Fire Research Note No.835

FIRE TESTS IN TWO CARAVANS

by

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September 1970

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F R Note No. 835
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SUMMARY

This report describes fire tests carried out in two caravans, the purpose of which was to determine the time available for escape in the event of fire. This is of considerable importance because a sleeping risk is involved.

Both caravans had identical linings and furniture. They had smoke and heat detectors fitted, and in addition one caravan had a simple sprinkler installed.

The fire in both caravans developed quickly, and the results of the tests show that the time available for the occupants to make their escape is very limited.

KEY WORDS: Caravans, Fire tests, Sprinkler, Escape means, Time.

MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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INTRODUCTION

The purpose of the two tests described in this report was to determine the time available for the occupants of a caravan to make their escape in the event of fire. This is of considerable importance because a sleeping risk is involved.

Two identical caravan shells 7.62 m long x 3.01 m wide (25 ft x 9ft 4in) equipped with all the normal items of furniture were originally made available for two previous tests by the joint action of the National Caravan Council, the Fibre Building Board Development Organization, and the Fire Service Department of the Home Office. The present tests were carried out at the request of the Home Office by the Joint Fire Research Organization.

DETAILS OF CARAVAN CONSTRUCTION

The two caravans were of identical construction. The body was of timber framing with two 2 mm (0.079 in) thick skins of untreated hardboard between 19.1 mm (0.75 in) thick battens on the walls, insulation in the cavity being provided by 19.1 mm (0.75 in) thick mat of mineral wool. The floor was of 12.7 mm (0.5 in) thick plywood and the ceiling of 2 mm (0.079 in) thick untreated hardboard. The outer skin of the roof was of 0.92 mm (0.036 in) thick aluminium sheet while insulation in the cavity was provided by 9.4 mm (0.376 in) fibre insulating board.

PREPARATION OF CARAVANS

The furniture supplied was fixed in position as shown in Fig.1. Plates 1 and 2 are internal views of the caravan showing the furniture arrangements. The cupboards and wardrobes were filled with clothing etc. while the kitchen units were filled with cardboard, magazines and timber, and books and magazines were placed on the table and settees in the lounge area. The ceiling and wall lining of each caravan was wall-paper on hardboard and this gave a Class III Spread of flame rating.

EXPERIMENTAL ARRANGEMENTS

a) Positioning of Caravans

The two caravans, one of which is shown in plan in Fig.1 were placed on an open site at the Fire Research Station. Their position was such that the long axis was North to South with the large lounge window facing North in each case. They were placed approximately 14 m (45 ft) apart and well away from other buildings.

b) Measurements made during tests

During the tests the temperature of the gases within the caravan was measured at 6 points 0.46 m (18 in) from the ceiling level, at 6 points 0.92 m (36 in) from the floor level and at 2 points 76.2 mm (3 in) from the ceiling, by thermocouples whose positions are shown in Fig.1. The two thermocouples positioned 76.2 mm (3 in) from the ceiling were regarded as heat detectors and are denoted by the letter H in Fig.1.

In addition to temperature, measurements of the following were made:

a) In one caravan a simple sprinkler system was installed. This consisted of two 9.4 mm bore (0.375 in) sprinkler heads (pendent type) each with its own pressurized water supply of 9 l at 690 x 10^3 N/m^2 (2 gallons at 100 p.s.i.) designed to operate at 67.4°C (155°F) and giving a discharge time of 25 seconds. Their position is denoted by the letters SP in Fig.1.

b) Smoke detectors of a type using an ionization chamber were fixed to the ceiling in both caravans, their position is denoted by the letters SM in Fig.1.

c) Blocks of wood were used to determine the approximate levels of radiation obtained during the test, their positions relative to both caravans are given in Fig.11.

In addition, colour and black and white photographs were taken before and during both tests, and visual observations were taken by a number of observers.

IGNITION FOR THE PURPOSE OF TEST

Since the overheating of flue pipes of solid fuel space heaters is still the cause of a considerable number of fires in caravans it was decided to simulate this situation for the purpose of these tests.

Accordingly a small electric fire element, representing the overheated flue pipe was placed at one end of a ventilated cupboard 0.61 m x 0.61 m x 0.31 m (2 ft x 2 ft x 1 ft) deep, positioned 0.92 m (3 ft) from floor level as shown by the letter C in Fig.1.

TEST RESULTS

In each test the fire was started by the electric fire element placed as described above. The door to the bedroom was left fully open and ventilation to the caravan was via the bedroom window marked 1 on the plan, the bottom of which was opened a horizontal distance of 0.23 m (9 in) and the fan light in the lounge window marked 2 which was opened a horizontal distance of 0.10 m (4 in).

The weather on the afternoon of the day of the test was misty but dry and on occasions a hazy sun could be seen. The wind was light from a south-westerly direction and the average velocity was between 0.6 - 0.9 m/sec (2 - 3 ft/sec) during the tests.

During the two tests observations were taken and the following log has been drawn up.

TEST NO. 1

Caravan fitted with sprinklers

(Start 2.45 p.m.)

Initial start was at 14.45 but owing to power failure this ignition was not sustained. The timing in the log below starts from the re-ignition time which was 15.00

Time min	Time sec	
00	00	Ignition by switching on electric fire element situated in ventilated cupboard marked C.
00	28	Smoke detector in lounge operated.
00	37	Smoke detector in bedroom operated.
01	00	Flames 0.15 - 0.46 m (6 - 18 in) high from cupboard.
02	05	Cupboard door open, and flames licking ceiling above cupboard.
03	28	Sprinkler at South end of caravan operated.
03	38	Sprinkler at North end of caravan operated.
03	48	Supply to Southern sprinkler exhausted.
03	58	Supply to Northern sprinkler exhausted.
04	05	Flames reach ceiling and begin to travel sideways.
05	20	Flames extending 0.61 - 0.92 m (2 - 3 ft) towards bedroom area at ceiling level.
07	00	Wardrobe on left-hand side of ventilated cupboard beginning to flame.
07	05	Large plume of black smoke issuing from lounge window at Northern end of caravan.
09	30	Caravan completely smoke logged, some flames coming from windows on East side.
11	00	Temperature and gas analysis equipment switched off.
11	30	All windows appeared to be cracked but most of the glass still in place.
19	20	Flames issuing from window near the door on West side.
22	05	All glass fallen out from windows.
22	25	Flames now penetrating walls on North and West sides of caravan.

TEST NO. 2

Caravan with no sprinklers

(Start 3.30 p.m.)

Time min	Time sec	
00	00	Ignition by switching on electric fire element placed as in previous test.
00	30	Smoke detector situated in lounge operated.
00	35	Smoke detector situated in bedroom operated
01	05	Flames 12 inches above ventilated cupboard.
01	30	Thin smoke layer 0.46 m (18 in) below ceiling.
01	40	Flames now licking the ceiling.
02	30	Flames extending 1.22 m (4 ft) below ceiling, smoke beginning to build up in bedroom area.
03	20	Door to ventilated cupboard well alight fallen to floor.
04	00	Black smoke layer lowering.
04	45	Dull red flames beneath smoke layer.
05	00	Caravan now completely smoke logged.
05	30	Partial flashover in lounge area.
07	30	Fire burning steadily, glass cracking, but still in place. No flaming outside the caravan.
12	00	Temperature and gas analysis equipment switched off.
12	30	Glass out and flames outside on West side. Flashover in bedroom area.
13	40	Flames 0.92 m (3 ft) long, out of central window on West side.
15	05	Lounge window at North end of caravan out, flashover in lounge area.
15	30	Flames 4.57 m (15 ft) above roof of caravan, all glass out.
18	00	Extensive fire penetration of roof and walls.

TEMPERATURE MEASUREMENTS

Fig.2 shows the overall mean temperature curve in both caravans .

The slope of this curve for the two tests is very similar and the low temperatures recorded in the early part of Test 1 are due to a slower initial build up of the fire as well as to the operation of the sprinklers in the period 3 to 4 minutes.

Fig.3 shows the mean temperature of the thermocouples which were 76.2 mm (3 in) from the ceiling at the points marked H in Fig.1. These were intended to represent heat detectors and if these had been set to operate at 65°C (149°F) then they would have given an alarm at 114 sec and 76 secs after the start of the first and second test respectively.

Figs 4 and 5 also show the mean reading of the other two pairs of thermocouples placed at the points marked H. These were at head height, 0.46 m (18 in) below the ceiling and crouching height, 0.92 m (3 ft) from the floor respectively.

These two figures show the same general picture as that of Fig.2 but since they are in the sprinklered area the effect of the water cooling is more

marked particularly in Fig.5 which is for the low level thermocouples.

