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THE PERFORMANCE OF AN EXTRA LIGHT HAZARD SPRINKLER INSTALLATION

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SUMMARY

Two experiments were carried out to assess the effectiveness of an Extra Light Hazard sprinkler protection system, installed to the Fire Offices' Committee 29th Edition Rules, in a simulated open plan office.

The results of these tests showed that the design area of operation, which dictates the water supply requirements of the sprinkler system, is by far the most critical factor in the success or failure of the sprinkler system in controlling the fire.

Department of the Environment Fire Research Station of the Building Research Establishment

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1. INTRODUCTION

Two experiments were conducted at the Cardington laboratory on a simulated Extra Light Hazard (XLH) risk.

An existing building inside the hangar, 27.8 m long, 6.8 m wide and 3 m high, was modified to represent an open-plan office, with a sprinkler system installed to comply with the requirements of the 29th Edition FOC Rules for XLH occupancies[1]. In the first experiment the sprinkler spacing was not at the maximum allowed in the Rules, but in the second test the sprinklers were moved to approximately the maximum permissible spacing.

The fire loading in the compartment was provided by wood cribs, wall lining and carpeting.

The water supply was designed to give a discharge density of 2.25 mm/min from each of the first 4 sprinklers to operate. The flow was then to be maintained at this level. The number of sprinklers operating, their time of operation, and the spread of the fire was observed.

2. EXPERIMENTAL ARRANGEMENTS

The steel framed, steel clad building (Fig.1) was fitted with a suspended plasterboard ceiling at a height of 2.8 m above the floor.

Half the length of the building was carpeted, and the walls were lined with 20 mm thick fibreboard.

2.1. Fire loading

The fire loading of 400 MJ/m^2 was obtained from 13 wood cribs, (Fig.2) each covered with a 75 mm thick expanded flexible polyurethane foam layer and positioned as shown in Fig.3. Each crib was 2 m long, 1 m wide and 0.8 m high, constructed of 38 mm^2 pine wood (pinus sylvestris) sticks, and weighed approximately 153 kg. The spacing of the sticks was approximately 15 cm apart and the weight of the polyurethane foam on each crib was 3.5 kg.

This gave an average fire loading of about 400 MJ/m^2, from the cribs, assuming a calorific value of 17 MJ/kg for wood. The additional fire loading of carpet and wall lining was not calculated.

2.2. Sprinkler system

The sprinklers used were of the 10 mm pendent spray glass bulb type, with a temperature rating of 68^{o}C.

The sprinkler spacing was 3.57 m x 4.09 m in Experiment 1 and 4.65 m x 4.65 m in Experiment 2. This gave assumed areas of coverage for each sprinkler of 14.6 m^2 and 21.6 m^2 respectively. The sprinkler positions relative to the building are shown in Figs 4 and 5.

The operation of sprinklers was electrically monitored. Air temperatures were measured by thermocouples positioned on the ceiling, as shown in Figure 4; they were kept in the same positions for both experiments.

2.3. Water supply

Water was supplied to the sprinkler alarm valve through 70 mm hose from a petrol driven pump. Flow to the system was measured electrically and recorded. The water flow was controlled by varying the pump speed manually.

The flow required to give an average discharge density of 2.25 mm/min from each sprinkler that operated was:-

33 dm^3/min for 1 sprinkler
66 dm^3/min for 2 sprinklers
99 dm^3/min for 3 sprinklers
132 dm^3/min for 4 or more sprinklers

in Experiment 1, and

49 dm^3/min for 1 sprinkler
98 dm^3/min for 2 sprinklers
147 dm^3/min for 3 sprinklers
196 dm^3/min for 4 or more sprinklers

in Experiment 2.

These four rates represent the absolute minimum that would be allowed, and in practice higher flow rates would be found, especially for the first sprinkler to operate.

3. EXPERIMENTAL PROCEDURE

At the start of each experiment ambient temperature and humidity were measured, together with the moisture content of the timber in the crib.

The water pump was then started, and run at low speed, to give a pressure of about 0.3 b at the alarm valve.

Crib 13, (Fig.3) was ignited using a strip of fibreboard, 1 m long and 75 mm wide, which had been previously soaked in methylated spirits.

The water flow was increased as sprinklers operated, and adjusted as closely as possible to the required rate.

When control of the fire had been obtained, the water was turned off and the damage to the fire load examined.

The actual water density at various flow rates was measured by placing a collecting tray on top of crib 13, after completion of each experiment.

A video recording was made during Experiment 1, and photographs taken throughout each experiment.

4. RESULTS

In Experiment 1, the fire was controlled, and eventually extinguished by the operation of 3 sprinklers.

One half of crib 13 was charred, and a small area of polyurethane foam on the top of crib 5 was burnt (Fig.6). The measured water density on crib 13 at the final flow rate of 119 m^3/min was 2.3 mm/min. The water flow and air temperature (recorded by T6) are shown in Fig.7.

In Experiment 2, the rate of fire development was greater than in Experiment 1, as can be seen from the air temperature graph for T6, shown in Figure 8. All sprinklers opened, and the fire spread to the wall lining on both sides of the building. At this stage, from $3\frac{1}{2}$ to 5 min after ignition, the actual water density on crib 13 was zero. The water flow was then increased to 436 dm^3/mm, Fig.8 which gave a density of 1.8 mm/min on crib 13. The fire was contained, and the air temperature (recorded by T6) began to fall, (Fig.8).

Tables 1 and 2 give a detailed account of the progress of each experiment.

4.1. Sprinkler operation

The operating time of the sprinklers in the two experiments, together with the rise in air temperature received at the nearest thermocouple, at the time of sprinkler operation, are shown in Tables 3 and 4.

