Fire Research Note

No.914

EXPERIMENTS WITH SPRINKLERS IN HIGH-RACKED STORAGES

(2) EXTINCTION WITH FACE-MOUNTED SPRINKLERS

by

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SUMMARY

A series of experiments has been carried out to determine the effectiveness of sprinklers, mounted on the faces of a storage rack, in the extinction of fires developing in the goods in the rack. It was concluded that a reasonably effective extinction system could be arranged (provided that the sprinklers were activitated by a line detector system) but that the arrangement would generally be less satisfactory than a system employing centrally-mounted sprinklers.

KEY WORDS: Fire spread, high-piled, sprinkler, storage.

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1. INTRODUCTION

All the previous experiments conducted by JFRO using sprinklers in a high-racked storage system have been with the heads at various positions on the central vertical longitudinal plane through the stack, with the fire propagating up the face of the stack[1,2,3]. The experiments described in this note have used sprinklers on the faces of the stack with the fire started either in the centre or on the face. The effect of these changes on the ease of extinction of the fire has been assessed in this report.

2. EXPERIMENTAL DETAILS

2.1. Racking

The small racking was used, as for the previous series at Cardington[1]. It was tubular steel, 4.88 m (16 ft) long, 2.95 m (8 ft 2 in) deep, and 5.68 m (18 ft 7½ in) high.

2.2. Loading

As before, the rack contained thirty-two standard wooden pallets, 1.02 m x 1.22 m (40 x 48 in), each loaded with nine cardboard cartons. Each carton held three empty 5-gallon drums, and some wood wool loosely packed in the spaces between the drums. The load height was again 1.37 m (54 in).

2.3. Sprinklers

Each of the four levels was provided with 5 sprinkler positions (Fig. 1) on each face, corresponding to those previously used in the centre. The four distribution pipes on one side were fed from one 50 mm (2 in) riser. This was repeated on the other side, and the two risers were coupled at the bottom.

The ends of the distribution pipes remote from the riser were used for connections to pressure gauges and the other positions, except the central ones, were fitted with $\frac{1}{2}$ in (15 mm) 68°C (155°F) glass bulb sprinklers of conventional pattern. The central positions were fitted with open or closed sprinklers as required for each experiment.

Some preliminary experiments were carried out without any boxes in the rack, to find which type of sprinkler gave the best distribution of water. The final arrangement used a sidewall sprinkler, mounted at an angle as shown (Plate 1), so that water would be bounced off the pallet above it towards the central flue, and also directed down the face below the sprinkler.

The pressure used was about 6 bars in all experiments.

2.4. Instrumentation

Thermocouples were fitted near each sprinkler head on the vertical centre line of the rack face, on one side, in addition to the ones used previously in the centre of the rack.

Radiometers were again positioned one metre from the stack at heights of 1.67 m (5.5 ft) and 4.4 m (14.5 ft), but since the fire was lit in the centre of the stack, their view of the fire was severely restricted.

The obscuration produced by smoke was measured at the top of the stack by means of a light source and photocell with a 1 m path length.

All the above were connected to a U.V. recorder giving a continuous trace for each parameter.

Immediately before each fire, the moisture content of the cardboard cartons was measured at several points chosen at random.

3. TEST PROCEDURE

Some fires were lit on the face of the stack as in previous series of experiments, and some were lit in the centre of the stack as given in the fire chronologies. In each case a box was torn, and the torn edge lit with a match. The recorder and clocks were started at the same time. The pump was operating, and the line charged, up to a quick-acting valve near the stack.

When the flames were judged to be at the predetermined level, the valve was opened, except in the cases where the sprinklers were allowed to operate automatically.

A hose line was used for 'mop-up' operations after the sprinkler system had controlled the fire.

4. RESULTS

Figure 2 shows the progress of each fire relative to the arrangement of open sprinklers used. In the first experiment, though it was intended to apply water when the flames reached the top of the first level, a few seconds delay occurred and this enabled the fire to get away. This experiment was thus considered a failure, and the fire was extinguished by applying water to the central sprinklers which had been left open for this purpose if the need arose.

In experiment 2, more water was applied to the face of the stack by using spray sprinklers. Despite two open heads being used on each side, with water being applied when the flames were estimated to be $1\frac{1}{2}$ levels high, the amount of water reaching the centre was insufficient to stop spread, and so the fire was again extinguished with the central sprinklers.

In experiment 3, the spray sprinklers were used with their usual glass bulbs, but the fire was lit on the face of the stack to give them a higher chance of operating. They still failed to control upward spread, so the central sprinklers were used again for extinction.

This failure led to the use of sidewall sprinklers (see section 2.3 above) for subsequent experiments, the first of which (experiment 4) used a block of eight pallet loads only (2 x 2 x 2) to check whether spread to the upper layer could be prevented by this arrangement, which proved to be successful.

Experiment 5 repeated the conditions of experiment 2 except for the type of sprinkler. It was successful, but required a second application of water from the sprinklers, for 1 minute only, to reduce burning in the centre. After this, only the usual "mop-up" operations with a hose were necessary.

Experiment 6 extended the size of fire to a little over 2 levels high, and was again successful, using 4 levels of sprinklers. This was considered to be an unnecessarily expensive arrangement for practical use and so a staggered arrangement was used for experiment 7. The fire height was also extended to 3 levels, but the fire was again controlled.

The final experiment of the series (experiment 8) was also regarded as a failure since the fire spread into the centre, and reached the top of the rack. Several sprinklers operated automatically as well as the open sprinklers at the second level.

Typical graphs of air temperature rise are given in Figs 3 to 8 from which it may be seen that any high values (500°C and more) were only transitory and no danger to the structure existed at any time.

In all cases the radiant energy received at the radiometer positions was well below the level required for ignition of cardboard in an adjacent stack, and thus no figures for radiant intensity have been included.

Detailed fire chronologies are also given in the following pages.

FIRE CHRONOLOGIES

EXPERIMENT 1

Test conditions

Pallet loading	3 boxes high 1.5 m (5 ft).
Sprinklers	Conventional, on both faces at rt. angles to face, 155°F glass bulbs, open heads in centre of first level on each side.
Water supply	Water supplied to open heads when flames reached top of 1st level 2.1 m (7 ft).