Fig.6 shows the temperature curves of the individual thermocouples which were 0.46 m (18 in) from the ceiling and 0.92 m (3 ft) from the floor in the bedroom area. It can be seen from the curves that in so far as the danger is from temperature then a definite advantage can be obtained in respect of survival in the bedroom if the person concerned takes up a crouching position on the floor.

GAS ANALYSIS RESULTS

Figs 7, 8 & 9, 10 show the levels of gas concentration monitored during the two tests from the sample points indicated in Fig. 1. Due to difficulties in drawing the gas samples from the caravans to the indicators in the first test readings were not obtained during the 6-9 minute period of the first test. For this reason estimated values have been shown on the curve for this period.

COMPLETION OF TESTS

The comprehensive measurements described in this report, were as recorded in the respective logs of the tests terminated at 11.00 min and 12.00 min in the first and second tests respectively, though the caravans were allowed to burn out completely. Plates 3-9 give a visual record of the test No.1 and can be viewed in conjunction with the log.

Figs 7 and 8 show the build up of CO in both the lounge and bedroom areas. From the graphs it can be seen that after a period of 5 minutes the gas levels rise extremely quickly. Fig 9 shows the CO_2 concentration in the lounge area during the two tests and Fig.10 gives the mean values of CO concentration for the caravans.

RADIATION FROM CARAVAN

Fig 11 is a site plan of the two caravans and shows the position of the wood block radiometers used in the two tests. Table 1 sets out the radiation data obtained, and calculations have been made on two assumptions about the time of exposure namely one of 10 minutes and the other of 20 mins.

TABLE 1

Caravan Test	Position No.	Radiation Intensity (W/cm^2) assuming 10 min fire	Radiation Intensity (W/cm^2) assuming 20 min fire	Configuration factor of caravan with respect to wood block
1st	1	0.8	0.6	0.18
	2	1.1	0.9	0.31
	3	0.6	0.5	0.18
	7	0.6* 0.4+	0.5* 0.4+	0.18
2nd	4	0.8	0.65	0.18
	5	1.45	1.15	0.31
	6	0.7	0.55	0.18
	8	0.8	0.6	0.18

*Reflectivity measurement
+Reading from wood block surface temperature

The level of radiation falling on a given block divided by the approximate configuration factor gives an effective intensity for the radiation emitted by the fire of between 3 and 4 W/cm^2 assuming the whole caravan was emitting rather than just the windows alone.

This value of radiation intensity would suggest that the minimum separation distance between caravans should be 10 ft for the still air conditions which prevailed during the tests. However, the calm conditions in which the tests were carried out are relatively rare and therefore a longer separation distance should be used in practice to allow for the effect of wind on the flames emerging from a burning caravan, particularly those from the windows.

DISCUSSION

There are two factors which will control the time available for the escape of the occupants of a caravan which is involved in fires, these are the temperatures reached inside and the presence of toxic products of combustion.

There is some information available as to the temperature levels which can be tolerated for the short period which obtains while the person concerned is making his escape from the vicinity of the fire, but information concerning the limiting levels of products of combustion which can be accepted for short

periods of exposure is sparse.

LIMITATIONS DUE TO TEMPERATURE EFFECTS

Simms and Hinkley[2] have estimated that a man can tolerate an ambient temperature of 170°C for only 3 minutes when at rest and Buettner[3] has given a tolerance time of 2 minutes when parts of the body are exposed to temperatures of 150°C.

In Test 1 a temperature of 150° was reached in the bedroom in just over 7 minutes (Fig 6) but in the centre part of the lounge area this temperature was reached in 5⅔minutes. On the other hand in Test 2 the bedroom reached 150°C in 4⅓ minutes and the central lounge area in 2⅔ minutes. In Test 1 the sprinklers operated 3½ minutes after the start of the test and the cooling effect which the water spray had can be clearly seen in Figures 3, 4 and 5. It can be estimated from the graphs that if the sprinklers had not operated the temperature of 150° would have been reached in the central lounge area in 4 minutes and in the bedroom in 5½ minutes. The figures given in the foregoing were measured at head height in the caravans. Those for the crouching positions (1 metre from floor) occur after longer periods

The times to reach a temperature of 150°C (assumed here to be the limit for survival) for the various positions in the two tests are summarized in Table 2.

TABLE 2

Time (minutes) to reach limiting temperature of 150°C

Test	Centre part of Lounge area		Bedroom	
	Head height	Crouching position	Head height	Crouching position
1 With sprinklers	5⅔	8 5/6	7½	9½
1 Without sprinklers (estimated)	3⅔	5⅔	5½	-
2	2⅔	5	4⅓	5½

It can be seen from Figure 2 to 6 that the fire in Test 1 was slower in developing than in Test 2 even before the sprinklers operated. This initial difference between the two tests is the reason that an estimated figure for Test 1 without sprinklers has been given above.

From tje figures given in Table 2 it would appear that if temperature were the sole limiting factor and the figure of 150°C a correct criterion then the time available for escape in Test 1 would be some 6 - 8 minutes and in Test 2 some 3 -5 minutes. The additional time available for escape as a

result of the operation of sprinklers in Test 1 would appear to be 2 - 3 minutes.

EFFECTS OF PRESENCE OF CARBON MONOXIDE

Rasbash[4] has pointed out that although the number of toxic constituents in the products of combustion is large, nevertheless the main hazard is nearly always thought to be due to the carbon monoxide. Henderson and Haggard 5 have suggested that a level of 1 per cent of carbon monoxide can only be tolerated for 5 minutes before loss of consciousness and at higher levels this time will be shorter. Loss of consciousness means that unaided escape is no longer possible and therefore for the purpose of this test 1 per cent CO is taken to be the critical level. It is recognised that the additional presence of CO_2 and other products could well increase the hazard and make the time available for survival shorter. Rasbash[4] has suggested that the combined toxic effect of several constituents could be greater than merely additive but little is known on this point.

In Test 1 some difficulty was experienced with the analysing equipment and incorrect readings were recorded during the period 5 to 9 minutes. At 9 minutes the level of CO present was 5 per cent in both the lounge and the bedroom and it is estimated that a level of 1 per cent was reached about $4\frac{1}{2}$ minutes after ignition in both of these places.

In Test 2 the 1 per cent level of CO concentration was reached in the lounge in 4 minutes and in the bedroom in 5 minutes. The 5 per cent level was reached in the lounge in 6 minutes and in the bedroom in 7 minutes.

COMBINED EFFECT OF THE VARIOUS HAZARDS AND OVERALL PICTURE

It has already been remarked that the situation which obtains when more than one hazard exists will certainly be worse than for a single hazard but the extent of the increase in danger to life due to the simultaneous presence of both high temperature and a toxic atmosphere cannot readily be assessed. However it is fairly clear from the foregoing discussion that for escape from the fire to be possible it would have to have been completed before the 5 or 6 minute mark in both tests. In order to obtain an overall picture of the situation in the caravans during this period of the tests the sequence of the various events and situations during the first ten minutes have been tabulated in Table 3.

TABLE 3
Sequence of events, temperatures reached and CO concentration in tests

Time		Test 1		Test 2	
Mins	secs	Lounge (centre)	Bedroom	Lounge (centre)	Bedroom
0	30	Smoke detector operated		Smoke detector operated	
0	35		Smoke detector operated		Smoke detector operated
1	20			Heat detector signalled	
1	50	Heat detector signalled		Head height 50°C	
2	10				Head height 50°C
2	30			Head height 100°C	
2	40			Head height 150°C	
3	0	Head height 50°C			
3	10			Crouching 50°C	
3	30	Sprinklers operated		Head height 200°C	Head height 100°C
3	40			CO - 0.5%	
4	0	Water to sprinklers exhausted. CO 0.5%(estimated)	Head height 50°C	CO - 1.0%	Crouching 50°C
4	20				Head height 150°C
4	25			Crouching 100°C	
4	30	CO 1.0% (Estimated)	CO 0.5%		
4	40				Crouching 100°C
5	0			Crouching 150°C	
5	0				CO 0.5%
5	20	Head height 100°C		Crouching 200°C	Crouching 150°C. CO 1.0%
5	40	Head height 150°C			
6	0	Head height 200°C	Head height 100°C		CO 5.0%
6	30		CO 1.0%		
6	50	Crouching 50°C			

TABLE 3 (cont'd)

Time		Test 1		Test 2	
Mins	secs	Lounge (centre)	Bedroom	Lounge (centre)	Bedroom
7	0			CO 5.0%	
7	30		Head height 150°C Crouching 50°C		
8	10	Crouching 100°C			
8	30				
8	50	Crouching 150°C	Crouching 100°C		
9	0	CO 5.0%	CO 5.0% Head height 200°C		
9	20	Crouching 200°C			
9	30		Crouching 150°C		

CONCLUSIONS

1. The results of the tests on the two caravans as described in this report show that there was little time available for the occupants to make their escape. Both tests showed that for escape via the lounge area, if the limiting criterion was the level of toxic gases then escape had to be made before $4\frac{1}{2}$ min and 4 min after the start of Test 1 and Test 2 respectively. It is however probable that somewhat less time than those above was available due to a combined effect of temperature, smoke and toxic gases.

