Fire Research Note No 1068

THE PROTECTION OF HIGH-RACKED STORAGES BY COMMERCIAL ZONED SPRINKLER SYSTEMS

by

Mrs S P Rogers and R A Young

April 1977

LIBRARY REFERENCE ONLY

FIRE
RESEARCH
STATION

Fire Research Station
BOREHAMWOOD
Hertfordshire WD6 2BL

Tel:01 953 6177

Fire Research Note 1068
April 1977

THE PROTECTION OF HIGH-RACKED STORAGES BY COMMERCIAL ZONED SPRINKLER SYSTEMS

by

Mrs S P Rogers and R A Young

SUMMARY

As a result of the successful development by FRS of a high-speed zoned sprinkler system for the protection of high-racked storages, two systems designed specifically with commercial requirements in mind, were purchased from two British sprinkler manufacturers.

Nineteen full scale fire experiments were conducted using one or other of these systems and the results showed that both were very effective in controlling fires within high-racked storages, limiting fire, water and smoke damage to a minimum.

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

THE PROTECTION OF HIGH-RACKED STORAGES BY COMMERCIAL ZONED SPRINKLER SYSTEMS

by

Mrs S P Rogers and R A Young

INTRODUCTION

A high-speed zoned sprinkler system was developed for the protection of high-racked storages by the Fire Research Station (FRS). The need for such a system became evident when previous experimental work on fires in racked storages in UK[1-4], USA[5] and Germany[6] was evaluated. In nearly all the experiments considered, the fire spread to the top of the racking, causing considerable fire, smoke and water damage. The high speed system consisted essentially of a number of 'zones' of open sprinklers, each zone being on a single vertical supply pipe, which was fed from a mains supply pipe on the operation of a suitable valve.

Each valve was operated by a line heat detector distributed throughout the racking within the protected zone, so that a fire starting within the zone brought the appropriate sprinklers into action.

It was shown experimentally[7] that this system was very successful in detecting and controlling fires in a wide range of goods in their early stages.

The experimental system successfully demonstrated at Cardington by FRS had a number of features which would not normally be present in a commercial installation. The most critical feature was the valve, which was of the frangible disc type. This design allowed only one means of operation, and meant that if, for some reason, the electrical supply to the system were to fail, the valve would not operate. This system did not incorporate a standby power supply, and had minimal control and indicating equipment.

In order to find out if systems designed specifically with commercial requirements in mind could perform as well as the experimental system had done, systems were commissioned from and installed by two British sprinkler manufacturers. Full scale experiments were then carried out on each of these systems.

EXPERIMENTAL ARRANGEMENTS

Racking

The two systems were installed side by side, in the rack at Cardington.

The rack used was 11.4 m high x 16.9 m long x 1.4 m (frame only) deep. It comprised six levels, each 1.7 m high and was six 'cells' wide. Each 'cell' was two pallets wide x 2 pallets deep, Fig.1.

Both commercial companies divided their section of the rack into six zones, each zone being three levels high and one 'cell' wide, Fig.2.

Pallets

The pallets used were of the standard wooden 4-entry type made to BS 2629 (Type B)[8]. They were housed on transverse runners extending 325 mm beyond each side of the main structure. There were twelve pallets per zone (4 pallets/level).

Fire load

Each pallet was stacked with fourteen boxes, each containing an empty 23 litre steel drum and 1 kg of wood wool. This was the same fire loading as used in the previous tests with the FRS zoned system.

Ignition sources and positions

Two reproducible sources of ignition were used to simulate fires starting from a smouldering cigarette end and from a spillage of flammable liquid.

Fibreboard, 100 mm x 30 mm x 8 mm, soaked in methylated spirits, was used as the small ignition source and a petrol tray 1 m long x $\frac{1}{2}$ m wide, containing 2 litres of petrol, was used as the larger source. This produced a flame about 2 m high, which burnt for about 2 min.

Positions for ignition, shown in Fig.3, were chosen to give the most difficult configuration of fire for the systems to control.

Although all the positions shown are on the first or ground level, experiments were carried out using the small ignition source, on the front face of the fourth level to investigate the effect of a fire starting higher up the racking.

The fibreboard was always placed in the groove of a pallet (1st or 4th level), while the petrol tray was placed on the ground.

SYSTEM DESIGN

Valves

Both systems used valves which were modifications of multiple controls in use for other purposes and are shown in Figs 4 and 5.

In System A the valves were positioned on the third and sixth levels in the rack, with the mains water supply fed along horizontal pipes at these levels. Thus each valve supplied water to three open sprinklers, one at the level of the valve and one at each level below it, (Fig.2).

System B had the multiple control valves on the second and fifth levels in the rack, with the mains water supplied through vertical pipes to these levels. The multiple control valve within each zone supplied water to three open sprinklers one at its own level, and one at each level above and below it, (Fig.2).

The main difference between the systems was in the positioning of these valves, which would not affect the systems' performance when the electrical detection was in operation. It may be an important factor if the electrical supply fails and detection then becomes dependent upon the secondary means which is the standard glass bulb incorporated in the valves.

Control and indicating equipment

The control and indicating equipment associated with each system was located adjacent to the racks, at a sufficient distance from the racks to avoid damage in the course of the experiments.

The control equipment in each case was provided with lamps and sounders to indicate 'fire' and 'fault' conditions. Also incorporated were a power supply, battery charger and batteries capable of operating the detection system, and the firing circuits for the actuators in the valves, for a period of 72 hours, in the event of a mains failure.

In addition to the main control unit, System A was provided with indicating lamps on the front face of the rack at the head of each zone.

Line detector wire

The commercially manufactured 'line detector' wire used in both systems, was to a specification developed by the Fire Research Station, and had a nominal operating temperature of 68°C. It was attached to the racking by copper clips in System A, and by nylon clips in System B. The layouts of the zones and wire for each system are shown in Figs 6 and 7, where it can be seen that the wire was installed in positions least likely to suffer damage due to misplaced pallets or falling boxes.

Power and monitoring cables between control, indicating equipment and the zones were of mineral insulated cable in the case of System A and short term fire resistant cable (insulated with modified PVC) in System B.

Water supply

The water supply pipes and sprinkler system components were to the same specification as those normally used in FOC approved sprinkler installations. The pipework layouts are shown in Fig. 2.

The water supply was controlled to give a flow of approximately 300 dm^3/min per zone, and therefore about 100 dm^3/min per sprinkler. This was achieved with a pressure of approximately 2 b at the control valves in System A and 3.5 b at the control valves in System B.

If an area of operation of 45 m^2 at each level is assumed, as in the FOC Rules[9], then the flow rate of 100 dm^3/min per sprinkler resulted in a discharge density of 11 mm/min.

Both systems used open 15 mm conventional sprinklers.

EXPERIMENTAL PRELIMINARIES

On completing the systems the electrical supply to each was connected, and as far as possible, the power was left switched on throughout the duration of the experimental programmes. This enabled any faults arising from damage to the detector wires, valves or component failures, to be assessed.

