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JOINT FIRE RESEARCH ORGANIZATION

THE SPREAD OF FIRE IN U.S.A. TYPE TEMPORARY BUNGALOWS

by

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Introduction

There are about 8.000 U.S.A. type temporary bungalows in the United Kingdom, and there have been several fires in them, most of which have been characterised by the rapid growth and spread of fire. The City of Birmingham Housing Management Department are responsible for about 500 of these dwellings and they have been investigating methods of ensuring the escape of occupants in the event of fire. Two proprietary flame retardant treatments were tried but maintenance difficulties and costs led to the consideration of the installation of a fire alarm system. The main life risk is likely to occur during a fire at night. To find how long the bedrooms would be tenable if a fire occurred, and how much warning would be given by a proprietary fire alarm installation, a replica of the U.S.A. bungalow was built in Birmingham and destroyed by fire. The Joint Fire Research Organization were invited to cooperate in this experimental fire, and they undertook the temperature and visibility measurements and an analysis of the atmosphere in one of the bedrooms during the fire.

The experimental bungalow

The experimental bungalow was of similar construction to the existing bungalows. The external walls were of bitumen bonded fibre insulating board on a 3 in. timber framing. Fibre insulating board was used for all partitions and ceilings, and, with a water proof paper backing for internal linings to the walls. The roof was covered with bituminous roofing felt. The internal walls and partitions were treated with one coat of an oil bound water paint. The ceilings were covered with one coat of an oil free distemper. A plan of the bungalow together with furnishings and the positions of fire alarms and thermocouples is shown in Figure 1. The furniture was made up from softwood and was supplemented by a three piece suite in the living-room. The fire alarms were fitted in each room so that the most effective positioning could be found. Temperatures were measured by 26 S.W.G. chromel-alumel thermocouples. The heights of these above floor level were 2 ft. and 5 ft. 6 in. in both bedrooms 1 and 2, to represent bed level and normal breathing level. In the living-room there was one thermocouple 2 in. from the ceiling. Gas samples were taken at bed level in bedroom No. 1. The door to bedroom No. 2 and both doors to the outside were left closed, and all other doors were open. It was thought that this would represent the worst conditions for escape from bedroom No. 1. One pane of glass, approximately 1 ft. 6 in. square was removed from the living-room window so that photographs could be taken of the growth of fire, all other windows in the bungalow were closed.

The fire

The two most likely places for a fire to start are the kitchen and the living-room. The fire in the experimental bungalow was started near the hearth, since a fire in the living-room would be more likely to endanger the life of occupants in the adjacent bedroom.

The stuffing in the armchair was set alight as well as some wood shavings and fibre insulating board between the armchair and the wall. The progress of the fire as noted by the observers is shown below, and photographs of the fire are shown in Plate 1.

TIME	PROGRESS OF FIRE
Mins. secs.	
00 - 00	Ignition.
00 - 35	Fire alarm No. 1 (Living-room) operated.
01 - 15	Fire alarm No. 2 (Kitchen) operated.
01 - 20	Fire alarm No. 6 (Lobby) operated.
01 - 45	Flames spreading up living-room wall and reaching ceiling.
02 - 10	Fire alarm No. 4 (Bedroom No. 1) operated.
02 - 12	Fire alarm No. 3 (Bathroom) operated.
02 - 15	Flashover - living-room full of flame.
02 - 30	Most of glass in living-room windows cracked - two panes fallen out.
02 - 30	Bedroom No. 1 full of black smoke, not possible to see anything in the room. (This may have happened earlier but first visual observations were made at bedroom window at this time).
04 - 00	Kitchen windows cracking and large quantity of black smoke coming out
05 - 00	Flaming still confined to living-room but all other rooms filled with black smoke.
06 - 00	Windows of bedroom No. 1 cracking.
07 - 30	Roof above living-room burned through, big increase in flaming, flames about 20 ft. high from this part of bungalow.
After this stage of the fire it was not possible to get nearer than about 40 ft. to the bungalow, and it was difficult to make any detailed observations.	
09 - 08	Fire alarm No. 5 (Bedroom No. 2) operated.
11 - 00	Windows of bedroom No. 2 cracking and falling out.
12 - 00	Bedroom No. 2 burning.
20 - 00	Nothing but smouldering frame of building left.

Note

An old railway sleeper, lying on the ground with its end facing the front of the bungalow and 28 ft. from the wall, ignited spontaneously during the fire. (The end grain of the timber was broken out and partially decayed).

Temperature records

Temperature records (Figures 2, 3 and 4) were taken until about 12 minutes after ignition when the leads from the bungalow to the recording instruments were destroyed by the fire.

