NBSIR 76-1021

Fire Spread Along A Mobile Home Corridor

Edward K. Budnick

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

July 1976

Interim Report

Sponsored in part by:

**Division of Energy, Building Technology and Standards,
Office of Policy Development and Research,
U.S. Department of Housing and Urban Development
Washington, D. C. 20410**

NBSIR 76-1021

FIRE SPREAD ALONG A MOBILE HOME CORRIDOR

Edward K. Budnick

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

July 1976

Interim Report

Sponsored in part by:
Division of Energy, Building Technology and Standards
Office of Policy Development and Research
U.S. Department of Housing and Urban Development
Washington, D. C. 20410

U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, *Secretary*
Edward O. Vetter, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

Date: August 17, 1976

MEMORANDUM FOR: Printing and Duplicating

FROM: Carol Thompson C. Thompson
Center for Fire Research
225 - B40

SUBJECT: Expediant printing of NBS report No. 76-1021

Attached is a manuscript by E. Budnick entitled "Fire Spread Along a Mobile Home Corridor." The author needs at least 100 copies to distribute at a meeting by the 25th of August. Therefore, we would like the attached manuscript printed in-house with a RUSH status. Via conversation with Mr. Rabbit, we were told this was possible.
Thank you.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

FIRE SPREAD ALONG A MOBILE HOME CORRIDOR[1]

Edward K. Budnick

Abstract

A series of tests was conducted in the corridor area of a typically constructed mobile home. These tests were designed to: (1) evaluate the performance of a variety of combinations of wall and ceiling materials as a result of exposure to a typical ignition in a full-scale mobile home corridor, and (2) determine the relationship between full-scale tests and laboratory flammability tests, particularly the ASTM E-84 tunnel test, a measure of surface flame spread.

The tests were restricted to one set of conditions in which the living room at the end of the corridor was exposed to a fire resulting from ignition of a standardized 6.4-kg (14-lb) wood crib. Nine tests were conducted with seven different combinations of wall and ceiling materials.

Performance of the various combinations of wall and ceiling materials was examined based on the time to reach untenable conditions in the corridor. Measurements utilized in evaluating levels of tenability included gas temperatures, surface temperatures, irradiance, concentrations of oxygen and carbon monoxide, and smoke densities.

Under this set of test conditions, it was found that the extent of fire spread and the time to reach untenable conditions are significantly influenced by the surface flame spread characteristics of the wall and ceiling finish materials in the corridor.

For a mobile home corridor with conventional wall and ceiling linings (ASTM E-84:FSC = 200 max), untenable conditions were reached in the corridor in less than four minutes. With class A (FSC = 25 max) wall and ceiling materials in the corridor, untenable conditions were not reached.

Key words: Corridor fire test; interior finish material; intumescent coating; life safety; mobile home; smoke detector; surface flame spread.

1. INTRODUCTION

Fire loss statistics indicate that fire safety may be a special problem n mobile homes. While the fire incidence rate is generally no greater, the ife and property loss due to fire in mobile homes has been estimated at three o five times greater than that of the conventional "stick-built" residence [1,2,3][2].

---

[1]This work was supported in part by funds provided by the U.S. Department of Housing and Urban Development and by the Mobile Home Manufacturers Association.

[2]Numbers in brackets refer to the literature references at the end of this paper.

Various design and structural features appear to be possible contributors to this problem, although no extensive research studies have, as yet, been performed to evaluate these possibilities.

While most residential fires are initially localized and small in size, the design characteristics inherent in mobile homes, such as fire load density, room geometry, and combustible finishes may provide the potential for rapid fire development, resulting in higher temperatures, smoke, and toxic gas generation in a relatively short period of time.

The typical design of a single-wide mobile home includes a corridor leading from the kitchen and living room into the sleeping areas. While the length of the corridor depends primarily on the number and location of bedrooms, the maximum length may range from 4.3 to 7.6 m (14 to 25 ft). The ceiling height is typically 2.1 to 2.3 m (7 ft to 7 ft 6 in). There is no test data available which provides an indication of how a fire which enters the corridor area in a mobile home will progress. The fire could be vented due to failure of a window in the corridor, or possibly burn up through the ceiling and out the roof, resulting in limited fire spread. However, fire testing experience in other types of occupancies indicate that the narrow corridor width, normally 71 cm to 81 cm (28 in to 32 in), and the combustible surface finish on the walls and ceiling may provide a tunnel-like passage for the spread of flame, hot gases and smoke to other parts of the mobile home.

The role of the mobile home corridor as a passageway from one area to another is a critical life safety feature. Statistics indicate that approximately 42 percent of mobile home fires occur during the sleeping hours [4]. The effectiveness of the corridor in not contributing to early fire spread resulting from a fire originating in the kitchen or living room area to the bedroom area may be a factor in reducing the potential hazard to life since it is the primary means of egress from the sleeping area.

The 1975 edition of the Standard for Mobile Homes (NFPA 501B, ANSI A119.1)[5] limits the surface flame spread rating on all wall and ceiling surfaces to a maximum value of 200 when tested in accordance with the Standard Method of Test for Surface Burning Characteristics of Building Materials (ASTM E84-70)[6]. However, a correlation between the flame spread rating and the contribution of the interior finish to fire growth under most full-scale conditions has not been established. In a recent study of fire growth in rooms, Fang [7] showed that full involvement of a room containing a single door opening could be represented by an upper room gas temperature of 450 to 650 °C (842 to 1202 °F), and that this could occur if the flame spread rating of the wall materials was less than 200 as well as in those cases where the flame spread rating was greater than 200. While the configuration was not representative of a corridor it does indicate the possibility that a flame spread value of 200 may not be a valid criterion.

Extensive research has been conducted to examine many of the characteristics of corridor construction which may influence the spread of fire.

In 1964 and early 1965, a series of three full-scale tests was conducted by the Forest Products Laboratories of the U.S. Department of Agriculture to examine the effects of fire performance of various wall linings in a 3.4 m wide by 22 m long by 9.5 m high (11 x 72 x 31 ft) corridor with a noncombustible ceiling [8]. The results of the tests indicated that with an ignition source consisting of two 113-kg (250-lb) wood cribs, the time to flashover did not vary appreciably when the walls were constructed of gypsum, 1/4-in hardboard,[3] or 15/32-in red oak planking. This would indicate that under conditions where there is a high fuel loading, flashover is not appreciably affected by the use of any of these three wall and ceiling assemblies.

[3] See table 10 for metric equivalents; where the value is descriptive of a particular material or item, English units will be used in the text.

McGuire [9] conducted a series of corridor tests in 1967 to investigate the fire spread characteristics of various combinations of ceiling, wall and floor materials. He concluded that flooring materials with a flame spread value less than 200 (ASTM E-84 Tunnel Test) did not appreciably influence the flame spread rate along a corridor. However, the types of materials used on the walls and ceiling did significantly affect the flame spread rate, with the walls showing the most influence. The ASTM E-84 flame spread values for the wall and ceiling materials varied, but were primarily less than 200. While the full-scale tests did correlate with the values of the ASTM E-84 flame spread rating, attempts to develop a 1/4-scale model during this test series were not promising due to the difficulties in scaling.

Christian and Waterman [10] conducted a series of full-scale corridor tests in 1970 to determine the effect of varying the location and area of a wall finish with a flame spread value of 90 (ASTM E-84) on flame propagation along the corridor. The tests included ceiling materials having a flame spread of either 0 or 25, and various wall configurations using the 90 flame spread material including: (1) 90 flame spread material below the wainscot and noncombustible material above; (2) 90 flame spread material and noncombustible material alternated in four-foot vertical strips from floor to ceiling; and (3) 90 flame spread material on the total wall. It was concluded from these tests that various combinations of the above test conditions can successfully restrict flame propagation in a 1.8-m (6-ft) wide corridor. However, the test results indicated that when a ceiling material of flame spread 25 was used, any of the wall combinations resulting in greater than 50 percent of the surface area being covered with material having a flame spread rating of 90 resulted in propagation of flames over the entire length of the corridor. It was further concluded that the hazard associated with various combinations of materials would be increased as the corridor width was reduced from 1.8 m (6 ft).

Further full-scale testing by Waterman in 1972 utilizing a controlled propane gas fire in a conventional 1.8 m wide by 16.8 m long by 2.4 m high corridor (6 x 55 x 8 ft) revealed that many materials with flame spread ratings in the ASTM E-84 Class B range (26-75) were capable of extending propagation to full involvement of the corridor [11]. It was further concluded that wall materials having flame spread values less than or equal to 54 prevented progress of the fire to total involvement, and actually provided a level of performance similar to that for a Class A (0-25 flame spread) material.

These conclusions indicated that reliance on the classes of the ASTM E-84 Tunnel flame spread values (e.g., A = 0-25; B = 26-75; C = 76-200) established by various building code and standards groups may not provide the anticipated level of fire safety. A further indication was that reliance on surface flame spread as a single criterion for limiting the fire hazard of interior finish materials may not necessarily provide an indication of the performance of the materials in a full-scale corridor configuration. Further, the combined performance of a wall and ceiling may not be predictable from the individual surface flame spread rating of each material in accordance with the ASTM E-84 Tunnel Test.

A considerable amount of experimental work has been done in full-scale corridor testing at the National Bureau of Standards. However, to date these activities have been directed at corridor designs typically found in conventional construction such as nursing homes and multi-story apartments. Extensive experimentation has been performed to investigate thermal characteristics, fluid movement, flashover and many other phenomena associated with fire growth, including energy and radiation modeling.

While these efforts both at the Bureau of Standards and other research facilities have provided a great deal of experimental information on fire growth in corridors, the need exists to determine the fire growth characteristics in a corridor of dimensions unique to mobile home design and the relationship between these factors and the relative hazard classifications based on the ASTM E-84 Tunnel Test. Since under normal conditions the corridor is free of any additional (movable contents) fire loading, the effectiveness of the corridor in not providing a means for early rapid flame spread is primarily a function of geometry, the type of finish materials on the walls and ceiling, and the characteristics of the fire exposure.

This test series was designed (a) to provide experimental data on the relative performance of various combinations of wall and ceiling materials in a full-scale mobile home corridor from exposure to a typical ignition; and (b) to determine the relationship between the full-scale tests and several laboratory flammability tests, including ASTM E-84, which is one of the standard tests utilized to control interior finish materials.

In the test setup, the living room end of the corridor in a mobile home was exposed to a fire resulting from ignition of a 6.4-kg (14-lb) wood crib. This crib was used to simulate a medium sized chair (or a piece of upholstered furniture) typically found in residences but whose burning characteristics were more reproducible for a series of tests [12]. The crib was positioned to provide an exposure to the wall materials typical of that which may occur from ignition of a piece of furniture positioned in a corner adjacent to a wall partition. Essentially, the tests were limited to one set of conditions. The same type of ignition source and exposure was repeated for each of nine tests, with the primary test variable being the type of finish materials used on the walls and the ceiling.

This report is limited to tests of fire growth in mobile home corridors. Other research areas which are being addressed include fires originating in the bedroom and living areas, and on kitchen ranges.

2. EXPERIMENTAL DETAILS

2.1. Test Configuration

The tests were conducted during the period from February to May 1975 in the corridor of a two-bedroom mobile home which was typical of mobile homes constructed in accordance with the NFPA 501B standard in effect in 1972. The basic floor plan of the 3.7 x 18.3 m (12 x 60 ft) mobile home is illustrated in figure 1, providing details of instrumentation and equipment, and the basic test setup, including the location of the ignition source.

Partitions of noncombustible asbestos-cement board were installed from floor to ceiling (identified by the symbol A in figure 1) to restrict the fire spread to the corridor area. The noncombustible partition adjacent to bedroom No. 2 in the dining area was installed over an existing partition, while the other partition was constructed to obtain the corner configuration. This was done to provide test data on the relative levels of performance of a variety of combinations of wall and ceiling assemblies in which test conditions such as air movement and oxygen availability could be reproduced for each test. Limitation of fire spread into bedroom No. 2 and the living room reduced the possibility of a significant change in test conditions due to failure of a window or involvement of an excessive amount of fuel loading at a location remote from the corridor test area itself.

The corridor measured 5.2 m in length, 0.76 m in width, and 2.1 m from floor to ceiling (17 ft x 30 in x 7 ft) (see figure 2). Within the corridor area there was one exterior door, one door to bedroom No. 2, one door to the bathroom, and one door opening into the furnace compartment. The three hollow core interior doors were refinished by covering the doors with 5/32-in lauan plywood over No. 26 manufacturer's standard gage sheet steel for all nine tests. This was done to simulate the surface flame spread characteristics of a typical hollow core door without requiring replacement of the doors after each test. These doors remained closed during the test. The door to bedroom No. 1 was removed simulating an open doorway at the end of the corridor. The 10 cm (4-in) lintel extending down from the ceiling to the top of the doorway remained at the entrance to bedroom No. 1.

The method for installation of the corridor materials was the same for all nine tests. Figure 2 provides a detail of the corridor area. The corridor walls were lined with 1.2 x 2.1 m (4 x 7 ft) panels, attached by staples or nails to nominal 2 x 2 in pine studs, installed 40 cm (16 in) on center. The exterior wall was insulated with 6.4 cm (2-1/2 in) (R-7) glass fiber batts, containing an aluminum foil vapor barrier. Interior walls were not insulated. The floor was constructed of 3/4-inch particle board, and covered with vinyl asbestos floor covering. The ceilings were installed by fastening the materials to nominal 1 x 2-inch pine furring strips, 30 cm (12 in) on center. The furring strips were attached to the ceiling trusses, parallel to the longitudinal axis of the corridor.

2.2. Test Criteria

Tenability test criteria were selected to evaluate the principal factors affecting the life safety of occupants of the bedrooms in the event of a fire originating in the living room or kitchen area in the mobile home. Performance of the various combinations of wall and ceiling materials installed in the corridor was analyzed based on the time to reach untenable conditions along the path of egress in the corridor. The conditions which were monitored for untenability were temperature, incident heat flux, concentrations of carbon monoxide and oxygen, and smoke density.

2.2.1. Temperature

The most prominent characteristic of a fire is the increased temperature due to the release of thermal energy. In terms of human exposure to elevated temperatures this can result in dehydration, heat exhaustion, sloughing of the trachea lining and hemorrhaging in the respiratory tract, skin surface burns, and shock due to pooling of blood at the body surface [13,14].

Extensive research has been conducted involving investigation of thresholds for exposure to temperature which results in adverse physiological effects. In the Los Angeles School Burns conducted in the 1950's, a temperature of 65 °C (approximately 150 °F) at the five-foot level was selected as the critical temperature for teachers and children to enter and egress through a corridor [15]. In fire tests conducted by the National Research Council of Canada, 150 °C (approximately 300 °F) was considered the maximum level for breathing. Temperatures at this level can be endured for short periods, provided there is little moisture in the air. Further, experiments with animals revealed that death occurs in two minutes when exposed to a temperature of 100 °C (212 °F) [16].

