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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

EXPERIMENTAL FIRES IN 'BACK-TO-BACK' HOUSES IN BIRMINGHAM

by

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Introduction

In the latter half of the nineteenth century large numbers of terrace houses of the 'back-to-back' type were built in many of the industrial towns in the United Kingdom. Although some of the houses have been demolished and more are due for demolition there are considerable numbers of them that are likely to be occupied for many years. The incidence of fires in this type of dwelling is no higher than in other types of house of traditional construction but since there is no separate staircase (Figure 2) escape must be made through the downstairs living-room and there is a great risk of the occupants being trapped should fire occur.

There are 26,000-27,000 back-to-back houses in Birmingham and of these about 17,000 are of the three-storey type. There have been five serious fires in these dwellings in the last twenty years and as a result thirty-six lives have been lost (1). The Housing Committee of the City Council of Birmingham have been looking for means of improving the chances of escape in the 11,000 back-to-back houses in municipal ownership and they considered that an escape hatch should be fitted in the party wall of the top floor and that a simple fire alarm should be fitted in the living-room. To test the efficiency of these proposals the Housing Management Committee decided to carry out full-scale tests on three-storey houses due for demolition. The Joint Fire Research Organization was invited to assist in this work.

In the event of fire in the living-room of these houses it was considered that the times available for escape are likely to depend very much on whether the door to the staircase is left open or closed. In view of this two tests were planned, one to be carried out with the door open, and the other with the door closed. The conditions known to affect escape during a fire are the air temperatures, the state of the atmosphere and the visibility. It was decided therefore to start the experimental fires in the living-room and to take measurements of these three conditions at key points in the houses.

The houses

For the two experimental fires a block of four houses (Figure 1) was utilised. The detailed plan of each floor of one of the test houses (Figure 2) shows the positions at which gas samples and temperature measurements were taken. Only the ground floor was furnished, old stuffed furniture, tables and chairs being used. The moisture content of the furniture in the tests varied from 14 per cent - 18 per cent as compared with the usual figure of 10 per cent - 12 per cent for living-rooms in occupation.

The fire alarms

The alarms fitted in the test houses were of a simple mechanical design (Plate 1). They were similar to the type of door bell in which the clockwork mechanism is wound up by rotating the dome, which in this case was kept in the fully-wound position by means of a fusible link having a temperature rating of about 130°F.

Tests were carried out by the Birmingham Housing Management Department to determine the audibility of the alarms when fitted in various positions in the living-room. The results, shown in the Appendix, indicate that the audibility was best if the alarm was fitted on the back of the door to the staircase, and worst if it was fitted to the ceiling of the living-room. Even with the alarm on the ceiling, however, it was

considered that it would awaken the occupants of the first floor bedroom.

Comparisons were made of the response times of the alarms, fitted in three different positions, to a heat source comprising a 17 in. metal tray mounted 3 feet above the floor in the centre of the room and containing 3 pints of methylated spirits. These are shown in Table 1.

Table 1

Response times of alarms

Position of alarm	RESPONSE TIME	
	Stairs door open	Stairs door closed
1. Back of door to stairs	min. sec. Alarm did not operate	min. sec. 2 00 1 16
2. Wall above door to stairs (approximately 6 in. from ceiling) fusible link UP.	3 45	2 35
3. Wall above door to stairs (approximately 6 in. from ceiling) fusible link DOWN.	NO TEST	Tested stopped after 5 min. when alarm had not operated.
4. Ceiling between centre of room and door to stairs.	NO TEST	0 30

In deciding the most suitable position for the alarms the two criteria, audibility and sensitivity must be considered. The stairs door was ruled out because of the insensitivity if the door were left open. It was agreed that two alarms, one on the ceiling and the other on the wall above the stairs door, should be fitted in each of the experimental houses, to see if there was an appreciable difference in their response times under fire conditions.

Escape hatch

An escape hatch was fitted in each house in the party wall in the position shown in Figure 2. The majority of the party walls were plastered $4\frac{1}{2}$ inch brickwork. The hatch, about 3 feet square, consisted of two sheets of $\frac{3}{8}$ inch plasterboard, the face of one sheet being flush with the plaster in one house, and the face of the other sheet flush with the plaster in the adjoining house. The paper on the unexposed side of both sheets of plasterboard is secured vertically

down the middle of the sheet, and in tests carried out by the Birmingham Housing Management Department a six year old child kicked out the panels easily.

Tests and results

Test No. 1 (door to stairs closed)

The fire was started in the armchair near the cupboard by the side of the fireplace. The cupboard contained some magazines and waste paper. A piece of glass about 1 foot square was removed from the lower pane of the living-room window, the windows in the first floor bedroom were closed and those in the attic were left open about 6 in. The door at the bottom of the stairs was closed and both first floor bedroom and attic doors were left fully open. After the fire was started observers stayed in the living-room until both alarms had operated. The progress of the fire as noted by observers is shown below.

Time		Progress of fire
min.	sec.	
0	00	Ignition.
5	00	Living-room filled with smoke - fire confined to armchair and cupboard and starved of air.
6	15	Alarm on ceiling operated.
10	10	Alarm on wall operated.
14	00	Living-room windows cracking.
		After 22 minutes it was evident that the fire was not going to involve the whole room, and to see how the conditions in the bedrooms would deteriorate with the whole room involved an attempt was made to build up the fire by adding more combustible material.
23	30	Fire burning up but confined to corner assembly.
33	30	Plaster off ceiling above cupboard and fire through to first floor.
35	00	Fire still confined to corner assembly.
		Water on.

Test No. 2 (door to stairs open)

The fire was started similarly in the second test and apart from the door to the stairs being open conditions elsewhere were similar to those in the first test. The progress of the fire is shown below.

Time		Progress of fire
min.	sec.	
0	00	Ignition.
7	30	Fire still small in armchair.
14	00	Alarm on ceiling operated.
16	00	Alarm on wall operated.
16	30	Cupboard well alight.
16	45	Windows cracking.
18	00	Fire spreading over ceiling.
20	00	Paint on first floor door jamb blistering.
22	00	Table alight.
23	30	Most of furniture alight.
24	15	Glass falling out of windows.
24	30	Paper peeling off attic ceiling.
25	30	Flash over - flames visible on staircase at first floor level.
27	45	Water on.

Temperature records

Throughout the fires air temperatures, as measured by 26 S.W.G. chromel-alumel thermocouples, were recorded and summaries of these are shown in Figures 3 and 4.

Visibility measurements

An instrument for assessing visibility was mounted at eye level on the staircase between the first floor bedroom and the attic. This consisted of a photo-electric cell mounted 18 in. from a 100 watt lamp supplied by the mains, the voltage being kept constant. The lamp was enclosed in a box with a 3 in. diameter hole facing the cell which was fixed to a steel strip secured to the box. The visibility was assessed by the decrease in response of the photo-electric cell due to the attenuation of light by passage through the smoke (Figure 5). The response of the cell is affected by temperature, a temperature of 100°C causing the output to increase by about 10 per cent. Since the temperature on the staircase did not reach 100°C in test No. 1 and only reached 100°C after some twenty minutes in the second test, this change has been neglected.

