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The fire hazard of building boards

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PREFATORY NOTE

When used in certain ways some kinds of building boards can contribute to the rapid spread of fire in buildings. In view of the importance of these materials to the building industry, it is essential to know where they may be used with safety. This report describes the results of experiments that have been carried out to show how common types of board might be expected to behave in actual fires. The conclusions are given in a form that is designed to help in answering questions that arise when considering the use of these materials.

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THE FIRE HAZARD OF BUILDING BOARDS

INTRODUCTION

Building boards have, in recent years, increasingly supplanted older, conventional structural materials. Although boards of the laminated fibre wallboard type were produced as far back as 1906, it was during and after the last war that the big increase occurred. Among their advantages are the possibility of production in large standardized sheets and ease of handling which facilitates speedy erection and repair. Certain types have the added advantage that they provide good thermal and acoustic insulation.

Some building boards present an outstanding fire hazard since they permit extremely rapid growth of fire, particularly in the early stages. It is, therefore, necessary to have practical means of assessing the fire hazard and comparing the relative hazards of different kinds of board accurately, so that it is possible to distinguish where they may be used with safety, and also of assessing the improvements conferred by flame-retardant treatments.

Two tests, which are described in B.S. 476 (1), are available for this purpose, namely the combustibility test, and the surface spread of flame test. The first of these classifies materials arbitrarily into two groups, the combustible and the non-combustible. The second, or surface spread of flame test, assesses the relative ease with which flame can spread over the surface of a board, and places materials in one of four classes, permitting very low, low, medium, or rapid spread of flame. Many combustible building boards which have desirable properties as building materials are rated in the lowest class by this test. There are, however, various ways of treating them to reduce the spread of flame on their surfaces. They can be raised to the "very low" rate of spread class by some flame-retardant paints and impregnation treatments.

Post War Building Studies Nos 20 (2) and 29 (3) indicate where the use of each class might be considered. The recommendations were made in the light of experience of actual fires in buildings, supplemented by the large-scale tests on corridors carried out by the Building Research Station in the development of the surface spread of flame test. There was ample evidence of the hazards of some untreated boards in service, but little of the practical significance of the flame-retardant treatments which raised the rating of the boards in the surface spread of flame test. Because of the newness of the problem, some of the recommendations were necessarily arbitrary, and it was thought desirable to explore the problem in greater detail as soon as opportunity permitted, and particularly to try to relate the results of tests with behaviour under fire conditions. Since the issue of the Post-War Building Studies it has been possible to carry out experimental fires involving two full-scale dwelling houses, and a large number of fires on a smaller scale.

The experiments were designed to throw light on three aspects of the behaviour of building boards. Firstly, the ease with which they can be ignited by a small source of heat would indicate the likelihood of their becoming the first material to be ignited in a fire. Secondly, it was necessary to discover how the boards would influence the development of a fire which started in the contents of the room in which the building boards were not the first material to be involved, and thirdly, how the boards would affect the spread of fire in corridors where there is little combustible material in the form of furniture or fittings.

IGNITION BY SMALL SOURCES OF HEAT

Samples of building board, each 1 ft. x $1\frac{1}{2}$ ft. were mounted vertically, and a non-luminous Bunsen flame played on the lower part of the sample. With untreated fibre insulating board and hardboard a self-propagating fire was easily started on all samples. With samples that had received a surface treatment of oil-bound distemper or whitewash, there was only limited spread beyond the area of flame contact (Plate 1). Glowing combustion continued, however, after the flame was extinguished. Apart from hardboard (Class III) there was no appreciable spread of flame beyond the area of contact of the igniting source on boards rated in Classes I-III in the surface spread of flame test.

GROWTH OF FIRE IN ROOMS

In the past many experiments have been carried out to observe the development of fire in average-sized living-rooms furnished in a standard manner. In 1949 an experiment was carried out to compare the development of fire in two houses, both of which were lined with fibre insulating board, but one having an additional layer of plasterboard fixed to it[4]. The surfaces of the walls of both houses were covered with coats of oil-bound distemper. The essential characteristic of the fire was that it started in the contents of the room, and the furniture was arranged in such a way that there was the high probability that, once started, a fire would develop to involve all the furniture. The aim of the experiment was to compare the contribution made by the wall linings to the rate of development of a fire.

Since 1949 a large number of experiments have been made with replicas of the living-room in the full-scale house on one-tenth, one-fifth and half scale. The room was furnished as shown in Fig. 1. Following the indications of preliminary tests, the dimensions of the room and its components were scaled linearly, except that the thickness of the timber was approximately constant for all scales. Thus the floor was of seven-eighth inch deal, the wall linings were of full thickness, and the wood used for the table and chair tops was one inch thick.

Table 1 gives the range of times taken for the whole room to become involved for both full scale and models for the three types of structure for which full-scale results are available. Fig. 2 gives comparative temperature records for two of these tests.

It was considered from this evidence that the growth of fire could be simulated sufficiently accurately by the use of small-scale models to justify the use of this method in a comparative study of the behaviour of building boards under fire conditions.

TABLE 1 TIME TAKEN FOR FIRE TO INVOLVE WHOLE ROOM FOR BOTH FULL SCALE AND MODELS

Type of structure	Time taken for fire to involve the whole room	
	Full scale min	Models min
Traditional (Incombustible walls and ceiling)	14 - 20	15 - 19
Fibre insulating board walls and ceiling	5	5
Plasterboard walls and ceiling	23*	14 - 18

*Under exactly similar conditions the plasterboard room could not take longer than the traditional type room, since the paper facing of the plasterboard would make some contribution. The probable reason for the longer time taken by the full-scale plasterboard structure was that the ventilation was more restricted than with the incombustible structure.

The manner in which development of fire is influenced by the lining of the room is of considerable interest. In all the experiments the fire was started between the cupboard and the chair as indicated in Fig. 1. The mutual support given by the flames from these two pieces of furniture was sufficient to ensure the development of a substantial fire, irrespective of the surroundings.