Visibility measurements

To get a simple assessment of the visibility in bedroom No. 1 a 250 watt photoflash bulb was mounted in the corner opposite to the door, and cards printed with a black letter O, ($5\frac{1}{2}$ in. outside diameter, $3\frac{1}{2}$ in. inside diameter) on a white background were mounted at eye level, 5 ft. 6 in. above the floor, at distances of 6 ft., 9 ft. and 12 ft. from the lamp. These cards were photographed at 5 second intervals during the early part of the fire, by a camera mounted as shown in Figure 1 and sighted through a 9 in. square observation port 4 ft. above floor level. The photographs taken by this camera are shown in Plate 2.

Gas analysis

During the fire test samples of the air in bedroom No. 1 were withdrawn every minute. These were subsequently analysed and the oxygen, carbon monoxide and carbon dioxide contents determined. The results are shown in Figure 5.

Discussion

The speed with which the fire developed in the living-room emphasised again the hazards associated with combustible internal linings (1), (2). Although the fire was confined to the armchair when the first alarm went off, the whole of the living-room was involved in fire in a further 2 minutes, making escape from the bedrooms through the living-room unlikely. There are three possible ways in which escape could be jeopardised.

1. By breathing hot air

Little medical evidence is available as to the exposure to hot gases which may be tolerated, but it is known that the breathing of air above 100°C can lead to pulmonary oedema, and death may follow some time later, although no ill effects may be felt at the time. An air temperature of 200°C has been taken as the danger level by the National Advisory Committee for Aeronautics (3) and although this figure is arbitrary it will be used in this report.

2. By asphyxiation or breathing toxic gases

The hazard 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 (4) state that oxygen concentrations of less than six per cent are extremely dangerous, and that rapid loss of function occurs at less than ten per cent. 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 1500 or over as dangerous.

Jacobs (5) states that twelve to fifteen per cent of carbon dioxide rapidly produces unconsciousness.

It appears therefore that the atmosphere in bedroom No. 1 reached dangerous conditions about four minutes after the start of the fire. Considerable care is necessary in applying the results, however, since each gas has been considered separately, and the effects will probably be cumulative. This would reduce the time during which the atmosphere was safe.

3. By dense smoke

The decrease of visibility can be seen from Plate 2.

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

TABLE 1

Times at which escape would be severely hampered by various hazards (to nearest ¼ min).

Room	Breathing hot air	Very dense smoke	Atmosphere unsafe
Bedroom No. 1	5 mins.	2 mins	4 mins
Bedroom No. 2	10 mins.	Between 2 & 5 mins.	Not measured

Conclusions

The object of the test was to find how much time there would be for escape in the event of fire if fire alarms were fitted in the bungalows. Under the worst conditions with both living room and bedroom doors open the occupants would have had about 1½ mins. after the first alarm, to make their escape before very dense smoke severely hampered them. Conditions in the bedroom with the door closed were better although the occupants would have been hampered by smoke in something less than 4 mins. after the alarm. Conditions in bedroom No. 1 deteriorated rapidly to an unsafe condition within about 3½ mins. of the alarm.

Without a fire alarm system escape would be unlikely. Even with the alarms the escape times are very short, and the utmost expedition would be necessary for escape. For the same reason it is unlikely that assistance from outside would be effective unless given very rapidly, and backed by the Fire Brigade.

If the fibre insulating board linings of these bungalows cannot be faced with plaster board or given a skim coat of plaster, the longest time for escape would be ensured by:-

(1) Fitting fire alarms in the living-room, kitchen and lobby. It is considered that the two rooms, (living-room and kitchen) in which there is the greatest risk of a fire starting should each have an alarm. The alarm in the lobby would give warning to the occupants of either bedroom of a fire in the airing cupboard, bathroom or other bedroom.

(2) Ensuring that the door from the living-room to the lobby and in both bedrooms are kept closed at night.

(3) Fitting an escape panel in the wall separating the two bedrooms.

(4) Having a door, with one large pane of glass big enough to escape through, opening to the outside from one bedroom.

Although not directly relevant to the question of escape, the fact that a railway sleeper 28 ft. from the front of the bungalow was ignited spontaneously, points to the dangers of spread of fire between bungalows in colonies of this type of dwelling.

Acknowledgement

The Authors wish to record their appreciation of the ready cooperation of the City of Birmingham Housing Department in the conduct of this experiment. The City of Birmingham Fire Service were in attendance during the fire.