Water was supplied to the systems via a petrol driven pump, drawing water from a 91 m^3 storage tank. Pressure connections were made at the level of the valves, and gauges installed near to the pump controls, so that the pump operator could maintain the chosen pressures throughout the experiments.

Thermocouples were placed within the rack, and on the face of the rack, so that measurements of air temperature rise could be made during the tests.

The racking was fully loaded with boxes using a fork lift truck.

EXPERIMENTAL PROCEDURE

This procedure was followed during each test.

The sprinkler system being tested was primed, and measurements of the moisture content of the boxes on pallets C1 and D1 were recorded. Depth of water in the tank, ambient temperature and humidity were also noted before the ignition source was placed in position and lit. The progress of the fire was recorded by two observers and a time/event table produced. Two examples of such tables are shown in Tables 1 and 2. Photographs were taken at 30 second intervals throughout the test and at intermediate times as thought necessary.

The time of operation of the system was noted, and checks were made that the control and indicating equipment functioned properly, showing the correct indication for each zone that operated.

Water pressure to the system was maintained at the chosen value until the fire was judged to be substantially controlled, and there was no likelihood of further flame spread. At this time the water supply was turned off and an assessment of the damage made.

Having completed an experiment, the depth of water in the tank was again measured, so that the quantity of water used could be calculated.

Valves which had operated were refurbished, the line detector wire in the zones replaced and new boxes loaded in readiness for the next test.

In experiments 7-9, with System A and 7-10 with System B, the electrical detector circuit was switched off, so that the valves operated on the shattering of the heat sensitive glass bulb incorporated in them.

RESULTS

General

In the nineteen experiments carried out, no damage resulted to the racking, and in most cases the fire was restricted to the zone in which it started.

The performance of both systems with the electrical detection in operation was as good as or better than, the performance of the experimental prototype system developed earlier by FRS[7].

Both systems remained in operation for the full observed period of approximately 6 months. No faults were observed in the electrical circuits, and no false operations resulted from damage to the detector wire.

When detection was by the glass bulb in the valves only, both systems proved to be as effective as conventional in-rack sprinkler systems, designed according to the current FOC Rules, and as reported in FR Note 866[2].

Fire development

The nature of fire development in each experiment was largely governed by the size and position of the ignition source. With the large source, the reproducibility of the fire in each experiment was very good. The smaller ignition source gave varied rates of fire development as it depended more on environmental conditions in its initial stages of growth.

Positioning of the ignition sources played an important part in the fire growth again particularly with the small ignition source.

When placed at the front face of the rack the initial fire spread depended upon how quickly the flames found the opening between pallets. This opening then acted as a flue and the fire increased its growth rapidly from this time until detected.

Ignition in the centre of the rack, or between zones, meant that the source was already within the flue and resulted in a more rapid fire growth.

As a result of this, when comparing the performances of Systems A and B as detailed in Tables 3 and 4, the flame height at time of valve operation of the system gives a better indication of its success. Figures 8–11 illustrate the extent of fire spread in four of the experiments at and around the times of valve operation.

Temperature measurements

Since the fires within the rack were very localised in almost all the experiments, most thermocouples showed little or no rise in air temperature. However, those thermocouples above ignition sources at the top of the first level pallets, showed rapid rises in air temperature as the fires developed, and equally rapid falls in temperature as the systems operated, Fig. 12. Also illustrated in this figure is the more rapid fire development encountered by ignition within the flue as described previously.

SYSTEM PERFORMANCE

System A - Line detector in operation

The overall performance details are given in Table 3 and show that in all experiments the flame height at operation of the valve was less than 2.6 m, and with ignition at ground or first level the fire was controlled in the zone of origin.

With fourth level front face ignition (pallet D4) the flames did not spread directly into the flue in the centre of that zone, (which was only 250 mm from the point of ignition) as had been previously observed with ground or first level ignition sources. The flames spread across the face of the pallet load and into the flue formed with the adjacent zone, causing both zones to operate.

All valves did however operate satisfactorily on the 'shorting' of the line detector wire.

System A - Class bulb detection

The performance details are also given in Table 3. In experiment 7, the fire was started with a large source in the centre of zone 5 ground level (Fig.3 F). This zone, together with zone 3 relied upon the glass bulb in the valve to detect the fire and activate the system. The remaining zones were activated by line detector wire and it was these zones which operated between 24-35 seconds that restricted the vertical flame spread to 6 m. Zone 5 failed to operate because the bulb was being wetted from the zone above and in zone 3 the fire spread had been insufficient to raise the bulb to its operating temperature.

In experiment 8 the valves in zones 4 and 6 were blanked off and the remaining zones relied upon the glass bulbs, ie no electrics. The small ignition source was used on the front face and the fire developed until zone 2 operated in 6 min 15 sec with the vertical flame spread at a height of 7 m. Two other zones, 3 and 5 also operated.

Experiment 9 utilised the large ignition source placed on the front face and the vertical flame spread had reached 8 m when the first zone operated (zone 5) in 55 seconds. All of the zones relied upon the glass bulbs in the valves for detection of the fire and four of the remaining zones did in fact operate.

The multiple operation of zones and the need for a lengthy water duration in experiments 7-9 was caused by the 'mushrooms' on the valves coming off and blocking the water outlets.

The valves were examined at FRS and it was found that the 'mushrooms' unscrewed from the stems after about 2 minutes running time and the loose mushrooms blocked or partially blocked the outlet orifices. The valves have since been modified and subsequent tests have shown that the cause of failure has been eliminated.

System B - Line detector in operation

The overall performance details of this system are given in Table 4.

They show that in all the experiments the flame height at operation of the valve was 3 m or less, and with ignition at ground or first level the fire was once again controlled in the zone of its origin.

In experiment 4, when ignition was a small source on the front face at the 4th level (pallet D4) two zones operated, as with System A.

System B - Glass bulb detection

These performance details are also given in Table 4.

In experiments 8 and 10 using a small ignition source on the front face and in the centre of zone 5 at level one (Fig.3 A and B) only the valve in this zone operated at 4 minutes 47 sec (experiment 8) and 1 minute 59 sec (experiment 10). The vertical flame spread at these times was 4 m and 6 m respectively.

However, with a larger ignition source on the ground, across the front face of C1 and D1, in experiment 9 (Fig.3 E), two zones operated at 1 min 19 sec and 2 min 35 sec with the vertical flame height at the time of operation of the first at 8 m.

In experiment 7, large ignition source ground level between zones 5 and 6 (Fig.3 G), the vertical flame height after 51 seconds was 11.3 m. Zone 5 operated at this time and was followed by zones 6, 2 and 3 at times of 1 min 37 sec, 3 min 05 sec and 3 min 15 sec respectively.

RELIABILITY

In approximately 6 months of operation of the systems, only one failure of an electric component was observed. This was an LED lamp in the System B control unit.

There were no cases of damage to the line detector wire, causing either 'false' operation of a zone or a fault condition.

The only faults which were revealed were in the valves in System A, as described earlier and which have been rectified by the manufacturers.