2. Although a simple sprinkler system can retard the development of a caravan fire to some extent, the increase in the time available for the occupants to make their escape is relatively small.

3. Smoke detectors operating about 30 secs after the start of the tests, as against $1\frac{1}{2}$ min for heat detectors, are the most effective warning device for use in caravans in view of the small total time available for escape.

4. The information obtained during the tests from the radiation data suggests that the practice which allows for a separation distance of not less than 6.00 m (20 ft) is probably of the right order when allowance is made for the effect of wind on flames emerging from the windows.

ACKNOWLEDGMENTS

The authors wish to record their thanks to Messrs C.Shore and P.Collinson for their help in preparations for the test, to Mr G.Stark for the installation of gas analysis equipment and to Mr A.J.M.Heselden for the processing and supply of radiation data.

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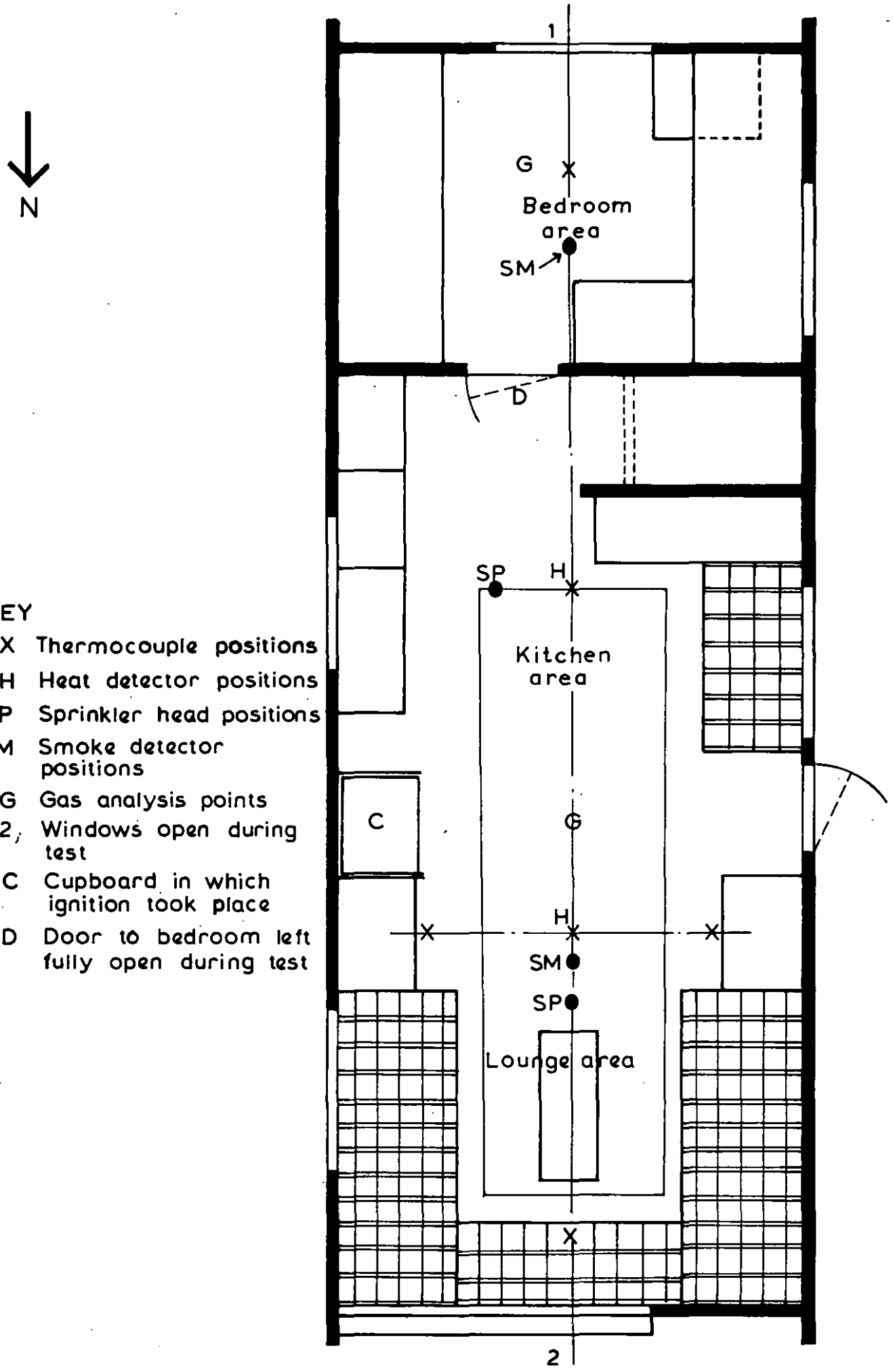


