to testing variance and should not be used without a rational sampling plan for testing.

Carpeting for use in rooms or compartments is effectively regulated by the existing DOC FF 1-70 and does not require any supplementary testing.

I. A. Benjamin, Chief
Fire Safety Engineering Division

C. H. Adams, Research Associate, SPI

May 1975

TABLE I
NBS CENTER FOR FIRE RESEARCH

PHASE I NBS/MMFPA/CRI INTERLABORATORY PROGRAM DATA
No Preheat

LABORATORIES	SAMPLE IDENTIFICATION							
	1. CT-4644-1 100% Acrylic-Level Loop (900 - 20)	1P. CT-4644-1 + Pad*	2. CT-4644-2 Nylon, Level Loop (900 - 11)	2P. CT-4644-2 + Pad*	3. CT-4644-3 Wool Plush (900 - 2)	5. CT-4644-5 Polyester (900 - 30)	6. CT-4644-6 Acrylic (900 - 21)	7. CT-4644-7 Nylon 6 Cut Pile Print
	Critical Radiant Flux, watts cm^{-2}							
1	0.48	0.25	0.96	0.31	0.56	0.38	0.16	0.56
	0.46	0.24	0.86	0.29	0.53	0.31	0.18	0.60
	0.44	0.29	0.76	0.34	0.55	0.32	0.17	0.51
2	0.60	0.32	0.64	0.43	0.78	0.36	0.20	0.64
	0.49	0.24	0.75	0.32	0.68	0.32	0.23	0.60
	0.46	0.32	0.72	0.36	0.58	0.52	0.25	0.70
3	0.51	0.36	0.71	0.36	0.67	0.34	0.26	0.64
	0.49	0.35	0.71	0.37	0.50	0.36	0.28	0.67
	0.48	0.32	0.70	0.42	0.80	0.40	0.26	0.68
4	0.49	0.24	0.71	0.27	0.55	0.38	0.19	0.45
	0.44	0.30	0.84	0.35	0.84	0.38	0.20	0.49
	0.44	0.21	0.63	0.33	0.63	0.38	0.17	0.55
5	0.38	0.31	0.66	0.32	0.66	0.43	0.30	0.76
	0.42	0.35	0.71	0.35	0.64	0.37	0.29	0.66
	0.45	0.34	0.84	0.37	0.66	0.47	0.29	0.66
6	0.43	0.22	0.60	0.32	0.64	0.42	0.21	0.52
	0.42	0.28	0.61	0.35	0.49	0.37	0.20	0.55
	0.40	0.36	0.63	0.38	0.59	0.30	0.19	0.55
7	0.40	0.28	0.58	0.31	0.58	0.52	0.24	0.60
	0.39	0.32	0.80	0.29	0.51	0.51	0.23	0.64
	0.43	0.30	0.84	0.27	0.69	0.54	0.23	0.69
8	0.47	0.40	0.76	0.40	0.73	0.33	0.35	0.59
	0.43	0.34	0.98	0.29	0.66	0.64	0.31	0.59
	0.64	0.39	0.74	0.29	0.73	0.24	0.30	0.58
9	0.50	0.27	0.80	0.26	0.60	0.60	0.25	0.50
	0.52	0.26	0.65	0.32	0.77	0.48	0.17	0.48
	0.42	0.26	1.23	0.28	0.82	0.33	0.19	0.60
10	0.49	0.30	0.74	0.43	0.58	0.49	0.22	0.62
	0.44	0.24	0.95	0.31	0.65	0.60	0.21	0.57
	0.53	0.31	0.90	0.42	0.53	0.54	0.21	0.63
11	0.39	0.30	0.74	0.25	0.53	0.20	0.19	0.67
	0.49	0.32	0.77	0.30	0.55	0.32	0.19	0.33
	0.57	0.22	0.76	0.32	0.47	0.34	0.21	0.58
12	0.48	0.34	0.66	0.39	0.60	0.39	0.18	0.53
	0.47	0.27	0.59	0.36	0.55	0.46	0.26	0.51
	0.42	0.37	0.71	0.34	0.62	0.38	0.22	0.52
13	0.50	0.28	0.78	0.31	0.62	0.34	0.21	0.78
	0.57	0.27	0.85	0.34	0.68	0.39	0.22	0.74
	0.42	0.31	0.85	0.33	0.74	0.25	0.21	0.52

* Type II Rubber Coated Jute DDD-C-001023 (GSA-FSS)

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TABLE II
NBS CENTER FOR FIRE RESEARCH