4.2. Fire damage

While the damage in Experiment 1 was negligible, in Experiment 2, (Fig.9) the flames from crib 13 spread across the ceiling and ignited the fibreboard wall lining on both sides of the building. On each side the burning occurred from the ceiling down to about 1.5 m above the floor. The area damaged on each side was about 2 m^2 and the depth of burning was 2 to 3 mm. An area of approximately 4 m^2 of the plasterboard suspended ceiling above crib 13 collapsed, due to deformation of the aluminium support structure.

5. DISCUSSION

The experiments, although basically similar, produced markedly different results. In the first case, the fire was controlled quickly by the operation of 3 sprinklers. In the second case, all the sprinklers in the building operated, and it was necessary to increase the water flow rate above the planned maximum level to bring the fire under control.

The three major differences in the experiments were:-

a) Spacing of sprinklers. The distance of the nearest sprinkler from the ignition point of the fire was increased by approximately 400 mm for S6 and S13, and 800 mm for S7 and S14. Previous research work shows that the differences in operating times due to the extra distance of the sprinklers from the starting point of the fire would not be more than 3 seconds. This slight delay in operation is not considered to be a significant factor in the fire control situation. The temperature rise at T6 at time of operation of the first sprinkler in both experiments was 118°C.

b) Rate of fire development. Although the cribs were basically the same in both experiments, the moisture content of the wood was 4 per cent less in the second experiment, and this resulted in a more rapid rate of fire development, as can be seen from the graph of temperature rise at ceiling level in Figure 8. The average increase in temperature to time of sprinkler operations was 0.75°C/s in Experiment 1, and 1.0°C/s in Experiment 2. The greater rate of temperature rise of 33% in Experiment 2 probably contributed to the number of sprinklers operating, although it is difficult to quantify this effect.

c) Delay in water application. The delay, from operation of the first sprinkler to application of water from that sprinkler was approximately 15 s in Experiment 1 and 30 s in Experiment 2. This delay was due to a concern not to exceed the flow requirements in Experiment 2, as had happened in Experiment 1.

6. OBSERVATIONS

The fire tests were more severe than might be expected in premises which are likely to be considered for the installation of sprinkler systems, designed to the minimum requirements of the FOC Rules. The fire load was high, and arranged to give rapid fire spread, and the inclusion of uncovered polyurethane foam added to the rapid increase of heat output from the fire in its early stages. The delay in application of water after the operation of the sprinklers was also longer in the second experiment than would be expected to be found in practice.

Despite the severe conditions, the fire was controlled with minimal damage in the first experiment. In the second experiment, more sprinklers operated than the system was designed to supply. This showed, that in extreme conditions, the requirements of the FOC Rules for Extra Light Hazard occupancies may be inadequate.

7. CONCLUSIONS

The experiments showed the effect of three factors on the performance of sprinklers in Extra Light Hazard occupancies with large undivided compartments, namely:

a) Sprinkler spacing. The sprinkler spacing was not found to be critical within the limits used, either with regard to operating time, which was delayed approximately 3 seconds for each metre greater distance of the sprinkler from the ignition point of the fire, or with regard to water distribution which was adequate at the largest spacing used, provided that the pressure at the sprinkler heads was maintained above 0.4 bar.

b) Rate of water application. The minimum rate of water application specified in the FOC Rules, of 2.25 mm/min, has been shown to be adequate. In the second experiment the fire was brought under control with a rate of application of 1.8 mm/min, measured at the centre of the array.

c) Assumed maximum area of operation. The number of sprinklers likely to operate in large areas such as open plan offices is the dominating factor in the success or failure of a sprinkler system to control a fire.

8. REFERENCES

1. FOC 29th Edition Rules. Rules of the Fire Offices' Committee for Automatic Sprinkler Installations. 29th Edition issued December 1968 (revised November 1973) FOC, London, 1973.

9. ACKNOWLEDGEMENTS

The authors would like to thank Mr D Barnes and Mr C Lambert for their assistance in carrying out the experiments, also members of the British Automatic Sprinkler Association for installing the sprinkler system.

TABLE 1

TIME - EVENT CHART EXPERIMENT 1

TIME min - sec	EVENT
0 - 00	Ignition.
0 - 30	Flames to top of crib 13.
0 - 10	Flames still beating under PU foam on crib 13.
1 - 30	PU foam alight on crib 13.
1 - 45	Flames 1m high above crib 13.
2 - 00	Flames touching ceiling.
2 - 15	Smoke layer 1m deep, whole length of building.
2 - 30	Foam alight on crib 5.
2 - 35	1st sprinkler operated, S13, water flow $20dm^3/min$.
2 - 45	2nd sprinkler operated, S6, water flow still $20dm^3/min$.
3 - 00	3rd sprinkler operated, S14, water flow $128dm^3/min$.
3 - 15	Water flow increased to $217dm^3/min$.
3 - 20	Flames subdued, $\frac{1}{2}$m high above crib 13.
4 - 00	Water flow reduced to $159dm^3/min$.
5 - 00	Flames level with top of crib 13.
6 - 40	Water flow reduced to $119dm^3/min$.
7 - 00	Only small flames in crib 13, PU foam still burning on crib 5.
13 - 00	Flames in crib 13 extinguished, PU foam burning on crib 5.
22 - 00	Test terminated.