FIG. 1. PLAN OF CARAVAN

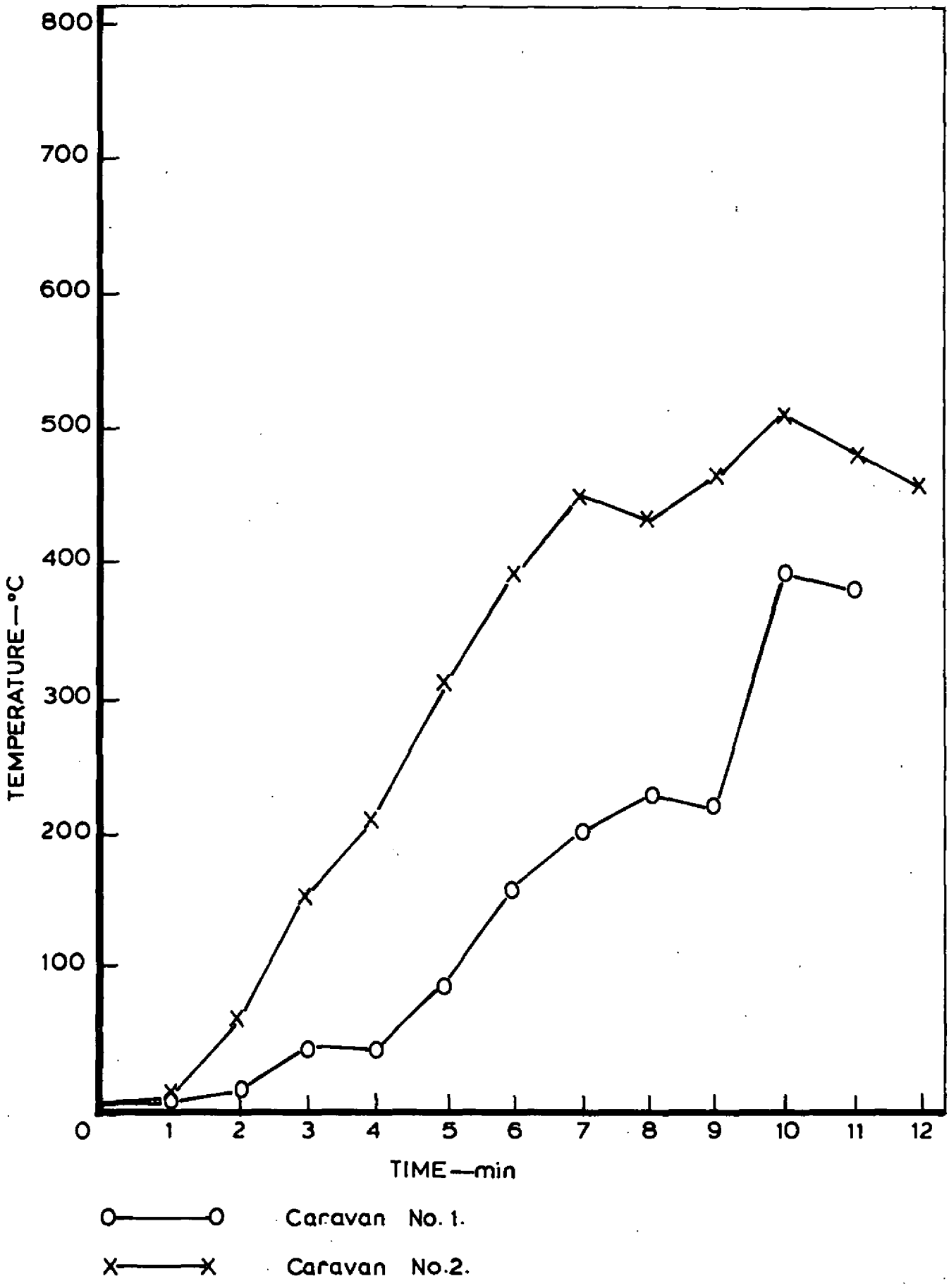


FIG. 2. MEAN TEMPERATURE IN CARAVANS

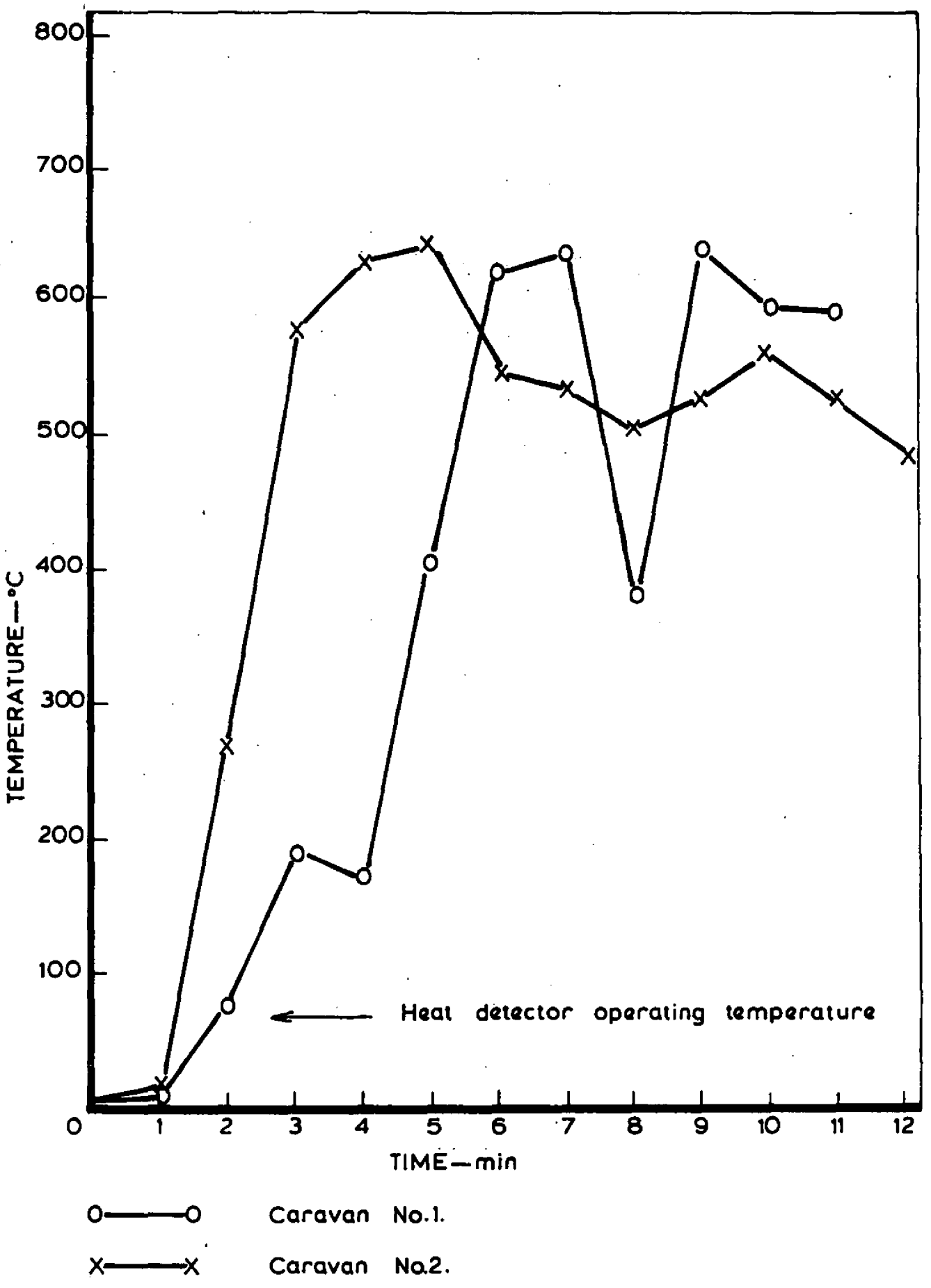


FIG. 3. MEAN TEMPERATURE RECORDED BY THERMOCOUPLES WHICH WERE USED TO REPRESENT HEAT DETECTORS

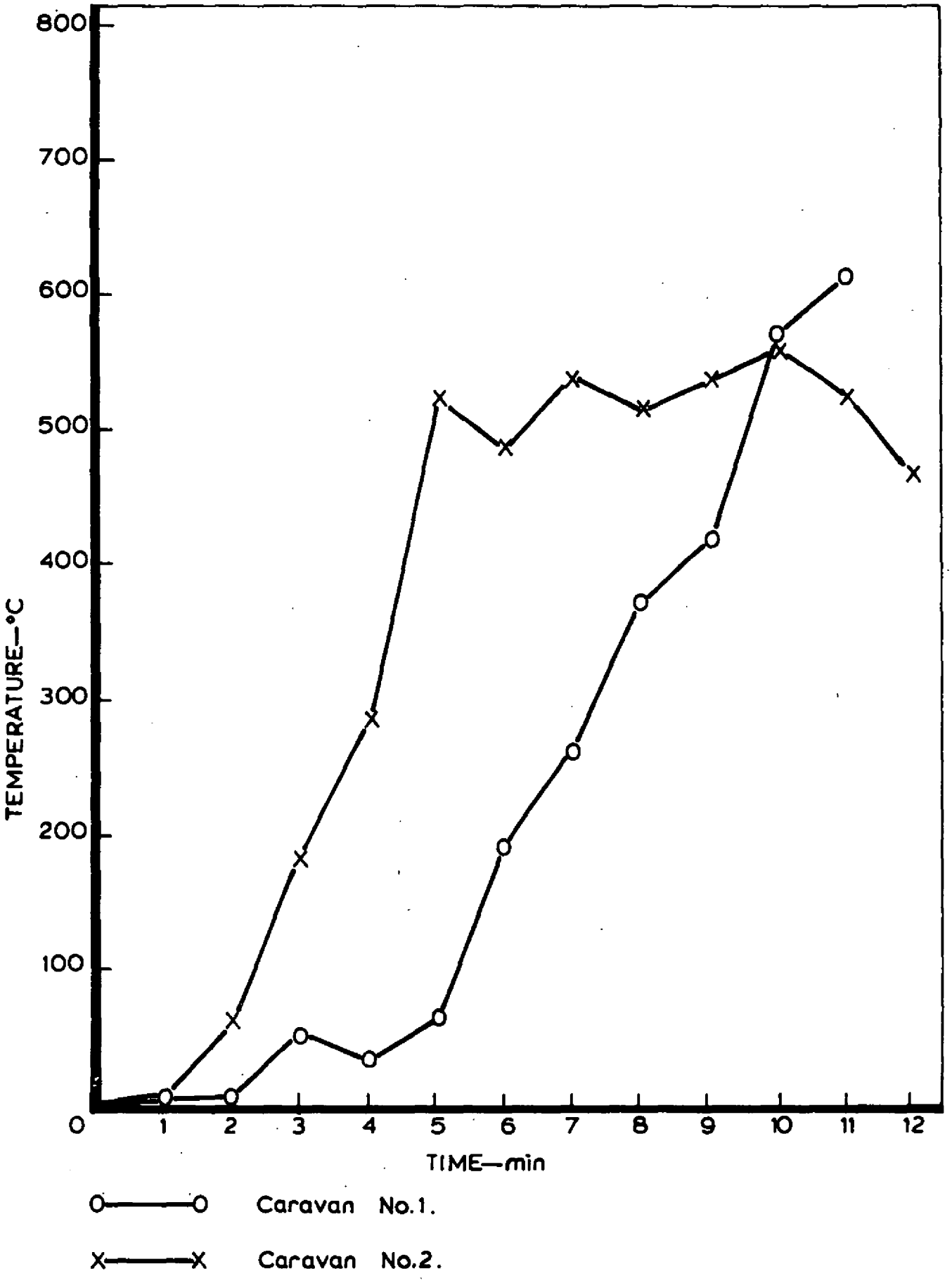


FIG. 4. MEAN TEMPERATURE 0·46m (18') BELOW CEILING IN CENTRAL LOUNGE AREA

