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Forest Service

EXPERIMENTAL DWELLING-ROOM FIRES

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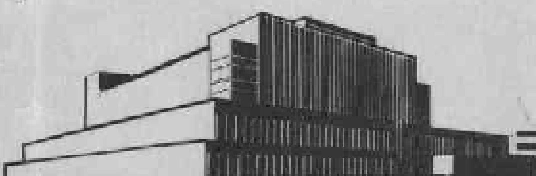

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

EXPERIMENTAL DWELLING-ROOM FIRES[1]

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Summary

This report descirbes the behavior, progress, and effect of fire in a simulated dwelling room. Temperatures, air pressures, and the concentration of gases in a burning room were measured and recorded.

The critical point in the test fires was reached in 4 to 7 minutes. It was rapidly followed by increased temperatures and burning action that would be unbearable to human beings.

The wall and ceiling materials, whether combustible or noncombustible, had little effect on the time or temperature of the critical point. The nature of the fuel (furniture) and the direction of the flames, however, did affect the rate at which the fires became critical.

The time-temperature curves for these experimental fires were unlike the curve adopted by the American Society for Testing Materials for testing fire resistance.

Introduction

Uncontrolled fire in a building is so spectacular and extinction is so urgent that there rarely is opportunity or inclination for scientific observations on the fire's behavior. Such information, nevertheless, is needed as a basis for sound building codes and is desirable as a background to devising rational procedures for testing the fire properties of building materials and structures. For this reason, the Forest Products Laboratory conducted six "burn-out" tests in which fire was kindled in a simulated dwelling room and allowed to proceed naturally until the room was a mass of flame. Various temperature measurements were taken, samples of gas were collected, and observations were made on the progress and behavior of the fire.

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[1] These burn-out experiments were performed by the late Arthur Van Kleeck, Chemist, and T. J. Martin, Technologist, in cooperation with the Technical Committee of the Insulation Board Institute and the Housing and Home Finance Agency. Report originally published June 1953.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Purpose

These burn-out tests were conducted: (1) to obtain information on the rate at which temperature rises when a dwelling room is on fire, (2) to measure the magnitude of the air pressures developed in a burning room, (3) to learn the composition of gases in a burning room, (4) to observe how the fire may be influenced by furnishings, wall materials, and amount of draft.

Test Method

Test Structure

An 8- by 12-foot test room with an 8-foot ceiling height was built inside the Laboratory's concrete fire-test house (fig. 1). The room had two wood-frame windows and one wood door. The door was paneled in exterior-grade plywood. The roof was of 1/4-inch cement board covering the ceiling joists. The floor was 6-inch softwood flooring laid on a softwood subfloor.

The north and east walls were hollow cement tile with no interior paneling. The south and west walls were conventional wood-frame structures of 2- by 4-inch softwood lumber studding finished on the outside with Portland cement stucco applied to metal lath. The interior surfaces of these two walls, as well as that of the ceiling, were covered by nailing the following materials to the studding and joists:

Test No.	Materials
1	1/4-inch interior-grade Douglas-fir plywood
2	1/2-inch fiber insulation board
3	1/2-inch sanded gypsum plaster applied to 3/8-inch fiber insulation board lath
4	1/2-inch unfinished fiber insulation board
5	1/2-inch factory finished fiber insulation board
6	3/8-inch gypsum wallboard

The floor was finished with two coats of gray floor enamel containing zinc sulfide, barium sulfate, and varnish. For burn-out tests 1, 2, and 3, the walls were finished with one coat of linseed-oil primer and one coat of flat wall paint. For test 4, no finish was applied. The fiber insulation board used in test 5 had a standard factory finish. One coat of a proprietary resin-emulsion paint was applied to the gypsum board used in test 6. These finish coatings were formulated and applied in accordance with conventional practice.

Furnishings

For five of the burn-out tests, mock-up furniture was made of sweetgum lumber to simulate chairs, tables, a bookcase, and a hall tree (fig. 2). The chairs were upholstered with burlap padded with wood shavings. The mock-up furniture was finished with a mahogany water stain, a coat of lacquer sealer, and two coats of pyroxylin lacquer. The dry weight of the finish was 4.75 grams for each square foot. The furniture was conditioned to a moisture content of approximately 6 percent before use in the test, and arranged as indicated in figure 3.

Included among the furnishings were burlap floor coverings to simulate rugs, cotton cloth drapes at the windows, a cotton table cloth, magazines in the bookcase and on the table top and table shelf, and pieces of burlap hanging from the hall tree to simulate clothing. For test 4, wood cribs of 1- by 2-inch sweetgum lumber were used in place of furniture. These cribs were the approximate weight of the table, chairs, and other furniture and were placed at the location and heights of the furniture used in the other tests.

The total weight of the combustible materials in the room was 375 pounds, or about 3.9 pounds for each square foot of floor space. This is within the normal limits for an occupied dwelling room in the United States.

Draft

Six inlet draft-ports, 8 by 16 inches, were located along the bottoms of the two cement-block walls, and seven outlet ports were located along the tops. The ports were opened to full draft in the first four tests, but were partly closed for the fifth and sixth tests to diminish the supply of oxygen and provide more favorable conditions for production of carbon monoxide.

In tests 4, 5, and 6, the gases from the upper parts of the room were led into two chimneys extending above the roof.

Ignition

After considerable experimenting with waste-paper baskets and other common causes of fires in dwellings to find a dependable method for starting the fires that could be standardized, a crib was chosen as the ignition source. It consisted of 36 pieces of 1/2- by 1/2- by 12-inch sweetgum of 12 percent moisture content arranged in six tiers above a sand bath. The crib weighed 1,030 grams.

This igniting crib was set next to a chair near a table and a large piece of filter paper wet with 25 cubic centimeters of gasoline was laid on the sand and lighted by match (figs. 3 and 4). Ignited in this way, these fires had an accelerated start compared to accidental fires that smolder or burn slowly in the early stages.

The progress of the fire was recorded by observers with stop watches, by black and white and colored photographs and moving pictures, and by thermocouples in various parts of the room. The fires were extinguished by water sprinklers before serious damage was done to the wall and ceiling framing members.

Gas Sampling

At various stages of the fires in tests 4, 5, and 6, specimens of the flue gas were collected by means of vacuum through water-cooled condensers into glass flasks provided with stop-cocks. These gas specimens were later chemically analyzed for carbon dioxide, oxygen, and carbon monoxide. Some samples were analyzed for hydrogen, and saturated and unsaturated hydrocarbons.

Air Pressure

In fire tests 4, 5, and 6, the air pressure in the burning room was measured through a 3/4-inch pipe installed through the roof of the room with its open end 12 inches below the center of the ceiling. The pipe led outside to a vertical manometer for registering high pressures and to an inclined manometer for registering low pressures. Pressures were recorded frequently during each fire, and a special effort was made to record the highest values registered on the gages.