Mr. H. G. H. Wraight and Mr. W. Ross of the Joint Fire Research Organization assisted in the measurement of temperature and the sampling of the atmosphere, and Mr. E. Jackson was the photographer.

References

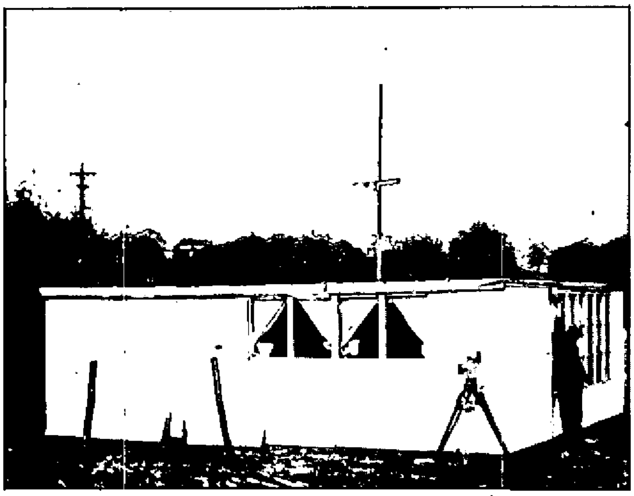
(1) Fire Research 1950. London 1951. H. M. Stationery Office.

(2) Hird, D. and Fishl, C.F. Fire hazard of internal linings. National Building Studies Special Report No. 22.

(3) Appraisal of hazards to human survival in airplane crash fires. National Advisory Committee for Aeronautics. Technical Note 2996. Washington 1953.

(4) Henderson, Y. and Haggard, H. W. Noxious gases and the principles of respiration affecting thir action. New York 1943 (2nd Edition) Rheinhold Publishing Corporation.

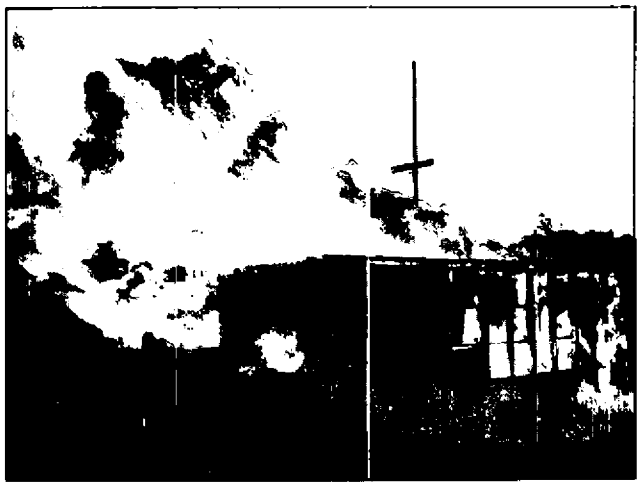
(5) Jacobs, M. B. The analytical chemistry of industrial poisons, hazards and solvents. New York 1949 (2nd Edition) Interscience Publishers Inc.



