41

NBSIR 73-200

# A Model Corridor for the Study of the Flammability of Floor Coverings

Wells Denyes

Research Associate
Man–Made Fiber Producers Association, Inc.
Washington, D. C. 20036

and

James W. Raines

Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

May 1973

Final Report

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NBSIR 73-200

# A MODEL CORRIDOR FOR THE STUDY OF THE FLAMMABILITY OF FLOOR COVERINGS

Wells Denyes

Research Associate
Man-Made Fiber Producers Association, Inc.
Washington, D. C. 20036

and

James W. Raines

Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

May 1973

Final Report

U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

ACKNOWLEDGEMENT

The authors wish to thank the following people for their contributions to this program.

Dr. James Quintiere and Mr. Philip Oglesby of the Combustion Section for their design of the special thermal flux sensors.

Mr. William Zahavi of the Computer Services Division for computer programming assistance.

Messrs. Clark and McKneely of the Plant Division for physical design for the air control system.

Messrs. Spangenberg, Ruegg, and Allion of the Engineering Mechanics Division for their help in designing the air flow system.

Mr. William Bailey and his staff of the Center for Building Technology for their help in setting up the test facility.

# PREFACE

This report describes the apparatus constructed for the study of one of several concepts examined at the National Bureau of Standards for a floor covering flammability test which could be related to performance in real fire conditions. We believe that the work carried out in this facility provides substantial support for the critical energy concept as a measure of hazard potential for floor coverings. A test method based on this concept but substituting a radiant panel as the energy flux source is now being investigated in detail at NBS.

J. E. Clark
Chief, Fire Technology Division
June 1973

CONTENTS

## 1. INTRODUCTION

In April 1971 a mandatory carpet flammability standard DOC FF 1-70 [1] became effective. This standard requires that all carpets entering commerce in the United States pass the methenamine tablet test. This test was designed to ban from commerce those carpets which could be ignited by relatively small sources such as cigarettes, matches, or embers from fireplaces. At this same time many regulatory agencies of federal, state, and local governments were expressing a need for a more severe flammability test to control floor coverings to be used in public buildings, especially floor coverings used in exits, corridors, and stairways.

Several test methods have been considered and a few are being used on a limited basis to regulate carpet flammability. Among those considered have been ASTM E84-68 Tunnel Test [2], UL Subject 992 Floor Covering Chamber Test [3], ASTM E162-67 Radiant Panel Test [4], and Armstrong Cork Company Flooring Radiant Panel [5]. At the present time, none of these test methods provides repeatability nor has been shown to be a reliable measure of the contribution of floor coverings to the hazards of building fires.

In an effort to fill this need, a Research Associate program sponsored by Man-Made Fiber Producers Association, Inc. was begun at the National Bureau of Standards in July 1971. The objective of this program was to develop a laboratory test procedure which would provide a high degree of confidence in prediction of flammability and flame propagation characteristics of floor coverings in full-scale real-life situations.

It is the purpose of this report to summarize the design, construction, instrumentation and operation of the "model corridor" facility that was used for this program. A separate report, "Experimental and Analytical Studies of Floor Covering Flammability With A Model Corridor" [6] discusses the program that has been carried out.

## 2. DESIGN OF FACILITY

The site selected for the location of the facility was at the National Bureau of Standards located in Washington, D. C. in the basement room of Building 65.

A model corridor was designed in which a number of the parameters expected to influence flame spread over floor coverings could be controlled and their effects quantified. Variables selected for investigation included:

1) Model dimensions (up to 8 ft in length, 4 ft in width, and 4 ft in height).

2) Input air velocity (50 to 300 ft per minute).

3) Rate of heat input (up to 2000 Btu per minute).

Figure 1 is a schematic diagram of the model corridor. Cross-sectional dimensions in the test section are varied by relocating the movable wall and ceiling located within the section. Input air velocity is varied by adjusting the pressure drop across the multiple hole orifice plate. Rate of heat input is varied by changing the rate of natural gas feed to the diffusion flame burner which impinges on the floor mounted samples.

A 20-channel data acquisition system with rapid response time was designed so that temperature gradients and energy fluxes could be recorded. A computer program was developed which provided rapid data conversion.

Both the construction of the test facility and the instrumentation are described in detail in the following sections.

## 3. CONSTRUCTION

Construction of the model corridor was carried out in four parts:

(1) design and assembly of the test section.

(2) design and assembly of the air control section.

(3) design and assembly of the exhaust duct.

(4) assembly of the total system.

The overall test section is a 4 ft x 4 ft x 8 ft duct containing an inner movable ceiling and wall that allows the interior working dimension to be reduced in both height and width. The framework is made of slotted steel angle, mitered and butt welded at all corners. The top, back wall, and bottom are made of 4 ft x 8 ft x 3/8 in asbestos board bolted directly to the outside of the slotted angle frame. The door, also made of asbestos board, is attached with a piano hinge at the top to allow easy accessibility to the test section. The framework of the door opening is covered with asbestos paper attached with furnace cement to provide a gasket. The exterior of the door is framed with slotted angle to give it strength and ridigity. Three 95% silica plate glass windows were placed in the door 6 in above the floor level to allow viewing of tests. A lattice framework at the entrance and exit of the test section provide support for the asbestos board movable interior wall and ceiling. Figure 2 shows the test section with the door open and the movable wall and ceiling installed. The actual dimension of the test section as shown in the photograph is reduced to 24 in wide x 11 in high. Figure 3 shows the test section with the door closed.

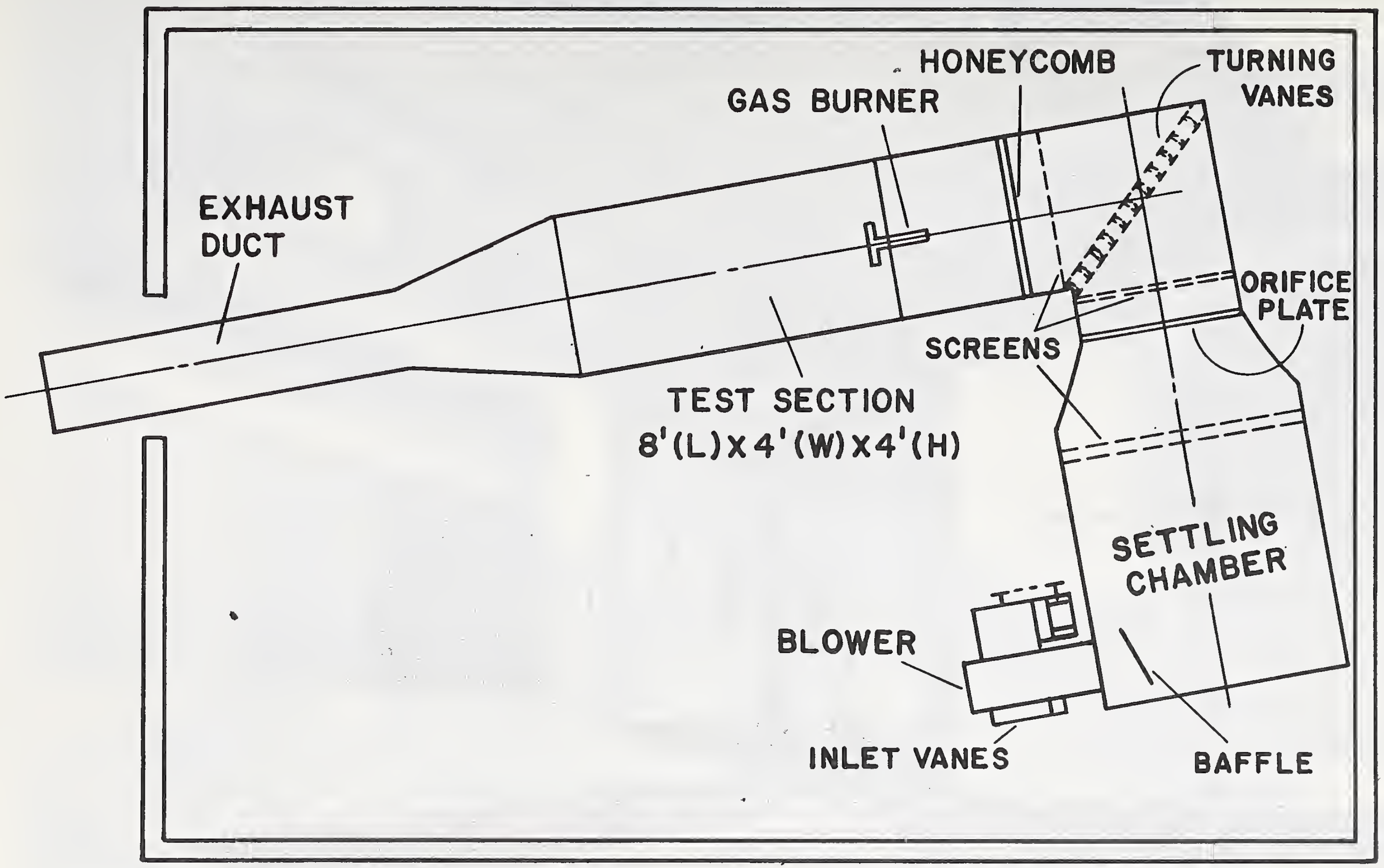



Figure 1. Total system layout.

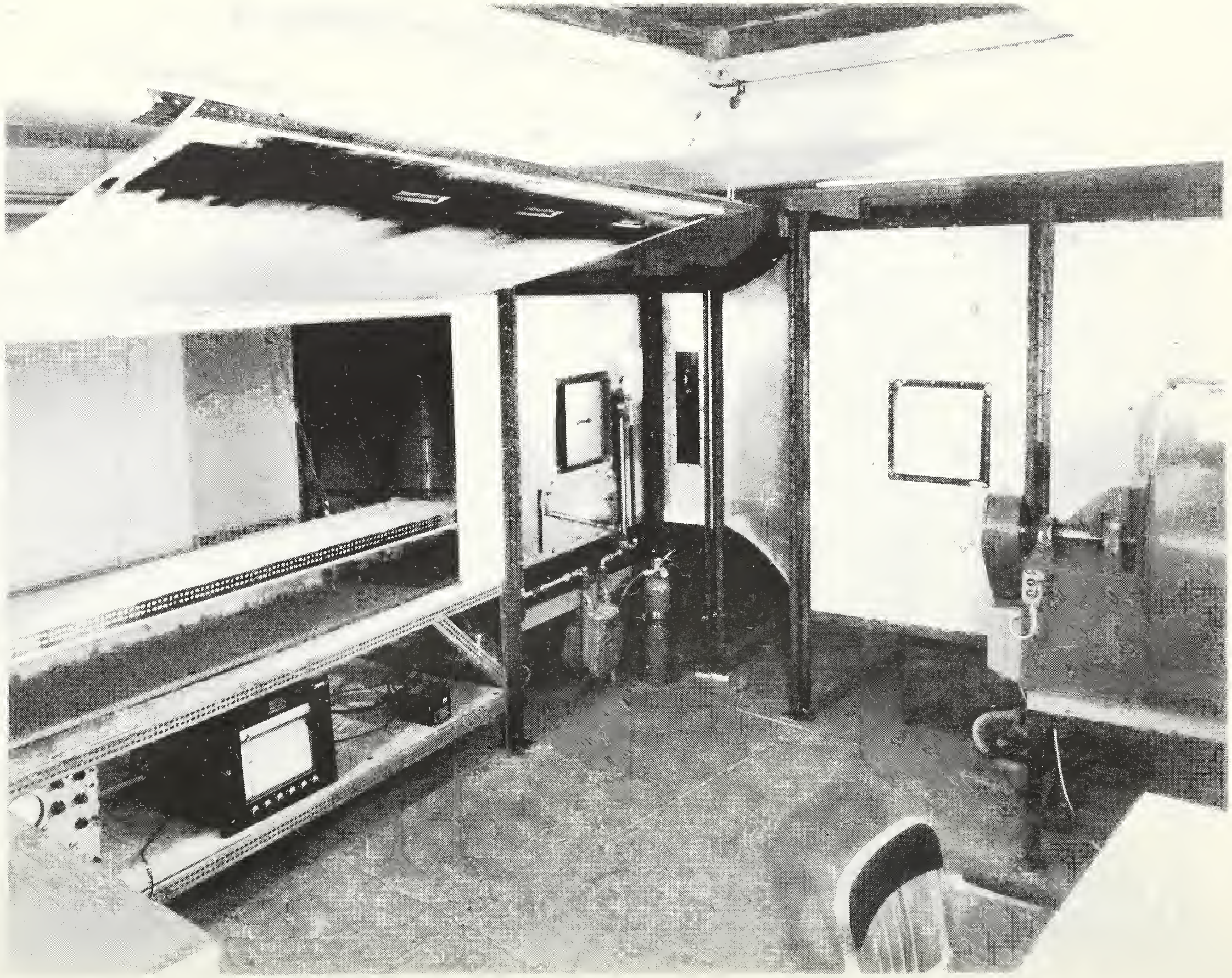


Figure 2. Test section - door open.