In the traditional type of room the flames spread on the floor, assisted by radiation from the burning cupboard, until the table was involved. When the fire was well established in the table it spread quickly over the rest of the room, giving the condition known as "flash-over", which is illustrated in Plate 2.

In the rooms lined with building boards on wall and ceiling, once the flames from the cupboard reached the ceiling, the fire developed in an entirely different manner. With untreated fibre insulating board or strawboard, the ceiling was ignited almost immediately and the flames spread rapidly across the ceiling and down the walls, igniting the furniture before the flames had begun to spread along the floor from the cupboard. Plate 3 illustrates this point in a one-fifth scale room.

In the rooms lined with treated fibre insulating board there were slight differences depending upon the treatments used. With silicate paint, the covering cracked very quickly and the protection offered under these circumstances was small. With the better type of surface treatment and with impregnated fibre insulating board the development of the fire was retarded until the fire in the cupboard was well established.

Once this occurred flammable gases were given off from the protected lining in sufficient quantities to accelerate the spread of fire in the room. The mechanism from this point was similar to that in the rooms lined with the untreated board. This can be seen in Plate 4, which shows the development of fire in a room lined with fibre insulating board with a flame-retardant surface treatment applied.

The only exception to this method of development with treated fibre insulating board, was in the tests in which the board was protected by a 3/16-in. skim plaster coat. In these tests the development was similar to that in a traditional type room. The plaster formed an impermeable covering and although some cracks appeared in the plaster, flammable gases were not given off through these cracks in sufficient quantities to affect the development of the fire. The adhesion of the plaster appeared to be good, since no plaster fell until some time after "flash-over" in the room.

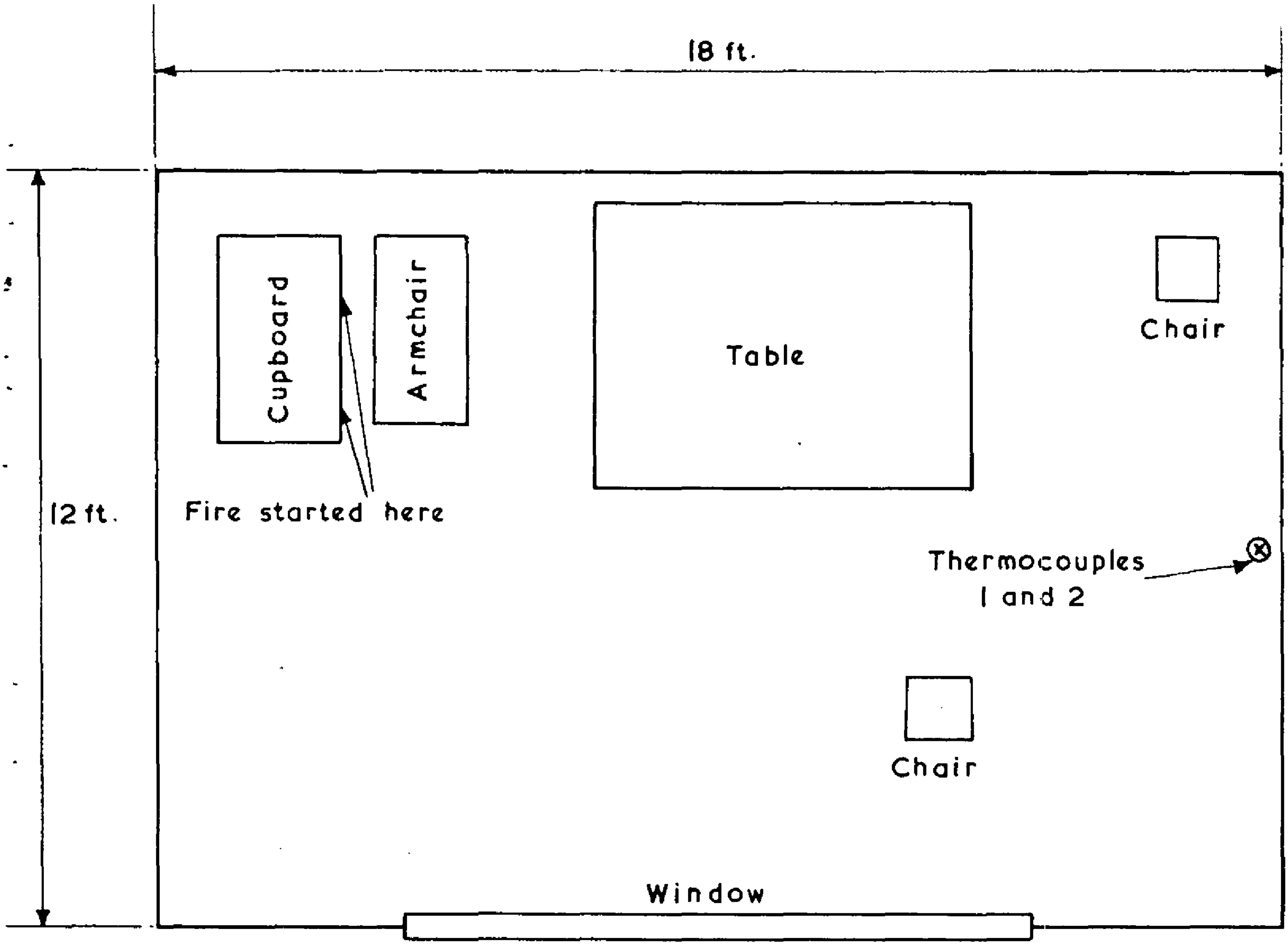
With the impregnated and surface treated hardboards used and with plasterboard linings the mechanism of development was again more like that in the traditional room, although there was some contribution from the boards in all three cases, there being most from the hardboard with a surface treatment.

The classifications of the various boards on the surface spread of flame test, together with the time taken for the whole room to become involved in fire when lined with the boards, are given in Table 2. These results are the averages of at least three tests in each case, the maximum deviation from the mean being about 10 per cent. A selection of temperature records is shown in Fig. 3.