Before fire

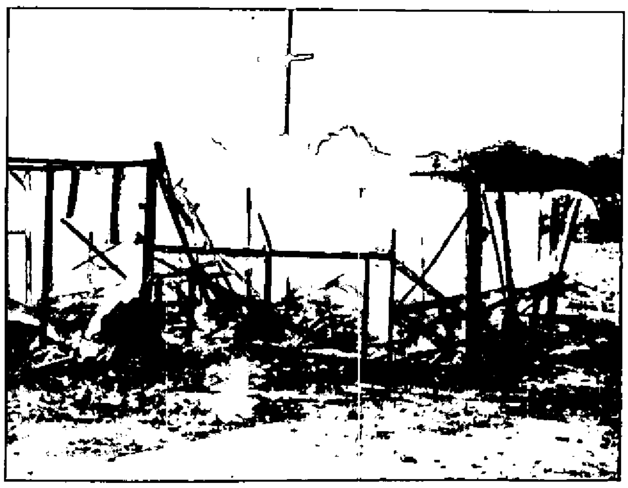
After 7 min

After 8 min



After $10\frac{1}{2}$ min

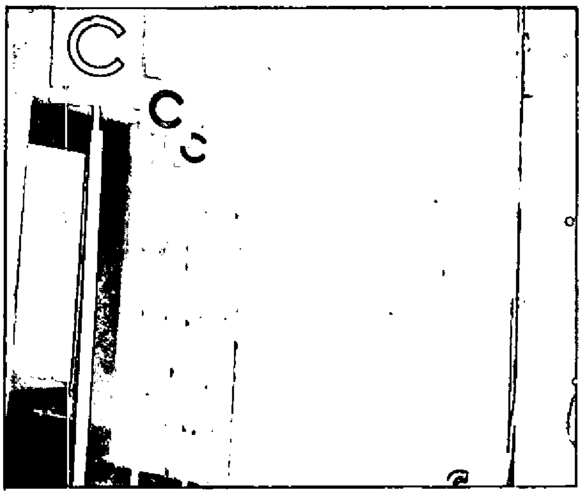
After $15\frac{3}{4}$ min



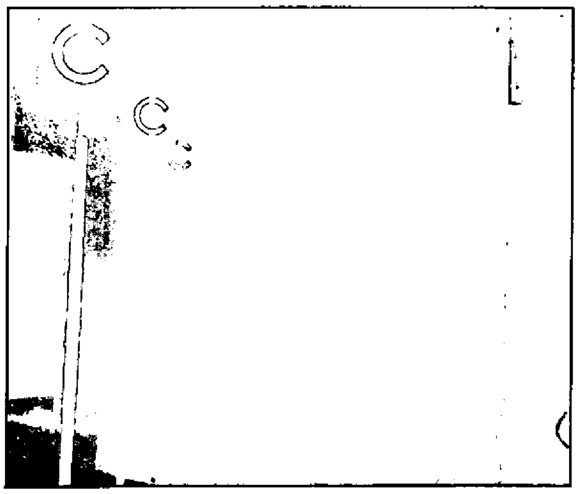
After 21 min

PLATE. I. FIRE IN EXPERIMENTAL BUNGALOW