PHASE II PART A NBS/MMFPA/CRI ? LABORATORY PROGRAM DATA
Two Minute P _ eat

SAMPLE IDENTIFICATION

LABORATORIES	101 Wool, Level Loop, Velvet, Latex Backing 46 oz/yd^2	202* Nylon 6/6, Level Loop, Tufted, Jute Backing 28 oz/yd^2	202 + Pad*	207 Nylon 6, Level Loop, Tufted, 16 oz/yd^2 Integral Foam Backing	215 Nylon 6/6, Cut Loop, Woven, Latex Backing 34.7 oz/yd^2	301 Acrylic, Level Loop, Tufted, Jute Backing 42 oz/yd^2	301 + Pad*	402 Polyester, Level Loop, Tufted Jute Backing 42 oz/yd^2	507* Polypropylene, Level Loop Tufted, Jute Backing, 28 oz/yd^2 + Pad*	601 Acrylic/Nylon, Level Loop Tufted, 37 oz/yd^2, Integral Foam - FR Backing
	Critical Radiant Flux, watts cm^{-2}									
1	0.87	DNI	0.18	0.16	0.73	0.59	0.32	0.69	<0.10	0.64
	0.80	DNI	0.23	0.24	0.65	0.59	0.30	0.69	<0.10	0.77
	0.80	DNI	0.18	0.20	0.82	0.56	0.21	0.67	<0.10	0.75
2	0.87	DNI	0.17	0.16	0.77	0.61	0.25	0.79	<0.10	0.63
	0.82	DNI	0.23	0.22	0.78	0.64	0.21	0.81	<0.10	0.52
	0.86	DNI	0.24	0.23	0.78	0.59	0.25	0.76	<0.10	0.66
3	0.91	DNI	0.23	0.21	0.58	0.60	0.26	0.61	<0.10	0.56
	0.87	DNI	0.20	0.29	0.72	0.56	0.26	0.66	<0.10	0.55
	0.89	DNI	0.19	0.24	0.85	0.61	0.29	0.81	<0.10	0.54
4	0.85	DNI	0.17	0.24	0.53	0.67	0.23	0.70	<0.10	0.52
	0.86	DNI	0.17	0.12	0.63	0.59	0.20	0.79	<0.10	0.42
	0.89	DNI	0.16	0.16	0.76	0.58	0.25	0.72	<0.10	0.62
5	0.76	DNI	0.20	0.20	0.82	0.64	0.24	0.64	<0.10	0.76
	0.90	DNI	0.21	0.17	0.85	0.77	0.26	0.68	<0.10	0.73
	0.83	DNI	0.24	0.17	0.84	0.97	0.22	0.72	<0.10	0.78
6	0.78	DNI	0.16	0.17	0.47	0.59	0.20	0.72	<0.10	0.51
	0.67	DNI	0.20	0.26	0.56	0.60	0.19	0.54	<0.10	0.52
	0.68	DNI	0.15	0.20	0.56	0.51	0.19	0.56	<0.10	0.52
7	0.92	DNI	0.20	0.18	0.61	0.64	0.21	0.68	<0.10	0.68
	0.72	DNI	0.22	0.22	0.57	0.55	0.24	0.63	<0.10	0.64
	0.72	DNI	0.17	0.15	0.64	0.51	0.25	0.57	<0.10	0.68
8	0.94	DNI	0.15	0.15	0.49	0.53	0.20	0.68	<0.10	0.74
	0.87	DNI	0.16	0.14	0.51	0.57	0.21	0.63	<0.10	0.83
	0.83	DNI	0.14	0.21	0.52	0.49	0.22	0.57	<0.10	0.74
9	0.84	DNI	0.16	0.19	0.57	0.54	0.24	0.77	<0.10	0.66
	0.75	DNI	0.10	0.17	0.65	0.60	0.17	0.59	<0.10	0.67
	0.93	DNI	0.17	0.11	0.52	0.54	0.17	0.68	<0.10	0.56
10	0.97	DNI	0.25	0.21	0.98	0.67	0.36	0.56	<0.10	0.87
	0.88	DNI	0.23	0.27	0.68	0.60	0.32	0.55	<0.10	0.88
	0.90	DNI	0.19	0.22	0.64	0.64	0.36	0.56	<0.10	0.85
11	0.79	DNI	0.23	0.17	0.71	0.58	0.21	0.60	<0.10	0.44
	0.85	DNI	0.17	0.18	0.87	0.60	0.27	0.65	<0.10	0.60
	0.75	DNI	0.24	0.17	0.67	0.63	0.26	0.77	<0.10	0.54
12	0.97	DNI	0.22	0.17	0.74	0.58	0.26	0.67	<0.10	0.58
	0.88	DNI	0.23	0.17	0.78	0.57	0.27	0.58	<0.10	0.67
	0.85	DNI	0.19	0.20	0.58	0.60	0.26	0.69	<0.10	0.62
14	0.55	DNI	0.21	0.22	0.40	0.53	0.29	0.58	<0.10	0.52
	0.78	DNI	0.18	0.23	0.85	0.55	0.30	0.60	<0.10	0.66
	0.72	DNI	0.24	0.20	0.58	0.54	0.19	0.67	<0.10	0.63

* Not included in statistical analysis.
* Type II Rubber Coated Jute DDD-C-001023 (GSA-PSS)

6-4-75
C.H.A.