Based on this information, the temperature criterion selected as the threshold for untenability in the mobile home corridor was 100 °C (212 °F).

2.2.2. Carbon Monoxide Concentration

Carbon monoxide (CO), while not the most toxic combustion gas, is produced in such abundant quantities in most fires that it is an important life safety consideration. How much CO a human being can tolerate is a function of both time and concentration. The threshold limit for exposure to carbon monoxide for an 8-hour period is 50 parts per million (ppm) [17]. However, in fires where ventilation is restricted, incomplete oxidation of carbon occurs. This leads to concentrations of CO as high as 138,000 ppm [18].

Carbon monoxide poisons by asphyxiation; that is, it reduces the oxygen-carrying ability of the blood by combining with hemoglobin to form carboxyhemoglobin. Various effects of exposure to CO include dizziness, dimness of vision nausea, increased pulse and breathing rates, loss of orientation, unconsciousness, convulsions and death [19].

Table 1 illustrates the physiological effects of exposure to CO [19]. This information reveals that a person's ability to function reliably can be significantly affected by low levels of CO concentration. For this series of tests, CO concentration in excess of one percent by volume (10,000 ppm) was ascertained to be an untenable condition in the corridor.

2.2.3. Oxygen Depletion

Excessive reductions in oxygen are normally confined to the immediate environment of the fire. Due to the geometry of the mobile home and the fact that the test conditions included the closing of doors and windows before each test, the oxygen depletion phenomenon may be significant throughout the unit. Based on the physiological effects of reduction in oxygen as illustrated in table 2, the threshold for minimum oxygen concentration for tenability in the corridor was set at 14 percent.

2.2.4. Smoke Concentration

The type and concentration of smoke can produce a number of adverse psychological and physiological effects. These include fear and confusion, as well as eye irritation, respiratory tract swelling and irritation, and difficulty in breathing. Smoke particles also absorb and scatter light, thereby reducing visibility. The resultant effect on a person can be disorientation, accompanied by fear and anxiety [20].

What have been described are the two basic properties of smoke to be considered regarding life safety (1) toxicity of the airborne particles produced from combustion, and (2) density, and its affect on visibility. According to J. H. McGuire [21], in general, highly toxic smokes are usually very dense. Therefore, measurement of either property would provide information regarding development of smoke and its effect on life safety. Optical density per unit distance is primarily used to describe the concentration of smoke in relation to visibility.

A thorough literature survey was conducted to determine the level of smoke concentration representative of the threshold for untenable conditions Based on this survey and the geometry of the mobile home, the smoke density selected as the threshold for untenability for this series of tests was 0.26 OD/m (.08 optical density per foot). Optical densities in excess of this level would result in conditions of visibility which would obscure physical features and possibly disorient the individual [19,22,23].

2.3. Measurements

Observations were made of fire spread in the corridor, and continuous or periodic measurements were made of temperature, incident heat flux, carbon monoxide (CO) concentration, oxygen (O_2) depletion and smoke density along the corridor and in bedroom No. 1. Figure 1 illustrates the location of instrumentation utilized in monitoring the corridor tests. Figures 3 and 4 show the typical corridor construction prior to each test. Temperature was monitored at 30 locations in the corridor and 12 locations in bedroom No. 1. Three thermocouple "trees" were located along the longitudinal axis of the corridor to measure changes in the air temperature in the center of the corridor at distances of 210, 188, 132, 91 cm (83, 74, 52 and 36 in) above the floor. The thermocouples consisted of 20-gage Chromel-Alumel wires packed in mineral insulation and enclosed in a 3.15 mm (0.124-in) diameter inconel sheath.

The surface temperatures along the corridor walls and around the perimeter walls of bedroom No. 1 at distances of 210, 188, 132 cm (83, 74, and 52 in) above the floor were also monitored. These thermocouples were constructed of No. 24 gage Chromel-Alumel wires enclosed in glass fiber insulation.

A single thermocouple was positioned to monitor the changes in temperature 1.5 m (5 ft) above the floor at the back exit door. This thermocouple was connected to a potentiometer which provided continuous monitoring of temperature rise at the rear exit door during each test.

Incident heat flux was measured by three Gardon type, water-cooled, heat flux transducers, positioned at the floor level at the entrance to the corridor, the entrance to bedroom No. 1 and at the center of bedroom No. 1. The transducers faced the ceiling to provide experimental data on radiant and convective heat fluxes to the floor from the upper walls and ceiling.

Smoke density[4] was monitored at three locations: (1) at the furnace compartment, (2) the entrance to bedroom No. 1, and (3) the center of bedroom No. 1. All three measurements were taken 1.5 m (5 ft) above the floor along the latitudinal axis (perpendicular to corridor length) by monitoring the attenuation of a horizontally aligned light beam on a photomultiplier tube.

Carbon monoxide concentration and oxygen depletion were monitored at the entrance to bedroom No. 2 and in the center of bedroom No. 1. Carbon monoxide was measured by continuously sampling the atmosphere, and passing the samples through a non-dispersive infrared gas analyzer. Oxygen was monitored at the entrance to bedroom No. 2 by continuous sampling through a combustion gas analyzer; oxygen was monitored in bedroom No. 1 by continuous sampling through a wet cell oxygen analyzer. All gas samples were taken at a distance of 1.5 m (5 ft) above the floor.

A commercially available ionization type smoke detector was installed on the interior corridor wall at the entrance to bedroom No. 1, approximately 20 to 25 cm (8 to 10 in) from the ceiling.

All data collection activities were performed through use of a mobile instrumentation van specially equipped with instrumentation for off-site full-scale fire testing. Carbon monoxide and oxygen were recorded continuously. The remaining channels were recorded every 20 seconds, and later processed by computer.

Visual documentation of the tests was obtained by 16 mm color cinematography from two separate vantage points, closed circuit black and white videotape, and 35 mm still camera.

2.4. Ignition Source

A wood crib, weighing approximately 6.4 kg (14 lbs) and constructed of 28 pieces of 5 x 5 x 35 cm nominal hemlock (2 x 2 x 14 in), was utilized as the ignition source for all nine tests. The crib was selected based on experimental work conducted by J. B. Fang at the National Bureau of Standards to simulate a fire due to the ignition of a small piece of incidental furniture; e.g., a small upholstered chair [12]. Fang concluded from his experiments that "the fire with a standardized wood crib can duplicate the essential characteristics, such as burning time, temperature and heat flux levels and the size and shape of the flame of typical incidental fires."

---

[4] Exposure of the smoke meters to excessive heat and flame early in the tests resulted in unreliable data and was therefore not included in the analysis.

Each test crib was conditioned at 70 °F and 50% relative humidity for a minimum of 72 hours prior to testing. Moisture content was measured for each crib immediately preceding the test.

2.5. Interior Finish Test Materials

Four types of wall materials and three types of ceiling materials were selected for testing. The materials were selected to provide a wide range of flame spread index values associated with the ASTM E-84 Tunnel Test, up to a maximum flame spread rating of 200 [Class A (0-25); Class B (26-75); Class C (76-200)]. The Class B rated wall material was obtained by application of a fire retardant intumescent coating to a Class C — 5/32-inch lauan plywood. Two coats of intumescent varnish were applied by roller to the lauan plywood in accordance with the manufacturer's recommended procedure. Proper conditioning time was provided before testing. Laboratory testing of the treated plywood indicated that the treatment successfully provided a Class B rating when applied to the lauan plywood. The nine tests were designed to examine the performance of various combinations of the wall and ceiling materials under a typical fire exposure. Table 3 lists the individual materials as well as some measured laboratory test data.

3. CORRIDOR TEST PROCEDURE

The moisture content of the wood crib and the finish materials were measured and recorded for each test. Outside and inside temperature and relative humidity were also recorded. Tests were not conducted during rainy periods or when relative humidity was exceptionally high. Table 4 lists the measured test conditions for each of the nine tests. Table 5 lists some of the critical results for each of the tests.

The corridor area of the mobile home was conditioned through the use of the heating system to 21 °C ± 3 °C (70 °F ± 5 °F) and 45 percent ± 15 percent relative humidity before each test. There was, however, no forced air circulation during the tests. All exterior doors and windows were closed, but not sealed.

The wood crib was positioned on a load cell in order to measure its weight loss throughout the test. The crib was 25 cm (10 in) above the floor, and approximately 2.5 cm (1 in) from both of the partitions of the corner configuration. A pan, 20 x 20 x 2.5 cm (8 x 8 x 1 in), containing 150 cm^3 of heptane was placed under the wood crib. The tests were started by ignition of the heptane by remote electrical ignition of a wooden match.

4. LABORATORY TESTS

Laboratory tests were conducted on each of the seven different materials used in the corridor tests. These consisted of:

a) Standard Method of Test for Surface Burning Characteristics of Building Materials (ASTM E-84 Tunnel Test);

b) NFPA 258 T, Smoke Density Chamber;

c) ASTM E-162 Radiant Panel Test;

d) ease of ignition [24]; and

e) NBS Rate of Heat Release Calorimeter [25].

Results of these tests are given in table 3.

5. TEST RESULTS

Nine corridor tests were conducted to examine the effects on fire growth of different combinations of wall and ceiling test materials.

Figure 5 illustrates the initial fire growth resulting from the exposure of a wall partition to ignition by a 6.4-kg (14-lb) wood crib. The burning of the wood crib was characterized by a maximum flame height of 1.5 m to 1.8 m (5 to 6 ft). This peak flame height normally occurred within the first 1-3/4 minutes of the test. Due to the positioning and size of the wood crib, the duration of direct impingement on the wall by this crib fire was approximately 2 to 2-1/2 minutes. Without significant contribution from the wall material, the test fire did not propagate beyond the crib.

The tests were terminated either when there was no further involvement of the wall and ceiling finish material or when the corridor was fully involved to the extent of flames reaching bedroom No. 1.

A majority of the tests ran approximately six minutes. This length of time insured total involvement of the corridor down to bedroom No. 1 when materials having the most severe flame spread characteristics were used. At the same time, this limitation prevented flashover which would have resulted in involvement of the test mobile home beyond the immediate areas of the corridor. A manually operated sprinkler system was installed in the test unit to limit the extent of fire growth. It should be noted that a number of tests were allowed to run longer than six minutes when there was no indication that conditions were approaching flashover. One test, Test No. 2, was terminated after 3-1/2 minutes. The burn rate of the wood crib had decreased, no longer exposing the wall finish, and there was no involvement of the wall and ceiling materials.

Table 5 summarizes some important test results obtained by instrumentation and visual observation. Details of fire growth and pertinent observations regarding severity are included. (Appendix A provides a detailed chronological documentation of events for each test.)

Carbon monoxide concentrations and oxygen depletion were monitored by continuous sampling of the atmosphere near the entrance to bedroom No. 2 and in the center of bedroom No. 1. The concentrations of carbon monoxide and oxygen at the 2, 4 and 6 minute points in each test as well as maximum carbon monoxide concentration and minimum levels of oxygen were extracted from the data and recorded in tabular form in table 6. The absence of data in this table reflects experimental difficulties in obtaining reliable carbon monoxide and oxygen concentration data in a number of the tests.

6. DISCUSSION

6.1. Analysis

6.1.1. Fire Growth and Spread

Initial fire growth due to ignition of the wood crib was relatively consistent for all nine tests. The maximum flame height resulting from the burning crib was approximately 1.8 m (6 ft) above the floor. Some fuel contribution from the wall material adjacent to the wood crib was necessary for flames to impinge on the ceiling. In tests numbered 4, 6, 7, 8 and 9 the wood crib burned down early in the test before the walls or ceiling became extensively involved. There is some indication that this occurred after exhaustion of the 150 cm^3 of heptane ignitor. The peak burn rate of the wood crib was reached at approximately 2 minutes, after which the burn rate began to decrease.

This occurred in the time range associated with the reduction in intensity of the fire for each of these tests. However, after a short period of time during which the materials pyrolysed, each of the test fires redeveloped and resulted in fire development similar to those tests not characterized by burning down of the crib in the early stages.

In Test No. 2, in which the walls and ceiling were constructed of Class A materials, the wood crib burned down after igniting the paper surface on the wall immediately exposed. In this case, the lack of available combustible materials prevented the test fire from redeveloping.

Tests No. 5 and No. 8 resulted in the most severe fire growth. Test No. 5 developed somewhat sooner than Test No. 8, but both were characterized by propagation along both the interior and exterior corridor walls (both walls burning in Test No. 5 at 2 minutes-35 seconds) the full length of the corridor. Flame penetration of the exterior skin occurred at 4 minutes in Test No. 5 and at 4 minutes-15 seconds in Test No. 8. Both tests resulted in extensive lateral fire spread above the ceiling, and in Test No. 5, there was evidence of flame spread into bedroom No. 2 and the bathroom due to burn-through of the corridor walls.

Fire growth in Test No. 1 was not as severe as in Tests Nos. 5 or 8 due to the installation of a class A ceiling. The wall material was ignited at 1 minute into the test, with propagation down both corridor walls within 3 minutes; there was some evidence of burn-through of the exterior skin. However, while there was full involvement of the walls in the corridor, the ceiling did not ignite, and there was no evidence of flame propagation above the ceiling assembly.

General fire severity in Test No. 4 was similar to that in Test No. 1 with some variance in the fire development. The wall material was somewhat slower to ignite (1 minute-40 seconds). However, the ceiling sustained ignition immediately after involvement of the wall, resulting in flame spread into the corridor in less than 2 minutes. There was no evidence of flame penetration of the 5/16-inch gypsum subpartition, but surface flame spread occurred on both corridor walls, and failure of the ceiling above the wood crib resulted in extensive lateral propagation of the fire above the ceiling assembly. The fire spread above the ceiling resulted in flame penetration of the exterior skin even though the wall partition maintained its integrity.

Initial fire development in Test No. 3 was similar to that of Test No. 4 in that the wall and ceiling surfaces ignited within 2 minutes. The paper surface on the wall provided an avenue for flame spread to the ceiling, but did not continue to burn due to the minimum amount of fuel. While there was no further contribution to fire growth from the walls, gas phase burning was observed at the ceiling level at 3 minutes-15 seconds, followed by flame penetration of the ceiling and extensive lateral propagation in the space above the ceiling after approximately 4 minutes-20 seconds.