Ambient conditions: Temperature $12^{o}C$, Humidity 68%

Moisture content: 18.5%

TABLE 2

TIME - EVENT CHART EXPERIMENT 2

TIME min - sec	EVENT
0 - 00	Ignition.
0 - 20	Centre of crib 13 burning.
0 - 25	Flames beating under PU foam on crib 13.
1 - 08	PU foam alight on crib 13, flames 0.5m high.
1 - 20	Flames touching ceiling.
1 - 30	Smoke layer building up beneath ceiling.
1 - 45	PU foam on crib 11 starting to burn.
1 - 55	PU foam on crib 5 alight, 1st sprinkler operated, S13.
2 - 00	2nd sprinkler operated, S6.
2 - 00) 3 - 06)	Between these times all the remaining sprinklers operated, the last being S9.
3 - 06	Water flow 216dm^3/min.
3 - 30	Water flow increased to 264dm^3/min.
5 - 30	Water flow increased to 436dm^3/min.
6 - 00	Air temperature falling, smoke layer down to floor level at fire end of building.
15 - 00	Air temperature much reduced, fire under control.
22 - 30	Test terminated.

Ambient conditions	Temperature	22°C
	Humidity	68%
Moisture content	14.6%	

TABLE 3

OPERATION OF SPRINKLERS. EXPERIMENT 1

Sprinkler	Operating Time min - sec	Air Temperature Rise ^{o}C
S13	2 - 35	135
S 6	2 - 45	125
S14	3 - 00	125

TABLE 4

OPERATION OF SPRINKLERS. EXPERIMENT 2

Sprinkler	Operating Time min - sec	Air Temperature Rise ^{o}C
S13	1 - 55	-
S 6	2 - 00	120
S14	2 - 10	110
S 7	2 - 12	140
S 4	2 - 15	100
S 5	2 - 15	105
S12	2 - 20	-
S11	2 - 30	110
S10	2 - 50	-
S 3	2 - 55	-
S 2	3 - 00	85
S 9	3 - 06	90