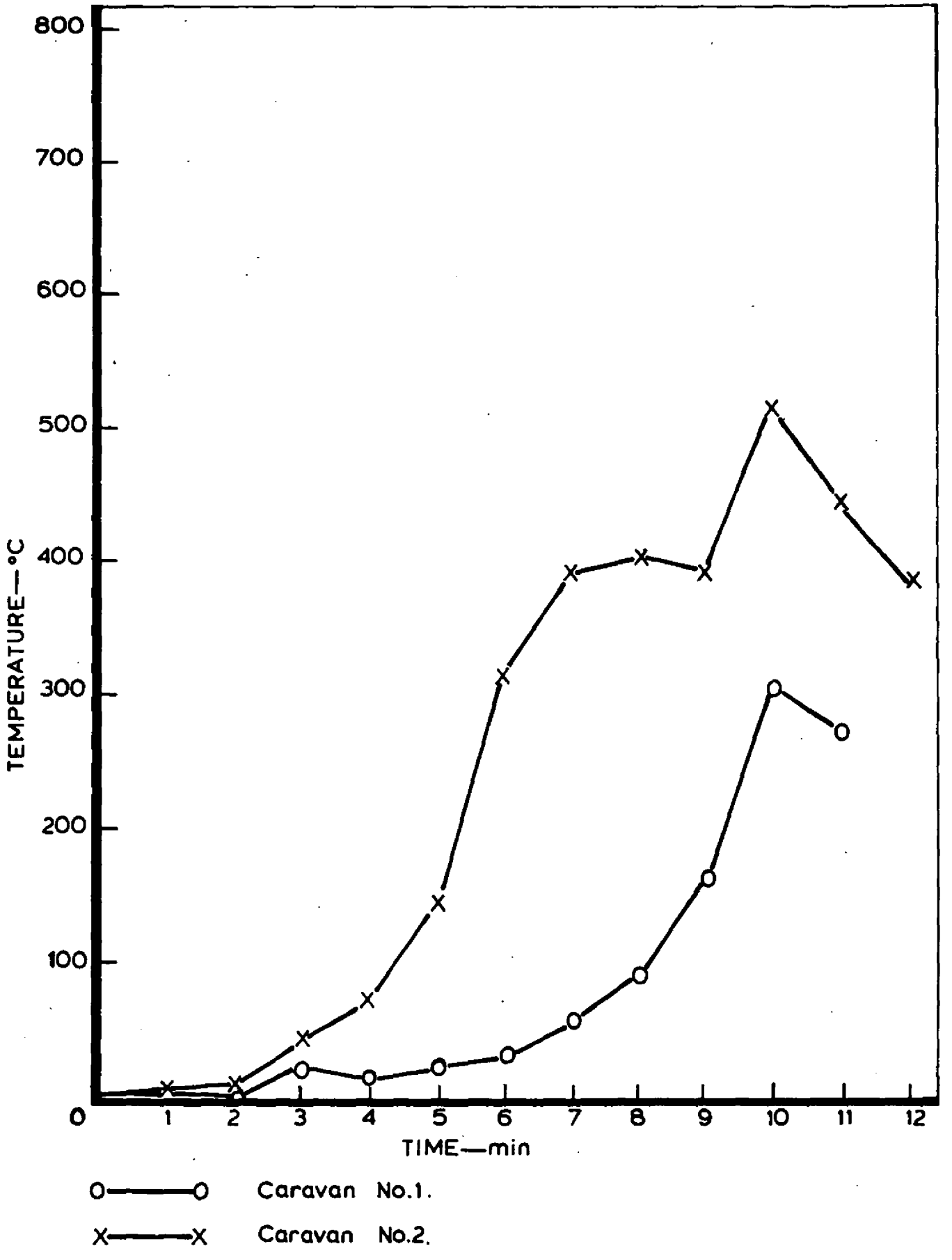
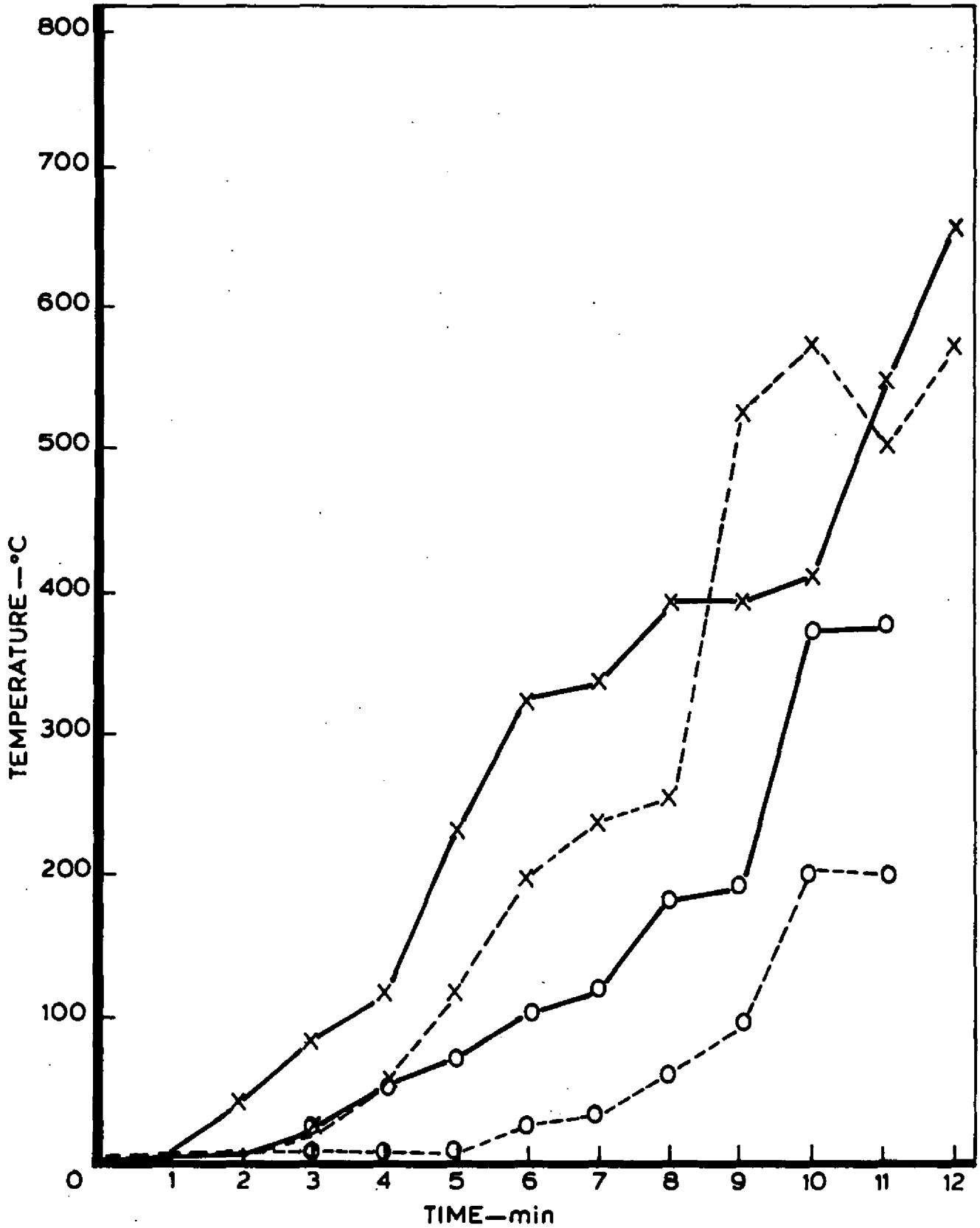


FIG. 5. MEAN TEMPERATURE 0·92m (3ft) FROM FLOOR IN CENTRAL LOUNGE AREA



Bedroom temperature, thermocouple No. 6, 0·46m (18") from ceiling

O——O Caravan No. 1.

X——X Caravan No. 2.

Bedroom temperature, thermocouple No. 14, 0·92m (3") from floor

O- - - - -O Caravan No. 1.

X- - - - -X Caravan No. 2.

