Fire Research Note No 1061

PRELIMINARY EXPERIMENTATION ON THE SPRINKLER PROTECTION OF CARPETS IN STORAGE

by

Mrs S P Rogers

November 1976

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SUMMARY

With the increasing concern shown by carpet manufacturers and insurance companies on the fire protection of rolled carpets in storage, a series of experiments were carried out by the Fire Research Station (FRS).

The initial small scale work on a selection of rolled carpet samples, enabled the least and most flammable carpets to be selected for simulated full scale experiments in an open rack, to study the effectiveness of sprinklers in controlling the fire.

These experiments showed that conventional in-rack sprinklers with a sufficiently high rate of water application would probably only prevent damage to building and racking.

The fire hazard presented by the two carpets varied to such an extent that further work is necessary, to enable a relationship to be established between the rate of water application ('water density') required, to the types of carpet stored. This would then allow sufficient sprinkler protection to be given to the type of carpet, and ensure maximum fire control.

Further work is also required on simulated full scale closed racks to study the burning characteristics of the carpets and the sprinkler protection required in this type of storage.

Department of the Environment and Fire Offices' Committee
Joint Fire Research Organization

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INTRODUCTION

With heights of carpet warehouses increasing from a norm of 10 m to 20 m or more, and the carpets becoming more flammable with the transition from wool to man made fibres, both manufacturers and insurers were concerned about the adequacy of existing fire protection methods.

There are over 40 flammability tests for carpets at the present time[1]. These are concerned to a large extent, with the contribution individual carpets laid on floors make to fires occurring in offices and private dwellings.

Two of the principal tests, one used primarily in the United Kingdom[2] and the other in America[3] measure the ease with which a horizontal carpet sample ignites when a small hot object is placed on it. No work has been reported to date, on the flammability of carpets stored in rolls.

Research into the flammability of stored carpets was therefore conducted by FRS, in co-operation with the British Carpet Manufacturers' Association (BCMA) and the Fire Offices' Committee (FOC), and a three stage programme was carried out.

Stage 1. Examination of existing test results on carpet flammability[2] from the laboratories of Wira, to enable a selection of carpets to be chosen for Stage 2 tests. Visits by FRS staff to carpet manufacturers to view present day storage and handling methods.

Stage 2. Small scale experiments, burning carpet samples under various conditions.

Stage 3. Large scale experiments in open racking, to examine the burning characteristics of full sized carpet rolls, and the effectiveness of an automatic sprinkler system.

For the purposes of this report, the carpets were classified into two groups PILE and FIBREBONDED. It must be emphasized that this is strictly an FRS classification, and is independent of the classifications defined by manufacturers and carpet associations.

This report is divided into two parts. Part I consists of Stages 1 and 2 with Part II containing the Stage 3 work.

The terms closed and open racks used in this report refer to racking with and without compartmentation respectively.

PART I - STAGES 1 AND 2 OF THE PROGRAMME

STAGE 1 CHOICE OF CARPETS

Five PILE and five FIBREBONDED carpets were selected for use in the small scale experiments, and are shown in Table 1.

Of the five PILE carpets chosen, four were amongst the most flammable in the Wira 'Hot Metal Nut test'[2] and the remaining, one of the least flammable. They covered a variety of pile and backing compositions, from a woven 100% wool with a jute foundation, to a nylon sculptured loop pile with a foam rubber backing.

The five FIBREBONDED originally chosen were also representative of the whole range shown in the Wira tests and included carpet tiles. Unfortunately only three of the five were supplied at the time of the tests.

Six wrapping materials were also selected as shown in Table 1. The visits to carpet manufacturers had shown that from 5-20 per cent of carpets in storages were wrapped.

STAGE 2 SMALL SCALE EXPERIMENTS

Strip flammability test

The apparatus used is shown in Fig.1. A carpet sample 300 mm wide x 450 mm long was clamped along its top edge in a steel frame. A circular tray (15 mm deep x 100 mm diameter) containing 50 cm^3 of methylated spirits was placed 10 mm below the lower edge of the sample, ignited, and allowed to burn for sixty seconds before being removed. The times were noted at which the carpet pile became charred, at levels of 100 mm, 200 mm, 300 mm and 400 mm from the base respectively (scale marked on Dexion frame). The back of the sample also charred, but the time at each level was not necessarily coincidental with that of the pile.

This method was also applied to the wrapping materials.

The results are shown for the carpets in Figs 2 and 3 and for the wrapping materials in Table 2.

This test method gave an immediate indication as to the ease of ignition of the carpets and their readiness to burn. It also enabled the wrapping materials to be evaluated, so that the most flammable (found to be hessian) could be used in future tests.

Roll burning of carpet samples in an open frame

A carpet sample, 1 carpet width x 500 mm long, was rolled with its pile outermost, around a steel pipe 50 mm diameter, 500 mm long. It was secured with three strands of copper wire and supported in a steel frame.

An identical carpet sample was rolled with its backing outermost, and placed in the frame parallel to and 20 mm apart from the first, as shown in Fig.4.

A circular tray, 100 mm diameter, was placed between the two carpet rolls 10 mm beneath them and 200 mm from the ends. Methylated spirits burnt in this tray for approximately $2\frac{1}{2}$ minutes and the time for the flames to spread to each end of both carpet rolls was noted. The fire was then extinguished, with the minimum amount of water, and the depth of burning in the rolls was measured.

Having applied this method to each carpet sample, the PILE carpets found to be least and most flammable (D and E respectively), were selected for further tests with the most flammable wrapping material (hessian).

Two samples of each carpet were wrapped, backing outermost around the steel pipes, and in turn covered with a single layer of hessian.

These samples were then burnt in the open frame as described previously and the results, together with those from the earlier tests, are shown in Tables 3a and 3b.

This method of burning the carpets simulated a carpet storage with open racking, and enabled a comparison to be made between the flammability of carpet pile and backing. It also allowed the effect of wrapping the carpets to be studied.

Roll burning of carpet samples in an asbestos box

An open fronted asbestos box, shown in Fig.5 was used for these tests. It measured internally 440 mm wide, 655 mm long, 270 mm high.

Two samples of a carpet, each one width x 500 mm, were rolled around the two steel pipes, used in the open frame experiments. Both samples had the backing outermost and were secured with three strands of copper wire. They were then placed on the floor of the asbestos box, with a tray, 150 mm x 50 mm x 10 mm between them. The 150 mm tray sides were parallel to the carpet rolls, and one of the 50 mm sides touched the back face of the asbestos box. 20 cm^3 of methylated spirits burnt in this tray for approximately $2\frac{1}{2}$ minutes and times

were noted for the flames to spread to the front of both carpet rolls and to issue from the front of the box beneath its roof.

After extinguishing the fire, both samples were removed and the depth of char on each was noted.

On completing this test with all the carpet samples, three PILE and one FIBREBONDED (A, C, E and F respectively) were retested covered with hessian wrapping material.

All the results using this test method are shown in Tables 4a and 4b.

This test was carried out to examine the effect of a restricted air supply on the burning of the carpets, and simulated an almost entirely enclosed shelved rack situation.

Summary of small scale experiments

The strip flammability test indicated the ease with which the carpets ignited and showed D and A to be the least and most flammable PILE carpets respectively, with H and G the least and most flammable FIBREBONDED.

Applying this test method to the samples of wrapping material, showed that hessian was the most flammable. In 24 seconds, 450 mm had burnt, and the sample totally disintegrated after one minute.

On testing each carpet sample, rolled, in an open frame, with pile and backing outermost, D and E were found to be the least and most flammable PILE carpets respectively. The least flammable FIBREBONDED was F and the most flammable G.

By this test method it was also possible to assess the differences in the burning characteristics of pile and backing. A, E and G, the most flammable PILE and FIBREBONDED carpets each had a backing more flammable than the pile. In the remaining samples the pile was found to be more flammable than the backing.

Burning the samples, backing outermost, in a closed asbestos box, produced the same results as the open frame, except that A was found to be the most flammable PILE carpet. This was also true when the test was repeated with a selection of the carpets wrapped in hessian.

A summary of these results is shown in Table 5. Of the PILE carpets, D is clearly the least flammable and A the most flammable. These two carpets can thus be considered (in terms of flammability) as representative of the PILE carpet range.

Since only three FIBREBONDED carpets were assessed in the Strip Flammability Test and two in the remaining tests, the least and most flammable shown in Table 7 cannot be taken as representative of the FIBREBONDED range.

CONCLUSIONS FROM STAGES 1 AND 2

Wrapping some of the carpet samples in hessian and retesting in the open frame and asbestos box appeared to make very little difference to the relative flammability of the individual carpet samples. It was therefore decided that wrapping material could be neglected in future tests.

The strip flammability, open frame, and asbestos box test methods, enabled all the carpet samples to be assessed for their ease of ignition, together with their flammability in simulated open and closed racks respectively.

The pile and backing burning characteristics of each sample were also studied in the open frame method and there was no marked difference between them for any of the samples.

These small scale experiments showed D and A to be the least and most flammable PILE carpets respectively, and therefore these were chosen to be used in the Stage 3 larger scale experiments.

Measurements of the depth of burning in each test, allowed the minimum number of layers required for realistic larger scale experiments, to be assessed.