The decrease in visibility in the attic was recorded by photographing illuminated cards printed with a black letter C of $5\frac{1}{2}$ in. and $3\frac{1}{2}$ in. external and internal diameter respectively on a white background, these were mounted at eye level at distances of 15, 12 and 9 feet from a camera sighted through an observation port in the party wall between the houses. Photographs were taken at 5 second intervals throughout the tests (Plates 2 and 3).

Through a second observation port in the party wall opposite the first bedroom door, an observer recorded his impressions of the visibility in the bedroom.

Gas analysis

During the test, samples of the air in the first floor bedroom and the attic were withdrawn. These were subsequently analysed and the oxygen, carbon monoxide and carbon dioxide contents determined. The results are shown in Figures 6, 7 and 8.

Discussion of results

Although the arrangements for ignition were similar in both tests, the initial fire developed more rapidly in test No. 1, causing the earlier operation of the alarms. The fact that the moisture content of the furniture in both tests was high tended to impede the spread of fire. This is not likely to invalidate any conclusions on the time given for escape after the alarms had operated, as the effect of increased moisture content was likely to lengthen the initial stages of the fire rather than the time between operation of the alarm and envelopment of the room.

There are three possible ways in which escape could be jeopardised.

1. By breathing hot air

A temperature of 200°C has been taken as the danger level in an earlier report (2) and this arbitrary figure will be used. It can be seen from Figure 3 that the temperatures in the first floor bedroom and at breathing level at the attic door did not rise above 50°C until about 36 minutes after ignition (30 minutes after first alarm) in Test No. 1. In the second test (Figure 4) air temperatures of 200°C were not recorded until the flashover at about 25 minutes, that is, 11 minutes after the first alarm had operated.

2. By asphyxiation or breathing toxic gases

The hazards from the combustion products will be due to the presence of carbon dioxide and carbon monoxide and the consequent deficiency of oxygen. Henderson and Haggard (3) state that rapid loss of function occurs at less than 10 per cent and that oxygen concentrations of less than 6 per cent are extremely dangerous to life. They also assess the hazard from carbon monoxide in terms of the product of the concentration (parts per million) and exposure time (hours). They consider values of this product of less than 300 as safe, and of 1,500 or over as dangerous.

Jacobs (4) states that 12 to 15 per cent of carbon dioxide rapidly produces unconsciousness.

In test No. 1 in which the door at the bottom of the stairs was closed, the atmosphere did not deteriorate appreciably in either the attic or the first floor bedroom, and if the occupants had been evacuated within 36 minutes of ignition (30 minutes after first alarm) no serious hazards from toxic gases would have occurred.

In the second test with the stairs door open conditions in both bedrooms deteriorated rapidly at the flashover, and it appears that dangerous conditions were reached at this time, about 25 minutes after ignition (11 minutes after first alarm).

3. By dense smoke

The decrease in visibility in the attic in the two tests can be seen from Plates 2 and 3. In test No. 1 the visibility did not become bad until after 24 minutes, that is 18 minutes after the first alarm operated. In test No. 2 with the stairs door open the visibility due to the collecting smoke was seriously reduced in 4 or 5 minutes, some 10 minutes before the first alarm. Visibility in the first floor bedroom deteriorated rapidly after 25 minutes (10 minutes after first alarm) in the first test and after about 6 minutes (8 minutes before alarm) in test No. 2.

In both tests the visibility on the staircase was considerably better than in either of the bedrooms. This was noted by the observers at the ports at first and attic floor levels and is borne out by the response from the photo-electric cell (Figure 5). It can be seen that the visibility was never greatly reduced on the stairs in test No. 1 and it was about 19 minutes after ignition (5 minutes after first alarm) in the second test before there was any serious drop in visibility.

The times after which escape would have been severely hampered in the two tests by these three causes are given below in Table 2. There would probably be a cumulative effect from the three causes which would tend to decrease the time available for escape.

Table 2

Times after ignition at which escape would have been severely hampered by various hazards

	Room	Breathing hot air	Atmosphere unsafe	Dense smoke	Alarms operated	
					On ceiling	On wall
Test No. 1. Door to stairs closed	First floor bedroom	Longer than 35 minutes	Longer than 36 minutes	24 minutes	6·15	10·10
	Attic	Longer than 35 minutes	36 minutes	24 minutes		
	Staircase	Longer than 35 minutes	Not measured	Longer than 35 minutes		

Table 2 (contd.)

	Room	Breathing hot air	Atmosphere unsafe	Dense smoke	Alarm operated	
					On ceiling	On wall
Test No. 2. Door to stairs open.	First floor bedroom	27 minutes	25 minutes	6 minutes		
	Attic	25½ minutes	25 minutes	5 minutes	14.00	16.00
	Staircase	25 minutes	Not measured	19 minutes		

With the door at the bottom of the stairs closed there was ample time for escape after the alarm had operated and with the restricted air supply, the fire in the living-room did not involve the whole room. With the door to the stairs left open escape of the occupants would have been severely hampered by dense smoke before the fire alarm operated.

In both tests conditions in the living-rooms when the alarms operated, although not dangerous (observers stayed in the room until this time), would undoubtedly have appeared so to an inexperienced person and it is considered unlikely that the occupants would have attempted escape by this route.

Conclusions

It is concluded from the tests that -

1. The fire alarm can serve a useful purpose but its value is doubtful if the stairs door is left open.

2. An escape hatch would greatly increase the chances of occupants escaping in the event of fire.

Acknowledgment

The authors wish to record their appreciation of the ready co-operation of the City of Birmingham Housing Management Department and the City of Birmingham Fire Service in these tests.

Mr. H. G. H. Wraight, Mr. P. S. Tonkin, and Mr. W. Ross of the Joint Fire Research Organization assisted in the preparatory work and the taking of temperature records and gas samples. Mr. E. Jackson was the Photographer.

References

(1) House fire hazards. Fire Protection Review. Sept. 1954.
(2) P. Nash, D. Hird and P. S. Tonkin. The spread of fire in U.S.A. type temporary bungalows. F.R. Note No. 133/1954.
(3) Henderson, Y. and Haggard, H. W. Noxious gases and the principles of respiration affecting their action. New York 1943 (2nd edition) Rheinhold Publishing Corporation.
(4) Jacobs, M. B. The analytical chemistry of industrial poisons, hazards and solvents. New York 1949 (2nd Edition) Interscience Publishers Inc.

PC.