FIG 6 TEMPERATURE IN BEDROOM AREA

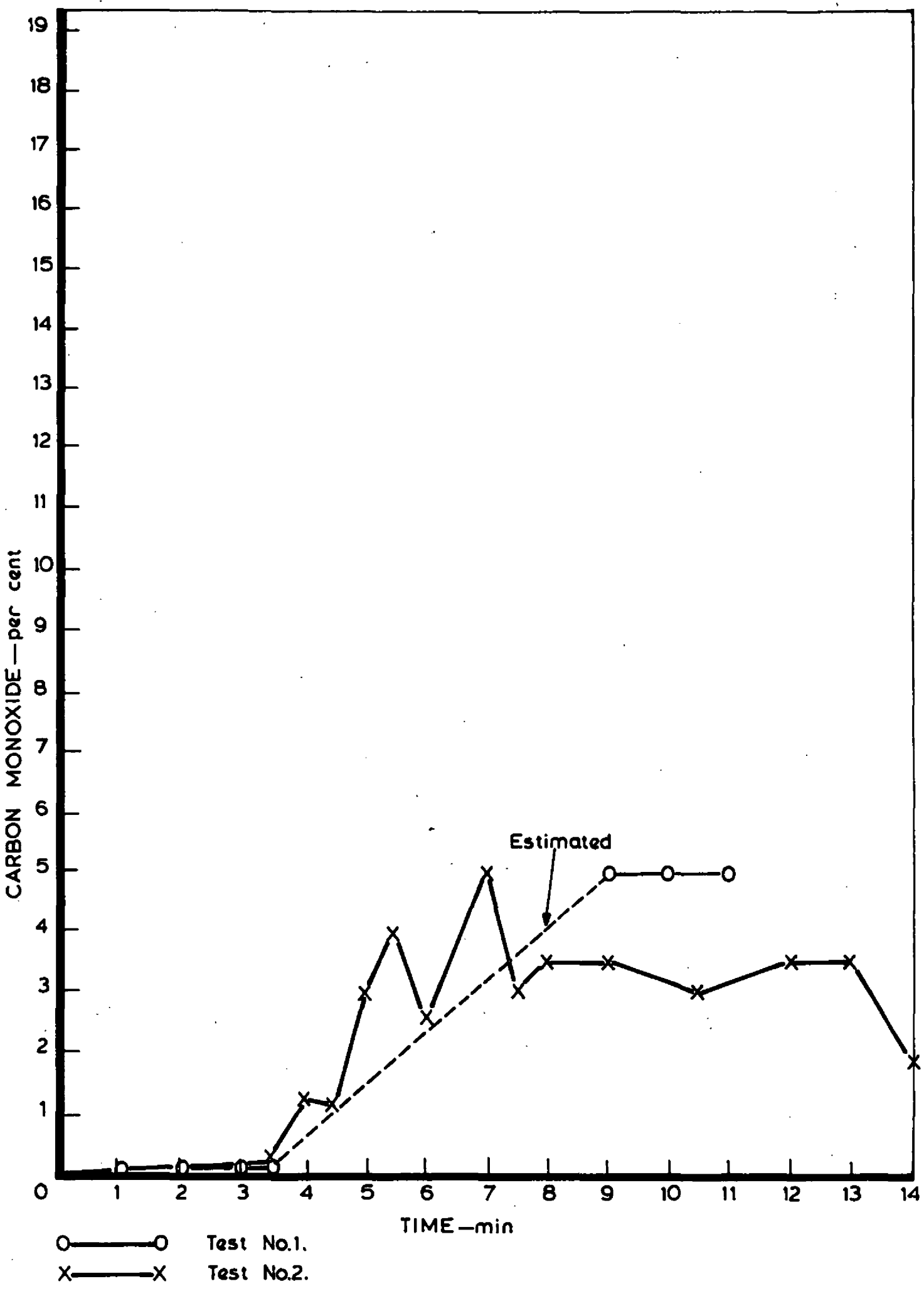


FIG. 7. PERCENTAGE CARBON MONOXIDE IN LOUNGE AREA

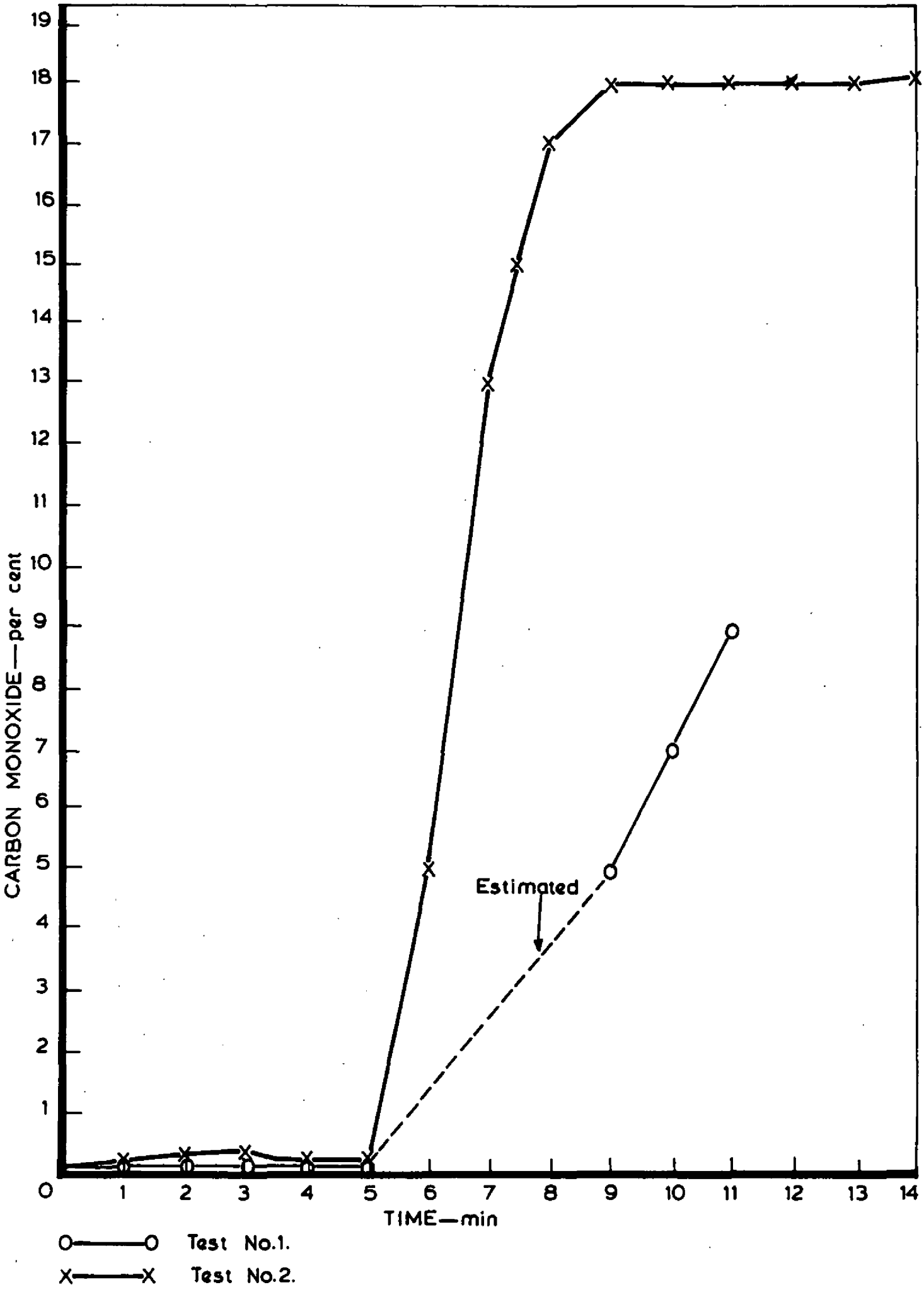


FIG. 8. PERCENTAGE CARBON MONOXIDE IN BEDROOM AREA

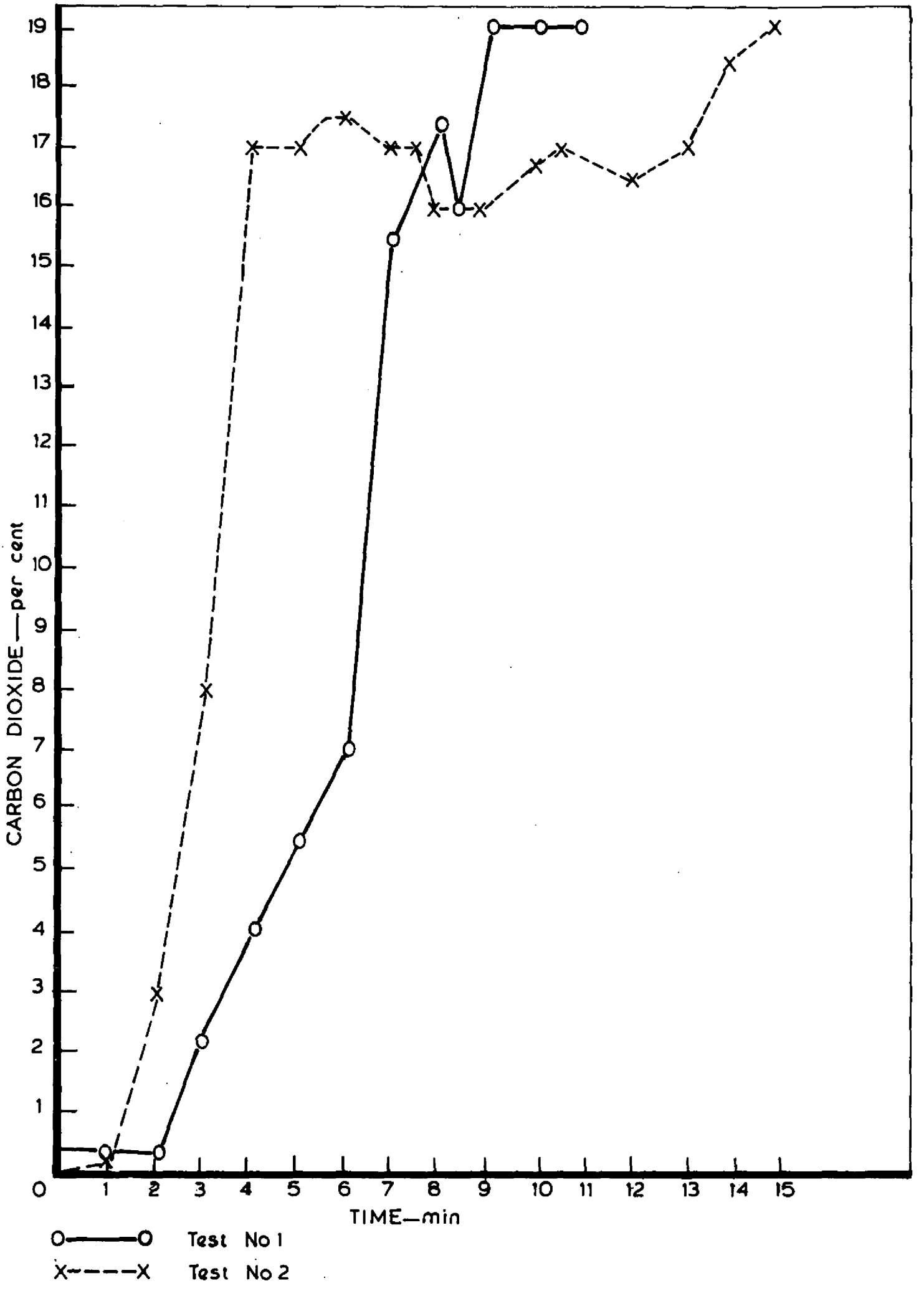


FIG. 9. PERCENTAGE CARBON DIOXIDE IN LOUNGE AREA

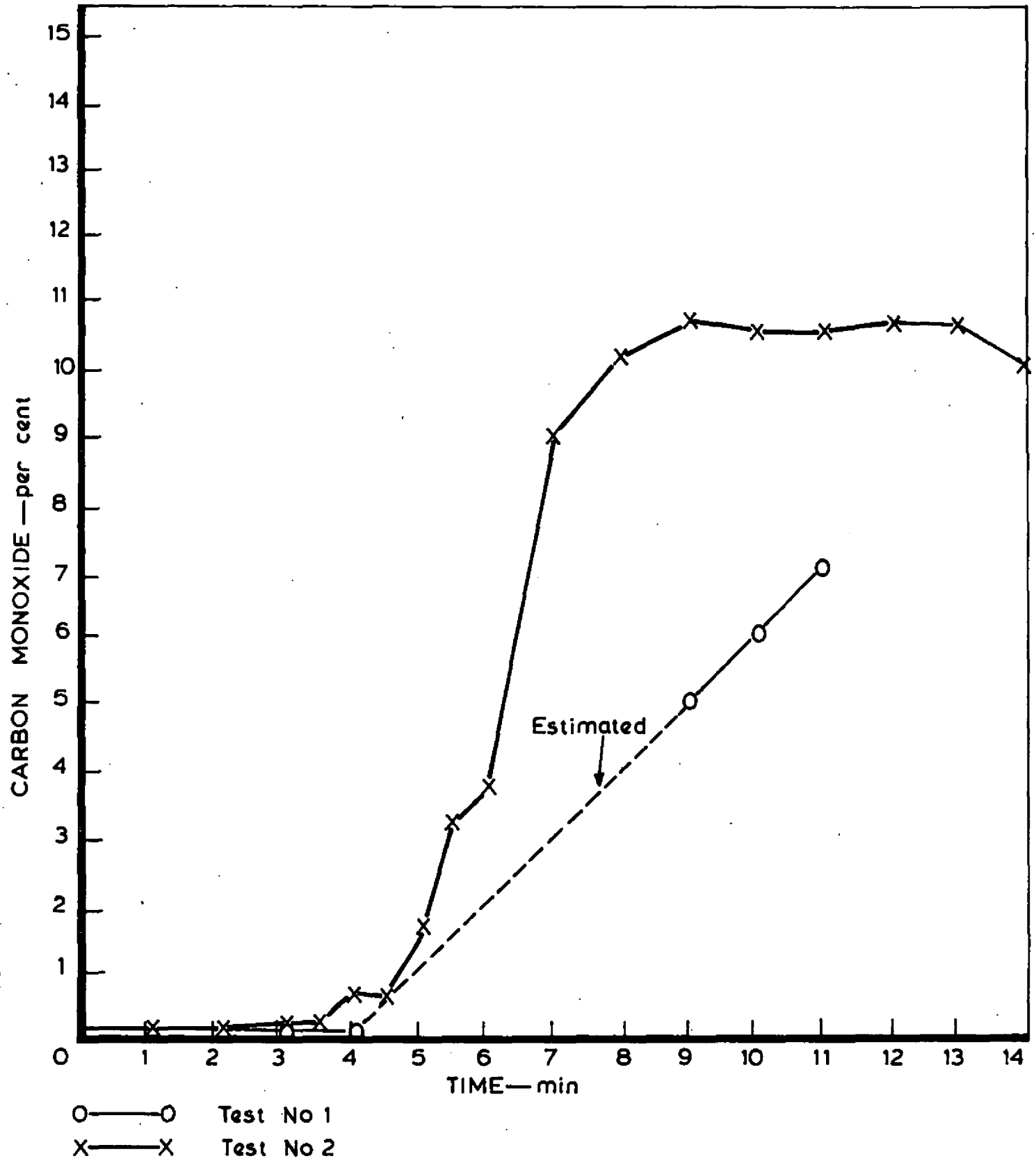