TABLE 1. CLASSIFICATION OF CARPET SAMPLES & WRAPPING MATERIALS

	Code	Description	Results of hot metal nut test[2] by Wira Greatest radius of char	
			Face (mm)	Back (mm)
PILE	A	80/20 polyester/nylon, 5 mm foam rubber backing. Tufted	Reached ring*	Reached ring*
PILE	B	Polypropylene, 2½ mm flame retardant foam backing. Tufted	Reached ring*	Reached ring*
PILE	C	Acrylic cut loop, hessian backing, bonded with latex. Tufted	Reached ring*	Reached ring*
PILE	D	Wool. 100% wool with a jute foundation. Woven	15	10
PILE	E	Nylon. Sculptured loop pile, 2½ mm foam rubber backing. Tufted	Reached ring*	Reached ring*
FIBREBONDED	F	Unbacked fibre bonded needle punch.	75	70
FIBREBONDED	G	Textured plush pile needle punch.	Reached ring*	Reached ring*
FIBREBONDED	H	PVC backed needle punch (carpet tile).	35	15
WRAPPINGS	X1	Polythene		
WRAPPINGS	X2	"		
WRAPPINGS	X3	"		
WRAPPINGS	Y1	Polypropylene		
WRAPPINGS	Y2	"		
WRAPPINGS	Z1	Hessian		

*Reached ring - radius of ring was 125 mm

TABLE 2. RESULTS OF STRIP FLAMMABILITY TEST ON CARPET WRAPPINGS

Type of carpet wrapping	Fire spread	Time min – sec	Observations
X1	Burnt to 310 mm self-extinguished	0 32	Sample disintegrated in advance of the flame. Burning pieces fell onto the tray below
X2	Burnt to 350 mm self-extinguished	0 42	" "
X3	300 mm, disintegrated	0 23	Sample did not burn, but disintegrated. No burning pieces fell onto the tray below
Y1	160 mm disintegrated 240 mm " 290 mm " 340 mm "	0 11 0 30 1 23 1 40	Sample disintegrated. No flames
Y2	100 mm disintegrated 200 mm " 250 mm " 300 mm "	0 05 0 10 0 24 0 54	" "
Z1	Burnt to 450 mm Totally disintegrated	0 25 1 00	-

TABLE 3a. RESULTS OF OPEN FRAME TEST ON ROLLED CARPET SAMPLES

	Carpet	Outer covering	Time for flame to spread 250 mm min - sec	Depth of burning
	A	Pile	8 - 55	3 layers
		Backing	7 - 35	" "
	B	Pile	11 - 55	3 layers
		Backing	14 - 00	" "
*	C	Pile	11 - 00	1 layer
*		Backing	12 - 30	3 layers
**	D	Pile	3 - 45	1 layer
***		Backing	12 - 20	1½ layers
	E	Pile	7 - 30	3 layers
		Backing	6 - 50	1 layer
	F	Pile	9 - 30	3 layers
		Backing	9 - 54	3 layers
	G	Pile	3 - 36	3 layers
		Backing	2 - 54	3 layers

* - Only spread 200 mm in total, then self-extinguished
** - " " 120 mm " " " " "
*** - " " 240 mm " " " " "

Each time is an average of two readings except with carpets C and D where a single reading has been recorded, as the flames did not reach the ends of the carpet rolls.

TABLE 3b. RESULTS OF OPEN FRAME TEST ON ROLLED CARPET SAMPLES WRAPPED IN HESSIAN

	Carpet rolled backing outermost with hessian wrapping	Distance of flame spread mm	Time min - sec	Depth of burning
*	D	270	10 - 24	1 layer
**	E	250	5 - 08	2 layers

* - Average total flame spread 270 mm, then self-extinguished (flames did not reach the ends of the carpet rolls). Time is an average of two readings.

** - Time is an average of four readings (flames reached the ends of both carpet rolls).

TABLE 4a. RESULTS OF ASBESTOS BOX TEST ON ROLLED CARPET SAMPLES

Carpet	Time for flame to spread to front of carpet roll (ie 500 mm) min	sec	Depth of burning
A	3	49	2 layers
B	41	25	3 layers
C	5	49	3 layers
D	12	18*	1 layer + 2nd layer charred
E	10	22	3 layers
F	5	15	3 layers
G	4	00	3 layers

*Flame spread only 160 mm along carpet

TABLE 4b. RESULTS OF ASBESTOS BOX TEST ON HESSIAN WRAPPED CARPET SAMPLES

Carpet backing outermost wrapped in hessian	Time for flame to spread 500 mm min	sec	Depth of burning
A	1	35	1 layer
C	7	20	3 layers
E	7	34	2 layers
F	3	00	2 layers

All times are an average of two readings

TABLE 5. SUMMARY OF RESULTS ON SMALL SCALE CARPET EXPERIMENTS

Test method	Least flammable		Most flammable	
	PILE	FIBREBONDED	PILE	FIBREBONDED
Strip flammability	D	H	A	G
Open frame	D	F	E	G
Asbestos box	D	F	A	G
Asbestos box (Sample, hessian wrapped)	-	-	A	-