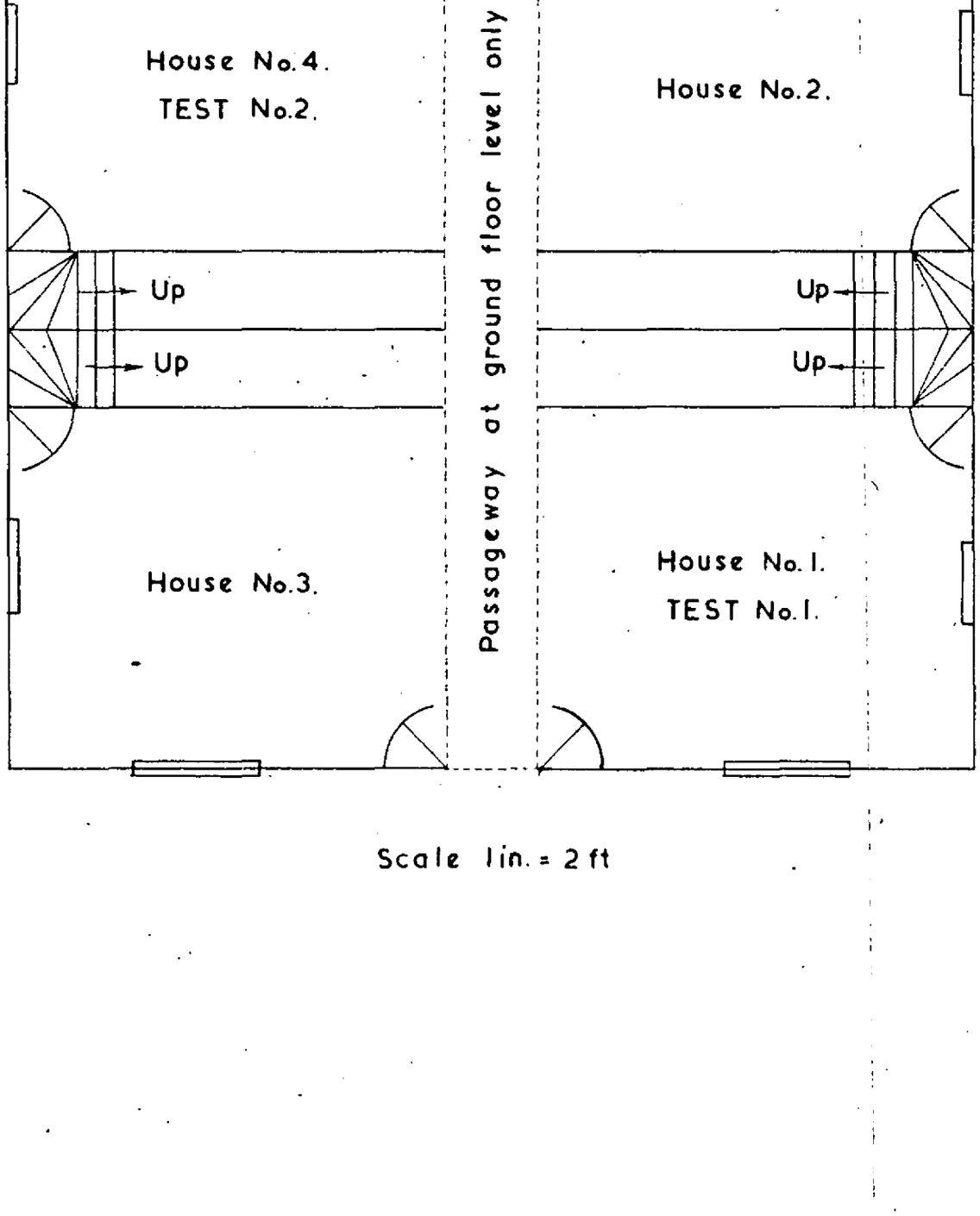
APPENDIX

Audibility tests carried out by Birmingham Housing Management Department

Position of bell	Position of stairs door	AUDIBILITY as percentage of maximum audibility	
		Team A ATTIC	Team B BEDROOM
On stairs door	Shut	Door shut 78	Door shut 78
	Shut	" open 85	" open 75
	Open	" shut 70	" shut 65
	Open	" open 83	" open 75
On wall above stairs door in living-room	Shut	Door shut 55	Door shut 50
	Shut	" open 65	" open 65
	Open	" shut 65	" shut 53
	Open	" open 83	" open 70
On ceiling above breast in living-room	Shut	Door shut 38	Door shut 38
	Shut	" open 63	" open 55
	Open	" shut 55	" shut 43
	Open	" open 80	" open 65
		TEAM B ATTIC	TEAM A BEDROOM
On stairs door	Shut	Door shut 83	Door shut 73
	Open	" " 88	" " 73
On wall above stairs door in living-room	Shut	Door shut 73	Door shut 38
	Open	" " 80	" " 60

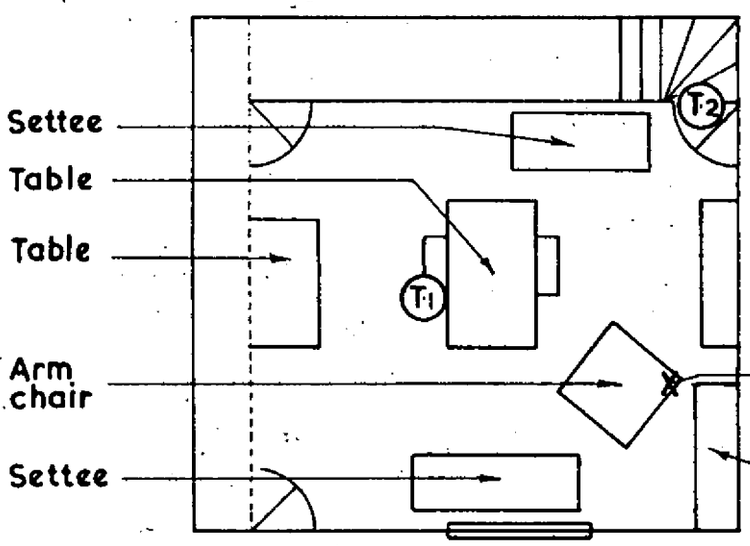
There were two members per team and the figures above are the average of their markings.

PC.