DS23810/2/150 60 10/64CL

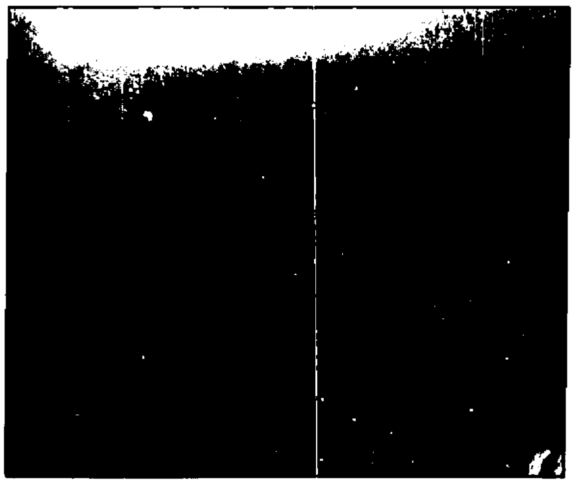


60 sec after ignition



90 sec

100 sec



105 sec

110 sec

120 sec

PLATE. 2. VISIBILITY IN BEDROOM I

DS238K/1/150 60 10/54CL

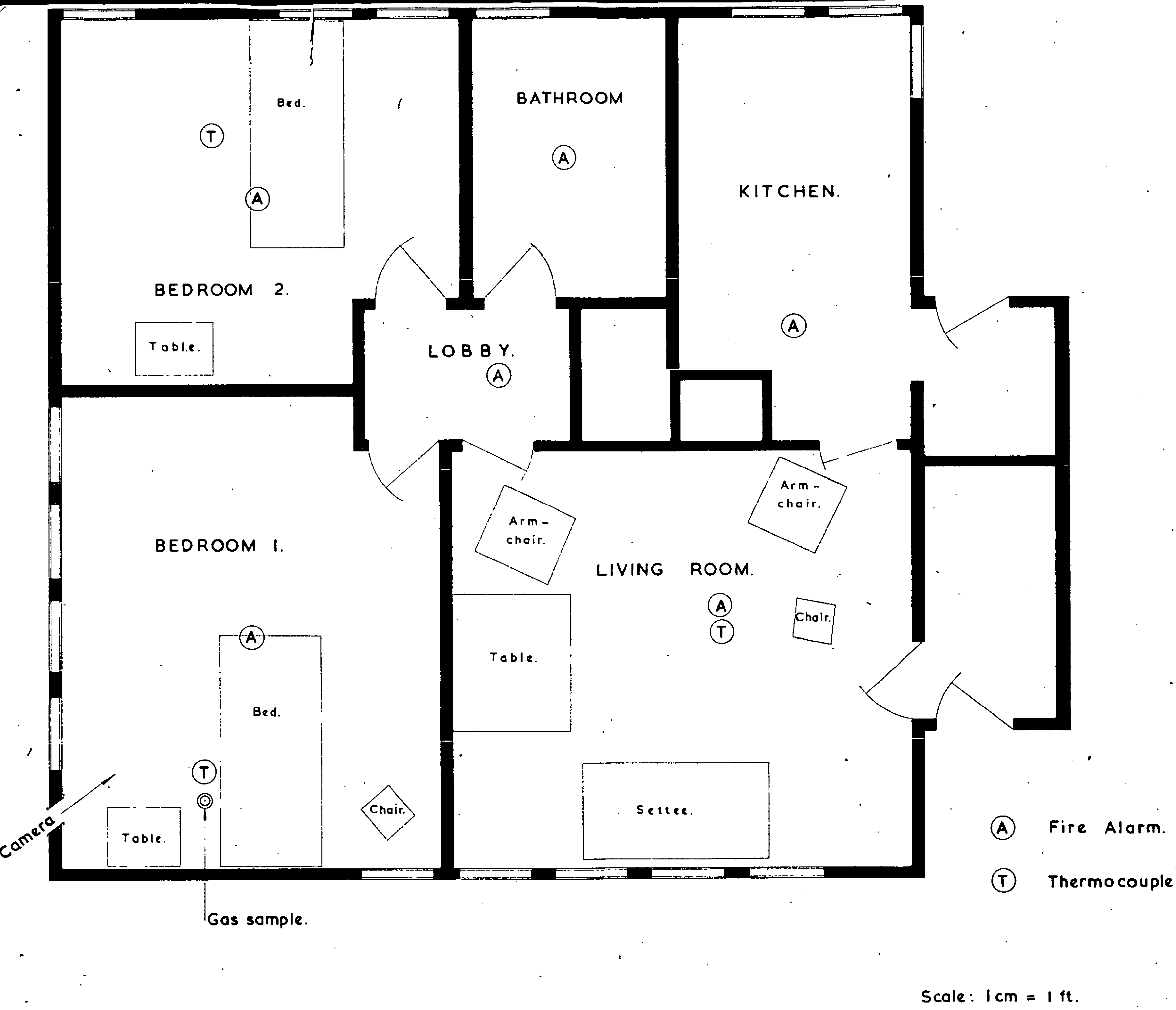


Fig. 1
1.

PLAN OF EXPERIMENTAL BUNGALOW.