NB H was only tested in strip flammability experiment

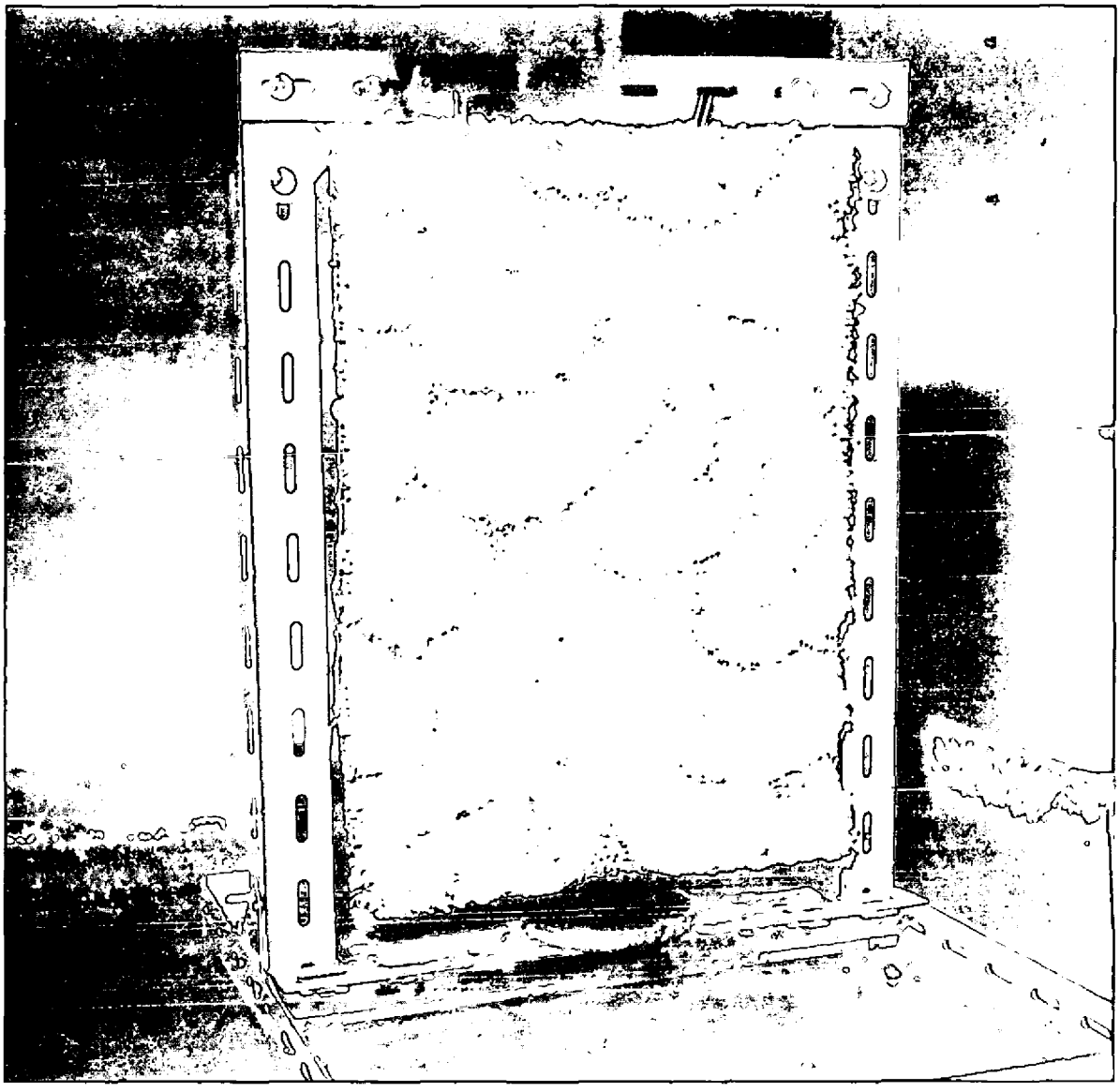

FIG. 1. STRIP FLAMMABILITY TEST

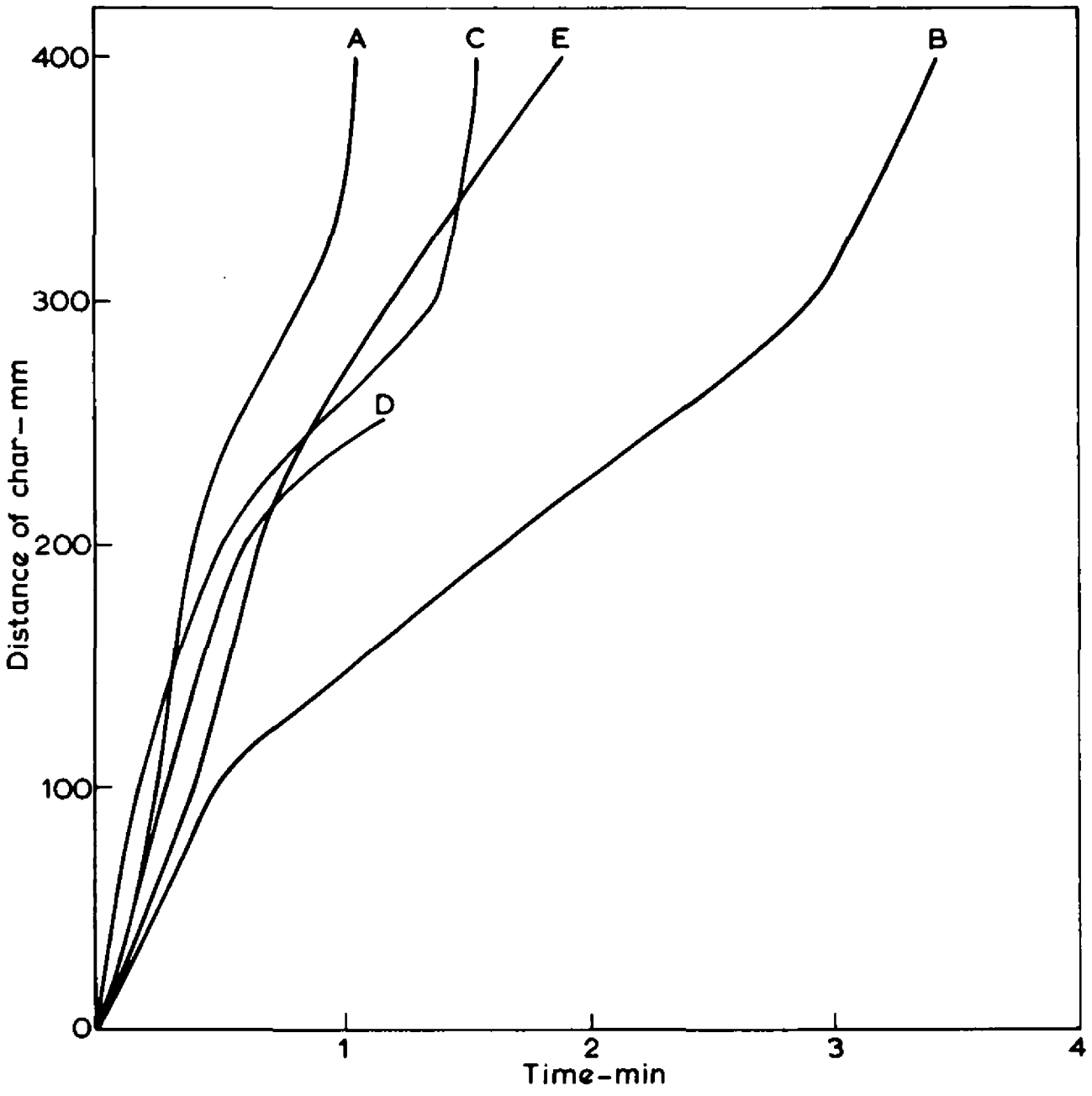

Figure 2 Results of strip flammability test on PILE carpets

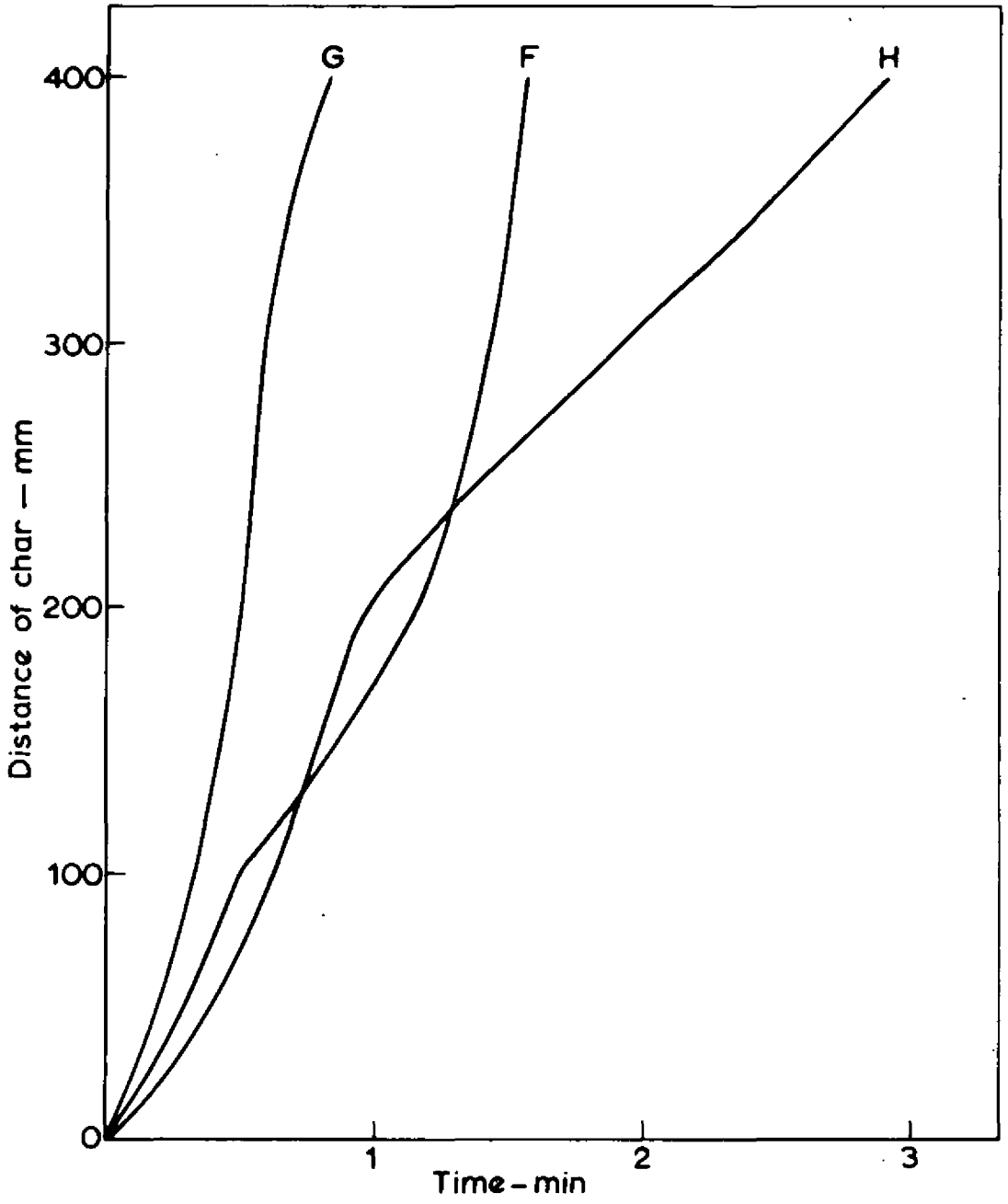

Figure 3 Results of strip flammability test on FIBREBONDED carpets

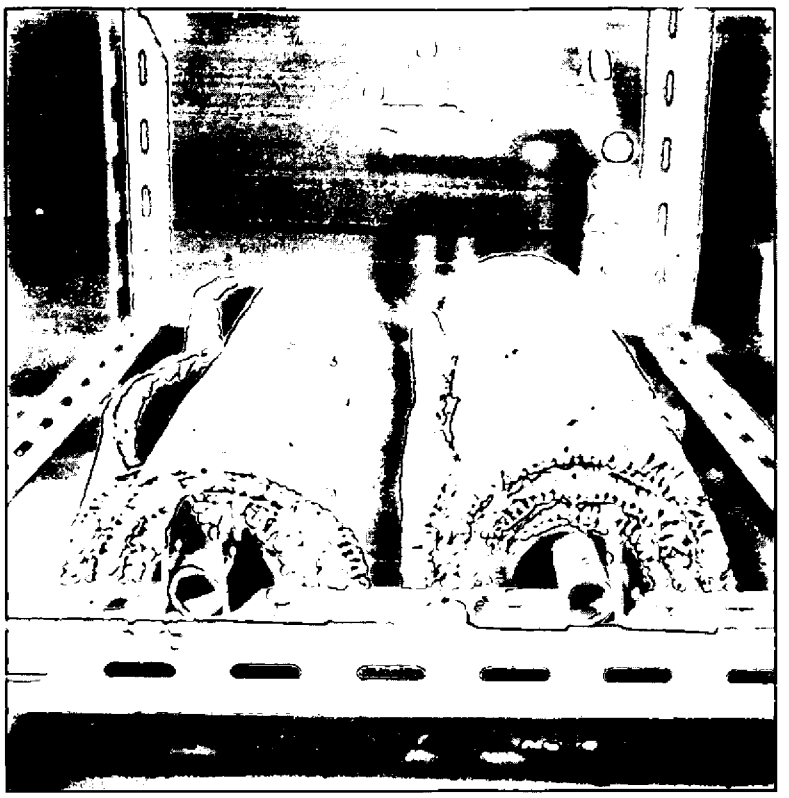

FIG.4. BURNING OF CARPET ROLLS
IN AN OPEN FRAME

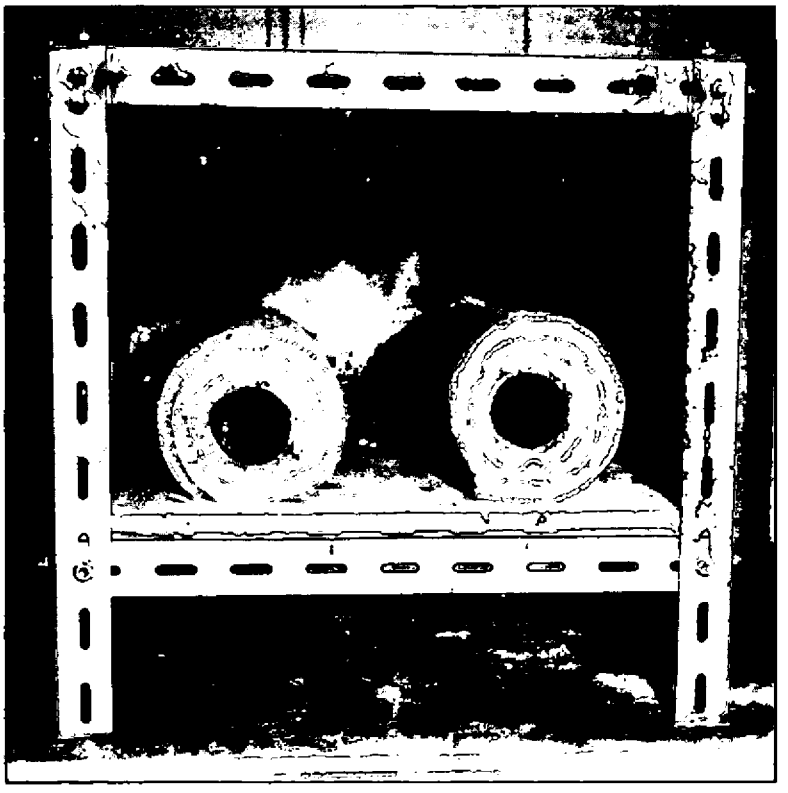

FIG.5. BURNING OF CARPET ROLLS
IN AN ASBESTOS BOX

PART II - STAGE 3 OF THE PROGRAMME

STAGE 3 LARGE SCALE EXPERIMENTS IN OPEN RACKING
EXPERIMENTAL ARRANGEMENTS AND PROCEDURE

At this stage, the two carpets selected (A and D) were tested on simulated full size carpet rolls in an open rack.

A sample of carpet was rolled three times, backing outermost, around each of 9 steel formers, Fig.6. Three layers were chosen as a result of the depths of burning observed in the small scale experiments. 50 mm wide strips of the same carpet were wrapped around the cone at the end of each former, in order to simulate the end face of a carpet roll, (details of carpets Table 6).

The spacing between rolls, Fig.7, was the closest found in open racked carpet warehouses, with the rolls supported on plywood shelves as shown in Fig.8.

Experiments were conducted using 9 rolls of carpet A (expts 3 and 5), 9 rolls of carpet D (expts 1 and 4) and mixed rolls of carpets A and D (expts 2 and 5). In the latter experiments, the arrangement of the rolls in the rack were: carpet A on Y1, Y3, X2, Z2 and carpet D in the remaining positions, Fig.7.

The ignition source for all experiments consisted of two fibreboard strips, each 200 mm x 20 mm x 10 mm thick, soaked in methylated spirits and placed either side of roll Y1. The 200 mm sides were parallel to the carpet roll and one of the 20 mm edges of each strip was 250 mm from the front face of the carpet.

Chrome/alumel thermocouples (T1 - T6) were positioned on the front face and within the rack, as shown in Fig.8 and were used in the respective experiments as indicated in Table 6.

Glass bulb sprinklers (S1 - S5) with a temperature rating of 68°C were placed at each level in the rack, Fig.8, so that the operating times of sprinklers situated at different levels within the rack could be found. They were not, however, connected to a water supply. When the fire had developed to its maximum extent within the rack and all the 'dry' sprinklers had operated, water was supplied through an open sprinkler positioned at 4 m (W1) from the floor in experiments 1-3, and 2.5 m (W2) above the floor in experiments 4 and 5 (Fig.7). This water was supplied at a pressure of 2 bar (measured at floor level) by the manual operation of a valve.

In experiment 6, the open sprinkler was replaced by a glass bulb sprinkler, rated at 68°C. It was placed in an upright position at W2, with its deflector plate 2.5 m above floor level. The pipework was pressurized to 2 bar (measured at floor level) to give a flow of 110 dm^3/min. This sprinkler was sited assuming two rows of sprinklers, each spaced at 0.6 m from the end face of a 4 m wide rack.

Throughout all experiments observations of the fire spread were noted, time/event charts (Appendix) were kept, and photographs taken.

RESULTS

There was a marked difference between the fires produced from the two types of carpet.

With the ignition source used, the fire did not spread from the ignition roll when woollen carpet D was tested.

However with the 80/20 Polyester/Nylon carpet A, and carpets A and D together there was rapid fire spread throughout the rack, as soon as the flames had reached the top of the ignition roll.

Fire spread, temperature rise and sprinkler operating times in the respective experiments are considered as follows.

Fire spread

Experiments 1 and 4 Carpet D

The course of the fire in both experiments were very similar, and flames never reached a height of more than 0.7 m above the ignition source. Figure 9 illustrates the negligible fire spread in experiment 1, 10 min 26 s from ignition.