Scale 1in. = 2 ft

FIG. I. PLAN OF GROUND FLOOR OF BLOCK OF HOUSES USED FOR TESTS

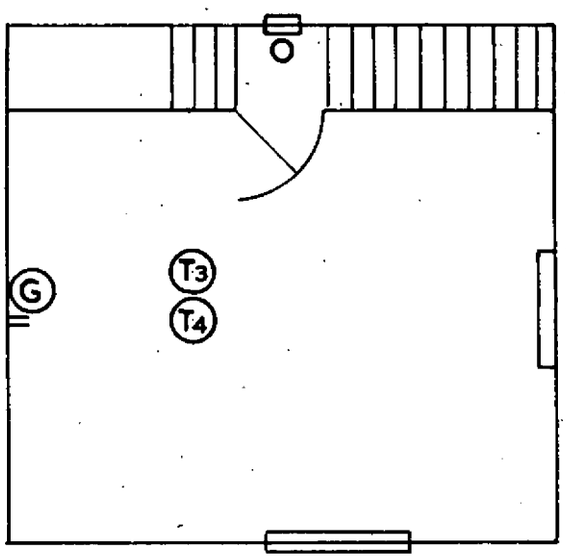


GROUND FLOOR PLAN

Position of thermocouples

T_1 – 4 ft above floor

T_2 – 6 in. from ceiling on wall above door



FIRST FLOOR PLAN

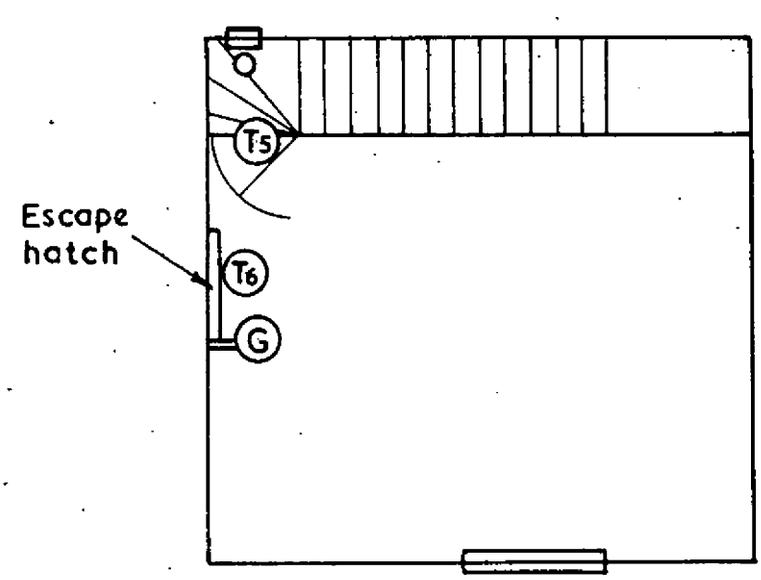
Position of thermocouples

T_3 – 3 ft above floor

T_4 – $5\frac{1}{2}$ ft above floor

Gas withdrawn at (G) for analysis – 3 ft above floor

O – Observation port to house No.2.



ATTIC PLAN

Position of thermocouples

T_5 – $5\frac{1}{2}$ ft above floor

T_6 – 3 ft above floor

Gas samples withdrawn at (G) for analysis – 3 ft above floor

O – Observation port to house No.2. camera mounted through this port

scale :- 1 in. = 2 ft

FIG. 2. DETAILED PLAN OF ALL FLOORS OF HOUSE No. 1.

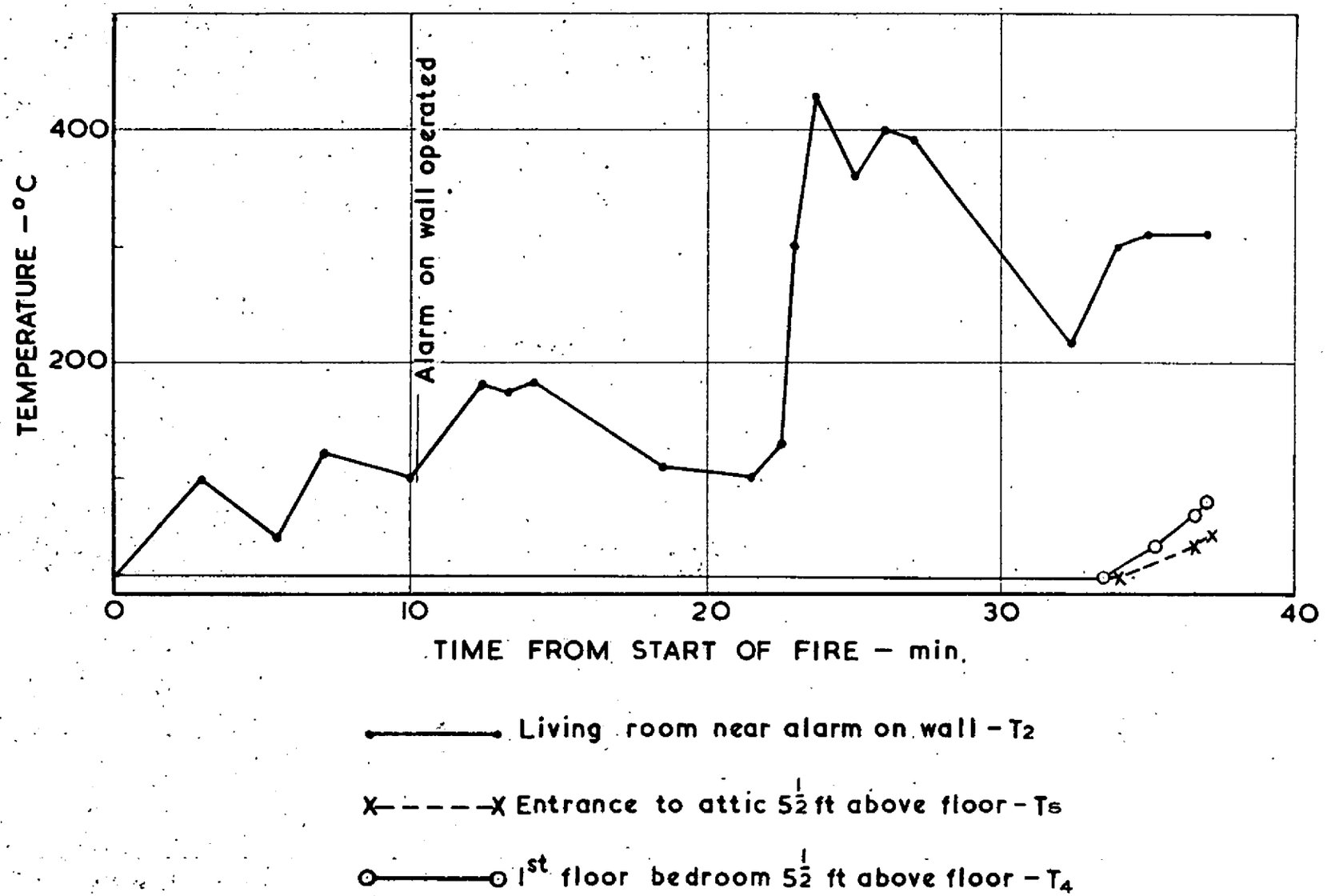


FIG. 3. REPRESENTATIVE TEMPERATURE RECORDS OF TEST No. 1.