Temperature Measurements

Temperatures were measured by means of thermocouples at intervals of 1 minute or shorter. Wall temperatures were measured by four thermocouples located flush with the geometric centers of the four walls. Flue temperatures were measured by two thermocouples near the ceiling and one inside each of the two chimneys. As the individual thermocouples comprising these groups of four showed similar rise and fall of temperature, their readings were averaged to obtain values for the wall temperatures and for the flue temperatures at various times in the six tests.

Information as to transfer of heat through the wall panels was obtained in tests 5 and 6 by means of thermocouples on the unexposed surfaces.

Results of Tests

Temperature Effects

The temperature of the flue gases, as indicated by thermocouples near the ceiling and in the flues, are shown in figure 5. The temperatures of the walls, as indicated by thermocouples flush with the surface at the center of each wall, are shown in figure 6. In these experiments there was a period of only 5 to 10 minutes in which a person could have endured the temperature and taken measures to extinguish the blaze. Beyond these times, the temperatures rose rapidly to the kindling point of wood and cotton fabric.

In regard to the time to reach any stage of burning, it is important to realize that these experimental fires received a fairly rapid start and that accidental fires might take more or less time, depending on how they become ignited, to reach a similar stage.

The temperatures recorded on the unexposed surfaces of the wall panels during the fires in tests 5 and 6 are plotted in figure 7. For the first 7 minutes these two fires behaved similarly and almost equal temperatures were reached on the backs of the 3/8-inch gypsum board and the 1/2-inch fiber insulation-board wall panels.

Fire Behavior

Table 1 lists the progress of the fires and the average temperatures on the exposed wall surfaces at various time intervals from the instant of ignition until the water sprinklers were turned on. An analysis of these data reveals four stages in the progression of these experimental fires.

1. The burning crib stage.--The room temperatures at the start of the fire were from 69° to 82° F. The cribs took fire equally, and burned nearly alike in appearance and temperature effects, sending flames to the height of the table tops in 18 to 24 seconds. The crib fire raised the wall temperature an average of 14 degrees by the time the first chair frame had taken fire. Variations in the crib fire had little effect on the ultimate fire behavior, as indicated by the similarity of the curves in A and B of figure 8.

2. The burning crib-chair stage.--The upholstery of the chair near the crib was always the first to catch on fire, but the time required was to some extent a matter of chance, depending on the way the flames from the crib lapped around the chair (fig. 4). Less than 1 minute after the upholstery started to burn, the frame of the chair caught on fire.

As the flames mounted above the crib and chair, the edge of the table cloth would show signs of charring and some magazines on the table shelf or top would take fire. This appeared to be largely a matter of chance and not important in the progress of the fire.

Although the cribs seemed to burn uniformly in all tests, the chairs nearest the cribs burned in different ways. In tests 1, 2, and 3, the upright backs were first to catch and were the principal location of the fires until the tables ignited. In tests 5 and 6, the under frames of the seats were the principal location of the fires during the crib-chair stage. This difference is probably responsible for the early separation of the curves for tests 5 and 6 from those for tests 1, 2, and 3 in figures 5 and 6, and the greater amount of heat given off by the fires in tests 5 and 6 between the second and fourth minutes. In tests 1 and 3, the chairs burned evenly but slowly, without liberating as much heat as in tests 2 and 5, until the tables were afire. Variations in the chair fires had an important effect on the fire behavior as indicated by the relative positions of curves B and C in figure 8. From curve C, figure 8, it would appear that all fires except test fire 6, which was partly smothered after the third minute, behaved very much alike after the tables started to burn.

3. The chair-table stage.--The cribs became unstable and fell to the floor between the third and fourth minute, and within 12 seconds thereafter the rugs were on fire. These rug fires spread more or less circularly and in each case ignited one table leg. This occurred in the several tests in 3.80 to 6.70

minutes, depending on the fire pattern on the floor. The table-leg fires, however, were not responsible for setting the tables ablaze. They were ignited by the flames from the burning chairs, which sometimes ignited the table shelf, sometimes the table top. The tables burned uniformly in the several fires with only minor variations in the early stages (fig. 8, C and D).

From 1.00 to 1.80 minutes after the tables ignited, they were burning briskly and starting to evolve heat very rapidly (fig. 6). This point was reached in 4.30 to 7.05 minutes in all tests except test 4 with the flue temperatures averaging 259° F. and the wall temperatures 149° F. This was a critical point in all fires. It was followed by very rapid acceleration in the burning action and by conditions that would be unbearable by human beings in the room.

Although the cribs in the fourth test fire approximated the table, chairs, and other pieces of furniture in weight and location, they were not good simulations of furniture in their fire behavior. They ignited with more difficulty and burned more slowly. The fire took 10 to 11 minutes to reach the point of rapid acceleration. This sluggishness is revealed in figures 5 and 6.

Soon after the critical point of rapid acceleration was reached, the wall temperatures rose sharply at maximum rates that averaged more than 300 degrees a minute. The insulation-board walls and plastered walls showed differences in this respect. The maximum rate of temperature rise averaged 370 degrees a minute for the fiber insulation-board and plywood walls but only 180 degrees a minute for the plastered walls. It is probable that the evaporation of moisture from the plastered walls (only in these two cases was moist condensate observed on the windows) held down the rate of temperature rise.

Although the flames and hot gases from the chairs and table burning in the center of the room went up towards the ceiling, the ceiling caught on fire at approximately the same time as the walls and wall furniture.

4. The burning-room stage.--About 2 minutes after the wall temperature showed signs of rapid upward acceleration, the "flash-over" occurred, and the curtains, combustible walls, window frames, door sill, and distant chairs burst into flame. The white curtains and burlap "clothing" hanging on the hall tree were darkened by the intense radiation and then flashed on fire generally a little before the woodwork. The flash-over appeared to be brought about by the radiant heat without direct contact by flame, but it was undoubtedly associated with an accumulation of combustible gases within the room.

The flash-over to walls and furniture occurred 6.50 to 12.80 minutes after ignition and 2.80 to 4.00 minutes after the tables caught on fire. At the flash-over, the average temperature of the walls was 498° F.

After the tables ignited, the fires in tests 3 and 4, which had gotten off to a slow start in the crib and crib-chair stages, followed the normal trend shown by test fires 1, 2, and 5 up to and beyond the flash-over. The fire in test 6, however, behaved unlike the others after the flash-over. In this case, the table was enveloped in flames after 5.70 minutes, but had nearly stopped burning after 8.45 minutes. Likewise, the chairs burned slowly after 7.00 minutes and occasionally, except on the north side, the flames died out. This slow action was the result of insufficient ventilation. After 10.60 minutes, the lower draft ports were opened wide and soon the entire room was ablaze.