Experiments 3 and 6 Carpet A

The time taken for the flames to spread above roll Y1 differed in these experiments from 3 min in test 3, to 7 min in test 6. In both cases, however, there was very rapid spread as soon as the flames were above this roll. The flames were 2.8 m high, in experiment 3 by 3 min 12 s, and in experiment 6 by 8 min. The rate of flame spread from the top of the ignition roll to this height being approximately 6 m/min and 4.6 m/min respectively.

Figure 10 shows the extent to which the fire has spread in experiment 3, 3 min 23 s after ignition.

The variation in times for the flames to reach the top of a 'first cell' in a rack, in this case carpet roll Y1, is a common occurrence with many combustibles, where small ignition sources are used.

Other work in open racks[4] has shown that the rate of vertical fire spread is very similar for a given rack and type of goods, once the flames have become well established, which is usually when the fire has reached the second level.

Experiments 2 and 5 Carpets A and D

Although there was a variation in the time taken for the flames to reach the top of Y1 in the two experiments, 3 min in experiment 2, 4 min in experiment 5, having reached this point there was a rapid fire spread of approximately 2 m/min in both tests. The flame height was thus 2.8 m after about another minute in each test.

The extent of fire spread 4 m 57 s from ignition in experiment 2 is shown in Fig. 11.

The rate of fire spread in each of the six experiments is shown in Fig. 12.

Categorization

In the 29th Edition of the Fire Offices' Committee Rules for Automatic Sprinkler Installations[5], stored goods are categorized according to their fire risk.

The fire spread results from these experiments would indicate that, while carpet D might fit into the lowest category of fire risk (Category I), carpet A would be in one of the higher categories (possibly Category III).

Air temperature rise

There was a maximum temperature rise of 30°C recorded by thermocouple T1 (situated above the ignition roll on the front face) using carpet D in all positions in the rack.

In the remaining experiments however, where carpet A alone and carpets A and D together were used, this thermocouple measured temperature rises of over 650°C within 4–8 min of ignition.

'Dry' sprinklers (S1 - S5)

These had been installed in the rack at each level Fig.8 so that the times at which water would have been applied to the fire could be noted, together with the corresponding flame heights.

Experiments 1 and 4

As the fire did not spread beyond Y1 none of the 'dry' sprinklers operated.

Experiments 3 and 6

In experiment 3, four of the five 'dry' sprinklers operated at times between 3 min 25 s and 3 min 52 s. The flame height at these times had reached over 2.06 m, ie above the top carpet rolls in the rack.

In experiment 6 all five 'dry' sprinklers operated between 7 min 47 s and 8 min 10 s, the flame height was again over 2.06 m.

Experiments 2 and 5

In both experiments, all the sprinklers operated when the flame height had reached above the top carpet rolls in the rack.

The operating times in experiment 2 were between 4 min 06 s and 4 min 28 s and in experiment 5 between 4 min 47 s and 5 min 25 s.

Open 'wet' sprinkler

In experiments 2, 3 and 5 water was supplied to the fire through this sprinkler, by manual operation of a valve, when the fire had spread throughout the rack. The times of operation of this valve were 4 min 28 s, 4 min and 5 min 30 s respectively.

The operation of the sprinkler at this late stage in the fire development had little initial effect on the intensity of the fire. After a period of about 1 minute an obvious decrease in the intensity of burning became evident, and after a further 10 minutes most of the flames had been extinguished.

In these experiments different effects would have been seen if full carpet rolls had been used, because in some cases the carpet was burnt right through to the steel former, before the water had any marked effect.

