NBSIR 79-1954

Development of the Flooring Radiant Panel Test as A Standard Test Method

C. Howard Adams, Research Associate

The Society of the Plastics Industry
New York, New York

and

Sanford Davis

Center for Fire Research
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, D.C. 20234

March 1980

Final Report

Sponsored in part by:

**The Society of the Plastics Industry
355 Lexington Avenue
New York, New York 10017**

NBSIR 79-1954

DEVELOPMENT OF THE FLOORING RADIANT PANEL TEST AS A STANDARD TEST METHOD

C. Howard Adams, Research Associate

The Society of the Plastics Industry
New York, New York

and

Sanford Davis

Center for Fire Research
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, D.C. 20234

March 1980

Final Report

Sponsored in part by:
The Society of the Plastics Industry
355 Lexington Avenue
New York, New York 10017

U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, ***Secretary***

Luther H. Hodges, Jr., ***Deputy Secretary***
Jordan J. Baruch, ***Assistant Secretary for Productivity, Technology, and Innovation***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

DEVELOPMENT OF THE FLOORING RADIANT PANEL TEST AS A STANDARD TEST METHOD

C. Howard Adams* and Sanford Davis

Abstract

This report deals with the standardization phase of the Flooring Radiant Panel Test. It describes work done to develop the test as a standard for measuring one of the major factors contributing to the potential fire hazard of floor covering systems used in corridors and exitways.

The investigation involved major interlaboratory test programs and focused on: 1) establishing realistic test conditions; 2) defining and minimizing variability; 3) drafting a complete and concise test procedure; and 4) demonstrating the soundness of the method.

Required flux profile instrumentation calibration procedures were developed and proven. "Critical radiant flux" data obtained on representative floor covering systems showed the rank ordering of important products such as man-made and natural fiber carpets, vinyl asbestos tile, and hardwood flooring. Acceptable repeatabilities of about 20 percent (within-laboratory variability) and reproducibility of about 35 percent (between-laboratory variability) were demonstrated in two major NBS/MMFPA/CRI interlaboratory carpet system test programs. Fourteen laboratories participated in these full factorial statistically designed experiments with each laboratory testing eighteen carpet materials.

Key words: Critical radiant flux; fire safety; flame spread; flammability; floor coverings; flooring radiant panel test; test method.

---

*This work was conducted while Mr. Adams was a research associate at the National Bureau of Standards for The Society of the Plastics Industry.

1. INTRODUCTION

1.1 Problem Statement

The first U.S. national standard for the surface flammability of carpets and rugs was DOC FF 1-70 (the pill test). This test provides a mandatory limit on the propagation of flame on a carpet sample exposed to a small timed burning tablet and is intended to assure that the carpet will not be: 1) the first item ignited by a small flame, spark or ember, nor 2) the sole mechanism by which a fire propagates. In January 1970, well before the standard became mandatory in April 1971, a serious fire spread along a corridor in a Marietta, Ohio nursing home claiming 31 lives. This fire, and others in which the corridor floor covering was a major contributor to fire spread, confirmed the need for another type of test, one which would measure how carpets burn when involved in a larger fire. The problem restated was to develop a test which would measure 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, i.e., the tendency for a floor covering system to produce sustained flame spread after ignition, in the presence of a radiant energy load. This is a historical document and deals with the standardization phase of the Flooring Radiant Panel Test.

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, i.e., the tendency of a floor covering system to produce sustained flame spread after ignition, when exposed to external radiant heat.

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 potential flame propagation under zero incident radiant energy conditions. Floor coverings which meet the requirements of 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 one aspect of the fire propagation assessment of floor covering systems in corridors and exitways at a time prior to the corridor's involvement in the fire. The potential fire exposure spans the range from low to high heat flux levels from a room fire source and the test therefore imposes a moderately high radiant energy load on the flooring system combined with a flaming ignition. The test measures a single fire property which by itself does not relate directly to fire hazard. The test does not measure smoke or toxic combustion products which may be of overriding importance and it also does not measure fire propagation potential of carpeting mounted on walls and ceilings.

1.2 Background

The need for fire risk assessment had been anticipated and acted on by the U.S. Public Health Service as early as 1965 when a directive was issued regulating the use of carpets in hospitals receiving financial aid under the Hill-Burton Act [1][1]. The directive established a tentative flame spread limit of 75 (by the ASTM E 84 Tunnel Test) for carpeting and other floor covering materials used in patient occupied areas. The tentative qualification is supported by a 1967 critique of E 84 in which it was concluded "... use of the test method for this purpose can be justified only on the basis that a suitable fire test for floor covering does not exist" [2].

In 1969, the Department of Health, Education, and Welfare (HEW) undertook the development of a "suitable" test by sponsoring work at Underwriters Laboratories (UL) which culminated in the development of the UL 992 Chamber Test [3]. This test generates an index but it has not been shown that the test environment relates to the potential hazard of fire growth in a full-scale corridor. The NBS Model Corridor [4], essentially an extension of the UL work, lead to the concept of critical radiant flux, the basis for ranking of floor covering systems in the Flooring Radiant Panel Test.

The Flooring Radiant Panel Test had its beginnings in the laboratories of the Armstrong Cork Company in 1966. This was followed by the test development phase which was completed by an Armstrong NBS Research Associate during the 1972-73 period [5]. The standardization work was done during 1974-75 and is the subject of this report.

---

[1] Numbers in brackets refer to the literature references listed at the end of this report.

While these small-scale tests were being developed, full-scale corridor studies designed to gain a better understanding of the mechanism controlling the spread of fire along a carpeted corridor were being carried out at NBS, IITRI, and NRC (Canada). This work provided important insights of value to the Flooring Radiant Panel Program, one of which is summarized in the following quotation:

> "... In a floor covering application, material acceptance may be based on a critical radiant flux level anticipated in a building corridor due to a given room fire exposure. Although this concept ignores many factors, it does focus on the significant factor which contributes to flame over." [5]

1.3 Approach to Standardization

The approach to standardizing the Flooring Radiant Panel Test was the straightforward one of building on the work of previous investigators. Among the important steps taken to achieve the desired result were these:

1. Selection and standardization of test conditions which are relevant to a fire situation, i.e., spread of flame on a corridor floor given a fire in an adjoining room.

2. Identifying and minimizing causes of variability.

3. Drafting a complete and concise test procedure.

4. Promoting major interlaboratory test programs designed to determine the utility of the test.

5. Development of guidelines, background, and data in support of proposed criteria for potential use of the method as a regulatory tool.

2. OBJECTIVE

The objective of this project was to develop the Flooring Radiant Panel Test as a relevant, reproducible, standard method for measuring one important fire hazard characteristic of floor covering systems in corridors and exitways.

3. THE TEST PROCEDURE

The original procedure describing the "Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source" has been published in an earlier report [7]. The reader is referred to ASTM E 648-78 for the current test procedure and apparatus details [8]. This latest version of the test procedure incorporates slight changes based on comments and inputs from the many individuals who are currently operating the test apparatus--approximately forty.

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° to the horizontal. A pilot burner provides a source of 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 W/cm^2 at the 10-cm location to 0.1 W/cm^2 minimum at the 90-cm location.

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 of the specimen by the radiant panel, the pilot burner flame is applied. The test continues until the specimen flaming goes out (extinguishment). The maximum distance burned is converted to the corresponding radiant flux level from the calibrated flux profile graph and the result is reported as a critical radiant flux, W/cm^2. This value represents the minimum flux necessary to sustain flame propagation on the flooring surface under the test conditions.

4. DEVELOPMENT OF THE TEST PROCEDURE

4.1 Selection of Test Conditions

Selection of test conditions was based on the 1972-73 flooring radiant panel work of Hartzell and full-scale corridor investigations during the period 1971-74 [9]. Hartzell studied four combinations of panel angle, panel distance to specimen plane, and panel temperature. He concluded that a panel angle of 30°, a panel to specimen distance of 14 cm, and a panel radiance corresponding to that of a blackbody operating at a temperature[2] of $\sim$500°C produced the best results. The radiant flux profile along the specimen, ranging from $\sim$1 W/cm^2 to $\sim$0.1 W/cm^2, provided the differentiation needed, i.e., spaced the critical flux values obtained on a common group of carpets more broadly than the other three conditions. Further, this combination of geometry and temperature gave a radiant energy flux distribution that more nearly approximated linearity than the others.

4.2 Flooring System Concept

The work of previous researchers in the floor covering field showed the importance of system testing as opposed to single element testing. For example, it was observed in the full-scale corridor studies, in the model corridor program, and in the Flooring Radiant Panel Test development, that a carpet placed directly on a high density inorganic board substrate would generally be more resistant to the spread of flame than the identical carpet over a rubberized jute pad on the same inorganic board substrate. Other system variables which may affect flame propagation are: choice of substrate, e.g., plywood or cement asbestos board, and method of attachment to the substrate, e.g., edge clamped or adhesive bonded. The specimen mounting frame was designed to accommodate system assemblies up to 4.5 cm (1-3/4 in) in thickness. The procedure presents system assembly and mounting guidelines.

4.3 Tester Start Up

The specifics of chamber start-up will be determined to a degree by the type of safety devices installed on a particular unit. The description of steps involved in putting the tester in operation must therefore be generalized. First, with the sliding specimen platform out of the chamber, the fuel mixture flow settings are made and the gas/air mixture issuing from the panel face is ignited. The bottom of the chamber is open during the equilibration which may require 1 hour. It will be helpful to read the panel equivalent blackbody temperature about 30 minutes after ignition. If it has reached the prescribed temperature, in accordance with the procedure, the chamber is ready for use, i.e., testing or flux profile determination. The procedure treats these steps in detail.

---

[2] References to blackbody temperatures in this report are to radiant panel operating conditions which yield a radiance at the panel surface equivalent to that of a blackbody at the temperature referenced, as measured by the radiation pyrometer.

4.4 Flux Profile Determination

The flux profile determination must be done with great care in view of its importance as the base line for the critical radiant flux measurement. Instrumentation and calibration issues are treated below in section 5.4. This portion of the report covers the work done to define the operational parameters that could impact on the character of the flux profile curve and the precision of its determination. It is axiomatic that the measured flux profile should reflect in high degree the actual radiant energy levels incident on the specimen plane at or near the critical radiant flux point at the time of flameout during an actual test. For this to be accomplished, the chamber with the specimen plane closed with the dummy specimen in place must be at thermal equilibrium. Consequently, studies were conducted to determine the rate at which chamber stabilization occurred. The starting point was the bottom open chamber radiant panel equilibrium condition. The bottom closed time to thermal equilibrium investigation was started by mounting the dummy specimen in the specimen frame and mounting the assembly on the specimen frame transport. It was then moved into the chamber and the lower door closed. Total radiant flux readings at the 40-cm location on the specimen plane were taken after 5 minutes and at 5-minute intervals thereafter until equilibrium conditions were established. Stack temperature measurements were made at the same times and the data showed that thermal conditions were stabilized within the 30-minute period called for in the procedure.