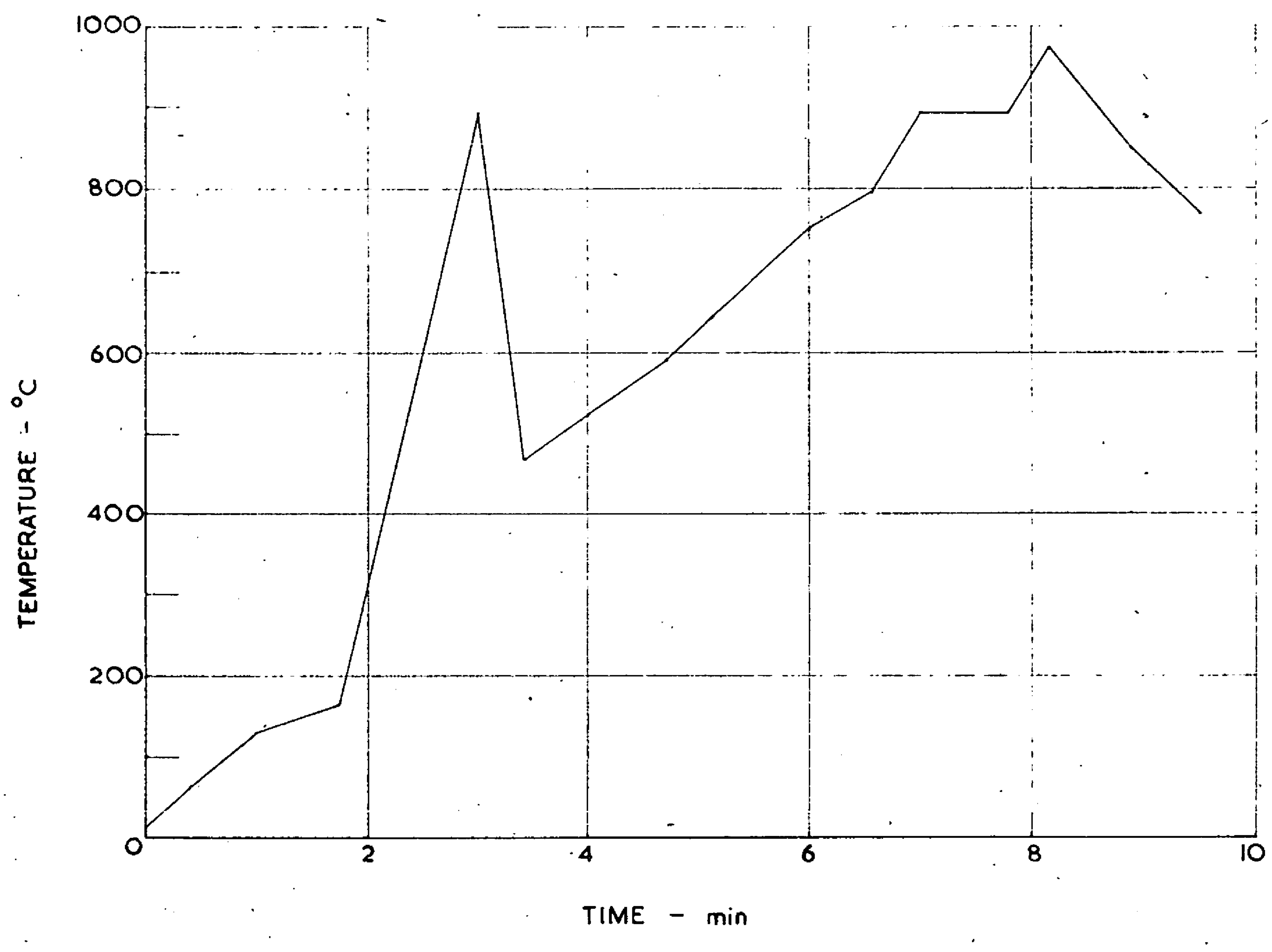


FIG. 2. AIR TEMPERATURE 2" BELOW CEILING IN LIVING ROOM.