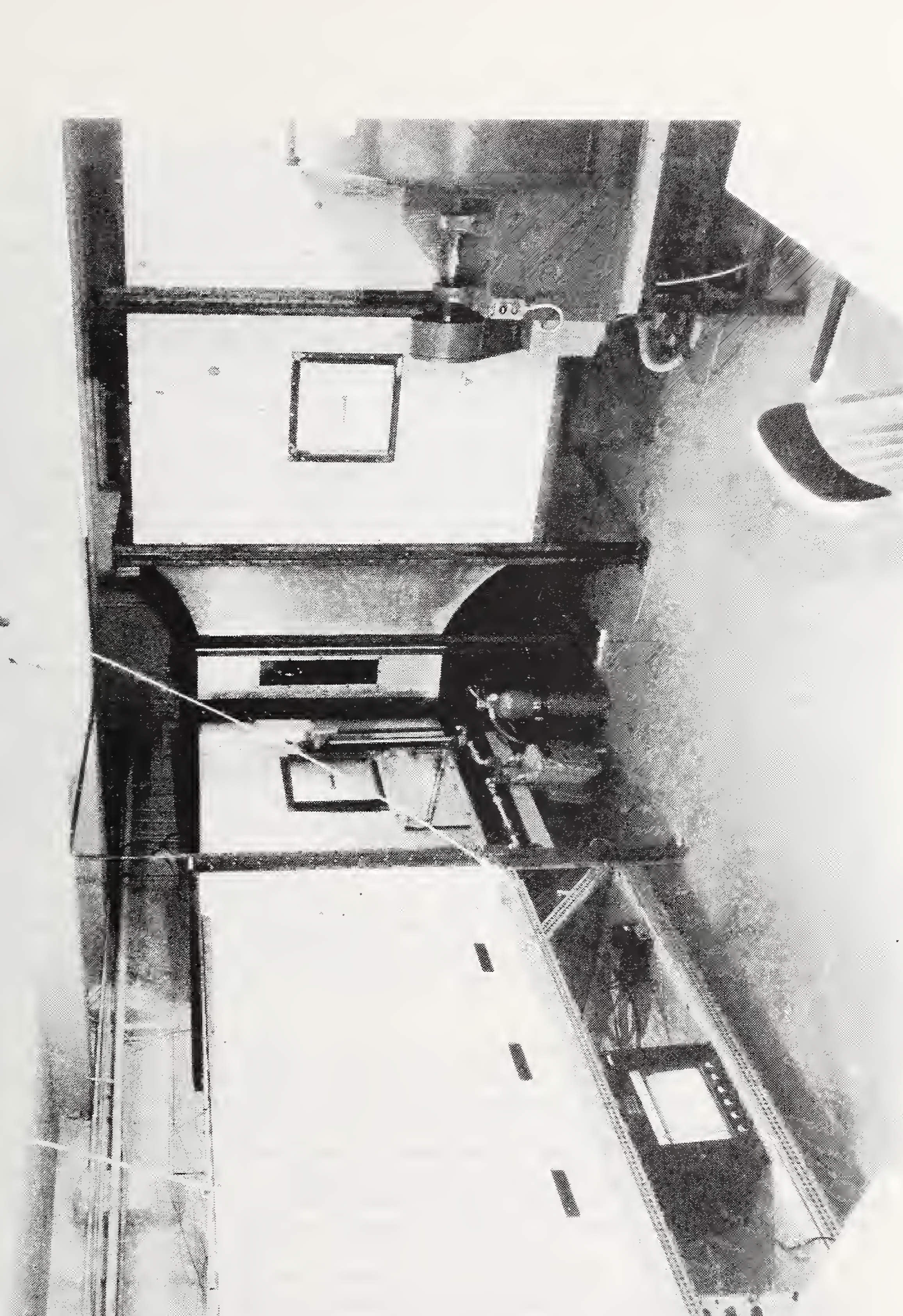


Figure 3. Test section - door closed.

The burner is mounted in the center of the entrance of the test section. When the test section width is altered the burner is always placed in the center. It is adjustable vertically so that for varying thicknesses of floor covering the burner is always 1/2 in above the surface of the sample. Gas flow to the burner is indicated by a flowmeter, and measured by a totalizing meter (figure 4). The burner is of the same design as used in the Underwriters' Laboratory Subject 992 Floor Covering Chamber Test [3]. It is a diffusion type burner and impinges on the floor covering surface at an angle of 27° from the horizontal. Experimentation has shown that this angle is not critical. The burner is 6 in wide and the flame is approximately 8 in wide.

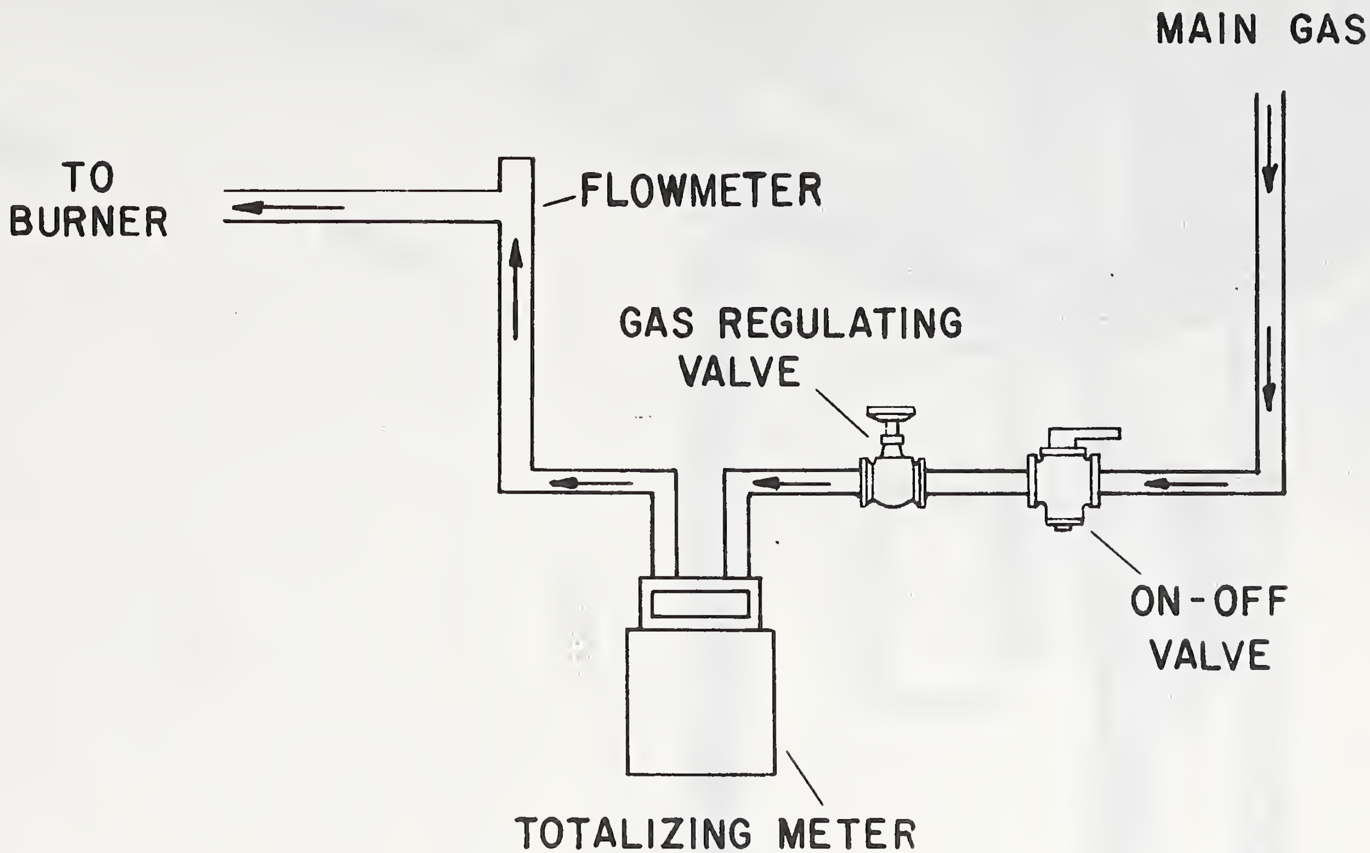
One of the parameters chosen for the test program was the rate of heat input to the test section. Natural gas with an energy content of 1020 Btu/ft$^3$ was supplied to the burner. Table 1 shows the relationship between the reading of the flowmeter used to monitor the gas flow and the Btu input from the burner. The burner is ignited with an electric spark generated by a transformer.

The air control section posed many design problems which had to be solved before construction could be started. A stable, uniform, tempered air flow that could be varied from 50 to 300 ft per minute was required. This requirement calls for a maximum of 4800 cubic feet of air per minute. The room in which the section was to be located was small, measuring approximately 20 ft x 29 ft x 8 ft. This meant that additional air had to be drawn from another source. A 4 ft x 6 ft access door in the ceiling, which opened up into a large storage room containing some 50,000 cubic feet of space, was utilized to provide the additional tempered, but not conditioned, air for the system.

It was determined that because of the limited space available a 90° turn in air flow was necessary to provide a stable, uniform air flow. Also, air should flow through the entire test section at all times, even when the movable interior wall and ceiling are in place. This would make air velocity control easier.

The question of whether or not air flow would be uniform over a small section arose. There was concern in the early design of the system that a fire in the small test section would disrupt the air flow pattern, but later experimentation showed this was not the case. The pressure drop created by the fire was small compared to the pressure drop across the rest of the system and air flow remained stable. This information was verified by checking the air velocity over the total cross-sectional area of the test section with a hot wire anemometer before and during test runs.

Another question that had to be answered was whether air should be blown into the system, or whether an exhaust fan would be suitable. The corrosive nature of the gases involved made it desirable to blow air into the system, although this did require extra care in sealing the test section. Additionally, with the forced air system it was possible to control air flow at ambient conditions rather than at the varying temperatures and densities produced by a fire.




GAS FLOW

Figure 4. Gas flow.

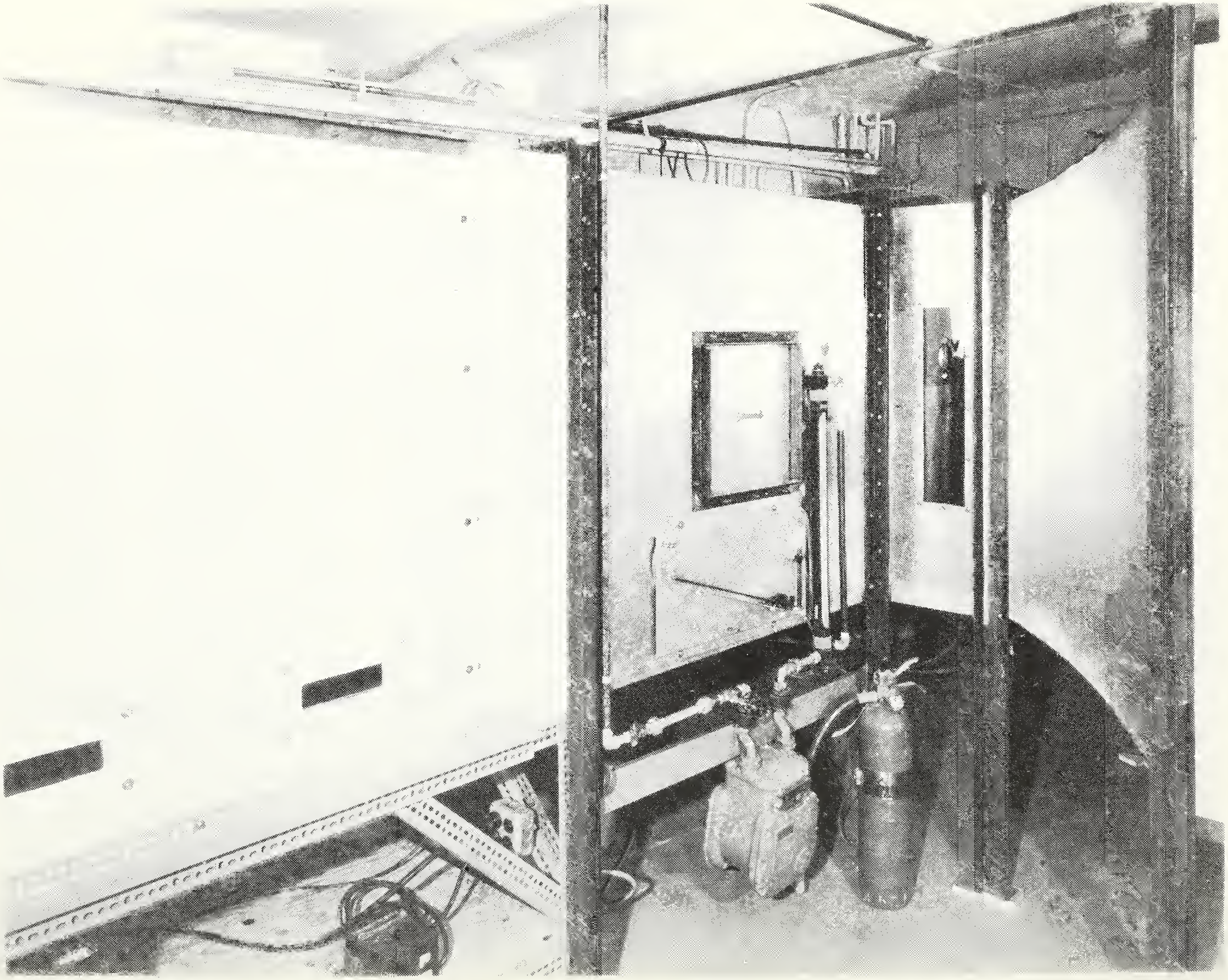


Figure 5. Gas and air monitoring equipment.

TABLE 1

GAS FLOW RATE*

| Btu/min | Flowmeter Setting |
|---|---|
| 250 | .32 |
| 300 | .38 |
| 350 | .44 |
| 400 | .51 |
| 450 | .58 |
| 500 | .64 |
| 600 | .76 |
| 750 | .96 |
| 1000 | 1.27 |
| 1250 | 1.59 |
| 1500 | 1.91 |

*Calibrated for natural gas with a content of 1020 Btu/ft$^3$.