The flux profile determination was made with the dummy specimen in place and the chamber at equilibrium as described above. The flux profile measurements begin with the 10-cm point. The flux meter is inserted 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 to simulate the average projection of carpet specimens above the plane of the dummy specimen. Its output is read after 30 ± 5 seconds based on experimental evidence which showed flux meter reading stabilization was achieved at 20 seconds. The effect of height of flux meter detecting plane above the dummy specimen plane was studied and shown to be insignificant from 0.96 cm (0.38 in) to 0.13 cm (0.05 in) which brackets the above recommendations (see table 1). The 10-cm procedure was repeated for the 20-cm point and at 10-cm intervals thereafter, up to and including the 90-cm location. The effect of the flaming ignition source (pilot burner) at selected distances along the specimen plane on the flux profile was investigated and found to be beneath the level of detection (see table 2). As indicated in the procedure, the final step in the profile operation was to plot the radiant heat energy flux data as a function of distance along the specimen plane on rectangular coordinate paper.

4.5 Preheat Study

The advantage of using a preheat period was demonstrated following analysis of data scatter (poor repeatability) observed for a group of wool carpets. Preheat time refers to the interval between moving the specimen into the chamber test position (with the chamber then being closed) and the application of the flaming ignition source to the specimen. The first column of table 3 lists the results with no preheat. The third column documents the improved data repeatability obtained with the introduction of a 5-minute preheat step. Another experiment, the effect of preheat and ignition flame contact time on a representative group of carpets was studied (table 4). The data confirmed the need for a preheat with wool carpets but showed that the acrylic and polyester fiber carpets, in general, were affected only to a small degree, if at all; also, the flame contact time was not a factor. Table 5 summarizes the results of an experiment designed to evaluate the effect of preheat on a tufted acrylic carpet as a function of four cushion pad types. The effect of preheat is less pronounced than that resulting from the use of a pad; also, the type of pad does not cause significant differences. The preheat effect on oak flooring and resilient flooring was investigated in a limited experiment (table 6). These data show that preheat times up to 5 minutes had no effect on the critical radiant flux values obtained. The observation holds for the resilient sheet flooring with a urethane wear surface. Of the three sheet vinyl flooring products, one of the sample C specimens flashed during the 5-minute preheat, presumably due to volatile plasticizer being ignited by the pilot flame which during preheat is about 5 cm (2 in) above the specimen plane. This occurred following 4-minute exposure in the preheat cycle. The final preheat time selected for the procedure was 2 minutes, an arbitrary choice based on analysis of the data on wool carpets and consideration for the flashing observed in the above resilient flooring product.

4.6 Ignition Source Definition

The flaming ignition source is described in section 5.6. In much of the early work at NBS, the acetylene-air pilot burner flame was left in contact with the specimen throughout the run. While this had no known effect on the results obtained, it did use fuel, and it did damage the specimen frame and the substrate. It seemed advisable to limit flaming ignition contact time either to 10 minutes or until the specimen flame goes out for times less than 10 minutes. This was an arbitrary decision supported in part by the data of table 4 in which ignition times of 2 minutes and 5 minutes were studied. As the data indicate, no effect was observed. Having defined propane as the standard fuel for the pilot burner, limiting the ignition time to 10 minutes and extinguishing the pilot burner will increase the number of tests that can be run with one Bernz-O-Matic TX-101[3] fuel bottle to 75. The bottle is good for 15 hours continuous burning. Assuming a conservative figure of 12 minutes pilot burner time per test gives five tests per hour of fuel supply or 75 total from one TX-101 bottle. The standard flame for the tests is one having a blue inner core length of 1.3 cm (1/2 in).

4.7 Specimen Geometry Effect

In developing guidelines for use of the Flooring Radiant Panel Test, the need for tests of smaller-than-standard specimens became apparent at an early stage. Critical radiant flux data on carpet remnants from three serious corridor type fires were available in the Flammable Fabrics Accident Case and Testing System file. These were clean, new condition samples but in two instances insufficient material was available to test at the standard specimen size, i.e., 20 x 100 cm. An exploratory study of the effect of specimen size was therefore initiated. As a first step, width and length effects were investigated on carpets that were in good supply at NBS (table 7). It was found that a 5.1-cm (2-in) wide strip, pieced together in 30- to 39-cm (∿12- to 15-in) segments gave essentially the same results as the full size specimen. With this relationship established, 5.1-cm (2-in) wide strip specimens from the Harmer House, Marietta, Ohio, and Baptist Towers, Atlanta, Georgia, samples were bonded to and along the center line of 0.64-cm (1/4-in) cement asbestos board substrates and tested.

Sufficient material was available from the Pioneer Hotel, Tucson, Arizona, sample so that full size specimens could be run. The carpet in this instance was mounted over rubberized jute cushion pad so that the assembly was representative of the actual installation. All three carpets, i.e., Marietta, Atlanta, and Tucson, burned the full 100-cm test distance to give critical radiant flux levels of less than 0.1 W/cm^2 (table 8). A radiant flux of 0.1 W/cm^2 approximates the incident radiant energy from the sun at the surface of the earth at noon on a clear summer day.

---

[3] Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

5. APPARATUS DESIGN, ENGINEERING, AND DEVELOPMENT

5.1 Safety Precautions

The possibility of a gas explosion in the test chamber mandates that suitable safeguards consistent with sound engineering practice be installed in the panel fuel supply system. The initial NBS chamber handled this requirement by providing a gas feed cut off activated by air supply failure. When this failure occurs, a Honeywell[3] Gas Pressure Sensing Switch shuts off a Maxon[3] Series 808-0 manual reset valve on the gas line. Other laboratories have used fire sensors directed at the panel surface that stop fuel flow when the panel flame goes out. The new NBS chamber uses a commercial gas water heater or gas-fueled furnace pilot burner control thermostatic shut off which is activated when the gas supply fails. This is a low cost reliable approach which has been demonstrated to be effective. Undoubtedly, there are other devices that will handle the need; however, note that manual reset is a requirement of any safeguard system used.

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 exhaust capacity of the hood should be in the 28.3 to 85 NTP m^3 per min (1000 to 3000 CFM) range. Ceiling exhaust vents are a recommended option. These will prevent combustion product buildup in the laboratory. The operator should be instructed to minimize his exposure to combustion products by following sound safety practice, e.g., ensure that the exhaust system is working properly, wear a suitable mask, etc. A back-up operator safety system is a breathable air apparatus (e.g., Mine Safety Appliance[3] Cat. No. 10-46539, Demand Flow Air Line Respirator with "ComFa" Facepiece, or equivalent) located in the laboratory.

5.2 Fuel Control and Monitoring

Flow meters should be installed on the gas and air lines supplying the radiant panel. Further, they should be calibrated to read volumetric flow rate of each gas directly. The instruments used in the present NBS unit are of the ball-tapered tube type and were obtained from Dwyer Industries, Inc.[3], Michigan City, Indiana.

5.3 Radiant Panel

The gas-air fueled radiant panel used in the test apparatus was obtained from Radiant Heating Limited[3], Foleshill Road, Coventry, England. The panel is described as a No. 1 type radiant burner in cast iron container with a heating surface of 30.5 cm x 45.7 cm (12 in x 18 in), pattern no. 2458. This type is used in all testers built to date.

The blackbody temperature of the panel is determined with a calibrated Honeywell[3] Miniature Radiation Pyrometer, Model RL 2. The pyrometer is positioned to sight on a line originating from the center point and normal to the plane of the panel. It should be located at a distance from the panel that will give a 25-cm (10-in) diameter target viewing area. This is about 1.37 m (54 in) for the NBS tester. The location and size of the pyrometer target can be checked by gridding the unheated panel surface with chalk marks and running a signal trace using a small radiant energy source.

For one panel, the distribution of blackbody temperatures appeared to the eye to be non-uniform. This was confirmed by measuring temperatures at 12 uniformly spaced locations on the panel surface (figure 2). A cone was mounted on the pyrometer to limit the field of view to a target diameter of 2.5 cm (1 in) at a distance of about 20.3 cm (8 in) from the pyrometer to the panel. One third of the lower segment of the panel was about 35°C higher in blackbody temperature than the mean temperature of the panel. The effect of this non-uniformity on the flux profile along the specimen plane was measured and found to be insignificant. Profiles were run on the specimen center line and 6.3 cm (2-1/2 in) on either side of the center line. The differences appeared to be related primarily to chamber design, i.e., a slightly lower flux toward the front of the chamber where the viewing window is located.

5.4 Radiant Energy Flux Profile Instrumentation

5.4.1 Requirements

Precise definition of the incident radiant flux profile generated by the flooring radiant panel tester is the prime determinant of data quality. To achieve this goal radiant energy flux instrumentation must: 1) be carefully calibrated against a standard of known accuracy and precision, 2) respond to the total incident energy spectrum, 3) maintain calibration for an extended period of at least 12 months, and 4) have an uncertainty less than 5 percent.

5.4.2 Instrument Selection

The copper disc calorimeter used by Hartzell did not appear to meet requirement 4) for low flux levels and was therefore ruled out. The Schmidt-Boelter type total flux meter was selected for use in the flux profile determination. The actual instrument used was Model No. 64-2-20 manufactured by Medtherm Corporation[3], Huntsville, Alabama.

5.4.3 Calibration

The calibration issue was investigated at an early stage and identified as a problem in need of study and resolution. The calibration supplied by the manufacturer was shown to vary from one transducer to another leading one to postulate that the accuracy specification of ± 3 percent in the manufacturer's literature might be suspect. It was at this juncture that the NBS Optical Radiation Group was called upon to calibrate two total flux meters and one radiometer with a CaF_2 window.

Good to excellent agreement between the NBS and Medtherm calibrations was achieved with the total flux meters; the radiometer calibrations differed by 12 percent. Appendix A is the NBS Optical Radiation Group report describing the calibration procedure and summarizing the results. Note that this calibration is based on a single point radiant energy source that is very carefully controlled and stabilized to within ± 0.6 percent of the true value. The source generates a flux of 0.150 W/cm^2 (one solar constant). Transducer linearity was assumed. This was subsequently confirmed in work that will be discussed later in this section.

Following the completion of the initial NBS calibration work, each of the laboratories with an operational flooring radiant panel apparatus was visited to field calibrate its flux transducer(s). The NBS total flux meter (serial number 124421) served as the working standard for these calibrations. This work was done during the Phase I NBS/MMFPA/CRI Interlaboratory Program and was a necessary step in the attainment of acceptable repeatability and reproducibility levels. This type of calibration, i.e., against a verified working standard in a test chamber, has been continued by NBS for new flux meters enroute to laboratories operating the flooring radiant panel apparatus. The technique used is highlighted in appendix B which is the calibration report sent to each laboratory. A digital voltmeter was used to measure flux meter output. The range setting was 0 to 10 mv, reading to 0.01 mv. Table 9 summarizes the results of this calibration program for the period January through July 1975.