Test No. 9 was characterized by an early build-up of the fire in which the embossed paper face on the wall panels blistered and peeled off. The initial maximum flame height was reached at 2 minutes into the test and then began to recede due to the initial contribution from the heptane ignitor; but after approximately one minute the crib fire began to grow in intensity and reignited the wall. From this point on, the test development was similar to the other tests, with flame propagation into the corridor at 3 minutes-40 seconds. The test fire spread along both the interior and exterior walls at the ceiling level down the corridor to the rear exit door. There was, howeve: no indication of flame penetration of the ceiling.

A fire retardant intumescent coating was applied to the plywood wall panels in Tests Nos. 6 and 7; the primary difference in test conditions was the installation of different ceiling materials. In both tests, sustained burning of the wall panel directly exposed to the crib occurred after about 3 minutes. In Test No. 6, the fire burned through the intumescent coating after 7 minutes, but flame spread never extended beyond the first two exterior corridor wall panels. While the fire penetrated the exterior skin after 10 minutes-15 seconds and the fire retardant coating intumesced along the upper part of the interior and exterior walls of the full length of the corridor, there was no evidence of flame spread into the corridor.

Test No. 7 varied from Test No. 6 in that the ceiling ignited after 3 minutes-20 seconds, resulting in flame spread into the corridor. The fire penetrated the ceiling at 6 minutes-25 seconds into the test, resulting in extensive lateral fire spread above the ceiling assembly. The extensive fire propagation at the ceiling level resulted in penetration of the intumescent coating and the plywood panels in the corridor as far away from the test crib as the back exit door.

Due to the configuration of the corridor test setup and the absence of furnishings it was concluded that the time to reach untenable conditions would be primarily influenced by the interior lining on the walls and ceiling of the corridor. The criteria for untenability outlined in section 2.2. was utilized to evaluate the performance of the various combinations of interior finish materials. An illustration of the times at which untenable conditions were reached for each of the tests is provided in table 7.

6.1.2. Temperature Data

Thermocouples located in the center of the corridor, 132 cm (52 in) above the floor, were used to monitor the typical exposure received by an individual attempting to utilize the corridor as a means of egress. At this height, the air temperatures at the surface of the interior and exterior walls were slightly higher than the air temperature in the center of the corridor.

Figure 6 provides a typical comparison of the air temperature in the center of the corridor, thermocouple No. 37, with the average temperature of thermocouples numbered 11, 12 and 37. (Reference table 8 for identification and location of instrumentation.) Thermocouples Nos. 11 and 12 were positioned at the same height and in the same cross-sectional plane as No. 36, to measure temperatures on the interior and exterior walls respectively at the same distance from the ignition source as No. 36. This array of thermocouples was located 132 cm (52 in) above the floor adjacent to the furnace compartment, approximately 4.1 m (13-1/2 ft) from the ignition source.

Vertical gas temperature profiles illustrating maximum temperature levels at three locations along the corridor's longitudinal axis, from all nine tests, are illustrated in appendix B. The profiles indicate a vertical temperature stratification of heated gases along the ceiling.

Surface flame spread did not occur along the floor level in any of the tests. The extent of propagation along the ceiling and upper walls of the corridor appeared to be influenced specifically by the radiative and convective energy produced in the upper part of the corridor. The temperature profiles in appendix B further illustrate the relative degree of severity and the temperature stratification at the ceiling.

The air temperature at 132 cm (52 in) above the floor, resulting from this convection and radiation was selected to monitor tenability from the standpoint of heat. An occupant in a standing or slightly crouched position could be exposed at this level while attempting to egress by way of the corridor. The temperatures along the centerline of the corridor were considered representative and appropriate.

Two thermocouples, one located adjacent to the furnace compartment approximately 4.1 meters down the length of the corridor (No. 37), and one located just beyond the rear egress door at the entrance to bedroom No. 1 (No. 41), were selected as representative locations for evaluating critical temperatures. Figures 7 and 8 show the experimental data on air temperatures measured at these two locations for each of the nine tests.

Temperature levels at 2, 4 and 6 minutes as well as peak temperatures at 188 cm (74 in) and 132 cm (52 in) above the floor in the three thermocouple trees positioned along the corridor's longitudinal axis provided indications of the heat contribution of the interior finish materials. This data has been arranged in tabular form in appendix C.

The test which resulted in the greatest fire severity and highest temperatures was Test No. 5 which was representative of conventional corridor construction. This combination is designated W-4/C-3. (Table 3 provides descriptions of wall and ceiling materials; the designated symbols will be used to reference the particular materials.) Four minutes after ignition, the air temperatures were in excess of 100 °C (212 °F) along the full length of the corridor at a distance of 132 cm (52 in) above the floor.

Test No. 2, utilizing the combination of W-1/C-1, resulted in the least severe exposure. While the 100 °C (212 °F) criterion was reached at the 188 cm (74 in) level (above the floor) within 2 minutes, this condition was not reached at the 132 cm (52 in) level during the test period. The maximum temperature levels at 188 cm (74 in) and 132 cm (52 in) in the thermocouple tree located at the entrance to bedroom No. 1 were 225 °C (437 °F) and 57 °C (135 °F) respectively. In this test, damage to the interior finish was limited to the 1.2 x 2.1 m (4 x 7 ft) panel directly exposed to the wood crib (figure 9).

While Test Nos. 2 and 5 represent the extremes in fire growth, data from the remaining seven tests provide information regarding relative levels of fire development. Figures 7 and 8 appear to divide into four distinguishable levels or groups of temperature curves which provide indications of the extent of the contribution of the interior finish materials.

The highest temperature group includes Test No. 5 (W-4/C-3) and Test No. 8 (W-4/C-2). These tests, with "Class C" wall and ceiling materials, resulted in the most rapid and extensive fire growth, with the temperature reaching the 100 °C (212 °F) limit for untenability in the shortest period of time of all the groups (see figure 12).

The next group includes Test No. 1 (W-4/C-1), Test No. 4 (W-4 on W-1/C-3) and Test No. 9 (W-2/C-1). While post-test observations indicated a reduction in severity, extensive damage was still found in the corridor and the adjacent rooms. Figures 10a, 10b, 11a and 11b, illustrate the damage resulting from Test No. 5 and Test No. 9. The temperature exceeded the 100 °C (212 °F) criterion level approximately 50 seconds later than for the tests in the first group (see figure 12). In all three tests, the 100 °C (212 °F) temperature criterion was exceeded at one or both of the points where temperature was monitored (TC 37,41) before six minutes had elapsed.

The next group includes Test No. 3 (W-1/C-3), Test No. 6 (W-3/C-1) and Test No. 7 (W-3/C-2). The temperature remained below the 100 °C (212 °F) level for over 6 minutes for all three tests.

Test No. 2 (W-1/C-1) was distinctly different from the other groups. The wood crib ignition source burned out with no sustained burning of the walls or ceiling after the paper covering burned out at approximately 1 minute-45 seconds into the test. The temperature never reached the critical 100 °C (212 °F) at 132 cm (52 in) above the floor, with the maximum temperatures remaining below 50 °C (122 °F) at thermocouples No. 37 and No. 41.

Figures 7 and 8 illustrate that while some effect on temperature levels was observed due to different ceiling materials, the most significant influence on temperature level and fire growth occurred when different wall materials were used.

The influence of changing only the ceiling material can be illustrated by comparing three different ceiling materials (C-1, C-2, C-3) tested with the same wall material; the wall material was conventional lauan plywood (W-4). These were Test Nos. 1, 8 and 5, respectively. While changes in the temperature levels are indicated, they are not as great as those observed with changes in the wall material. The use of the conventional wall construction in combination with any of the ceiling materials tested did not keep temperature levels below the 100 °C (212 °F) criterion under these test conditions.

The comparison of temperature curves for Test Nos. 3 and 5, or Test Nos. 1, 2, 6, and 9, illustrates the effect of changing the wall materials with the same ceiling material. A substantial reduction in fire growth is indicated when utilizing materials on the walls which have lower ASTM E-84 flame spread ratings. It should be emphasized that this test series represented a situation in which there was a direct exposure of the wall partition to the ignition source. Further testing would be necessary to determine the contribution of the walls and ceiling to fire growth and spread under a variety of conditions.

6.1.3. Incident Heat Flux

Examination of the test data indicated that the incident heat flux at the floor level increased proportionally to the changes in gas temperatures in the upper atmosphere in the corridor. However, due to the location of the heat flux meters at the floor level, the values for incident heat flux are relatively low. Table 9 illustrates the levels of incident heat flux at the floor level at the entrance to bedroom No. 1, and in the center of bedroom No. 1.

6.1.4. Carbon Monoxide and Oxygen Concentrations

Table 6 illustrates the levels of carbon monoxide and oxygen in the vicinity of the entrance to bedroom No. 2 and bedroom No. 1 for all 9 tests. The levels of CO and O_2 were found to correspond to high air temperatures. In the tests characterized by more extensive fire growth and spread, carbon monoxide concentrations were higher, and oxygen levels were lower. The criteria selected for CO concentrations was a maximum of one percent by volume (10,000 ppm) and for O_2 a concentration of less than 14 percent.

The results of Test No. 8 indicate that the level of oxygen at the entrance to bedroom No. 2 had dropped below 14 percent before 6 minutes had elapsed. Coinciding with this was an increase in CO beyond one percent concentration at the same location. Figure 13 illustrates the CO concentrations in bedroom No. 1 four minutes into the test. While the actual concentration of CO in Test No. 8 could not be determined due to limitations of the instrumentation, it appears that the CO concentration was considerably higher than in any of the other tests. While it is unfortunate that CO and O_2 concentrations were not available for Test No. 5 (conventional construction), the same wall materials utilized in Test No. 8 provide some indication of the levels of CO and O_2 that can be expected.

6.1.5. Smoke Density

Reliable smoke density data were not obtained due to instrumentation problems. Exposure of the smoke meters to excessive heat and flame early in the tests rendered the instrumentation inoperable.

Although as a result of this difficulty smoke obscuration was not examined as a criterion for untenability, excessive smoke obscuration has been identified as the untenable condition first reached in other full-scale fire testing. In subsequent full-scale testing the design of the instrumentation for collection of smoke data will be altered to minimize difficulties in order to provide reliable data on levels of smoke obscuration and the time to reach untenability conditions.

6.2. Laboratory Testing of Materials

The seven materials utilized in the corridor tests were also tested on a laboratory scale to examine the correlation between a variety of laboratory tests and the full-scale tests. The laboratory tests selected provided data on characteristics of materials such as ease of ignition, surface flame spread, the rate of heat release and smoke development (table 3).

Normally, the ASTM E-84 Tunnel Test would not be expected to provide a high degree of correlation with full-scale tests where the attainment of untenable conditions (temperature, smoke, gas concentrations) is of primary concern. These corridor tests indicated that the simple ASTM E-84 classification provided an approximate guide to the relative contribution of the wall lining of the corridor to the development of untenable temperature conditions down the corridor.

Further examination of the correlation of laboratory tests and full-scale corridor tests will be included in a final report.

7. SUMMARY AND CONCLUSIONS

The following conclusions are based on a limited number of full-scale tests conducted in the corridor of a typical mobile home under a specific set of test conditions. The test conditions were as follows: (a) all exterior doors and windows were closed, but not sealed; (b) all doors in the corridor except the door to bedroom No. 1 were closed; (c) the mobile home was conditioned to 21 °C ± 2.5 °C (70 °F ± 5 °F) and a maximum relative humidity of 60 percent; and (d) the ignition source was a 6.4-kg (14-lb) wood crib.

The primary objective of this test series was to examine the performance of various combinations of wall and ceiling finish materials with regard to the time to reach untenable conditions in the corridor from exposure to a typical ignition. Thresholds for untenability were set at: 100 °C (212 °F) temperature, one percent carbon monoxide concentration (10,000 ppm), 14 percent oxygen concentration, and 0.26 OD/m (.08 optical density per foot) smoke concentration.

Based on the results of the nine tests conducted under this one set of test conditions, the following conclusions are drawn:

1. The tests indicated that a fire entering the corridor in a mobile home, rather than venting itself by burning up through the roof or out the windows located along the corridor, or burning through partitions into adjacent areas, will initially progress directly down the length of the corridor, significantly limiting egress. This confirmed that the corridor leading to the sleeping areas in a mobile home, due to its location and design characteristics, is a critical path for flame spread and fire development.

2. The extent of fire spread and the time to reach untenable conditions, based on the various criteria provided, is significantly influenced by the surface flame spread characteristics of the wall and ceiling finish materials in the corridor.

3. The extent of propagation vertically from ceiling to floor along the corridor appear to be influenced specifically by the radiative and convective energy produced by burning of the upper part of the walls and the ceiling.

4. The available data indicate that levels of heat flux, carbon monoxide, oxygen and temperature were directly effected by the extent of fire propagation along the wall and ceiling finish materials in the corridor.

5. For fire which may spread down the corridor, a principle means of egress in event of fire, a corridor wall and ceiling lining with a flame spread rating in the vicinity of 200, produces untenable temperature conditions in the corridor in less than four minutes.

6. Based on these tests, the use of Class A wall and ceiling materials in the corridor could significantly increase the fire safety for occupants and reduce the property losses from fires. For a fire starting in the living room, this could represent the difference between the fire burning into the bedroom area or not.

8. ACKNOWLEDGMENTS

The author would like to thank Mr. B. Buell, Mr. D. Klein, Mr. J. Lawson, Mr. R. Lindauer, Mr. T. Maher, Mr. B. Ramey, Mr. S. Steel, Mr. W. Stull, Mr. C. Veirtz and Mr. M. Womble for their assistance in the experimental work, Ms. M. Harkleroad and Mr. J. Raines for their assistance in developing a computer program and reduction of experimental data, and Mr. R. O'Laughlin and Mr. B. Buell for assistance in data analysis.

Some of the materials selected for this test series were provided by the Armstrong Cork Company and the National Gypsum Company.

This work was sponsored in part by the United States Department of Housing and Urban Development and the Mobile Home Manufacturers Association.

9. REFERENCES

[1] U.S. Department of Health, Education and Welfare, Accidental Injury Hazards in Mobile Homes: Fire and Carbon Monoxide, Report No. FY 72-R2, (Dec. 1971).

[2] U.S. Department of Health, Education and Welfare, Report on the Risk of Fire in Mobile Homes, prepared by Division of Community Injury Control.

[3] Stickney, C. W., The Mobile Home Fire Protection Problem, a talk presented to Fire Marshals Association of North America.

[4] MH/RV Document No. 75-14, California Fire Loss Experience, Mobile Homes/ Travel Trailers vs 1 & 2 Family Dwellings, Calendar Year 1974 (May 1975), (Committee on Mobile Homes and Recreational Vehicles, National Fire Protection Association, Boston, Mass.).

[5] Standard for Mobile Homes, NFPA 501B-1974, ANSI A119.1, Paragraph 7.3.