The blower selected was a load limit fan with a single inlet. Air intake was controlled by variable inlet vanes. The blower was designed to operate at a 4 in water pressure drop. A D.C. motor driven fan would have allowed simpler control of the air at the intake, but cost, delivery time, and non-availability of D.C. power determined that the A.C. blower assembly described above should be installed.

An orifice plate was determined to be the best method of controlling air flow. It serves two functions. It creates a pressure drop upstream from the test section which is very large compared to the pressure drop created by the fire in the test section. This resulted in a constant air flow rate to the test section during a test. Air flow measurements taken during Carpet Flammability Tests (hereafter referred as CFT) 286-291 verified this flow behavior. An appreciable change in air velocity only occurred well after "flameover" (i.e. a rapidly accelerating flame front leading to total involvement of the sample). These data are shown in table 2. The other function served by the orifice plate is to control the quantity of air flow. The orifice plate is a 4 ft x 4 ft x 1/4 in aluminum plate containing 100 holes evenly distributed in a 10 x 10 array. Hole diameters and spacing were calculated so that with a pressure drop of 4 in of water the total flow of air would be 4800 ft$^3$ per minute. When translated across a 4 ft x 4 ft cross section the average air velocity is 300 ft per minute. The pressure drop is monitored with an inclined manometer with a range of 0-6 in of water. Before the experimental program began, the pressure differential around the perimeter of the orifice plate was measured. These measurements showed a uniform pressure drop across the entire surface. By plugging selected holes distributed uniformly over

TABLE 2

AIR VELOCITY MEASUREMENTS CFT 286-291

| Elapsed Time Min:Sec | 286 Air Flow 75FT/Min | 287 Air Flow 75FT/Min | 288 Air Flow 125FT/Min | 289 Air Flow 125FT/Min | 290 Air Flow 125FT/Min | 291 Air Flow 100FT/Min |
|---|---|---|---|---|---|---|
| 0::0 | 72 | 71 | 127 | 128 | 127 | 100 |
| 0::30 | 72 | 70 | 127 | 128 | 126 | 100 |
| 1::00 | 72 | 70 | 128 | 128 | 127 | 100 |
| 1::30 | 73 | 70 | 128 | 127 | 127 | 100 |
| 2::00 | 72 | 71 | 129 | 128 | 128 | 102 |
| 2::30 | 73 | 71 | 129 | 128 | 127 | 100 |
| 3::00 | 73 | 71 | 130 | 128 | 127 | 102 |
| 3::30 | 74 | 70 | 130 | 128 | 128 | 104 |
| 4::00 | 74 | 72 | 131 | 130 | 128 | 104 |
| 4::30 | 74 | 72 | 131 | 130 | 130 | 104 |
| 5::00 | 75 | 72 | 132 | 131 | 130 | 104 |
| 5::30 | 75 | 73 | 133 | 130 | 130 | 105 |
| 6::00 | 75 | 73 | 132 | 132 | 129 | 105 |
| 6::30 | 76 | 73 | 132 | 132 | 130 | 107 |
| 7::00 | 76 | 73 | 133 | 132 | 131 | 106 |
| 7::30 | 77 | 73 | 132 | 131 | 131 | 108 |
| 8::00 | 77 | 73 | 132 | 131 | 130 | 105 |
| 8::30 | 78 | 73 | 132 | 131 | 131 | 105 |
| 9::00 | 77 | 73 | 132 | 132 | 130 | 107 |
| 9::30 | 78* | 73 | 132 | 132 | 131 | 105* |
| 10::00 | 95 | 73 | 133 | 132 | 131 | 110 |
| 10::30 | 108 | 73 | 133 | 131 | 130 | 118 |
| 11::00 | 103 | 73 | 134 | 132 | 130 | 115 |
| 11::30 | 95 | 73 | 133 | 131 | 132 | 110 |
| 12::00 | 88 | 74 | 134 | 132 | 131 | 103 |

* "Flameover"

the orifice plate and adjusting the pressure drop by means of variable inlet vanes of the blower, exact air velocities within the desired range can be obtained. Table 3 contains information needed to calculate air velocity.

With these conditions in mind, the air control system was designed and built in the following manner. The first section consisted of a 6 ft x 6 ft x 7 ft box to act as a settling chamber for the intake air. A baffle was placed immediately in front of the blower discharge to diffuse the air. At the exit end of this settling chamber two galvanized wire screens were installed to further diffuse the air. The second section is a transition section (figure 1) which was installed to reduce the cross-sectional dimensions from 6 ft x 6 ft to the desired 4 ft x 4 ft. The previously discussed orifice plate was installed at the end of this section. The third section is used to make the required 90° turn. Double reflecting turning vanes are used to move the air around this corner. There are also four, fine mesh screens used to further diffuse the air so that lateral pressure differences across the test section do not exist. The fourth section has a 4 ft x 4 ft x 2 in piece of aluminum honeycomb that functions as an air flow straightener. The cells are hexagonal, measuring 1/4 in across the flat surfaces. The output from this section empties into the test section as described earlier. Figure 6 shows the construction drawings of the completed air control assembly.

After completing the construction of the air flow system velocity measurements were made at many locations. Some of the screens described above were installed to correct various flow pattern problems. After final construction a stable, uniform air flow was achieved. During the experimental program air flow was not monitored continuously but was checked at random intervals to insure good air flow.

Following the test section another reducing section was used to further reduce the cross-sectional measurements to 2 ft x 2 ft. This transition is 4 ft long and is made from 2 in x 2 in steel angle covered with asbestos board.

The final section is a 2 ft x 2 ft steel duct which shuttles the exhaust out of the model corridor and into the atmosphere. In order to reach the outside of the building the duct has to make a 2 ft rise. Figure 7 shows how this was accomplished. There was some fear that a chimney effect might be created by even the small rise in the exhaust duct, however, this was not the case. Air velocity measurements were taken at the exit end of the test section both with and without the burner ignited. No change in air velocity was noticed.

The first experiments demonstrated the need for some device that would prevent edge burning of the test samples. Initially, tackless stripping was used to hold the samples down. It did not prevent edge burning, and had to be replaced after each test. Curbs, 1 in x 1 in, made of asbestos board were also tried. They were clamped in place on top of the carpet next to the walls. Edge burning was not completely

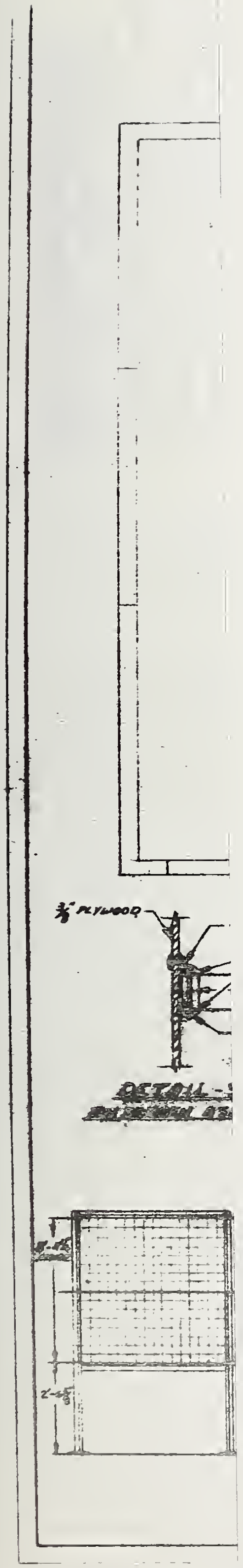
TABLE 3

AIR FLOW IN MODEL CORRIDOR

Pressure Across Orifice Plate (In. of Water)

| Air Flow (ft/min) | | Holes in Orifice Plate | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 | 80 | 60 | 40 | 20 | 10 |
| | 300 | 4" | | | | | |
| | 250 | 2.8" | 4.3" | | | | |
| | 240 | 2.6" | 4" | | | | |
| | 200 | 1.8" | 2.8" | 4.9" | .. | | |
| | 180 | 1.4" | 2.3" | 4" | | | |
| | 150 | 1.0" | 1.6" | 2.8" | | | |
| | 120 | | 1.0" | 1.8" | 4" | | |
| | 100 | | | 1.2" | 2.8" | | |
| | 60 | | | | 1.0" | 4" | |
| | 50 | | | | | 2.8" | |
| | 30 | | | | | 1.0" | 4" |
| | 25 | | | | | | 2.8" |

Air flow (ft/min) = Holes x Pres. x 1.5



3/8" PLYWOOD

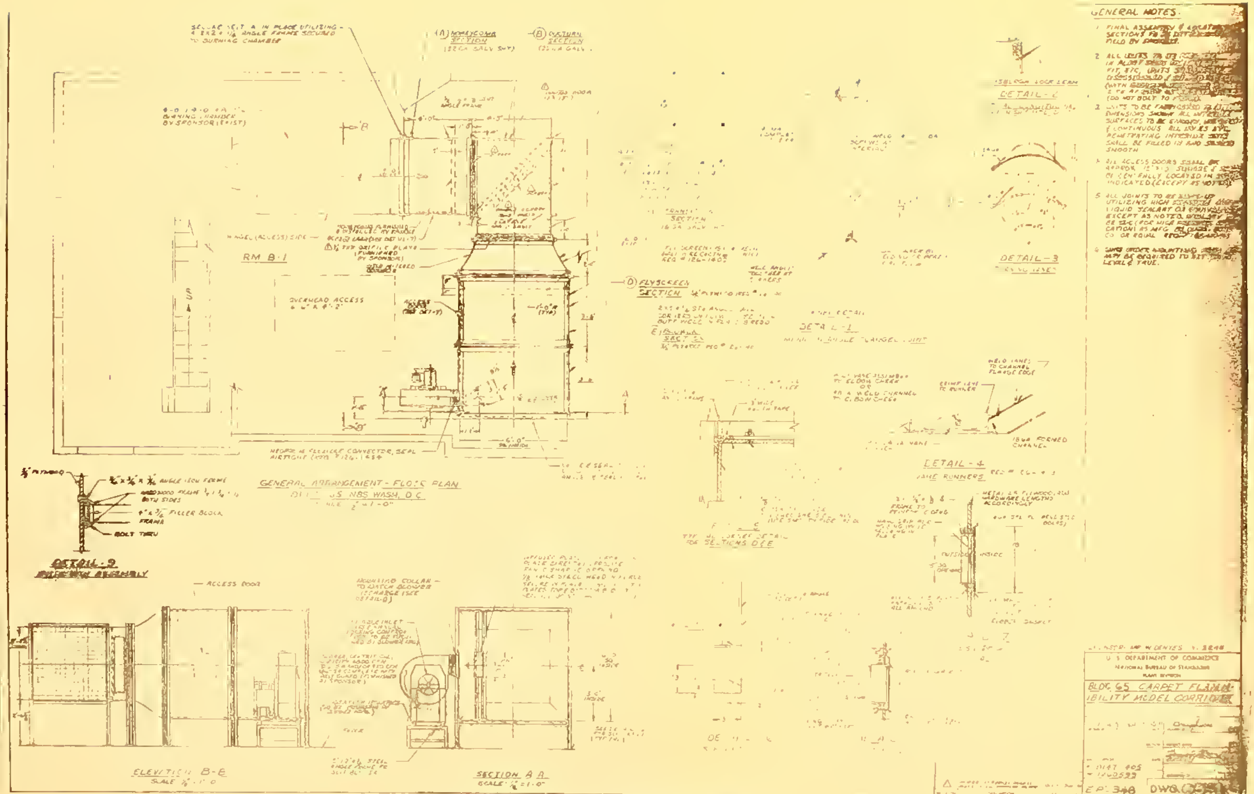




Figure 6. Air control assembly

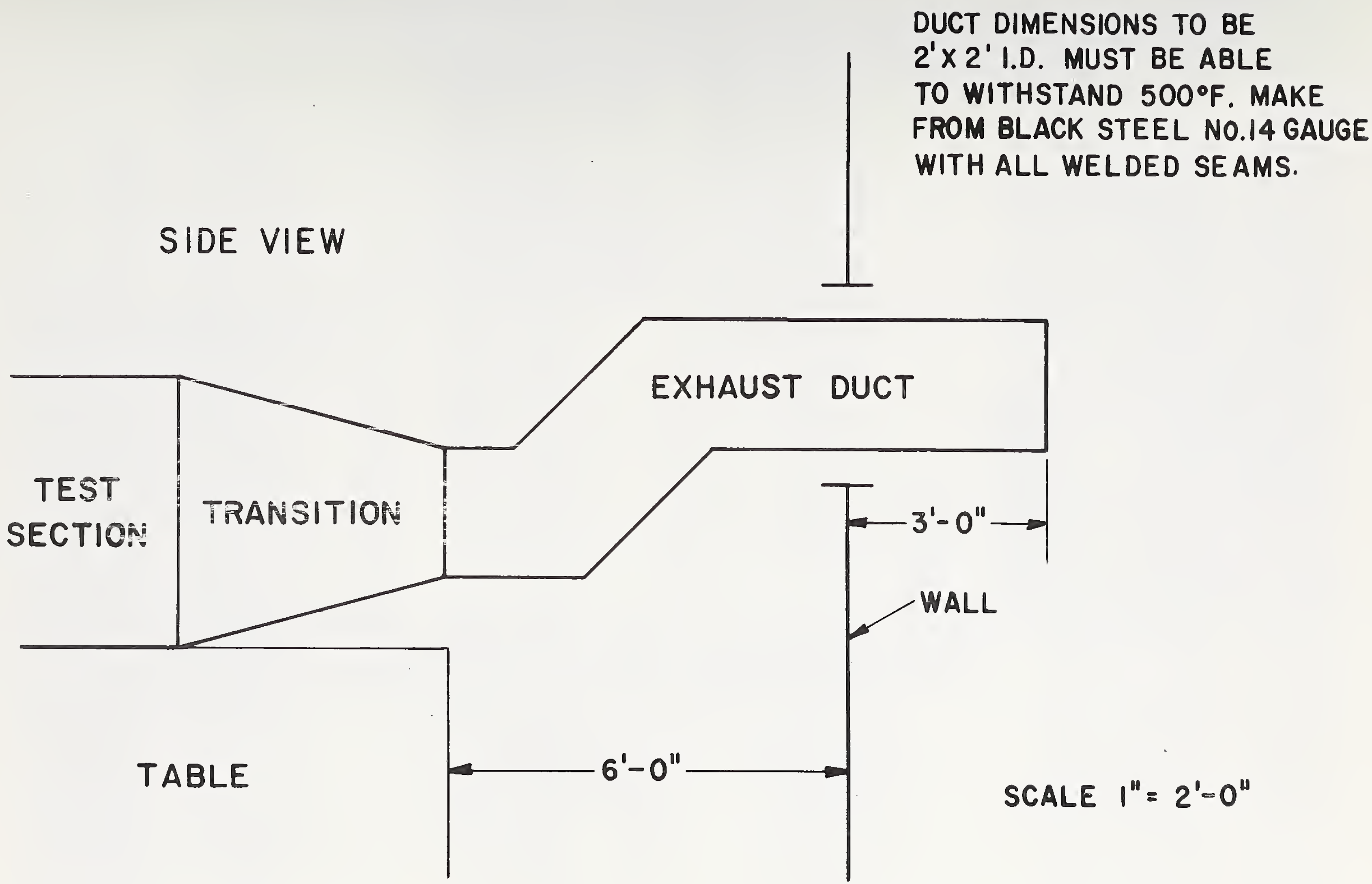



Figure 7. Exhaust duct.

inhibited and eventually these curbs were replaced with 1 in x 1 in rectangular steel tubing which has performed satisfactorily. They successfully held the carpet in place and inhibited edge burning.