As noted earlier in this section, the NBS Optical Radiation Section calibration of the NBS total flux meter was a single point calibration, the single point being nominally one solar constant incident on the flux meter. The desirability of a multi-point range bracketing calibration which had been apparent since project inception was realized in early 1974. Through a contact at Purdue University's Thermophysical Properties Research Center, arrangements were made with Goddard Space Flight Center, Greenbelt, Maryland, to have the NBS working standard total flux meter calibrated at five points spaced at appropriate intervals over the 0 to 1.2 W/cm^2 service range of the transducer. The radiation source was a xenon lamp beam directed to an optical bench apparatus on which an absolute radiometer (Kendall Mark IV[3], High Intensity Radiometer, JPL) and the total flux meter were mounted. For each radiant energy output setting, the reference standard radiometer was located in the beam path and an output reading taken. It was then moved out of the path and the total flux meter moved in for a reading. Table 10 shows the average values obtained and the linearity of the calibrated flux meter.

Subsequent to the completion of this test method development, arrangements were made with the Radiometric Physics Division (534) at NBS for a similar calibration service.

5.5 Chamber and Stack Thermocouples

The two thermocouples recommended in the proposed procedure have as their prime function monitoring chamber operation before, during and after a test. The data generated are not routinely reported. For minimum maintenance, i.e., ease of cleaning, these should be 0.32-cm (1/8-in) diameter stainless steel sheathed grounded junction chromel-alumel thermocouples.

5.6 Flaming Ignition Source - Pilot Burner

A premixed acetylene-air pilot burner was used as the flaming ignition source in the previous work and throughout most of this project. It was and is a satisfactory source from the standpoint of performance. Its relatively high intensity flame ignited all materials that could be ignited and that would propagate fire. However, because of industrial safety regulations, this burner was replaced in several laboratories by other premixed or diffusion burners using natural gas or propane. The interlaboratory program results indicated that certain pilot burners were probably operating below the threshold ignition energy levels for some materials and that a uniform, relatively high intensity flaming ignition source was needed. In addition to the stated performance need, the improved pilot burner had to meet the safety requirements noted above.

The second generation and universally acceptable pilot burner finally adopted satisfies these requirements. It is a commercial propane venturi torch (Bernz-O-Matic TX 101[3] or equivalent) with an axially symmetric burner tip having a propane supply tube with an orifice diameter of 0.0076 cm (0.003 in). It is positioned so that the flame generated will impinge on the center line of the specimen at the zero reference point and at right angles to the specimen length.

5.7 Specimen Mounting System

The specimen mounting frame developed in the Hartzell project was used throughout the standardization program. It did a satisfactory job and would be difficult to improve upon in any important way. Quick connect-disconnect fasteners were a minor improvement feature incorporated in later units manufactured commercially.

The specimen transport system used in the 1972-73 project was sound and quite satisfactory. The commercial unit currently available uses a lighter, less rigid design with substantially greater free air access area around the specimen. The latter is of the order of 3225 cm^2 (500 sq in). Initially, the NBS chamber air access area was about 970 cm^2 (150 sq in). It was increased to 1950 cm^2 (300 sq in) prior to the start of the Phase I NBS/MMFPA/CRI Interlaboratory Program. There is no evidence to indicate that the size of this area has a significant effect on results, a conclusion which has been borne out in subsequent interlaboratory programs.

5.8 Chamber Details

The chamber as used throughout this investigation is the same as in the earlier program. The sheathing was upgraded for durability reasons to a medium density marine board consisting of calcium silicate asbestos fiber of 0.58 g cm^{-3} (36 lb ft^{-3}) density and 1.3 cm (0.5 in) thick. This was an improvement recommended by Hartzell.

To streamline operations and improve the safety of the chamber to a minor degree, the small bottom-panel door was hinged to open downward. This change simplifies chamber construction. To make access to the radiant panel and chamber thermocouples easier, the top portion of the front panel was hinged to open up. This change has proven to be a good one and has been incorporated in one commercial unit.

A view window 30 cm (12 in) x 16.5 cm (6-1/2 in) was added at the low flux end of the chamber. This enhanced the observational capability and added a new photographic record potential.

6. NBS DATA ON FLOORING SYSTEMS

The major impact of the Flooring Radiant Panel Test is expected to be in the carpet field. Consequently, the prime data generating effort was directed at carpeting systems. However, since the test is designed to deal with all flooring systems, several other types of flooring products were evaluated. Among these were red oak, vinyl asbestos tile, resilient vinyl roll goods, and urethane wear surface vinyl cushion sheet flooring. In each instance every effort was made to build the specimen so that it simulated field practice. Thus, the red oak hardwood flooring strips were nailed to a 1.59-cm (5/8-in) plywood subfloor over building paper, then sanded, sealed, and waxed. The oak was tested at a moisture content of about 7 percent (50 percent R.H. equilibrium). The vinyl asbestos tile was bonded to 0.64-cm (1/4-in) thick cement asbestos board. Data on the red oak, vinyl resilient roll goods, and urethane surfaced vinyl, previously cited in the section on preheat, are shown in table 6. All of the vinyl asbestos tile samples gave values greater than 1.1 W/cm^2 (2-min preheat). Figure 3 is an overview chart showing the relative position on the critical radiant flux scale of all of the flooring materials tested during this investigation. The rank ordering would appear to be consistent with field experience for this group of products. The effect of cushion pad is shown in tables 5, 11, 12, 13, 14, and 16. It is important to note that the wool carpets tested (tables 12 and 16) showed little or no decrease in critical flux levels between the samples tested with and without cushion pads. This is in marked contrast to most of the synthetic fiber carpets tested where the pad reduced the critical flux value to a significant degree. Table 11 confirms this observation which further shows that this particular carpet, a tufted nylon 6,6, was relatively insensitive to cushion pad type.

7. INTERLABORATORY PROGRAMS

7.1 Phase I NBS/MMFPA/CRI Interlaboratory Program

The Phase I NBS/MMFPA/CRI 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. All specimens were mounted over 0.64-cm (1/4-in) cement asbestos board with a 1.3-cm (1/2-in) calcium silicate/asbestos backer board. The carpet systems were held in the mounting frame by clamp force only, i.e., no adhesive bonding.

7.1.1 Sample Selection

Sample selection was handled by a committee composed of fiber and carpet manufacturers drawing on the NBS data listed in table 12. The six carpets were chosen to:

1. Be representative of current commercial practice.

2. Include thermoplastics and char formers.

3. Cover a broad critical flux range.

The carpets ultimately selected were:

a. Acrylic - level loop
b. Nylon - level loop
c. Wool - plush
d. Nylon - cut pile print
e. Polyester - shag
f. Acrylic - plush

The specimens were cut, numbered, randomized, and sent to each of the participating laboratories by Tennessee Eastman Company. The procedure was based on the July 1974 NBS draft, i.e., no preheat.

7.1.2 Testing Phase

The first two carpets were tested with and without a 55-oz/yd^2 rubberized jute pad. All laboratories operated their testers at the "C" condition, i.e., panel apparent blackbody temperature about 500°C and a radiant flux of 0.50 ± 0.02 W/cm^2 at the 40-cm point on the specimen plane. During this program it was established by Tennessee Eastman statisticians that the NBS field calibration of all flux measuring instruments upgraded the quality of the data to an acceptable reproducibility level. As noted earlier, laboratories with total flux meters generated generally acceptable data prior to field calibration. The data from those laboratories with CaF_2 windowed radiometers would have been lost had there been no field calibration. Thus, definition of the preferred flux measuring instrumentation was an important result of this "calibration" experiment.

The data obtained from the participating laboratories are given in table 13.

7.1.3 Statistical Analysis

The statistical analysis of the data was done by Dr. John Mandel at NBS using the proposed ASTM E 11 procedure for interlaboratory evaluation studies. His analysis showed the test to be suitable for use as a standard. Defining a test result as the average of three replicate determinations, the "repeatability" [10] (within-laboratory variability) was about 20 percent of the measured value and the "reproducibility" [10] (among laboratory variability) was of the order of 35 percent of the measured value; these variabilities are good for fire tests, particularly when compared to the ASTM E 84 Tunnel Test and the UL 992 Chamber Test for carpets. When precision for all three methods is calculated by the same procedure, the Flooring Radiant Panel Test is shown to have the best repeatability and reproducibility [11].

This program pointed up a minor potential problem in the conduct of the test uniformity of pilot ignition energy among the participating laboratories. Laboratory 4 experienced ignition difficulties with the polyester carpet CT-4644-5. Therefore, this data block was replaced with the "all-laboratory" mean value of 0.40 W/cm^2. Laboratory 9 (on sample 2) had some trouble also. This issue was resolved by the use of a commercial propane pencil flame jeweler's torch.

7.2 Phase II NBS/MMFPA/CRI Interlaboratory Program

The Phase II NBS/MMFPA/CRI Interlaboratory Program was an extension and expansion of Phase I. The procedure used was that of the March 13, 1975 draft, i.e., a 2-minute preheat.

7.2.1 Sample Selection and Testing

Only carpets that were sold to what is identified as the contract market were selected by the CRI/MMFPA Committee for this evaluation. Carpets in this category are used in regulated public occupancy buildings, e.g., hospitals, nursing homes, hotels, office buildings, apartment buildings, et al. The program was divided into two parts. Part A was a classic 13-laboratory, 10-carpet systems interlaboratory factorial design experiment with replication at the three level. Part B involved an additional 64 carpet systems with each of the 13 laboratories testing only a fraction of the total specimens. The Part B selection process has as its objective that the carpets be representative of the 800+ products of current commercial importance. For the Phase II program, all carpets tested without separate cushion pad were bonded to the 0.64-cm (1/4-in) cement asbestos board with adhesive. Carpets tested with separate cushion pad were held in place by the clamping force of the mounting frame assembly. The standard 1.3-cm (1/2-in) backer board was used in both cases. The 2-minute preheat step was used in all Phase II testing as prescribed in the June 9, 1975 draft of the proposed procedure.

7.2.2 Statistical Analysis

The statistical analysis of the data was again done by Dr. Mandel using the proposed ASTM E 11 procedure with only Part A of the Phase II program being amenable to statistical treatment. Prior to the statistical work, the data were carefully examined for anomalies and for validity. Where critical radiant flux values greater than 1 W/cm^2 were reported, e.g., one value out of the three data points as >1 W/cm^2, it was decided to replace the high value (equivalent to a "did not ignite") by a number which was the mean of the two remaining data points. The basis for this judgment and action was the earlier observation that the energy of the flaming ignition source does affect the critical flux level obtained for difficult-to-ignite carpets. The >1 W/cm^2 critical flux value where the other data points were significantly lower is identified with a marginal flaming ignition energy source. In this program as in the first, a variety of pilot burner geometries and fuels was used. When all radiant panel laboratories have converted to the propane pencil flame torch system, this problem is expected to disappear. The Part A data are listed in table 14. Numbers in parenthesis are replaced data points.

The analysis based on eight materials showed that the repeatability and reproducibility levels were of the same order as those of the Phase I experiment. It is appropriate to note that a repeatability of 20 percent approximates a within-laboratory coefficient of variation of 7 percent and that a reproducibility of 35 percent approximates a between-laboratory coefficient of variation of 12.5 percent.

7.2.3 Optimum Number of Specimens

The statistical study was broadened for Phase II Part A to deal with the issue of optimum number of specimens needed to generate a meaningful test result. Repeatability and reproducibility levels achieved with one, three, and ten specimens contributing to the test result were determined. This work confirmed that three specimens were necessary and desirable (table 17).