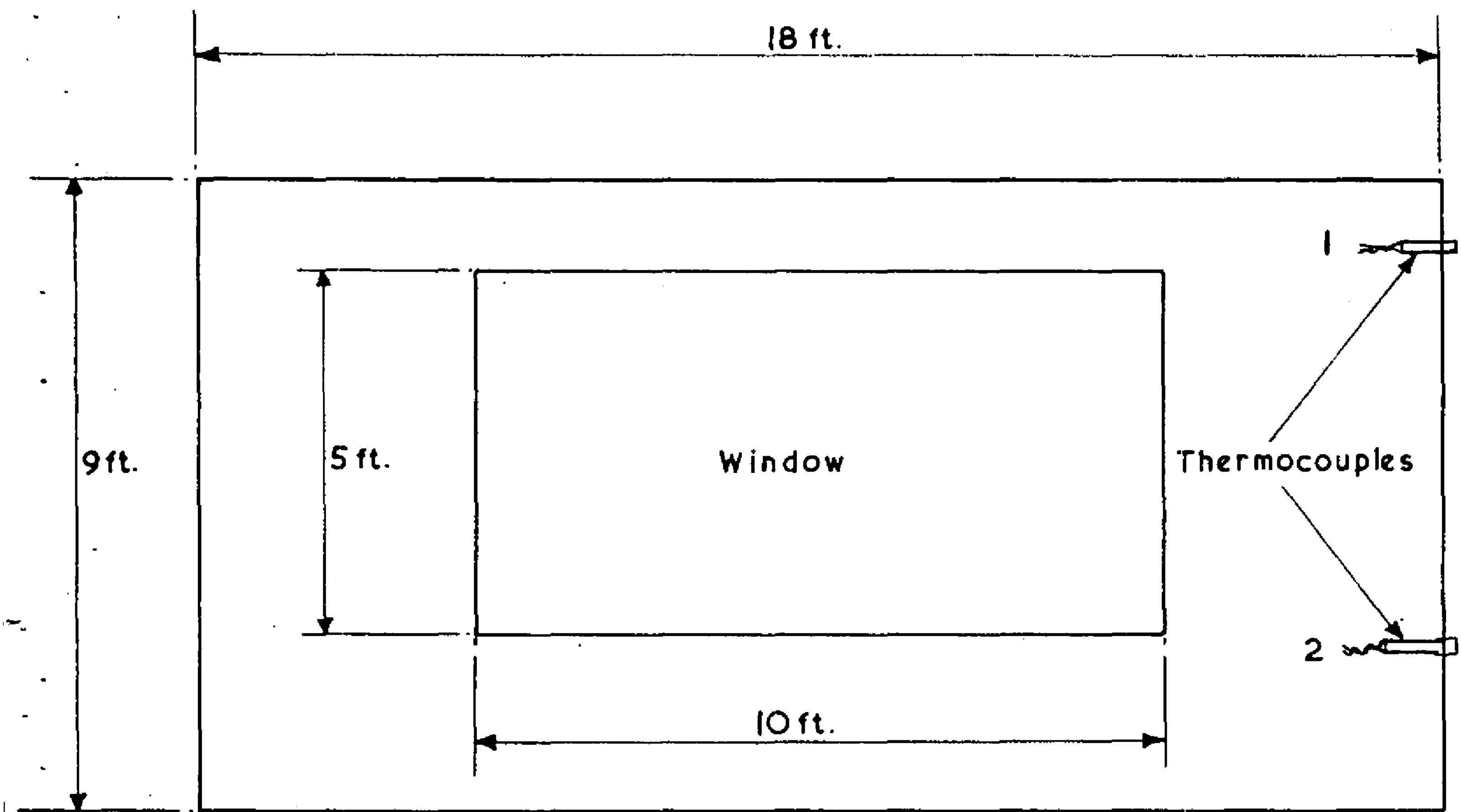
TABLE 2 PARTICULARS AND RESULTS OF BOARDS TESTED IN FULLY-LINED ROOMS

Particulars of wall and ceiling linings	Classification on spread of flame test of B.S. 476	Mean time for all room to become involved in fire min	sec
Incombustible		17	10
Fibre insulating board with 3/16-in. skim plaster coat	Class I	17	45
Wood wool	Class I	16	45
Plasterboard	Class I	16	35
Hardboard impregnated with monammonium phosphate. (Retention of salt - 18 to 20 per cent by weight)	Class I	15	45
Hardboard with surface treatment of paint A (30 g/sq.ft.)	Class I	13	30
Fibre insulating board with surface treatment of paint A (30 g/sq.ft.)	Class I	10	35
Asbestos paper faced fibre insulating board	Class I	10	30
Fibre insulating board with surface treatment of paint A (15 g/sq.ft.)	Class I	9	25
Fibre insulating board impregnated with monammonium phosphate. (Retention of salt - 9 per cent by weight)	Class I	9	00
Fibre insulating board with surface treatment of silicate paint	Borderline Class II-III	7	45
Treated fibre insulating board	Class III	6	00
Untreated hardboard	Class III	6	15
Untreated strawboard	Class IV	5	45
Untreated fibre insulating board	Class IV	5	00

Some tests were also carried out in which the building boards formed only the ceiling, or only the walls of the room. As would be expected, the fire took longer to develop than in the previous series