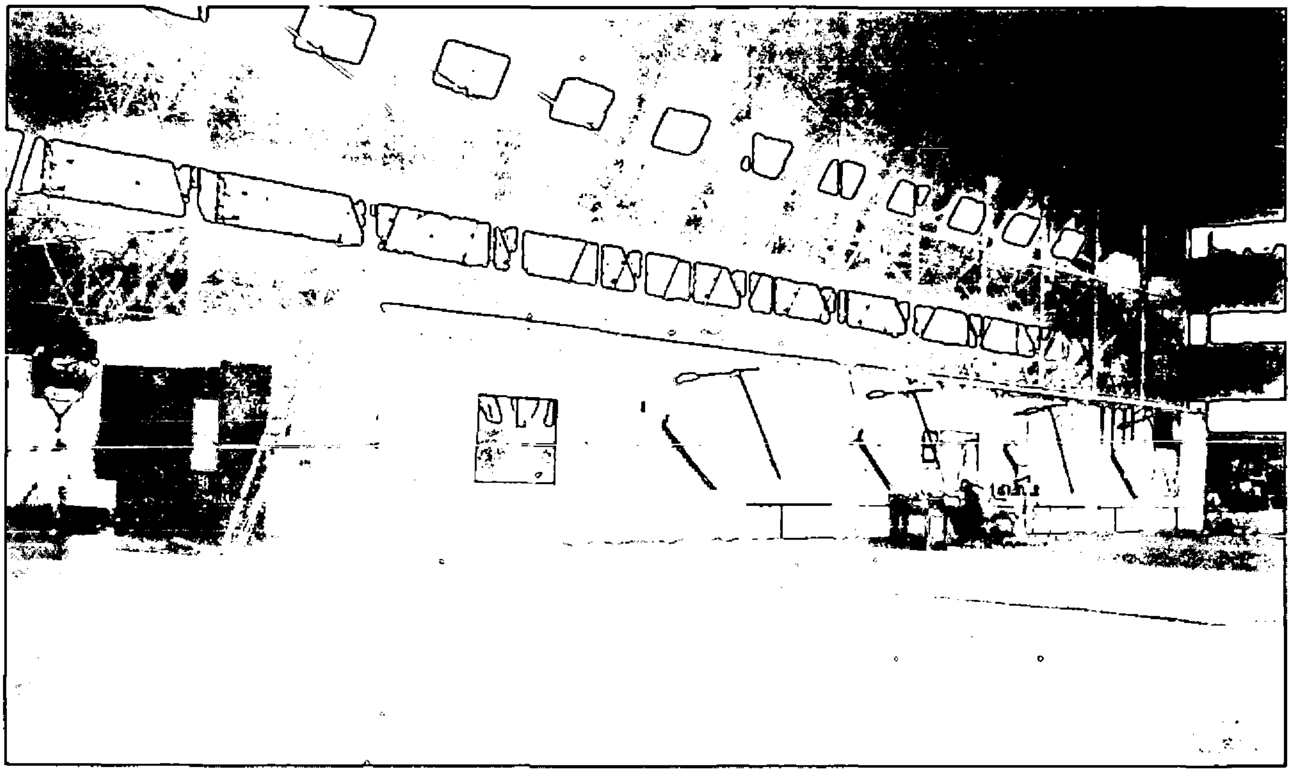


FIG.1. OUTSIDE VIEW OF TEST BUILDING

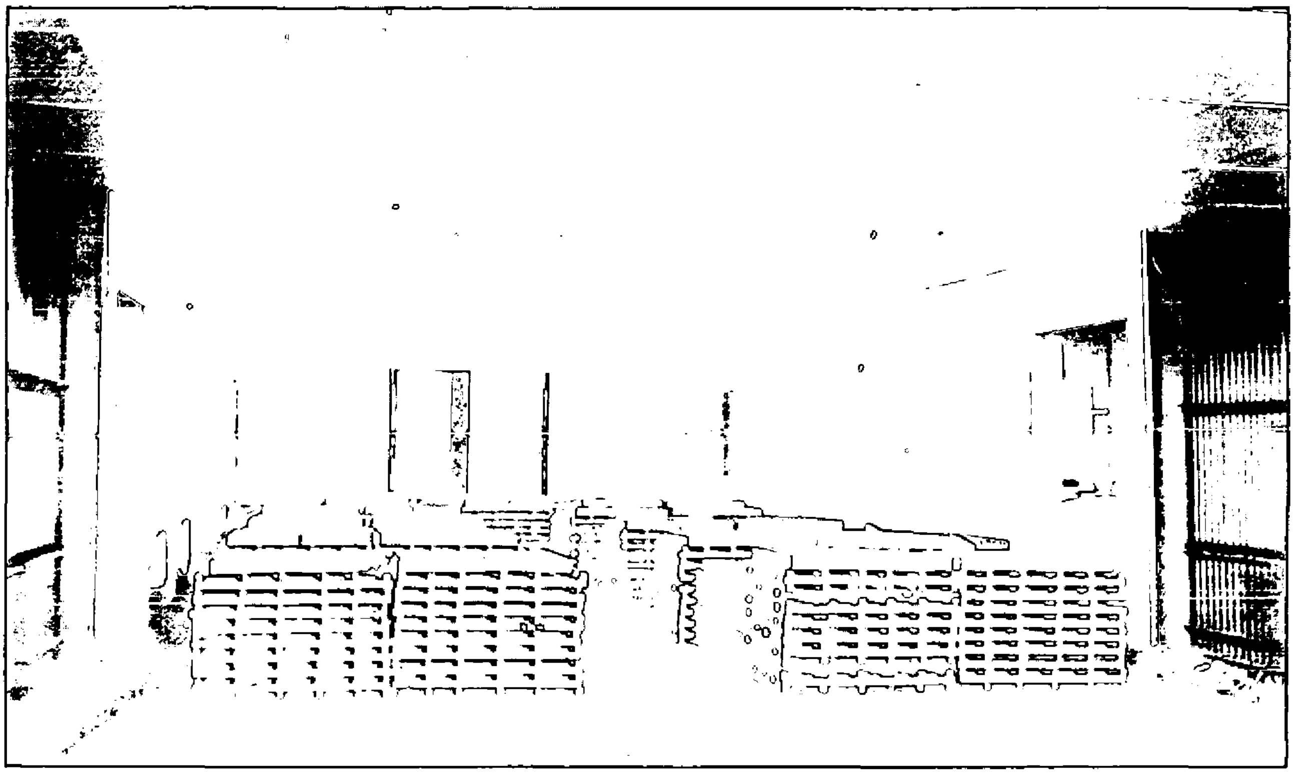
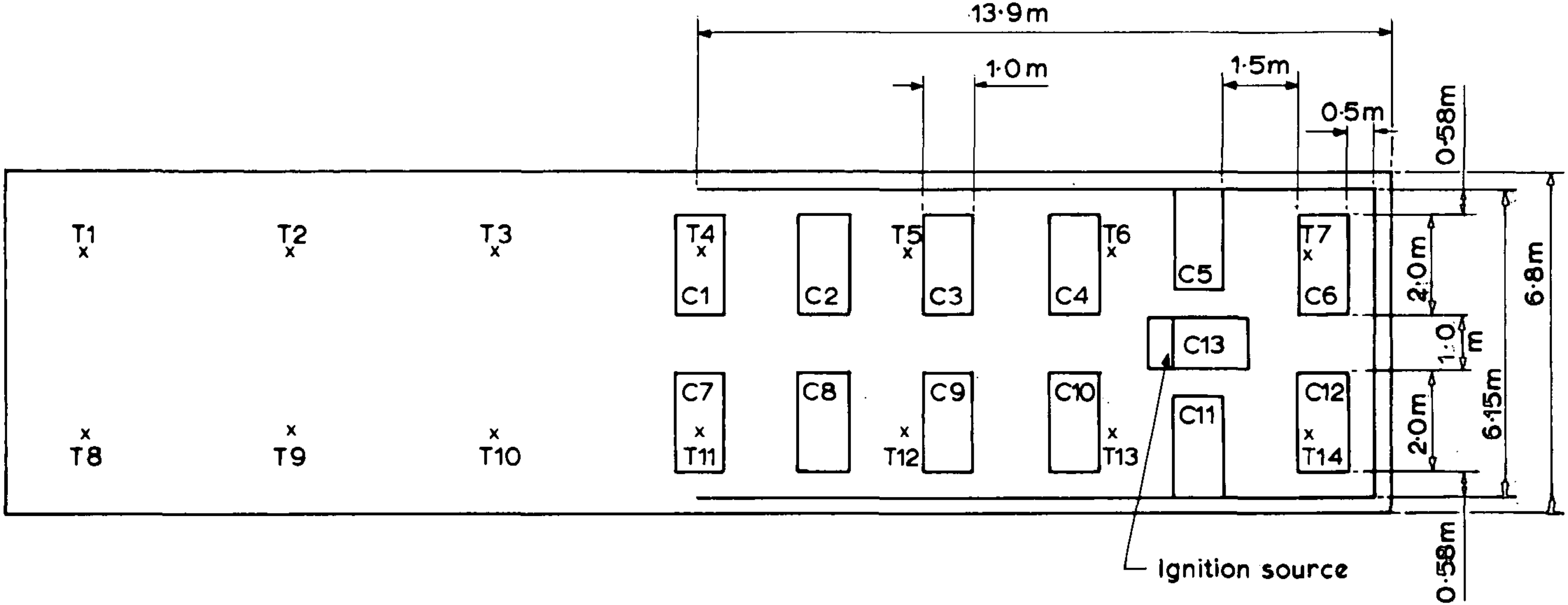