7.2.4 Contract Carpet Performance

The data of Part B are summarized in table 16. As already indicated, they are not amenable to statistical treatment. Average values are presented which may include data from four up to seven laboratories. Although specimen distribution was randomized, the lack of a formal experimental plan precluded formal analysis. The data are useful for the picture they give of the critical radiant flux spectrum of the contract carpet mix. Figure 4 shows in a histogram treatment that carpets are available that cover the entire radiant flux range of the flooring radiant panel tester - and beyond, at both the low and high radiant energy limits. Note from table 16 that most of those carpets when tested with and without a pad give critical radiant flux values significantly lower when tested with an intervening cushion pad.

7.3 Concluding Statement

The Interlaboratory Programs have demonstrated the ability of the Flooring Radiant Panel Test to provide good differentiation among flooring systems at an acceptable repeatability and reproducibility level.

8. CONCLUSIONS

The Flooring Radiant Panel Test is now ready for use as a standard test for floor covering systems with these demonstrated advantages over the ASTM E 84 Tunnel Test, the UL 992 Chamber Test, and the NBS Model Corridor:

1. The fire property measured is one important component which must be considered in any analysis of fire risk from corridor fires.
2. Test results are expressed in terms of a quantitative energy flux level.
3. The total flooring system is tested in the horizontal plane as used.
4. Reproducibility and repeatability are relatively good.
5. The apparatus is compact and suitable for use in a standard laboratory space.
6. The test procedure is simple and straightforward, with due consideration to necessary calibration procedures.

9. ACKNOWLEDGEMENTS

The work reported herein represents the results of a major team effort involving the NBS Center for Fire Research and the several associations and companies that make up the floor covering system industry. The Man-made Fiber Producers Association, together with the Carpet and Rug Institute, played key roles in the Interlaboratory Programs with member firms supplying test samples and participating in the experimental program. Their help was invaluable and is hereby acknowledged. Other significant contributors were the Wool Bureau and the Resilient Tile Institute. Their inputs were important and much appreciated.

The encouragement and guidance of NBS Center for Fire Research management provided the impetus and direction needed to bring the project to a successful conclusion. Special thanks are due I. A. Benjamin for his support. C. Huggett made important contributions. The professional assistance of J. Quintiere was much appreciated. And to engineering aid David Swanson, who handled the experimental work load, a special word of thanks is appropriate.

10. REFERENCES

[1] Hoenack, A., Use of Carpeting in Hospitals, Directive, Division of Hospitals and Medical Facilities, U.S. Public Health Services, March 5, 1965.

[2] Yuill, C. H., Floor Coverings: What is the Hazard?, Fire J., Vol. 61, No. 1, 11-19 (1967).

[3] Subject 992, Standard Method of Test for Flame-Propagation Classification of Flooring and Floor Covering Materials, Underwriters Laboratories Inc. (Feb. 1971).

[4] Denyes, W. and Quintiere, J., Experimental and analytical studies of floor covering flammability with a model corridor, Nat. Bur. Stand. (U.S.), NBSIR 73-199 (May 1973).

[5] Hartzell, L. G., Development of a radiant panel test for flooring materials, Nat. Bur. Stand. (U.S.), NBSIR 74-495 (May 1974).

[6] Quintiere, J., Some Observations on Building Corridor Fires, Proceedings of the Fifteenth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pa., 163-174 (1975); held in Tokyo, Japan, 1974.

[7] Benjamin, I. A., and Adams, C. H., Proposed criteria for the use of the critical radiant flux test method, Nat. Bur. Stand. (U.S.), NBSIR 75-950 (Dec. 1975).

[8] American Society for Testing and Materials E 648-78, Standard Test Method for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source, 1916 Race Street, Philadelphia, Pa. 19103.

[9] Quintiere, J. and Huggett, C., An evaluation of flame spread test methods for floor covering materials, 59-104, Butler, M. J. and Slater, J.A., editors, Fire Safety Research, Nat. Bur. Stand. (U.S.), NBS Special Publication 411 (Nov. 1974).

[10] Mandel, J., Repeatability and Reproducibility, Materials Research and Standards, Vol. 11, No. 8, p. 8 (Aug. 1971).

[11] Zabawsky, Z., private communication.

Table 1. Position of the flux meter

Flux profiles run with flux meter protruding 0.96 cm (0.38 in) above dummy specimen and 0.13 cm (0.05 in) above specimen

Panel blackbody temperature 508°C

Distance along specimen plane cm	Flux meter height above dummy specimen 0.96 cm (0.38 in)	0.13 cm (0.05 in)
	W/cm^2	W/cm^2
10	1.17	1.15
20	0.95	0.95
30	0.71	0.72
40	0.49	0.51
50	0.34	0.36
60	0.24	0.25
70	0.17	0.17
80	0.13	0.14
90	0.11	0.11

Table 2. Effect of the acetylene-air pilot flame on the radiant energy flux profile

Flux meter #124421; blackbody - 490°C

Distance cm	Panel on Pilot up	Panel on Pilot down	Panel on No pilot
	W/cm^2	W/cm^2	W/cm^2
10	1.05	1.07	1.07
20	0.88	0.87	0.87
30	0.64	0.65	0.64

Distance cm	Panel off Pilot up	Panel off Pilot down
	W/cm^2	W/cm^2
10	0.01	0.01
20	0.01	0.01
30	0.01	0.01

Table 3. Effect of 2- and 5-minute preheat times on seven wool carpet samples

		Critical radiant flux, W/cm^2		
Sample identification		No preheat	2 min preheat	5 min preheat
WB - 1		>1.05	0.58	0.61
level loop, face wt 46 oz,		0.59	0.56	0.68
tufted		>1.05	--	0.66
	$\bar{x}$	--	0.57	0.65
	σ	--		0.07
	V	--		11.1%
WB - 2		0.58	0.35	0.39
plush, face wt 75 oz,		0.63	0.36	0.38
woven		0.57	--	0.38
	$\bar{x}$	0.59	0.35	0.38
	σ	0.03		0.01
	V	5.4%		1.5%
WB - 3		>1.05	0.70	0.73
level loop, face wt 44 oz,		0.79	0.64	0.76
tufted		0.81	--	0.75
	$\bar{x}$	--	0.67	0.75
	σ	--		0.02
	V	--		2.0%
WB - 4		1.16		0.68
plush velvet, face wt 64 oz,		1.17		0.69
woven		1.02		0.74
	$\bar{x}$	1.12		0.70
	σ	0.08		0.03
	V	7.5%		4.6%
WB - 5		0.70		0.34
plush, face wt 44.5 oz,		0.56		0.45
tufted		0.58		0.41
	$\bar{x}$	0.61		0.40
	σ	0.08		0.06
	V	12.4%		13.9%
WB - 6		1.18	0.75	0.73
level loop, face wt 44 oz,		1.18	0.78	0.77
woven		1.15	--	0.73
	$\bar{x}$	1.17	0.76	0.74
	σ	0.02		0.02
	V	1.5%		3.1%
WB - 7		0.64		0.56
level loop, face wt 68 oz,		1.10		0.57
tufted		1.12		0.55
	$\bar{x}$	0.95		0.56
	σ	0.27		0.01
	V	28.6%		1.8%

$\bar{x}$ = arithmetic mean
σ = estimated standard deviation
V = coefficient of variation

Table 4. Effect of preheat and ignition flame contact time on typical carpets

Sample identification	Preheat time, min	Pilot flame contact time min	Critical radiant flux W/cm^2
WB-1 Wool, level loop face wt 46 oz, tufted	0	10, 2.1, 7.2[a]	>1.05, >1.05, 0.60
	3	2	0.74
	3	5	0.63
	5	2	0.61
	5	5	0.66
	10	2	0.59
	10	5	0.57
NC-W Nylon, 6,6, BCF, level loop (RFY-74-14) white	0	2, 5, 9.1[a]	1.1, 0.98, >1.1
	3	2	>1.05
	3	5	>1.05
	5	2	>1.05
	5	5	>1.05
	10	2	>1.05
	10	5	>1.05
NC-B Nylon 6,6, BCF, level loop (RFY-74-14) black	0	2, 5, 17.3[a]	0.78, >1.1, 0.96
	3	2	>1.05
	3	5	>1.05
	5	2	>1.05
	5	5	>1.05
	10	2	>1.05
	10	5	>1.05
900-20 Acrylic, level loop, face wt 42 oz, tufted	0	13.4 ± 0.06[a]	0.42 ± 0.01
	3	2	0.38
	3	5	0.43
	5	2	0.44
	5	5	0.40
	10	2	0.39
	10	5	0.42
900-31 Polyester, level loop face wt 42 oz	0	40.3 ± 3.3[a]	0.35 ± 0.04
	3	2	0.36
	3	5	0.36
	5	2	0.33
	5	5	0.39
	10	2	0.41
	10	5	0.34

---

[a] Burn duration

Table 5. Effect of pad type and preheat on tufted acrylic carpet

Sample identification	Critical flux (W/cm^2) No preheat	Critical flux (W/cm^2) 5 min preheat
No pad[a]	0.64	0.65
No pad	0.74	0.62
No pad	0.69	0.63
$\bar{x}$	0.69	0.63
σ	0.05	0.02
V	7.2%	3.2%
Hartex synthetic fiber felt	0.38	0.39
Hartex synthetic fiber felt	0.37	0.45
Hartex synthetic fiber felt	0.60	0.39
$\bar{x}$	0.45	0.41
σ	0.13	0.03
V	28.9%	7.3%
72 oz waffle	0.56	0.47
72 oz waffle	0.49	0.49
72 oz waffle	0.61	0.44
$\bar{x}$	0.55	0.47
σ	0.06	0.03
V	10.9%	6.4%
Rubberized hair jute	0.43	0.31
Rubberized hair jute	0.40	0.39
Rubberized hair jute	0.50	0.33
$\bar{x}$	0.44	0.34
σ	0.05	0.04
V	11.4%	11.8%
Foam, rebonded urethane	0.36	0.35
Foam, rebonded urethane	0.45	0.43
Foam, rebonded urethane	0.41	0.40
$\bar{x}$	0.41	0.39
σ	0.05	0.04
V	12.2%	10.4%

$\bar{x}$ = arithmetic mean
σ = estimated standard deviation
V = coefficient of variation

[a] Carpet mounted directly on cement asbestos board

Table 6. Test data on wood and resilient flooring products

Sample	Description	Critical radiant flux, W/cm^2		
		No preheat	5 min preheat	2 min preheat
Vinyl sheet flooring A	wear layer 0.010" foam back 0.050"	0.96	>1.1 >1.1	
Vinyl sheet flooring B	wear layer 0.030" foam back 0.040"	0.99	>1.1 >1.1	
Vinyl sheet flooring C	wear layer 0.020" foam back 0.060"	0.59	0.43[a] 0.96	
Resilient sheet flooring	surface layer 0.004" urethane pattern & wear layer 0.035" PVC backing inorganic fiber felt 0.037"	0.45	0.45 0.43	
Red oak, unfinished	∿7% H_2O, stapled together, mounted over CAB	0.34 0.37 0.43		
Red oak, finished	∿7% H_2O, sanded two coats sealer waxed, nailed over bldg. paper to 5/8" plywood	0.43	0.46	0.37 0.40

---

[a] Flashed

Table 7. Specimen geometry study
Small specimen - standard specimen equivalency
(No preheat unless indicated)

Sample identification	Standard specimen	Variable width, standard length		Variable length, standard width	
	W/cm²	Width, cm	W/cm²	Length, cm	W/cm²
CT-4644-1	0.43	5	0.41 (35- cm seg.)	40	0.50
100% acrylic, level loop	0.42	5	0.48 (35-cm seg.)	20	0.54
face wt 42 oz, tufted	0.40			20	0.47[b]
	0.42			10	0.43
CT-4644-2	0.60	5	0.51 (35-cm seg.)	40	0.67
nylon 6,6, level loop	0.61	5	0.47 (35-cm seg.)	20	0.74
face wt 28 oz, tufted	0.63			20	0.76[b]
	0.61			10	0.65
WB-5	0.56	2.5	0.32		
Wool plush	0.61	6.3	0.39		
face wt 44.5 oz tufted	0.58	7.6	0.35		
H 4894	0.14	5	0.16		
nylon level loop	0.13	5	0.13		
face wt 22 oz, tufted	0.13	5	0.13 (20-cm seg.)		
integral foam back	0.13	5	0.13 (20-cm seg.)		
		5	0.18 (35-cm seg. bonded to CAB)		
		5	0.14[a] (35-cm seg. bonded to CAB)		
		5	0.16[a] (35-cm seg. bonded to CAB)		
J 4394	0.26	5	0.25		
nylon level loop	0.23	5	0.22		
face wt 22 oz, tufted	0.22	5	0.22 (35-cm seg.)		
	0.24	5	0.24 (35-cm seg.)		