Some tests were conducted with a sample adherred to the floor. This was done to determine the effect of whether carpets glued down would perform differently in a fire environment than normally installed carpets. In these tests a portable floor was constructed from asbestos board and fitted into the test section. Correspondingly, the ceiling was raised the thickness of this portable floor. Sixty grams per $ft^2$ of either latex or insulating adhesive was used to attach the sample to the portable floor. This amount of adhesive satisfactorily holds the carpet in place and is typical of commercial applications.

## 4. INSTRUMENTATION

In order to understand the phenomena of floor covering flammability adequate instrumentation to make measurements was necessary. These resulting data then must be assembled and processed in some manner which is fast and economical. It was decided to use available electronic instrumentation, where feasible, that would allow quick data reduction utilizing the central computing facilities at NBS.

### 4.1 Data Collection

Data are collected by a digital data acquisition system designed and built at NBS. It consists of a digital clock, a reed relay scanner, a high speed analog to digital convertor, a system controller, and a high speed paper tape perforator. The system accepts up to twenty analog signals and scans them sequentially at a rate of 16 channels per second when activated by the digital clock. Figure 8 shows the system setup.

### 4.2 Data Reduction

The data are processed with SPEED [7], a problem-oriented language for computer use written in FORTRAN IV. The program was developed at NBS for general purpose data processing. The program converts instrument readings to engineering units and displays them in tabular and graphic form. Figures 9 and 10 are sample data printouts.

Figure 11 is a flow chart of data from sensor to completion of the data reduction program.

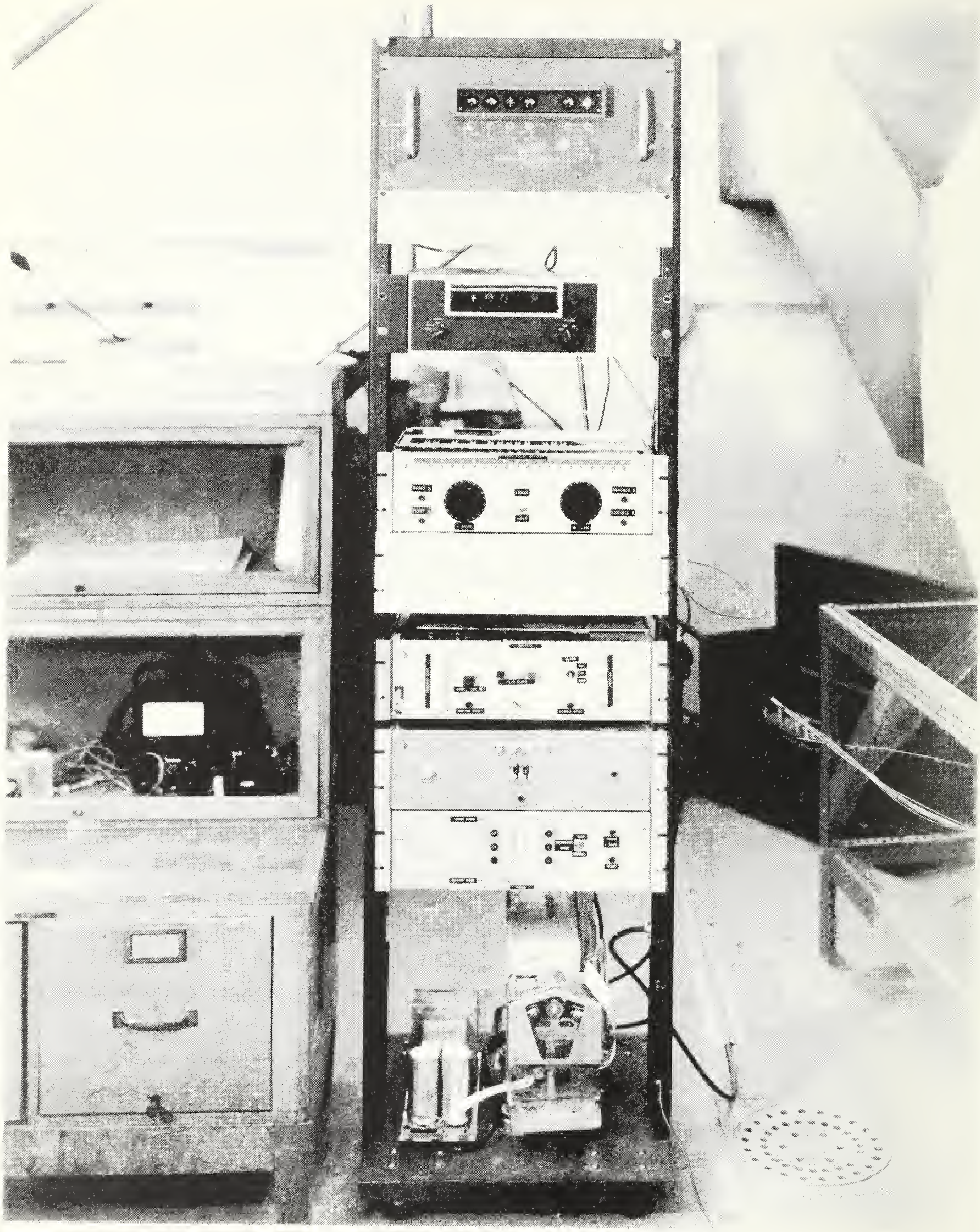


Figure 8. Data acquisition system.

CFT 75 30?-292 ACRYL 4-L RUB HAIR/ WTE PAD 24X14 100 FPM 500 RTH/MIN 3 FEB 72

DATA BLOCK NO.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | 22.00 | 22.00 | 22.00 | 20.00 | 22.00 | 20.00 | 20.00 | 22.00 | 22.00 | 22.00 | 24.00 |
| 10.00 | 10.00 | 24.00 | 27.00 | 27.00 | 24.00 | 27.00 | 24.00 | 24.00 | 24.00 | 27.00 | 27.00 | 29.00 |
| 20.00 | 20.00 | 39.00 | 29.00 | 29.00 | 56.00 | 46.00 | 71.00 | 44.00 | 29.00 | 49.00 | 29.00 | 32.00 |
| 30.00 | 30.00 | 49.00 | 27.00 | 27.00 | 68.00 | 54.00 | 83.00 | 63.00 | 29.00 | 59.00 | 27.00 | 29.00 |
| 40.00 | 40.00 | 63.00 | 27.00 | 27.00 | 80.00 | 61.00 | 93.00 | 78.00 | 34.00 | 71.00 | 27.00 | 29.00 |
| 50.00 | 50.00 | 76.00 | 27.00 | 27.00 | 95.00 | 71.00 | 105.00 | 90.00 | 37.00 | 78.00 | 27.00 | 29.00 |
| 60.00 | 60.00 | 95.00 | 27.00 | 24.00 | 105.00 | 78.00 | 122.00 | 125.00 | 37.00 | 90.00 | 27.00 | 29.00 |
| 70.00 | 70.00 | 115.00 | 32.00 | 24.00 | 112.00 | 85.00 | 125.00 | 201.00 | 37.00 | 98.00 | 27.00 | 29.00 |
| 80.00 | 80.00 | 140.00 | 32.00 | 24.00 | 120.00 | 90.00 | 130.00 | 305.00 | 39.00 | 105.00 | 27.00 | 29.00 |
| 90.00 | 90.00 | 208.00 | 34.00 | 24.00 | 125.00 | 95.00 | 130.00 | 393.00 | 39.00 | 112.00 | 27.00 | 29.00 |
| 100.00 | 100.00 | 360.00 | 34.00 | 24.00 | 130.00 | 95.00 | 132.00 | 346.00 | 39.00 | 110.00 | 24.00 | 27.00 |
| 110.00 | 110.00 | 486.00 | 44.00 | 27.00 | 137.00 | 105.00 | 135.00 | 325.00 | 41.00 | 117.00 | 27.00 | 29.00 |
| 120.00 | 120.00 | 512.00 | 56.00 | 27.00 | 142.00 | 110.00 | 135.00 | 313.00 | 41.00 | 115.00 | 27.00 | 32.00 |
| 130.00 | 130.00 | 379.00 | 73.00 | 27.00 | 150.00 | 117.00 | 140.00 | 337.00 | 41.00 | 117.00 | 27.00 | 32.00 |
| 140.00 | 140.00 | 388.00 | 88.00 | 29.00 | 152.00 | 122.00 | 142.00 | 435.00 | 41.00 | 122.00 | 27.00 | 32.00 |
| 150.00 | 150.00 | 426.00 | 107.00 | 29.00 | 157.00 | 125.00 | 142.00 | 459.00 | 41.00 | 125.00 | 27.00 | 34.00 |
| 160.00 | 160.00 | 491.00 | 125.00 | 34.00 | 165.00 | 132.00 | 155.00 | 491.00 | 44.00 | 130.00 | 27.00 | 34.00 |
| 170.00 | 170.00 | 552.00 | 147.00 | 37.00 | 167.00 | 137.00 | 160.00 | 512.00 | 44.00 | 135.00 | 27.00 | 34.00 |
| 180.00 | 180.00 | 598.00 | 172.00 | 41.00 | 175.00 | 142.00 | 162.00 | 509.00 | 46.00 | 140.00 | 27.00 | 34.00 |
| 190.00 | 190.00 | 563.00 | 197.00 | 46.00 | 180.00 | 147.00 | 170.00 | 610.00 | 46.00 | 145.00 | 27.00 | 34.00 |
| 200.00 | 200.00 | 582.00 | 223.00 | 54.00 | 187.00 | 155.00 | 180.00 | 568.00 | 49.00 | 155.00 | 27.00 | 34.00 |
| 210.00 | 210.00 | 552.00 | 255.00 | 63.00 | 195.00 | 160.00 | 185.00 | 629.00 | 54.00 | 165.00 | 29.00 | 37.00 |
| 220.00 | 220.00 | 549.00 | 277.00 | 68.00 | 195.00 | 162.00 | 185.00 | 598.00 | 56.00 | 167.00 | 27.00 | 34.00 |
| 230.00 | 230.00 | 556.00 | 299.00 | 73.00 | 197.00 | 165.00 | 182.00 | 521.00 | 59.00 | 162.00 | 27.00 | 37.00 |
| 240.00 | 240.00 | 563.00 | 308.00 | 80.00 | 197.00 | 167.00 | 182.00 | 433.00 | 71.00 | 162.00 | 27.00 | 39.00 |
| 250.00 | 250.00 | 575.00 | 322.00 | 83.00 | 198.00 | 167.00 | 180.00 | 382.00 | 71.00 | 162.00 | 27.00 | 39.00 |
| 260.00 | 260.00 | 566.00 | 332.00 | 83.00 | 200.00 | 167.00 | 177.00 | 360.00 | 63.00 | 160.00 | 24.00 | 37.00 |
| 270.00 | 270.00 | 568.00 | 341.00 | 85.00 | 198.00 | 170.00 | 177.00 | 353.00 | 63.00 | 157.00 | 24.00 | 37.00 |
| 280.00 | 280.00 | 573.00 | 351.00 | 88.00 | 201.00 | 172.00 | 175.00 | 353.00 | 73.00 | 157.00 | 27.00 | 41.00 |
| 290.00 | 290.00 | 568.00 | 358.00 | 90.00 | 206.00 | 177.00 | 177.00 | 337.00 | 76.00 | 160.00 | 29.00 | 41.00 |
| 300.00 | 300.00 | 561.00 | 360.00 | 88.00 | 208.00 | 177.00 | 175.00 | 320.00 | 71.00 | 157.00 | 27.00 | 41.00 |
| 310.00 | 310.00 | 559.00 | 365.00 | 88.00 | 208.00 | 180.00 | 180.00 | 305.00 | 66.00 | 157.00 | 27.00 | 41.00 |
| 320.00 | 320.00 | 535.00 | 368.00 | 88.00 | 208.00 | 180.00 | 177.00 | 300.00 | 71.00 | 157.00 | 27.00 | 41.00 |
| 330.00 | 330.00 | 533.00 | 372.00 | 90.00 | 208.00 | 180.00 | 177.00 | 275.00 | 71.00 | 157.00 | 27.00 | 41.00 |
| 340.00 | 340.00 | 509.00 | 372.00 | 93.00 | 211.00 | 182.00 | 180.00 | 270.00 | 63.00 | 157.00 | 27.00 | 44.00 |
| 350.00 | 350.00 | 505.00 | 375.00 | 95.00 | 211.00 | 182.00 | 185.00 | 250.00 | 61.00 | 157.00 | 27.00 | 44.00 |
| 360.00 | 360.00 | 502.00 | 377.00 | 98.00 | 211.00 | 182.00 | 182.00 | 243.00 | 63.00 | 157.00 | 27.00 | 44.00 |
| 370.00 | 370.00 | 475.00 | 377.00 | 105.00 | 213.00 | 185.00 | 185.00 | 225.00 | 61.00 | 160.00 | 27.00 | 44.00 |
| 380.00 | 380.00 | 431.00 | 379.00 | 110.00 | 213.00 | 182.00 | 185.00 | 216.00 | 59.00 | 157.00 | 27.00 | 46.00 |
| 390.00 | 390.00 | 409.00 | 379.00 | 115.00 | 216.00 | 187.00 | 185.00 | 201.00 | 61.00 | 160.00 | 29.00 | 49.00 |
| 400.00 | 400.00 | 375.00 | 379.00 | 112.00 | 213.00 | 185.00 | 182.00 | 187.00 | 56.00 | 157.00 | 27.00 | 46.00 |
| 410.00 | 410.00 | 329.00 | 377.00 | 115.00 | 213.00 | 185.00 | 180.00 | 182.00 | 56.00 | 157.00 | 27.00 | 49.00 |
| 420.00 | 420.00 | 298.00 | 375.00 | 117.00 | 213.00 | 185.00 | 177.00 | 165.00 | 56.00 | 157.00 | 27.00 | 46.00 |
| 430.00 | 430.00 | 279.00 | 370.00 | 120.00 | 213.00 | 185.00 | 177.00 | 160.00 | 54.00 | 152.00 | 27.00 | 46.00 |
| 440.00 | 440.00 | 267.00 | 368.00 | 122.00 | 211.00 | 182.00 | 175.00 | 152.00 | 54.00 | 150.00 | 27.00 | 49.00 |
| 450.00 | 450.00 | 255.00 | 363.00 | 125.00 | 211.00 | 182.00 | 175.00 | 145.00 | 54.00 | 150.00 | 27.00 | 46.00 |
| 460.00 | 460.00 | 250.00 | 360.00 | 127.00 | 211.00 | 185.00 | 177.00 | 142.00 | 54.00 | 152.00 | 29.00 | 51.00 |
| 470.00 | 470.00 | 248.00 | 356.00 | 125.00 | 208.00 | 180.00 | 175.00 | 140.00 | 51.00 | 150.00 | 27.00 | 49.00 |
| 480.00 | 480.00 | 238.00 | 351.00 | 130.00 | 203.00 | 180.00 | 172.00 | 142.00 | 51.00 | 147.00 | 27.00 | 49.00 |
| 490.00 | 490.00 | 240.00 | 348.00 | 130.00 | 203.00 | 180.00 | 170.00 | 140.00 | 49.00 | 150.00 | 27.00 | 49.00 |
| 500.00 | 500.00 | 235.00 | 346.00 | 130.00 | 203.00 | 180.00 | 172.00 | 132.00 | 49.00 | 150.00 | 27.00 | 49.00 |