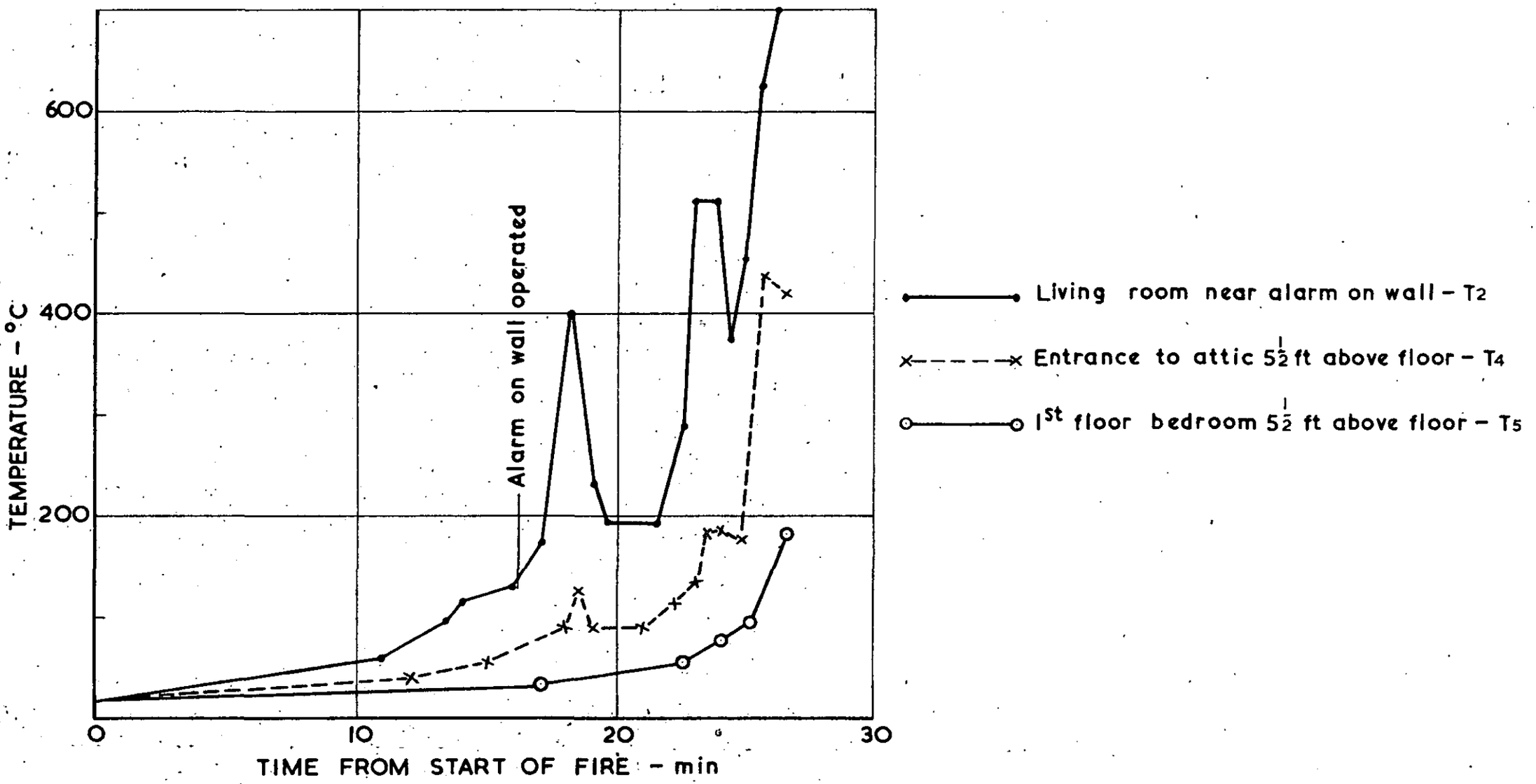


FIG. 4. REPRESENTATIVE TEMPERATURE RECORDS OF TEST No. 2.

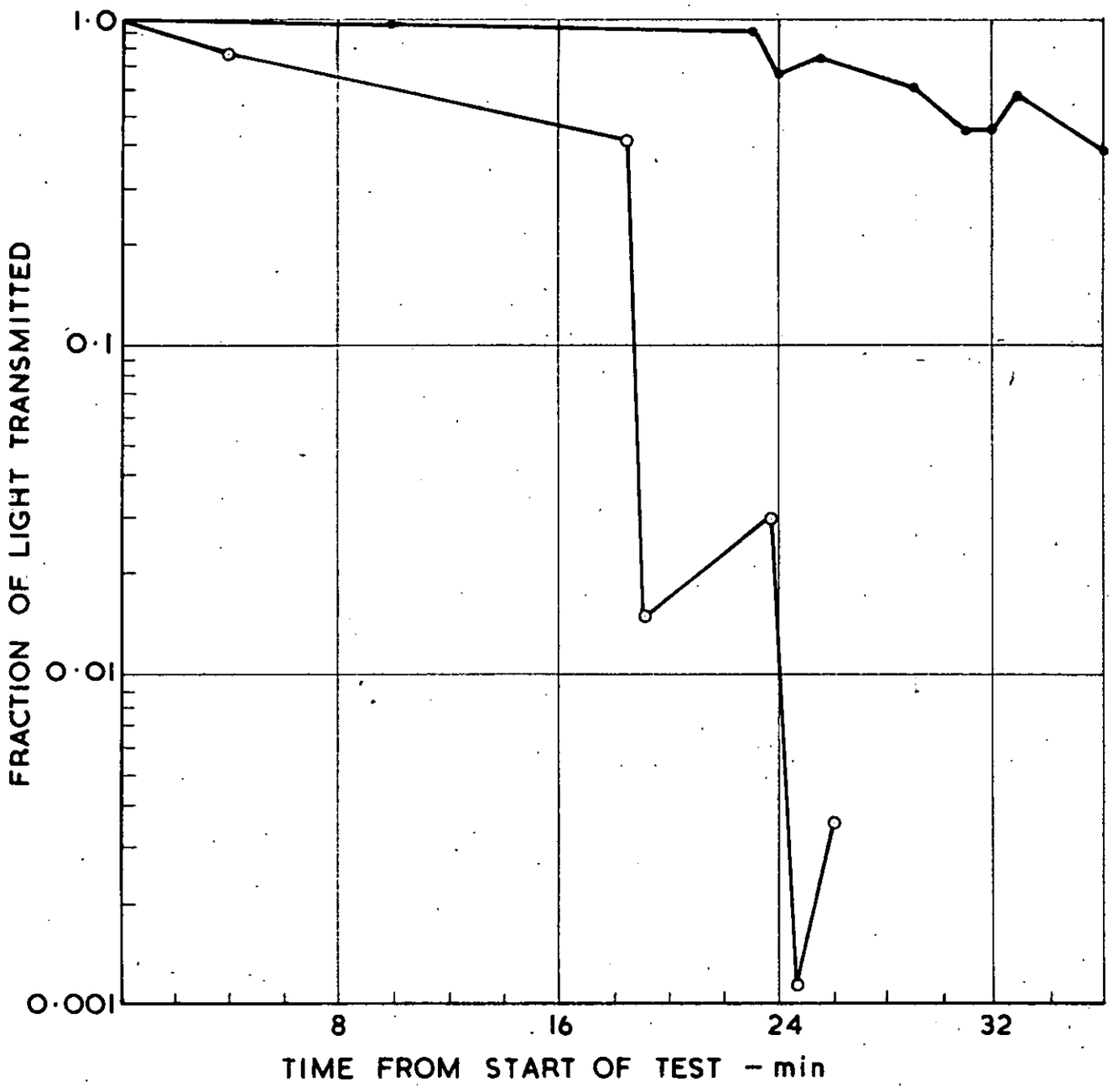


FIG. 5. RELATIONSHIP BETWEEN FRACTION OF LIGHT TRANSMITTED TO PHOTOELECTRIC CELL AND TIME AFTER IGNITION IN THE TWO TESTS