Sequence of events

Time	Event
0.00	Ignition, centre of stack.
0.30	Flames 1 m high.
2.00	Flames 1.8 m high, in centre.
2.10	WATER ON, flames 2.1 m high in centre of stack.
3.00	Flames drawn outwards towards sprinklers.
3.30	Flames still 2.1 m high, spreading outwards from centre.
4.10	Flames 4 m high in centre.
4.30	Flames 5.8 m high.
4.50	Flames 7.6 m high in centre of rack, no sprinklers on face operating except original open sprinklers.
5.00	Experiment abandoned.

EXPERIMENT 2.

Test conditions

Pallet loading	3 boxes high 1.5 m (5 ft).
Sprinklers	Spray type, on both faces at rt. angles to face, 155°F glass bulbs, open heads in centre of bottom 2 levels on each side.
Water supply	Water supplied to open heads when flames reached 1½ levels high (3 m).

Sequence of events

Time	Event
0.00	Ignition in centre of stack.
3.00	Flames 1.7 m high in centre.
4.00	Flames to top of 1st level, 2.1 m high.
5.20	Flames 1½ pallets high (3 m). WATER ON to face sprinklers.
6.10	Flames 2 m high.
7.00	Flames 4.8 m high in centre.
7.10	Flames 5.8 m high in centre, and burning through base of pallets on 3rd level.
8.20	Flames to top of rack. Experiment stopped. WATER ON to centre sprinklers.
9.00	WATER OFF to face sprinklers.
10.15	WATER OFF to centre sprinklers.

EXPERIMENT 3

Test conditions

Pallet loading 3 boxes high 1.5 m (5 ft).

Sprinklers Spray type 155°F perpendicular to stack faces, all automatic operation.

Sequence of events

Time	Event
0.00	Ignition in centre of front face.
3.00	Flames 1 m high in centre.
4.00	Flames to top of 2nd box, main burning in face of 'C'.
5.45	Flames to top of 1st pallet load.
6.00	Burning under pallet 'G', also whole of face of 'C' burning.
7.40	Flames igniting all boxes of 'G' pallet from underneath, burning up G/H gap.
8.00	Flames to top of 2nd level.
8.40	Sprinkler operated on front face (position marked E on diagram).
9.30	Fire through to back on 2nd level.
10.40	Flames right through on 3rd level.
10.50	Water applied to open heads in centre of stack to gain control. Experiment abandoned.

EXPERIMENT 5

Test conditions

Pallet loading	3 boxes high 1.5 m (5 ft).
Sprinklers	Angled side wall, open heads in centre of bottom 2 levels on each side.
Water supply	Water supplied to open heads when flames reached 1½ levels high (3 m).

Sequence of events

Time	Event
0.00	Ignition in centre of stack.
2.00	Flames touching bottom of 2nd level pallets.
2.40	Flames reach outside edge. Flames between boxes on 2nd layer, not up centre.
3.15	WATER ON.
4.00	Flaming contained in 1st and 2nd layers.
5.30	WATER OFF.
8.30	WATER ON, burning in centre of stack at second level.
9.30	WATER OFF. Smouldering in centre of stack.

EXPERIMENT 6

Test conditions

Pallet loading	3 boxes high 1.5 m (5 ft).
Sprinklers	Sidewall sprinklers angled 20°, open heads at all 4 levels on each side.
Water supply	Water supplied to sprinklers when flames 2 levels high.

Sequence of events

Time	Event
0.00	Ignition in centre of stack.
1.45	Flames reach top of first pallet.
2.05	Flames ignite face of 2nd level.
3.00	Fire burning up through 2nd pallet.
4.40	Flames reach top of 2nd level. WATER ON.
5.10	Third level alight.
6.20	WATER OFF, almost complete extinction. Burning in bottom layer only.
12.45	WATER ON. Burning in centre of bottom level.
14.50	WATER OFF.

EXPERIMENT 7

Test conditions	Pallet loading	3 boxes high 1.5 m (5 ft).
	Sprinklers	Angled sidewall, open on 2nd and 4th levels on front face, - 1st and 3rd levels on rear face.
	Water supply	Water supplied to open heads when flames reach bottom of 4th pallet level.

Sequence of events

Time	Event
0.00	Ignition in centre of front face.
0.45	Flames to top of first box.
2.15	" " " " 2nd box.
3.30	" " " " 3rd box.
4.10	Flames reach bottom of 2nd level pallet moving down gaps.
4.30	Flames reach bottom of 3rd pallet.
4.50	WATER ON. Flames reach bottom of 4th pallet.
5.00	Flames reach boxes in 3rd level - gaps alight.
5.20	Flames extinguished on faces of 3rd level boxes.
8.00	Boxes alight inside on 3rd and 1st levels.
11.30	Only visible flaming on bottom level.
12.00	A little flaming on all 3 levels
13.30	WATER OFF.
18.00	Remaining flaming on 2nd level extinguished by jet.

EXPERIMENT 8

Test conditions

Pallet loading 3 boxes high 1.5 m (5 ft)

Sprinklers Angled sidewall, open at 2nd level on each face.

Sequence of events

Time	Event
0.00	Ignition in centre of front face.
0.35	Flames reach top of first box.
1.50	" " " " 2nd box.
2.20	" " " " 3rd box.
3.00	Flames reach bottom of 2nd level.
3.30	" " " " 3rd level.
3.45	" " " " 4th level.
4.00	3rd and 4th level sprinklers in centre of rack surrounded by flames but not operating. WATER ON.
5.10	Top centre sprinkler front face operating. Main burning on third level.
6.30	Centre sprinklers on 3rd and 4th levels operate.
8.00	Flaming still in all levels. Extinguished by brigade.

5. CONCLUSIONS

1. Control of a developing fire in the centre of a racked system of stored goods by means of sprinklers positioned on the faces of the rack, is less effective than control by means of centrally-positioned sprinklers.

2. The most effective water distribution from face-mounted heads is obtained from angled sidewall sprinklers, (Plate 1) in the absence of a special design for this position.