Figure 9. Computer printout of reduced data.

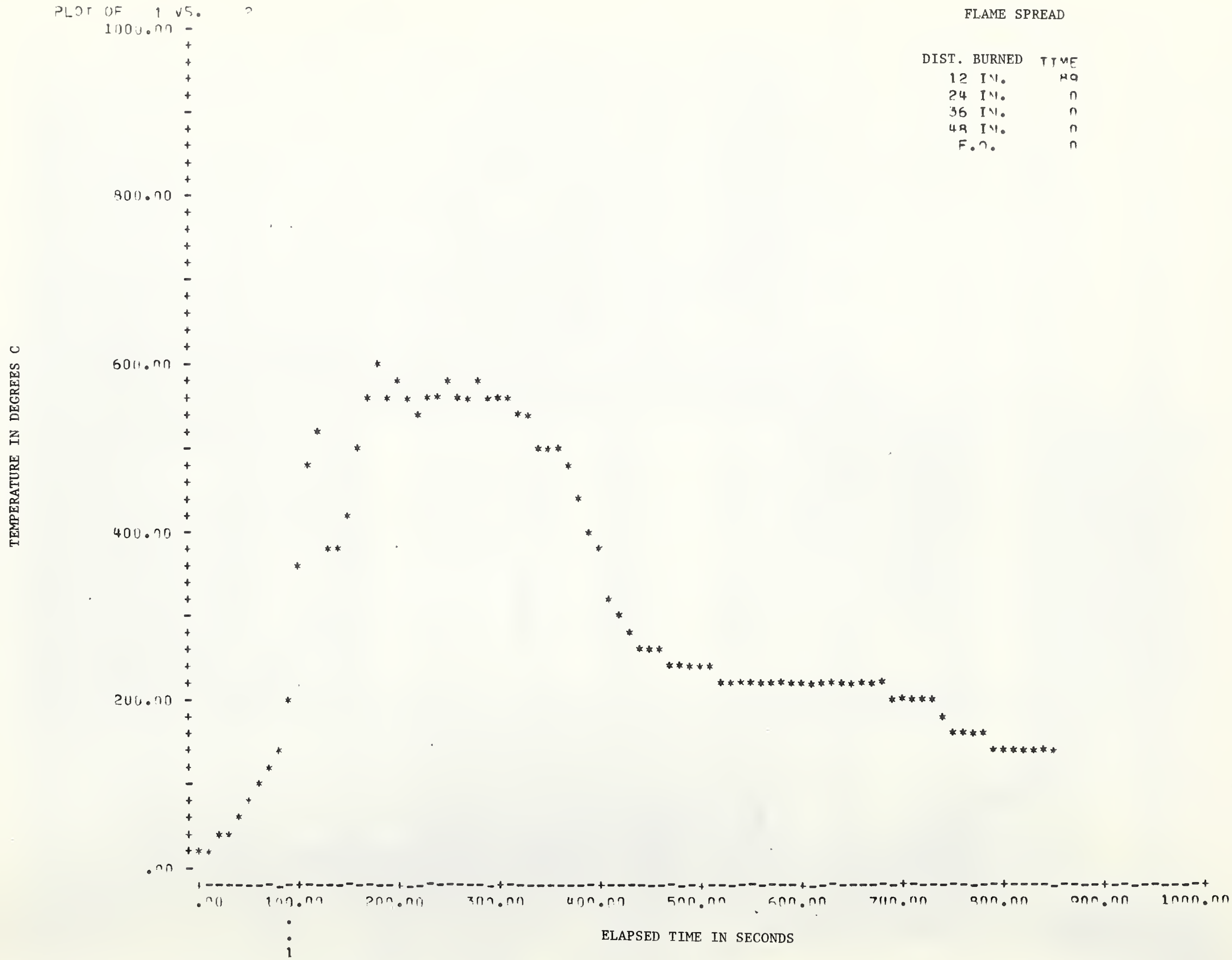
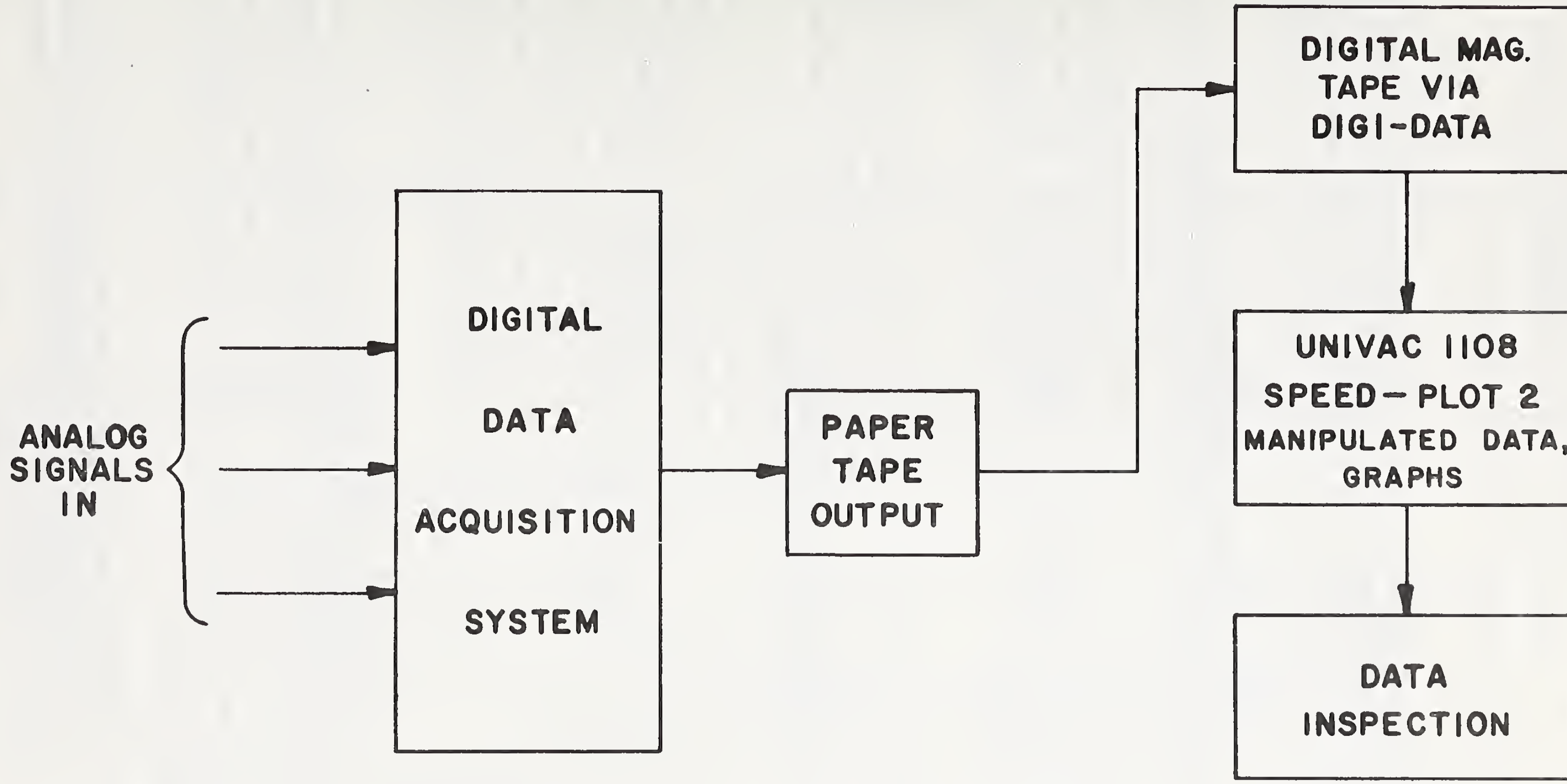



Figure 10. Computer plot of reduced data.




DATA FLOW

Figure 11. Data flow.

## 4.3 Sensors

Temperature gradients are measured during the test program with #24 gauge Type K chromel-alumel thermocouples placed at strategic locations throughout the model corridor (figure 12). The 20-channel capacity limit of the data system makes necessary the many schemes of instrumentation noted.

Thermal flux measurements are made with three types of instruments. The first type is an incident radiant heat flux transducer (radiometer). Two of these were placed on the floor of the model at 18 in and 36 in along the center line. They were chosen with a viewing angle of 90° and with a sapphire window. They are water cooled and air purged, and have a maximum rating of 5 $BTU/ft^2$-sec. While much useful information was acquired, it must be noted that some error does exist with these sensors due to the opaqueness of the sapphire window beyond a wavelength of 5 μm and also due to heating of the sapphire window from nearby flames.

During CFT 183-196, measurements were made of the heat losses through the walls and out of the exit duct of the model corridor by using a second type of heat flux meter which measures transmitted heat flow. It consists of an aluminum oxide plate and a thermopile which measures temperature difference across the thickness of the plate.

The sensors were calibrated at several temperature levels, however calibration problems exist at high temperatures due to the lack of a good high temperature standard. Locations of these heat flux meters can be seen in figure 12c. These tests require modifications of the test section to make heat loss measurements which would enable an overall heat balance analysis to be done. Transported energy flow rate was measured by using an orifice plate with an opening of 29 $in^2$ placed at the exit end of the test section, and several baffles placed in front of this plate to get thorough mixing of the air. Because of these system modifications the bypass portion of the test section was blocked for these tests at the inlet end. This was done to insure uniform and adequate air flow at the entrance to the actual test section.

The third type of flux measurement was made by a total incident heat flux meter placed across the floor center line at 25 in. This experimental sensor consisted of length of metal tubing through which a metered flow of water was passed. A differental thermocouple measured water temperature rise. Two problems were encountered with this sensor. There was a time lag, and boiling of the water at high heat fluxes. This heat flux meter was used on CFT 293-294.

During CFT 190-191 oxygen concentration was monitored with an oxygen cell installed at the exit end of the burning chamber, and recorded on a strip chart recorder. It was observed that the cell was temperature sensitive and showed a definite time lag.