Table III
DISTRIBUTION OF CONTRACT CARPET PRODUCTS
BY CRITICAL FLUX RANGES

CRITICAL RADIANT FLUX RANGES - watts/cm^2

<0.1	.1-.19	.2-.29	.3-.39	.4-.49	.5-.59	.6-.69	.7-.79	.8-.89	.9-.99	>1.0
Carpet System Code Numbers - Phase II Part B NBS/MMFPA/CRI Interlaboratory Program										
2007[1]	2021[1]	2011[1]	2020	2051	2026	2004[1]	2003	2001[1]	2017[2]	2010
2009[1]	2031[1]	2016[1]	2043[1]	2005[1]	2036[1]	2012[2]	2008	2019[2]	2027	2014[2]
2023[1]	2037	2018[2]	2049	2006	2042	2013[2]	2063	2029[2]		2015
2025[1]	2039	2028	2054	2024	2061	2030		2041[2]		2022
2038[1]	2045[1]	2032[2]	2056		2064[1]	2059[2]		2044		2033
2048	2046	2034[1]			2002[1]			2060[2]		2035
2050	2047	2040[1]								
2052[1]	2062[1]	2053[2]								
2055[1]		2057[2]								
		2058								

1 Tested over Type II - Rubber Coated Jute and Animal Hair or Fiber DDD-C-001023 (GSA-FSS), Amendment-1, March 10, 1972.

2 Integral Foam Cushion Back.

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C.H.A.