CONCLUSIONS

The experiments conducted with commercial versions of the FRS zoned sprinkler system, showed that with electrical detection in operation, fires could be detected, controlled and extinguished with flames spreading no more than 3 m vertically up the rack. Most fires were extinguished with a single zone operating, but if the fire spread between two zones a second zone operated and restricted further fire growth.

The fire control was accompanied by minimal fire, smoke and water damage.

These experiments also showed that if the electrical detection system were disconnected for any reason, the glass bulb incorporated in the valve with a rating of 68°C activated the system and supplied water to the open sprinklers, giving fire control, as well as, or better than, a standard 29th Edition sprinkler system.

It has been shown that both systems are effective and reliable in the forms tested. They have considerable potential for wide use in the protection of high-racked storages.

ACKNOWLEDGEMENTS

The authors wish to thank Mr D Barnes and Mr C Lambert (both now with FIRTO) for their assistance during these experiments.

REFERENCES

1. YOUNG, R A. Fire tests with sprinklers on high piled stock. Fire Research Station, Fire Research Note 814, Borehamwood, 1970.

2. NASH, P, BRIDGE, N W and YOUNG, R A. Some experimental studies of the control of a developing fire in high-racked storages by a sprinkler system. Fire Research Station Fire Research Note 866, Borehamwood, 1971.

3. NASH, P, BRIDGE, N W and YOUNG, R A. Experiments with sprinklers in high-racked storages (2) Extinction with face mounted sprinkler. Fire Research Station Fire Research Note 914, Borehamwood, 1972.

4. NASH, P, BRIDGE, N W and YOUNG, R A. Experiments with sprinklers in high-racked storages (1) Extinction with centrally mounted sprinklers. Fire Research Station Fire Research Note 916, Borehamwood, 1972.

5. Rack storage fire protection test reports. Factory Mutual Research Corporation.

6. Report on tests of Walther sprinkler systems. Walther and Cie, 1970.

7. NASH, P, BRIDGE, N W and YOUNG, R A. The rapid extinction of fires in high-racked storages. Building Research Establishment Current Paper CP 68/74, Borehamwood, 1974.

8. Specification for pallets for materials handling for through transit, dimensions, materials and marking. BS 2629 : Part 1 : 1967. British Standards Institution, London, 1967.

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

Table 1

System A. Experiment 1

Time	Event
min s	
0 - 00	Ignition at A. (Small source, front face)
1 - 25	Flames to the top of 1st box, front face, D1
2 - 21	" " " " " 2nd " " " "
2 — 30	Flames between C1 and D1
2 - 45	Flames to the top of D1
2 - 51	Flames around cross-member beneath D2
3 - 03	ZONE 5 OPERATED BY LINE DETECTOR SHORTING
4 - 00	Flames controlled - no further spread
6 - 00	Top box on D1 still burning
6 - 55	Fire completely extinguished, water turned off.
	DAMAGE: 6 boxes on D1 Charring on side of C1

Table 2

System B. Experiment 8

Time	Event
min s	
0 - 00	Ignition at A
0 - 53	Flames to the top of 1st box on D1
2 - 04	" " " " " 2nd " " "
2 - 49	" " " " " 3rd " " "
2 - 58	Flames just touching pallet D2
3 - 45	Flames from the centre of D1 beating under the centre of pallet D2
4 - 18	Flames to the top of 1st box on D2
4 - 42	Flames to the top of D2 centre and starting to go into centre of D3
4 - 47	ZONE 5 OPERATED BY GLASS BULB BURSTING
7 - 00	Fire under control, no further spread. Centre of D1 and D2 still burning.
17 - 30	Water turned off.
	DAMAGE: 2 pallet loads

Table 3

Experiments with zoned sprinkler System A

Experiment	Ignition source		Means of detection	System operation		Flame height at operation	Duration of water application (Note e)
	Size	Position		Time min – s	Zone	m	min – s
1	Small	A	Electrical	3 – 03	5	2.0	3 – 52
2	Small	B	"	1 – 53	5	2.0	3 – 07
3	Large	F	"	0 – 06	5	2.5	2 – 09
4	Small	A 4th level	"	4 – 10 12 – 10	2 3	2.0 2.5	9 – 50 1 – 50
5	Large	E	"	0 – 30	5	1.3	8 – 55
6	Small	D	"	1 – 56	5	1.8	3 – 04
7	Large	F	Note a	0 – 24 0 – 28 0 – 30 0 – 35	2 1 4 6	6.0	19 – 36 19 – 32 19 – 30 19 – 25
8	Small	A	Glass bulb Note b	6 – 15 Note c	2 3 5	7.0	19 – 30
9	Large	E	Glass bulb	0 – 55 3 – 15 6 – 00 Note d	5 3 1	8.0 11.3	26 – 05 23 – 45 21 – 00

Note a

Zones 1, 2, 4 and 6 – Line detector in operation.

Zones 3 and 5 – Bulb operation only.

Note b

Zones 4 and 6 – Valves blanked off.

Note c

Zones 3 and 5 also operated, but the 'mushroom' came off the valve in Zone 3.

Note d

Zones 2 and 4 also operated.

Zones 2, 4 and 5 had the 'mushrooms' come off the valves and block the outlets.

Note e

The lengthy duration of water application in the last 3 tests (7-9) was due to 'mushrooms' coming free from the valves and blocking the outlets, thus supplying insufficient water to the sprinklers.

Table 4

Results of experiments with zoned sprinkler system B

Experiment	Ignition source		Means of detection	System operation		Flame height at operation	Duration of water application
	Size	Position		Time min - s	Zone	m	min - s
1	Small	A	Electrical	4 - 10	5	2.0	4 - 20
2	Small	B	"	2 - 34	5	2.0	3 - 46
3	Large	F	"	0 - 08	5	2.5	6 - 12
4	Small	A 4th level	"	3 - 00 3 - 02	2 3	2.5 2.5	5 - 00 4 - 58
5	Large	E	"	0 - 18	5	3.0	6 - 42
6	Small	C	"	2 - 34	5	2.0	5 - 26
7	Large	G	Glass bulb	0 - 51 1 - 37 3 - 05 3 - 15	5 6 2 3	11.3	7 - 08 6 - 23 4 - 55 4 - 45
8	Small	A	"	4 - 47	5	4.0	12 - 43
9	Large	E	"	1 - 19 2 - 35	5 2	8.0	6 - 41 5 - 25
10	Small	B	"	1 - 59	5	6.0	4 - 01