[6] Standard Method of Test for Surface Burning Characteristics of Building Materials (ANSI A2.5-1970; ASTM E84-70; UL 723-1971; NFPA No. 255-1972).

[7] Fang, J. B., Fire Buildup in a Room and the Role of Interior Finish Materials, Nat. Bur. Stand. (U.S.), Technical Note 879 (June 1975).

[8] Schaffer, E. L. and Eickner, H. W., Corridor Wall Linings - Effect on Fire Performance, Fire Technology, Vol. 1, No. 4, 243 (Nov. 1965).

[9] McGuire, J. H., The Spread of Fire in Corridors, Fire Technology, Vol. 4, No. 2, 103 (May 1968).

[10] Christian, W. J. and Waterman, T. E., Flame Spread in Corridors: Effects of Location and Area of Wall Finish, Fire Journal, 25 (July 1971).

[11] Waterman, T., Corridor Flame Spread, IITRI Project J8142 (Feb. 1972).

[12] Fang, J. B., Measurements of the Behavior of Incidental Fires in a Compartment, Nat. Bur. Stand. (U.S.), NBSIR 75-679 (March 1975).

[13] Zikria, B. A., Sturner, W. Q., Astrajiam, N. K., Fox, Jr., C. L. and Ferrer, Jr., J. M., Respiratory Tract Damage in Burns: Pathophysiology and Therapy, Annals of New York Academy of Sciences, Vol. 150, Article 3, 618-626 (1968).

[14] Fire Protection Handbook, Revised 13th Edition, National Fire Protection Association, Boston, Mass., 4-36.

[15] Operation School Burning, National Fire Protection Association, Boston, Mass., 269 (1959).

[16] Bond, H., Ed., Fire Casualties of the German Attacks, Chapter 8, Fire and the Air War, National Fire Protection Association, Boston, Mass. (1946).

[17] Threshold Limit Values of Airborne Contaminants Adopted by ACGIH for 1973, American Conference for Governmental Industrial Hygienists, Cincinnati, Ohio (1973).

[18] Yuill, C. H., The Life Hazards of Bedding and Upholstery Fires, Journal of Fire and Flammability, Vol. 1, 312-323 (Oct. 1970).

[19] Custer, Richard L. P. and Bright, Richard G., Fire Detection: The State of the Art, Nat. Bur. Stand. (U.S.), Technical Note 839 (June 1974).

[20] Zikria, B. A., Ferrer, J. M. and Floch, A. B., The Chemical Factors contributing to Pulmonary Damage in Smoke Poisoning, Surgery, Vol. 71, No. 5, 704-709 (1972).

[21] McGuire, J. H., Tamura, G. T. and Wilson, A. G., Factors Controlling Smoke in High Buildings, Ashrae Symposium: Fire Hazards in Buildings (Jan. 1970).

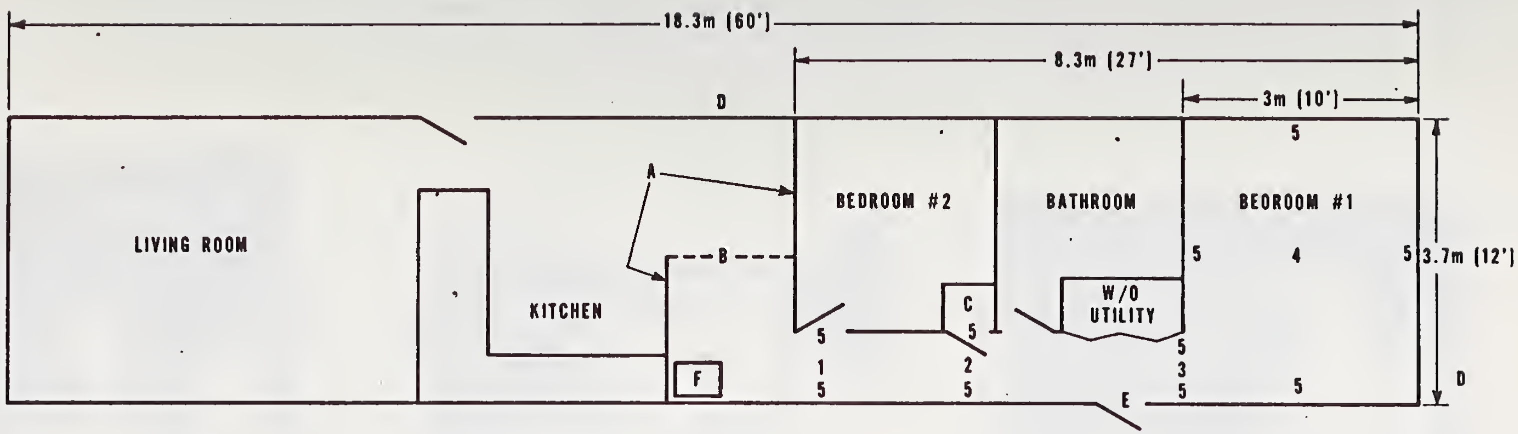
[22] Watanabe, A., Testing Methods of Fire Detectors in Buildings, Symposium on Automatic Detection, London (March 1972).

[23] Rashbash, D. J., The Role of Fire Detection Systems in Protection Against Fires, Symposium on Automatic Fire Detection, London (March 1972).

[24] Parker, W. J., The Development of a Test for Ease of Ignition by Flame Impingement, NBS Report 10495 (Feb. 1972).

[25] Parker, W. J. and Long, M. E., Development of a Heat Release Rate Calorimeter at NBS, ASTM-STP 502, American Society of Testing and Materials, 135-151 (1972).

[26] Claudy, W. D., Respiratory Hazards of the Fire Service, National Fire Protection Association, Boston, Mass. (1957).



A - Partitions covered with asbestos-cement board

B - Draft curtain extended down 20 cm from ceiling

C - Furnace

D - Video Windows

E - Thermocouple, 1.5 m above floor-continuously monitored during tests

F - Ignition Source

1* - Heat Flux, located at floor level (vertical view)
CO & CO_2 concentration, 1.5 m above floor
Thermocouple Tree (211, 188, 132, 91 cm) above floor

2 - Smoke Density, 1.5 m above floor
Thermocouple Tree (211, 188, 132, 91 cm) above floor

3 - Heat Flux, located at floor level (vertical view)
Smoke density, 1.5 m above floor
Thermocouple Tree (211, 188, 132, 91 cm) above floor

4 - Heat flux, located at floor level (vertical view)
Smoke Density, 1.5 m above floor

5 - Thermocouples (211, 188, 132, 91 cm) above floor

W/D - Washer/Dryer enclosure

*See Table 8 for instrument channel identification

Figure 1. Floor plan of mobile home test unit.

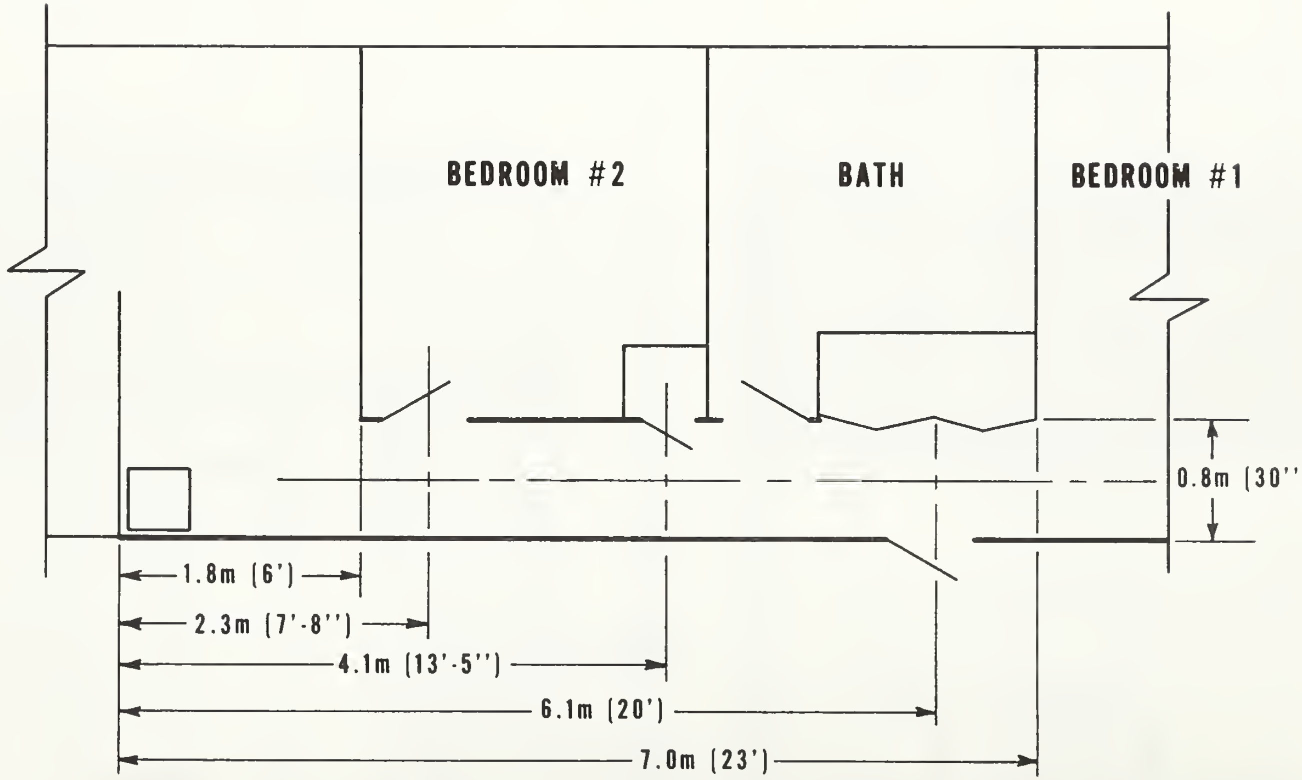


Figure 2. Detail of test corridor.

Figure 3. Typical corridor test setup, illustrating the location of the ignition source.

Figure 4. Typical corridor test setup illustrating the positioning of the ignition source in a corner configuration.

Figure 5. Illustration of the initial fire growth resulting from ignition of a 6.4-kg wood crib.

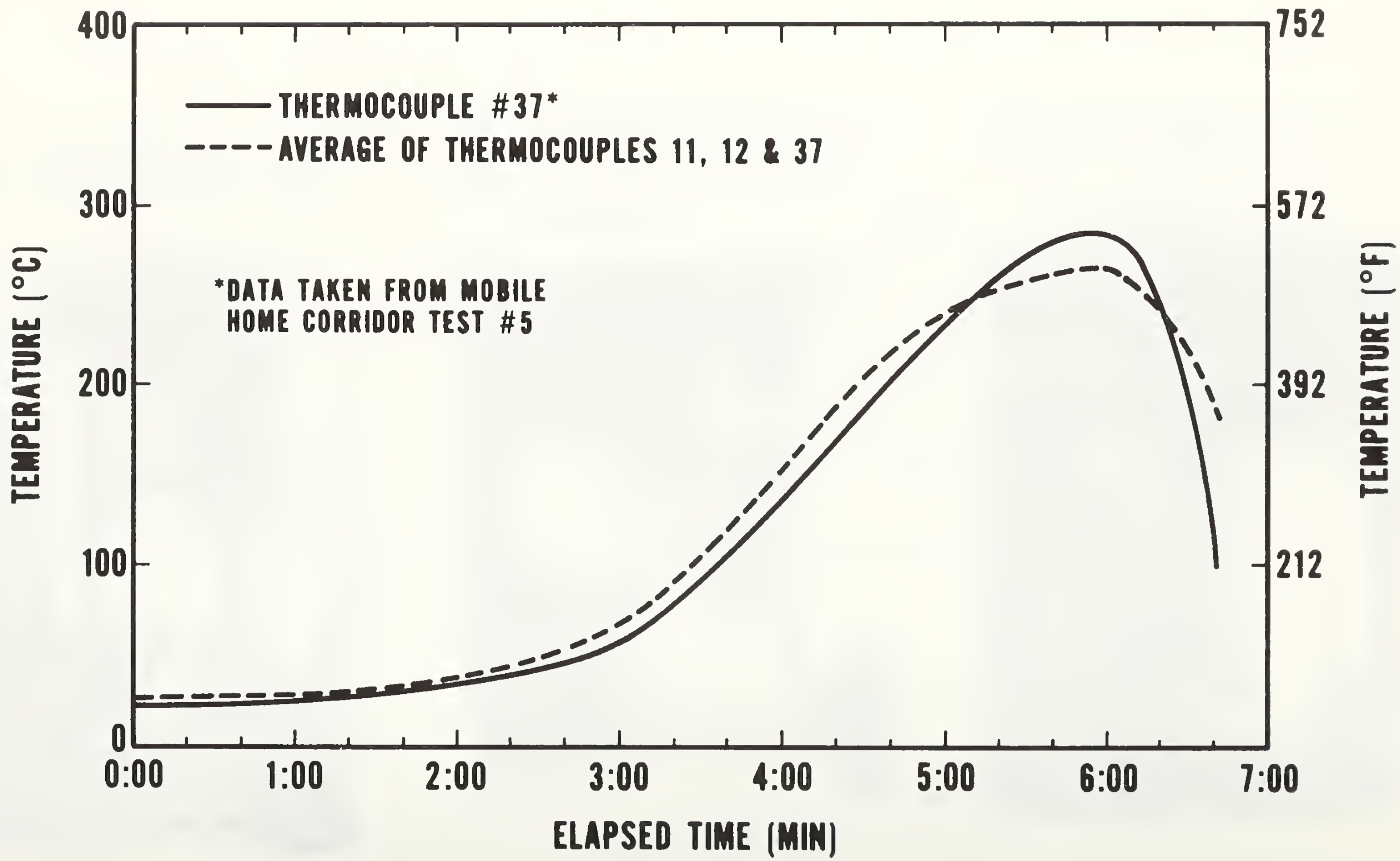
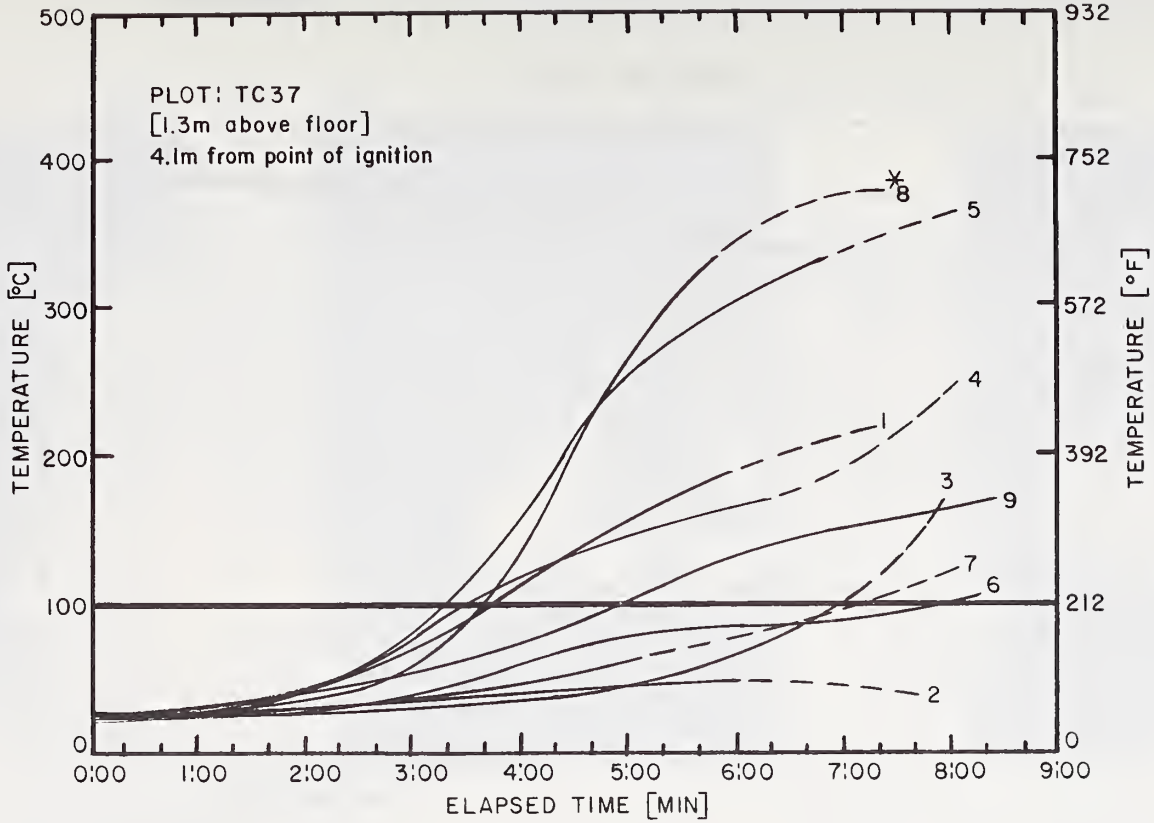