THE FLOORING RADIANT PANEL TEST

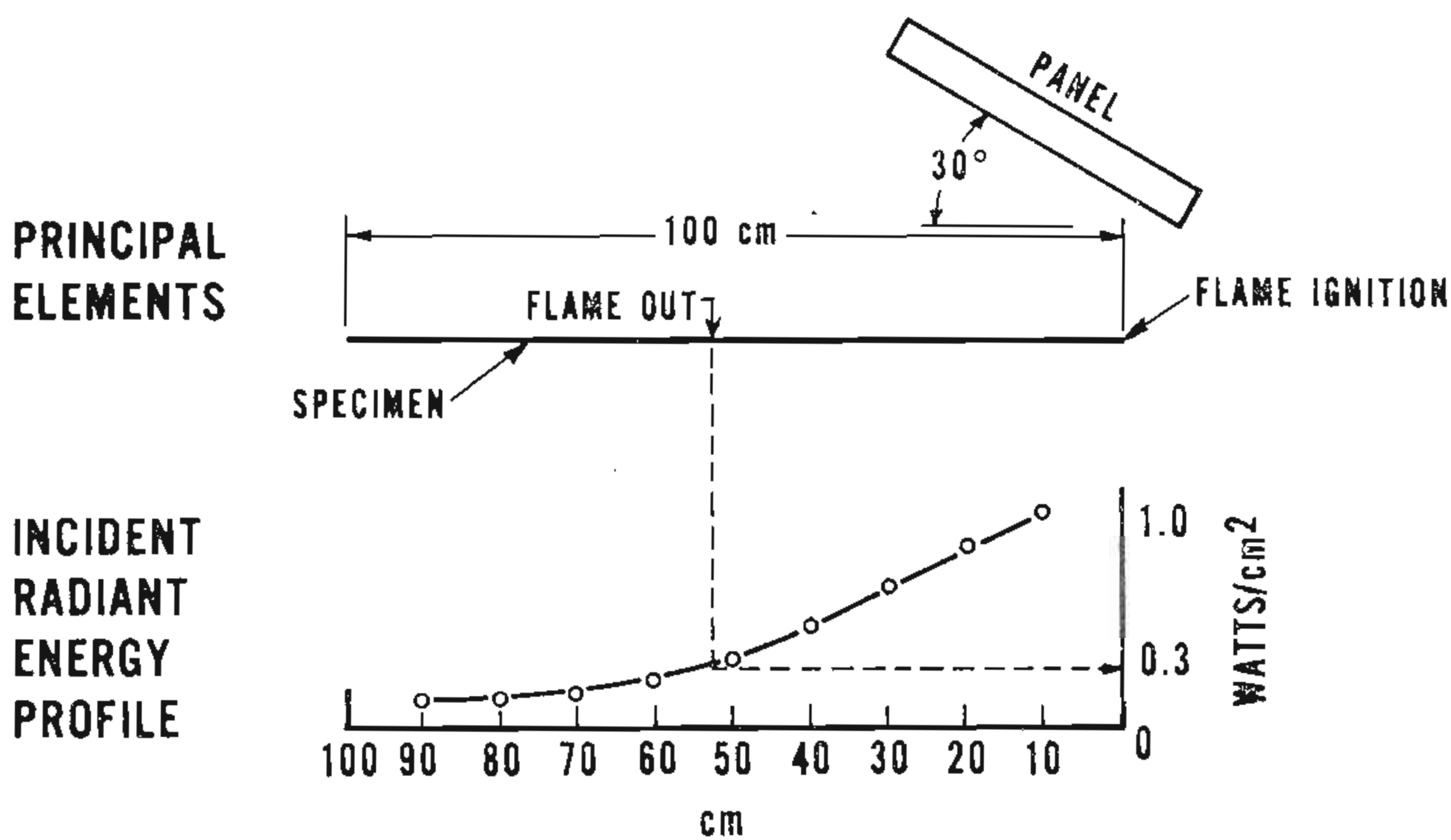

FIGURE 1

EFFECT OF CUSHION PAD ON CRITICAL RADIANT FLUX OF CONTRACT CARPET PRODUCTS

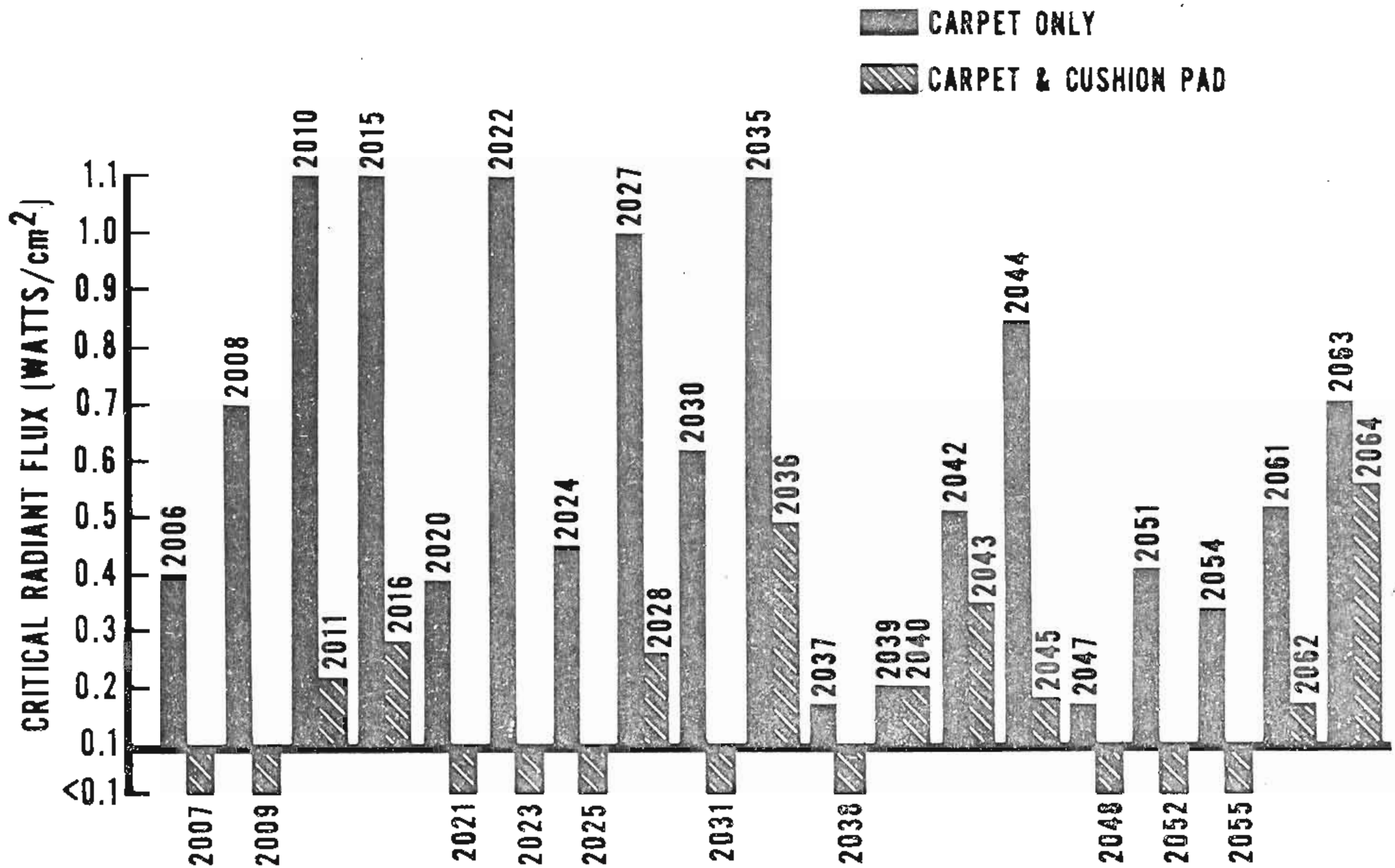

FIGURE 2

CRITICAL RADIANT FLUX MAP

COMMERCIAL FLOORING PRODUCT SYSTEMS

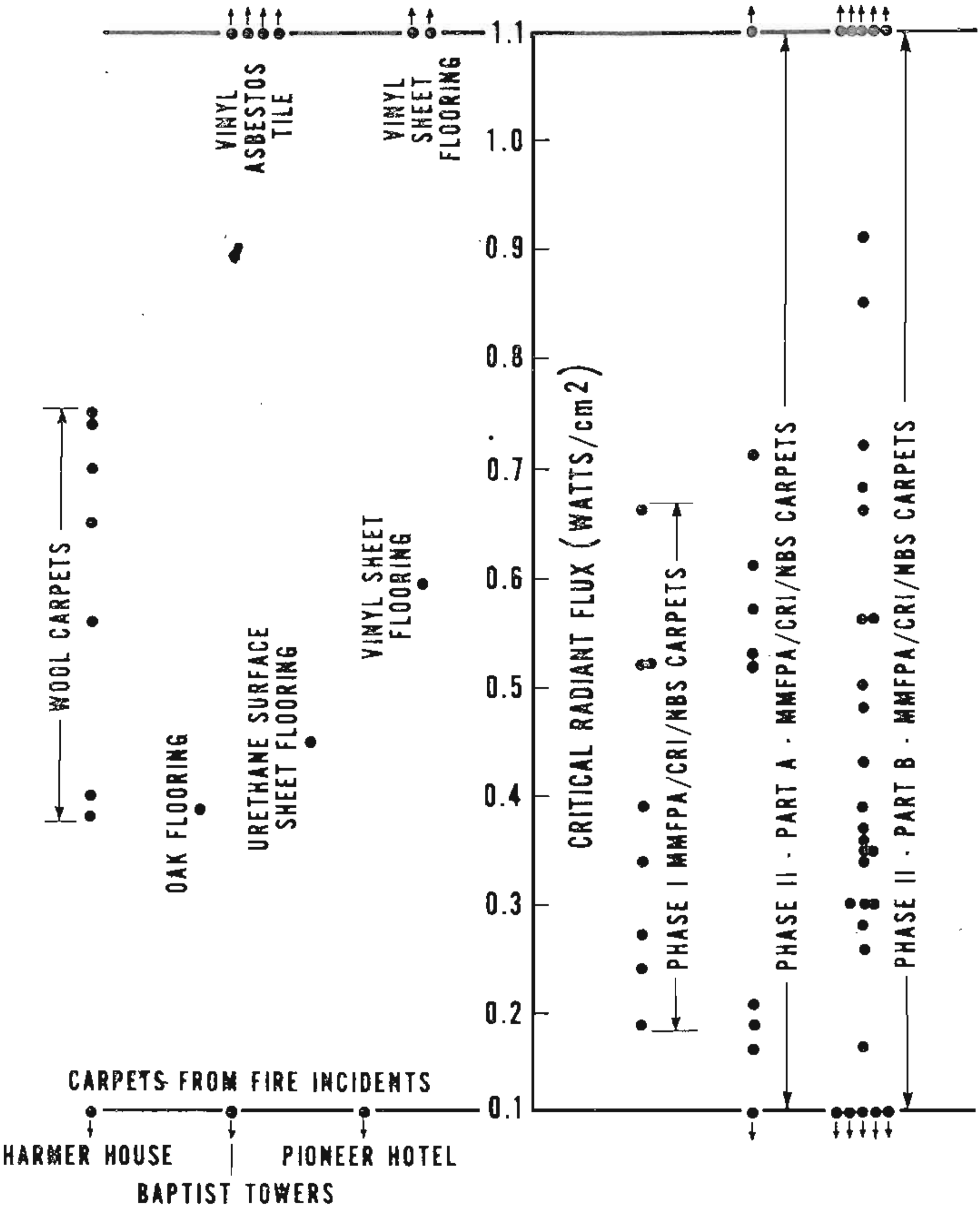

FIGURE 3

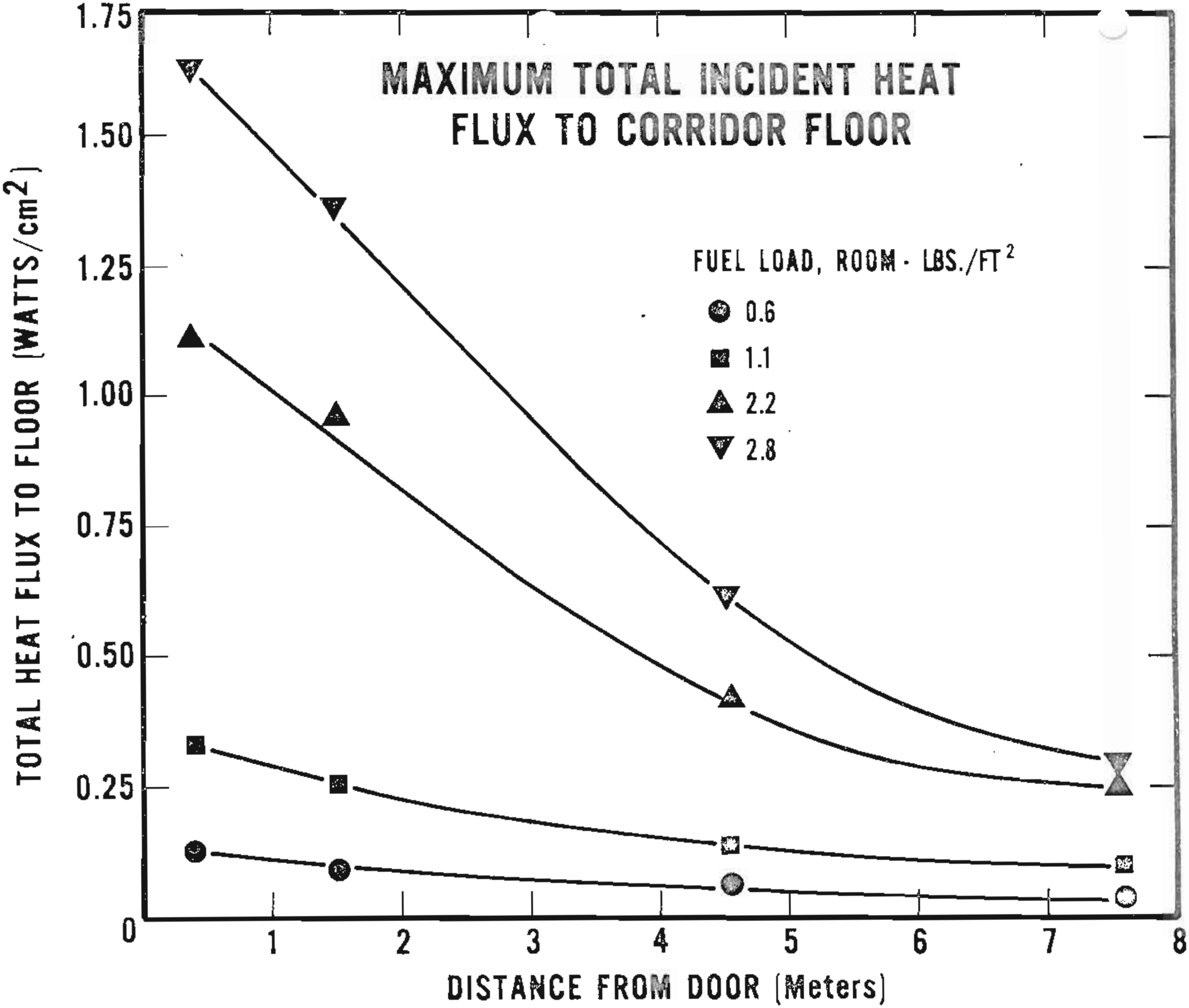
MAXIMUM TOTAL INCIDENT HEAT FLUX TO CORRIDOR FLOOR
FUEL LOAD, ROOM - LBS./FT 2
0.6
1.1
2.2
2.8
TOTAL HEAT FLUX TO FLOOR (WATTS/cm2)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
1
2
3
4
5
6
7
8
DISTANCE FROM DOOR (Meters)

FIGURE 4

ELDON B. NICHOLAS

10-25-76 Revision
ASTM Subcommittee letter ballot
76-2 12/27/76

DRAFT

of a Proposed ASTM Test Method

"TEST FOR HEAT AND SMOKE RELEASE RATES FOR MATERIALS AND PRODUCTS"

1. Scope:

1.1 This test method determines the release rates of heat and visible smoke from materials and products when exposed to different levels of radiant heat with or without pilot flame impingement.