Conventional sprinkler

In experiment 6 when a conventional glass bulb sprinkler at W2 was allowed to operate automatically it did so 8 minutes from ignition. The upward spread of flame which had reached 2.8 m (Fig.12) was arrested, but the intensity of the fire was not seen to significantly diminish immediately. The fire was however well under control after 10 minutes of water application.

Time/Event tables (Appendix) show the pattern of fire spread in each experiment, together with times of sprinkler operation and observations of the damage incurred.

Table 7 summarises these tables and in Table 6 the test conditions are given with the 'dry' and 'wet' sprinkler operating times.

CONCLUSIONS

1. It can be seen from these experiments, that carpet D, (shown to be the least flammable of those considered in the small scale experiments) constitutes little fire risk, because of difficulty of ignition when stored in open racking. The fire did not spread beyond the ignition roll (Experiments 1 and 4).

   Where carpet A was used there was a very high rate of fire spread. This carpet had shown itself to be the most flammable of those considered in the small scale experiments, and in the larger scale tests there was very rapid vertical flame spread through the rack, with all carpet rolls burnt out.

   When carpets A and D were stored in the rack together the rate of fire spread was very similar to that of carpet A on its own. Rolls of carpet A were either burnt out or 80% destroyed and carpet D had rolls which were either extensively damaged on one face, or severely charred.

2. These experiments showed the very wide variation in fire hazard presented by carpets manufactured from different materials. It is very important therefore when considering the fire protection of carpets in open racks, to first study the materials from which the carpets are made, and whether or not a mixture of carpets are to be stored.

3. The 'dry' sprinklers in the rack operated in each experiment after the flames had reached a level above the top rolls of carpet, 2.06 m. This means that even with in-rack sprinklers the fire would not necessarily have been extinguished for a considerable time, although vertical flame spread to levels above 2.06 m may have been restricted.

   In experiment 6 when a conventional sprinkler was installed in the rack at 2.5 m above floor level it did not operate until the flames were 2.8 m high. The upward spread of flame was reduced at this time but the intensity of the fire was not seen to change immediately.

Conventional in-rack sprinklers will probably prevent substantial damage to building and racking occurring, provided the density of water application is sufficient. However, it is likely that flames will spread vertically to the top of the racking, as in other open rack situations, and that a considerable amount of smoke and water damage will occur.

Further work would be necessary to establish a relationship between the water density required for most effective fire control, and the type of carpet stored.

4. Protection for other types of carpet racking.

   Simulated large scale closed rack storage experiments are also needed, in order that fire spread and burning characteristics of carpets under these conditions may be studied, and a suitable sprinkler system designed.

ACKNOWLEDGEMENTS

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TABLE 6. SUMMARY OF TEST CONDITIONS AND SPRINKLER OPERATING TIMES IN EXPERIMENTS 1-6

Test No.	Type of carpet	Test conditions	'Dry' sprinkler operating times min - sec	'Wet' sprinkler operating times min - sec	Manual or automatic
1	D	Thermocouples T1 - T6 'Dry' sprinklers S1 - S5 Open 'wet' sprinkler W1	-	-	-
2	A & D	" "	4 - 06 4 - 13 4 - 16 4 - 28 4 - 28	4 - 28	Manual
3	A	" "	3 - 25 3 - 26 3 - 37 3 - 52	4 - 00	Manual
4	D	Thermocouples T1 - T5 'Dry' sprinklers S1 - S3 Open 'wet' sprinkler W2	-	-	-
5	A & D	Thermocouples and Open 'wet' sprinkler as Test 4 'Dry' sprinklers S1 - S5	4 - 47 4 - 48 5 - 00 5 - 17 5 - 25	5 - 30	Manual
6	A	" except Open 'wet' sprinkler replaced by conventional sprinkler	7 - 47 7 - 53 7 - 55 8 - 00 8 - 10	8 - 00	Automatic

Carpet specifications

A - 80/20 Polyester/Nylon, width 915 mm, thickness 13 mm.

D - Wool, width 700 mm, thickness 9 mm.

TABLE 7. SUMMARY OF EVENTS IN EXPERIMENTS 1-6

Test No.	Carpet D	Carpets A and D	Carpet A
1	Fire did not spread from Y1 (ignition roll) although X1 and Z1 showed signs of charring. No 'dry' sprinklers operated. 2 layers on roll Y1 burnt through but no damage to remaining rolls.	-	-
2	-	9 rolls burning by 4 m 26 s. 'Dry' sprinklers all operated. Water applied through W1 at 4 m 28 s. All rolls of carpet A burnt out. Most rolls of carpet D extensively damaged on one face.	-
3	-	-	9 rolls burning by 3 m 14s. 4 'dry' sprinklers operated. Water applied through W1 at 4 min. A large proportion of carpet rolls burnt out.
4	Apart from slight smouldering on Z1 the fire did not spread from Y1. No 'dry' sprinklers operated. Two layers on roll Y1 burnt through.	-	-
5	-	'Dry' sprinklers all operated. Water applied through W2 at 5 m 30 s. 80% of carpet A rolls destroyed. Carpet D rolls were charred.	-
6	-	-	7 rolls burning by 7 m 48 s. 'Dry' sprinklers all operated. Conventional sprinkler at W2 operated automatically at 8 min from ignition. All carpet rolls virtually burnt out.

