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FIRES IN MODEL ROOMS

by

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Summary

$^1/_5$ and $^1/_{10}$ scale models of a traditional type room were used to study the mechanism of the growth of fire. In the first of two series of experiments the spread of fire in a furnished room was studied. In the second series the fire was started in the only major piece of furniture present and observations were made of the intensity of radiation, the velocity and final distance of spread of flame on the floor.

1. Introduction

In the build-up of a fire in a room of a typical dwelling house, a stage is reached when the contents of the room have been sufficiently heated for the fire to spread very quickly, and involve the whole room. This stage is known as the 'flash-over'. Before 'flash-over' is reached one person with a stirrup pump could control the fire; after this, extinguishing the fire would be much more difficult. Thus the control of a fire in a room depends largely on the time taken for the fire to reach the 'flash-over' stage. This, in turn, is controlled by such factors as the aeration of the room, the manner and place in which the fire starts, the type of flooring, walls and ceiling in the room and the type and placing of the furniture. To investigate the effect of these factors in a full-scale room would entail such a large number of tests as to be impracticable. It was decided therefore to examine the possibility of using small-scale models for this purpose.

2. Particulars of room and furniture

Models of a traditional type room, 18 ft x 12 ft x 9 ft were constructed from asbestos wood. A plan of the room is shown in Fig. 1 with the position of the furniture indicated. The measurements shown in Fig. 1 are those of a full-scale room, and the models were constructed with these linear dimensions scaled to $^1/5$ and $^1/10$. With the exception of the thickness of the material all the dimensions of the furniture in the different sized models were scaled linearly. The thickness was kept constant for $^1/10$ and $^1/5$ scales, and was made as nearly as practicable the same thickness as full-scale. Table 1 shows the full-scale dimensions of the furniture, and the materials used. The moisture content of the wood varied between 11 and 14 per cent.

12

Table 1

Particulars of furniture used in tests

urniture	Full-scale dimensions	Thickness and materials used	Weight full-sca (lb)
board (1)	3ft 4 in. x 2 ft x 6 ft 10 in.	Front - $\frac{1}{4}$ in. fibreboard Sides - $\frac{1}{2}$ in. fibreboard Back and top - $\frac{3}{4}$ in. wood	83
le	top - 5 ft 10 in. x 4 ft 7 in. height - 2 ft 6 in.	Top - $\frac{3}{4}$ in. wood legs - $\frac{3}{4}$ in. square	52
chair	seat - 3 ft 0 in. x 1 ft 6 in. height - 2 ft 6 in.	Back - $\frac{1}{2}$ in. wood Remainder - $\frac{1}{2}$ in. fibreboard	12
irs	back 2 ft 6 in. x 1 ft 3 in. seat 1 ft 3 in. square	$\frac{1}{2}$ in. wood	6 each
board (2)	5 ft 10 in. x 1 ft 3 in.	One board of $\frac{1}{2}$ in. wood	9

The floor of the models was of $\frac{7}{8}$ in. deal which rested on the asbestos wood base. The windows in the $^1/_5$ scale model consisted of 3 panes of ordinary window glass, and in the $^1/10$ scale of 2 panes. It had been found in a previous series of tests (1) that because of the means of support and the small area of glass concerned, the panes did not always fall out when they cracked. It was decided, therefore, to remove them on cracking to simulate conditions in the full-scale.

3. Some preliminary experiments on aeration

In all the experiments the fire was started in the position shown in Fig. 1 by two small pieces of metaldehyde. When the windows were completely closed the fire did not develop. Tests were therefore carried out to discover the effect of aeration.

The room was furnished with cupboard and armchair only and tests were carried out with the windows of both $^1/5$ and $^1/10$ scale models open 1 in., 2in., 3 in. and 4 in. and fully open. When the windows in either model were less than 4 in. apart, consistent results were not obtained. For instance, in one experiment on the $^1/5$ scale model with the windows open 2 in., the fire developed, whereas in some tests with the windows open 3 in. the fire did not develop. In all the tests on both scales with the windows open 4 in. or more the fire developed similarly and the results were repeatable. It was decided, therefore, that the windows should be 4 in. apart in both $^1/10$ and $^1/5$ scale rooms.

A possible reason for the unpredictable behaviour of the fire when the windows were open less than 4 in. is that the moisture content of the furniture varied between about 11 and 14 per cent. Small deviations in moisture content which would make little difference when the air supply was plentiful, may be very important near the critical level of aeration.

4. Results

4.1 Furnished rooms

There were three tests on the $^1/_5$ scale and three on the $^1/10$ scale room. Temperatures, measured by thermocouples at the positions shown in Fig. 1, were recorded throughout. These temperature records are shown in Figs. (2 and 3).

The development of the fire followed the same pattern in all the tests. During the first 8 or 9 minutes the temperature gradually increased until the fire was well established in the cupboard and chair. As flames from the cupboard spread across the ceiling the windows cracked and were removed. This generally occurred between 8 and 11 minutes after ignition. Once the windows were removed the fire burnt more fiercely and a corresponding temperature rise could be observed (Figs. 2 and 3). About this time, flames began to spread along the floor from the initial fire until they reached the table, which had already been heated by the radiation from the flames on the ceiling. In no test was the table ignited spontaneously. The next stage of development was the spread of flame on the floor underneath the table. Once this had started the mutually supporting radiation from the underside of the table and the floor produced a fire which quickly involved the whole room. Fig. 4 shows the fire in a $^1/5$ scale room in various stages of development.

'Flash-over' is quite definite, and a sharp temperature rise which can be seen in Figs. (2 and 3) is associated with a rapid increase in flame. Before this stage the flames have spread over quite a large area of floor but have died out behind the flame front, leaving the wood covered with a thin layer of charcoal. When the 'flash-over' is reached flames reappear on this part of the floor. The times at which the main features of the fire occur for the six tests are listed in Table 2, together with the times for Test 24, in which the windows were left fully open. Under this condition it took the fire slightly longer to reach the 'flash-over' stage.