A "black-out," when the room seemed to fill with smoke, took place shortly after the flash-over. The black-out was not a sharp phenomenon and its time of occurrence was not very definite. In test 6 the black-out developed slowly over a period of several minutes.

Pressures

After the flash-over and during the black-out period, flame and smoke puffed out from the draft ports and broken windows in great volume, giving the impression of high pressures inside the room. Nevertheless, under the conditions of these tests with openings into the room, only extremely small increases in pressures were observed. The maximum was 0.03 inch of water above atmospheric pressure.

Results of Damping

The air draft through the burning rooms was effectively restricted only in tests 5 and 6. The effect of damping was different in the two fires. In test 5, the limited amount of oxygen was largely consumed in the fire and a high concentration of carbon monoxide produced, but the rate of progress of the fire was undiminished. In test 6 there was much less consumption of oxygen and production of carbon monoxide, but the progress of the fire was greatly retarded. There is some evidence that this difference was the result of differences in the direction of the draft--up through the burning furniture in test 5, but up one wall corner in test 6.

Gas Analysis

Results of the analysis of gas specimens drawn from the chimney at various stages of test fires 4, 5, and 6 are given in tables 2, 3, and 4 and figure 9. The three fires varied greatly in gaseous composition. Consumption of the oxygen of the air was much more nearly complete in test 5 than in the other two fires. The oxygen content fell to about 12 percent in tests 4 and 6, but went down to a minimum of 0.8 percent in test 5.

Carbon monoxide reached a concentration of 1 percent about 11 minutes after the fire was started in test 6 and 15 minutes in test 4. It reached a concentration of 1 percent in test 5 about 6 minutes after the fires started and a maximum of 13.8 percent between the sixth and eleventh minute of burning. In an actual dwelling fire, the flue gases might ascend to occupied rooms upstairs where a concentration of 1 percent of carbon monoxide[3] would be seriously toxic to humans, even during the short period before the heat and smoke would become unendurable.

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[3] International Critical Tables, Vol. II, 1927.

Resume of Results

Since more than one condition was varied for each fire, and only single experiments were made, the conclusions that can be drawn are limited. The following summary of results, however, appears justified by these tests:

1. The nature of the fuel had an important effect on the rate at which the dwelling-room fires became critical. The fire in test 2, for example, became critical in 4.30 minutes, whereas the fire in test 4 took 10.50 minutes, largely because of the differences in the combustion of the wood cribs and the simulated furniture (fig. 6).

2. Small differences in the proximity of pieces of fuel or the chance direction of flames towards or away from combustible material, played an important part in the time required for the fires to become critical. The fire in test 5 became critical in 5.50 minutes, whereas the fire in test 3 took 7.05 minutes, largely because of chance differences in the ignition and burning of the first chair (fig. 6).

3. Within the burning rooms, with walls and ceilings of either combustible or noncombustible wallboard and with openings of a size frequently present in such a room, the increase in air pressure developed was very slight and never approached explosive magnitude. At no time during the progress of the fires, even immediately preceding, during, or after the flash-over, were excessive air pressures developed.

4. In these tests, regardless of type of board used on the interior walls and ceilings, the rate of temperature rise within the room during the early stages of the fires was slower than that of the standard time-temperature curve of American Society for Testing Materials E119-47. During the flash-over stage, however, the rate of temperature rise was faster than that of the standard curve, except in the case of a fire retarded by damped ventilation (fig. 5).

5. Radiation from fire in the center of the room raised the temperature of combustible materials of and near the wall, including fiber insulation board, plywood, woodwork of doors and windows, drapes, and clothing, to the ignition point.

6. The nature of the walls, whether plaster, fiber insulation board, or plywood, had little or no effect on the time or temperature of the critical point and only small effect on the flash-over. Regardless of the type of wall material or the rate of temperature rise in the early stages, fires of conflagration proportions eventually developed. The flash-over occurred in all cases at a wall temperature too high for human life.

7. The maximum length of time after initial ignition that a person could reasonably have stayed in these burning rooms ranged from about 4.30 minutes to 10.50 minutes (average 6.29 minutes). By this time, the burning contents of the room had advanced the fires to a stage hazardous to life. After 6.5 to 12.8 minutes (8.09 minutes average), the whole room was enveloped in flame, and escape would have been unlikely or impossible.

8. Carbon monoxide was produced in toxic concentrations in these test fires, both with plaster board and fiber insulation board as the wall and ceiling materials, although the concentration of this gas varied considerably depending on the supply of air to the fire and its path through the room. The intense heat would have made the burning room unbearable by a human occupant before the carbon monoxide. An upstairs room, however, into which fumes from the fire might have been rising, would probably have been made unbearable first by smoke and toxic gases.

9. It can be concluded from these test fires that the customary furnishings of most dwelling rooms provide enough fuel to create a serious fire regardless of whether the walls and ceilings are combustible or noncombustible. Once a fire is started, it spreads not only by direct contact of the flames and by movement of hot air and combustible gases through channels not provided with fire stops, but also by elevating the surface temperature of combustible materials to their ignition point by direct radiation.