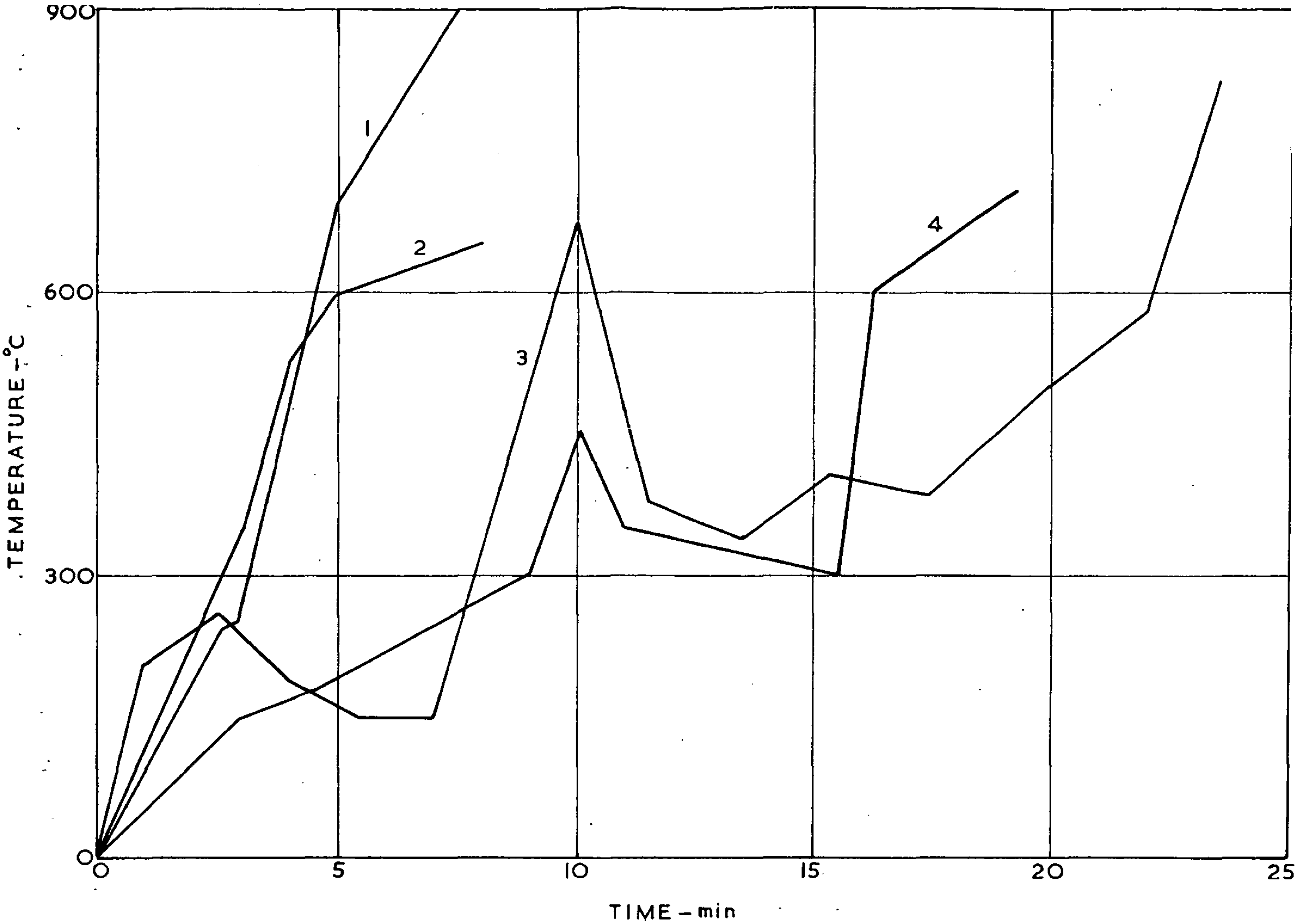


PLAN OF ROOM WITH FURNITURE



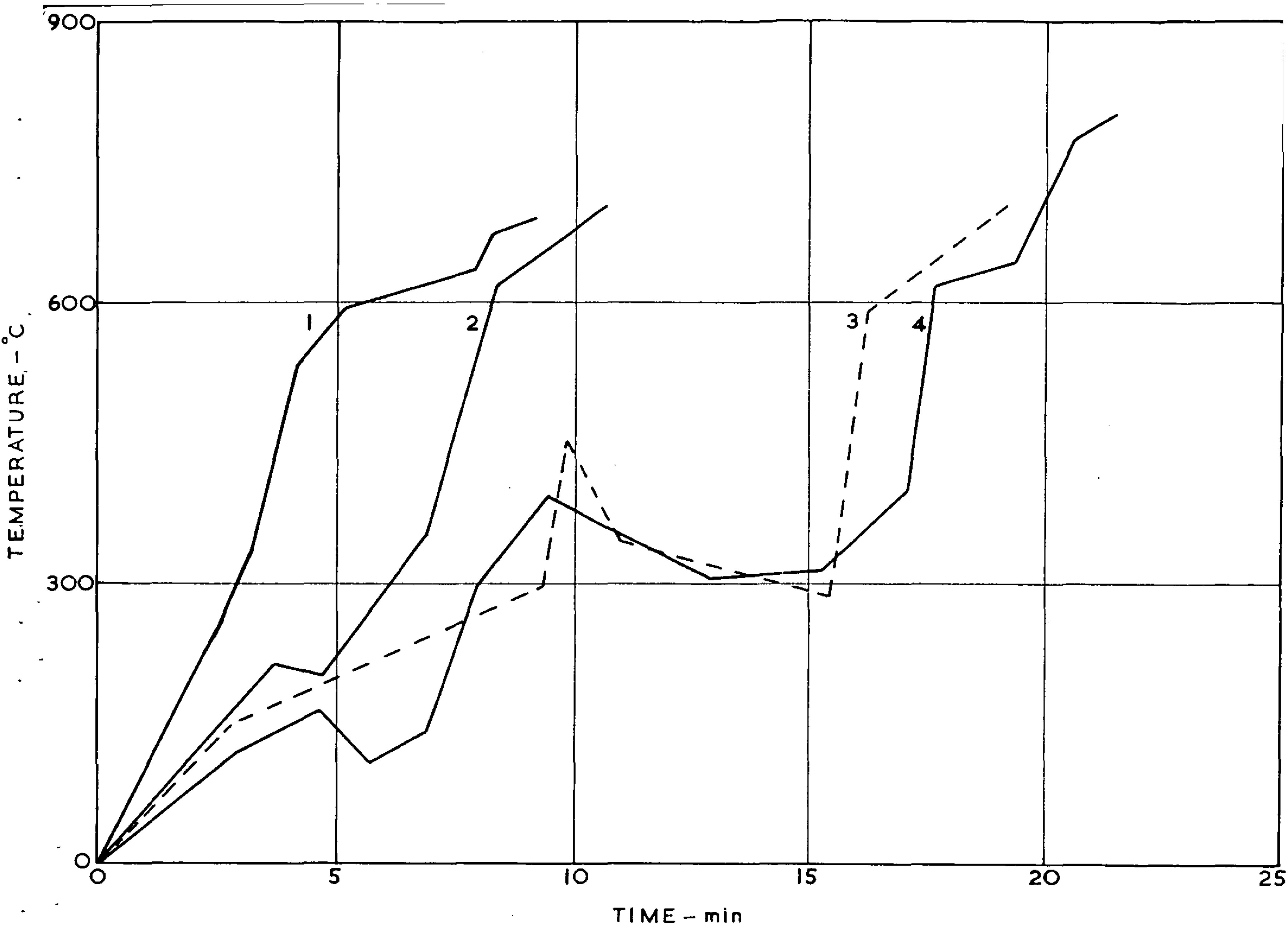
FRONT ELEVATION OF ROOM

FIG. 1. DIAGRAM OF ROOM



1. Full-scale room lined with fibre insulating board
2. Model room lined with fibre insulating board
3. Full-scale room lined with plasterboard
4. Model room lined with plasterboard

FIG. 2. COMPARATIVE TEMPERATURE RECORDS OF FULL-SCALE AND MODEL ROOMS



1. Untreated fibre insulating board (Class IV)
2. Treated fibre insulating board (Class I)
3. Plasterboard lining (Class I)
4. Incombustible lining

FIG. 3. SELECTION OF TEMPERATURE RECORDS OF MODEL ROOMS

of tests, but the relative merits of different boards and treatments were similar. The results are summarized in Table 3.

TABLE 3 PARTICULARS AND RESULTS OF BOARDS TESTED IN PARTIALLY LINED ROOMS

Treatment of fibre insulating board	Classification on spread of flame test of B.S. 476	Time for all room to become involved	
		Boards used as walls only, ceilings incombustible	Boards used as ceilings only, walls incombustible
Surface treatment of paint A	Class I	13.45	12.00
Surface treatment of silicate paint	Borderline Class II - III	13.00	12.00
Surface treatment of distemper	Class III	11.00	10.15
Untreated	Class IV	8.20	9.00

The times given in columns three and four of Table 3 are the average times of three tests, the maximum deviation from the mean being about 15 per cent.

THE SPREAD OF FIRE IN CORRIDORS

In a room lined with combustible building boards, the boards themselves form only a part of the fire load. A different set of conditions exists in a corridor lined with building boards., where the only other combustible material present is likely to be the floor. A knowledge of the behaviour of the boards under fire conditions when used as corridor linings is of importance since it is essential that escape routes in buildings should present as low a fire hazard as possible.

Tests were carried out in one-tenth and one-fifth scale models of a corridor 8 ft. 6 in. x 7 ft. 6 in. x 30 ft. long, connected to a model room by a door opening 6 ft. x 2 ft. 6 in. The room was furnished as in the previous tests and lined with a combustible board to represent the most hazardous conditions likely to occur. When the fire in the room was fully developed, the door separating room and corridor was removed and the flames and hot gases entered the corridor. Plate 5(a), shows a one-fifth scale corridor just after the beginning of a test.

A selection of boards, treated and untreated, were used as wall and ceiling linings to the corridor, the floor being of wood. A few tests were also made with boards on the ceiling only and on the walls only.

When the corridor was lined with untreated fibre insulating board the flames spread rapidly down the corridor. With the surface treatments used on the board giving Class II and III ratings on the spread of flame test there was little significant improvement, the flames reaching the end of the corridor in about 6 minutes. With the surface treatment on fibre insulating board giving a Class I rating there was a marked improvement in performance; in only one of these tests did the flames spread down the corridor and this did not occur until some 14 minutes after the start of the test. With a plasterboard lining the flames did not spread to the end of the corridor.