Table 2

Times (min) of occurrence of the main features of the fires

Test No	Scale	Windows crack			Table alight	Chair(1) alight	Chair (2) alight	Cupboard(2) alight	All room involved
18	$^1/10$	9.45		9.20	11.50	11.50	15.40	16.00	16.30
19	$^1/10$	11.20		11.20	13.20	14.25	16.30	16.50	17.30
22	$^1/10$	10.10		15.50	10.00	16.20	16.40	17.00	17.30
20	$^1/5$	7.30	11.45	9.0	10.15	14.20	14.20	14.20	15.00
21	$^1/5$	9.30	10.20	10.15	12.00	14.45	14.45	14.45	15.30
23	$^1/5$	8.30	8.10	10.50	12.05	18.00	18.15	18.25	18.45
				Test 24 with windows fully open					
24	$^1/10$				15.20	18.45	18.47	19.15	19.20

The picture of the development of fire in a room of this nature which is given by the models may be compared with the results of some full-scale tests done at the Building Research Station in 1943. A plan of this room, showing the distribution of furniture and the rate of spread of fire in one of these tests, is given in Fig. 5. Although the arrangement of the furniture and the ventilation are slightly different in the small-scale experiments, the main features of the problem are the same.

The fire was started in a major piece of furniture, and again, the development of the fire may be split up into three phases. The first phase is the build-up of the initial fire, which from Fig. 5 seems to have taken about 6 minutes. Secondly, the fire spread along the untreated deal floor until it reached another major piece of furniture, the table, about 12 minutes after ignition. The third phase was the establishment of the fire in the table, and then the rapid spread to involve the whole room in $17\frac{1}{2}$ minutes.

By comparing the times of occurrence of the main features of the fires in the models, (Table 2.), with those of the full-scale room indicated in Fig. 5, it can be seen that the mechanism of development of the fire in the model rooms is the same as in the full-scale test.

4.2 Partially furnished rooms

The final distance and velocity of spread of flame on the floor from the initial fire were determined using model rooms. For these tests no furniture other than that normally used for ignition, that is the cupboard and armchair, was included. Slight modifications to the cupboard were made for these tests to simulate more accurately the full-scale furniture. The cupboard was made of wood $\frac{3}{4}$ in. thick, except for the front and the top which were of $\frac{1}{8}$ in. plywood.

An attempt was made in these experiments to determine the intensity of radiation falling on the floor, by using gold-disc thermocouples, mounted parallel to and about $\frac{1}{2}$ in. above the floor. These gold discs were placed in the same relative positions in the $^1/10$ and $^1/5$ scale rooms and were removed before the flames reached them. The positions of the gold discs together with the results of one of these tests are shown in Fig. 6. Table 3 gives the final distances and the velocities of spread of flame in the tests.

Table 3

Final distances and velocities of spread of flame in tests (43 - 47)

Test No.	Scale	Time from ignition to start of spread (min)	Mean rate of spread (in./min)	Absolute distance (in.)	Final distance of spread related to full-scale. ft	in.	mean ft in.
43	$^1/10$	7.25	$^2/3$	8	6	8	
44	$^1/10$	6.40	1	$6\frac{1}{2}$	5	5	6 10
46	$^1/10$	7.00	1	10	8	4	
45	$^1/5$	9.55	2	16	6	8	$6\ 5\frac{1}{2}$
47	$^1/5$	5.30	2	15	6	3	

It can be seen from Table 3 that the distances of spread related to full-scale in the 1/5 and 1/10 scale models are of the same order, and that the mean velocity of spread in the 1/5 scale model is approximately twice that in the 1/10 scale. These results would be expected if the intensity of radiation at relative points on the floor of the different scale models were the same.

The output from the three gold discs in Tests (43 - 47) is shown plotted against time in Figs. (7, 8 and 9). Although there is some variation in the results from test to test in the same scale, and between 1/5 and 1/10 scale tests, the rate of rise is similar, and there is the same order of response from the gold-disc thermocouples in both scales. Some of the deviations near the end of the graphs are due to the difficulty in removing the gold discs as the flame approaches along the floor.

One of the gold discs was calibrated in front of a radiation panel, under conditions as nearly as possible the same as in the tests. The gold disc was mounted parallel to a piece of wood with the polished side about ½ in. from the wood, and arranged so that it could be moved along a line perpendicular to the centre of the lower edge of the radiation panel. The radiating temperature of the panel was found by using a total radiation pyrometer, and the intensity of radiation falling on the gold disc correlated with the output from the gold disc.

It can be seen from Figs. (7 and 8) that the intensity of radiation just before removal of the gold discs is generally in the region of 0.15 to 0.20 cal/cm^2/sec, which compares with the value given by Pickard et alia [2] of 0.13 cal/cm^2/sec for the threshold intensity for spread of flame on Columbian Pine.