Figure 6. Comparison of air temperature in center of corridor vs average air temperature (see table 8 for location of thermocouples).



*Test number
— — — Dashed lines represent extrapolated data

Figure 7. Time temperature curve at center of corridor.

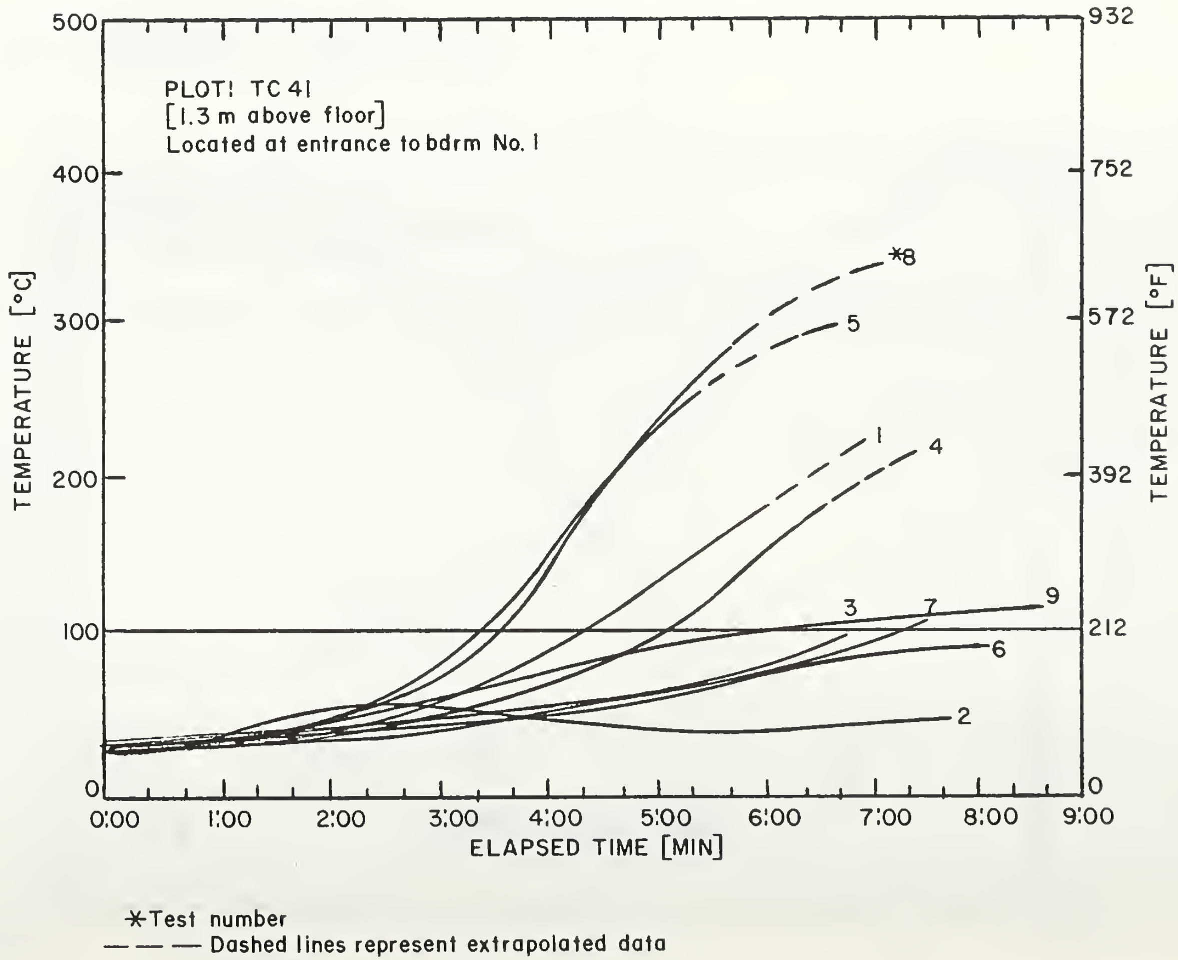


Figure 8. Time temperature curve at entrance to bedroom 1.

Figure 9. Illustration of results of Test No. 2.

Figure 10a. Illustration of damage along interior and exterior corridor walls in Test No. 5.

Figure 10b. Illustration of damage in the immediate area of the ignition source in Test No. 5.

Figure 11a. Illustration of damage along interior and exterior corridor walls in Test No. 9.

Figure 11b. Illustration of damage in the immediate area of the ignition source in Test No. 9.

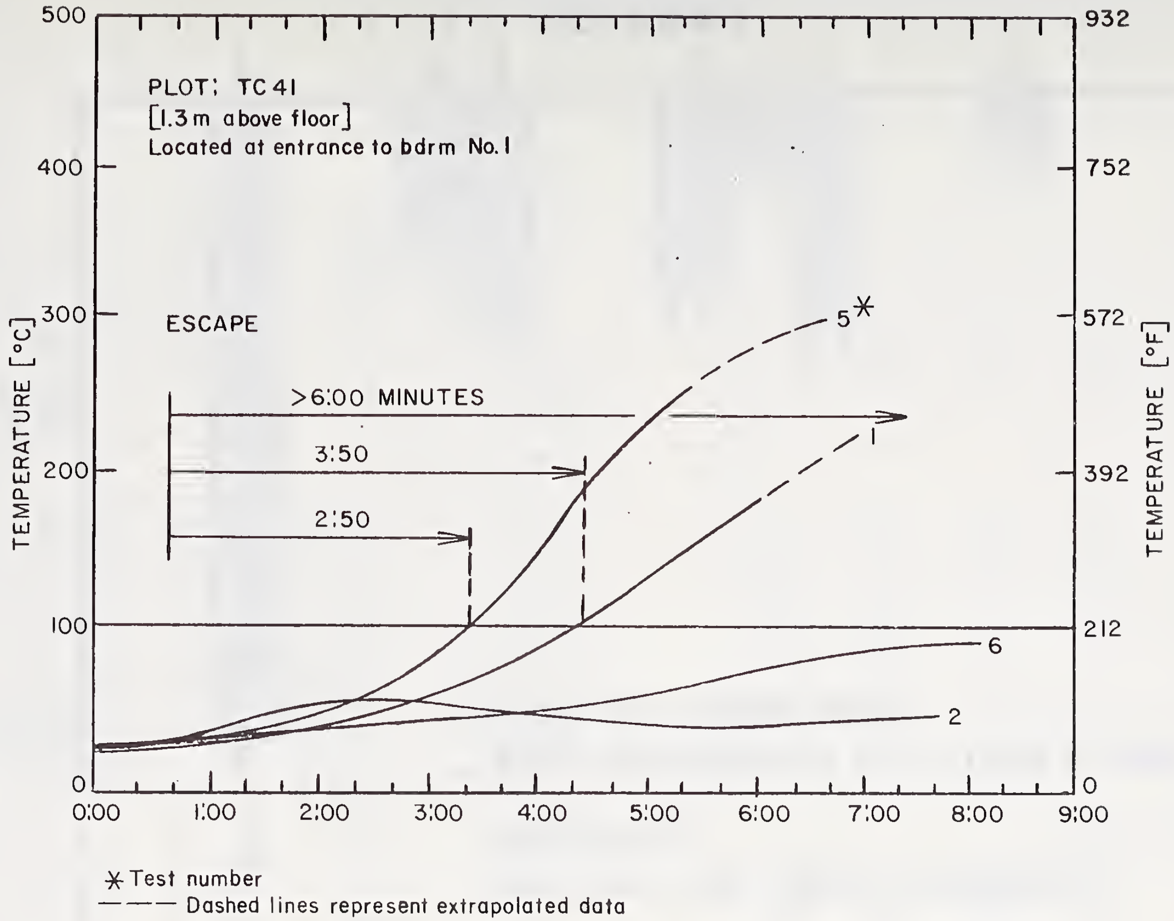


Figure 12. Time from alarm by single station smoke detector to untenable temperature conditions.

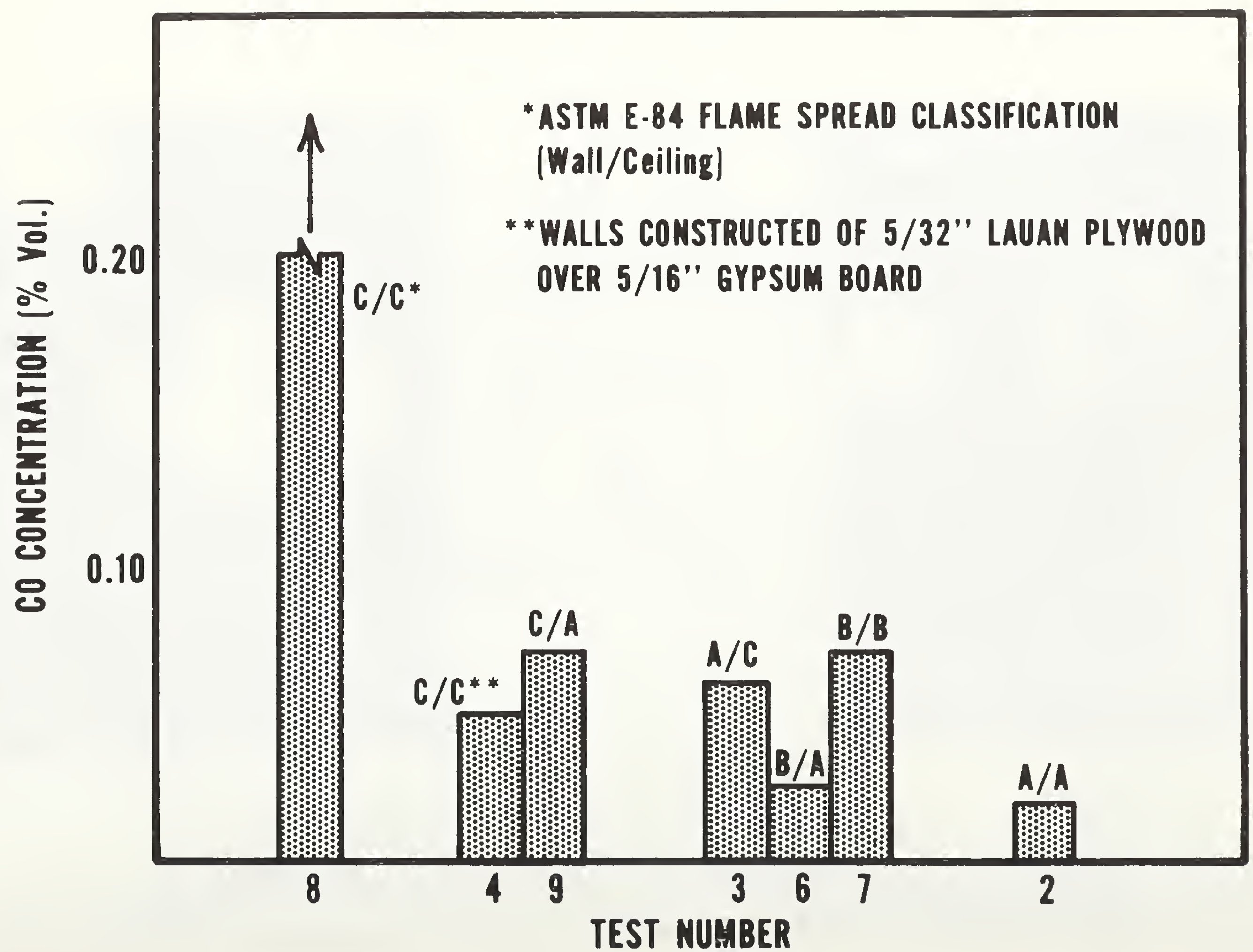


Figure 13. Carbon monoxide concentrations in center of bedroom No. 1, 4 minutes elapsed time.

Table 1. Effect of Carbon Monoxide Exposure
(After Claudy [26])

Percent Concentration	ppm	Time	Effect
0.02	200	2-3 hr	Mild headache
0.08	800	45 min 2 hr	Mild headache Death possible
0.32	3,200	10-14 min 30 min	Dizziness Death
0.69	6,900	1-2 min 10-15 min	Dizziness Death
1.28	12,800	2-3 breaths 1-3 min	Unconsciousness Death

Table 2. Effects of Oxygen Depletion*
(Based on Literature Survey)

Percent	Time	Effect
21-17	Indefinite	Respiration volume decreased, loss of coordination and difficulty in thinking
17-14	2 hr	Rapid pulse and dizziness
14-11	30 min	Nausea, vomiting and paralysis
9	5 min	Unconsciousness
6	1-2 min	Death within a few minutes

*These figures are only approximate as there are some variations in the literature.