Table 1.--Fire progress and exposed wall temperatures in burn-out tests

Fire progress	Period of burning since ignition						Average wall temperature					
	BO-1	BO-2	BO-3	BO-4	BO-5	BO-6	BO-1	BO-2	BO-3	BO-4	BO-5	BO-6
	Min.	Min.	Min.	Min.	Min.	Min.	°F.	°F.	°F.	°F.	°F.	°F.
Fire is ignited	0	0	0	0	0	0	71	77	72	82	70	69
Crib flames even with table top	.35	.35	.40	......	.30	.30	71	77	80	......	71	70
Chair upholstery afire	.82	2.00	1.50	......	1.50	.60	73	88	85	......	86	72
First chair frame afire	1.70	2.15	1.87	1.30	1.60	1.30	78	90	87	90	90	85
Table cloth charring	2.10	1.30	1.32	......	2.00	1.25	79	89	84	......	105	84
Magazines on table afire	2.55	1.70	......	......	5.00	5.00	80	85	......	......	189	172
Starting crib falls to floor	3.20	3.35	3.50	......	3.50	3.30	81	100	88	......	180	143
Rug on fire from crib coals	3.40	3.45	3.60	3.00	3.50	3.35	82	110	92	120	195	143
Table shelf afire	3.60	2.50	5.84	......	5.75	4.50	83	92	197	......	200	168
Dense smoke in room	5.50	......	7.00	7.00	3.00	2.90	116	......	126	136	170	116
Table leg on fire	4.30	4.50	6.70	......	4.15	4.00	88	155	250	......	197	160
Table top on fire	4.80	3.80	6.50	9.50	4.30	4.00	96	118	117	147	196	160
Table top burning briskly (critical point)	5.30	4.30	7.05	10.50	5.50	5.00	110	140	128	170	197	172
Flames reach ceiling above table top	6.95	6.25	9.08	12.00	6.70	7.00	425	435	308	270	430	385
Crutains begin to char	7.00	6.05	8.07	......	6.80	6.00	435	345	200	......	470	230
Flash-over occurs	7.30	6.50	9.30	12.80	7.05	7.60	535	540	365	575	570	410
Ceiling is on fire	7.30	6.50	......	12.75	7.05	......	535	540	......	555	570	......
Window glass cracks	7.62	6.00	8.40	......	7.00	6.11	615	340	238	......	555	247
Smoke puffs from ports	7.90	6.85	10.50	12.90	7.50	11.90	705	695	715	620	665	520
Room blacks out	8.30	6.70	10.00	13.00	7.50	11.30	780	620	585	660	665	430
Average time of maximum temperature occurrence on walls	9.20	8.10	15.05	14.11	9.44	13.85	......	......	......	......	......	......
Average maximum temperature on on walls	......	......	......	......	......	......	800	940	1,110	1,070	864	615
Water sprinklers opened	9.30	9.10	15.27	14.30	10.15	13.85	770	820	1,055	1,009	830	615

Table 2.--Composition of gas samples taken during burn-out test 4

Sample No.	Time samples were taken	Constituents of gas samples					
		Carbon dioxide	Oxygen	Carbon monoxide	Unsaturated hydrocarbons	Saturated hydrocarbons (calculated as methane)	Hydrogen
	Min.	Percent	Percent	Percent	Percent	Percent	Percent
1	2.0	0.6	19.8	0	0.1	0.6	0
2	4.1	.8	20.1	0	.1	.6	.2
3	7.5	1.0	20.1	.2	0	.8	.4
4	11.1	1.2	19.3	.3	.2	.6	.6
5	13.5	3.5	17.4	.4	0	.8	.3
6	14.0	3.9	16.8	.7	.1	0	1.0
7	14.3	8.0	12.5	.9	.5	.6	1.0
8	15.0	4.7	15.6	1.4	0	.3	.8
9	16.25	6.1	14.0	.4	.1	.3	.2
10	....	....	....	....	....	....	....
11	....	....	....	....	....	....	....
12	....	....	....	....	....	....	....

Table 3.--Composition of gas samples taken during burn-out test 5

Sample No.	Time samples were taken	Constituents of gas samples					
		Carbon dioxide	Oxygen	Carbon monoxide	Unsaturated hydrocarbons	Saturated hydrocarbons (calculated as methane)	Hydrogen
	Min.	Percent	Percent	Percent	Percent	Percent	Percent
1	0.1	0	20.8	0	....	....	....
2	3.0	1.5	20.0	0	....	....	....
3	6.0	2.6	17.8	0	....	....	....
4	6.8	13.6	3.3	2.6	....	....	....
5	7.4	18.4	.8	5.8	....	....	....
6	7.9	17.2	2.1	4.5	....	....	....
7	8.6	16.9	.9	5.7	1.0	1.3	6.6
8	9.2	18.1	1.0	10.0	....	....	....
9	9.7	10.4	2.3	13.8	1.6	1.2	6.0
10	10.1	15.2	1.7	12.8	1.8	1.5	5.6
11	10.5	11.7	6.9	3.4	....	....	....
12	11.2	2.4	17.8	.7	....	....	....

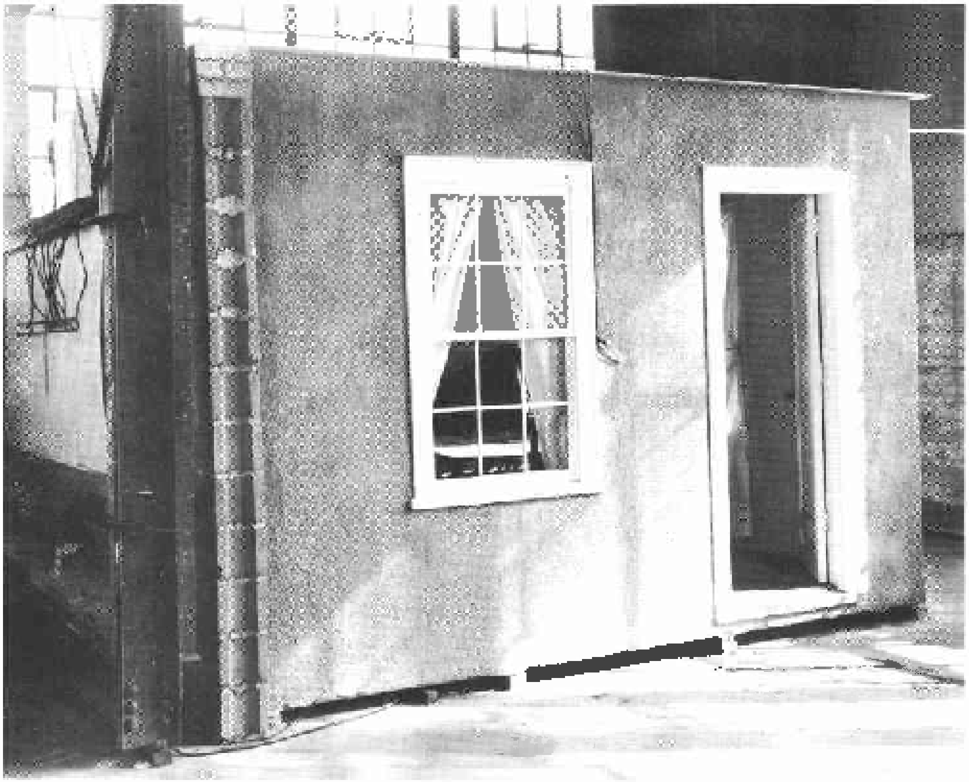

Figure 1. --Exterior of burn-out room.

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Table 4.--Composition of gas samples taken during burn-out test 6

Sample No.	Time samples were taken	Constituents of gas samples					
		Carbon dioxide	Oxygen	Carbon monoxide	Unsaturated hydrocarbons	Saturated hydrocarbons (calculated as methane)	Hydrogen
	Min.	Percent	Percent	Percent	Percent	Percent	Percent
1	3.0	2.5	17.9	0	....	....	....
2	6.0	4.4	16.0	0	....	....	....
3	6.2	8.1	12.1	.2	....	....	....
4	6.6	6.0	14.8	.3	....	....	....
5	7.0	6.6	13.0	.9	....	....	....
6	7.4	6.8	13.0	.6	....	....	....
7	8.0	8.2	11.8	.6	....	....	....
8	8.8	8.0	12.2	.5	....	....	....
9	9.8	6.9	13.1	.4	....	....	....
10	11.5	7.2	12.4	1.7	0	0.3	0.7
11	13.5	15.7	12.0	4.9	.4	.3	2.4
12	14.5	4.2	15.8	1.0	....	....	....