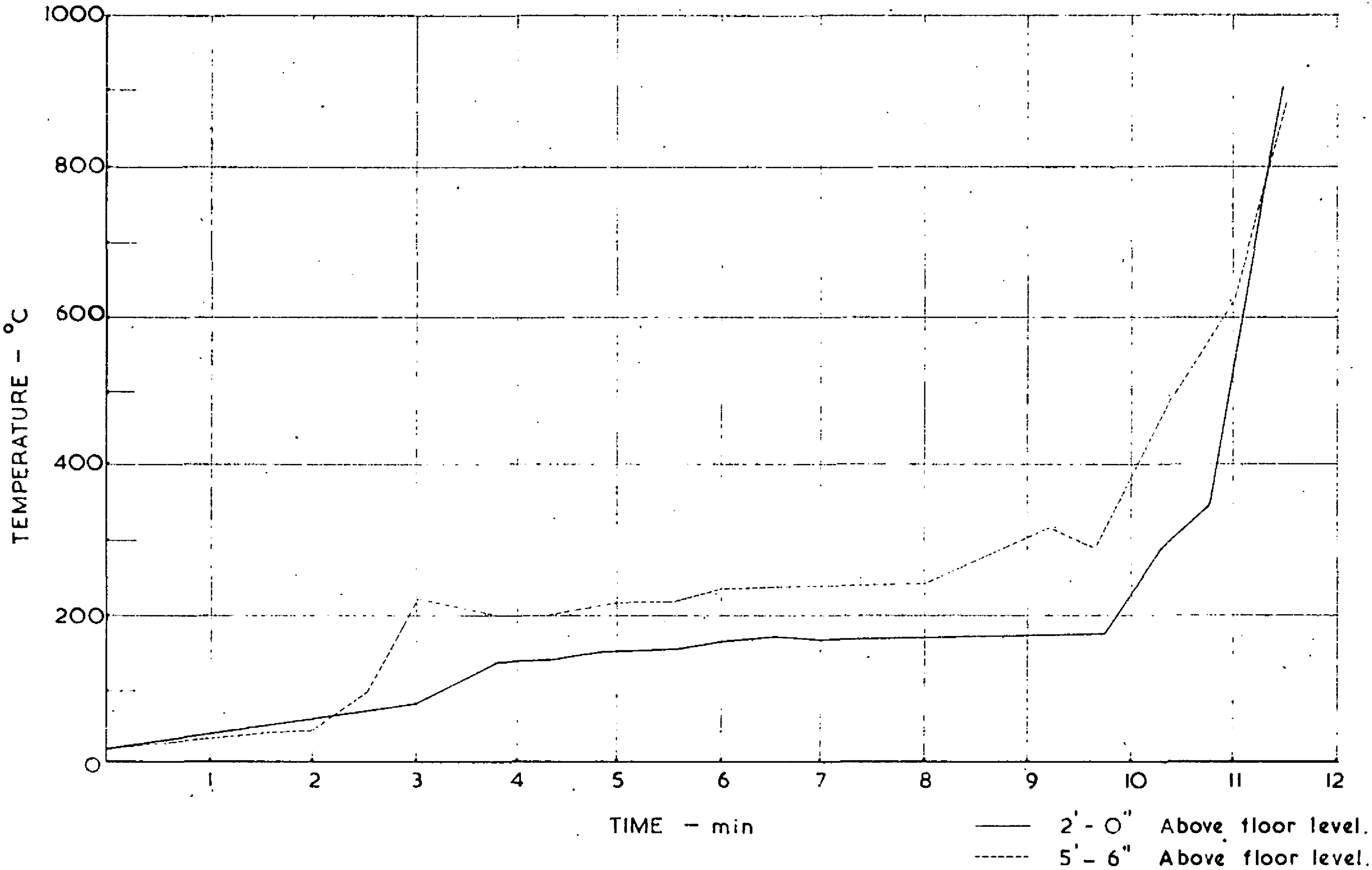


FIG. 3. AIR TEMPERATURES IN BEDROOM No. 1.

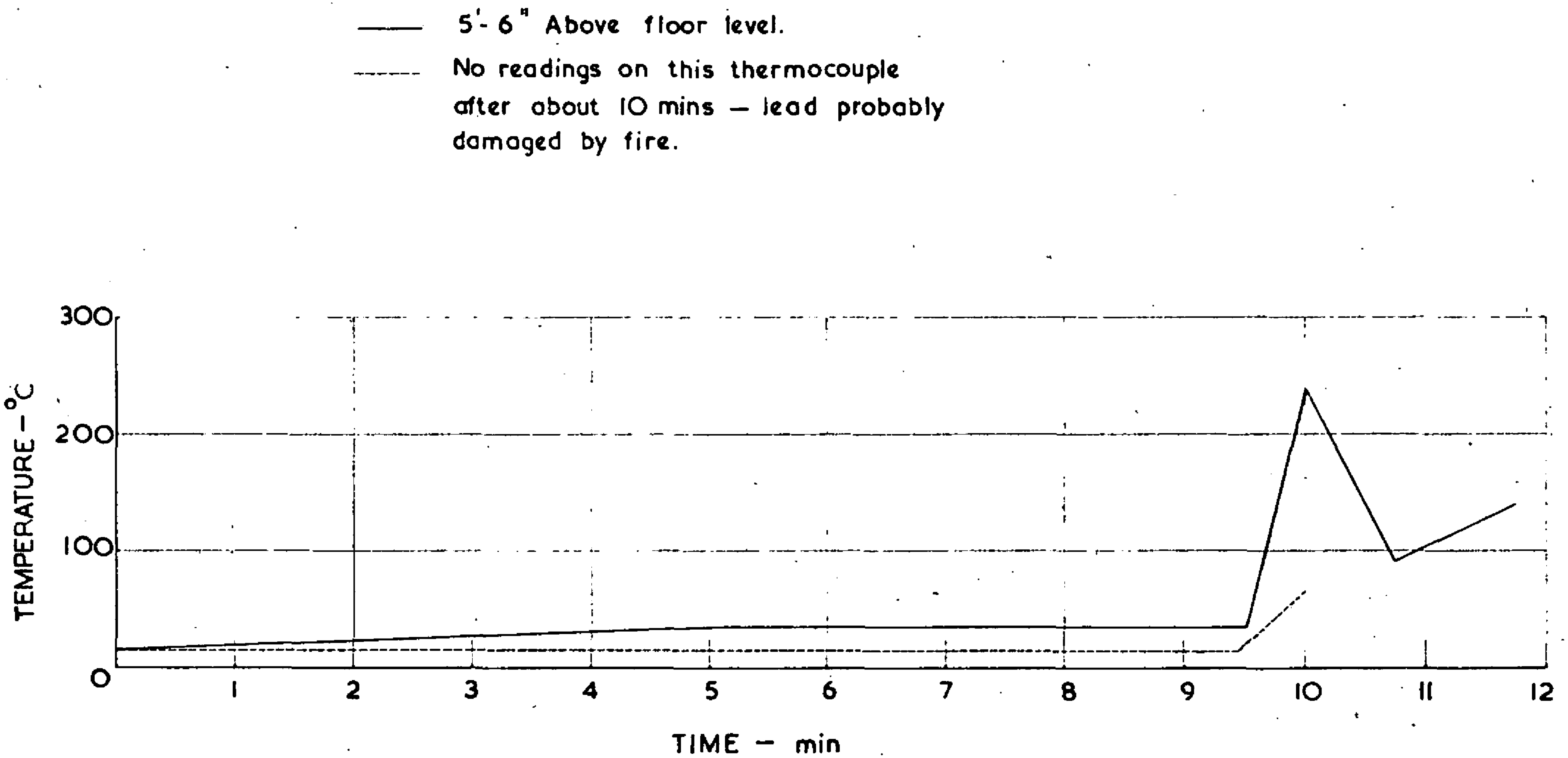


FIG. 4 AIR TEMPERATURES IN BEDROOM No. 2.