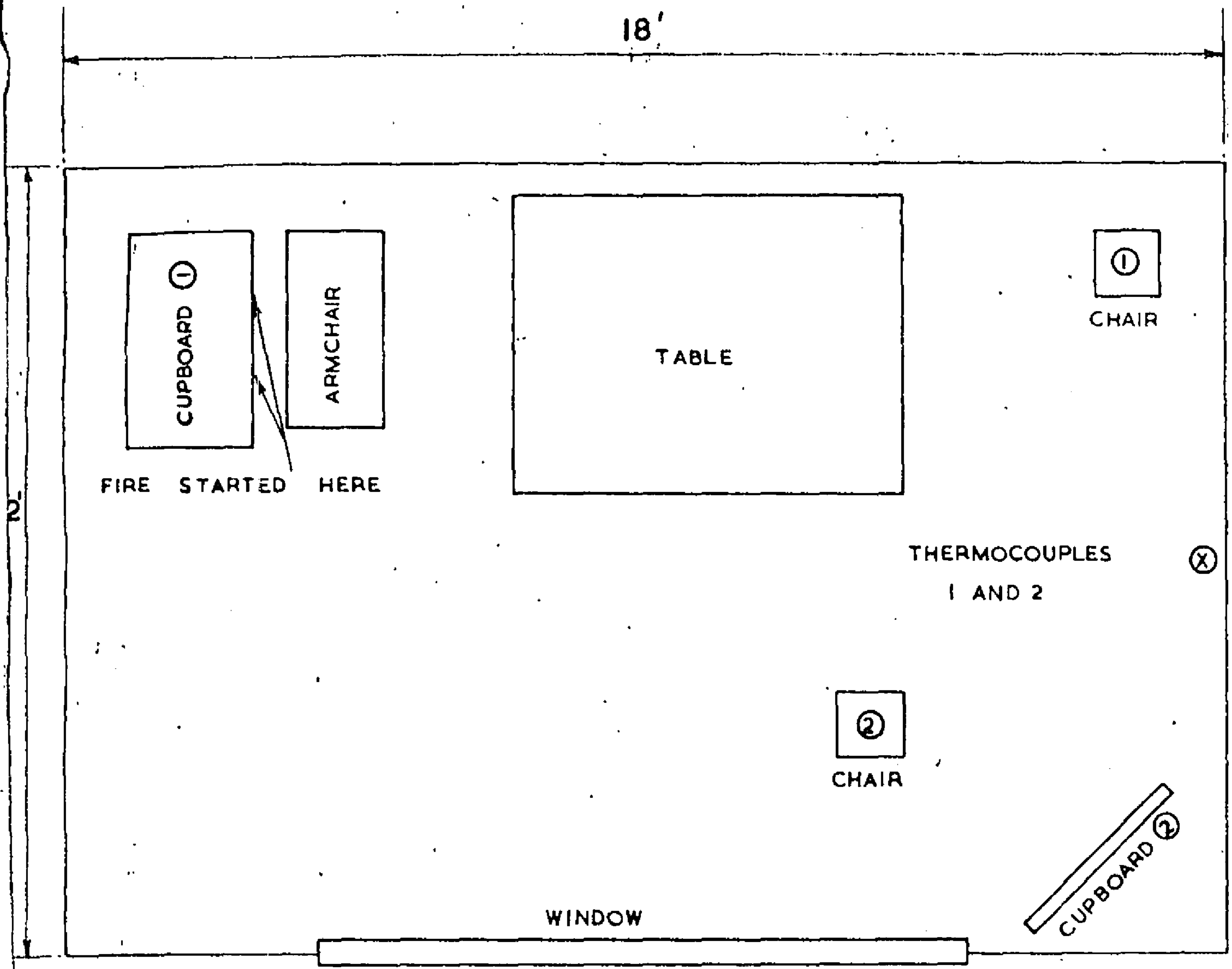
5. Conclusions

The tests outlined in this paper show that the devlopment of fire in a room can be simulated in small-scale models. This technique can therefore be used to investigate the influence of various factors such as type of wall linings and efficacy of various fire-retardant treatments, on the development of fire. An example of the possibilities of this method may be seen from Table 3. It is clear that if there is a major piece of furniture within 6 feet of the primary fire in this type of room, there is every possibility of the whole room being involved.

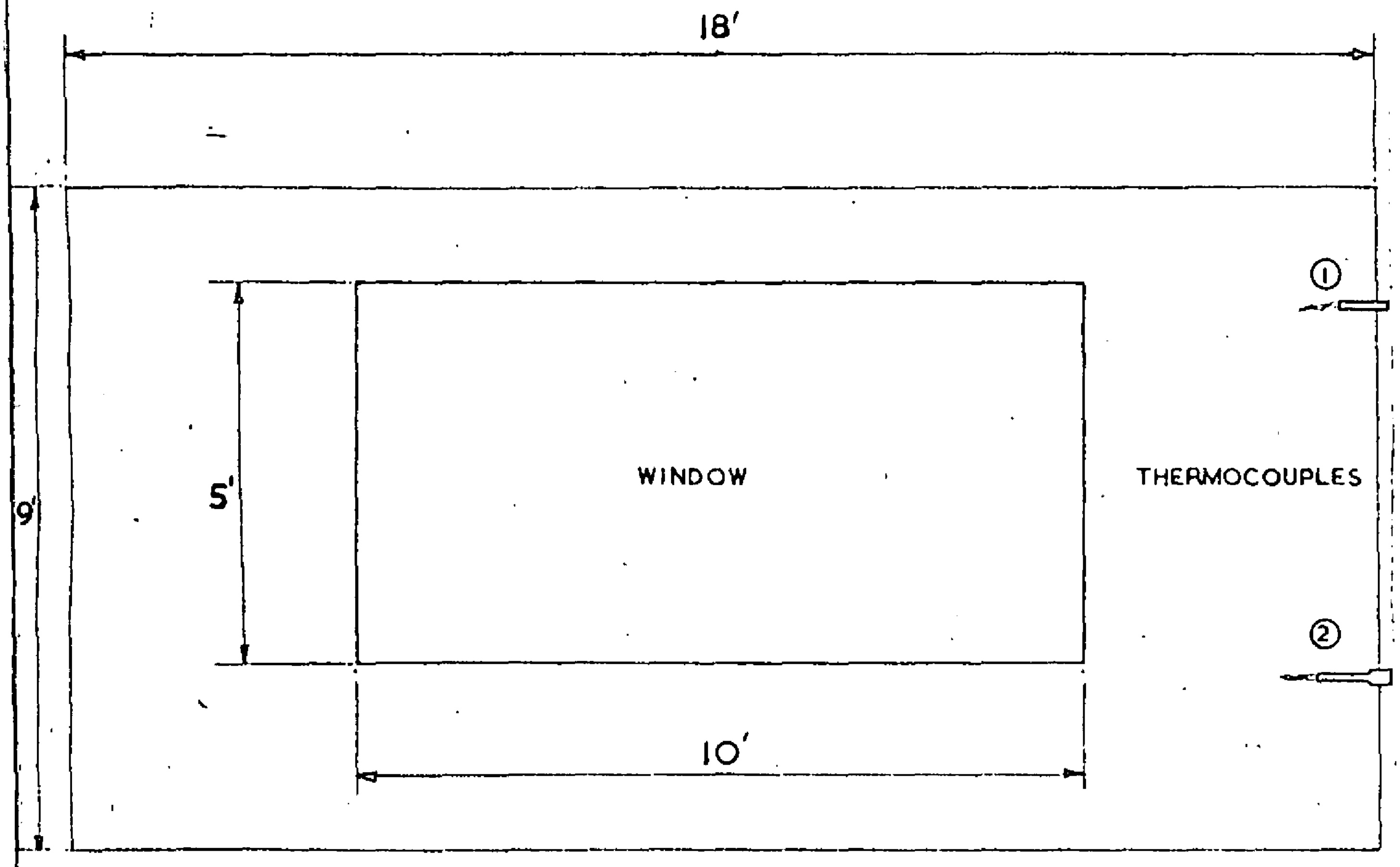
References

(1) D. Hird and C. F. Fischl. 'Fires in model houses'. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization. F.P.E. Note No. 72/1951.