1.2 The method is limited to specimen sizes of materials described in 5.1 and to products from which a test specimen can be taken that is representative of the product in actual use. The test is limited to exposure of one surface to radiant flux; the exposed surface can be either vertical or horizontal.

1.3 Due to the response time of the equipment to rapid changes in heat release rate, values of rate of heat release that are recorded during the time the change in rate of heat release is greater than 220 W/s (750 Btu/min^2) shall be considered as comparative values only, and not a measure of the actual rate of heat release that is occuring.

2. Significance:

2.1 The test method provides a description of the behavior of materials and products under a specific fire exposure, in terms of the release rate of heat and visible smoke. A surface of a specimen is exposed to an initially constant heat flux, and for piloted ignition, a small, impinging flame. By changing the radiant heat flux exposure for subsequent tests, the change in behavior of materials and products with different heat flux exposure can be determined.

2.2 The data obtained for a specific test describe the combustion properties of a specimen exposed to the environmental conditions of that test. The effect of the specimen on its environment should be small. For specimens which produce a sustained, high rate of heat release, a significant increase in imposed heat flux may occur.

2.3 The experimental results give a continuous scale of performance values per unite (exposed) surface area of the specimen.

2.4 Equipment and data obtained by this test method, have been described (1, 2).

3. Summary of Method:

3.1 The specimen to be tested in injected into an environmental chamber through which a constant flow of air passes. The specimen's exposure is determined by a radiant panel adjusted to produce the desired radiant heat flux to the specimen. The specimen is positioned so that a small pilot flame impinges on its surface when this type of ignition is wanted. The change in temperature and optical density of the gas leaving the chamber are monitored, from which the rate of heat and visible smoke release are calculated.