3. Fire detection by the sprinkler bulbs on the faces is less certain than detection by bulbs in the centre of the stack.

4. Provision of heat shields is very difficult on face-mounted sprinklers; cooling of heads by others which have operated above them could not therefore be prevented.

5. Face-mounted sprinklers may easily be damaged by material handling procedures, thus causing expensive water damage in the stack.

6. A greater amount of pipework will usually be required for a face-mounted system than for a centrally-mounted system.

REFERENCES

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i) Extinction with centrally-mounted sprinklers by P. Nash, N. W. Bridge and R. A. Young.

2. F.R. Note No. 814. Fire tests with sprinklers on high piled stock. by R. A. Young.

3. F.R. Note No. 866. Some experimental studies of the control of developing fires in high racked storages by a sprinkler system.by P. Nash, N. W. Bridge and R. A. Young.

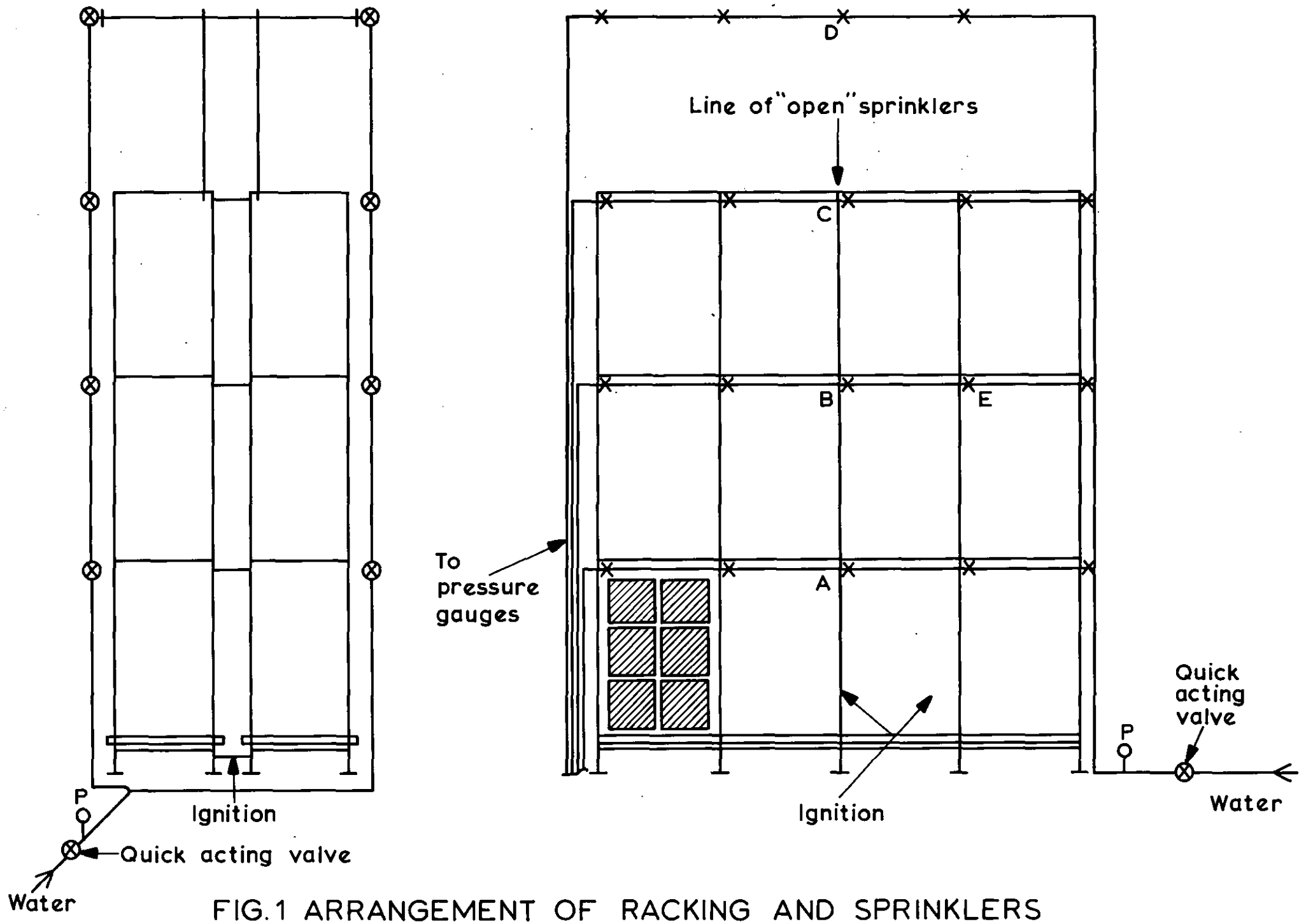


FIG. 1 ARRANGEMENT OF RACKING AND SPRINKLERS

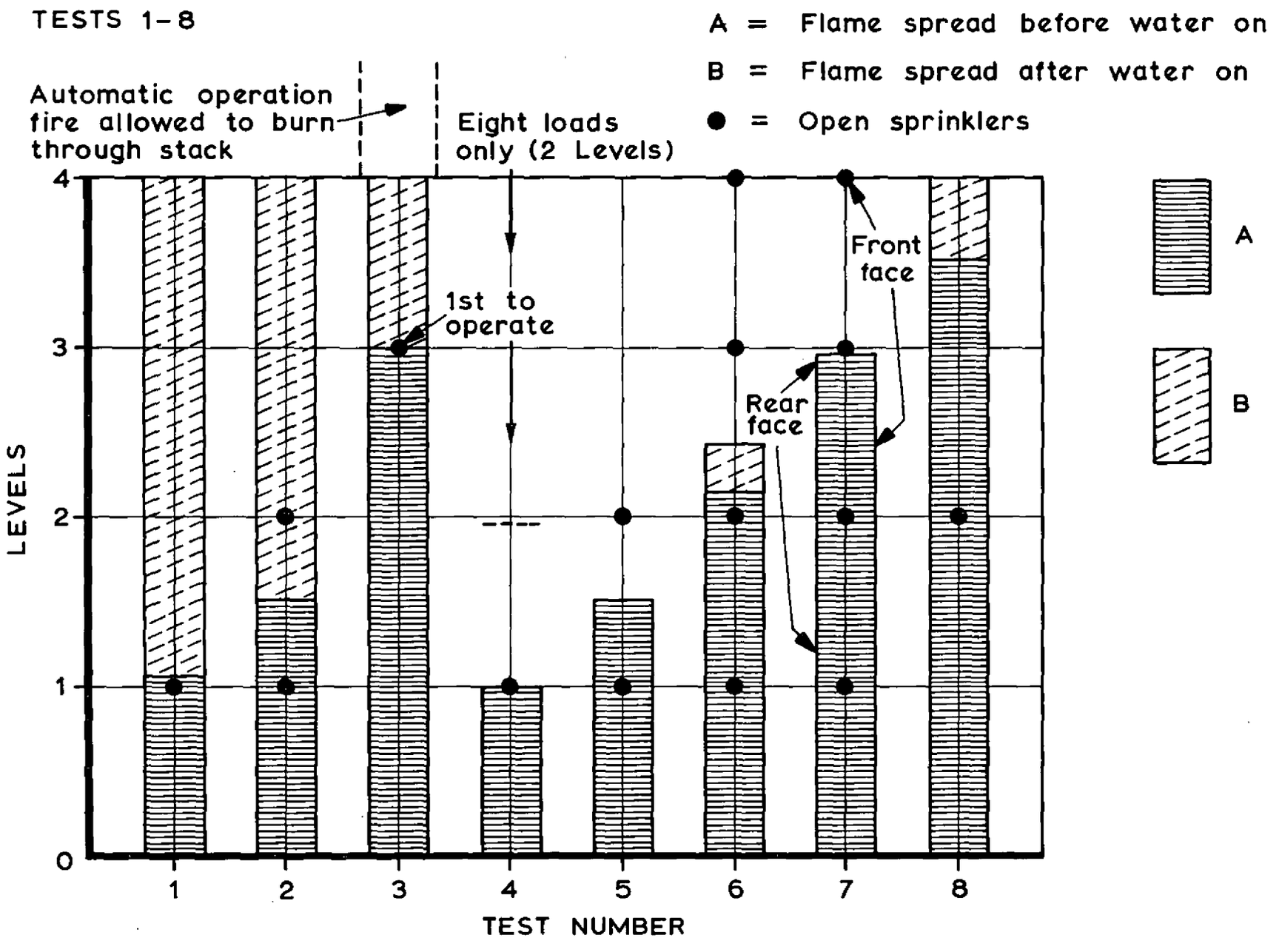


FIG. 2. PROGRESS OF FIRE RELATIVE TO OPEN SPRINKLERS USED