Figure 2. --Mock-up furniture used in burn-out tests.

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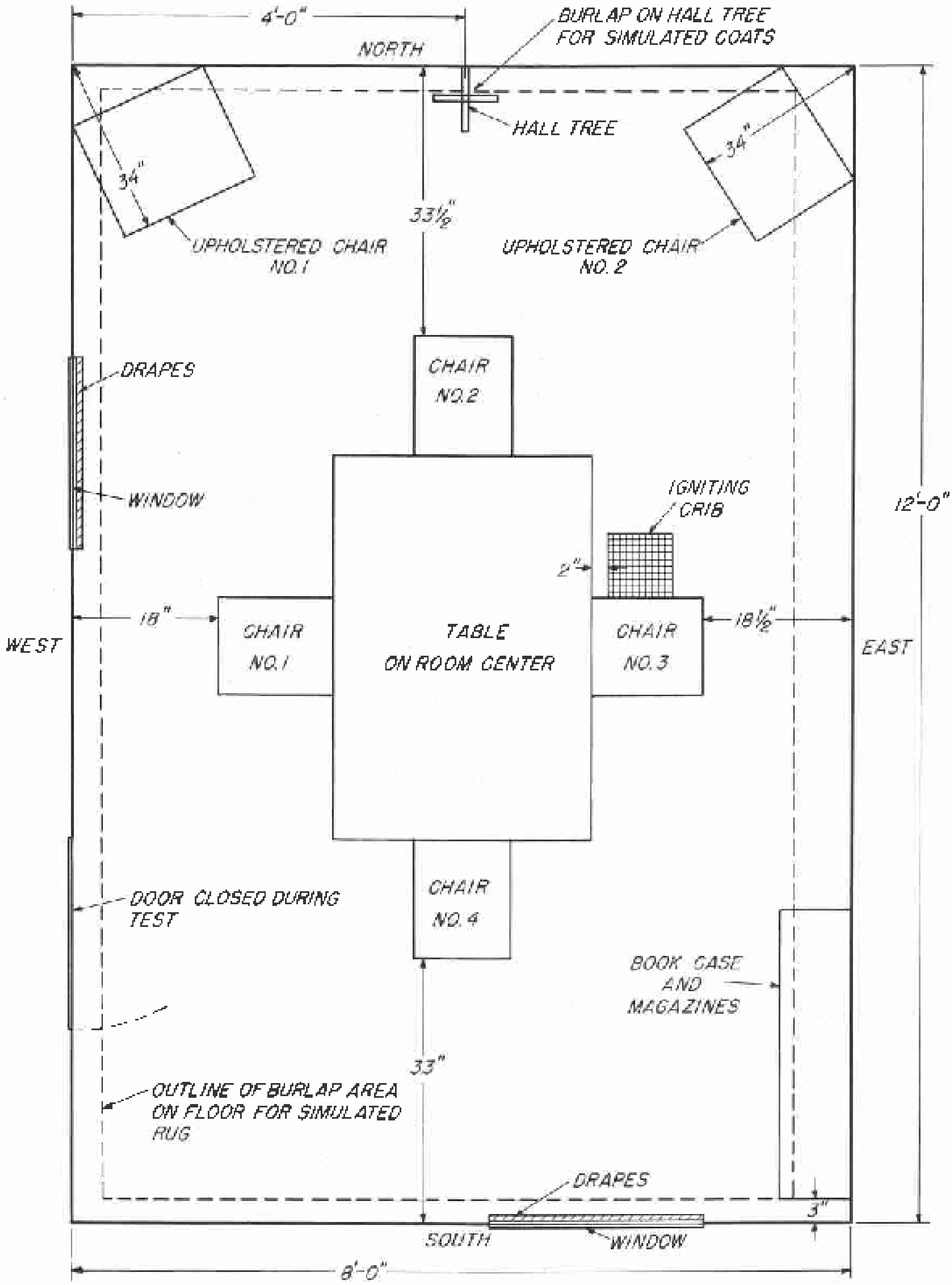

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Figure 3. --Furniture arrangement in burn-out room.

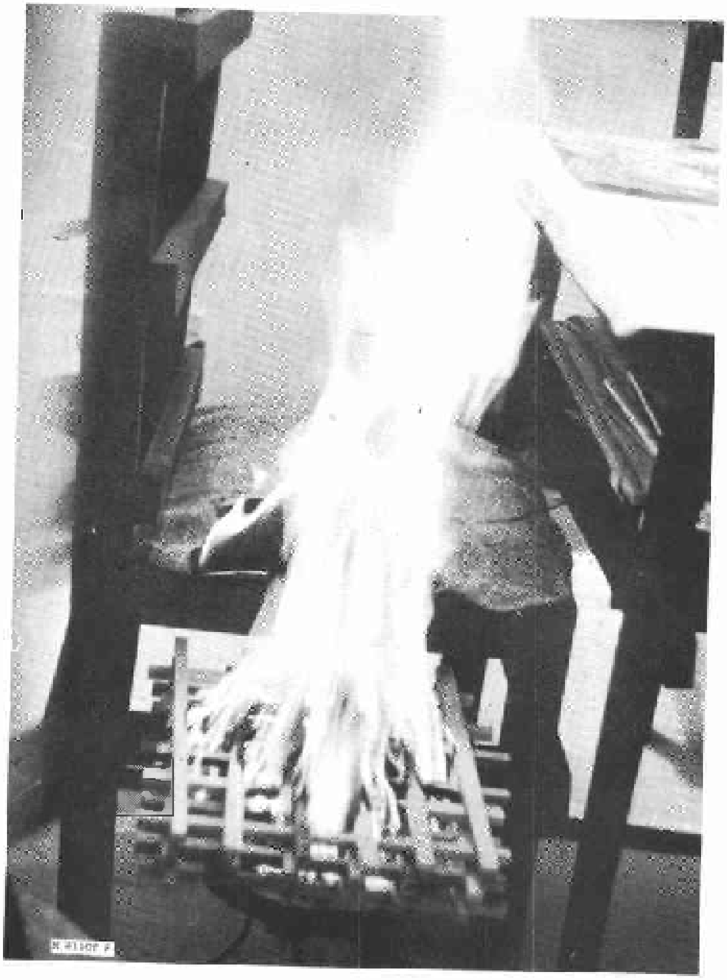

Figure 4. --Flame from igniting crib sets chair upholstery on fire.