(2) R. W. Pickard, D. L. Simms and J. E. L. Walters. 'Ignition of wood coated by some common paints'. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization. F.P.E. Note No. 61/1951.



PLAN OF ROOM WITH FURNITURE.



FRONT ELEVATION OF ROOM.

FIG. 1.

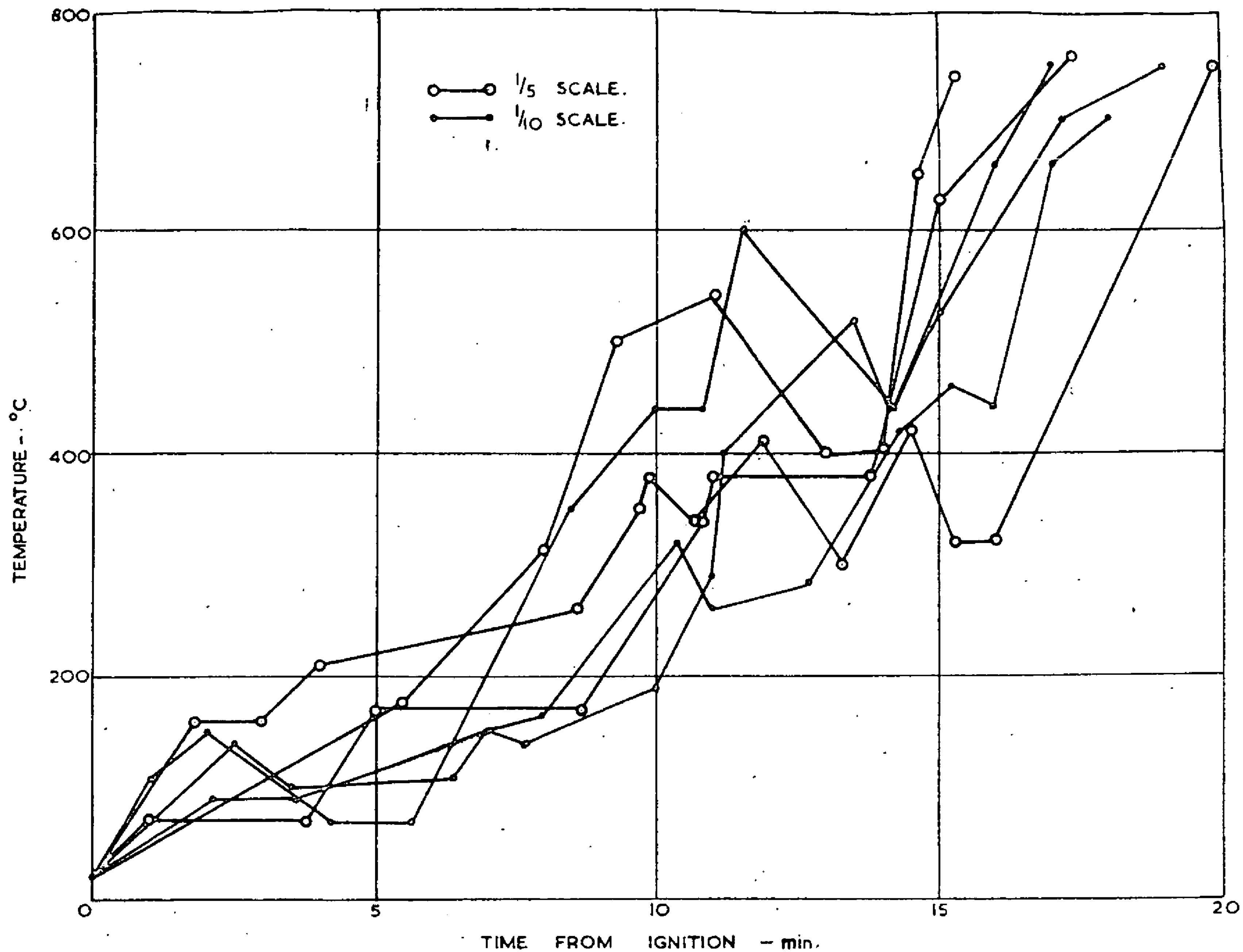


FIG. 2. TEMPERATURE RECORDS OF TESTS 18-23. MEASURED BY THERMOCOUPLE (1) (SEE FIG. 1.)