---

[a] 5-minute preheat

[b] 10-minute preheat

Table 8. Test data on carpets from actual corridor fire cases

		Critical radiant flux, W/cm^2			Specimen	
			Preheat, Time			
Fire case	Sample description	No preheat	2 min	5 min	Width	Mounting
Harmer House	nylon 6, level loop	<0.11		<0.11	5 cm	Segmented, bonded to CAB[a]
Convalescent Home	integral foam back			<0.11	5 cm	Segmented, bonded to CAB
Marietta, Ohio					5 cm	Segmented, bonded to CAB
The Baptist Towers	polypropylene, level		<0.11		5 cm	Segmented, bonded to CAB
Housing for the	loop		<0.11		5 cm	Segmented, bonded to CAB
Elderly, Atlanta	integral foam back		<0.11		5 cm	Segmented, bonded to CAB
Georgia, Nov. 30, 1972						
Pioneer Hotel	acrylic, level loop		<0.11		standard	55 oz hair jute pad over CAB
Tuscon, Arizona	over hair jute pad		<0.11		20 cm	55 oz hair jute pad over CAB
Dec. 20, 1970	3/8-1/2" thickness	<0.11				55 oz hair jute pad over CAB

---

[a] CAB = Cement asbestos board

Table 9. Flux meter[a] calibration log

Instrument serial no.	Lab	Medtherm calibration	NBS calibration	Date
		(W cm^{-2} mv^{-1})	(W cm^{-2} mv^{-1})	
3851	Ontario Research	0.207	0.199	5/14/75
3857	Bigelow-Sanford	0.211	0.201	4/25/75
9943	Monsanto (TC)	0.284	0.293	3/3/75
48336[b]	Monsanto (MRC)	0.043	0.036	7/1/75
62444	Allied	0.227	0.215	1/9/75
99424	Celanese	0.217	0.202	1/24/75
99429	Brunswick	0.253	0.250	6/12/75
99431	Hoechst	0.209	0.197	6/3/75
99438	Bigelow-Sanford	0.212	0.195	1/15/75
99448	Celanese	0.191	0.184	1/22/75
99450	Hercules	0.201	0.187	1/24/75
99450	Hercules	0.201	0.185	6/3/75
99456	Brookline	0.234	0.207	2/14/75

---

[a] Medtherm model no. 64-2-20 unless indicated otherwise

[b] HY-CAL model no. R-8015-B-03-072

Table 10. Total flux meter calibration
Engineering Applications Branch
Goddard Space Flight Center

Radiant energy level, xenon source, as measured by Kendall Mark IV High Intensity Radiometer[a]	Total flux meter output Medtherm model no. 64-2-20 serial no. 124421	Conversion factor
W cm^{-2}	Millivolts	W cm^{-2} mv^{-1}
$\bar{x} = 0.3444 \pm 0.0015$	$\bar{x} = 1.263 \pm 0.007$	0.2727
$\bar{x} = 0.5163 \pm 0.0015$	$\bar{x} = 1.894 \pm 0.006$	0.2726
$\bar{x} = 0.6491 \pm 0.0009$	$\bar{x} = 2.381 \pm 0.005$	0.2726
$\bar{x} = 0.7944 \pm 0.0008$	$\bar{x} = 2.928 \pm 0.006$	0.2713
$\bar{x} = 1.0984 \pm 0.0213$	$\bar{x} = 4.043 \pm 0.098$	0.2717

---

[a] Jet Propulsion Laboratory, California Institute of Technology

Table 11. Effect of cushion pad types on critical radiant flux for a nylon 6,6 carpet

Carpet samples from NBS-SPI Corridor Program

No preheat

Carpet code	Cushion pad	Critical radiant flux, W/cm^2
J-4894 Style - level loop Fiber - nylon 6,6 Backing, primary - polypropylene secondary - jute Face weight, oz/yd^2 -22 Construction - tufted	None	0.26 0.23 0.22 0.24 ± 0.02
J-4894	Rubber coated Jute 55 oz/yd^2	0.12 0.13 0.12 0.12 ± 0.01
J-4894	Virgin urethane	0.15 0.14 0.13 0.14 ± 0.01
J-4894	Rebond urethane	0.18 0.16 0.15 0.16 ± 0.02
J-4894	SBR waffle	0.13 0.14 0.13 0.13 ± 0.01
H-4894	Integral 1/8" bonded high density foam	0.14 0.13 0.13 0.13 ± 0.02

Table 12. Data on Carpet and Rug Institute, Man-made Fiber Producers Association samples

No preheat

Code	Style	Fiber	Backing	Face weight oz/yd^2	Construction	Pad	Critical radiant[a] flux, W/cm^2	Comments
900-1	Level loop	Wool		46	Woven	None	0.91 ± 0.2	3.7 min ± 2.8 charred 33-36 cm
900-2	Plush	Wool		42.5	Tufted	None	0.56 ± 0.07	6.1 ± 1.0 min charred 30-38 cm
900-2	Plush	Wool		42.5	Tufted	Hair Jute	0.62 ± 0.09	
900-10	Shag	Nylon 6 Nylon 6,6		24	Tufted	None	0.39 ± 0.09	46.7 ± 17 min high uneven flame
900-10	Shag	Nylon 6 Nylon 6,6		24	Tufted	Hair Jute	<0.10	
900-11	Level loop	Nylon 6,6		28	Tufted	None	0.51 ± 0.05	64.0 ± 7.4 min
900-13	Level loop	Nylon 6	38 oz foam	20	Tufted	None	0.55 ± 0.14	34.7 ± 15 min buckled, high flame, smoke
900-15	Level loop	Nylon 6,6	38 oz foam	14	Tufted	None	0.23 ± 0.06	70.4 ± 20.7 min buckled, heavy black smoke
900-20	Level loop	Acrylic		42	Tufted	None	0.46 ± 0.01	13.4 ± 0.1 min melting 20-28 cm
900-21	Plush	Acrylic			Tufted	None	0.22 ± 0.01	12 ± 0.8 min charred
900-30	Saxony plush	Polyester		45.2	Tufted	None	0.30 ± 0.03	71.2 ± 3.5 min heavy black smoke
900-30	Saxony plush	Polyester		45.2	Tufted	Hair Jute	<0.15	Very heavy black smoke
900-31	Level loop	Polyester		42	Tufted		0.39 ± 0.04	40.3 ± 3.3 min thick black smoke
900-32	Random shear	Polyester		37	Tufted		0.22 ± 0.01	76.7 ± 10.4 min heavy black smoke
900-32	Random shear	Polyester		37	Tufted	Hair Jute	<0.10	High flame, black smoke
900-40	Level loop	Polypropylene		22	Tufted		<0.10	99.8 ± 8.7 min high flame, black smoke

---

[a] Total flux meter #321223 used in flux profile determination

Table 13. 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[a]	2. CT-4644-2 nylon, level loop (900-11)	2P. CT-4644-2 + pad[a]	3. CT-4644-3 wool plush (900-2)	5. CT-4644-5 polyester (900-30) shag	6. CT-4644-6 acrylic plush (900-21)	7. CT-4644-7 nylon 6 cut pile print
	Critical Radiant Flux, W/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	0.71	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	0.40	0.19	0.45
	0.44	0.30	0.84	0.35	0.84	0.40	0.20	0.49
	0.44	0.21	0.63	0.33	0.63	0.40	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	0.85	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
Mean	0.47	0.30	0.76	0.34	0.64	0.40	0.23	0.59
Std. deviation	0.04	0.04	0.09	0.03	0.07	0.07	0.04	0.07
Coeff. of variation	7.5%	12.4%	11.3%	10.2%	10.3%	18.0%	18.6%	11.3%

---

[a] Type II rubber coated jute DD-C-001023 (GSA-FSS)

Table 14. Phase II Part A NBS/MMFPA/CRI Interlaboratory Program data

Two-minute preheat

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 (a)	202 + pad (b)	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 (b)	402 polyester, level loop, tufted, jute backing 42 oz/yd^2	507 poly-propylene, level loop, tufted, jute backing, 28 oz/yd^2 + pad (a) (b)	601 acrylic/nylon, level loop, tufted 37 oz/yd^2, integral foam - FR backing
	Critical radiant flux, W/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 (1.10)	<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 (1.06)	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 (DNI)	0.56	0.26	0.66	<0.10	0.55
	0.89(1.01)[c]	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(1.04)	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(1.09)	DNI	0.24	0.17	0.84 (DNI)	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 (1.04)	<0.10	0.56
10	0.97	DNI	0.25	0.21	0.98	0.67	0.36	0.56 (DNI)	<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
Mean	0.83		0.19	0.19	0.67	0.60	0.25	0.66		0.64
Standard deviation	0.07		0.03	0.03	0.10	0.06	0.04	0.06		0.11
Coefficient of variation	8.6%		14.3%	14.4%	15.3%	10.8%	16.8%	8.9%		17.1%

---

[a] Not included in statistical analysis

[b] Type II rubber coated jute DDD-C-001023 (GSA-FSS)

[c] Data in () replaced, ignition suspect. Plugged data point is average of the two good data points.