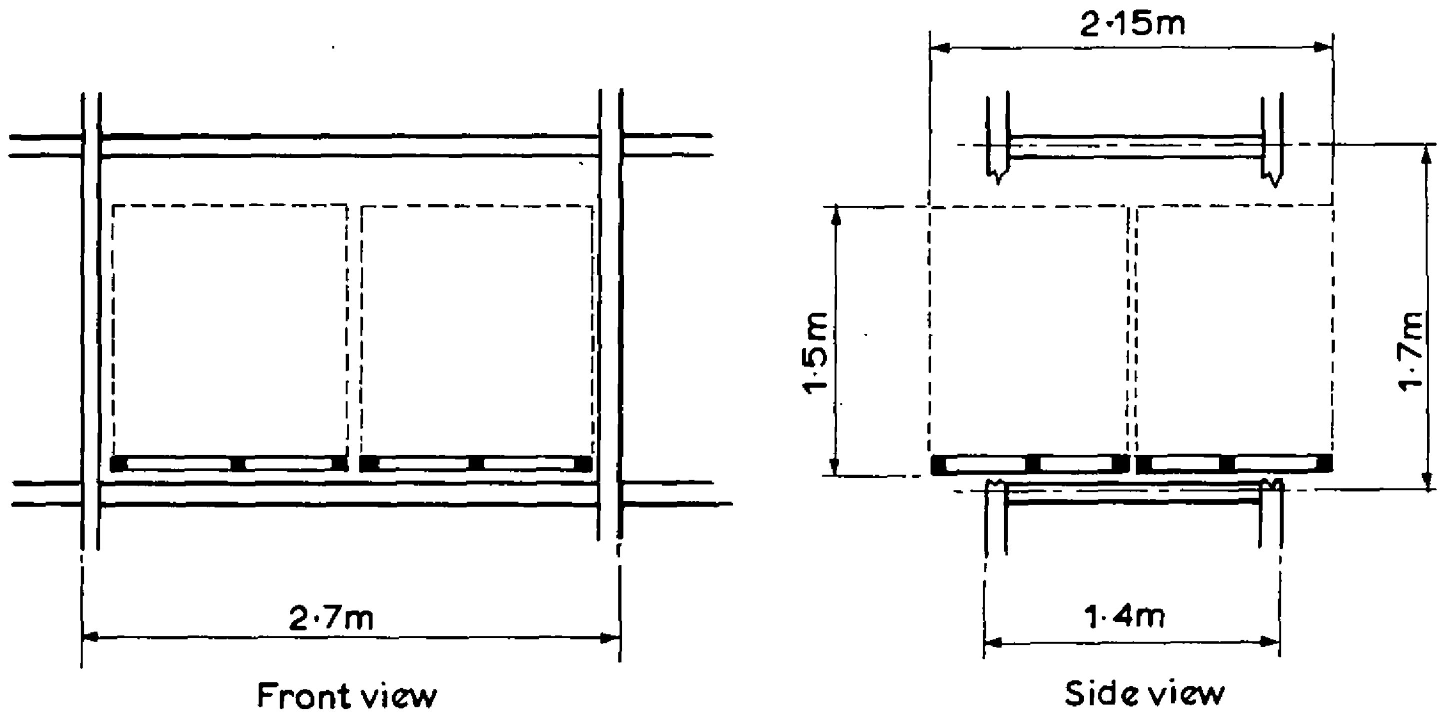


Figure 1 Dimensions of 'cell' within the rack