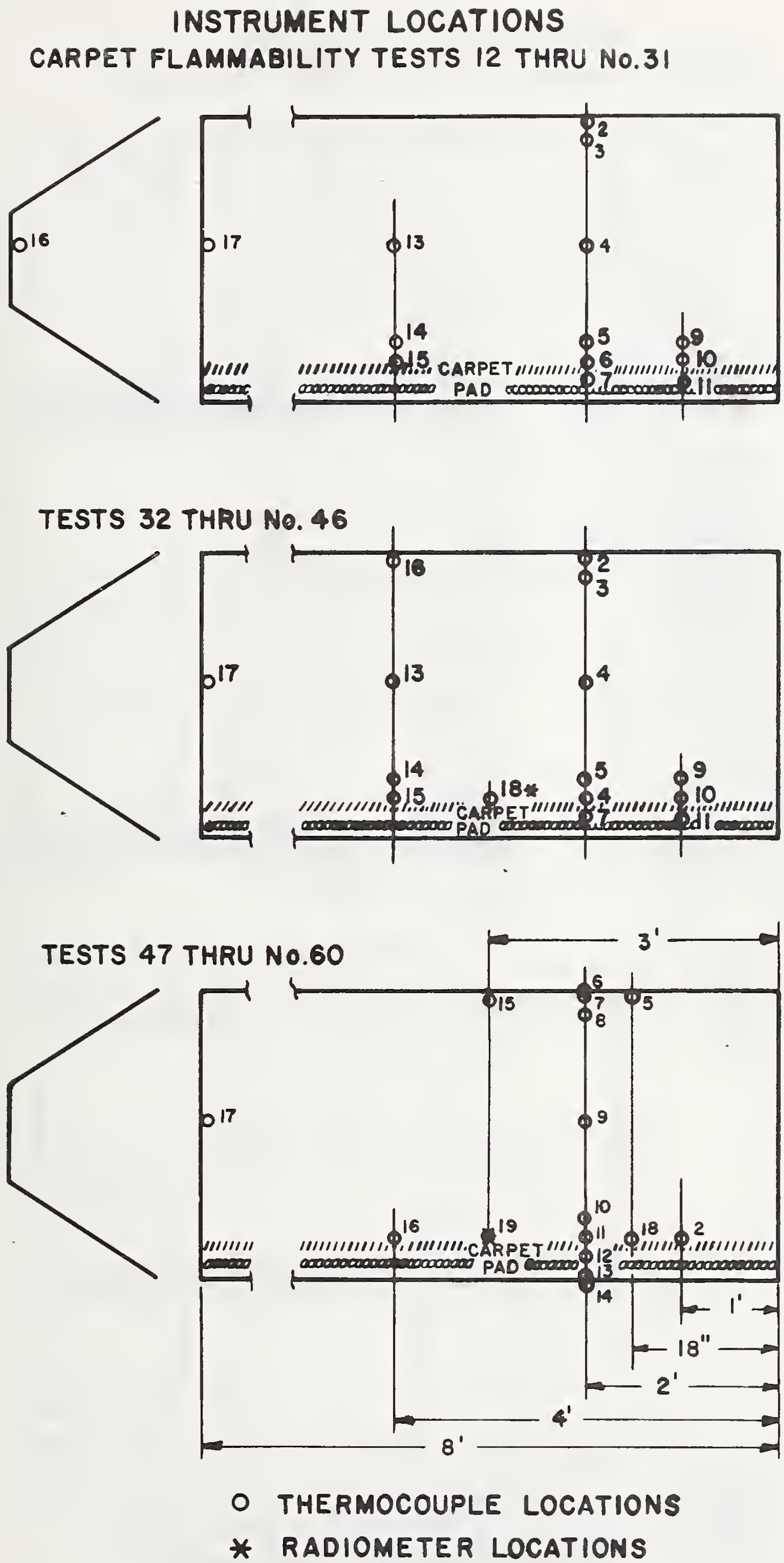



Figure 12A. Instrument locations.

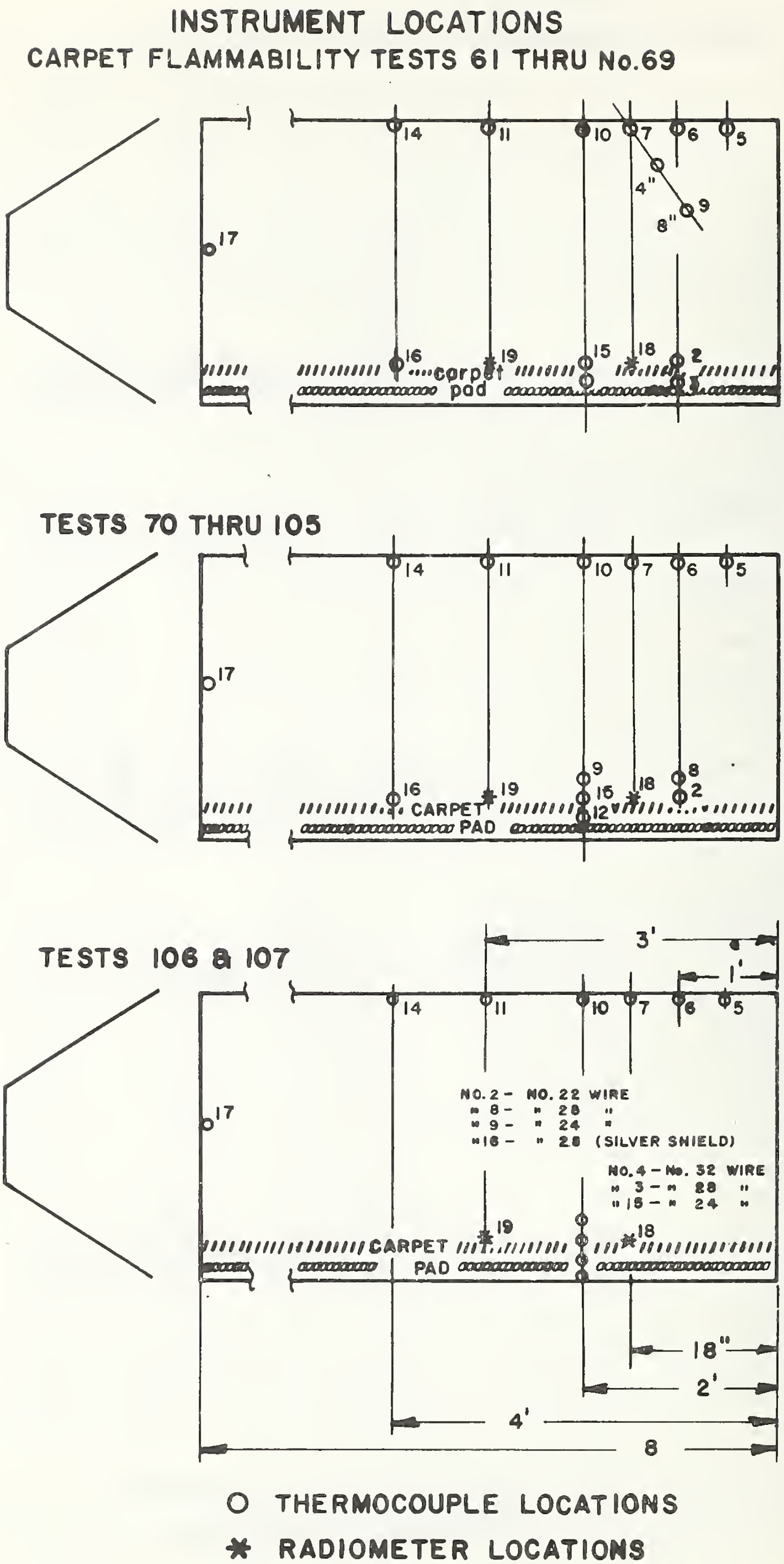



Figure 12B. Instrument locations.

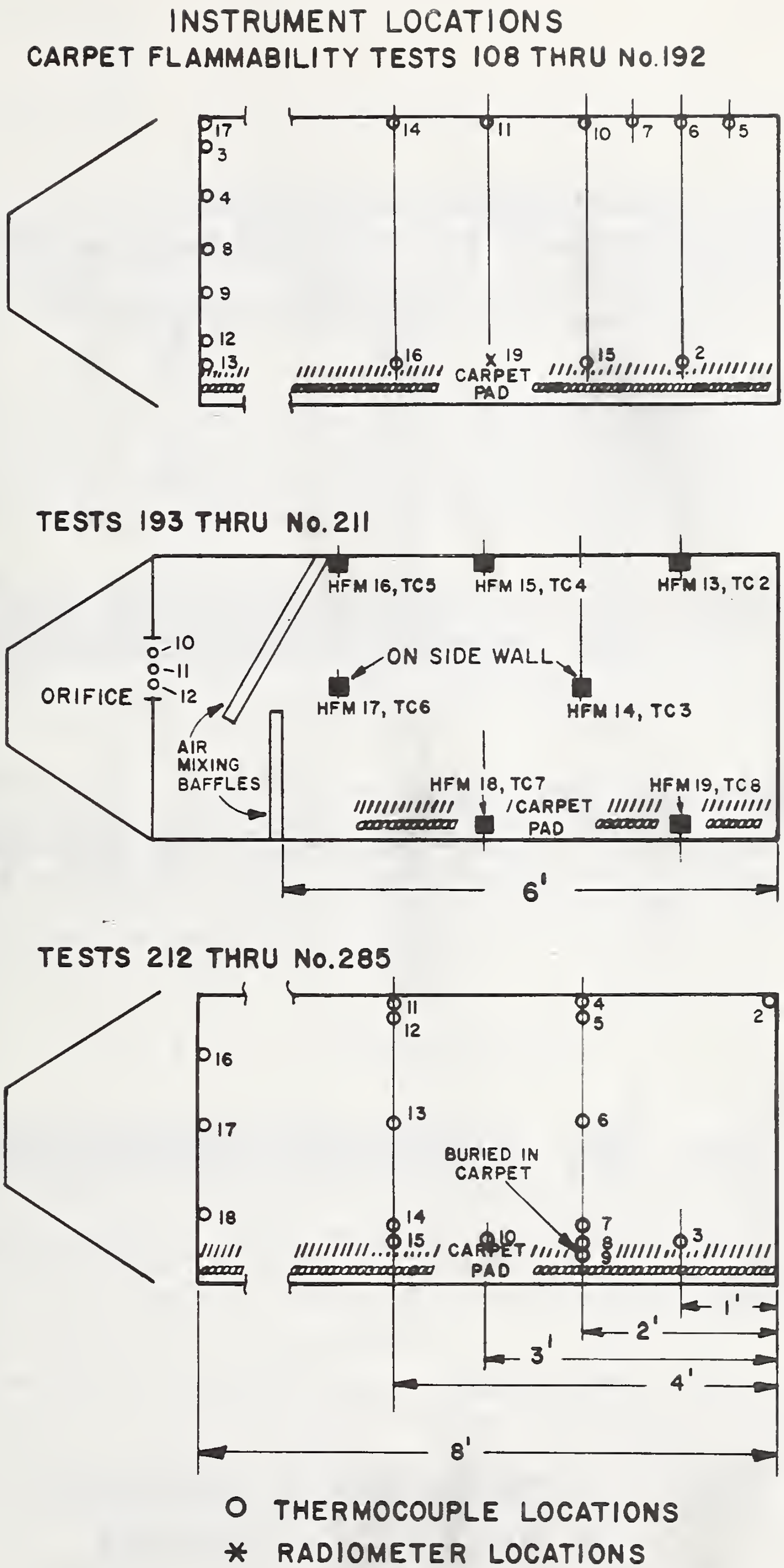



Figure 12C. Instrument locations.

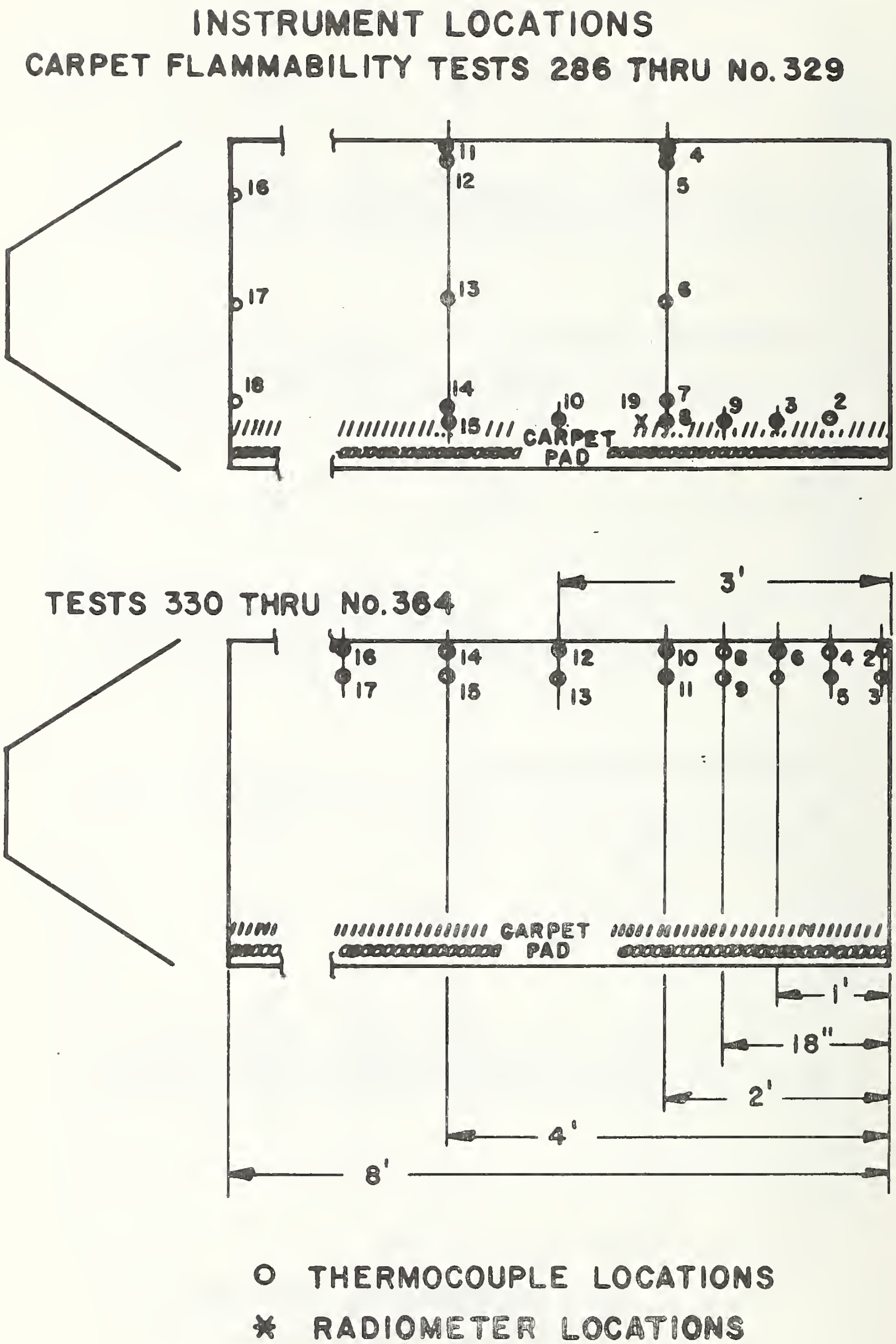



Figure 12D. Instrument locations.