FIG.2. LAYOUT OF WOOD CRIBS



× T1 – T14 Thermocouple positions in experiments 1 and 2

Figure 3 Diagram to show position of wood cribs in experiments 1 and 2

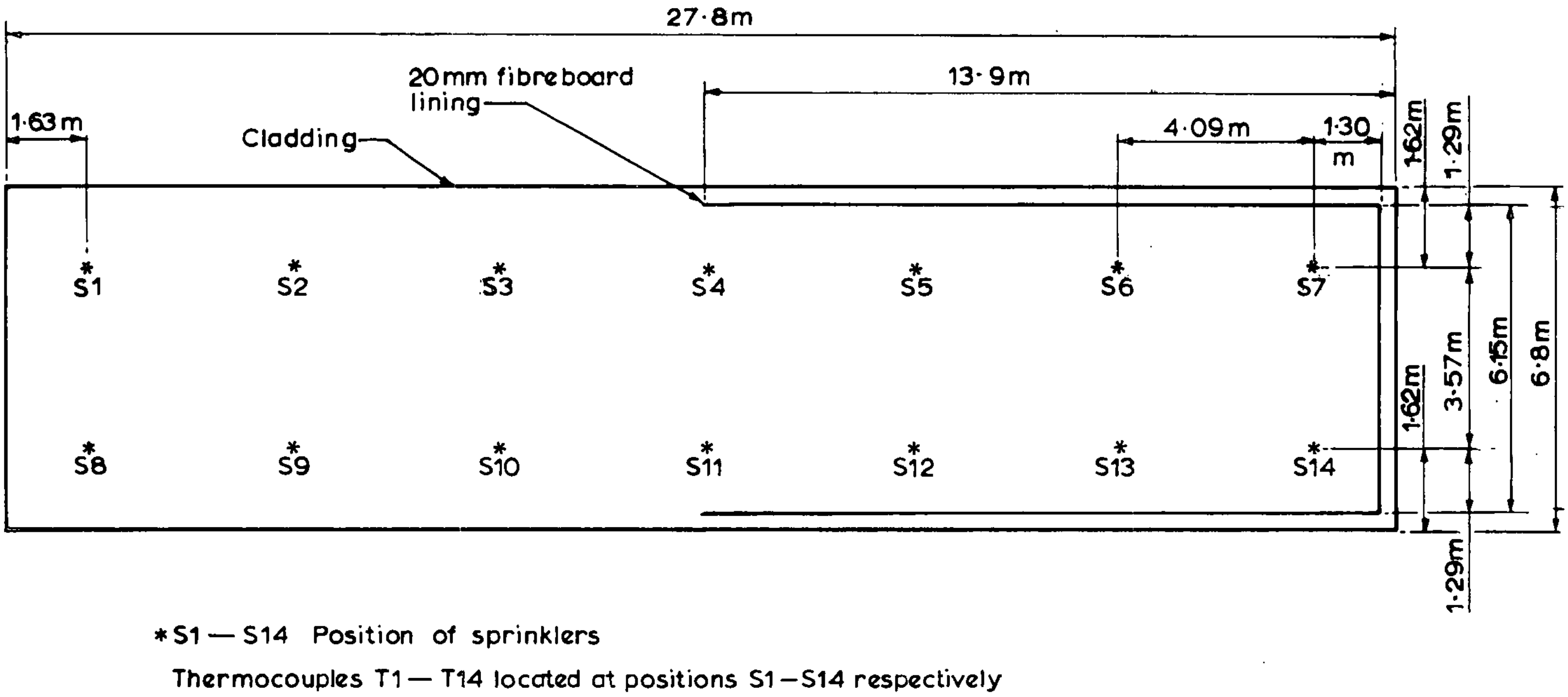


Figure 4 Diagram to show position of sprinklers and thermocouples in experiment 1