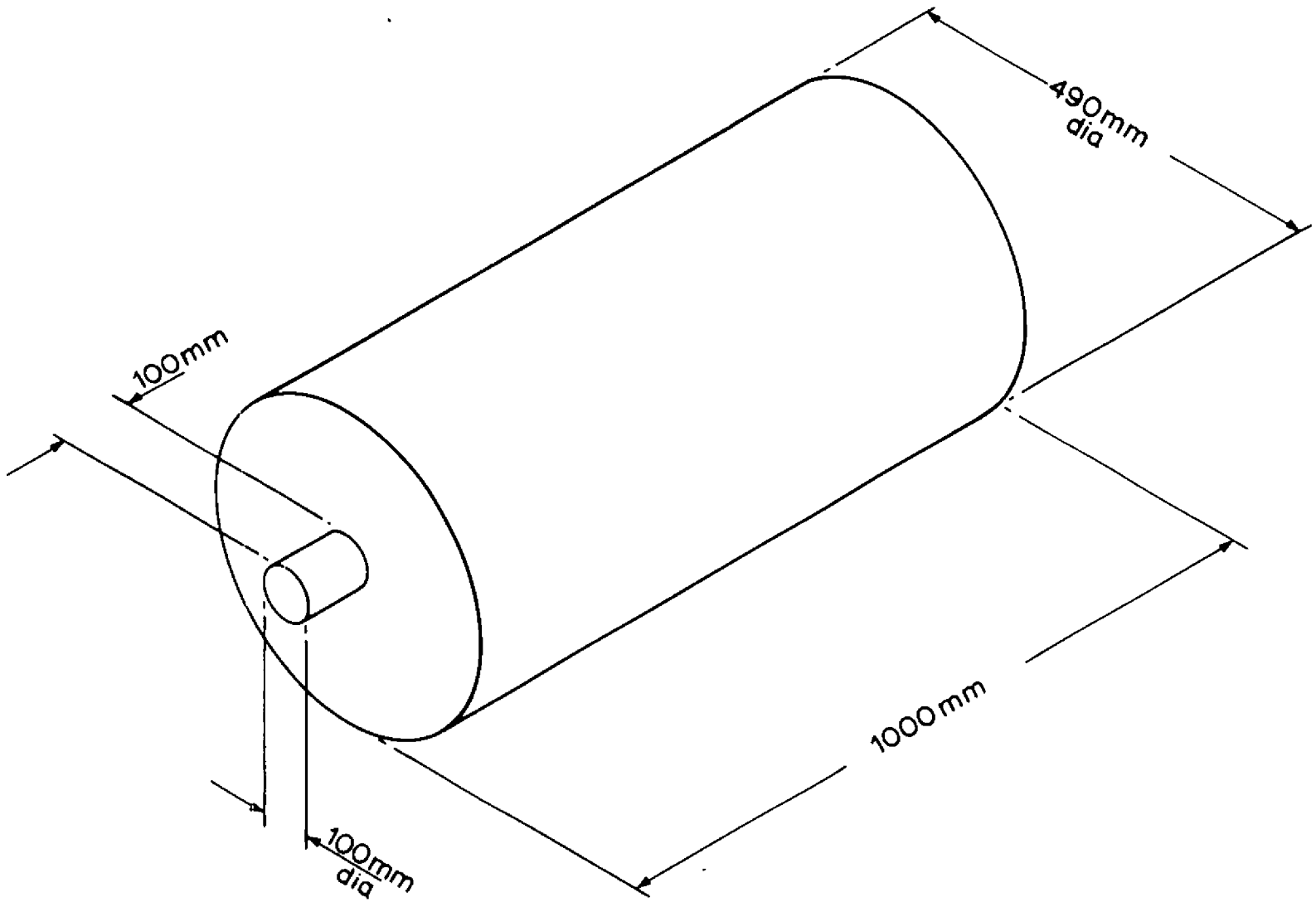

Figure 6 Steel former

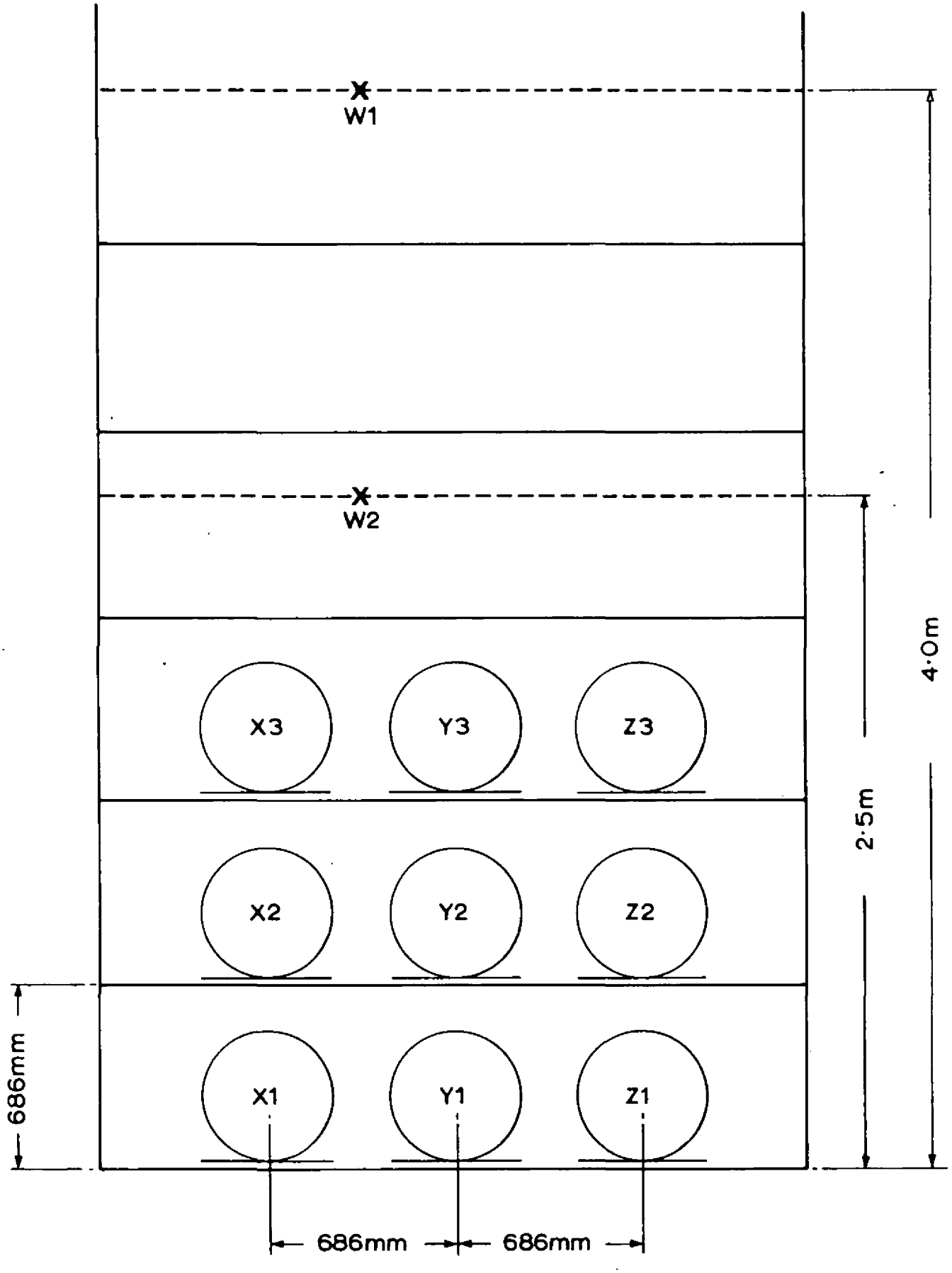

Figure 7 Diagram of open rack to show dimensions and spacing between formers

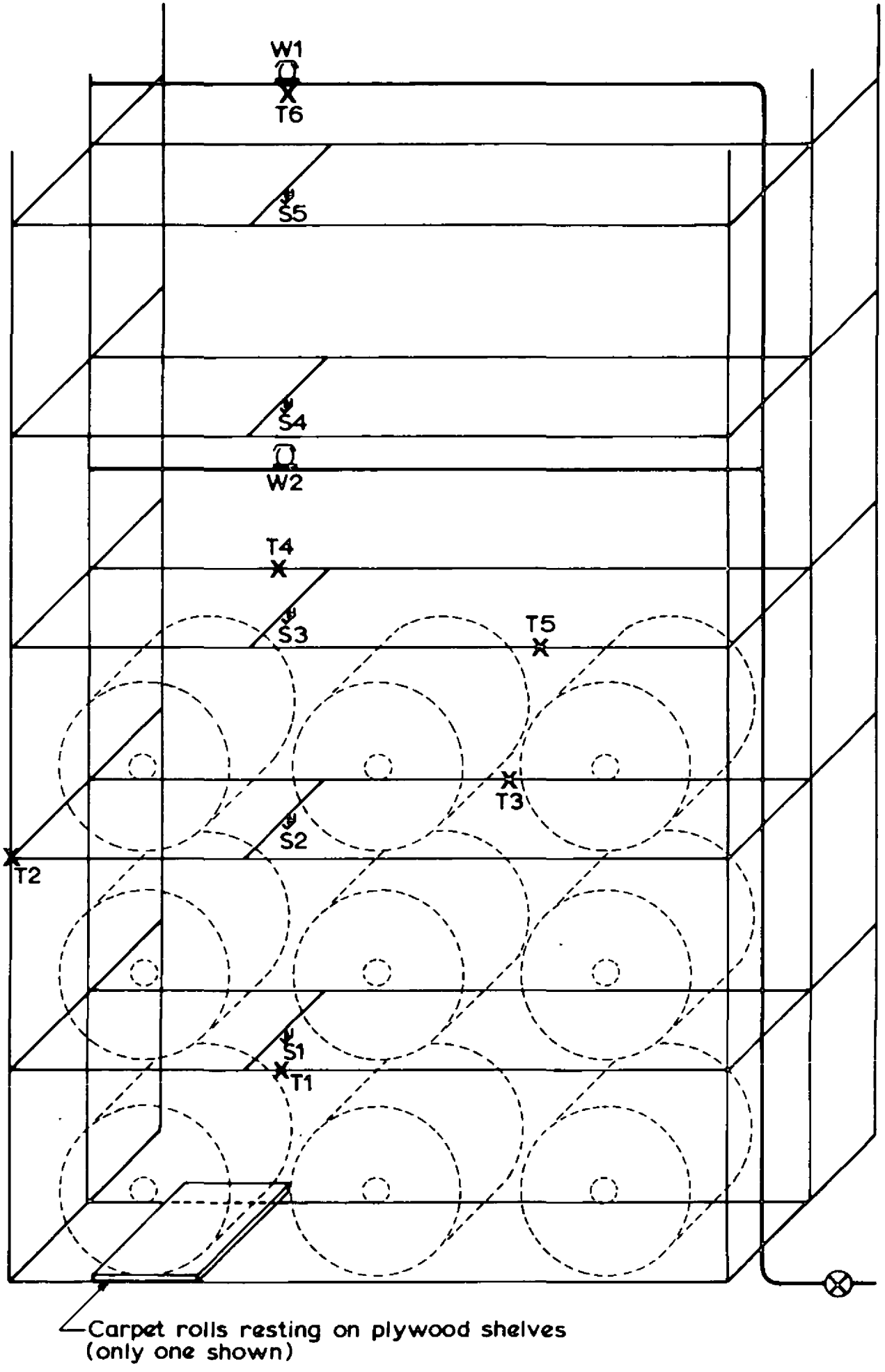

Figure 8 Diagram of open rack to show sprinkler and thermocouple positions

KEY TO FIG.8

T1 - T6	Thermocouples	T1, T2, T5 - Front face of rack T3 and T4 - Centre of rack
S1 - S5	'Dry' sprinklers	
W1 and W2	'Open' sprinklers	(Water supplied to them by manual operation of ⊗)