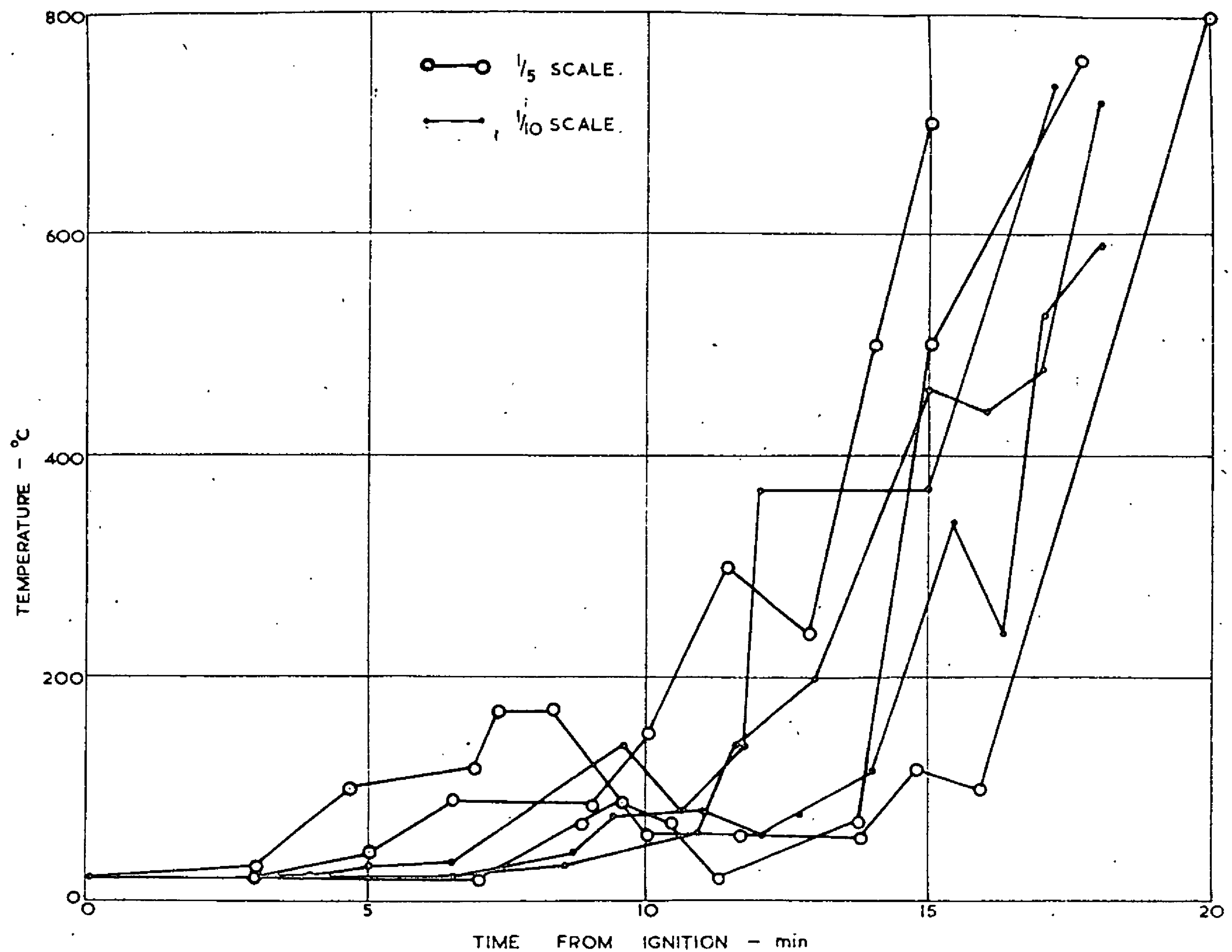
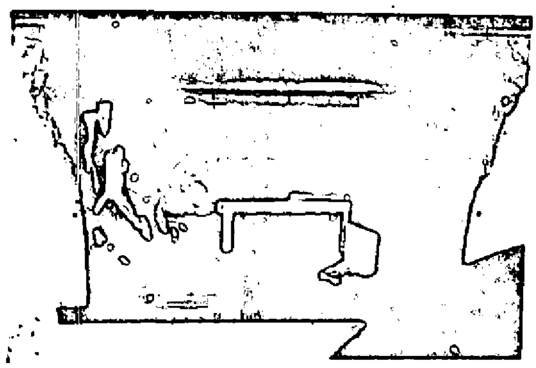
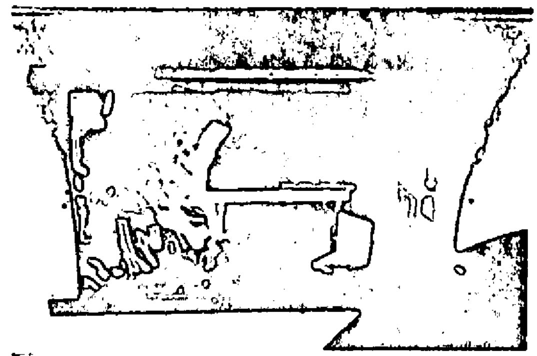


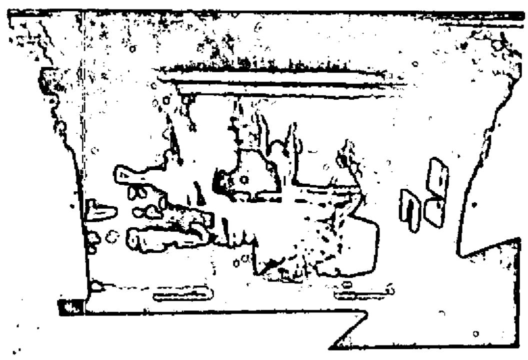
FIG.3. TEMPERATURE RECORDS OF TESTS 18-23. MEASURED BY THERMOCOUPLE (2.)(SEE FIG. 1.)



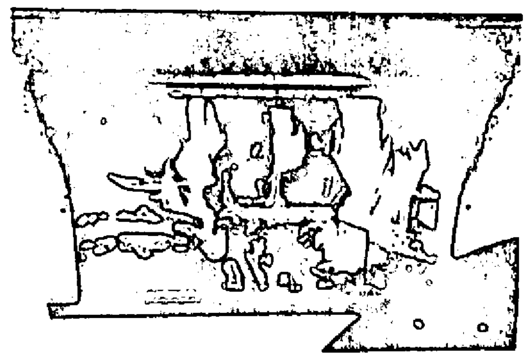
10min AFTER IGNITION



12min AFTER IGNITION



16min AFTER IGNITION



18min AFTER IGNITION

19min AFTER IGNITION. 'FLASHOVER'