4. Apparatus:

4.1 A Release Rate Apparatus such as shown in Figure 1 shall be used to determine release rates of heat and smoke by this test method. All exterior surfaces of the apparatus, except the holding chamber, shall be insulated with 25 mm thick, low density, high temperature, fiber glass board insulation. Owens-Corning Flat Duct Board, Type 475-FR; Density 4 lb/ft^3, Thermal Conductivity 0.23 $Btu\text{-}in/ft^2$, °F, hr, Thickness, 1 in; or its equivalent is satisfactory.

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(1) Smith, E. E., "Heat Release Rate of Building Materials" Ignition, Heat Release, and Noncombustibility of Materials, ASTM STP 502, American Society for Testing and Materials, 1972 pp. 119-134.

(2) Smith, E. E., "Measuring Rate of Heat, Smoke, and Toxic Gas Release" Fire Tech. 8 No. 3 Aug. 1972 pp. 237-245.

4.2 Thermopile: The temperature difference between the air entering the environmental chamber and that leaving is monitored by a thermopile having 3 hot and 3 cold 24 g. Chromel-Alumel junctions. The hot junctions are spaced across the top of the exhaust stack. Two hot junctions are located 25 mm (1 inch) from each side on diagonally opposite corners and the third in the center of the chimney's cross-section 10 mm (0.4 inches) below the top of the chimney. The cold junctions are located in the pan below the first air distribution plate.

4.3 Smoke Monitor: A photometer (Figure 2) measures the percent of light transmitted through the gases leaving the apparatus. A "Clairex" CL 505 photocell and circuitry shown in Figure 3 shall be used and calibrated as described in 8.2. The light source shall be No. 82 minature incandescent lamp operated at its recommended current, 1.0 (one) ampere.

4.3.1 The smoke monitor apparatus shall be mounted with the center line 25 mm (1 inch) above the exhaust stack and centered parallel to the length of the opening. The two elements of the optical system shall be 180 mm (7 inches) apart. A continuous flow of constant temperature air, approximately 0.004 m^3/min shall be maintained to the air lines to prevent smoke from entering the smoke monitor.

4.4 Radiation Panel: Two types of radiation panels have been used. For higher heat flux capabilities the panel described in Appendix A1 is suggested as an alternate to the standard panel described in 4.4.1.

4.4.1 The radiant panel shall consist of a 340 by 450 mm (13.5 by 18 inches) electrically heated heating element encased in a ceramic core. Two muffle furnace replacement elements "Thermolyne" No. EL 9X2 or their equivalent are satisfactory. The heating element is contained in a 356 by 457 by 50 mm deep (14 by 18 by 2 inches deep) pan. The power to the radiant panel is controlled by a 10 KVA (or larger) voltage controller adjustable from 0 to 200 volts (for parallel connection) or 0 to 400 volts (for series connection). Maximum heat flux is limited to approximately 4 W/cm^2.

4.5 Air Distribution System: To distribute the air entering the environmental chamber, a 6.3 mm (1/4 inch) aluminum plate having 8 No. 4 drill holes, 51 mm (2 inches) from sides on 102 mm (4 inch) centers is mounted at the base of the environmental chamber. A second plate having 120 evenly spaced No. 28 drill holes is mounted 150 mm (6 inches) above the aluminum plate. A well-regulated air supply is required.

4.5.1 The air supply manifold at the base of the pyramidal section has 48 evenly spaced No. 26 drill holes 10 mm from the inner edge of the manifold so that approximately three times more air flows between the pyramidal sections than flows through the environmental chamber.

4.6 Exhaust Stack: An exhaust stack, 133 by 70 mm (5.25 by 2.75 inches) in cross section, and 254 mm (10 inches) long, fabricated from 28 g. stainless steel is mounted on the outlet of the pyramidal section. A 25 by 76 mm (1 by 3 inch) plate of 31 g. stainless steel is centered inside the stack, perpendicular to the air flow, 76 mm (3 inches) below the top of the stack.

4.7 Specimen Holders: Vertically oriented specimens shall be mounted on supporting pans or plates that slip on the specimen holder shown in Figure 5A. A template for mounting bolts on the specimen pan or plate is shown in Figure 5B.

4.7.1 A holder for thin specimens which warp or slump when heated is shown in Figure 6. The specimen shall be backed by two layers of 0.025 mm aluminum foil and a 3.2 mm (1/8 inch) thick cement-asbestos board."Kaowool" Super Rigid Mill Board, Babcock Wilcox Refractories, Augusta, Ga.; or its equivalent is satisfactory. When excessive slumping or spalling occurs, the specimen may be faced by a 150 by 150 mm section of a 25 mm open mesh hardware cloth.

4.7.2 Pans or plates for supporting specimens that can not be mounted in the holder of Sec. 4.7.1 may be either 250 by 250 (10 by 10 inches) or 150 by 150 mm (6 by 6 inches). The smallest weight consistent with adequate support of the sample shall be used to reduce heat capacity of supporting structures.

4.7.3 For vertically mounted specimens, an adjustable radiation shield (Figure 1) which when the specimen is inserted, covers the opening made when the radiation doors are in their open position, is adjusted to position the front surface of the specimen 100 mm (4 inches) from the radiation panel.