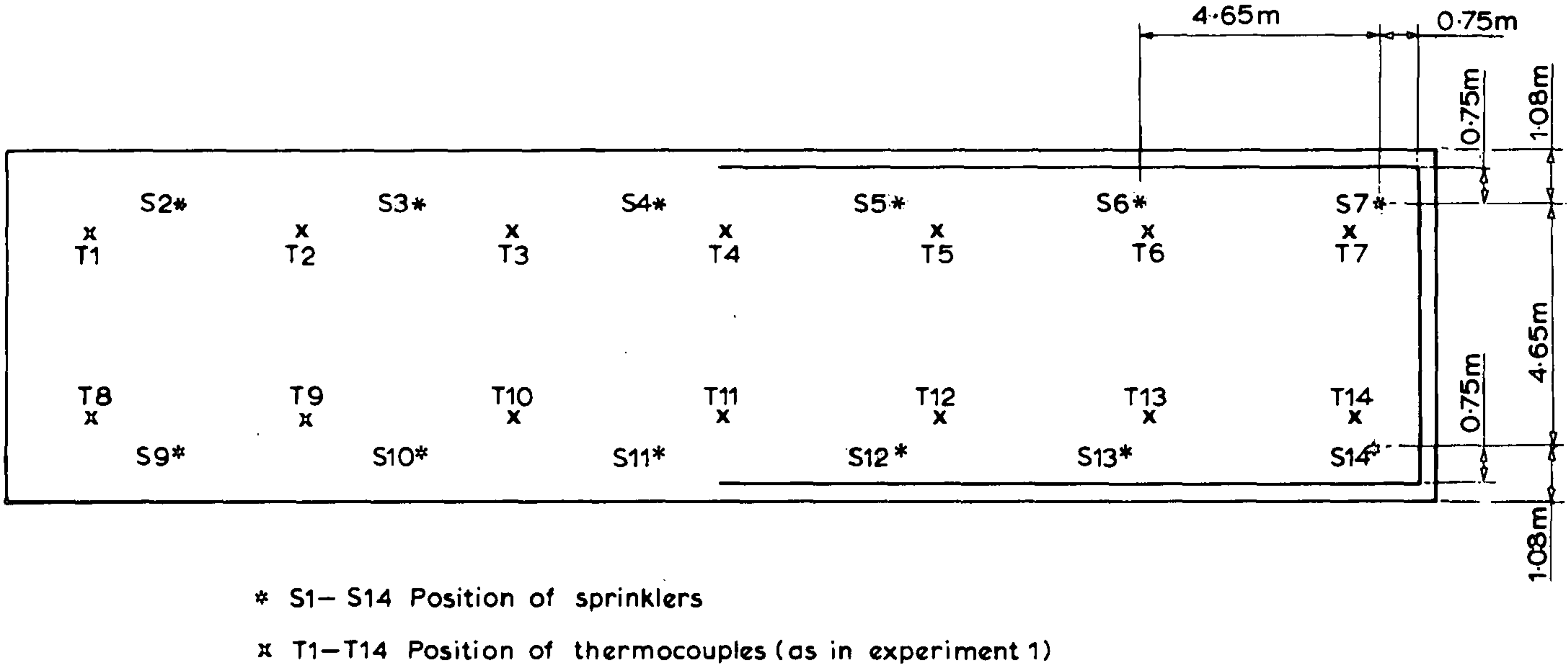


Figure 5 Diagram to show position of sprinklers and thermocouples in experiment 2