Table 3. Description of Materials and Laboratory Test Results

Material				ASTM E-84 Tunnel	ASTM E-162 Flame Spread Index	NBS Smoke Density Chamber (D_m)		Ease of Ignition	Rate of Heat Release Calorimeter** Sample Exposure		
Description	Designated Symbol	Thickness (mm)	Thickness (in)	Flame Spread		Flaming	Non-Flaming	Sustained Ignition Time (min:s)	(2 W/cm^2) 20 kW/m^2 $J/m^2 \times 10^5$	(4 W/cm^2) 40 kW/m^2 $J/m^2 \times 10^5$	(6 W/cm^2) 60 kW/m^2 $J/m^2 \times 10^5$
Printed, paper overlayed, embossed grooved gypsum board	W-1	7.92	5/16	24	27	46	40	2:40	10.8	13.8	21
Prefinished, paper overlay, grooved lauan plywood	W-2	6:35	1/4	109	103	85	263	1:55	114.6	127.8	162.6
Prefinished, printed grooved lauan plywood; intumescent coating*	W-3	4.00	5/32	55	2	291	61	∞***	39.0	70.2	78.0
Prefinished, printed, grooved, lauan plywood	W-4	4.00	5/32	194	149	31	237	1:30	94.8	111.6	100.2
Vinyl latex prefinished (12 x 12 in) mineral fiberboard	C-1	10.30	1/2	19	2	12	15	∞	7.2	15	24.6
Printed, grooved fiberboard back surface exposed	C-2	10.30	1/2	81	152	134	481	0.33	37.2	41.4	45.6
Prefinished fiberboard tile (12 x 12 in)	C-3	10.30	1/2	122	80	283	399	0:38	39.6	50.4	90.6

*Finish treated with 2 coats of U.L. listed fire retardant intumescent coating; clear varnish finish coat; roller application.

**Average of 3 samples: maximum 1 minute rate of heat release (Joules/square meter).

***Sustained ignition did not occur during a 10 minute exposure.

Table 4. Test Conditions for Full-Scale Mobile Home Corridor Tests

Test No.	Interior Conditions			Exterior Conditions			Wood Crib			Wall Paneling
	Temperature		Humidity	Temperature		Humidity	Weight		Moisture Content	Moisture Content
	(°C)	(°F)	(%)	(°C)	(°F)	(%)	(kg)	(lbs)	(%)	(%)
1	20	68	38	9	48	40	6.01	13.23	7.3	5
2	20	68	54	7	44	65	6.16	13.55	6.8	9
3	21	69	38	14	57	44	6.16	13.56	6.7	10
4	20	68	31	7	44	33	6.71	14.77	4.8	6
5	23	74	30	17	62	48	6.08	13.38	6.8	8
6	20	68	28	8	46	45	6.30	13.87	5.0	7
7	19	67	40	8	47	65	6.56	14.43	6.0	8
8	18	64	48	14	58	70	6.95	15.28	6.2	7
9	22	71	60	20	68	70	7.02	15.45	7.3	11

Table 5.. Results of Full-Scale Mobile Home Corridor Tests

Test No.	Wall Surface Material	ASTM E-84 - F.S. Index	Ceiling Surface Material	ASTM E-84 - F.S. Index	Time to Ignition of Walls (min:s)	Time to Ignition of Ceiling (min:s)	Lateral Propagation of Flame Front (min:s)	Surface Flame Spread into Corridor (min:s)	Ignition of Interior Partition (min:s)	Flame Penetration of Exterior Skin (min:s)	Detector Response Time (s)	Termination of Data Collection (min:s)	Termination of Test Observations (min:s)
1	W-4	194	C-1	19	1:00	—	1:10	1:12	3:00	4:48	33	7:40	6:15
2	W-1	24	C-1	19	(1:40)	—	1:30	—	—	—	30	6:00	3:30
3	W-1	24	C-3	122	(1:30)	1:45	1:55	2:20	—	—	31	6:40	6:45
4	W-4/W-1	194	C-3	122	1:40	1:45	1:48	1:50	4:45	5:50	32	7:00	6:25
5	W-4	194	C-3	122	1:35	1:45	1:45	1:55	2:35	4:00	34	6:40	6:33
6	W-3	55	C-1	19	3:20	—	2:30	7:10	—	10:15	32	12:40	12:30
7	W-3	55	C-2	81	3:10	3:20	4:25	5:15	5:55	7:35	33	5:00	10:30
8	W-4	194	C-2	81	2:05	3:10	2:45	2:50	3:55	4:15	31	6:20	6:00
9	W-2	109	C-1	19	1:15	—	3:10	3:40	4:00	—	34	11:20	11:00

Table 5 (continued). Observstions of Full-Scale Mobile Home Corridor Tests

Test No.	
1	No visual failure of ceiling assembly, hesvy smoke accumulation throughout mobile home at 2:40; total involvement of corridor at 4:40.
2	Printed paper surface burned — No spparent significance: crib burned down at 2:15.
3	Printed paper surface burned on first panel (4 x 7 ft) only; at 3:15 extensive burning above ceiling observed, excessive smoke throughout mobile home.
4	Plywood installed over gypsum board; fire died down at 2:00, at 3;10 fire began to spread toward corridor, ceiling fsiled st 5:00, gypsum subpartition showed no spparent failure.
5	Total involvement of corridor after approximately 2:35, 4:00; failure of interior psrtitions to sdjoining rooms.
6	Crib died down at 3:00, intumescence retarded propagation until 5:00 when wall behind crib sustained continuous burning; excessive smoke at 6:10, corridor never became involved.
7	At 2:25 crib died down; intumescent failed behind crib at 3:05; ceiling failed at 6:25; burning above ceiling.
8	Propagation above ceiling; burn-through of corridor partitions all the way to bedroom 1, failure of ceiling at 3:50.
9	The embossed paper face blistered and peeled off at 1:15.

Table 6. Carbon Monoxide and Oxygen Concentrations — Mobile Home Corridor Tests

Test No.	Percent CO Concentration* Bedroom 1					Percent O_2 Concentration Bedroom 1					Percent CO Concentration Entrance to Bedroom 2					Percent O_2 Concentration Entrance to Bedroom 2				
	2	4	6	Maximum	(Time)	2	4	6	Minimum	(Time)	2	4	6	Maximum	(Time)	2	4	6	Minimum	(Time)
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	.007	.020	.006	.037	(3:40)	20.3	19.8	19.5	19.5	(6:00)	—	—	—	—	—	—	—	—	—	—
3	.15	.060	.110	.130	(6:45)	20.3	19.0	17.0	17.0	(6:45)	—	—	—	—	—	—	—	—	—	—
4	.006	.050	>.200	>.200	(5:50)	20.1	19.9	18.0	17.0	(6:25)	.069	.1	.4	.47	(6:25)	20.3	20.1	19.8	18.0	(6:25)
5	—	—	—	—	—	—	—	—	—	—	0	0	.1	4.70	(7.40)**	20.8	20.8	20.8	19.0	(7.40)**
6	.010	.025	.045	>.200	(12:30)	20.3	20.3	20.3	18.5	(12:30)	—	—	—	—	—	20.7	20.5	20.5	20.5	(4:00)
7	.025	.070	.170	>.200	(6:30)	20.5	19.7	19.0	17.0	(8:00)	0	0	0	.12	(12:00)	20.6	20.4	20.3	16.8	(12:00)
8	.010	>.200	>.200	>.200	(3:40)	20.7	19.3	15.0	15.0	(6:00)	0	0	2.0	6.60	(5:40)	20.7	20.6	<14.0	<14.0	(5:40)
9	.010	.070	>.200	>.200	(4:45)	20.6	19.0	17.0	16.0	(8:00)	0	0	0	0	—	—	—	—	—	—

*Maximum capability of analyser — .2% concentration; in those tests where the maximum concentration exceeded .2%, the time recorded for maximum concentration reflects the point at which the concentration exceeded the limits of the analyser.

**Data taken from strip chart recorder after termination of data collection by high speed data system.

Table 7. Time at Which Untenable Condition was Reached

	Temperature 212 °F Max	CO 1% Max		O_2 14% Min		Smoke OD = .08/ft Max
Test	Corridor	Corridor	BR # 1	Corridor	BR # 1	Corridor
1	3:40	—*	—	—	—	—
2	NR**	—	NR	—	NR	—
3	6:50	—	NR	—	NR	—
4	3:40	NR	OS†	NR	NR	—
5	3:30	7.10	—	NR	—	—
6	8:00	NR	OS	NR	NR	—
7	6:50	NR	OS	NR	NR	—
8	3:10	5:15	OS	5:40	NR	—
9	5:30	—	OS	—	NR	—

*The hyphen indicates that no data were collected.

**NR = not reached.

†OS = Off scale, maximum capacity of instrument (0.2%) was reached during test.

Table 8. Location of Instrumentation

Measurement*	Location
	Instrumentation Located 2.34 m (7 ft 8 in) from Ignition in Test Corridor
TC 1	Outside wall, 211 cm (83 in) from floor
TC 2	Inside wall, 211 cm (83 in) from floor
TC 3	Outside wall, 188 cm (74 in) from floor
TC 4	Inside wall, 188 cm (74 in) from floor
TC 5	Outside wall, 132 cm (52 in) from floor
TC 6	Inside wall, 132 cm (52 in) from floor
TC 31	Center of corridor, 211 cm (83 in) from floor
TC 32	Center of corridor, 188 cm (74 in) from floor
TC 33	Center of corridor, 132 cm (52 in) from floor
TC 34	Center of corridor, 91 cm (36 in) from floor
R 1	Heat flux at floor level, center of corridor
O_2-2	Oxygen concentration 152 cm (5 ft) from floor
CO-2	Carbon monoxide concentration 152 cm (5 ft) from floor
	Instrumentation Located 4.09 m (13 ft 5 in) from Ignition in Test Corridor
TC 7	Outside wall, 211 cm (83 in) from floor
TC 8	Inside wall, 211 cm (83 in) from floor
TC 9	Outside wall, 188 cm (74 in) from floor
TC 10	Inside wall, 188 cm (74 in) from floor
TC 11	Outside wall, 32 cm (52 in) from floor
TC 12	Inside wall, 132 cm (52 in) from floor
TC 35	Center of corridor, 211 cm (83 in) from floor
TC 36	Center of corridor, 188 cm (74 in) from floor
TC 37	Center of corridor, 132 cm (52 in) from floor
TC 38	Center of corridor, 91 cm (36 in) from floor
SM 1	Smoke density, 152 cm (5 ft) from floor
	Instrumentation Located 7 m (23 ft) from Ignition in Test Corridor
TC 13	Outside wall, 211 cm (83 in) from floor
TC 14	Inside wall, 211 cm (83 in) from floor
TC 15	Outside wall, 188 cm (74 in) from floor
TC 16	Inside wall, 188 cm (74 in) from floor
TC 17	Outside wall, 132 cm (52 in) from floor
TC 18	Inside wall, 132 cm (52 in) from floor
TC 39	Center of corridor, 211 cm (83 in) from floor
TC 40	Center of corridor, 188 cm (74 in) from floor
TC 41	Center of corridor, 132 cm (52 in) from floor
TC 42	Center of corridor, 91 cm (36 in) from floor
SM 2	Smoke density, 152 cm (5 ft) from floor
R 2	Heat flux at floor level, center of corridor
	Instrumentation Located in Bedroom 1
TC 19	Outside corridor wall extended, 211 cm (83 in) from floor
TC 21	Outside corridor wall extended, 188 cm (74 in) from floor
TC 23	Outside corridor wall extended, 132 cm (52 in) from floor
TC 20	Interior partition adjacent to bathroom, 211 cm (83 in) from floor
TC 22	Interior partition adjacent to bathroom, 188 cm (74 in) from floor
TC 24	Interior partition adjacent to bathroom, 132 cm (52 in) from floor
TC 25	End wall, 211 cm (83 in) from floor
TC 27	End wall, 188 cm (74 in) from floor
TC 29	End wall, 132 cm (52 in) from floor
TC 26	Exterior wall opposite extended corridor wall, 211 cm (83 in) from floor
TC 28	Exterior wall opposite extended corridor wall, 188 cm (74 in) from floor
TC 30	Exterior wall opposite extended corridor wall, 132 cm (52 in) from floor
R 3	Heat flux at floor level, center of bedroom
SM 3	Smoke density, 152 cm (5 ft) from floor, center of bedroom
O_2-1	Oxygen concentration 152 cm (5 ft) from floor, center of bedroom
CO-1	Carbon monoxide concentration, 152 cm (5 ft) from floor, center of bedroom

*TC Thermocouple
CO Carbon monoxide
O_2 Oxygen
R Heat flux
SM Smoke density

A single thermocouple was located 1.5 m above floor at back exit door and monitored continuously by a potentiometer — this temperature change was noted in the observations, Appendix A.

Table 9. Test Data, Mobile Home Corridor Tests

Test No.	Thermocouple No. 41 — (°C)					Incident Heat Flux, kW/m^2 at Entrance to Bedroom 1			Incident Heat Flux, kW/m^2 in Center of Bedroom 1		
	2 Min	4 Min	6 Min	Maximum	Time	2 Min	4 Min	6 Min	2 Min	4 Min	6 Min
1	44	92	169	169	6:00	5.42	5.65	7.12	1.24	1.13	1.13
2	47	43	27	57	2:20	0.34	0.79	0.23	0.34	0.23	0.11
3	34	54	69	91	6:40	0.79	—*	0.23	0.34	0.11	0.34
4	45	61	145	179	6:20	—	0.34	2.49	0.23	0.34	0.68
5	38	137	252	259	5:20	1.36	4.18	—	0.57	1.24	0.90
6	28	42	50	73	12.40	1.36	0.68	0.57	0.57	0.57	0.57
7	36	49	—	56	5:00	1.81	1.70	—	0.79	0.79	—
8	27	116	286	289	5:40	1.36	4.63	5.31	0.57	1.47	2.15
9	36	57	93	115	8:40	1.02	1.47	1.92	0.68	0.79	0.68

*The hyphens indicate that no data were collected.