Table 15. Phase II Part A NBS/MMFPA/CRI Interlaboratory Program Effect of number of specimens on repeatability and reproducibility

No. specimens	Repeatability %	Reproducibility %
1	34	46
3	20	36
10	10	32

Table 16. Phase II Part B NBS/MMFPA/CRI Interlaboratory Program data

Two-minute preheat

Code[a]	Fiber	Style	Type	Secondary backing	Pile wt., oz/yd^2	Pad[b]	Average CRF, W/cm^2
2001	Wool	Level loop	Velvet	Latex	46	yes	0.78
2002	Wool	Plush	Tufted	Jute	42.5	yes	0.58
2003	Wool	Level loop	Tufted	Jute	42	no	0.76
2004	Wool	Level loop	Tufted	Jute	42	yes	0.70
2005	Wool	Plush	Velvet	Latex	51.9	yes	0.51
2006	Polyester	Shag	Tufted	Loktuft	48.5	no	0.38
2007	Polyester	Shag	Tufted	Loktuft	48.5	yes	<0.1
2008	Nylon 6,6	Shag	Tufted	Jute	24	no	0.71
2009	Nylon 6,6	Shag	Tufted	Jute	24	yes	<0.1
2010	Nylon 6	Level loop	Tufted	Jute	20	no	DNI
2011	Nylon 6	Level loop	Tufted	Jute	20	yes	0.23
2012	Nylon 6	Level loop	Tufted	Foam	20	no	0.63
2013	Nylon 6,6	Level loop	Woven	Sponge	18	no	0.67
2014	Nylon 6,6	Level loop	Woven	Sponge - FR	18	no	DNI
2015	Nylon 6	Cut pile	Tufted	Jute	32	no	DNI
2016	Nylon 6	Cut pile	Tufted	Jute	32	yes	0.28
2017	Nylon 6	Level loop	Tufted	Foam - FR	12	no	0.95
2018	Nylon 6	Level loop	Tufted	Foam	12	no	0.27
2019	Nylon 6,6	Level loop	Tufted	Foam - FR	19	no	0.78
2020	Nylon 6	Level loop	Tufted	Jute	28	no	0.40
2021	Nylon 6	Level loop	Tufted	Jute	28	yes	0.12
2022	Nylon	Multi-level	Tufted	Jute	20	no	DNI
2023	Nylon	Multi-level	Tufted	Jute	20	yes	<0.1
2024	Nylon 6,6	Level loop	Tufted	Jute	20	no	DNI
2025	Nylon 6,6	Level loop	Tufted	Jute	20	yes	0.13
2026	Nylon 6,6	Cut and loop	Woven	Latex	34.7	no	0.56
2027	Nylon 6,6	Level loop	Tufted	Jute	19	no	0.85
2028	Nylon 6,6	Level loop	Tufted	Jute	19	yes	0.28
2029	Nylon (Sol.)	Level loop	Tufted	Foam - FR	24	no	0.88
2030	Nylon 6	Cut pile	Axminster		36	no	0.63
2031	Nylon 6	Cut pile	Axminster		36	yes	<0.1
2032	Nylon 6/6	Level loop	Tufted	Foam	12	no	0.21
2033	Nylon 6,6/6	Shag	Tufted	Jute	32	no	0.76
2034	Nylon 6,6/6	Shag	Tufted	Jute	32	yes	0.17
2035	Nylon 6,6	Plush	Tufted	Jute	45	no	DNI
2036	Nylon 6,6	Plush	Tufted	Jute	45	yes	0.49
2037	Polypropylene	Level loop	Tufted	Jute		no	0.17
2038	Polypropylene	Level loop	Tufted	Jute		yes	<0.1
2039	Acrylic	Plush	Tufted	Jute	46	no	0.20
2040	Acrylic	Plush	Tufted	Jute	46	yes	0.17
2041	Acrylic	Level loop	Tufted	Foam - FR	36	no	0.82
2042	Acrylic	Loop	Knitted	Latex	60	no	0.50
2043	Acrylic	Loop	Knitted	Latex	60	yes	0.34
2044	Acrylic	Level loop	Tufted	Jute	32	no	0.75
2045	Acrylic	Level loop	Tufted	Jute	32	yes	0.17
2046	Polyester	Level loop	Tufted	Jute	42	yes	<0.1
2047	Polyester	MLRS	Tufted	Jute	37	no	0.30
2048	Polyester	MLRS	Tufted	Jute	37	yes	<0.1

Table 16 (continued)

Code[a]	Fiber	Style	Type	Secondary backing	Pile wt., oz/yd^2	Pad[b]	Average CRF, W/cm^2
2049	Polyester (PCP)	Level loop	Tufted	Jute	28	no	0.36
2050	Polyester (PCP)	Level loop	Tufted	Jute	28	yes	<0.1
2051	Polypropylene	Level loop	Tufted	Jute	22	no	0.43
2052	Polypropylene	Level loop	Tufted	Jute	22	yes	<0.1
2053	Polypropylene	Level loop	Tufted	Foam	22	no	0.23
2054	Polypropylene	Level loop	Tufted	Jute	16	no	0.32
2055	Polypropylene	Level loop	Tufted	Jute	16	yes	<0.1
2056	Nylon 6	Level loop	Tufted	Foam	16	no	0.39
2057	Polypropylene	Level loop	Tufted	Foam	16	no	0.28
2058	Polypropylene	Level loop	Tufted	Jute	28	no	0.26
2059	Acrylic/Nylon	Level loop	Woven	Sponge - FR	40	no	0.64
2060	Acrylic/Nylon	Level loop	Tufted	Foam	42	no	0.82
2061	Acrylic/Mod.	Level loop	Tufted	Jute	32	no	0.50
2062	Acrylic/Mod.	Level loop	Tufted	Jute	32	yes	0.21
2063	Acrylic/Mod.	Level loop	Tufted	Jute	42	no	0.68
2064	Acrylic/Mod.	Level loop	Tufted	Jute	42	yes	0.54

---

[a] Bracketed pairs indicate that the same carpet was tested with and without a pad.

[b] Type II rubber coated jute and animal fiber, DDD-C 001023 (GSA-FSS), Amendment 1.

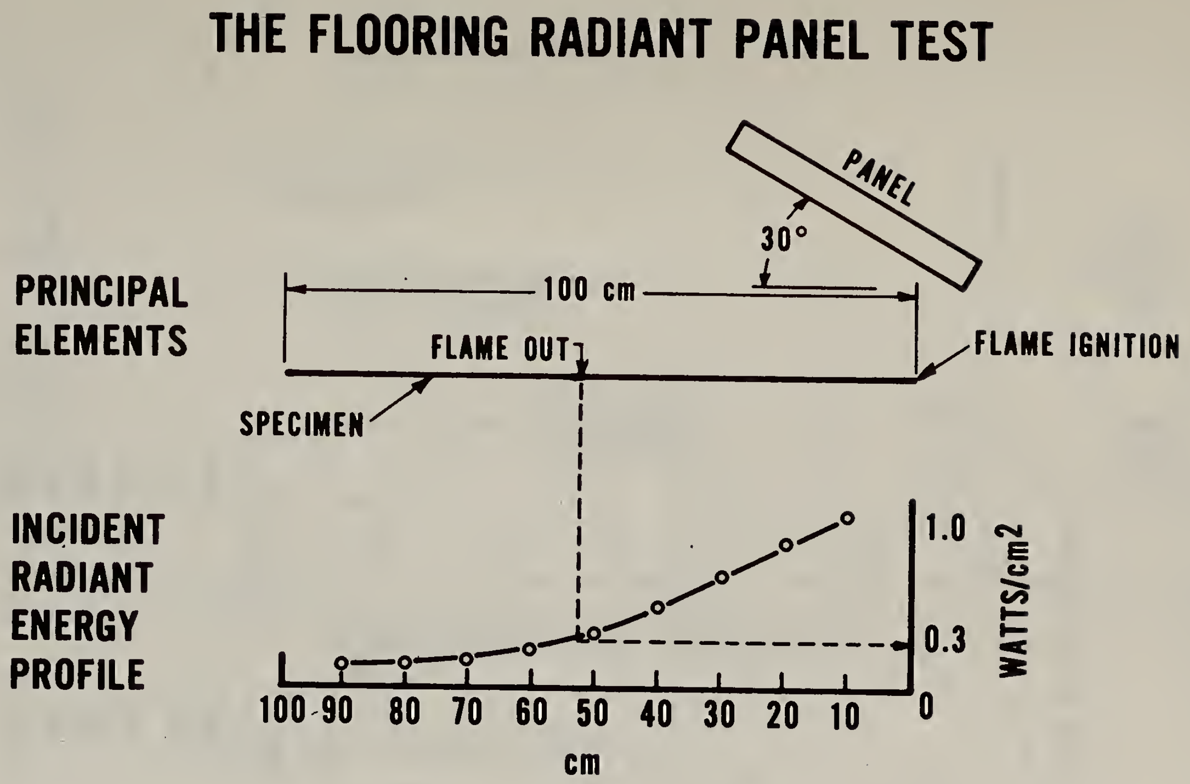
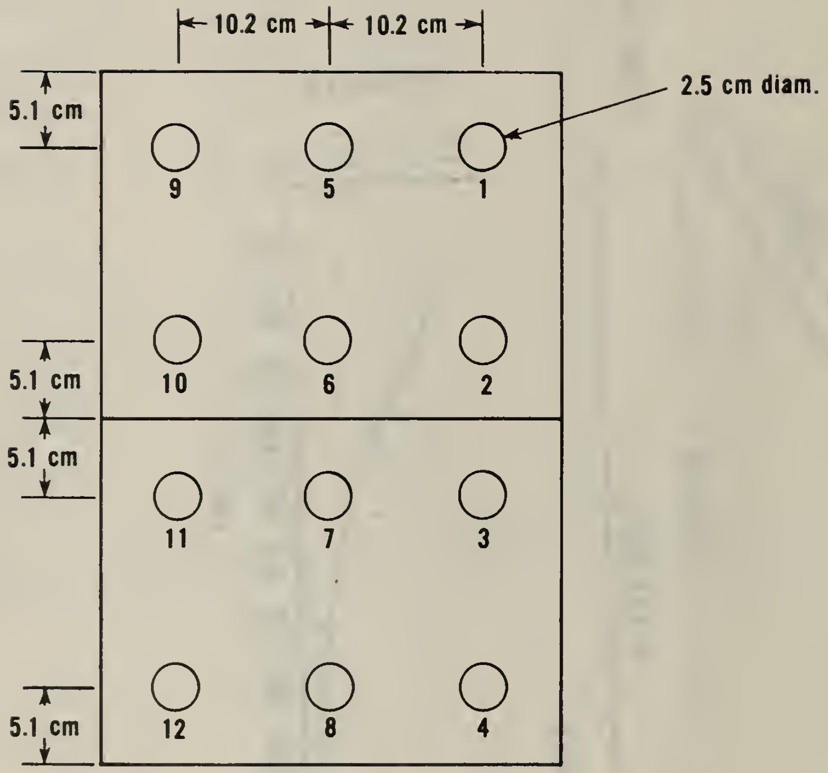


Figure 1. The Flooring Radiant Panel Test



No.	Temp., °C	No.	Temp., °C
1	490	7	495
2	490	8	485
3	510	9	470
4	495	10	495
5	500	11	545
6	500	12	525