## 4.4 Other Measurements

Weight loss measurements of materials were used to determine heat release rates. This was accomplished by cutting a three inch square sample from the floor covering material, and weighing it before and after burning. This procedure was followed generally throughout the test program.

More thorough weight loss measurements were made during CFT 131 and 137. A grid of 3 in squares was drawn 18 in wide beginning at the burner and extending 24 in down the model corridor. Forty-eight samples each were taken from the carpet and underlayment. The weight loss calculations were made based on weight before and after for each of the 3 in square samples.

Flame spread was observed visually during the tests and elapsed time recorded every 3 in burned. Carpet Flammability Tests 184-185 were run to get some idea of area burned in relation to elapsed time. Once again a grid was drawn on the sample and visual observation of the burned area was made every 30 seconds and recorded graphically.

For each test air temperature and relative humidity measurements were taken in the carpet storage area and at the air intake for the model corridor with sling psychrometer. These data were recorded on the data sheet as shown in figure 13. Outside temperature, relative humidity, air velocity and direction, and barometric pressure readings were obtained from the local weather information service before each test. This also is recorded on the data sheet in figure 13.

# 5. TESTING PROCEDURE

Before beginning tests each day it was found necessary to pre-heat the test section and then allow it to return to room temperature. This need arose because the room in which the facility was located was not air conditioned and tests showed that the construction material (asbestos board) was affected by moisture. This preheating might not be necessary if the test facility was located in an area with good temperature and humidity control.

Materials to be tested (carpet, underlay, etc.) are cut 1/4 in narrower than the inside width of the test section and to the desired length (up to a maximum of 94 in). They were allowed to condition in the test room for at least 24 hours. It would be desirable if this conditioning were done under controlled temperature and humidity.

A run sheet is prepared for each test on which test conditions are recorded. A copy of this form is attached as figure 13.

CFT 76

CARPET FLAMMABILITY TEST NO. 76

TEST PARAMETERS

Carpet Tested: 300-202 Acrylic Hi/Lo
Underlay: Rub Hair/Jute
Model Dimensions: 2 '(W) X 14" '(H)
Carpet Dimensions: 2 '(W) X 8 '(L)
Air Flow: 100 ft/min (40 holes 2.8 ")
Gas Input: 500 BTU/min (.64 setting)
Intake Air: 69 (54) °F, 35 %RH
Carpet Conditioning: 65 (54) °F, ~~55~~ 48 %RH
Outside Conditions: 40 °F, 89 %RH
NE 3 mph, 29.97 pressure
Date: 2-3-72
Ignition Time: 10:32:00

RESPONSES

Flame Spread

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3" | :09 | 27" | | 51" | | 75" | |
| 6" | :29 | 30" | | 54" | | 78" | |
| 9" | :49 | 33" | | 57" | | 81" | |
| 12" | 1:29 | 36" | | 60" | | 84" | |
| 15" | 3:05 | 39" | | 63" | | 87" | |
| 18" | 3:31 | 42" | | 66" | | 90" | |
| 21" | | 45" | | 69" | | 93" | |
| 24" | | 48" | | 72" | | | |

Flame front self Extinguished: 3:52 min
Reignited: min
final extinguishment: min

Total Ignition Time: 12 min

Maximum flame spread:
length: 19 " Width: 2 " @ 9 "

All Flame Out: 12 min

COMMENTS

Signed [signature]

Figure 13. Sample data sheet.

Prior to the start of each test the movable wall and ceiling are positioned to provide the desired cross-sectional dimensions of the test section. The proper number of holes in the orifice plate are opened so the desired air velocity can be obtained. The carpet assembly is placed on the floor of the test section and vacuumed. The curbs, burner ignition spark lead and instrumentation are positioned. The blower is then started and the inlet vanes adjusted to provide the specified air velocity as indicated by the manometer pressure. With the blower running, the stopcock on the gas line is opened and the valve adjusted to provide the proper gas flow as indicated by the flowmeter.

The data acquisition system is activated before starting each test and the first data scan is made 10 seconds before ignition. This first scan records ambient conditions in the system. A data scan is then automatically recorded every 10 seconds during the entire run (figures 9 and 10).

To initiate a test the gas is turned on and a spark generated by an ignition transformer ignites the burner (at time 0::00). During the test the position of the leading flame front (of the burning carpet) is observed visually through the glass windows in the door, and the position of the flame is lined up with distance markers placed every 3 in along the back wall as measured from the burner. As the flame front passes these markers, the time (in minutes and seconds from ignition) is recorded on the run sheet. With these data the flame spread can be plotted as illustrated on figure 14.

In the experimental program it was found that, under most sets of experimental parameters, one of two modes of flame spread would occur. Once the flame front moved beyond the immediate influence of the burner flame either a decelerating flame front leading to self extinguishment or a very slow burning rate, or a rapidly accelerating flame front leading to total involvement of the sample, would occur. This latter phenomenon has been termed "flameover". It is, therefore, necessary to record sufficient information on the run sheet to identify the type of flame spread that occurs. These data includes times at which extinguishment, any subsequent re-ignition of the flame front, or flameover occur. The time listed for flameover is that time when the flame front has reached 94 in. Additionally, any unusual burning conditions, such as edge-burning or carpet buckling, is noted.

The time selected for most tests was 12 minutes with the burner on plus an additional 12 minutes with the burner off. Flame spread is recorded and data are acquired for this 24 minute period. Within the first 12 minute period should flameover occur, or if the flame front extinguishes the test is terminated 2 minutes after the burner is turned off.

If a facility of this type is used for test purposes without a need to record temperature or heat flux data, the test could be stopped when flameover occurs or when it is certain that no further flame spread would occur.

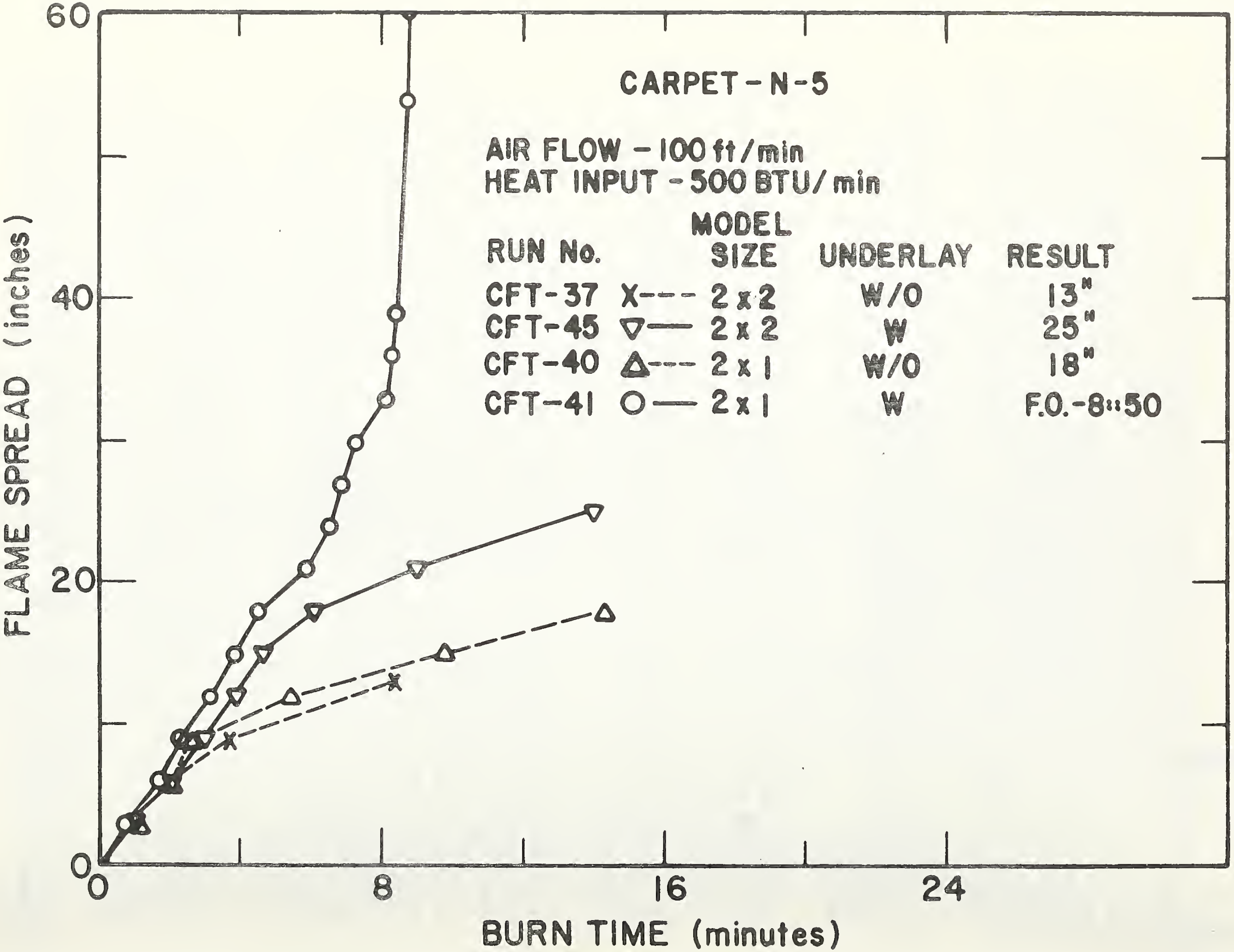



Figure 14. Flame spread data.

Upon completion of a test, the blower is stopped and the test section door is opened so that any flaming or smoldering can be extinguished. Exact distance of flame spread is measured and recorded on the run sheet. To approximate the total area burned, the maximum burnt width is also recorded. Following many of these tests, photographs of the samples were made (figure 15).

The final step in each test is to remove the burned sample, vacuum the test section, and allow the walls, ceiling, and floor to return to room temperature before another test is begun. Because of the relatively thin construction material (3/8 in asbestos board), this cooling can usually be accomplished in not more than 30 to 45 minutes, even following a severe burn or flameover. Floor and ceiling surface thermocouples have been used to check the test section temperature before proceeding with the next test.

## 6. TEST REPEATABILITY

Since the model corridor was designed to be an experimental facility and not a test apparatus, a statistical plan was not developed to determine the repeatability or reproducibility of such a facility. However, as part of the experimental program many tests were performed in replicate. A brief review of these data should be useful in indicating the reliability of results. Additionally, some of the replicate tests emphasize a few variables where better control was necessary. Table 4 summarizes the results of some of the tests that were replicated.

In series A and B, runs 62 and 63 were made immediately following the installation of new construction material (movable wall and ceiling) in the test section. In both cases flameover did not occur, whereas in earlier tests with the same carpet assembly and test condition flameover had resulted. The test section was then "conditioned" by heating for about one hour, cooled, and then runs 64 and 68 gave results similar to past experience. In series B, run 106 was made following a period of cold, damp weather in which no tests were conducted for twelve days. After preheating and cooling the system, run 107 gave the result anticipated. A similar experience resulted in run 130 which was made early on a cold, damp morning. Flameover did occur but required a longer time than in previous tests. Runs 65 and 66 were conducted to determine the effect of intake air temperature. Outside air was drawn directly into the system on a cold (45°F) day. In both tests flameover did occur but after longer time than had previously been experienced. These results indicate the need to control both the condition of the test section and the temperature (and relative humidity) of the intake air. The additional data shown on table 4 indicate quite good repeatability. Flame spread curves for Series A are plotted on figure 16.