Table 10. Metric Equivalents

English	Metric
1/4 inch	6.3 mm
15/32 inch	11.9 mm
5/32 inch	4.0 mm
3/4 inch	19.1 mm
5/16 inch	7.9 mm
1 x 2 inch	25.4 x 50.8 mm
2 x 2 inch	50.8 x 50.8 mm
14 pounds	6.4 kg
20 gage (.0359 in)	0.91 mm
24 gage (.0239 in)	0.61 mm
26 gage (.0179 in)	0.45 mm

APPENDIX A. CHRONOLOGICAL TABULATION OF TEST OBSERVATIONS

Corridor Test 1 — Observations 2/28/75

Test Materials

Walls — 5/32 in (4.0 mm) thick prefinished, printed, grooved, lauan plywood

Ceiling — 1/2" (12.7 mm) thick vinyl latex prefinished fiberboard

0:00 — Ignition
0:33 — Single station smoke detector alarmed
0:40 — Flames 1.5 m above floor
0:47 — Intermittent flame impingement on wall material
0:53 — Intermittent flame impingement on ceiling material
1:00 — Sustained ignition of wall material
1:10 — Lateral propagation at ceiling level
1:12 — Flame spread into corridor
1:20 — Smoke failure of exterior corridor wall
1:40 — Potentiometer temperature reading — 40 °C
2:00 — Propagation involves wall panels 0.3 m down from ceiling
2:40 — Dense accumulation of smoke in bedroom #1
3:00 — Both exterior and interior corridor walls are involved
3:25 — Potentiometer temperature reading — 40 °C
4:20 — Fire propagation beyond bathroom door
4:40 — Flame front reached bedroom #1
4:48 — Flame penetration of exterior wall
4:50 — Potentiometer temperature reading — 80 °C
5:05 — Potentiometer temperature reading — 90 °C
5:25 — Potentiometer temperature reading — 100 °C
5:45 — Involvement of walls 0.6 to 0.9 m down from ceiling — full length of corridor
6:15 — Termination of test

NOTE: Ceiling was not involved.

Corridor Test 2 — Observations 3/18/75

Test Materials

Walls — 5/16 in (7.9 mm) thick printed paper overlayed gypsum board

Ceiling — 1/2 in (12.7 mm) thick vinyl latex prefinished fiberboard

0:00 — Ignition
0:15 — Flames 0.6 m above floor
0:25 — Flames 0.9 m above floor
0:30 — Single station smoke detector alarmed
0:45 — Flames 1.5 m above floor
1:15 — Intermittent flame impingement on ceiling
1:30 — Slight lateral propagation at ceiling
1:40 — Ignition of paper face on gypsum walls
1:45 — Ignition of wood molding at ceiling
2:15 — Wood crib beginning to burn down
2:25 — Flames are no longer impinging on any materials
2:35 — No apparent further contribution from crib
3:30 — Termination of test

NOTE: No indication of ignition of walls or ceiling except for printed paper face on wall panel adjacent to test crib.

Corridor Test 3 — Observations 3/20/75

Test Materials

Walls — 5/16 in (7.9 mm) thick printed paper overlayed gypsum board

Ceiling — 1/2 in (12.7 mm) thick prefinished fiberboard

0:00 — Ignition
0:31 — Single station smoke detector alarmed
0:50 — Flames 1.5 m above floor
1:15 — Intermittent flame impingement on ceiling
1:25 — Flame impingement on wall
1:45 — Ignition of ceiling
1:55 — Lateral propagation at ceiling
2:20 — Flame spread into corridor
3:15 — Burning observed above ceiling
4:20 — Structural failure of ceiling — flame spread above and below ceiling
4:45 — Dense accumulation of smoke throughout
5:00 — Extensive propagation above ceiling
6:45 — Termination of test

NOTE: Crib burned down at approximately 3:00. Gas phase burning continued at ceiling until failure of the ceiling assembly. The ceiling cavity was involved prior to sustained burning of the exposed surface of the ceiling. No indication of contribution from walls except for the paper face on the panel exposed to the test crib.

Corridor Test 4 — Observations 3/26/75

Test Materials

Walls — 5/32 in (4.0 mm) thick prefinished, printed, lauan plywood installed over 5/16 in (7.9 mm) thick gypsum board

Ceiling — 1/2 in (12.7 mm) thick prefinished fiberboard tile

0:00 — Ignition
0:32 — Single station smoke detector alarmed
0:40 — Flames 1.5 m above floor
1:05 — Intermittent flame impingement on ceiling
1:30 — Impingement on ceiling
1:40 — Ignition of molding and wall material
1:45 — Ignition of ceiling
1:48 — Lateral propagation at ceiling
1:50 — Flame spread into corridor
Flame front receded — gas phase burning at ceiling
2:10 — Significant reduction in the fire — crib burned down
2:50 — Sustained burning of wall
3:30 — Flames impinging on ceiling
3:45 — Lateral propagation at ceiling
4:10 — Flame spread into corridor
4:45 — Both exterior and interior corridor walls are involved
5:00 — Failure of ceiling assembly
5:15 — Propagation above ceiling
5:40 — Noticeable increase in radiation at window
5:50 — Flame penetration of exterior wall
5:55 — Potentiometer temperature reading — 80 °C
6:20 — Potentiometer temperature reading — 100 °C
6:25 — Termination of test

NOTE: Both walls of the corridor were involved; flame spread on walls and ceiling throughout corridor. The gypsum partition showed no evidence of failure.

Corridor Test 5 — Observations 4/2/75

Test Materials

Walls — 5/32 in (4.0 mm) thick prefinished, printed lauan plywood

Ceiling — 1/2 in (12.7 mm) thick prefinished fiberboard tile

0:00 — Ignition
0:34 — Single station smoke detector alarmed
0:35 — Flames 1.5 m above floor
1:15 — Ignition of trim at ceiling
1:20 — Impingement of flames at ceiling
1:35 — Ignition of wall material
1:45 — Ignition of ceiling material
1:45 — Lateral propagation at ceiling
1:55 — Flame spread into corridor
2:05 — Gas phase burning at ceiling
2:10 — Wall material is burning 0.3 - 0.6 m down from ceiling
2:35 — Ignition of interior wall surface
4:00 — Flame penetration of exterior wall
4:00 — Failure of ceiling assembly
4:10 — Rapid increase in radiation level at window
4:55 — Potentiometer temperature reading — 64 °C
5:07 — Potentiometer temperature reading — 90 °C
5:27 — Potentiometer temperature reading — 110 °C
6:05 — Potentiometer temperature reading — 136 °C
6:18 — Potentiometer temperature reading — 144 °C
6:30 — Potentiometer temperature reading — 150 °C
Termination of test

NOTE: The plywood paneling on the exterior wall in the dining area ignited and burned approximately 2 feet down from ceiling; failure of dining room windows; failure of interior and exterior corridor partitions; evidence of flame propagation in bedroom #2 and bathroom.

Corridor Test 6 — Observations 4/10/75

Test Materials

Walls — 5/32 in (4.0 mm) thick lauan plywood with intumescent coating

Ceiling — 1/2 in (12.7 mm) thick vinyl latex prefinished fiberboard

0:00 — Ignition
0:10 — Flames 0.3 - 0.6 m above floor
0:30 — Flames 0.6 - 0.9 m above floor
0:32 — Single station smoke detector alarmed
1:00 — Intumescing action on wall panel directly exposed to crib
1:25 — Flame impingement at ceiling
1:30 — Intumescing action spreading to second panel
2:25 — Ignition of trim at ceiling
2:30 — Lateral propagation at ceiling
3:00 — Crib burning down, flame front no longer impinging on ceiling
3:20 — Slight failure of intumescent directly behind crib
4:15 — No apparent further fire growth on panel where intumescent failed
4:35 — Test fire growing in intensity
4:45 — Rapid increase in radiation at observation window in dining area
5:20 — Lateral propagation at ceiling
6:10 — Excessive smoke observed througout mobile home
7:00 — Failure of intumescent 0.6 - 0.9 m down from ceiling on exterior wall partition

7:10 — Flame spread into corridor
8:45 — Failure of wall panel exposed to test crib no sustained burning in the corridor itself
9:35 — Fire intensity reduced — only burning directly behind crib on wall
10:15 — Exterior wall failed adjacent to wood crib
11:45 — Potentiometer temperature reading — 50 °C
12:30 — Termination of test

NOTE: Acrid smoke generation from ignition of resins in the glass fiber insulation; failure of the corridor walls was limited to the panel exposed to the test crib; intumescent action at ceiling level on walls throughout corridor.

Corridor Test 7 — Observations 4/17/75

Test Materials

Walls — 5/32 in (4.0 mm) thick lauan plywood with intumescent coating

Ceiling — Back side of 1/2 in (12.7 mm) fiberboard

0:00 — Ignition
0:30 — Flames 1.5 m above floor
0:33 — Single station smoke detector alarmed
1:00 — Flame impingement on ceiling
1:10 — Intumescing action on panel exposed to crib
1:30 — Gas phase burning at ceiling
1:55 — Ignition of wood trim at ceiling
2:25 — Reduction in fire intensity-crib burned down
2:30 — Intermittent gas phase burning at ceiling
2:35 — Some smoke generation
3:00 — Test fire growing-fire intensity increasing
3:10 — Failure of intumescent on panel exposed to crib, slight burning
3:20 — Ignition of ceiling
4:25 — Lateral propagation at ceiling
5:15 — Flame spread into corridor-major contribution to fire growth from ceiling
5:55 — Both interior and exterior corridor walls are burning at the ceiling level
6:00 — Excessive smoke density, visibility significantly reduced
6:25 — Failure of ceiling assembly
6:40 — Flame propagation above ceiling assembly
7:20 — High level of radiation at observation window
7:35 — Failure of exterior wall behind crib
7:45 — Wall material not extensively involved-primary burning at ceiling
8:00 — Potentiometer temperature reading — 35 °C
8:15 — Extensive burning of ceiling
8:20 — No further contribution from test crib
9:15 — Potentiometer temperature reading — 105 °C
9:35 — Potentiometer temperature reading — 110 °C
10:30 — Termination of test

NOTE: Extensive propagation above ceiling; failure of intumescent coating 0.3 - 0.6 m down from ceiling throughout corridor; failure of interior corridor partition adjacent to bedroom #2; failure of exterior partition all along the ceiling level to the back exit door.

Corridor Test 8 — Observations 4/23/75

Test Materials

Walls — 5/32 in (4.0 mm) thick prefinished lauan plywood

Ceiling — 1/2 in (12.7 mm) thick fiberboard-back side

0:00 — Ignition
0:30 — Flame impingement at ceiling
0:31 — Single station smoke detector alarmed
0:45 — Ignition of wood trim
0:55 — Lateral propagation at ceiling
1:00 — Combination of surface and gas phase burning
1:15 — Fire intensity reduced-no exposure of ceiling
2:05 — Ignition of wall behind the crib
2:10 — Test fire beginning to grow again
2:15 — Flame impingement at ceiling
2:40 — Wall panel exposed to test crib burning to the ceiling
2:50 — Flame spread into corridor
2:50 — Flame spread over entire ceiling in the vicinity of the test crib
3:20 — Flame front has progressed beyond draft curtain and is exposing the exterior wall in dining area
3:50 — Full involvement of ceiling
3:55 — Interior and exterior corridor walls involved
4:15 — Failure of exterior wall behind crib
5:10 — Excessive propagation along walls and ceiling
5:40 — Potentiometer temperature reading-200 °C
6:00 — Termination of test

NOTE: Excessive smoke reduced visibility; radiation intense at observation window; no indication that ceiling material effectively reduced fire spread; extensive burning above ceiling; failure of interior and exterior corridor partitions.

Corridor Test 9 — Observation 5/5/75

Test Materials

Walls — 1/4 in (6.3 mm) prefinished, paper overlayed lauan plywood

Ceiling — 1/2 in (12.7 mm) vinyl latex prefinished fiberboard

0:00 — Ignition
0:34 — Single station smoke detector alarmed
0:55 — Flame impingement at ceiling
1:15 — Ignition of embossed paper face on wall material
1:25 — Lateral propagation at ceiling
1:45 — Paper face blistering off walls, contributing to reduction in visibility
1:55 — Flame spread into corridor-low intensity
2:00 — Intensity of test fire subsiding
2:20 — Flame front no longer impinged on ceiling
2:35 — Intensity of test fire increasing
2:55 — Ignition of wall material
3:10 — Lateral propagation at ceiling
3:40 — Flame spread into corridor on exterior partition
4:00 — Ignition of interior corridor wall
4:30 — Failure of wall at ceiling level
4:35 — Excessive radiation at observation window
5:30 — Potentiometer temperature reading — 68 °C
6:20 — Excessive smoke density-low visibility
8:00 — No significant growth observed
11:00 — Termination of test

NOTE: Paper face blistered and peeled throughout corridor; failure of wall material on interior and exterior corridor partitions down to back exit door.

APPENDIX B. VERTICAL GAS TEMPERATURE PROFILES

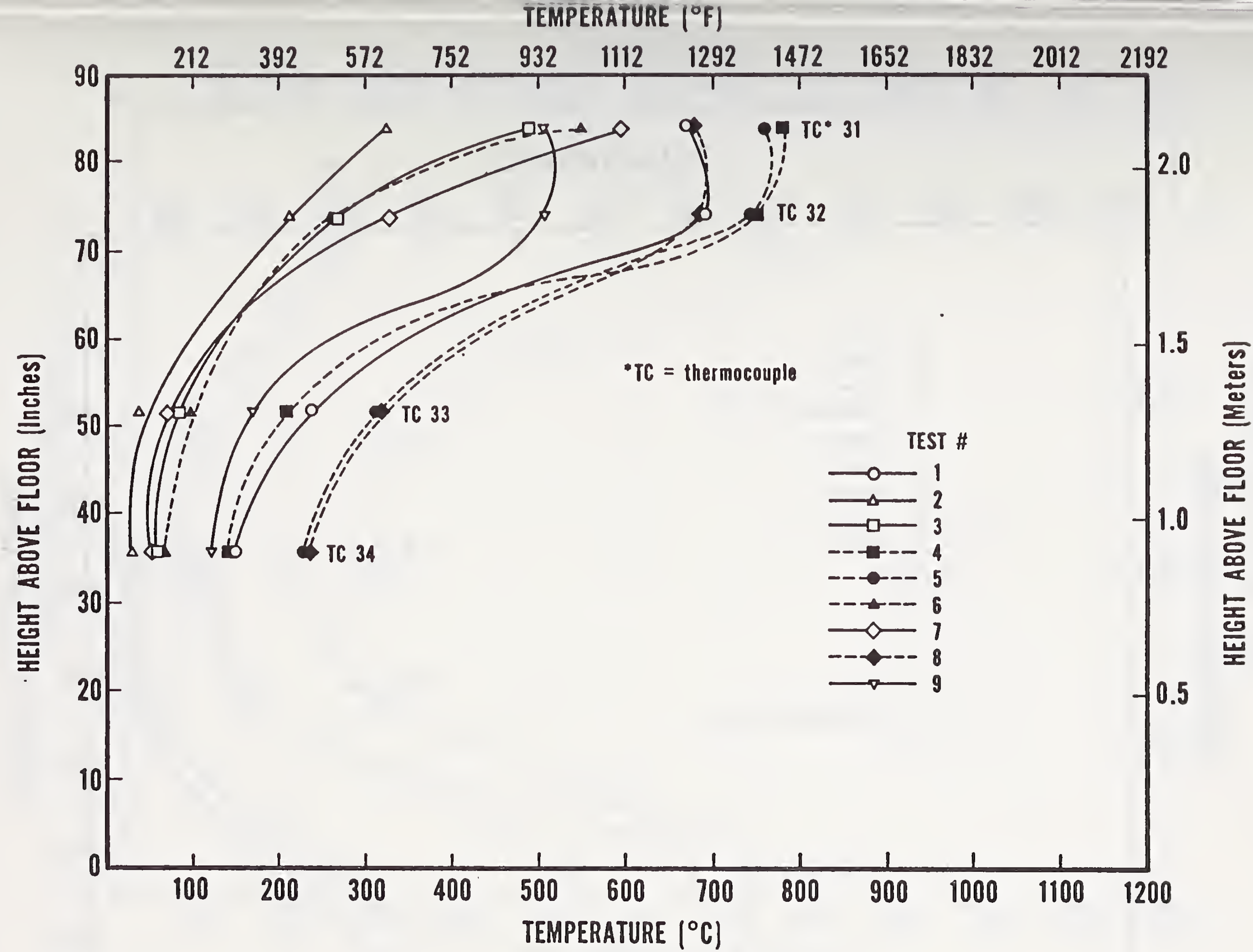


Figure B1. Maximum air temperatures for thermocouples 31, 32, 33, and 34 located in center of corridor 2.3 m from ignition source.