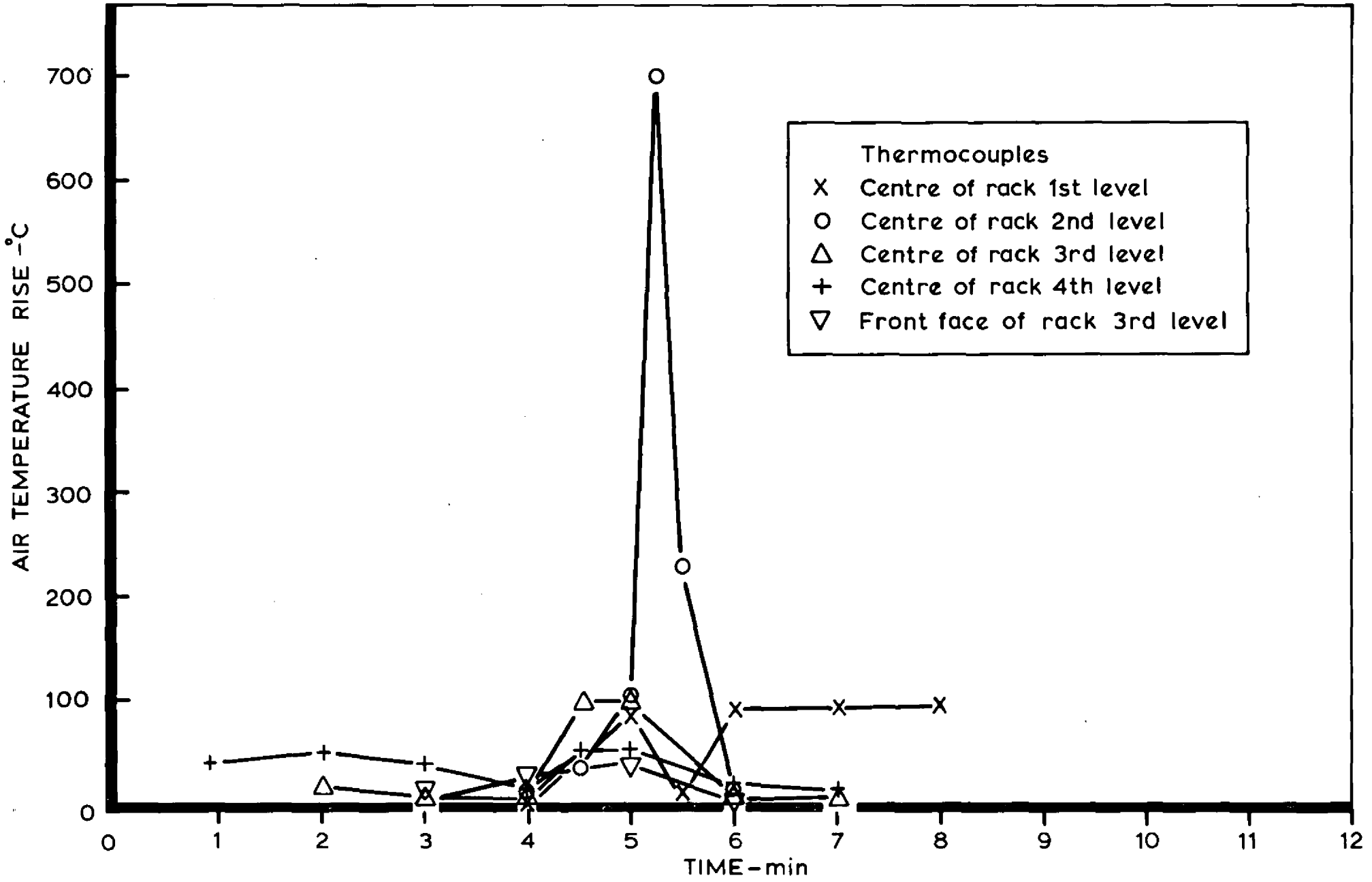


FIG. 3 AIR TEMPERATURE RISE. EXPERIMENT 1

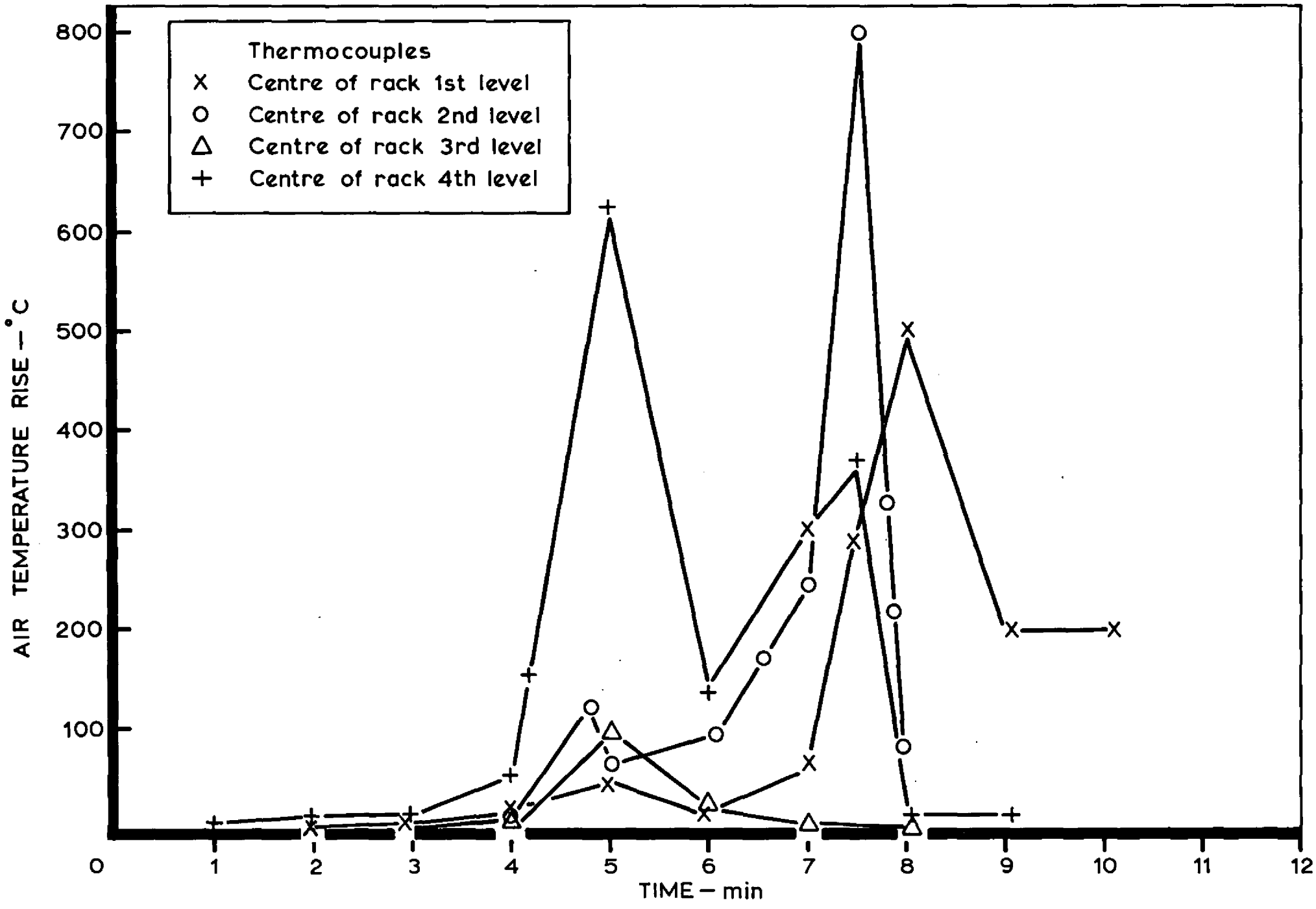


FIG. 4 AIR TEMPERATURE RISE. EXPERIMENT 2

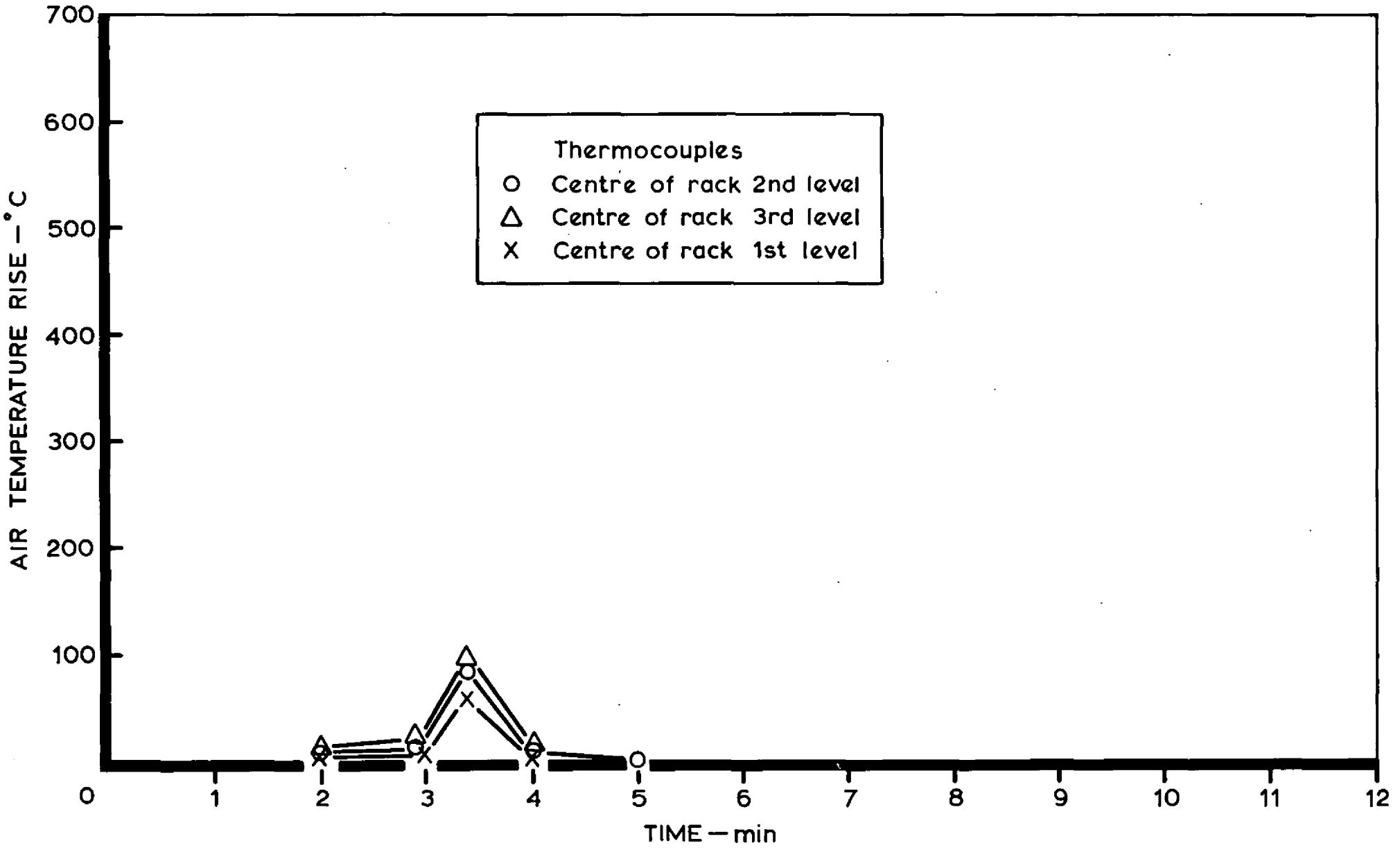


FIG. 5. AIR TEMPERATURE RISE. EXPERIMENT 4

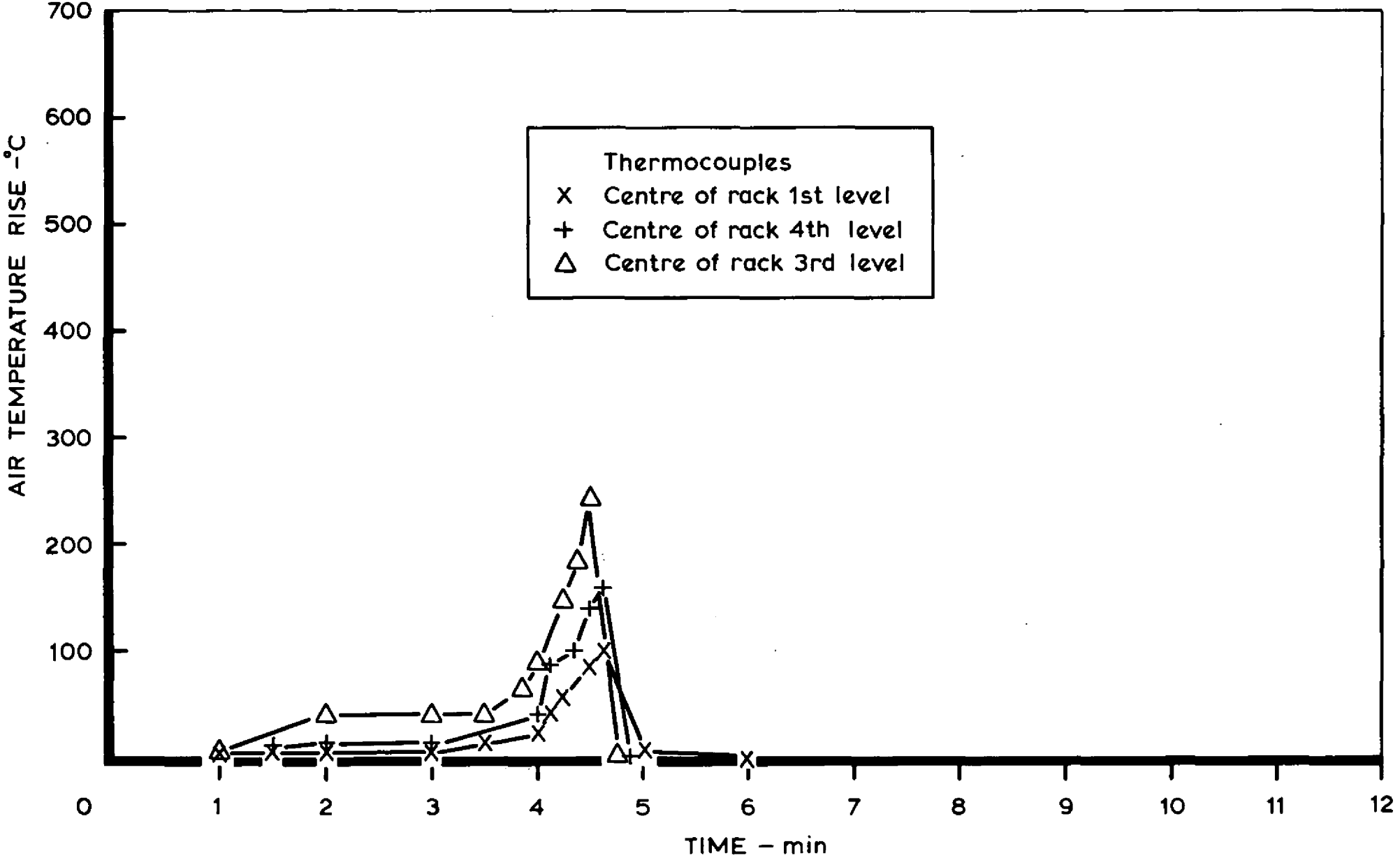