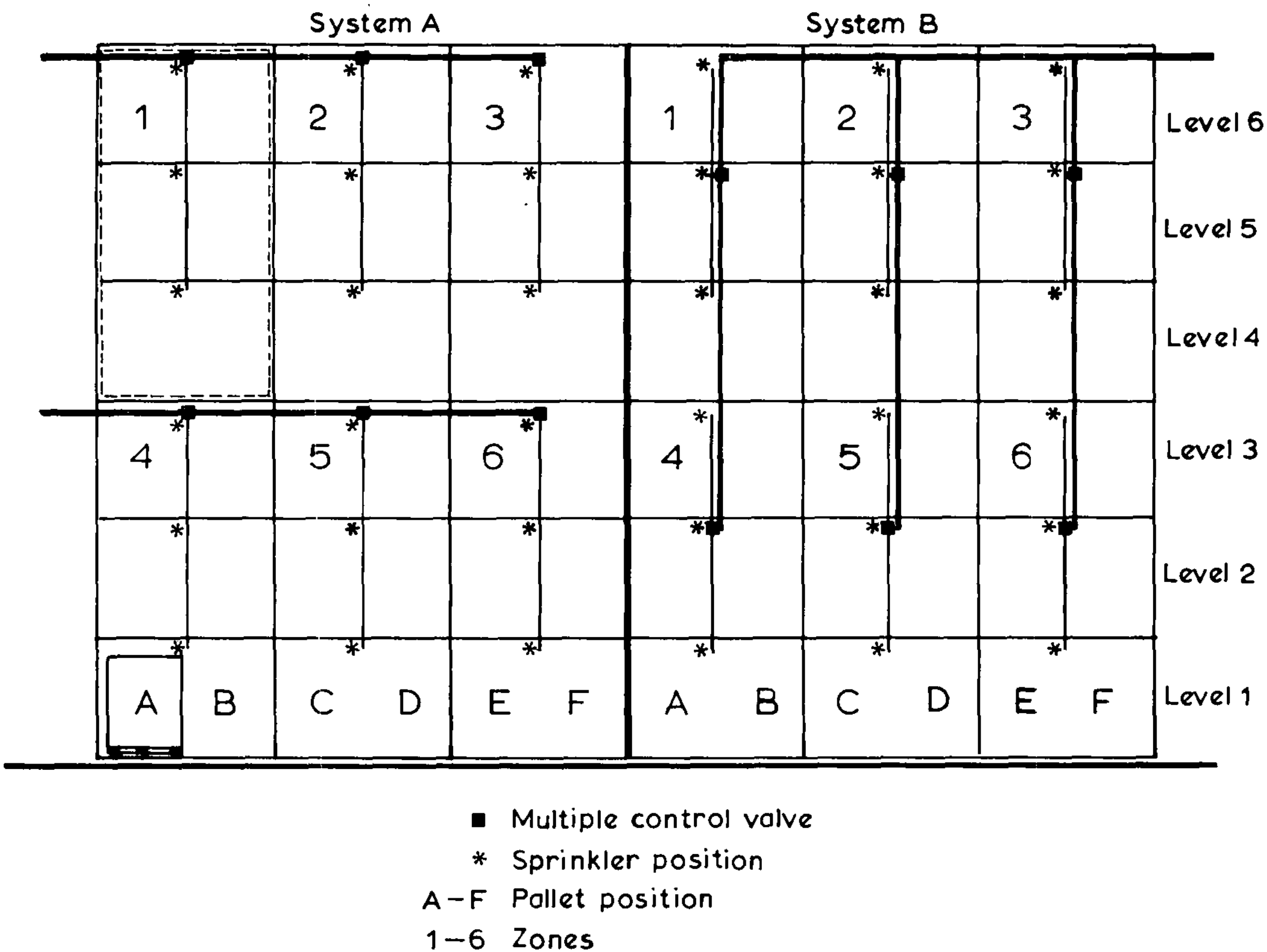
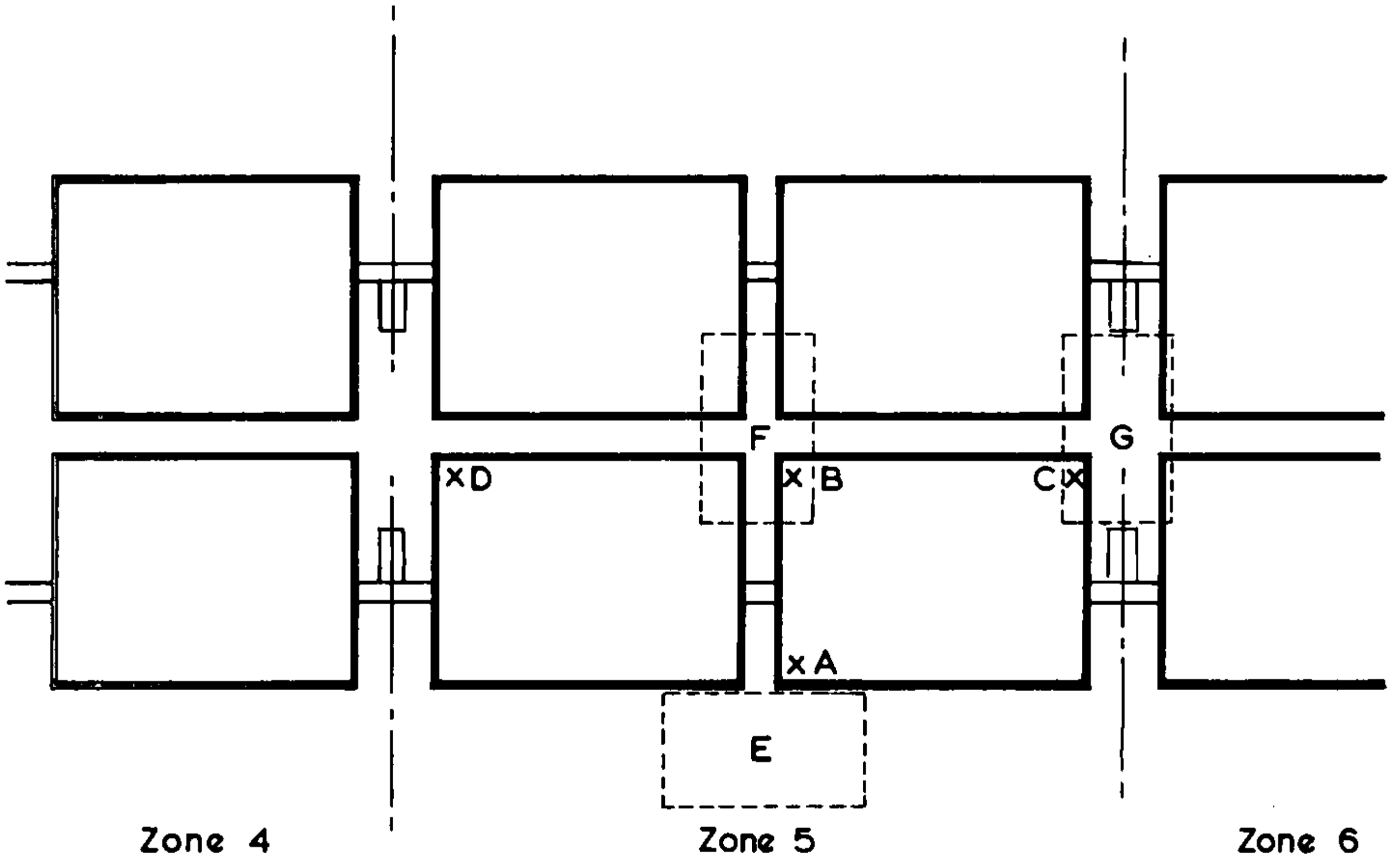