The results of these tests on corridors fully lined with building boards are given in Table 4.

TABLE 4 PARTICULARS AND RESULTS OF BOARDS TESTED IN MODEL CORRIDORS

Particulars of wall and ceiling linings	Classification on spread of flame test of B.S. 476	Average time for flames to reach end of corridor (min) (sec)
1. Plasterboard	Class I	No spread to end
2. Fibre insulating board with surface treatment of paint A	Class I	14 10 in one test. In other tests no spread to end
3. Fibre insulating board with surface treatment of paint B	Class II	5 40
4. Fibre insulating board with surface treatment of silicate paint	Borderline Class II - III	5 20
5. Untreated fibre insulating board	Class IV	2 25

The part which can be played by a combustible floor in a corridor was well illustrated in the only test with a Class I lining in which the flames spread down the corridor. The photographs in Plate 5 show the flames building up on the floor after some 11 minutes, and the subsequent rapid spread which is rather like the "flash-over" stage in a room. There is no doubt that in corridors lined with combustible building boards the risk could sometimes be reduced by having incombustible floors.

Tests were also carried out on corridors in which the building boards comprised only the walls, the ceiling being incombustible. When the walls were of untreated fibre insulating board the fire spread rapidly down the corridor; however with a surface treatment on the board giving a Class II rating on the spread of flame test it was $10\frac{1}{2}$ minutes before the flames spread to the end of the corridor. No tests were done on Class I materials since these do not even permit the flame to spread down the corridor when fully lined.

With incombustible walls to the corridor and an untreated fibre insulating board ceiling, the fire did not spread to the end of the corridor.

CONCLUSIONS

It is apparent from the result of the experiments described that the fire hazard of building boards depends on the conditions under which they are used and, in particular, on the nature and amount of other combustible materials with which they are associated. For practical purposes it is desirable to have a means of assessing the possibility of igniting the board by a small source of ignition, and of forming an opinion of the probable behaviour of the board when there is little other possible material present, for instance, when it is used as a lining to a corridor; and lastly, of its behaviour in the presence of an appreciable amount of combustible material, for instance, when it forms a lining to a furnished room. An attempt has been made in Table 5 to summarize the conclusions from the experiments in such a way that they can be used in considering these questions.