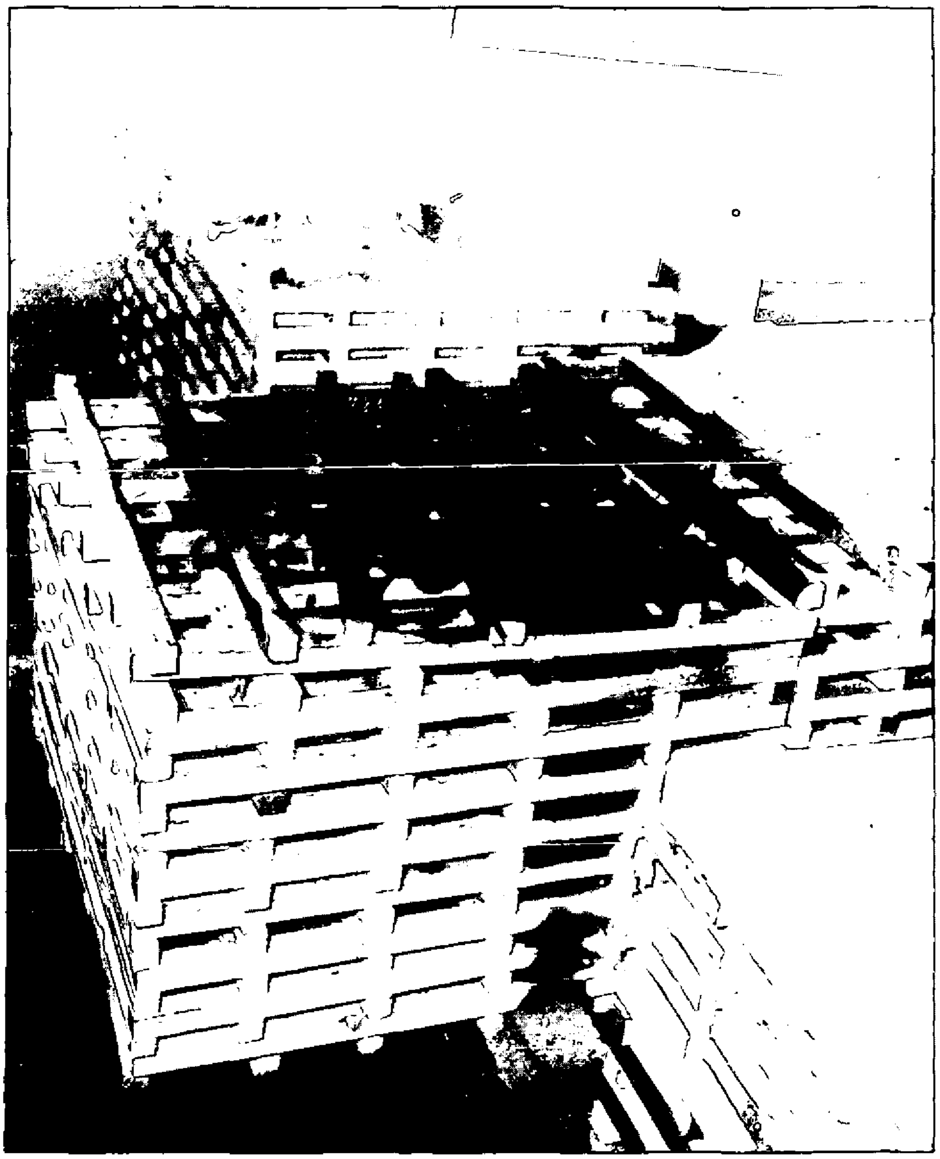


FIG.6. EXTENT OF DAMAGE IN EXPERIMENT 1

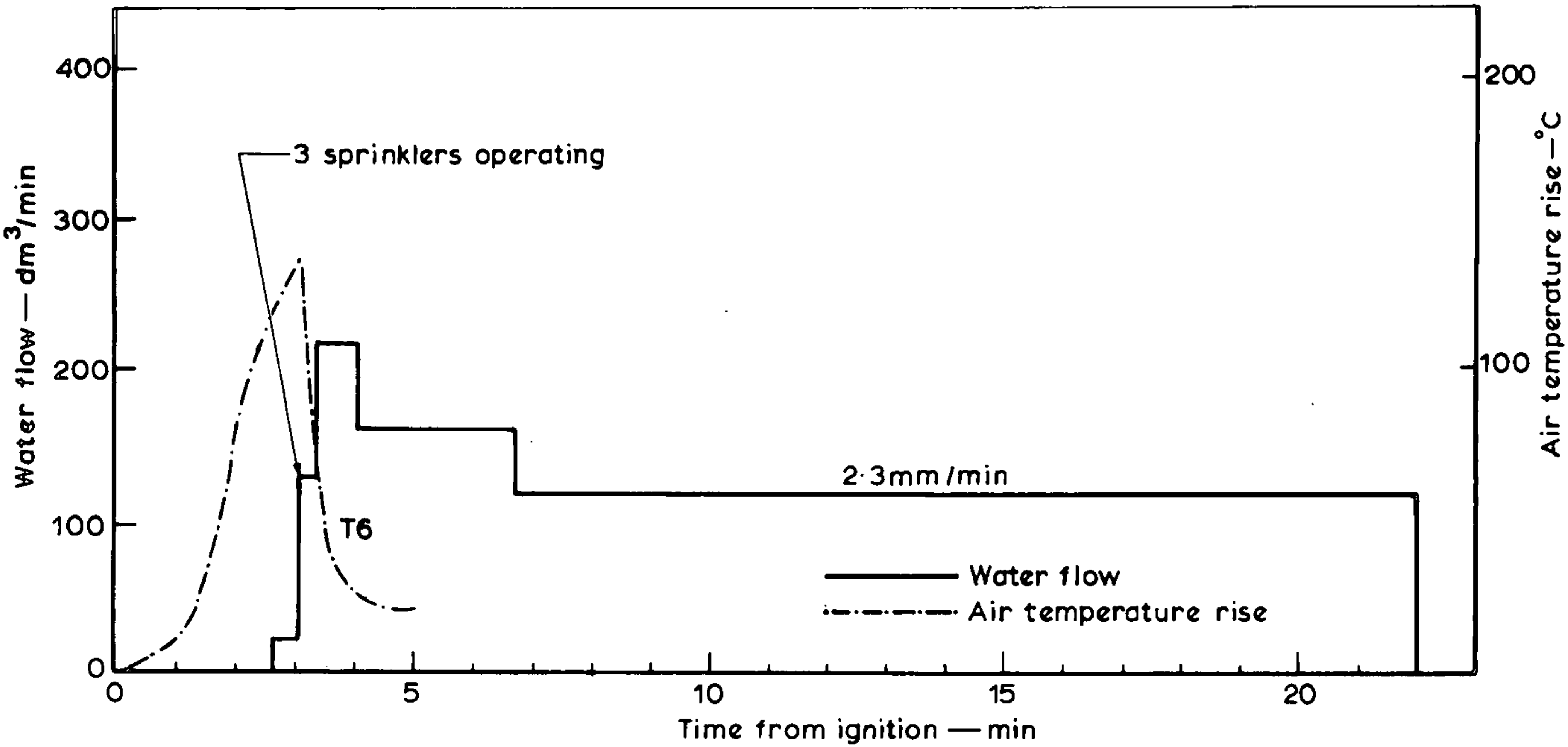


Figure 7 Water flow and temperature in experiment 1

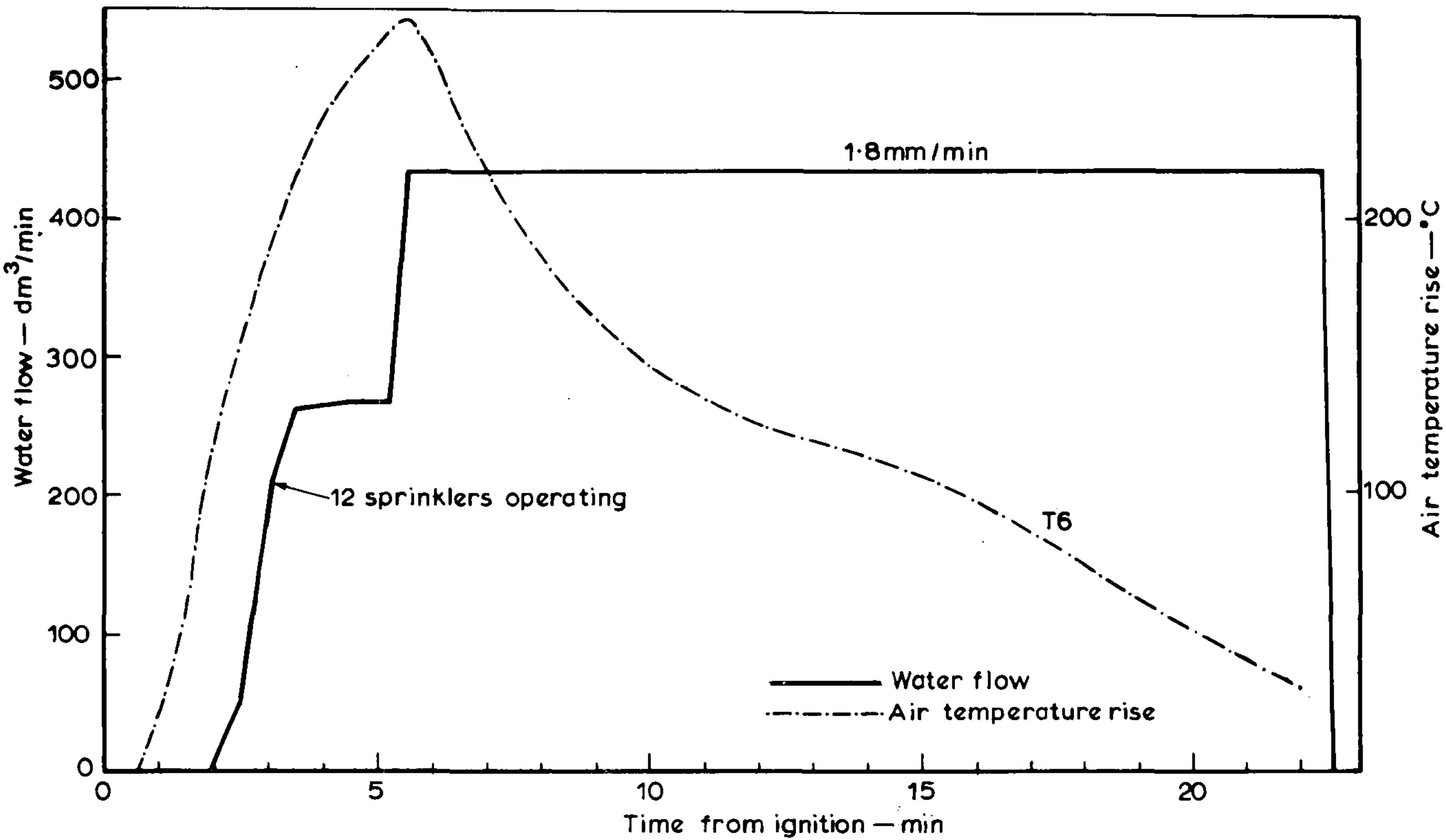