FIG. 4. FIRE IN 1/5 SCALE MODEL ROOM IN VARIOUS STAGES OF DEVELOPEMENT TEST No. 23

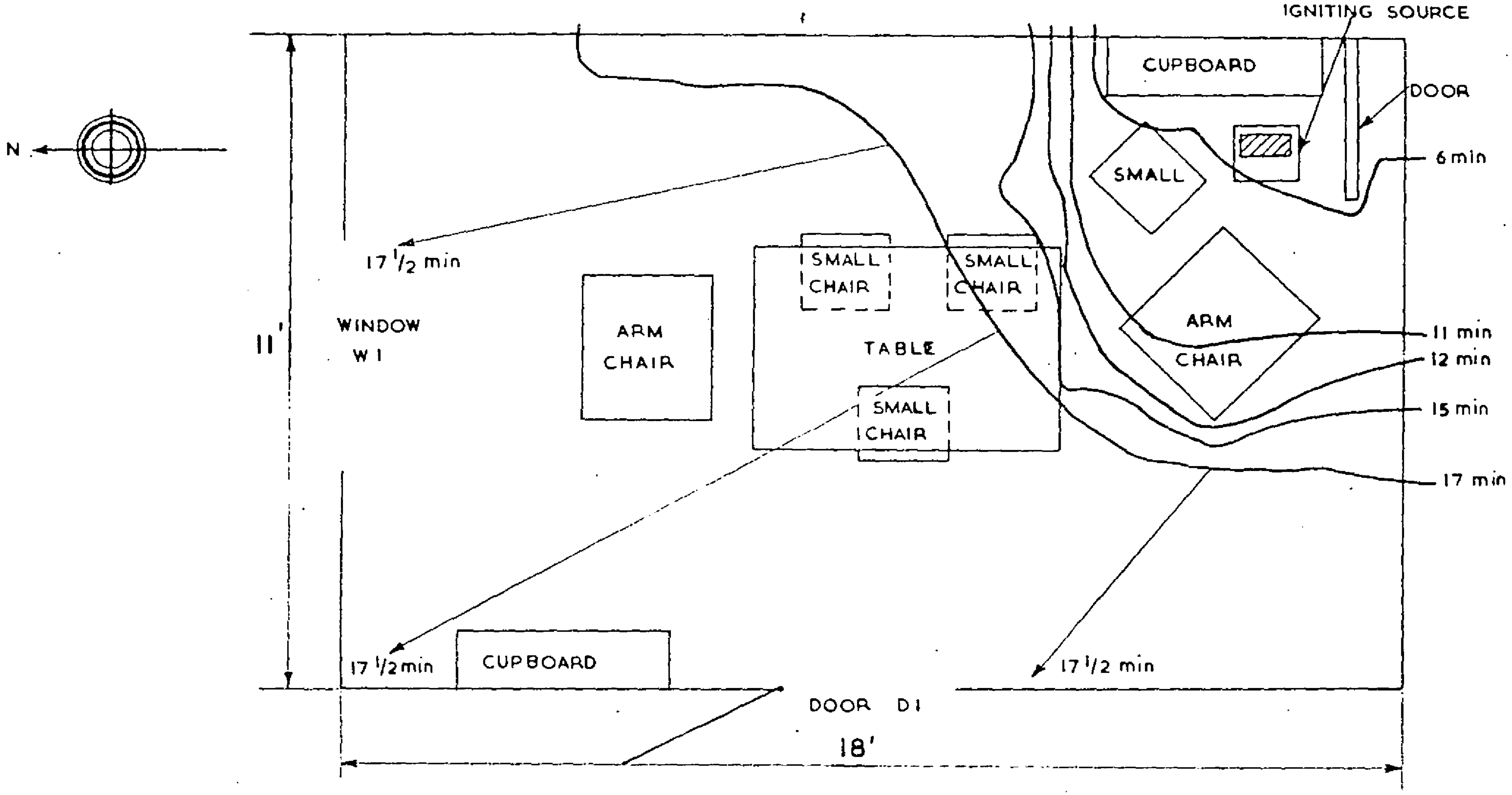
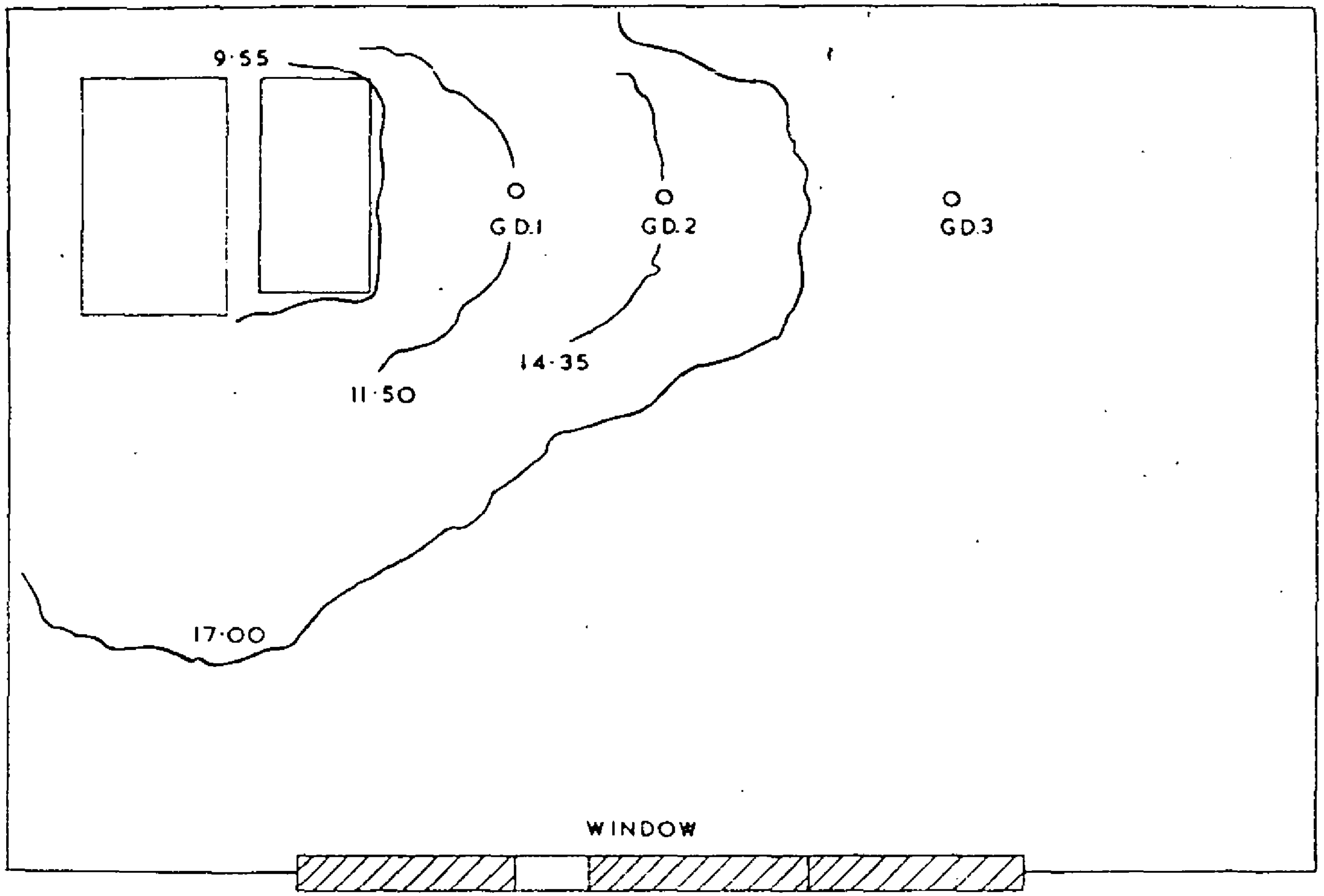


FIG 5 PLAN OF FULL SCALE ROOM SHOWING DISTRIBUTION OF FURNITURE AND RATE OF SPREAD OF FIRE.