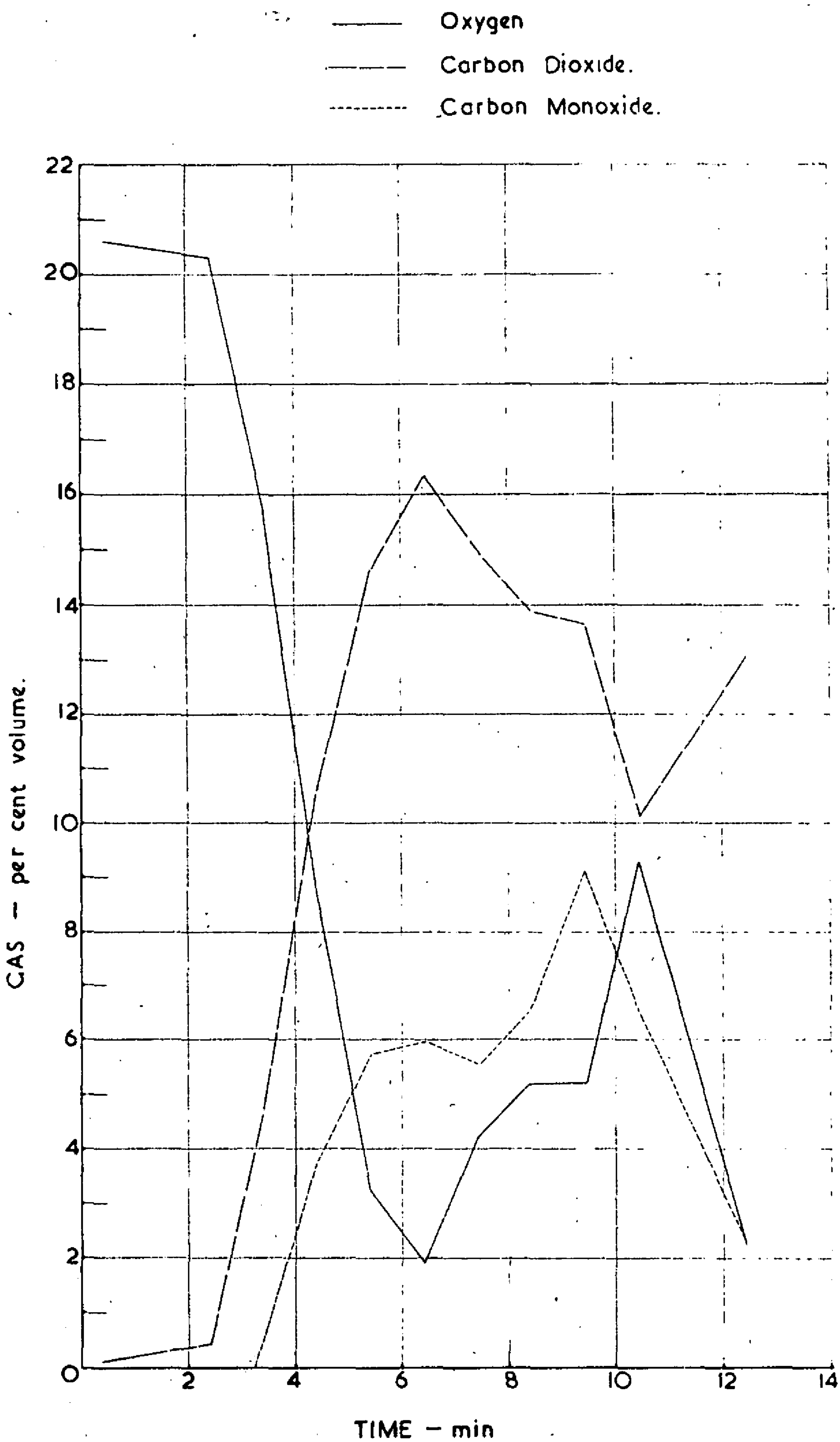


FIG. 5. VARIATION OF ATMOSPHERE WITH TIME IN BEDROOM No. 1.