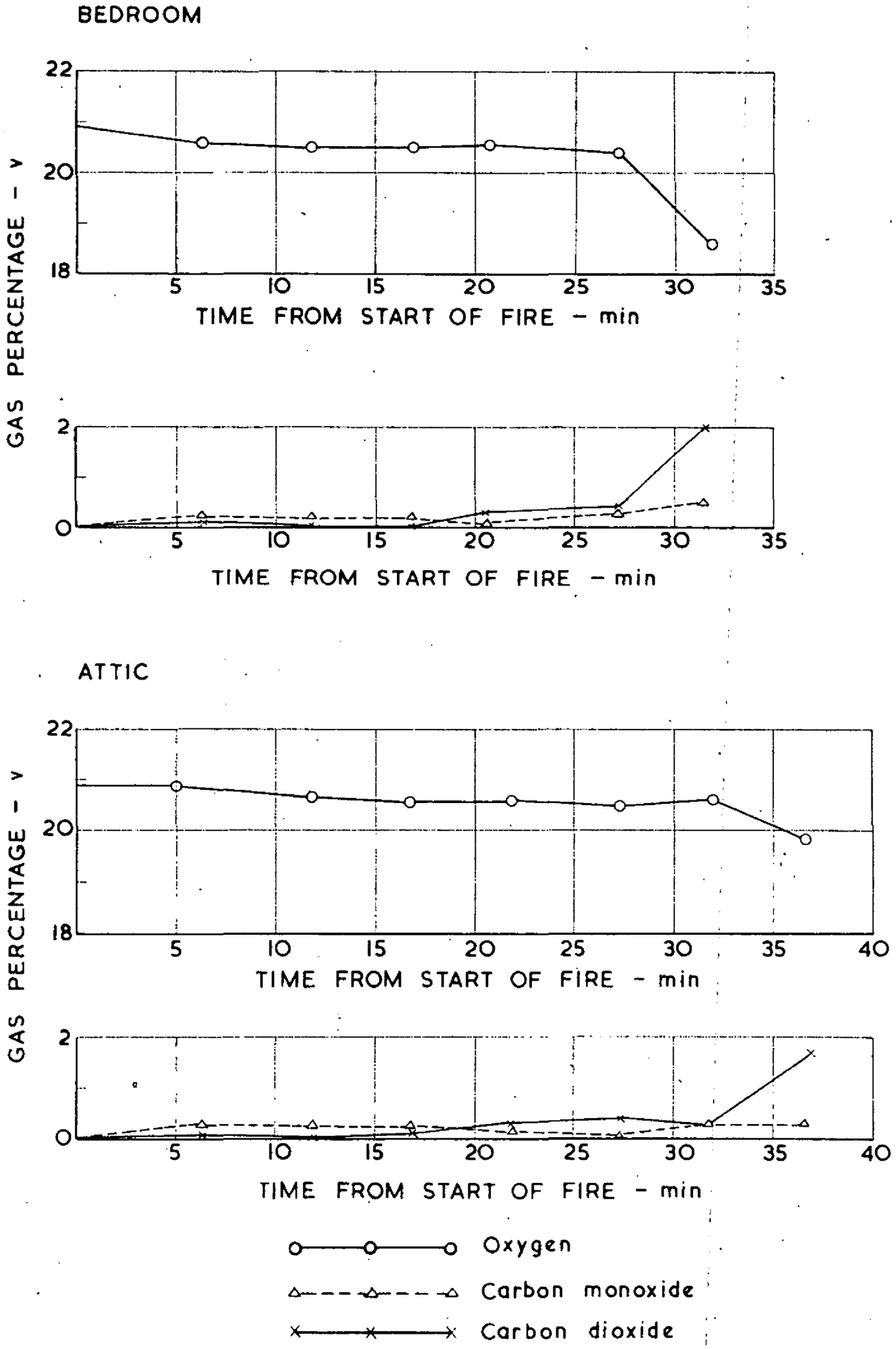


FIG. 6. VARIATION OF ATMOSPHERE WITH TIME IN TEST No.1. STAIRCASE DOOR CLOSED

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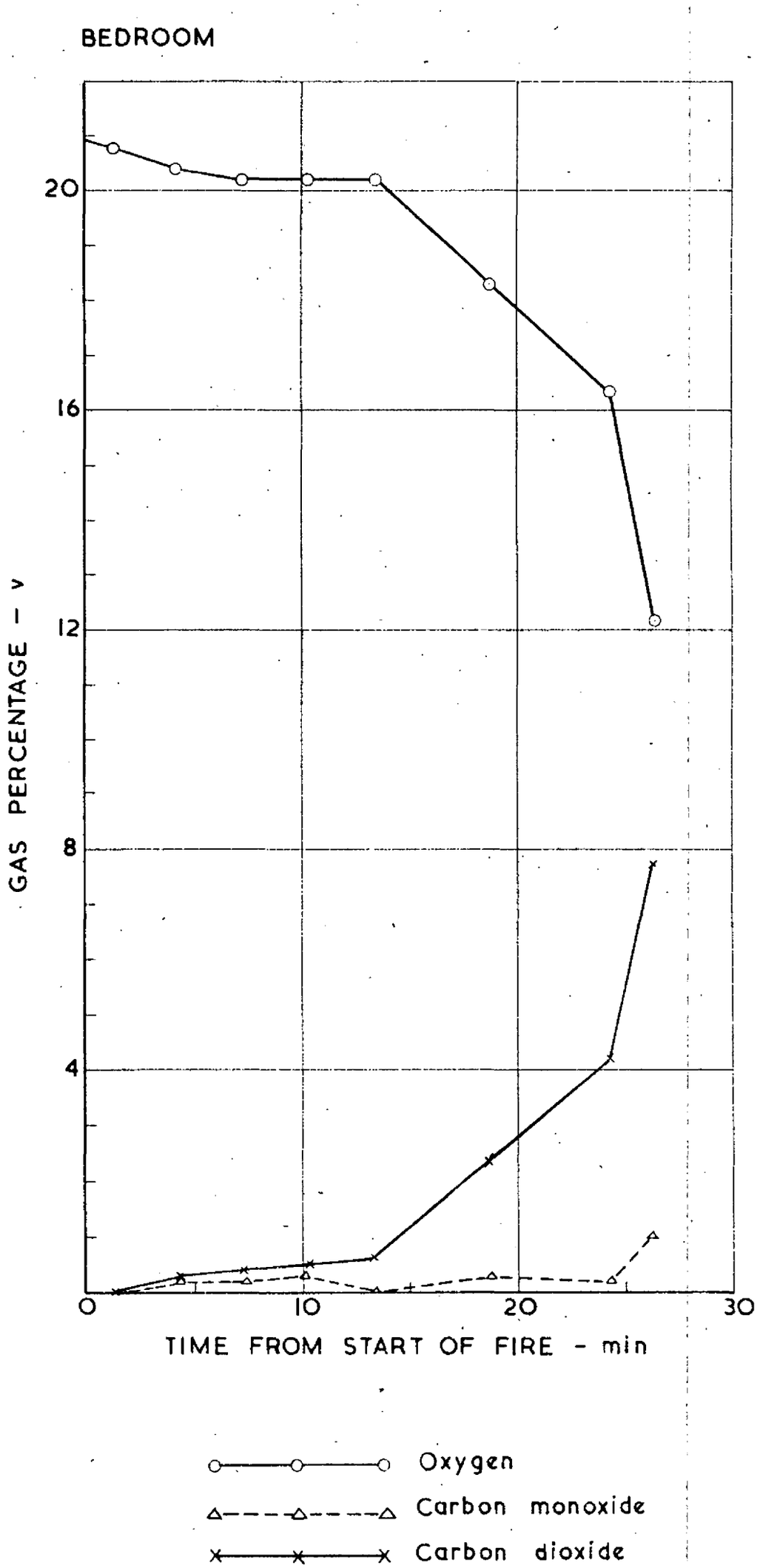