Figure 2. Blackbody temperature distribution on non-uniform radiant panel

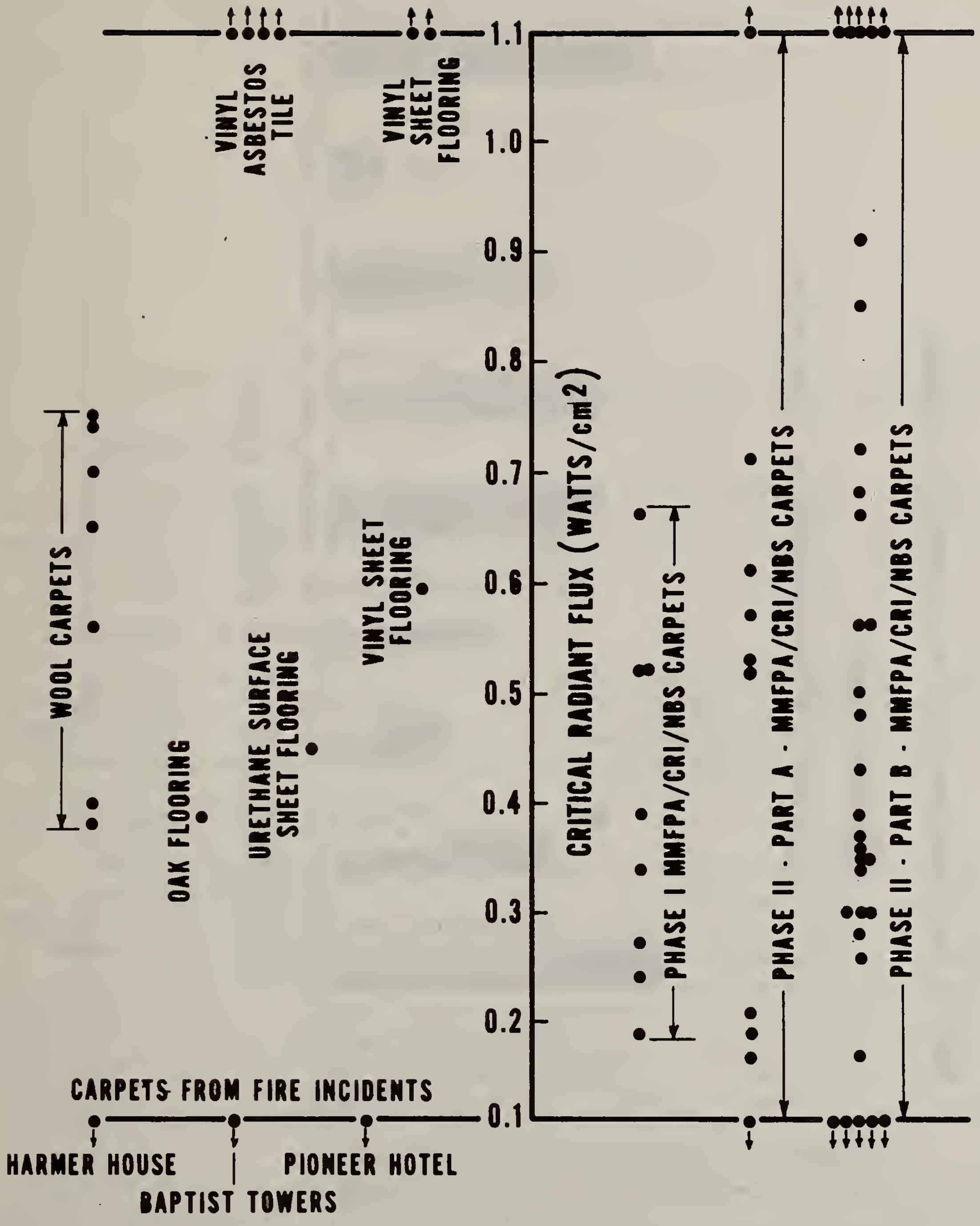


Figure 3. Critical radiant flux map

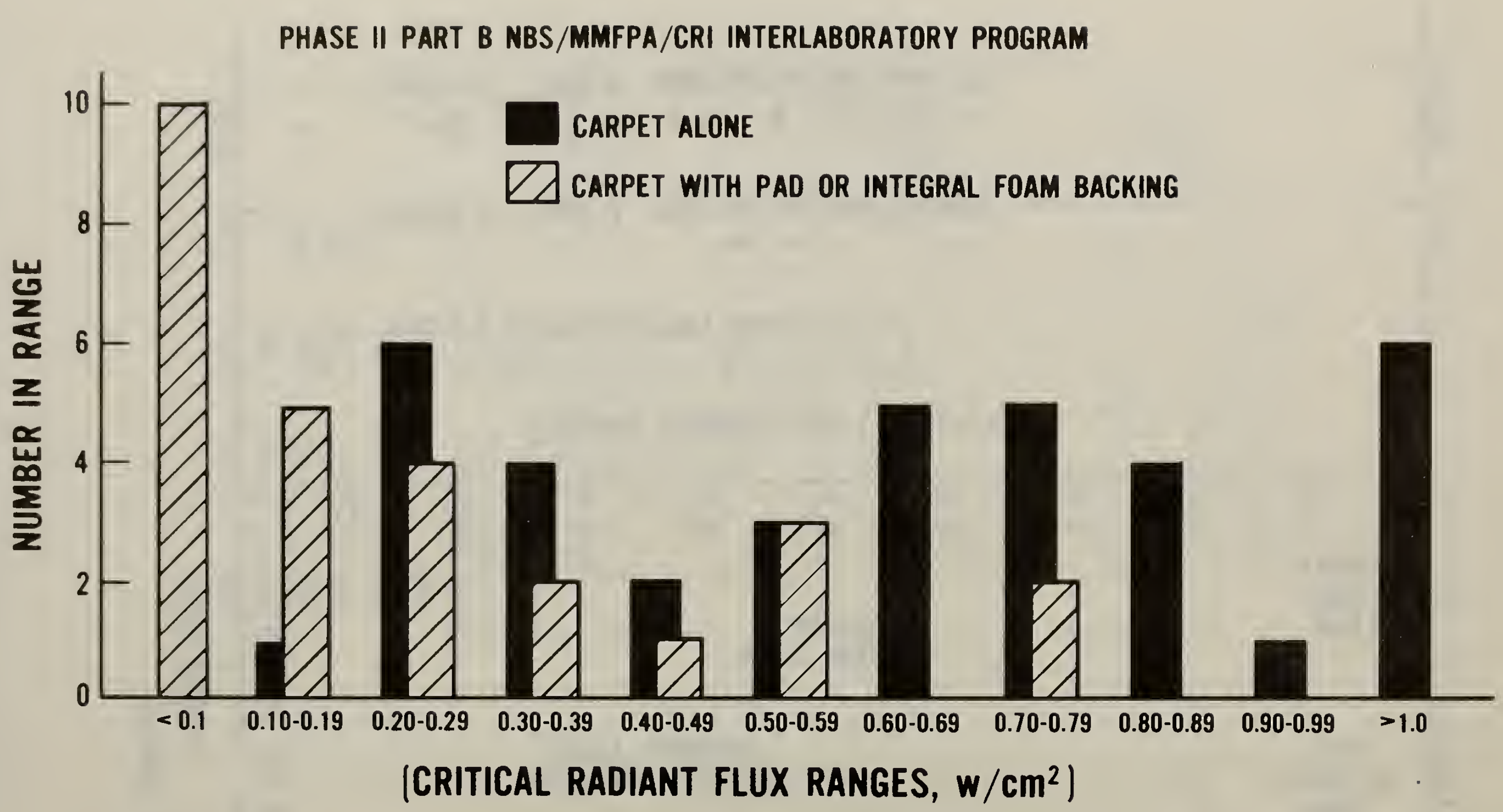


Figure 4. Distribution of contract carpet products by critical flux ranges

FORM NBS-443
(REV. 4-11-63)

APPENDIX A

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

NATIONAL BUREAU OF STANDARDS

REPORT OF CALIBRATION

SPECIAL TEST

Detector Responsivity

of

Three Thermal Detectors

Submitted by

Division 490.20

(See Interdivision Work Order No. 490-2220, dated 10/17/74)

I. Material Tested

Three thermal detectors manufactured by MEDTHERM were submitted for test. The detectors bear serial numbers 124421, 421223, and 124413, respectively. Each detector was mounted in a water-cooled housing. Detector #124413 had a CaF_2 window attached.

II. Purpose of Test

The detectors are to be used to determine the incident heat flux from gas-fired radiant panels in flammability testing chambers. The purpose of this test is to determine the responsivity of each detector to an incident radiant flux of approximately 150 mw cm^{-2}.

III. Method of Test

The MEDTHERM detectors were measured against a lamp standard of total irradiance maintained by the Optical Radiation Section of the National Bureau of Standards and designated T1. This standard is a type DXW 1000-watt, cc-8 tungsten filament, frosted quartz halogen lamp mounted in a slip cast fused silica parabolic reflector which has been flame sprayed with Al_2O_3. [1] The total irradiance of the lamp-reflector combination has been measured relative to the NBS electrically calibrated thermopile radiometer, ECR #2. [2] At a distance of 40.0 cm from the source, the radiant flux is 149.4 mw cm^{-2} (transfer precision approximately 0.2% [3]; estimated absolute uncertainty, 0.6% [4]).

Each detector was mounted with the geometric center of the blackened receiver area positioned along, and perpendicular to, the optic axis of the lamp. The distance from the center of the front surface of the lamp reflector to the front surface of the receiver area was set to the required 40.0 cm. The detector housing was cooled with tap water at 21.5 ±0.5 °C with a flow rate of approximately 20 ml/sec.

Test No.: 221.12/1B/74
Date: October 21, 1974

Page 1 of 5 pages

A movable water-cooled shutter (10.0 cm diameter opening) was placed at the midpoint of the optic axis between the lamp and the detector. A black cloth background was placed about 1.5 meters to the rear of the lamp. No other optics were used.

For a single lamp-detector alignment, a set of 25 measurements were made with a high impedance digital voltmeter. Each measurement consisted of reading the detector output with the shutter open and with the shutter closed. From these measurements the mean value of detector sensitivity and a standard deviation were calculated.

IV. Results

Detector Number	Detector Sensitivity ($W\ cm^{-2}\ mv^{-1}$)	Precision-3σ (%)
124421	0.271	1.5
421223	0.249	2.5*
124413**	0.234	1.4

*the poorer precision results from the greater inherent noise of this particular detector

**with CaF_2 window in place

V. Remarks

Some degree of caution is necessary in applying these results directly to other measurements, such as radiant power from a gas-fired radiant panel. This is especially true in the case of Detector #124413 with the CaF_2 window. It should be emphasized that no attempt has been made to completely characterize the detectors. In general, thermal detectors are usually fairly linear and spectrally flat over the wavelength region of interest, but no effort has been made to measure the absolute spectral response, linearity, or long-term stability of the three MEDTHERM detectors.

In addition, nothing is known about the geometrical properties of the detector response functions. It should be noted that lamp standard T1 produces a fairly collimated beam and was calibrated with a detector whose receiving surface is 0.025 cm^2, circular. The test detectors have receiving areas of about 3 cm^2 and are used in an environment that produces flux from all directions. In using these detectors, measurement errors could arise from either variations in the responsivity function across the sensitive surface of the detector or from variations in the responsivity with angle of incidence of the flux.