Figure 8 Water flow and temperature in experiment 2

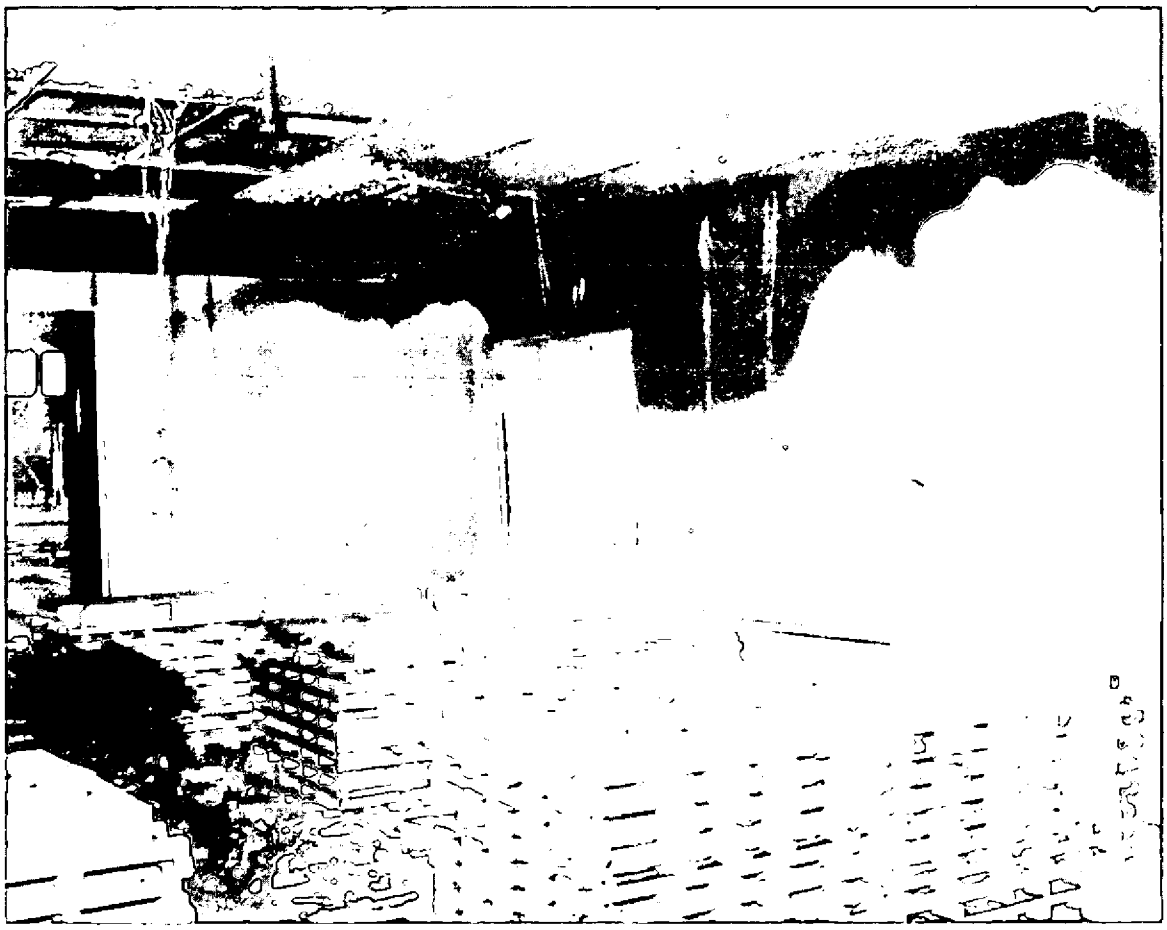


FIG.9. EXTENT OF DAMAGE IN EXPERIMENT 2

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