LOG OF TEST.	TIME (min)
IGNITION	0·00
SMOKE INCREASING, UNTIL VERY DENSE AT	4·00
FLAMES VISIBLE	5·15
FLAMES SPREADING OVER CEILING	7·30
WINDOW NO. 1. CRACKED	8·45
WINDOW NO. 2. CRACKED	9·30
WINDOW NO. 3. CRACKED	9·50
NO FLAMING ON FLOOR	18·30

G.D. — GOLD DISC

FIG 6. PLAN OF ROOM SHOWING POSITIONS OF GOLD DISCS AND RATE OF SPREAD OF FIRE (TEST 45)

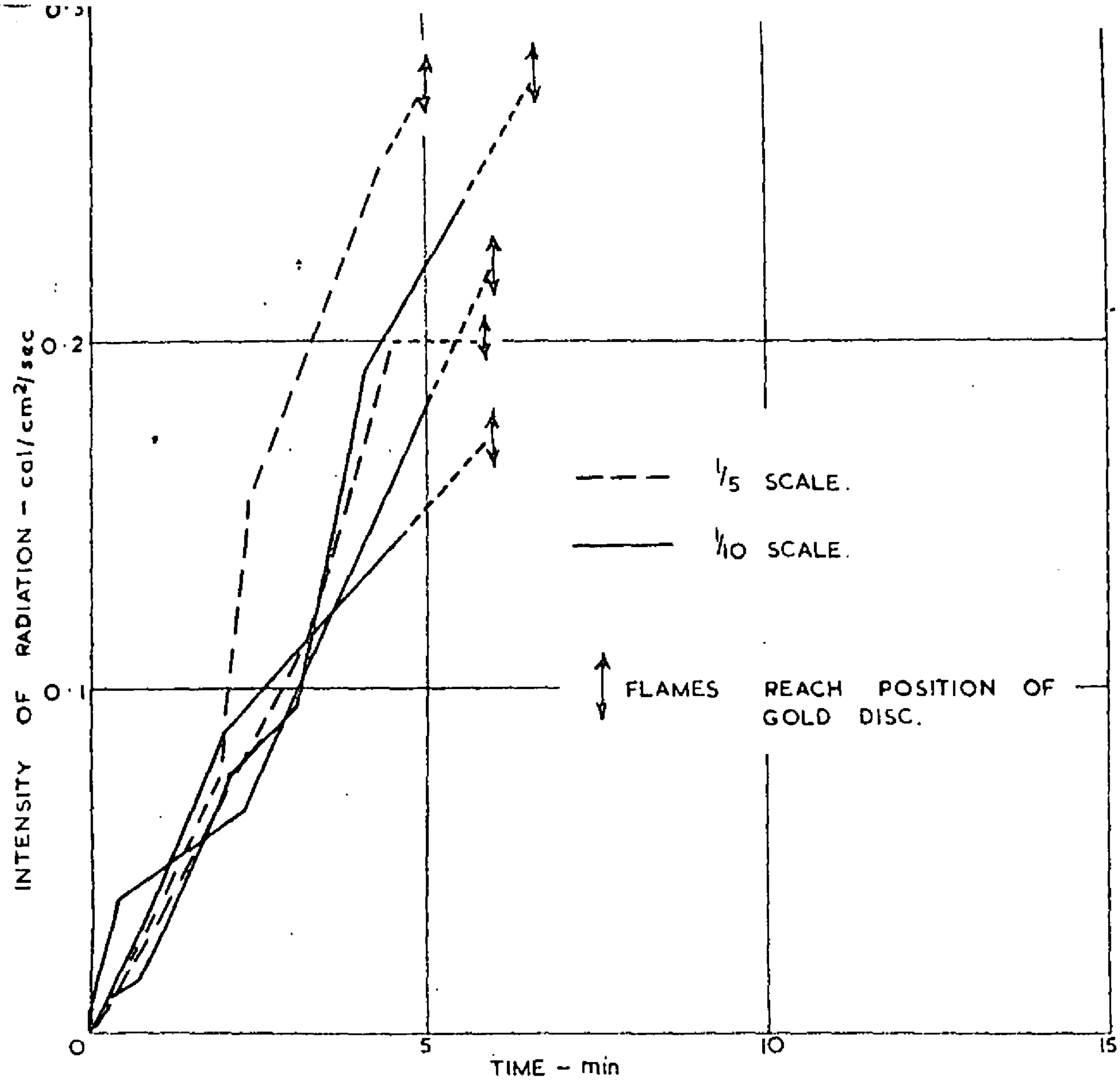


FIG. 7. RECORDS OF GOLD DISC NO. 1. FOR TESTS 43 - 47.