FIG. 7. VARIATION OF ATMOSPHERE WITH TIME IN TEST No.2. STAIRCASE DOOR OPEN

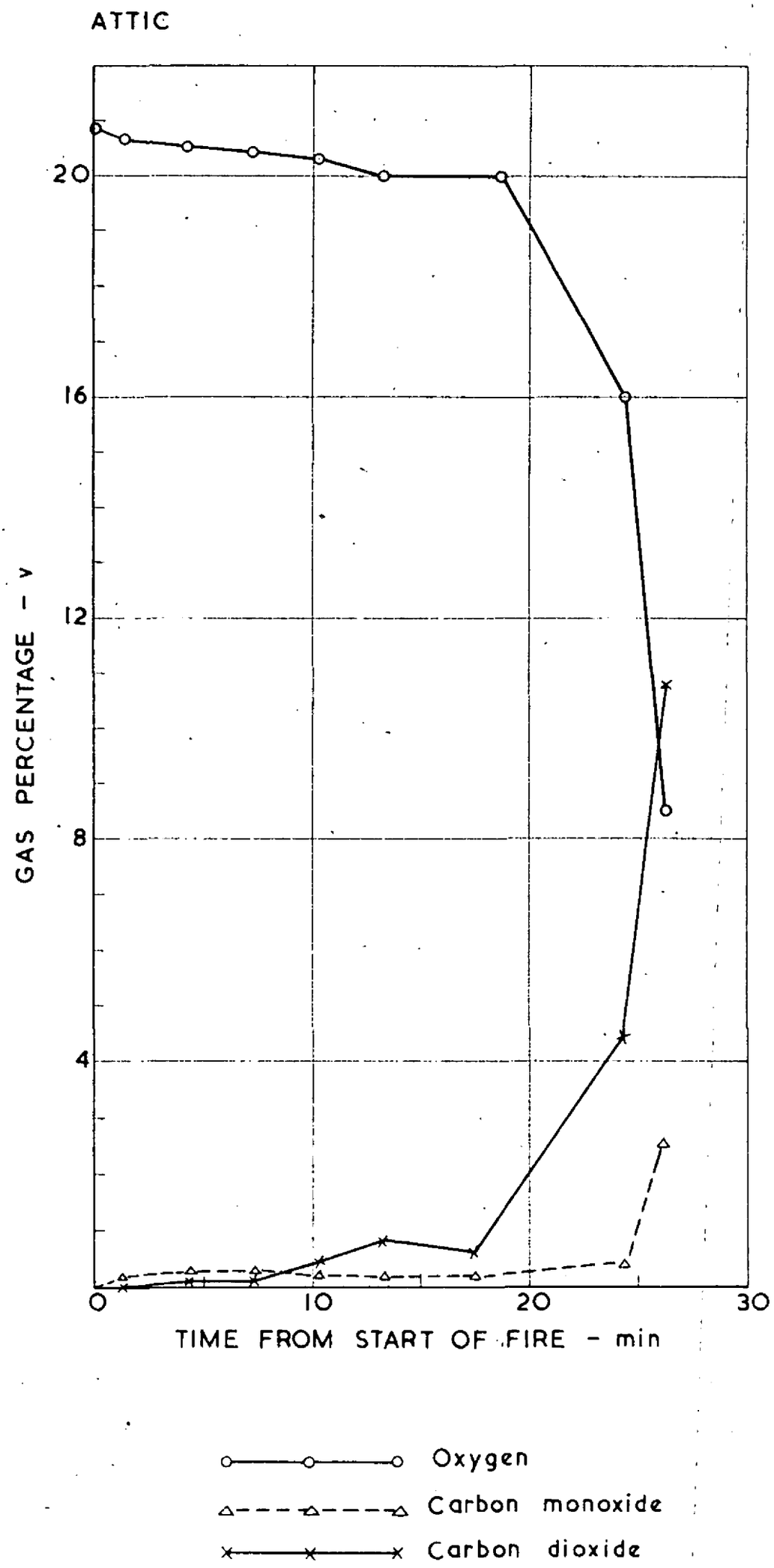


FIG. 8. VARIATION OF ATMOSPHERE WITH TIME IN TEST No.2. STAIRCASE DOOR OPEN

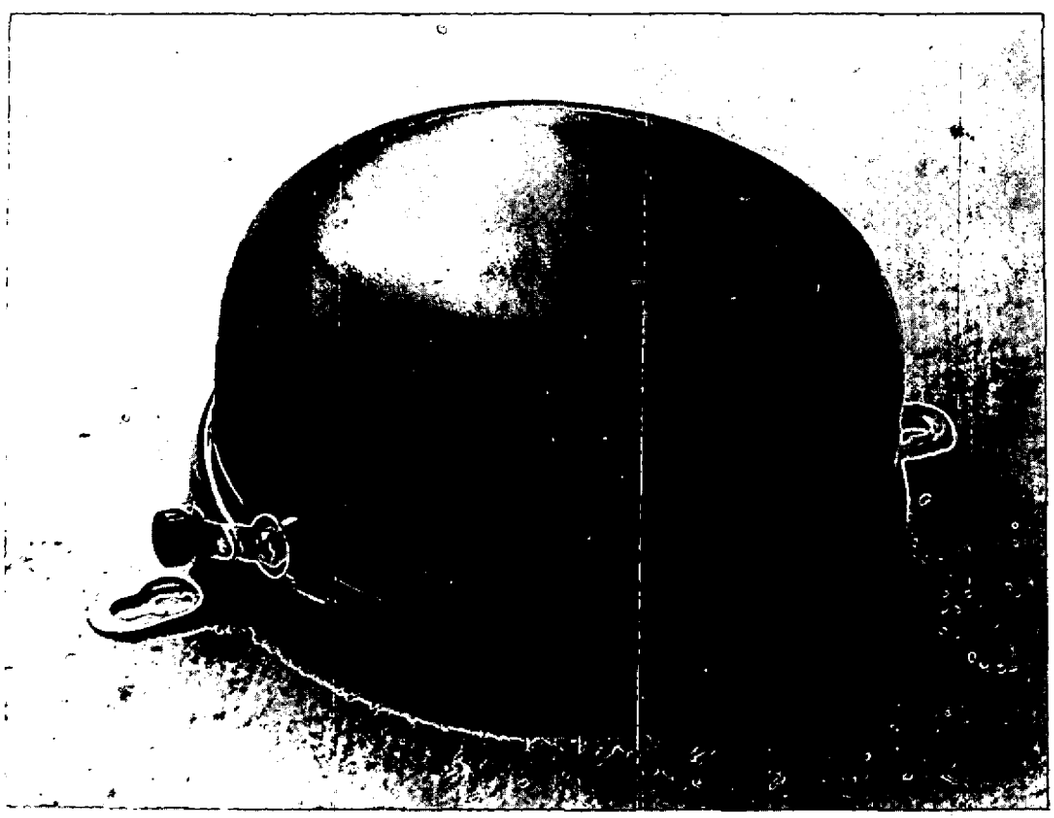
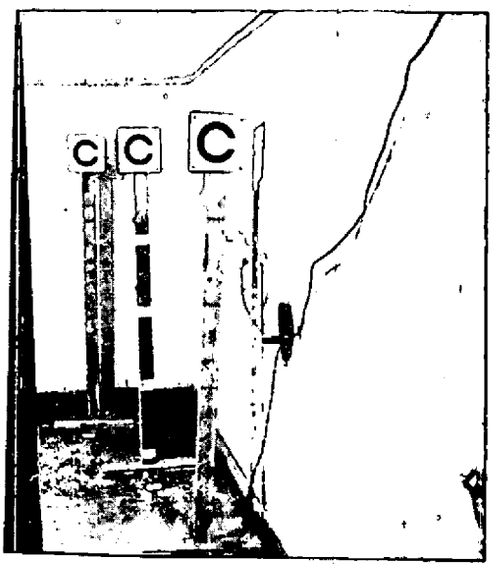