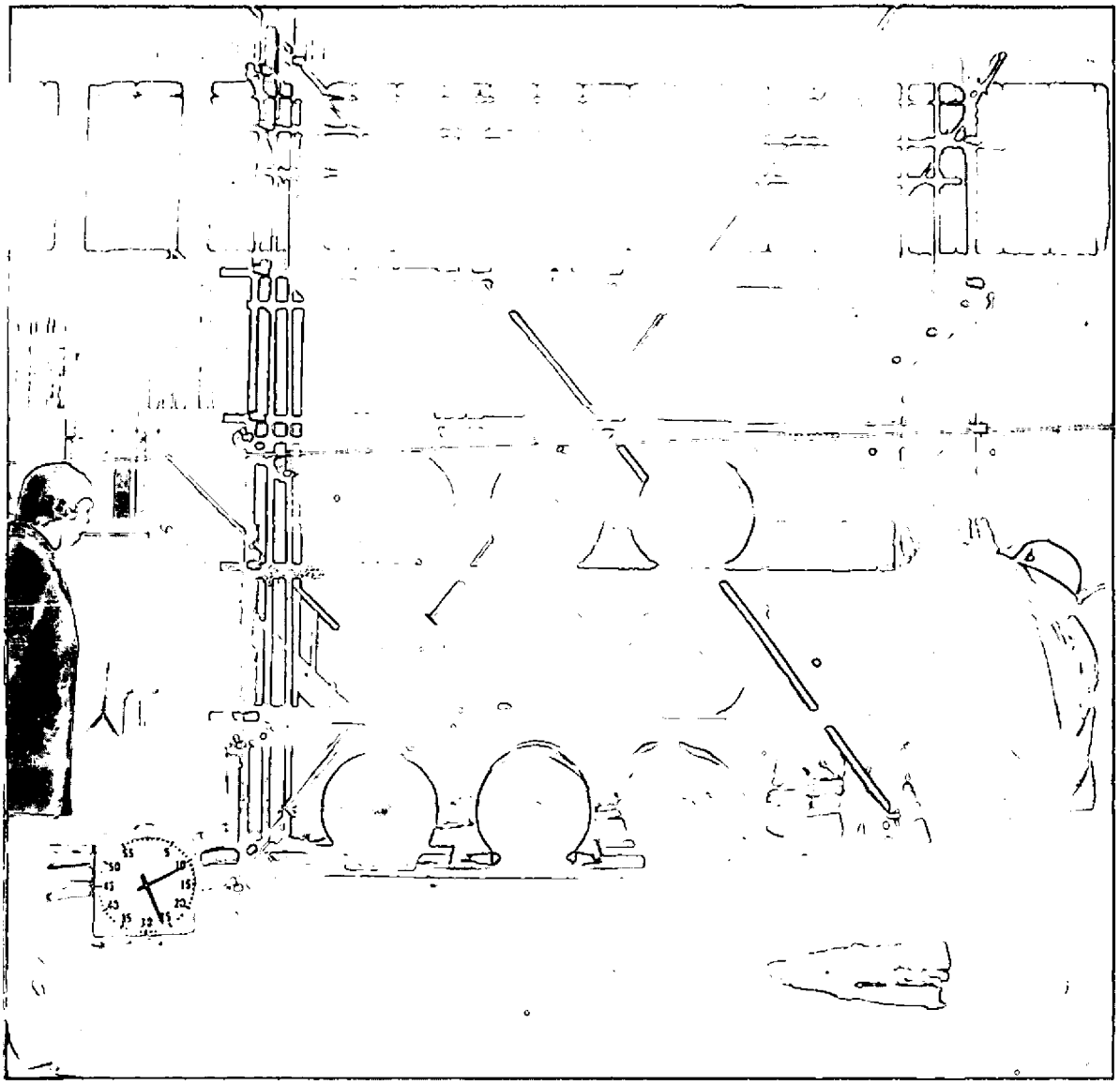

FIG.9. EXPERIMENT 1. 10 min 26 s FROM IGNITION

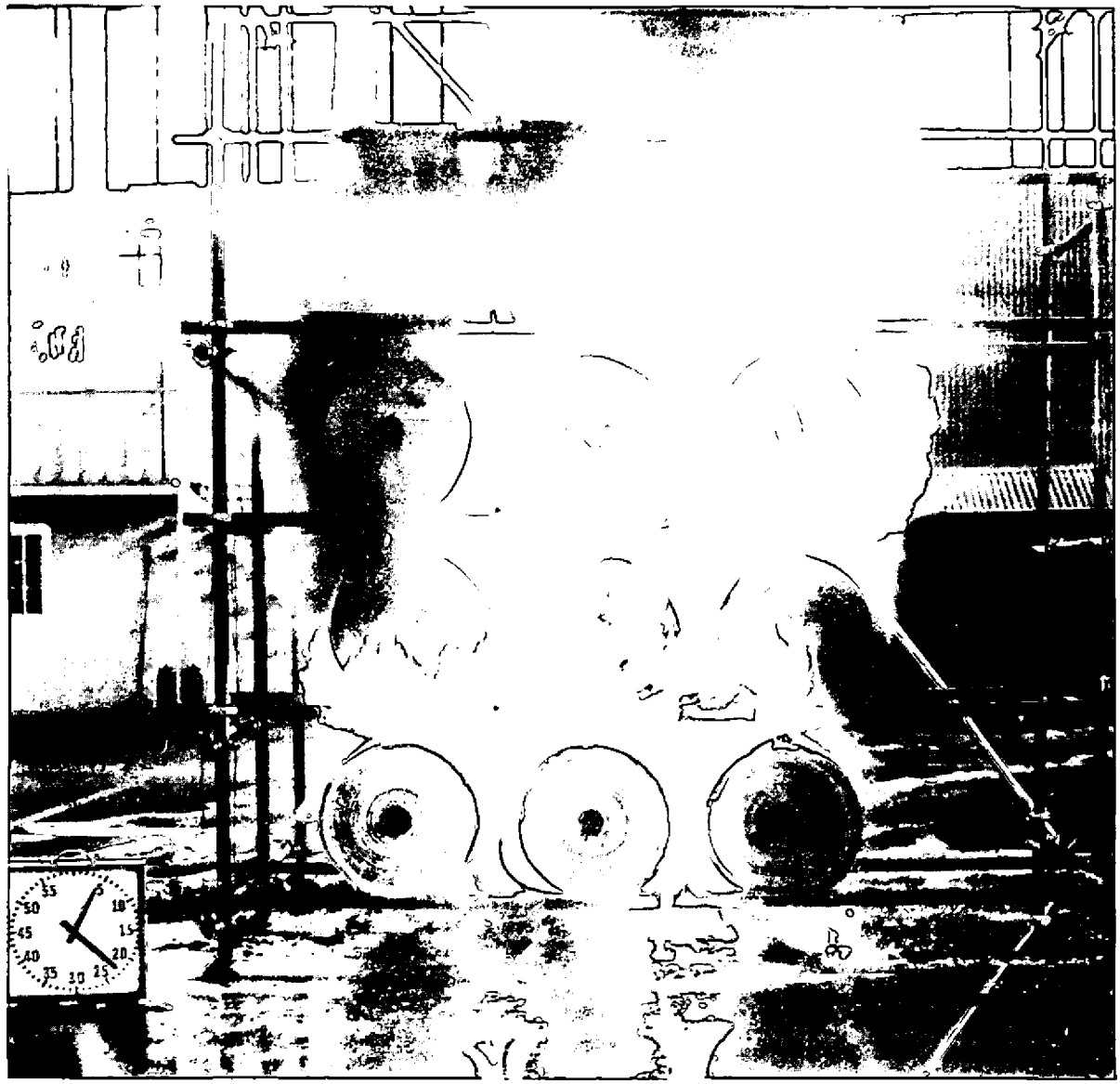

FIG.10. EXPERIMENT 3. 3 min 23 s FROM IGNITION

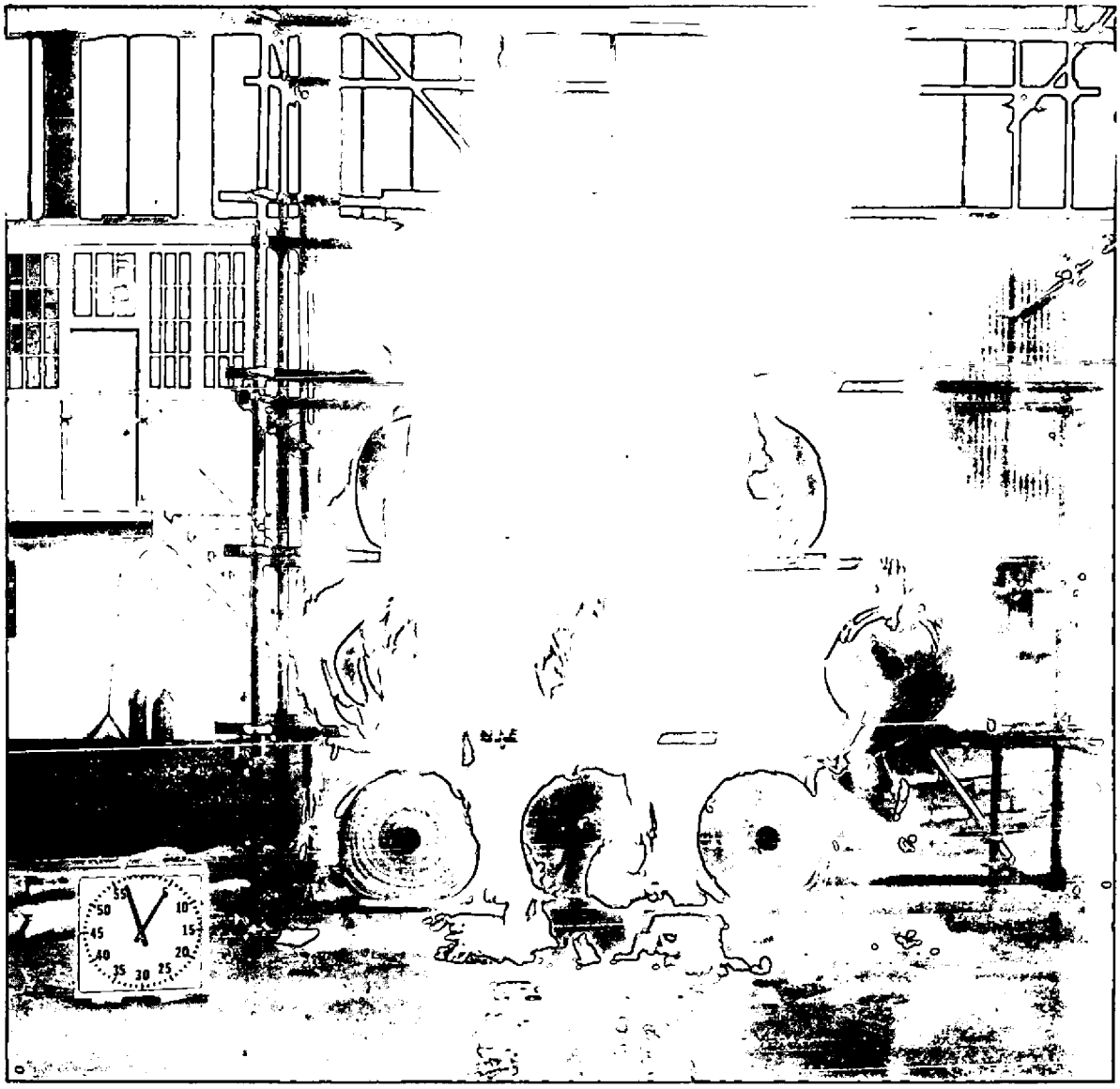

FIG.11. EXPERIMENT 2. 4 min 57 s FROM IGNITION

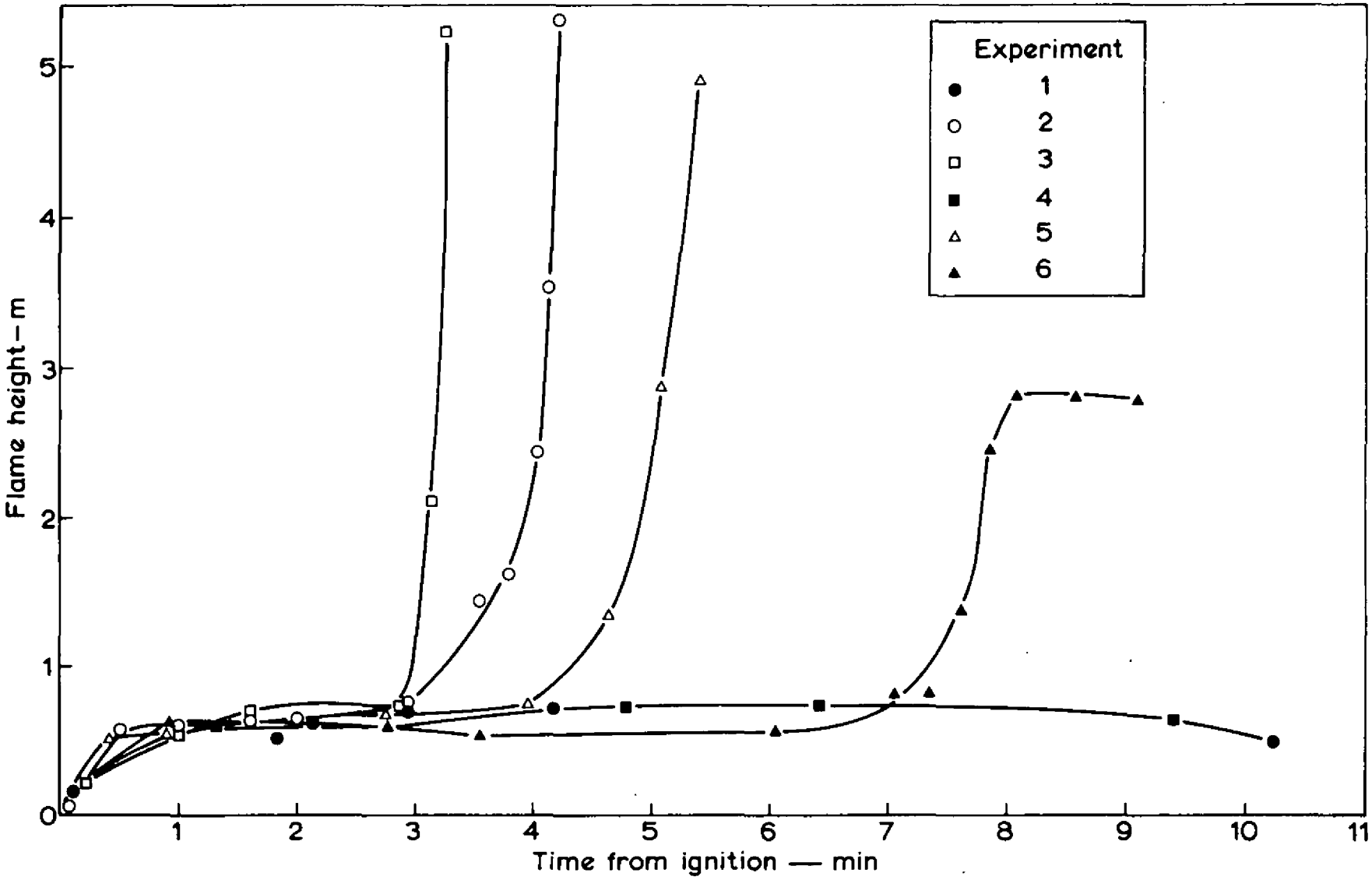

Figure 12 Rate of fire spread in carpets, on racks

APPENDIX - TIME/EVENT TABLES FOR EXPERIMENTS 1-6

TABLE A1

Experiment 1 Carpet D

Time	Event
0 - 00	Ignition (either side of roll Y1)
1 - 15	Flames both sides of Y1
1 - 40	Flames to the top on both sides of Y1
2 - 28	Sparks reaching the bottom of Y2, but roll not ignited
2 - 55	Flames just touching Y2 base board
5 - 00	Rolls X1 and Z1 show signs of charring
10 - 47	Flames to the front of Y1 on the XY side, and just starting to burn the front of the roll on that side
12 - 49	No longer burning on front of roll Y1 on XY side. Flames reached front of Y1 on YZ side but no burning on face
19 - 30	Test terminated. No 'dry' sprinklers operated

Observations of damage

Carpet roll Y1: Depth of burning - 2 layers

Front face - virtually untouched

TABLE A2

Experiment 2 Carpets A and D

Time	Event
0 - 00	Ignition (either side of roll Y1 - carpet A)
0 - 30	Flames to top of Y1
1 - 35	Flames under Y2 base board
2 - 24	Flames on face of Y1
2 - 45	Foam rubber dripping from roll Y1
3 - 00	Flames on face of Y2 (carpet D)
3 - 26	Flames between X2 and Y2
3 - 55	Flames between X3 - Y3 and Z3 - Y3
4 - 05	Six rolls alight
4 - 26	All 9 rolls well alight
4 - 28	Water applied manually through sprinkler W1
13 - 30	Test terminated. 'Dry' sprinklers operated at 4 - 06, 4 - 13, 4 - 16, 4 - 28, 4 - 28

Observations of damage

All rolls of carpet A were burnt through to the former

Most of the rolls of carpet D had extensive damage on one face

TABLE A3

Experiment 3 Carpet A

Time	Event
0 - 00	Ignition (either side of roll Y1)
1 - 00	Flames around Y1
1 - 36	Z1 alight