4.7.4 The frame for the horizontal radiation reflector is shown in Figure 7, and the horizontal assembly in burn position is shown in Figure 8. Horizontal specimens which melt are placed in a 150 by 100 mm (6 by 4 inch) pan of 0.025 mm aluminum foil to contain the liquid formed. The specimen is contained in an 0.025 mm aluminum foil pan so that the upper surface of the specimen is 6 mm (0.2 inches) below the top of the foil pan.

4.8 Radiation Reflector for Horizontal Mounted Specimens: A new 320 by 255 mm sheet of 0.025 mm (0.001 inch) aluminum foil shall be placed over the rod supports before each test with bright side toward panel. The foil shall be supported by crimping around all edges with a 25 mm overlap.

4.9 Radiometers: Total flux radiometers (calorimeters) shall be used to measure the total heat flux for both horizontal and vertical specimens at the point where the center of the specimen's surface is located at the start of the test. The total flux meters shall have view angles of 180° and calibrated for incident flux. A model R-8015-C radiometer for vertical specimens, and a model P-8400-J pyroheliometer for horizontal specimens from "Hy-Cal" Engineering, Santa Fe Springs, CA, or their equivalents, shall be used with water cooling and without quartz window.

4.10 Pilot Flame: Pilot flame tubing shall be 6.3 mm (1/4 inch) O.D., 0.8 mm (0.032 inch) wall, stainless steel tubing. Fuel shall be methane or natural gas having 90% or more methane. A methane-air mixture, 120 cm^3/min and 850 cm^3/min air shall be the fuel mixture to the pilot flame tubing.

4.11 Pilot Flame, Alternate Positions: In addition to piloted and non-piloted mode of operation, piloted ignition of a specimen may be accomplished by locating the pilot flame at different positions relative to the sample surface so that the flame may or may not impinge on the specimen's surface. The location chosen depends on the nature of ignition to be simulated by the test. In all piloted ignitions, pilot flame size shall be that described in 4.10. Standard pilot positions are described in 4.11.1. Alternate positions are described in Appendix A2.

4.11.1 Piloted Ignition - Vertical Specimen with Impinging Flame: Normal position of the end of the pilot burner tubing is 10 mm from, and perpendicular to, the exposed vertical surface of the specimen. The centerline at the outlet of the burner tubing shall intersect the vertical centerline of the sample, 5 mm above the lower edge of the specimen.

4.11.2 Piloted Ignition - Horizontal Specimen with Impinging Flame: Normal position of the end of the burner tubing is 10 mm above and perpendicular to the exposed horizontal surface of the specimen. The centerline at the outlet of the burner intersects the center of the specimen.

5. Sample Preparation:

5.1 The standard size* vertically mounted specimen is 150 by 150 mm (6 by 6 inch) exposed surface with thickness up to 100 mm (4 inches). The standard size

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*Note: If maximum heat release rate for the specimen exceeds 8500 watt (485 Btu/min), the heat release data at and beyond this point shall be considered outside the range of the standard test method. While an indication of performance may be given by reducing exposed surface area of the specimen, data for these specimens may not correspond to data obtained on standard size specimens. Specimens 75 mm by 100mm are recommended for those materials that exceed heat release rates of 8500 watts on standard size samples. However, the report of data on substandard size samples must clearly state the size of specimen used to obtain the data.

for horizontally mounted specimens is a 100 by 150 mm (4 by 6 inches) exposed surface, up to 45 mm (1 3/4 inch) thick.

5.2 Conditioning: Specimen shall be conditioned in Standard Laboratory Atmosphere (23 °C and 50% relative humidity) as described by Procedure A, ASTM D 618-61, "Standard Methods of Conditioning Plastics and Electrical Insulating Materials for Testing".

5.3 Only one surface of a specimen shall be exposed during one run. Specimens having a slab geometry shall be insulated on five sides. A double layer of 0.025 mm aluminum foil wrapped tightly on sides and back is satisfactory. For products whose exposed surface is not a plane, mounting and method of calculating surface area exposed must be described when reporting results.

6. Procedure:

6.1 If piloted ignition is to be used, the pilot flame is lighted and its position as described in 4.11 is checked.

6.2 The power supply to the radiant panel is set to produce the desired radiant flux. The flux is measured at the same point the surface at the center of the specimen will occupy when positioned for test. The radiant flux is measured with the pilot flame displaced to the side of the environmental chamber after air flow through the equipment is adjusted to the desired rate.

6.3 The air flow to the equipment is set at the desired rate, normally 0.04 m^3/s $\pm$ 0.001 (84 ft^3/min) (at atmospheric pressure and 25 °C). The stop on the specimen holder rod is adjusted so that the exposed surface of the specimen shall be positioned 100 mm (4 inches) from the radiant panel when injected into the environmental chamber, when testing vertically oriented specimens.

6.4 Steady state conditions, such that the radiant flux does not change more than 0.5 kW/m^2 (0.045 Btu/ft^2, sec) over a ten minute period, shall be maintained before the specimen is injected.