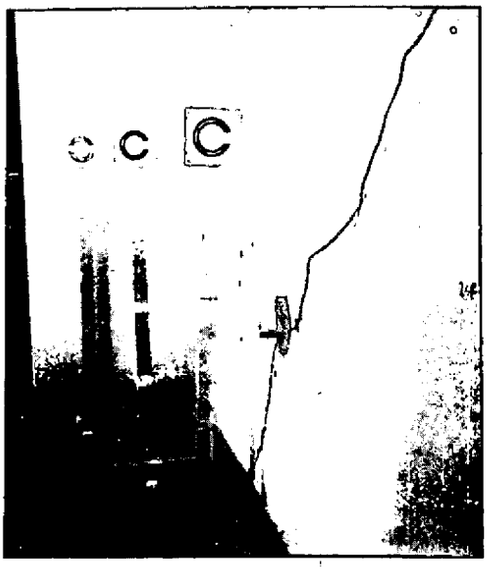
PLATE I. THE FIRE ALARM.

Before fire



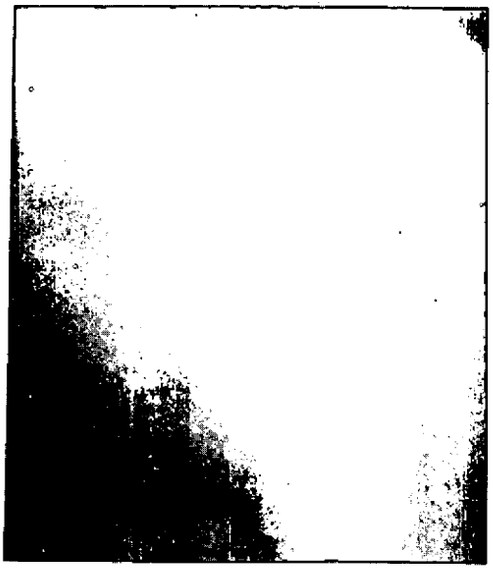
10 min. After ignition

15 min.



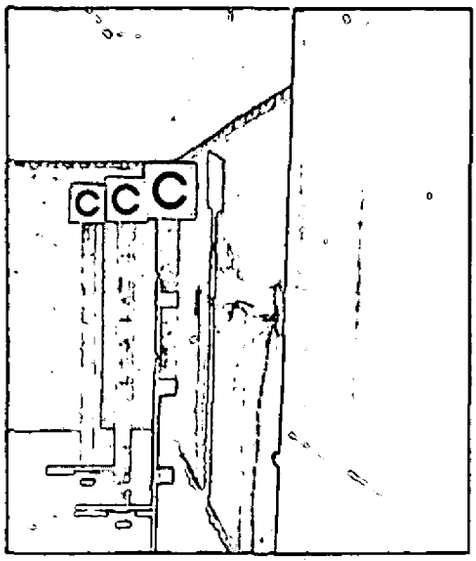
20 min.

24 min. 15 s

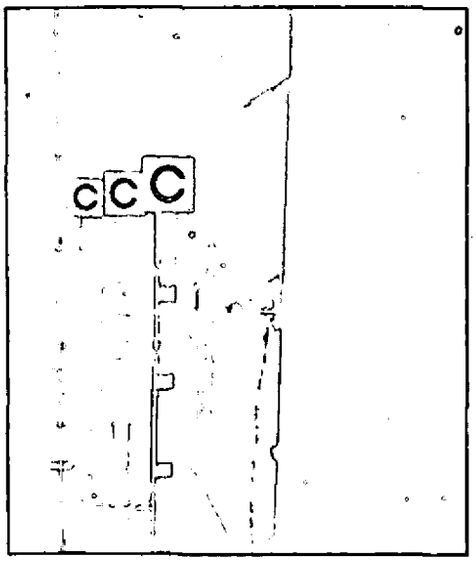


24 min 50 s

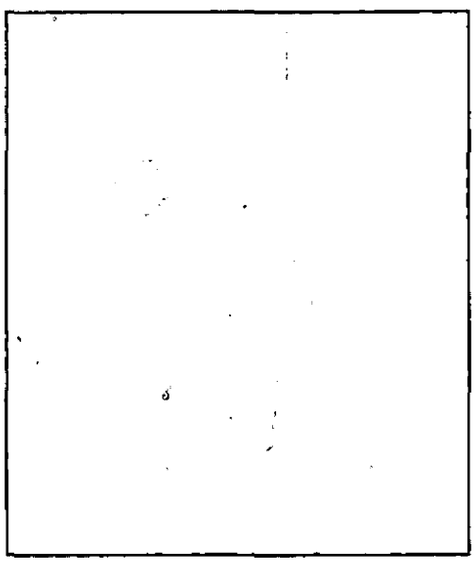
PLATE 2. VISIBILITY IN ATTIC IN TEST No. 1.



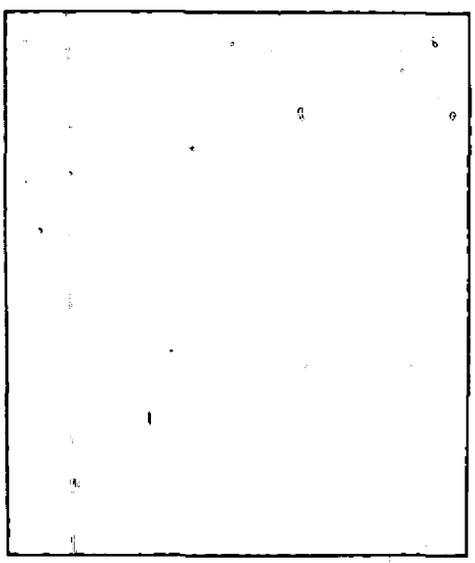
Before fire



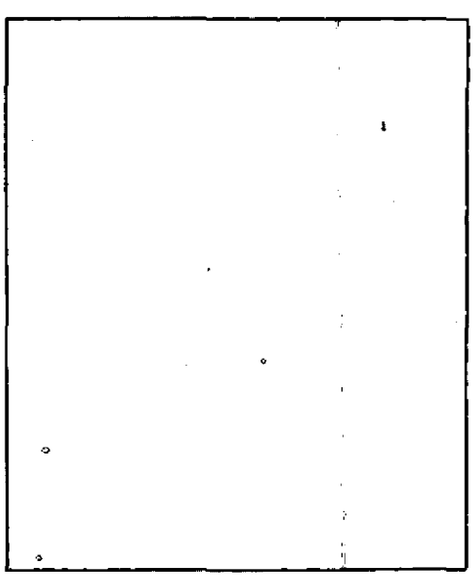
2 min After ignition



3 min



4 min



5 min

PLATE 3. VISIBILITY IN ATTIC IN TEST No. 2.

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