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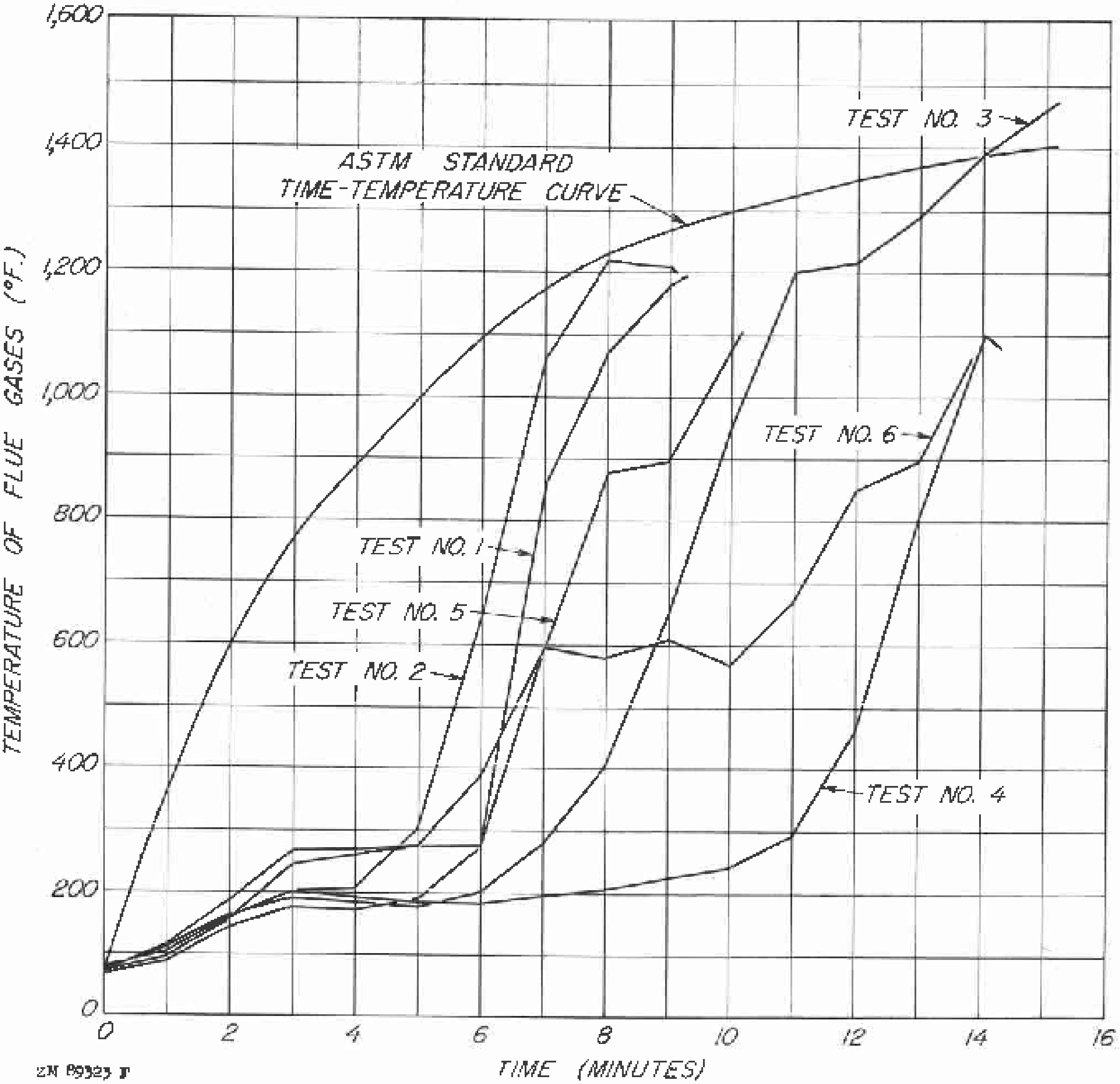

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Figure 5. --Flue temperatures (averages of four thermocouples) in burn-out tests.