FIG. 6. AIR TEMPERATURE RISE. EXPERIMENT 6

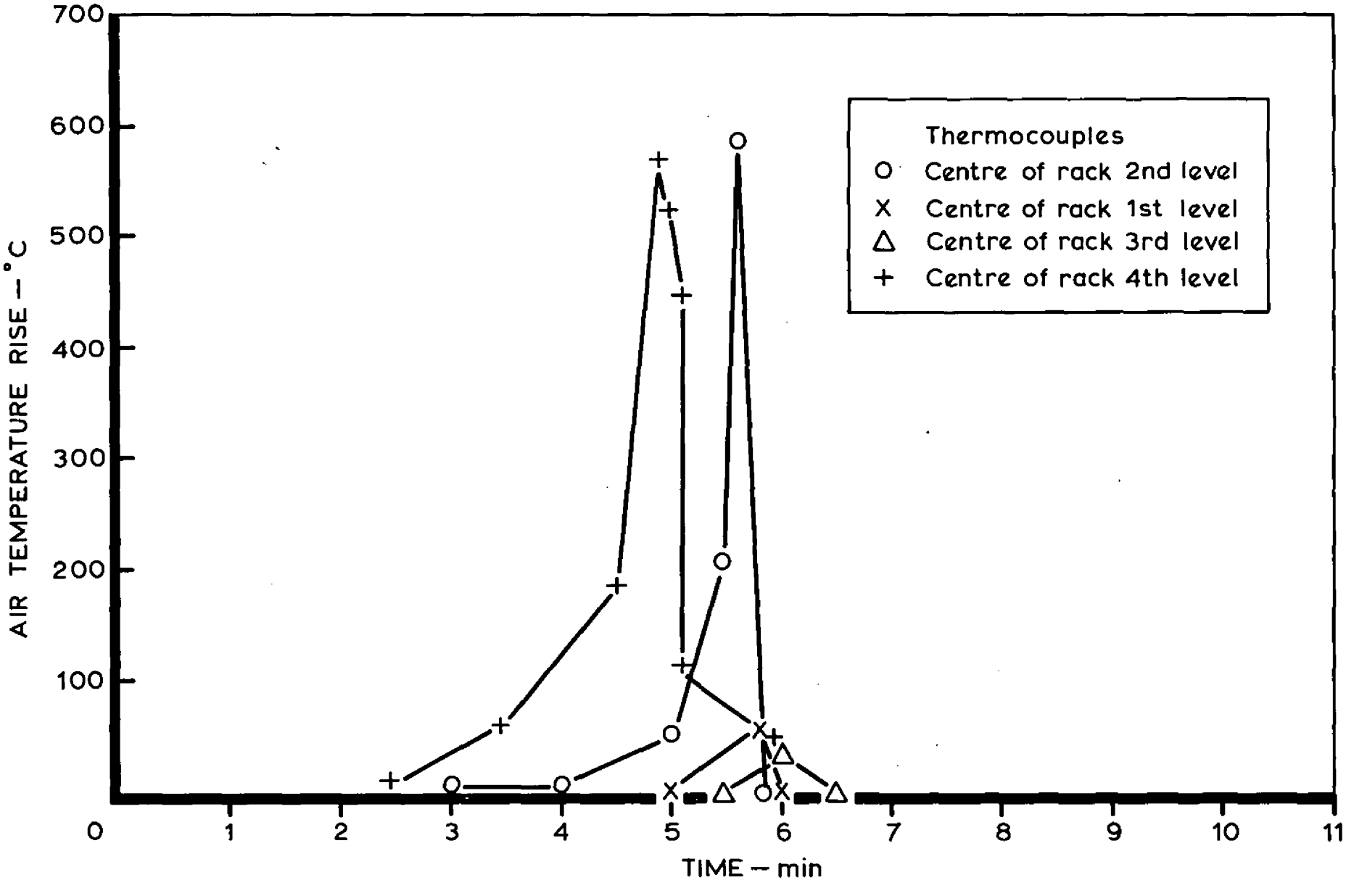


FIG. 7 AIR TEMPERATURE RISE. EXPERIMENT 7

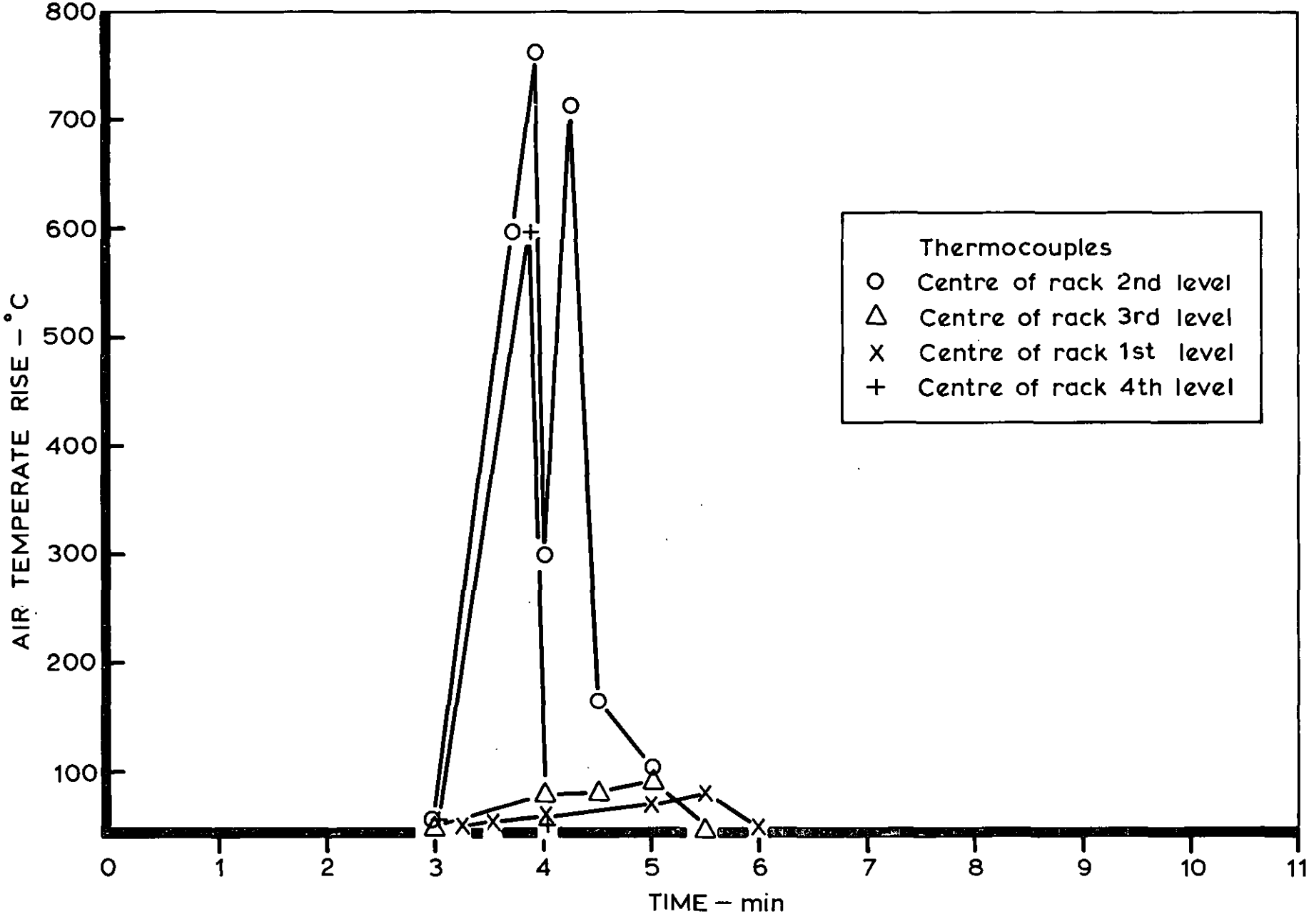
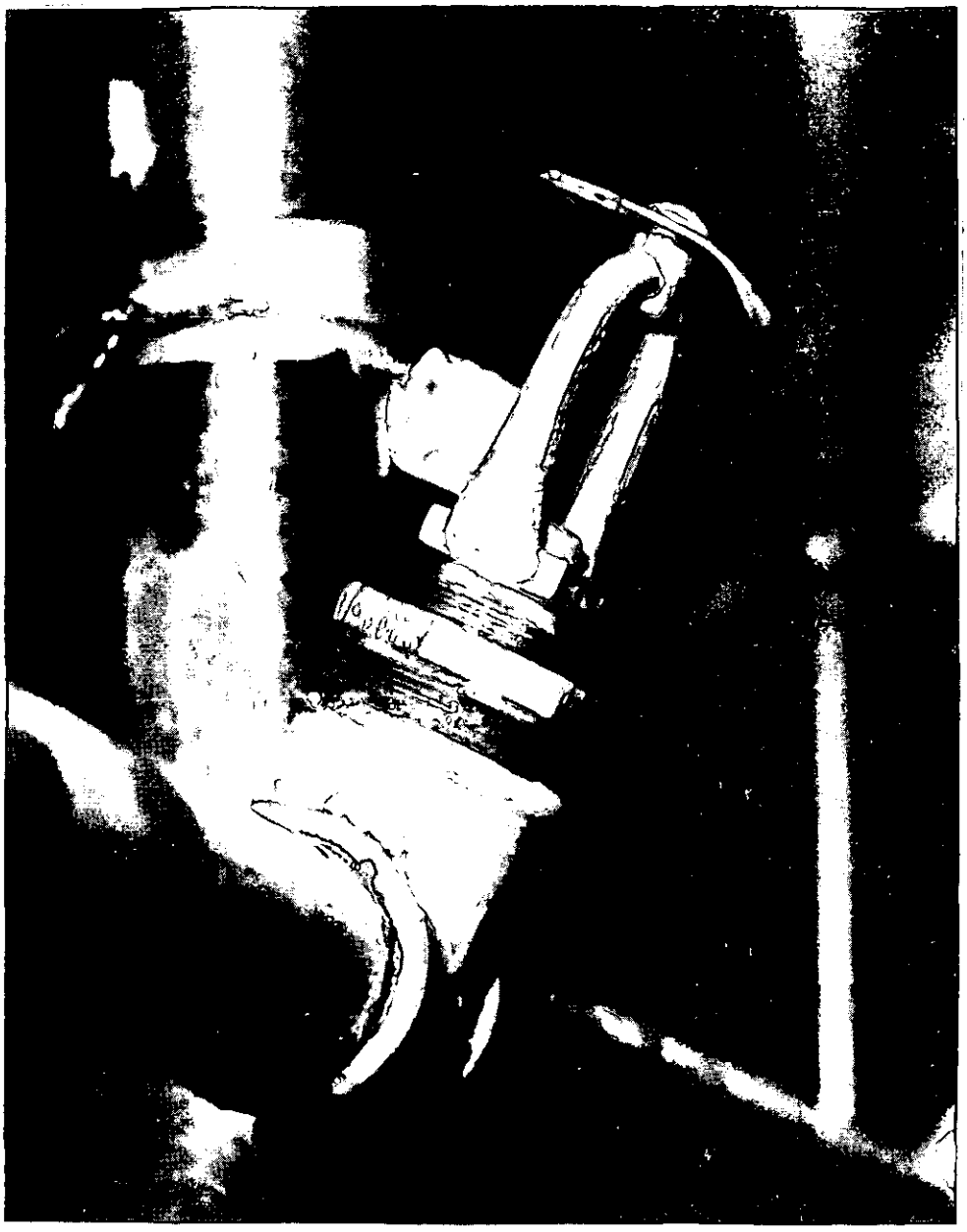


FIG. 8 AIR TEMPERATURE RISE. EXPERIMENT 8



ANGLED SIDEWALL SPRINKLER

PLATE 1