Another example of the reliability of the test method was seen through the experimental program. With any carpet assembly it was found that as the test conditions were increased in severity, an increasing flame spread

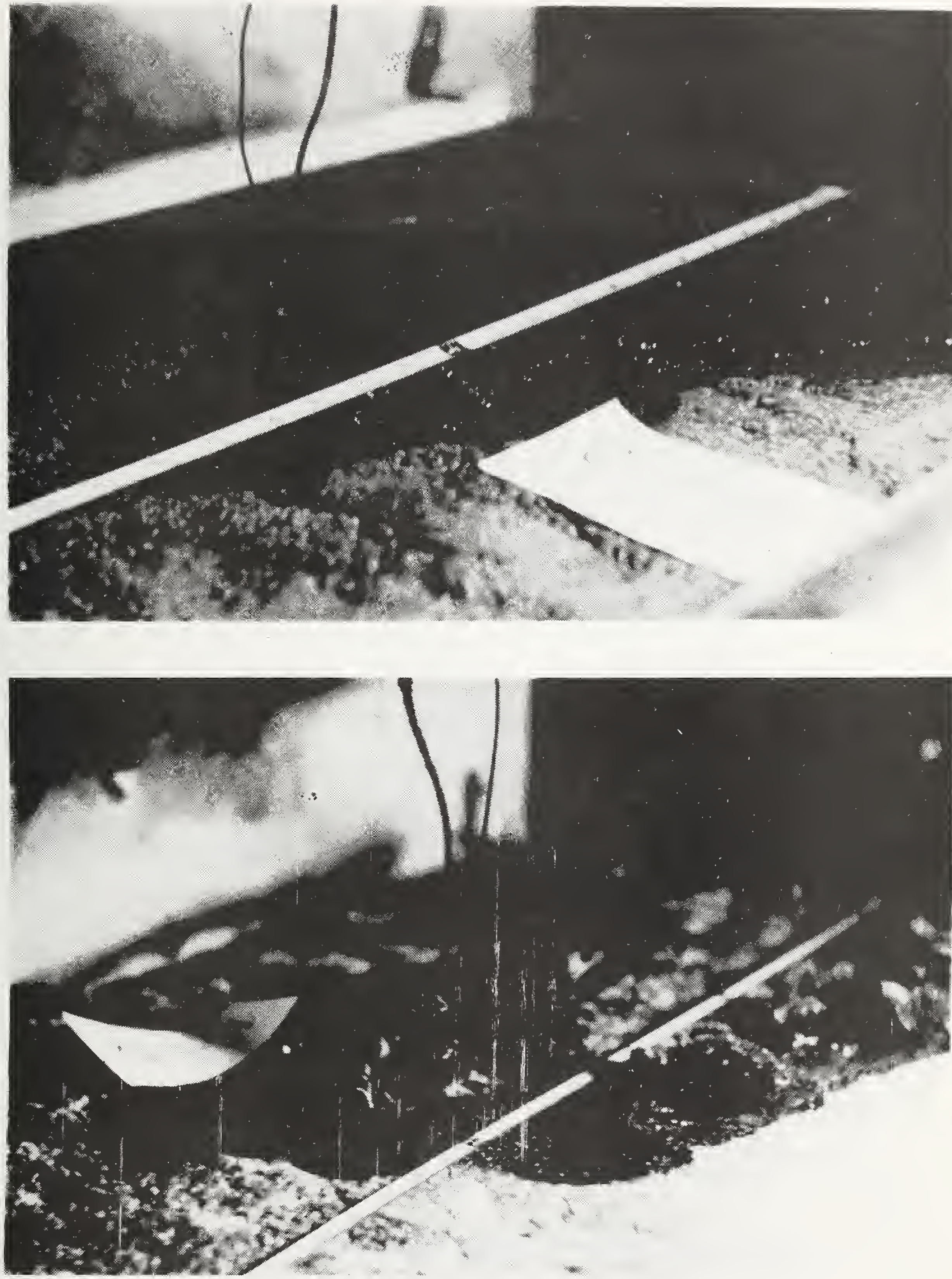


Figure 15. Typical samples after test.

TABLE 4

REPEATABILITY DATA

| Series | Carpet | Test Conditions* | Run No. | Result** |
|---|---|---|---|---|
| A | N-5/U | 24 x 11, 500, 100 | 41 | 8::50 |
| | | | 47 | 7::04 |
| | | | 63 | 35" |
| | | | 64 | 10::07 |
| | | | 65 | 14::30 |
| | | | 66 | 15::30 |
| | | | 130 | 18::06 |
| B | A-4/U | 24 x 11, 500, 100 | 49 | 5::28 |
| | | | 62 | 22" |
| | | | 68 | 4::25 |
| | | | 106 | 24" |
| | | | 107 | 5::24 |
| | | | 129 | 6::50 |
| C | W-1/U | 24 x 11, 500, 100 | 51 | 8" |
| | | | 139 | 10" |
| D | A-4/U | 24 x 14, 750, 100 | 82 | 5::40 |
| | | | 126 | 5::08 |
| E | A-3/U | 24 x 17, 500, 100 | 92 | 5::06 |
| | | | 96 | 11::57 |
| F | O-4 | 24 x 11, 500, 100 | 201 | 31" |
| | | | 202 | 29" |
| G | N-5/U | 24 x 11, 750, 150 | 301 | 29" |
| | | | 329 | 31" |

Note: * Test conditions shown are model dimensions (W x H) in inches, heat input in BTU/min., and air velocity in ft./min.

** Results are shown in inches burned if flameover did not occur or in time (min::sec) to flameover.

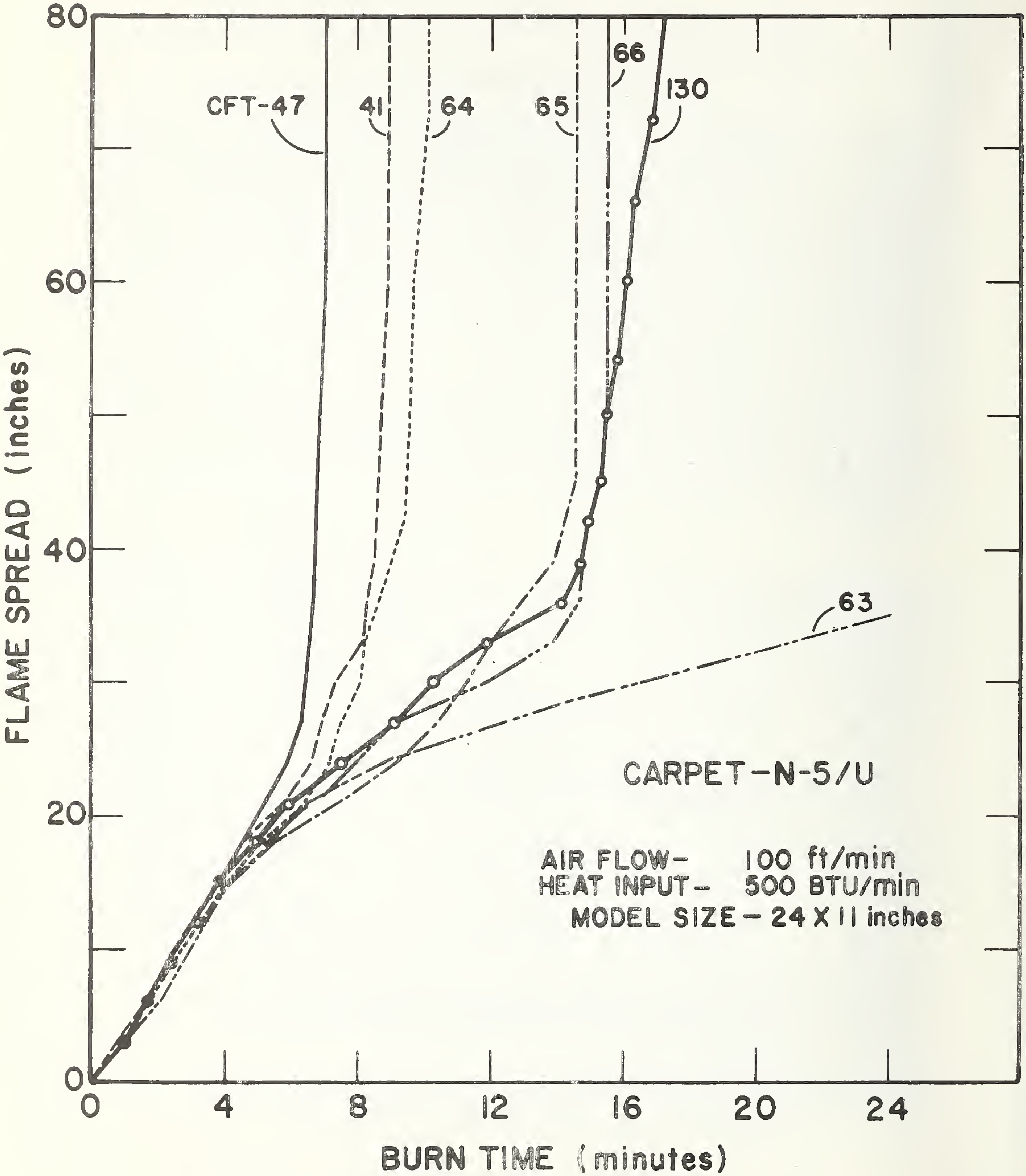



Figure 16. Series A flame spread curves.

distance would result up to the point at which flameover occurred. If test conditions were further increased in severity, the time to flameover decreased. An example of this is shown on table 5. In this experiment the severity of test conditions was increased both by increasing heat input and by lowering ceiling height.

These results indicate that test conditions must be carefully controlled to produce reliable data. With good control repeatable results have been obtained.

## 7. CONCLUSIONS

The design of the model corridor proved that good control of the numerous variables encountered in the study of the flammability of floor coverings could produce repeatable test results. The air handling system permitted a wide range of velocities, while providing a uniform, stable flow during a test. The 3/8 in asbestos board construction was durable, yet thin enough to allow rapid cooling between tests.

The operating proceedure that was developed provided accurate and repeatable results during the experimental program. The results of this program are compiled in a separate report [6]. A complete file of all experimental data obtained during the program is being maintained at the National Bureau of Standards.

TABLE 5

EFFECT OF CEILING HEIGHT & HEAT INPUT

| | | Ceiling Height | | | |
|---|---|---|---|---|---|
| | | 11" | 14" | 17" | 23" |
| Heat Input (BTU/min) | 300 | 23" | | | |
| | 400 | (17::08) | 13" | | |
| | 500 | (11::02) | (19::03) | 28" | 25" |
| | 600 | (9::40) | | 19" | |
| | 750 | (6::32) | | 90" | |
| | 1000 | | | (7::24) | |
| | 1250 | | | | 38" |
| | 1500 | | | | 38" |
| | 1750 | | | | 44" |
| | 2000 | | | | 65" |

Carpet - N-5/U

Air Flow 100 ft/min

Model Width - 24"

## 8. REFERENCES


1. "Carpets and Rugs" (Pill Test) Standard for the Surface Flammability of Carpets and Rugs, DOC FF 1-70, Federal Register, Vol. 35, No. 74, April 16, 1970, p. 6211.

2. "Standard Method of Test for Burning Characteristics of Building Materials", ASTM E84-68, American Society for Testing and Materials, Philadelphia, Pennsylvania (1968).

3. "Standard Method of Test for Flame-Propagation Classification of Flooring and Floor-Covering Materials", Subject 992, Underwriters' Laboratories, Inc., February, 1971.

4. "Surface Flammability of Materials Using a Radiant Heat Source", ASTM E162-67, American Society for Testing and Materials, Philadelphia, Pennsylvania (1968).

5. Memorandum from Z. Zabawsky to ASTM Subcommittee IV Task Group on Floor Covering, "Armstrong Cork Co. Flooring Radiant Panel", May 17, 1971.

6. W. Denyes and J. Quintiere, "Experimental and Analytical Studies of Floor Covering Flammability With a Model Corridor", NBSIR 73-199, May 1973.

7. J. M. Smith, "Automatic Data Evaluation, Manipulation, Display, and Plotting with SPEED", Computer Graphics, Vol. 4, No. 2, Fall 1970.

FORM NBS-114A (1-71)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET | 1. PUBLICATION OR REPORT NO. NBSIR 73-200 | 2. Gov't Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|

| | |
|---|---|
| 4. TITLE AND SUBTITLE<br>A Model Corridor for the Study of the Flammability of Floor Coverings | 5. Publication Date<br>6. Performing Organization Code |
| 7. AUTHOR(S)<br>Wells Denyes and James W. Raines | 8. Performing Organization NBSIR 73-200 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>NATIONAL BUREAU OF STANDARDS<br>DEPARTMENT OF COMMERCE<br>WASHINGTON, D.C. 20234 | 10. Project/Task/Work Unit No. 490 0572<br>11. Contract/Grant No. |
| 12. Sponsoring Organization Name and Address<br>Man Made Fiber Producers Association, Inc.<br>1150 Seventeenth St. N.W., Washington, D.C. 20036 and<br>National Bureau of Standards<br>Washington, D.C. 20234 | 13. Type of Report & Period Covered<br>Final<br>14. Sponsoring Agency Code |

15. SUPPLEMENTARY NOTES

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.)

A program was carried out to develop a laboratory test method that would measure the flame propagation characteristics of floor covering materials. A facility was designed which included a floor mounted specimen in a rectangular cross-sectional duct having a forced supply of air and a gas burner ignition source. The effects of variations in duct size, ignition source, and air flow were studied. Factors influencing repeatable test results were explored. Flame spread was measured by an observer and temperature and heat flux measurements were recorded on an electronic digital data acquisition system.

17. KEY WORDS (Alphabetical order, separated by semicolons)

Air flow, energy input; flameover; flame spread; floor covering flammability; model corridor; test repeatability.

| 18. AVAILABILITY STATEMENT | 19. SECURITY CLASS (THIS REPORT) | 21. NO. OF PAGES |
|---|---|---|
| [X] UNLIMITED. | UNCLASSIFIED | |
| [ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS. | 20. SECURITY CLASS (THIS PAGE)<br>UNCLASSIFIED | 22. Price |

USCOMM-DC 66244-P71