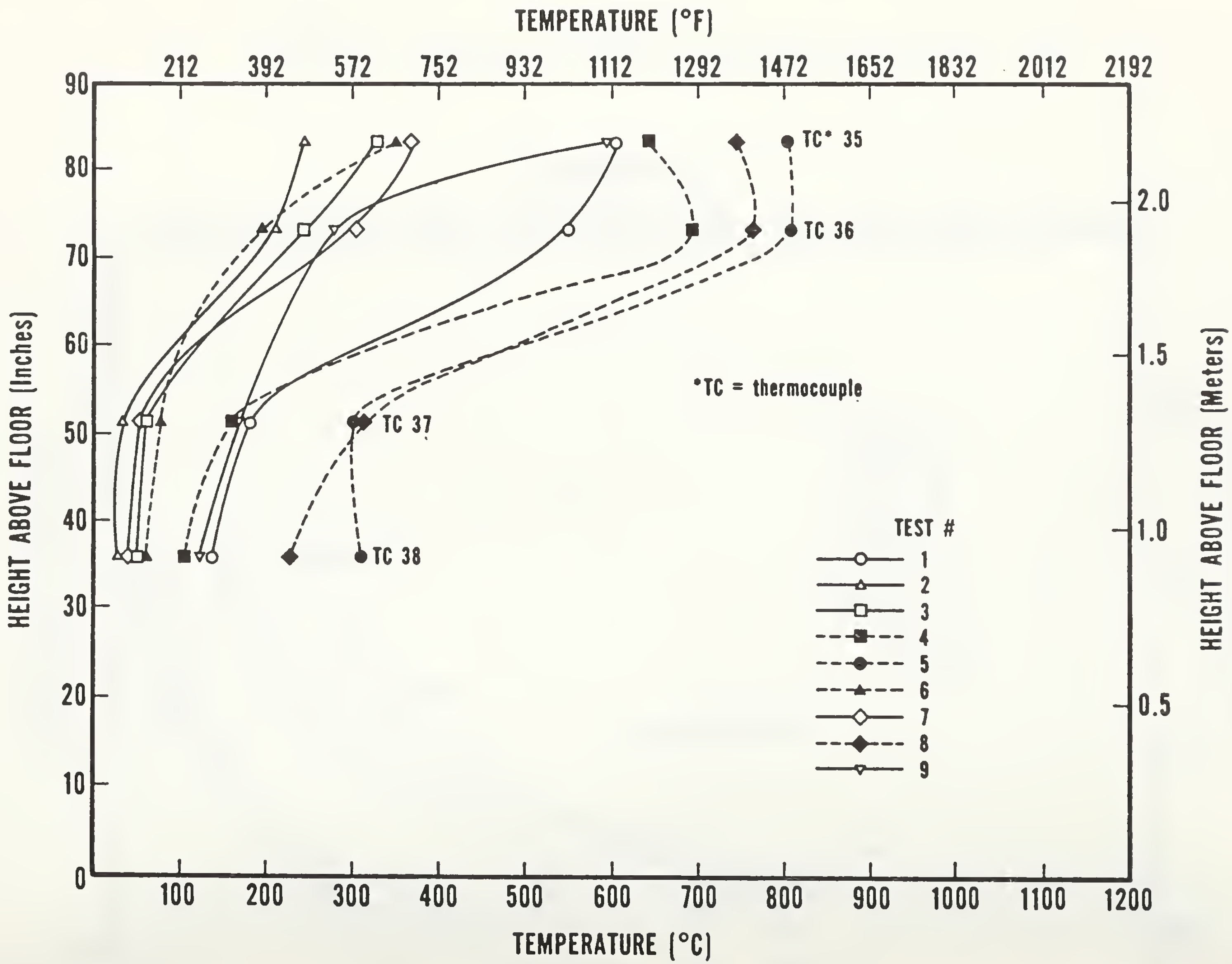


Figure B2. Maximum air temperatures for thermocouples 35, 36, 37 and 38 located in center of corridor 4.1 m from ignition source.

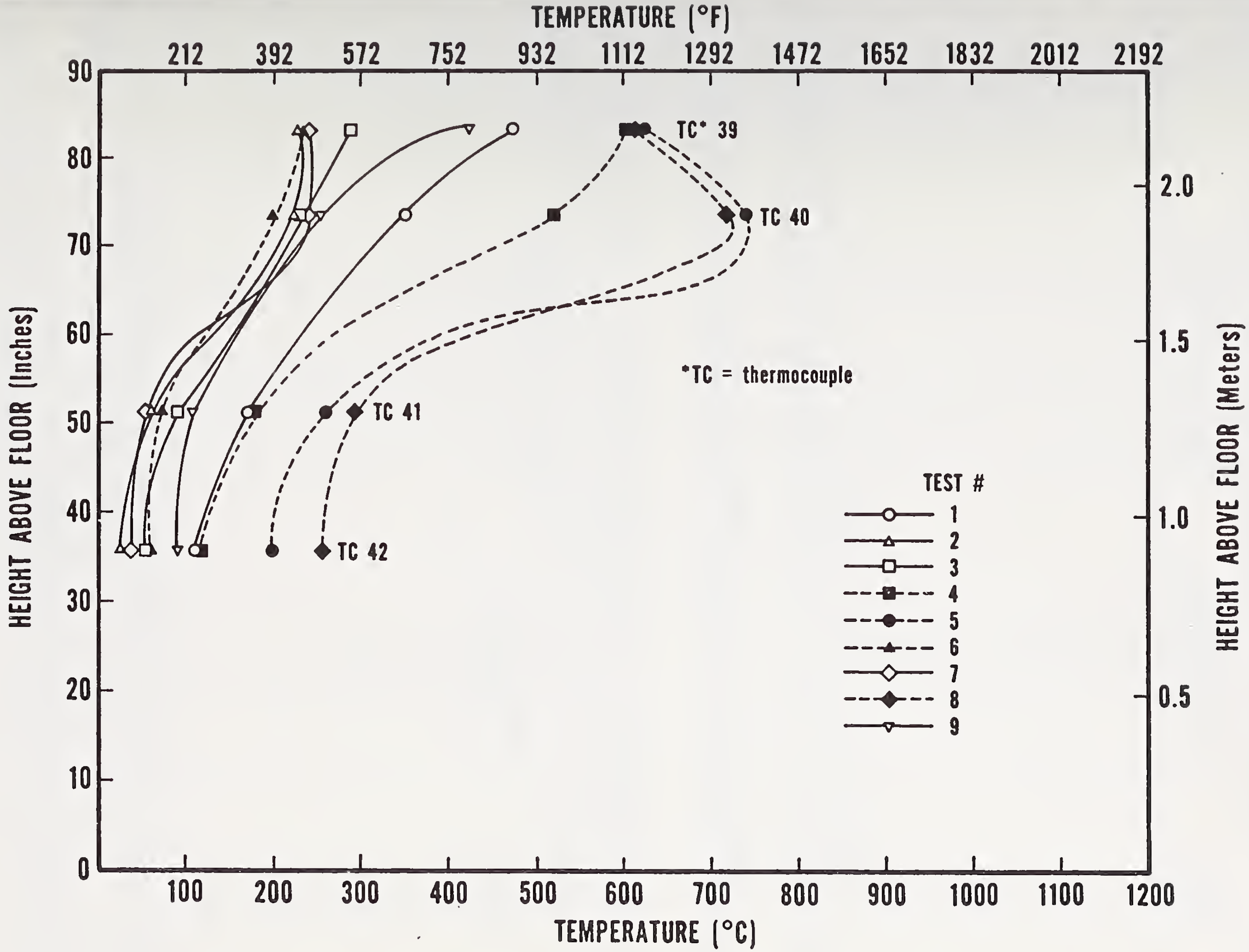


Figure B3. Maximum air temperatures for thermocouples 39, 40, 41 and 42 located in center of corridor 7.0 m from ignition source.

APPENDIX C. THERMOCOUPLE DATA FROM THREE THERMOCOUPLE TREES POSITIONED ALONG THE LONGITUDINAL AXIS OF THE TEST CORRIDOR

Table C1; Test 1. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	386	626	657	694	5:20
TC 36	284	533	342	541	4:20
TC 40	170	208	336	351	4:40
TC 33	68	170	237	237	6:00
TC 37	40	113	183	183	6:00
TC 41	41	92	169	169	6:00

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C2; Test 2. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	199	116	58	206	2:20
TC 36	208	112	57	208	2:00
TC 40	225	74	41	225	2:00
TC 33	33	32	26	35	2:20
TC 37	25	29	25	29	3:40
TC 41	47	43	27	57	2:20

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C3; Test 3. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	193	195	206	261	2:20
TC 36	198	163	177	229	2:20
TC 40	195	134	170	221	2:20
TC 33	40	49	67	79	6:40
TC 37	28	39	50	61	6:40
TC 41	34	54	69	91	6:40

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C4; Test 4. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	222	212	719	750	6:20
TC 36	249	246	687	688	6:20
TC 40	230	208	451	521	6:20
TC 33	42	58	193	208	6:20
TC 37	28	41	141	160	6:20
TC 41	45	61	145	179	6:20

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C5; Test 5. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	311	691	673	728	4:20
TC 36	196	705	746	804	5:00
TC 40	217	415	643	743	5:20
TC 33	54	180	305	311	6:20
TC 37	35	139	284	297	6:20
TC 41	38	137	252	259	5:20

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C6; Test 6. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	138	172	205	259	7:20
TC 36	120	155	175	193	7:20
TC 40	132	138	175	191	7:40
TC 33	30	42	59	86	7:40
TC 37	25	34	44	72	12:40
TC 41	28	42	50	73	12:40

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C7; Test 7. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	317	214		320	2:20
TC 36	297	214		297	2:00
TC 40	239	167		239	2:00
TC 33	49	58		71	5:00
TC 37	33	45		53	5:00
TC 41	36	49		56	5:00

*Data recorded up to 5 minutes.

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C8; Test 8. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	109	545	652	690	5:20
TC 36	111	576	667	763	5:20
TC 40	85	387	621	723	5:40
TC 33	26	158	315	315	6:00
TC 37	24	119	312	312	6:00
TC 41	27	116	286	289	5:40

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

Table C9; Test 9. Thermocouple Data from the 3 Thermocouple Trees Positioned Along the Longitudinal Axis of the Test Corridor

	Temperature (°C) at Elapsed Time (min) 2	4	6	Maximum Temp (°C)	Time (min:s)
TC 32	257	355	465	505	7:00
TC 36	129	164	224	275	8:40
TC 40	219	244	219	252	4:20
TC 33	53	96	157	173	7:20
TC 37	38	64	124	162	8:40
TC 41	36	57	63	115	8:40

TC 32, 36 and 40 measure air temperature 188 cm (74 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

TC 33, 37 and 41 measure air temperature 132 cm (52 in) above the floor at a distance of 2.3, 4.0 and 7.0 m (7 ft 8 in, 13 ft 5 in, 23 ft) respectively from the point of ignition.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET**	1. PUBLICATION OR REPORT NO. NBSIR 76-1021	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE FIRE SPREAD ALONG A MOBILE HOME CORRIDOR	5. Publication Date July 1976
	6. Performing Organization Code
7. AUTHOR(S) Edward K. Budnick	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS **NATIONAL BUREAU OF STANDARDS** **DEPARTMENT OF COMMERCE** **WASHINGTON, D.C. 20234**	10. Project/Task/Work Unit No. 4926389
	11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Division of Energy, Building Technology and Standards Office of Policy Development and Research, U.S. Department of Housing and Urban Development Washington, D.C. 20410	13. Type of Report & Period Covered Interim Report
	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 series of tests was conducted in the corridor area of a typically constructed mobile home. These tests were designed to: (1) evaluate the performance of a variety of combinations of wall and ceiling materials as a result of exposure to a typical ignition in a full-scale mobile home corridor, and (2) determine the relationship between full-scale tests and laboratory flammability tests, particularly the ASTM E-84 tunnel test, a measure of surface flame spread.

The tests were restricted to one set of conditions in which the living room at the end of the corridor was exposed to a fire resulting from ignition of a standardized 6.4-kg (14-lb) wood crib. Nine tests were conducted with seven different combinations of wall and ceiling materials.

Performance of the various combinations of wall and ceiling materials was examined based on the time to reach untenable conditions in the corridor. Measurements utilized in evaluating levels of tenability included gas temperatures, surface temperatures, irradiance, concentrations of oxygen and carbon monoxide, and smoke densities.

Under this set of test conditions, it was found that the extent of fire spread and the time to reach untenable conditions are significantly influenced by the surface flame spread characteristics of the wall and ceiling finish materials in the corridor.

For a mobile home corridor with conventional wall and ceiling linings (ASTM E-84:FSC = 200 max), untenable conditions were reached in the corridor in less than four minutes. With class A (FSC = 25 max) wall and ceiling materials in the corridor, untenable conditions were not reached.

Key Words: Corridor fire test; interior finish material; intumescent coating; life safety; mobile home; smoke detector; surface flame spread.

18. AVAILABILITY [x] Unlimited	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[ ] For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	56
[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13	20. SECURITY CLASS (THIS PAGE)	22. Price
[x] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED	$4.50

USCOMM-DC 29042-P74