REFERENCES

(1) Fire tests on building materials and structures. British Standard No. B.S. 476: 1953.

(2) Fire grading of buildings. Part I. General principles and structural precautions. Ministry of Works Post-War Building Studies No. 20. London, 1946. H.M. Stationery Office.

(3) Fire grading of buildings. Part II. Fire fighting equipment. Part III. Personal safety. Part IV. Chimneys and flues. Ministry of Works Post-War Building Studies No. 29. London, 1952. H.M. Stationery Office.

(4) Fire Research 1950. Department of Scientific and Industrial Research and Fire Offices' Committee. London, 1951. H.M. Stationery Office.

TABLE 5 SPREAD OF FLAME CLASSIFICATION AND FIRE HAZARD OF BUILDING BOARDS

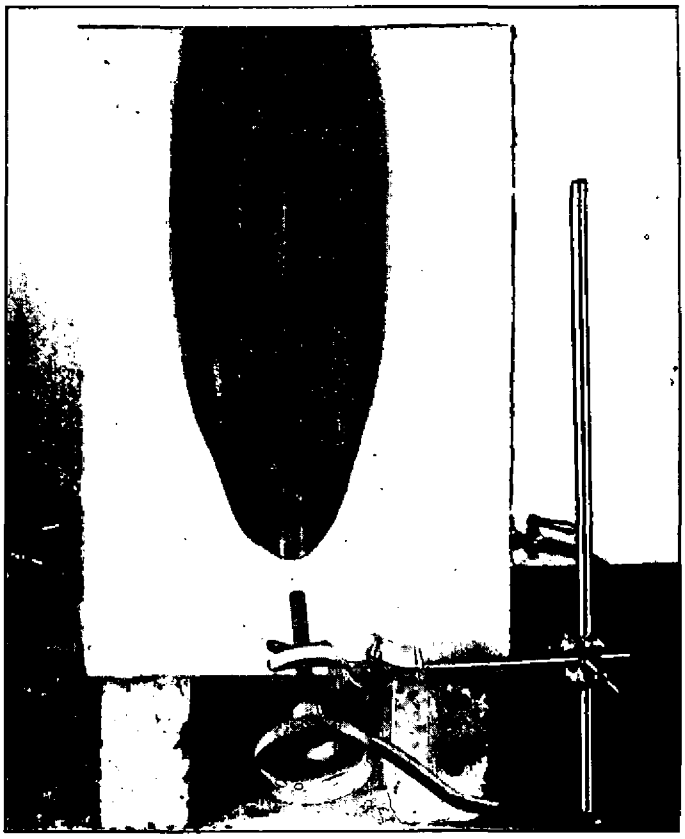
CLASSIFICATION OF BOARD ON SURFACE SPREAD OF FLAME TEST	SMALL SOURCE OF IGNITION	CORRIDORS			FURNISHED ROOMS[I]		
		w-incomb. c-building boards	c-incomb. w-building boards	w and c building boards	w-incomb. c-building boards	c-incomb. w-building boards	w and c building boards
CLASS I	WILL NOT start a	W I	L L N O T permit		WILL NOT appreciably increase	the	*
CLASS II	continu-ing	rapid	spread	WILL	speed of spread	of fire	WILL appreciably
CLASS III	fire (with the exception of hard-board.)	of	permit rapid		increase	the of	speed
CLASS IV	WILL start a continuing fire.	fire	spread of fire.		spread	of	fire

w - walls, c - ceiling.

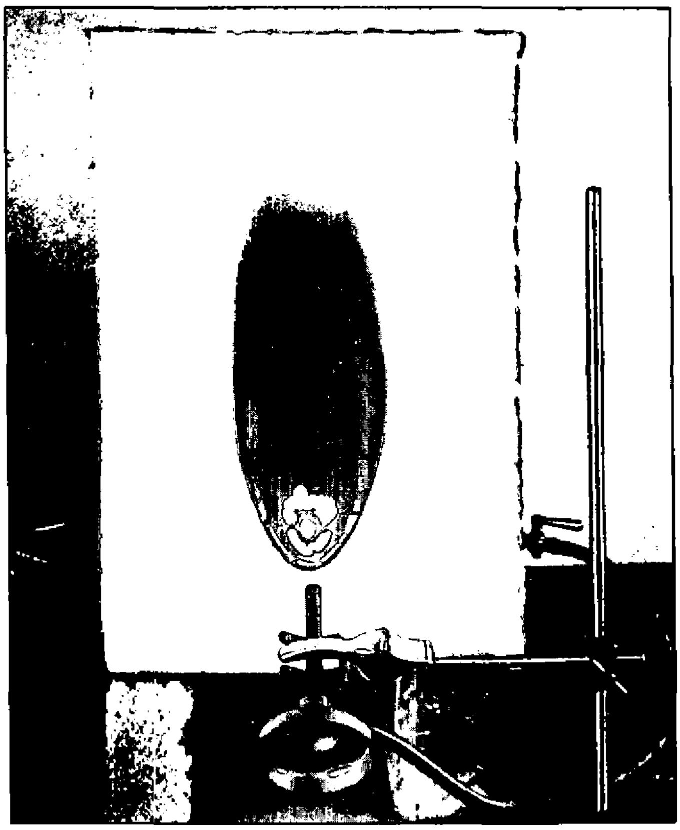
I From Tables 2 and 3 those boards which assist the fire to involve the whole room in less than 11 minutes are considered as appreciably increasing the speed of spread of fire.

* There are some boards in this Class which evolve heat slowly in a fire under these conditions and will not appreciably increase the speed of spread. There are also others which evolve heat at a rate sufficient to make them speed up the spread appreciably. There appear to be two types of board which evolve heat slowly, firstly, the boards which are mainly incombustible, (plasterboard and wood wool) where the little combustible material present burns slowly, and secondly, the combustible board which is adequately protected. The most adequate protection found was a skim plaster coat which formed a durable and substantial insulating layer. It also seems possible that impregnation in which there is a high retention of flame-retardant salt might be effective. One such hardboard has been tested, but such a high retention in a soft board would probably destroy the other desirable properties of such a board.