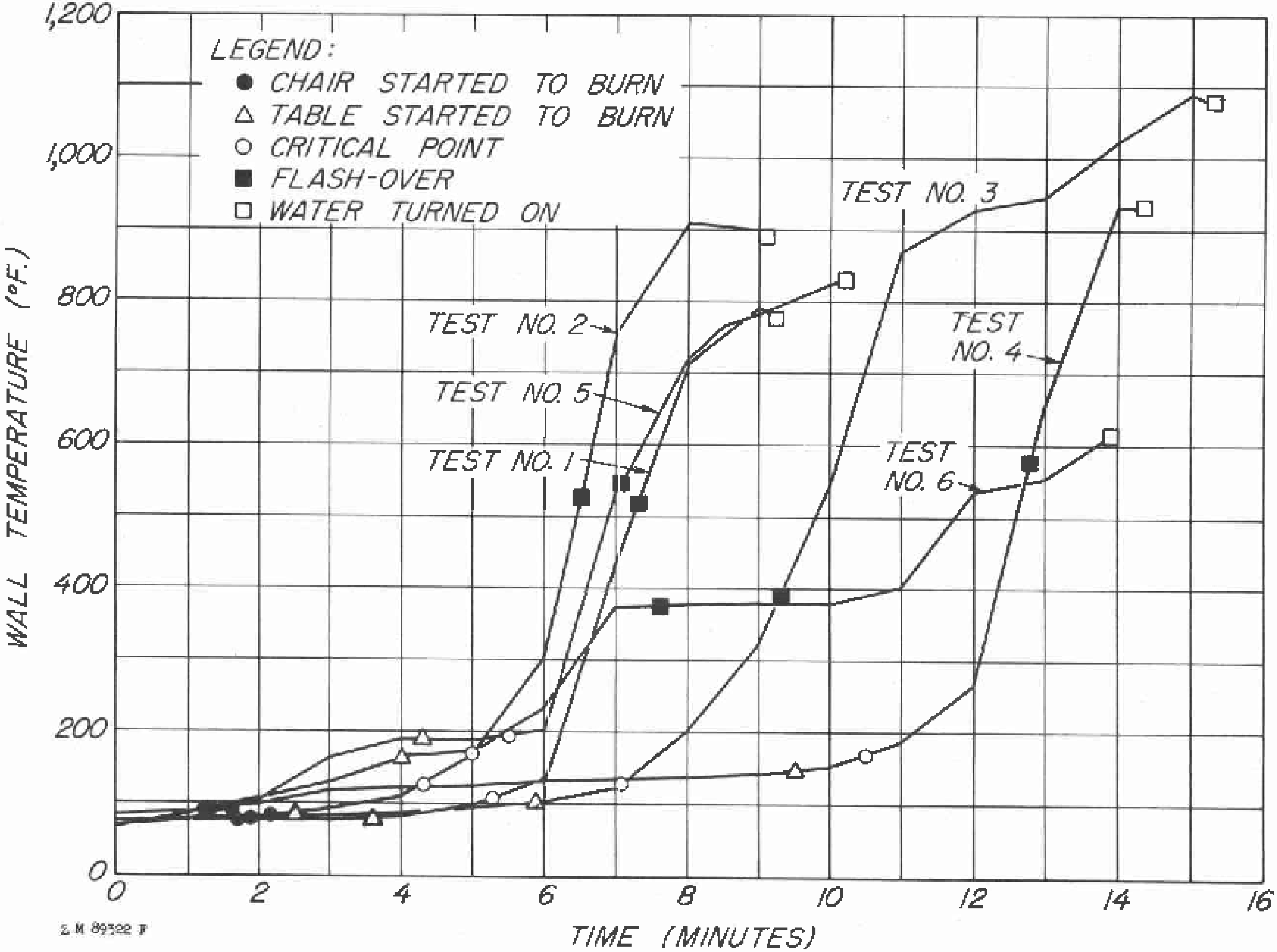

Figure 6. --Wall temperatures (averages of four walls) in burn-out tests.

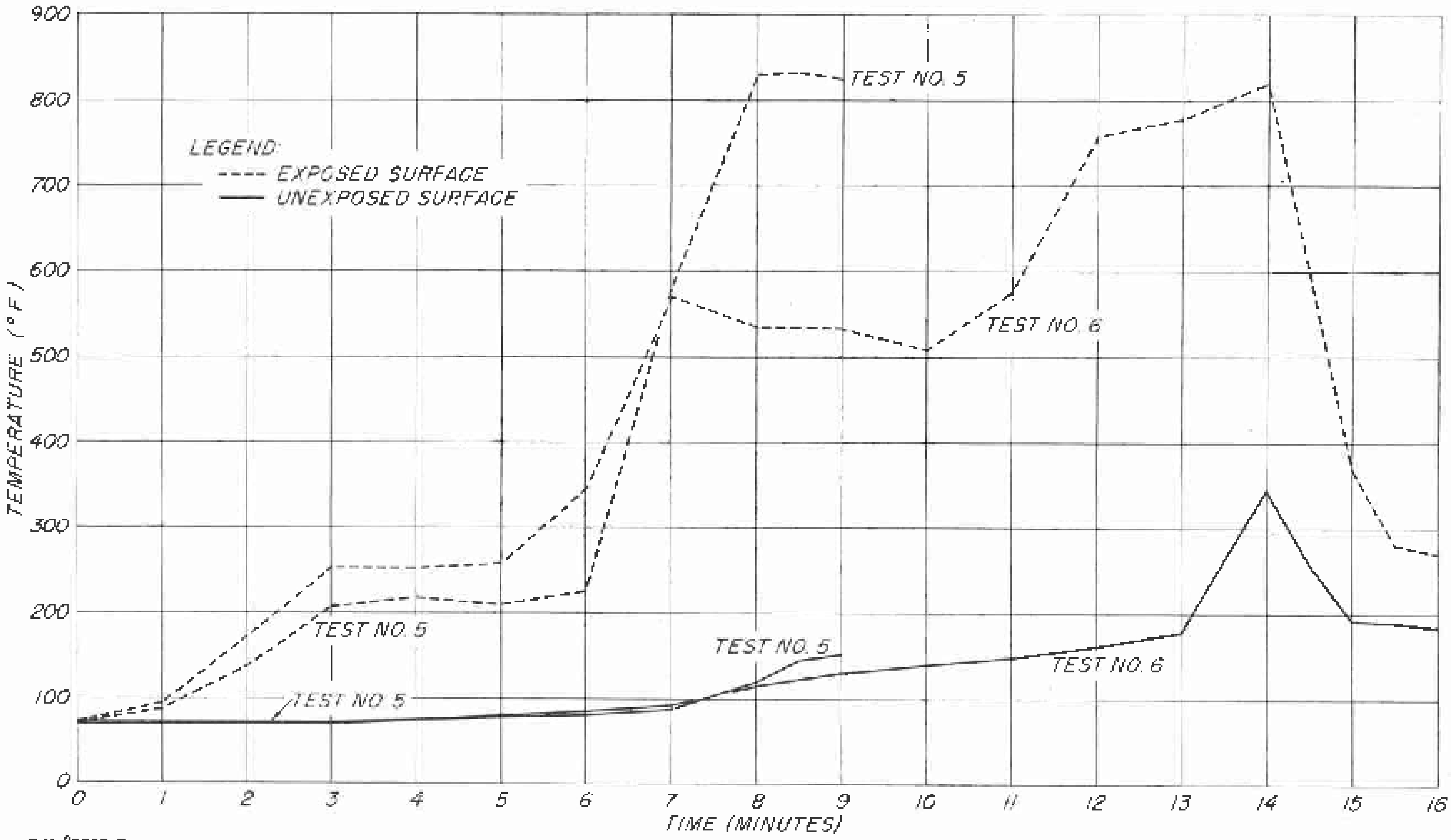

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Figure 7. --Temperatures on the surfaces exposed to the fire and on the unexposed surfaces of the ceiling and west wall.