FIG. 10. MEAN PERCENTAGE CARBON MONOXIDE IN CARAVAN

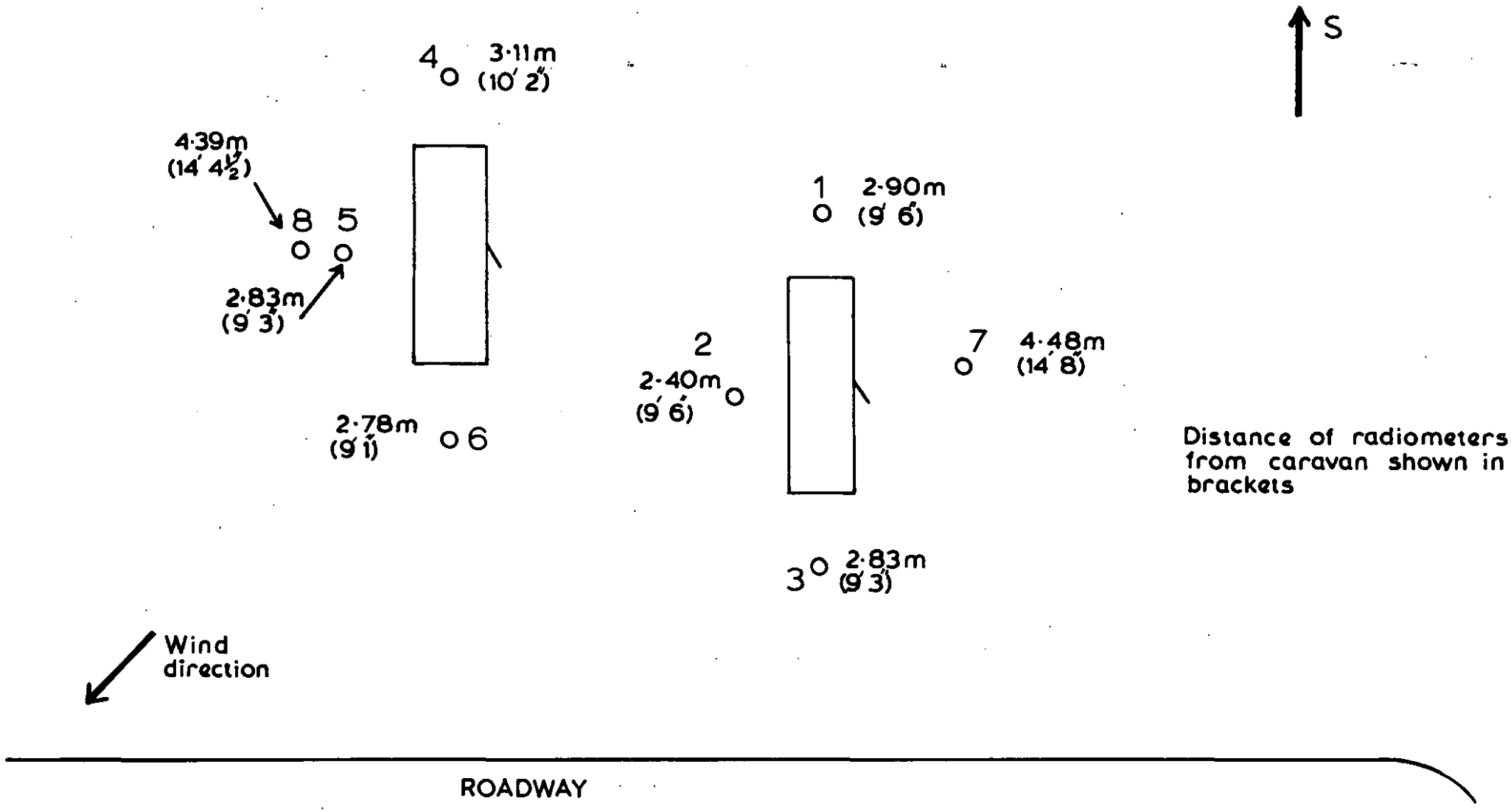


FIG 11 DIAGRAM SHOWING POSITION NUMBERS AND DISTANCES OF WOOD BLOCK RADIOMETERS FROM CARAVANS

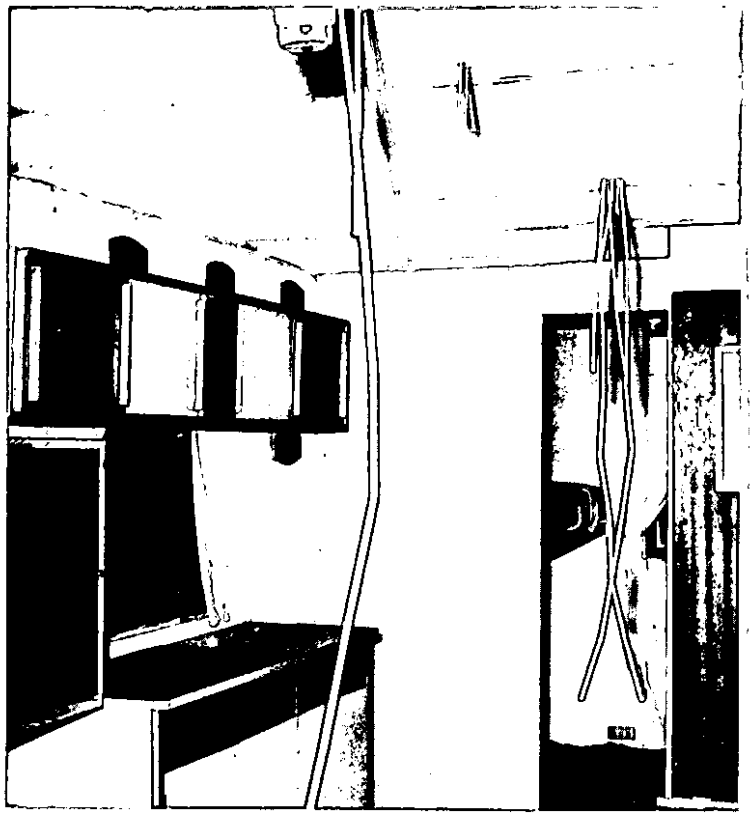
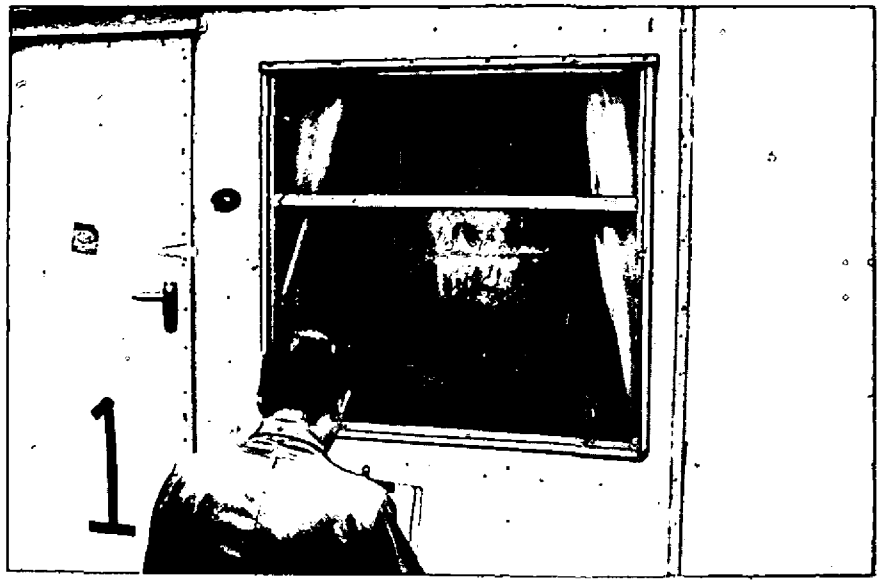
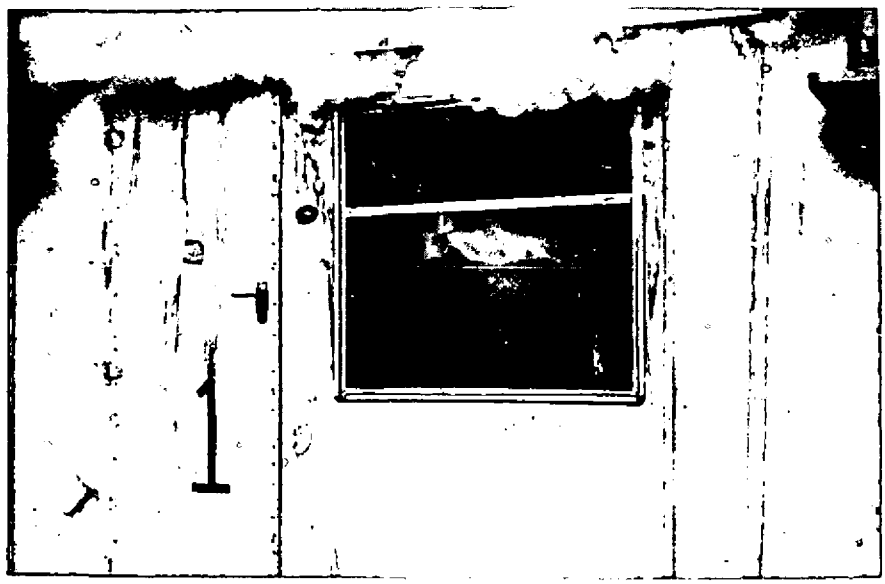


PLATE 1

PLATE 2
INTERIOR OF CARAVANS AND FURNITURE ARRANGEMENTS