Figure 2 Layout of the 2 zone systems



Small source : Fibreboard soaked in methylated spirits

A — Front face
B — Centre of zone
C, D — Between zones

Large source: Petrol tray

E — Front face
F — Centre of zone
G — Between zones

Figure 3 Fire ignition positions

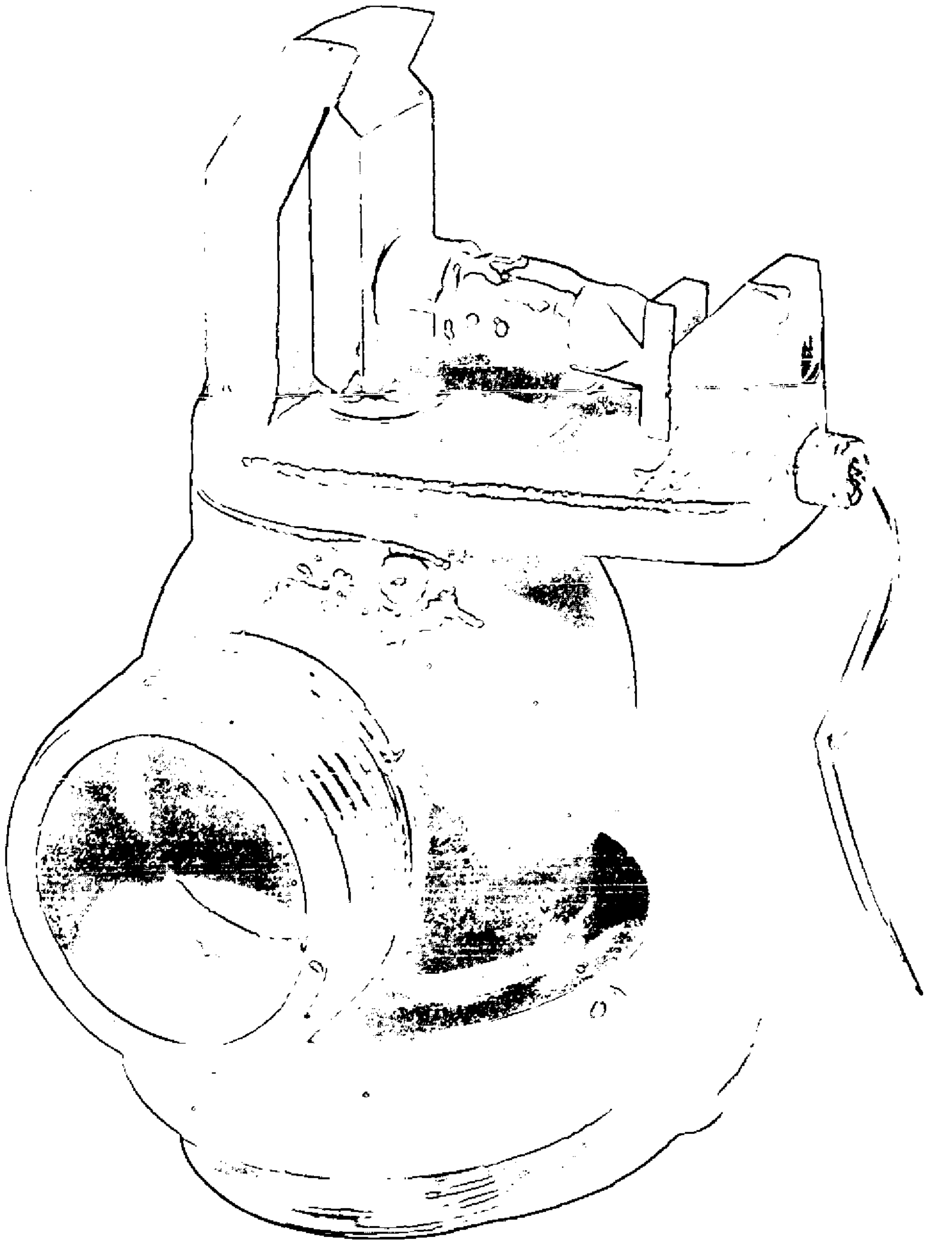


FIG.4. MULTIPLE CONTROL VALVE, SYSTEM A