PC

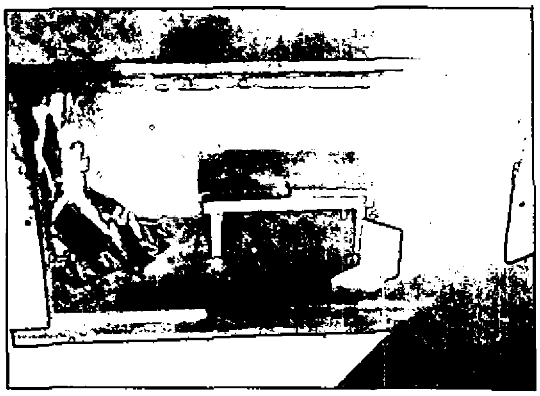


Spread on untreated fibre insulating board



Spread on fibre insulating board coated with oil bound distemper

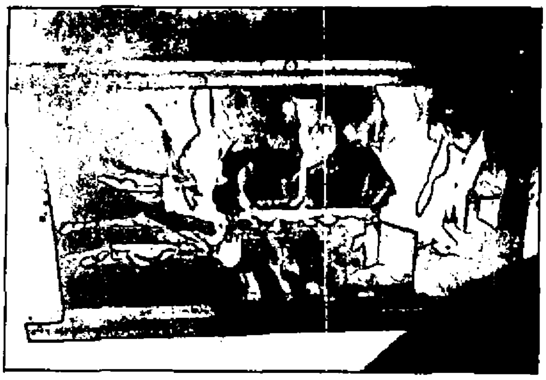
PLATE.I. SPREAD OF FIRE FROM SMALL SOURCE