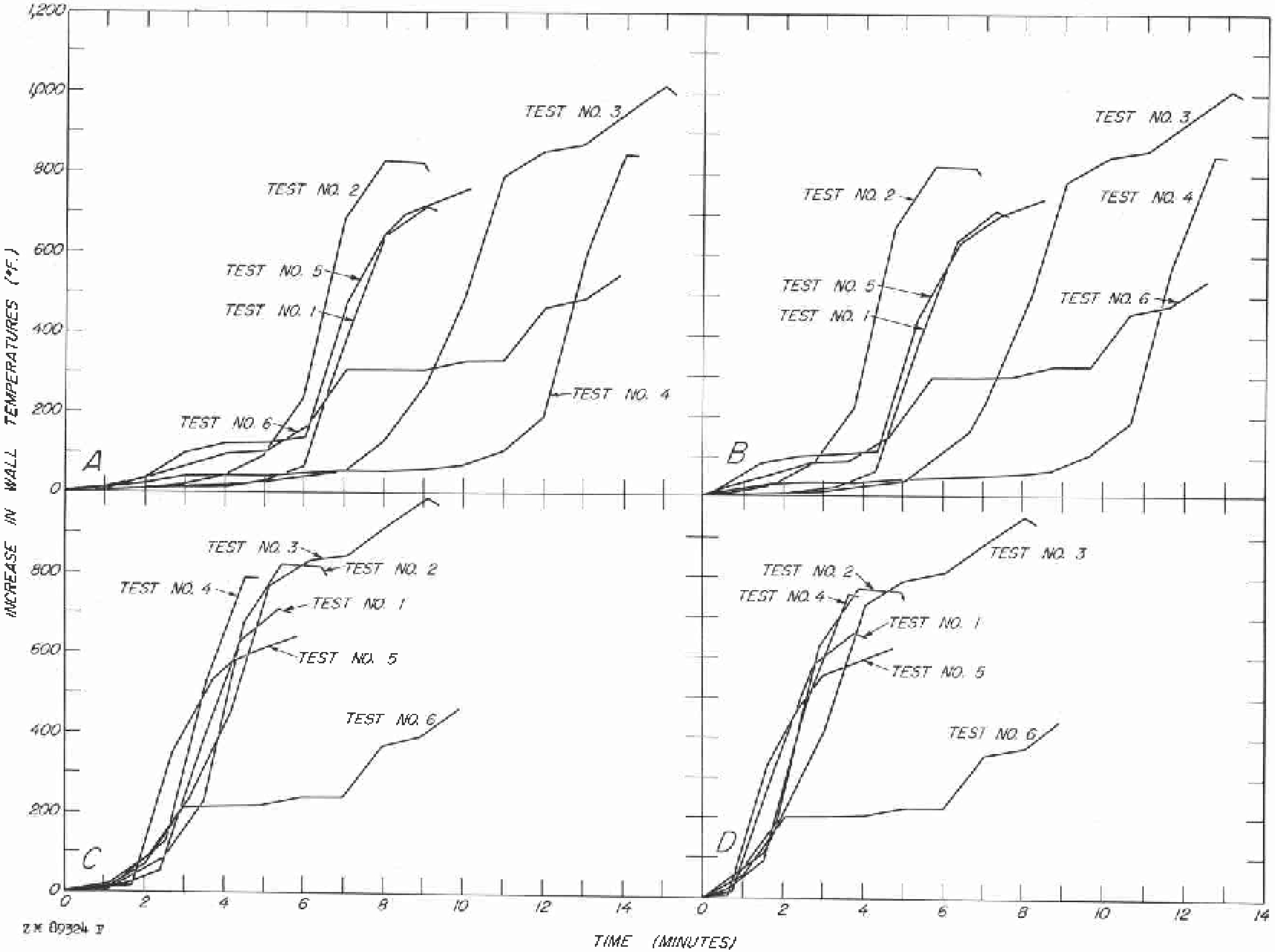

Figure 8. --Increase in wall temperatures after: A, the ignition of the crib fire; B, the first chair started to burn; C, the table started to burn; and D, the critical point.

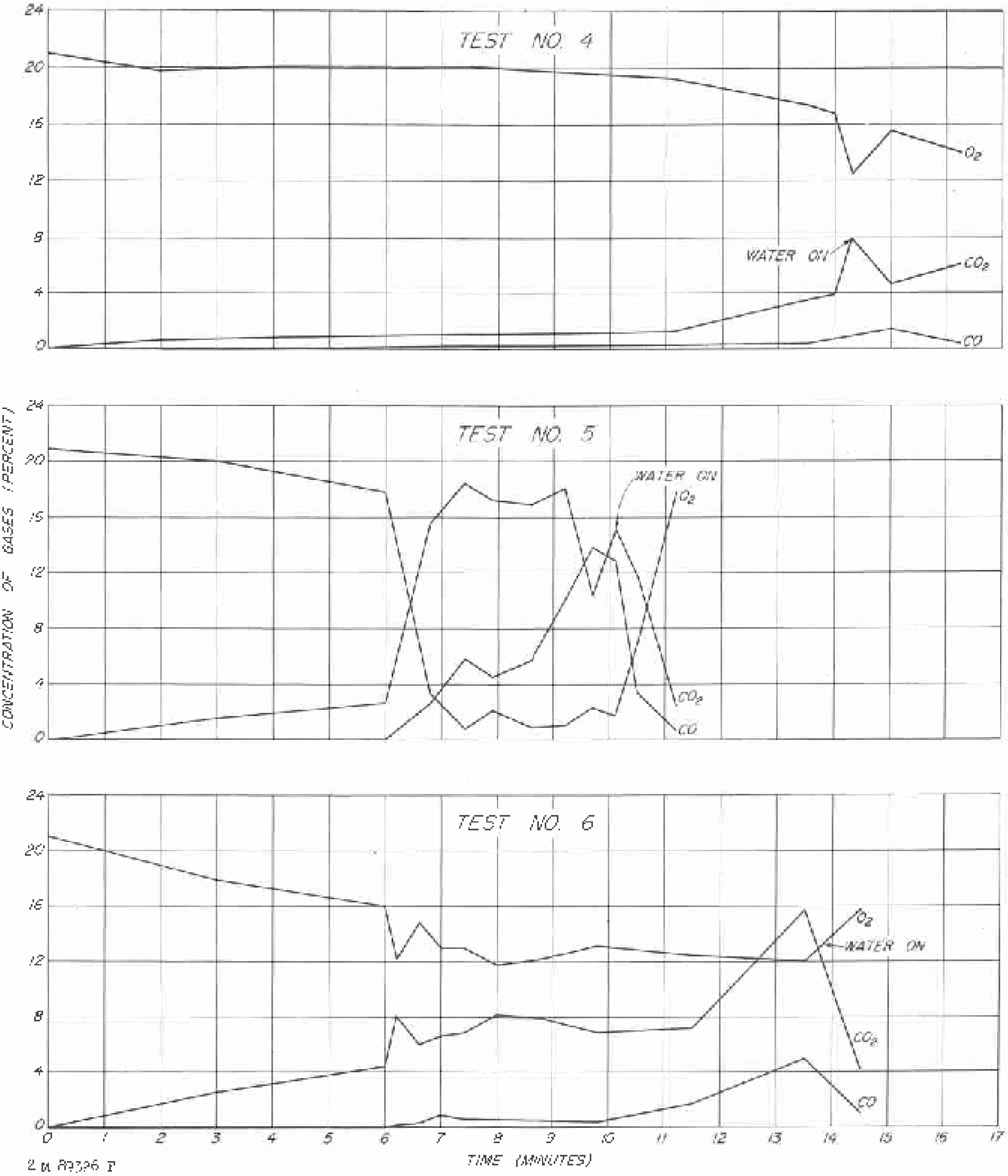

Figure 9. --Concentration of carbon dioxide, oxygen, and carbon monoxide in the flue gases.