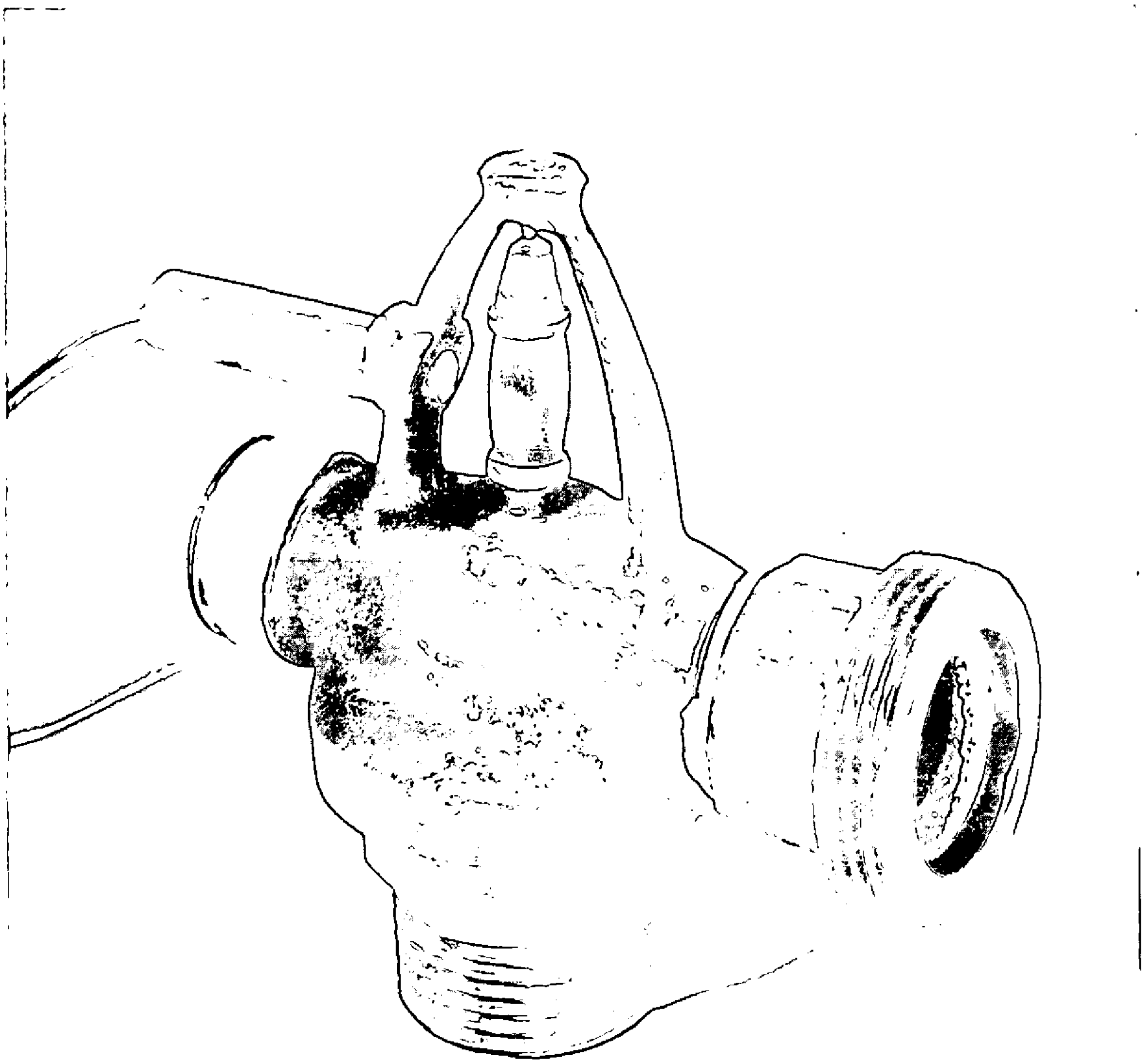


FIG. 5. MULTIPLE CONTROL VALVE, SYSTEM B

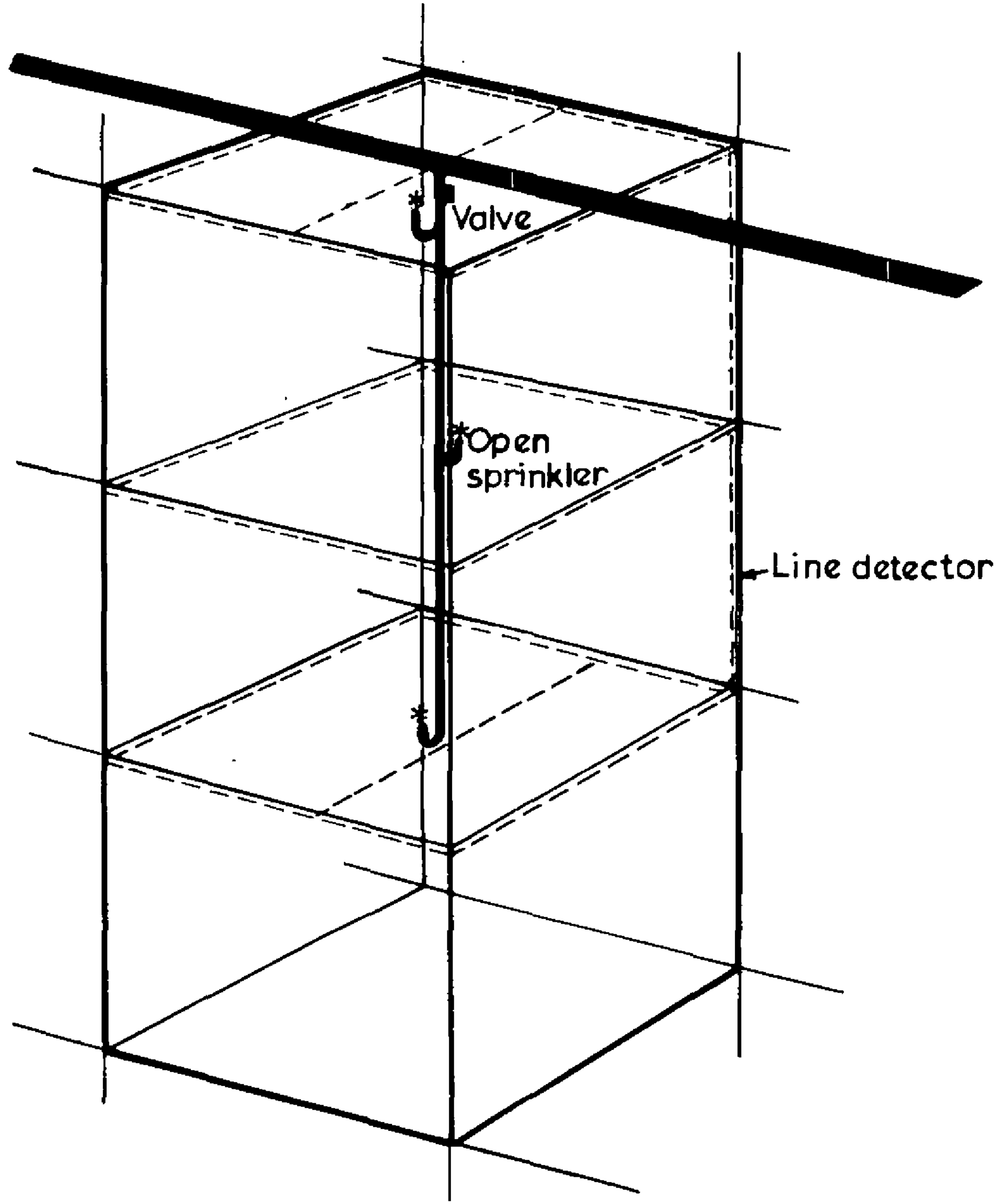


Figure 6 Layout of a single zone System A

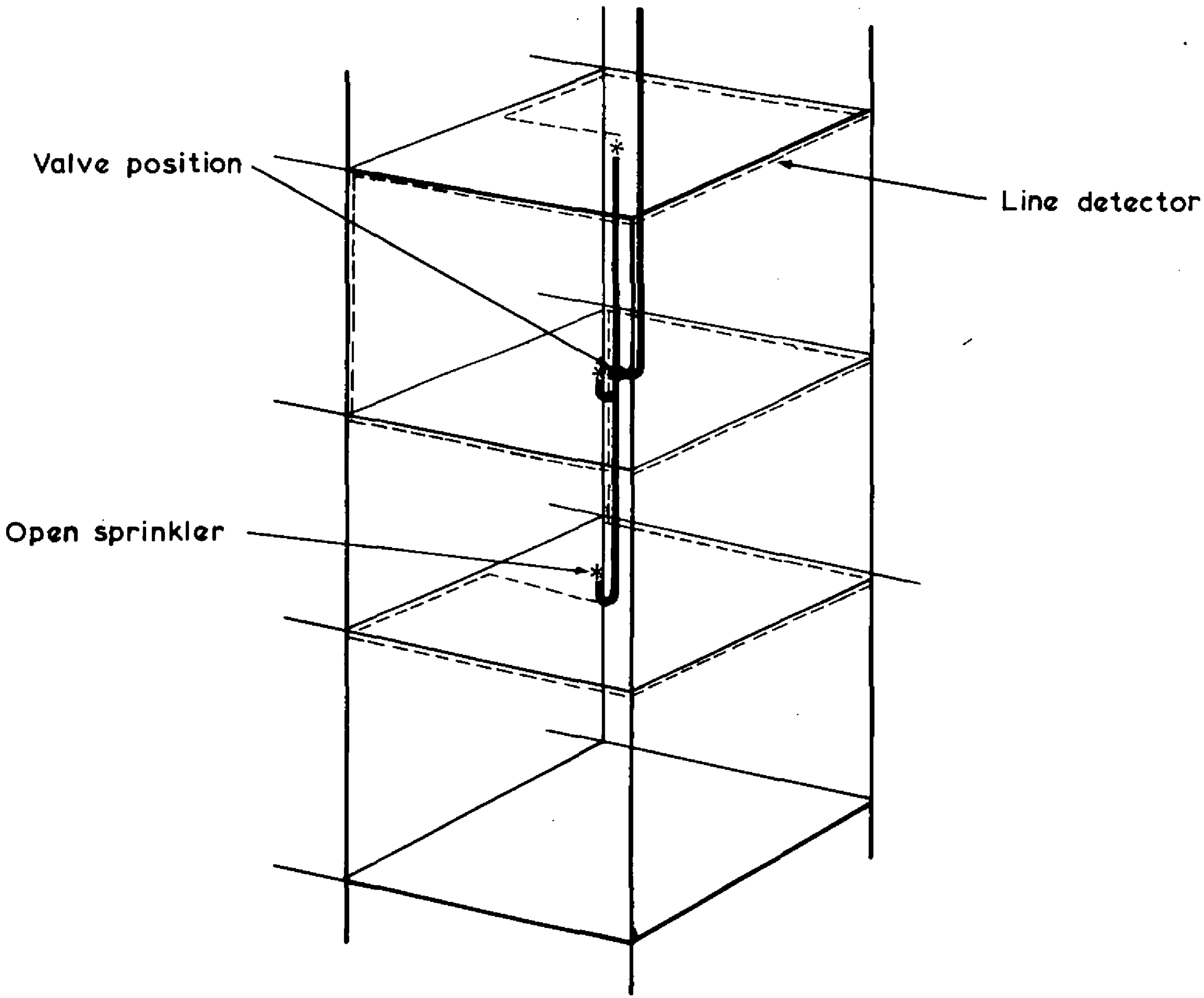


Figure 7 Layout of a single zone System B

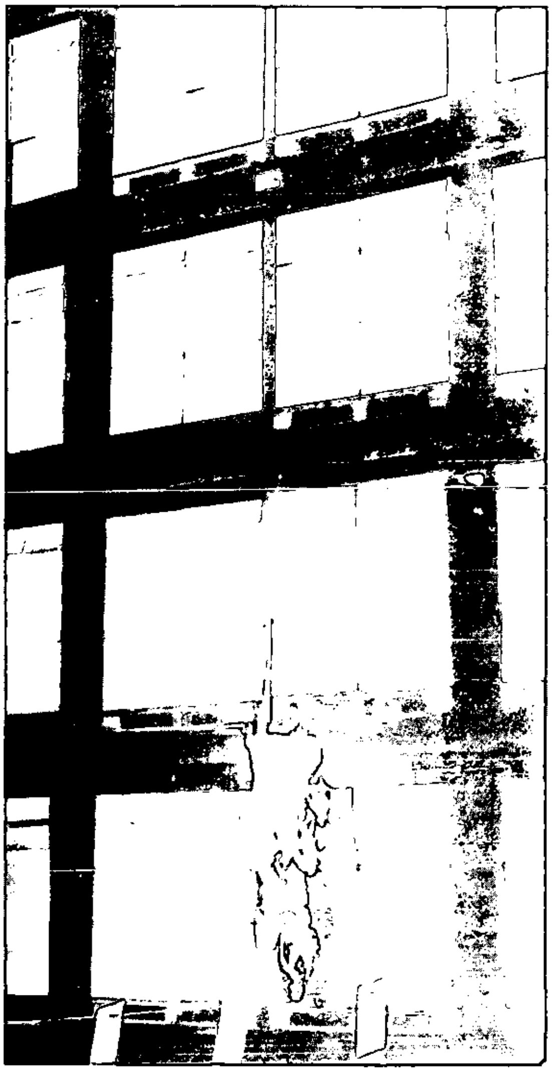


FIG. 8. EXTENT OF FIRE WHEN ZONE OPERATED ELECTRICALLY