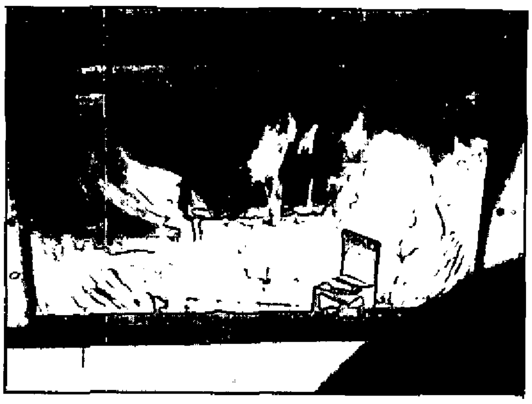
After 10 min

After 12 min

After 16 min

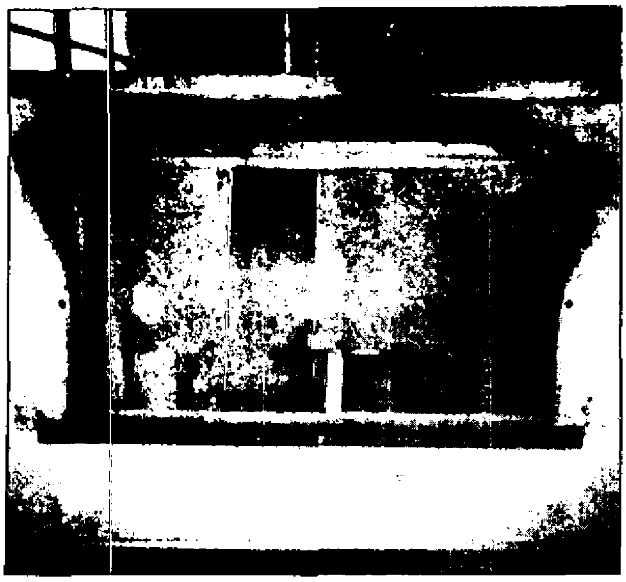


After 18 min

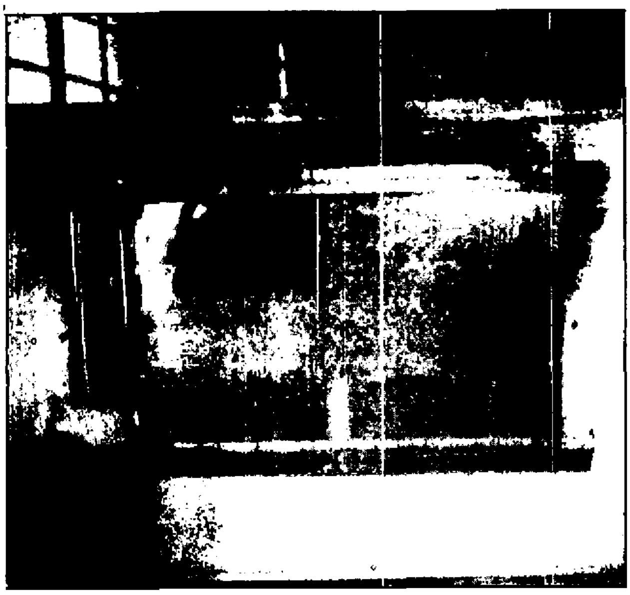


Flash-over
After 19 min

PLATE.2. DEVELOPMENT OF FIRE IN ONE-FIFTH SCALE MODEL ROOM OF TRADITIONAL TYPE



After 2 min



After 4½ min

After 5 min

After 5½ min

PLATE. 3. DEVELOPMENT OF FIRE IN MODEL ROOM LINED WITH UNTREATED FIBRE INSULATING BOARD

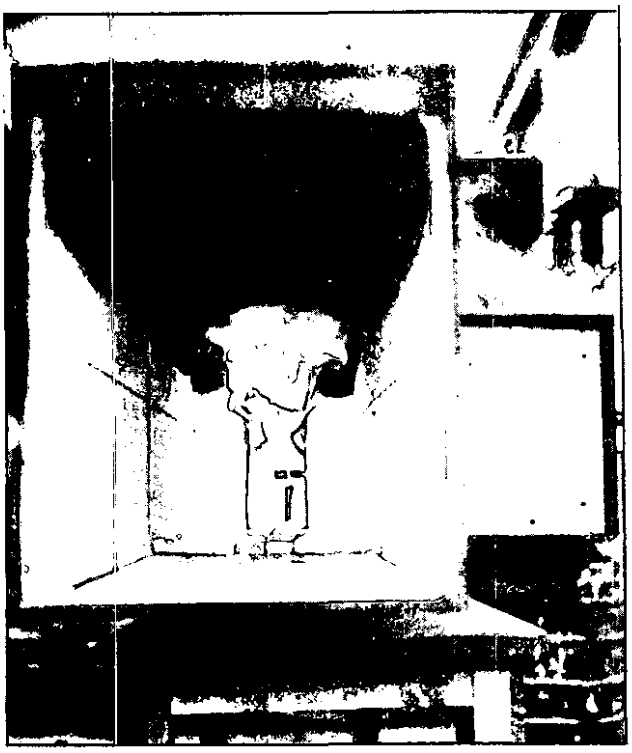
After 5 min

After 6 min

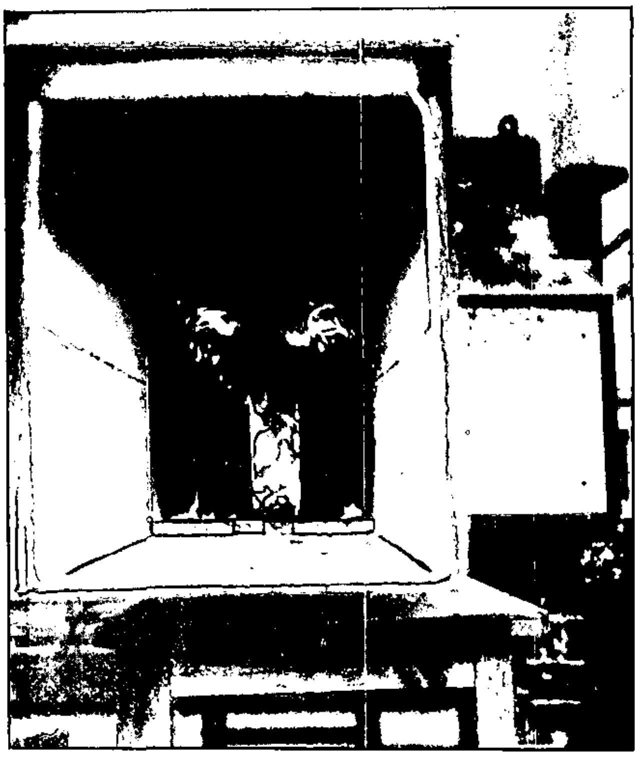
After 6¾ min

After 7¼ min

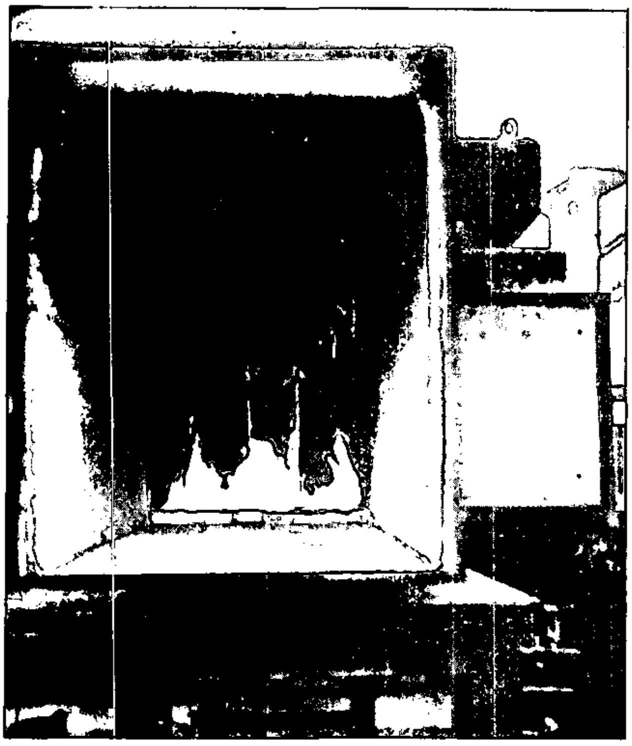
PLATE 4. DEVELOPMENT OF FIRE IN MODEL ROOM LINED WITH FIBRE INSULATING BOARD WITH FLAME-RETARDANT SURFACE TREATMENT



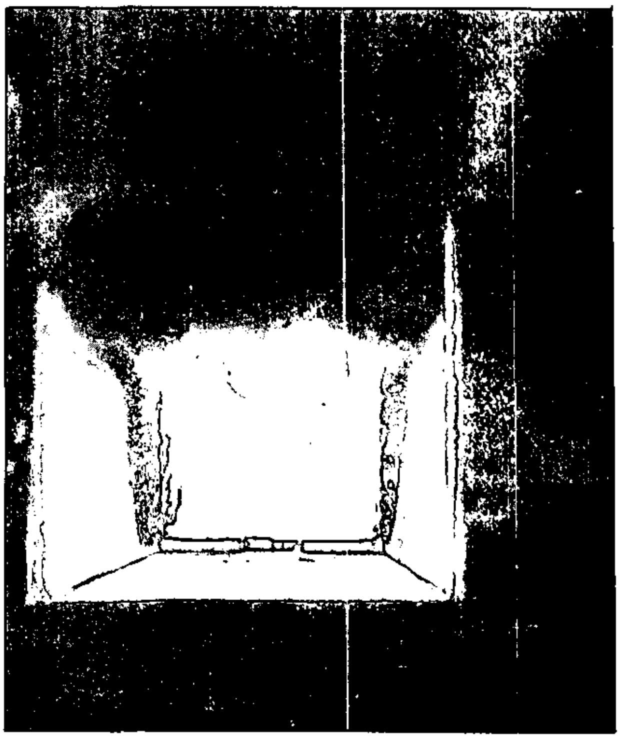
Beginning of test



After 9 min



After 11 min



After 13 min

PLATE. 5. SPREAD OF FIRE IN CORRIDOR LINED WITH FIBRE INSULATING BOARD WITH FLAME-RETARDANT SURFACE TREATMENT

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