2 - 00	Flames reaching Y2 base board
2 - 47	X1 smouldering
3 - 00	Y2 and Z2 alight
3 - 05	X1 alight
3 - 14	All 9 carpet rolls well alight
4 - 00	Water applied manually through sprinkler W1
14 - 30	Test terminated. 'Dry' sprinklers operated at 3 - 25 3 - 26 3 - 37 3 - 52

Observations of damage

A large proportion of the carpet on the formers was burnt out.

TABLE A4

Experiment 4 Carpet D

Time	Event
0 - 00	Ignition (either side of roll Y1)
1 - 00	Flames to top of Y1
2 - 30	Flames under Y2 base board
4 - 30	Very slight signs of scorching on Z1
6 - 30	Z1 almost alight
7 - 30	Smoke issuing from face of Y1
14 - 00	Burning on Y1 reduced Z1 still smouldering
16 - 00	Test terminated. No 'dry' sprinklers operated

Observations of damage

Carpet roll Y1 - two layers burnt through

TABLE A5

Experiment 5 Carpets A and D

Time	Event
0 - 00	Ignition (either side of roll Y1)
0 - 15	Flames to top of roll Y1
0 - 34	Flames touching Y2
2 - 00	Flames spreading to front and rear of Y1
2 - 28	Flames on front of Y1 on X-Y side
3 - 45	Z1 almost alight
4 - 32	X1 alight and Y2 also
5 - 30	Water applied manually through sprinkler W2
13 - 00	Test terminated. 'Dry' sprinklers operated at 4 - 47 4 - 48 5 - 00 5 - 17 5 - 25

Observations of damage

Rolls of carpet A: 80% destroyed (burnt right through)

Rolls of carpet D: Charred but not burnt through on any of the rolls

TABLE A6

Experiment 6 Carpet A

Time	Event
0 - 00	Ignition (either side of Y1)
0 - 48	Flames around Y1
2 - 50	Signs of scorching on X1 and Z1
3 - 30	Smoke issuing from front face of Y1
6 - 53	Front edge of Y1 burning
7 - 18	X1 alight
7 - 28	X2 alight
7 - 48	7 rolls alight
8 - 00	Sprinkler at W2 operated automatically
10 - 00	Flames diminishing, foam rubber still burning
14 - 00	Test terminated, water turned off. 'Dry' sprinklers operated at
	7 - 47
	7 - 53
	7 - 55
	8 - 00
	8 - 10

Observations of damage

All rolls virtually burnt out.

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