Enclosed is a typical spectral irradiance curve for the source that was used in the calibration. Notice especially that this source peaks at about 900 nm whereas the gas-fired radiant panel apparently peaks in the 2-4 μm range. [5] If one assumes that the detector spectral response is flat and linear, then the present calibration points would be directly applicable. These assumptions may be approximately correct in the wavelength region of interest for the two windowless detectors but are definitely incorrect for the windowed detector.

On comparing the present results with those supplied by MEDTHERM one finds the following disagreements:

Detector Number	NBS ($W\ cm^{-2}\ mv^{-1}$)	MEDTHERM ($W\ cm^{-2}\ mv^{-1}$)	Disagreement (%)
124421	.271	.269	0.7
421223	.249	.258	3.6
124413	.234	.262	12.0

On the basis of the calibration procedures outlined in the MEDTHERM report [6] a disagreement of 3-5% does not appear to be unreasonable. Furthermore, if one assumes that the third detector was calibrated without the window as detailed in the MEDTHERM report and the transmission of the CaF_2 window is 92% and flat over the regions of interest, then the present calibration and MEDTHERM's disagree by only 3%. It should be pointed out, however, that the actual reasons for the above discrepancies cannot be reliably inferred without a detailed on-site inspection of MEDTHERM's calibration procedures and facilities and a complete characterization of the detectors.

Principle Investigator:

Michael A. Lind

Michael A. Lind
Optical Radiation Section
Heat Division

For the Director
Institute for Basic Standards

Henry J. Kostkowski

Henry J. Kostkowski
Chief, Optical Radiation Section
Heat Division

Enclosures

References

[1] W. E. Schneider, A One-Solar-Constant Irradiance Standard, Appl. Opt. 9, p. 1410 (June 1970).

[2] Jon Geist, OPTICAL RADIATION MEASUREMENTS: Fundamental Principles of Absolute Radiometry and the Philosophy of This NBS Program (1968 to 1971), NBS Technical Note 594-1 (1972).

[3] Jon Geist, New NBS Scale of Irradiance, Appl. Opt. 12, [4], p. 907, (April 1973), and recent redeterminations, (June 1974).

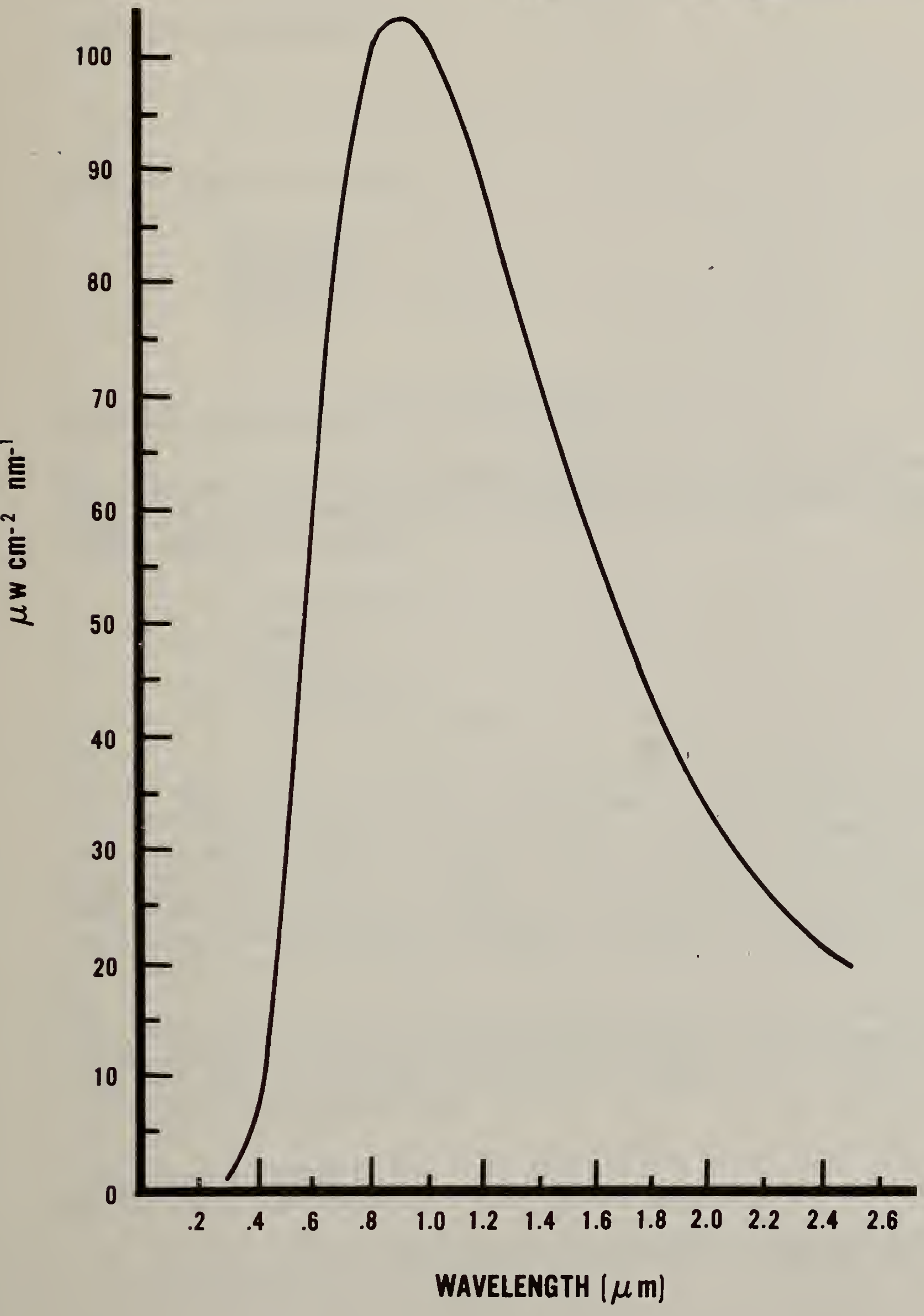
[4] The Thirty Milliwatt Standards of Irradiance (copy enclosed).

[5] J. J. Comeford, The Spectral Distribution of Radiant Energy of a Gas-Fired Radiant Panel and Some Diffusion Flames, Combustion and Flame 18, 125-132 (1972).

[6] MEDTHERM in-house report "General Description of Calibration Procedures for Heat Flux Transducers and Infrared Radiometers."

SPECTRAL IRRADIANCE

TYPICAL 1000 WATT
LAMP-REFLECTOR COMBINATION



APPENDIX B

NBS CENTER FOR FIRE RESEARCH
TOTAL RADIANT FLUX METER, REFERENCE CONVERSION FACTOR

TO:

FROM:

DATE:

SUBMITTING LABORATORY:

TOTAL RADIANT FLUX METER:

Manufacturer
Model No.
Serial No.
Date

REFERENCE CONVERSION FACTOR PROCEDURE

The reference conversion factor (RCF) for the Total Radiant Flux Meter submitted was determined by comparison with NBS Total Radiant Flux Meter (TRFM) working standard:

Manufacturer
Model No.
Serial No.
Calibration
Conversion Factor

in the NBS Flooring Radiant Panel Tester. The tester was operated under the conditions prescribed in the January 7, 1975 Draft Procedure, i.e. radiant panel temperature about 500°C. With the chamber at equilibrium, flux profiles were established with the TRFM instrument submitted and the NBS reference working standard. For each point on the profile, sequential instrument readouts were obtained within a 4-6 minute interval. This technique tended to minimize chamber fluctuation effects.

The reference conversion factor for each of the 10 measuring points on the dummy specimen was calculated by dividing the watts/cm^2 determined with the NBS working standard by the m.v. output of the TRFM submitted, see the calculation example below:

Calculation Example:
NOTE: Data are from the 40 cm measuring point.

Total Radiant Flux (TRF) by NBS-TRFM reference working standard No. 124421:

$$TRF_{40\ cm.} = 1.73\ m.v. \times 0.271\ \frac{watts}{cm^2\ m.v.} = 0.47\ watts/cm^2$$

m.v. output submitting laboratory TRFM = 2.20 m.v.

Reference Conversion Factor at 40 cm. for submitting laboratory TRFM = $\frac{0.47\ watts/cm^2}{2.20\ m.v.}$

$$RCF_{40\ cm.} = 0.214\ \frac{watts}{cm^2\ m.v.}$$

The $RCF_{40\ cm.}$ is then averaged with the RCF's from the other nine points to obtain the mean RCF. This is the reference conversion factor used in establishing the standard flux profile.

The Reference Conversion Factor for TRFM Serial No. is:

$$RCF = \qquad \frac{watts}{cm^2\ m.v.}$$

The basic data used in the RCF determination are tabulated in the attached data logs.

RADIANT FLUX PROFILE

Date __________

Black Body Temp.____________mv. ____________°C

Gas Flow ____________SCFH Air Flow _____________SCFH

Room Temp. _____________°C

Air Press. _____________ Gas ____________in. of H_2O

Flux Meter
Radiometer No. ________________

Conversion Factor ___________
From Calibration On _________

Distance (cm)	MV	Watts/cm^2	Conversion No. From NBS
5	_______	_________	________
10	_______	_________	________
20	_______	_________	________
30	_______	_________	________
40	_______	_________	________
50	_______	_________	________
60	_______	_________	________
70	_______	_________	________
80	_______	_________	________
90	_______	_________	________

Average Conversion
No. from NBS _______±__________

Conversion No.
From Manufacturer ____________

(Manufacturer: __________________________)
(Date: _________________)

Signed _______________________________

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 79-1954	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Development of the Flooring Radiant Panel Test as a Standard Test Method

5. Publication Date

March 1980

6. Performing Organization Code

7. AUTHOR(S)

C. Howard Adams and Sanford Davis

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, DC 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Sponsored in part by:
The Society of the Plastics Industry
355 Lexington Avenue
New York, New York 10017

13. Type of Report & Period Covered

Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report deals with the standardization phase of the Flooring Radiant Panel Test. It describes work done to develop the test as a standard for measuring one of the major factors contributing to the potential fire hazard of floor covering systems used in corridors and exitways.

The investigation involved major interlaboratory test programs and focused on: 1) establishing realistic test conditions; 2) defining and minimizing variability; 3) drafting a complete and concise test procedure; and 4) demonstrating the soundness of the method.

Required flux profile instrumentation calibration procedures were developed and proven. "Critical Radiant Flux" data obtained on representative floor covering systems showed the rank ordering of important products such as man-made and natural fiber carpets, vinyl asbestos tile, and hardwood flooring. Acceptable repeatabilities of about 20% (within-laboratory variability) and reproducibility of about 35% (between-laboratory variability) were demonstrated in two major NBS/MMFPA/CRI interlaboratory carpet system test programs. Fourteen laboratories participated in these full factorial statistically designed experiments with each laboratory testing eighteen carpet materials.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Critical radiant flux; fire safety; flame spread; flammability; floor coverings; flooring radiant panel test; test method.

18. AVAILABILITY ☒ Unlimited

☐ For Official Distribution. Do Not Release to NTIS

☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003-

☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PRINTED PAGES 55
20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price $7.00

USCOMM-DC