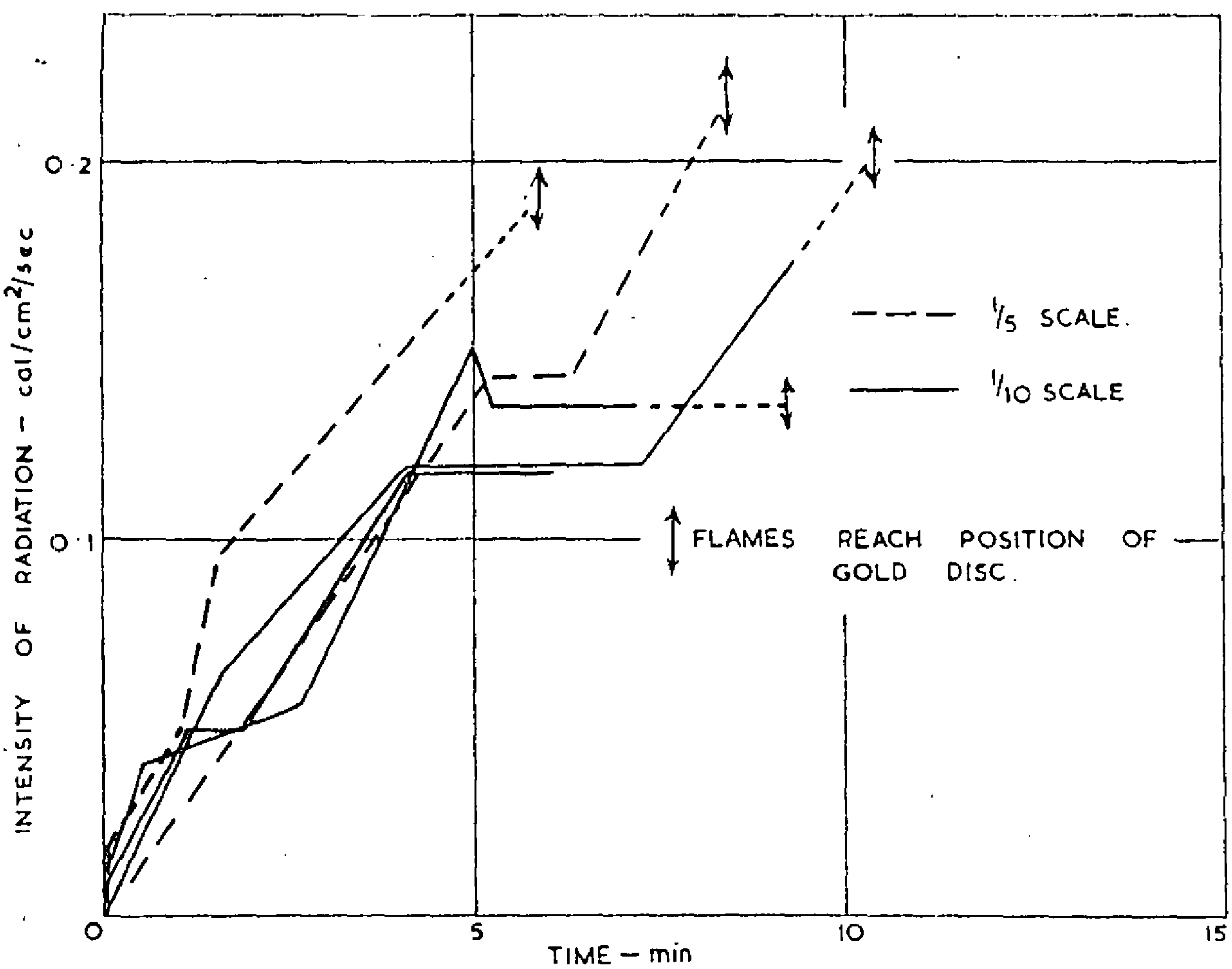
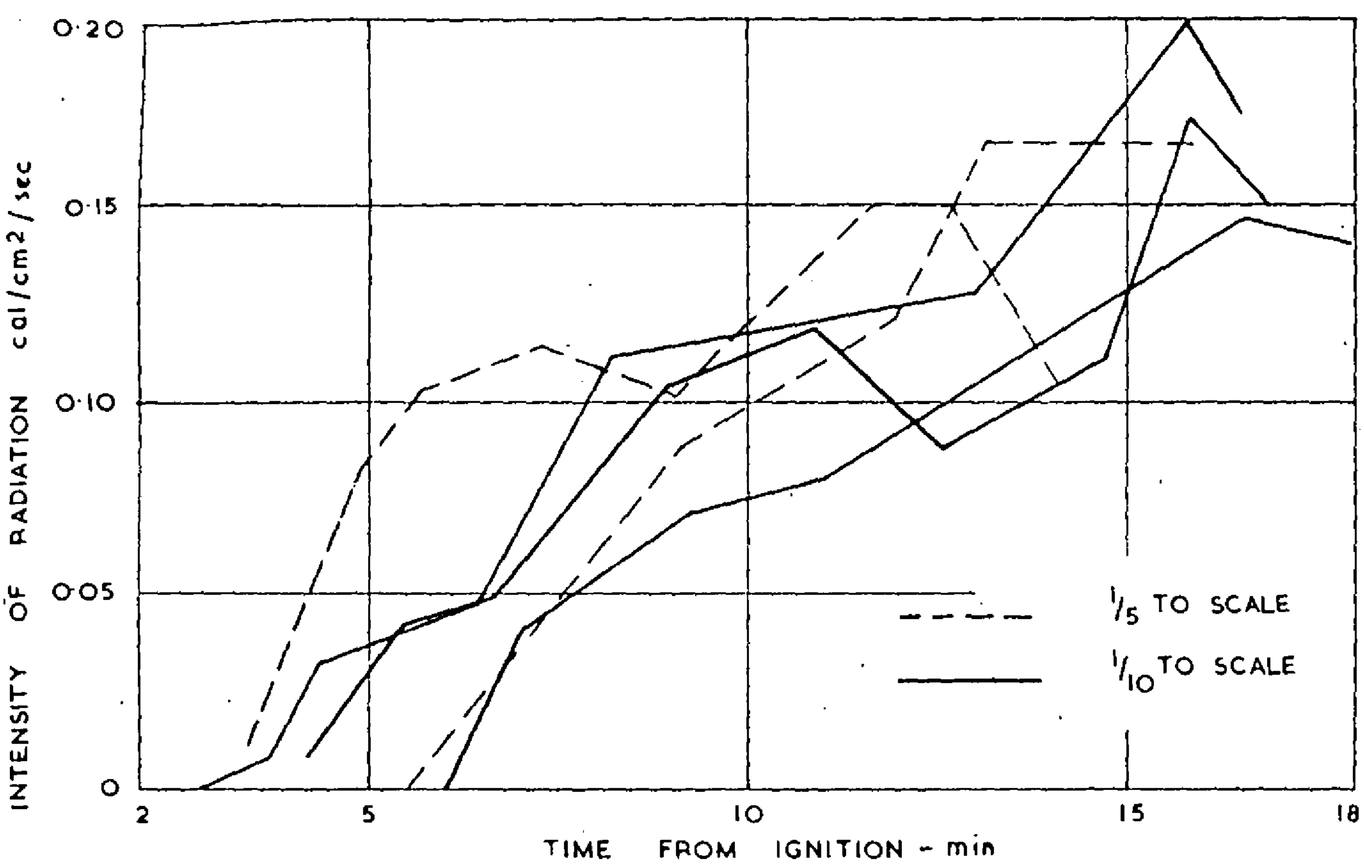


FIG. 8. RECORDS OF GOLD DISC No. 2. FOR TESTS 43 - 47.



G. 9 RECORDS OF GOLD DISC 3. FOR TESTS (43 - 47)