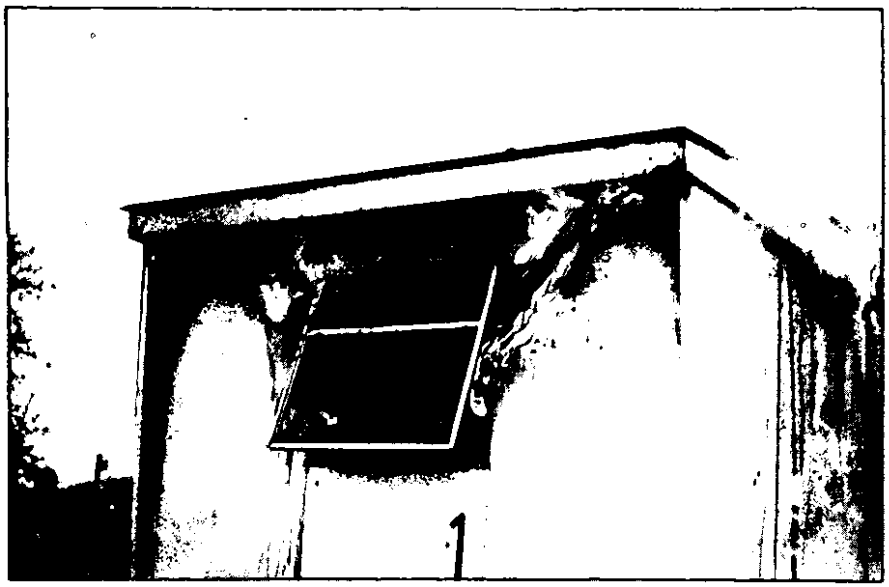
TEST NO. 1. 1 min AFTER START OF TEST
PLATE 3



TEST NO. 1. $3\frac{1}{2}$ min AFTER START OF TEST
PLATE 4

TEST No. 1. 5 min AFTER START OF TEST
PLATE 5

TEST NO. 1. 7 min AFTER START OF TEST
PLATE 6



TEST NO. 1. 11 min AFTER START OF TEST
PLATE 7

TEST NO. 1. 19 min AFTER START OF TEST
PLATE 8

TEST NO. 1. 23 min AFTER START OF TEST
PLATE 9