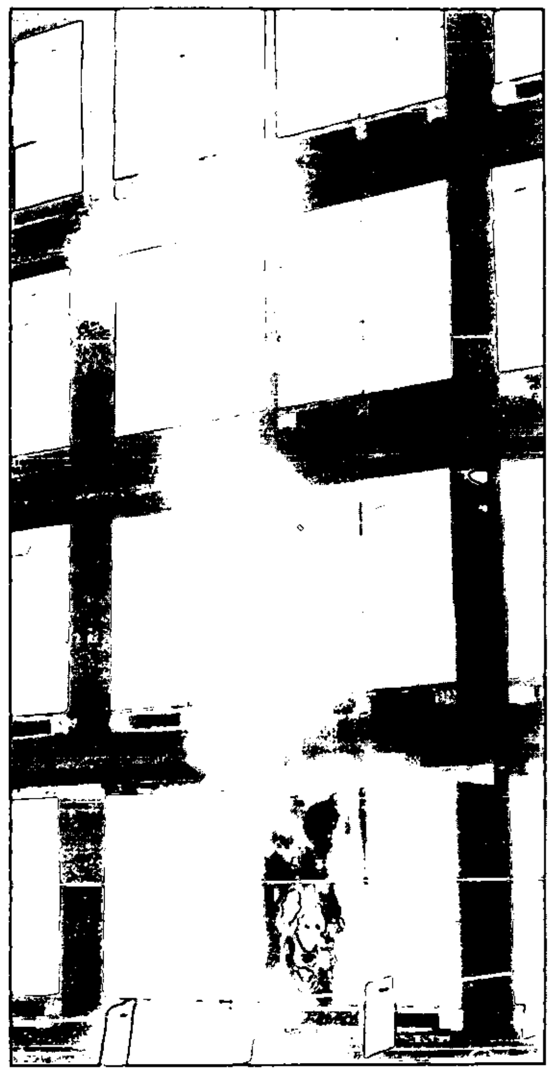


FIG.9. 8 SECONDS AFTER ZONE OPERATED

IGNITION SMALL SOURCE FRONT FACE

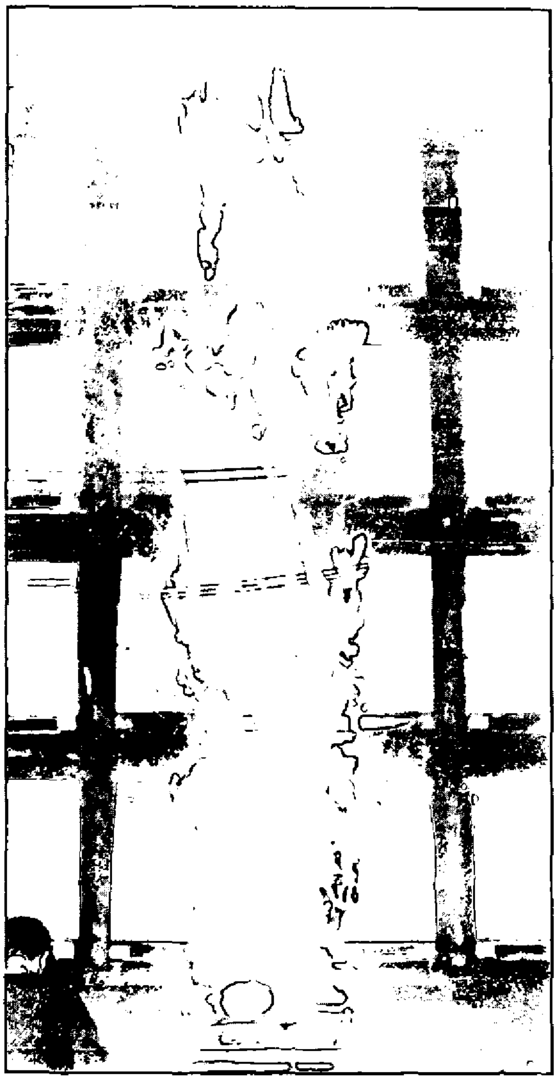


FIG.10. ZONE JUST OPERATED BY GLASS BULB ON VALVE

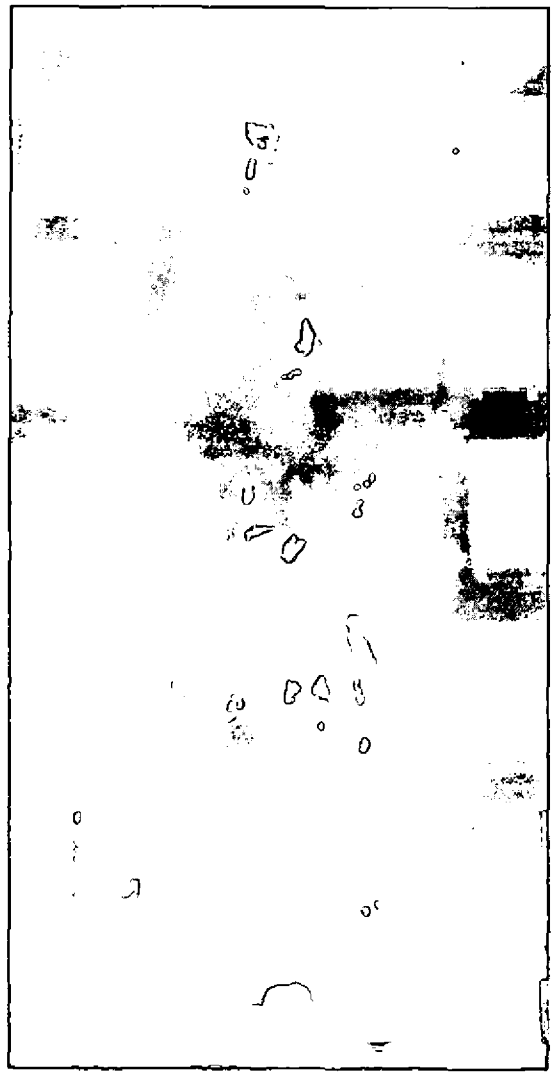


FIG.11. 40 SECONDS AFTER ZONE OPERATED. CONTROL OF FIRE ESTABLISHED.

IGNITION LARGE SOURCE FRONT FACE

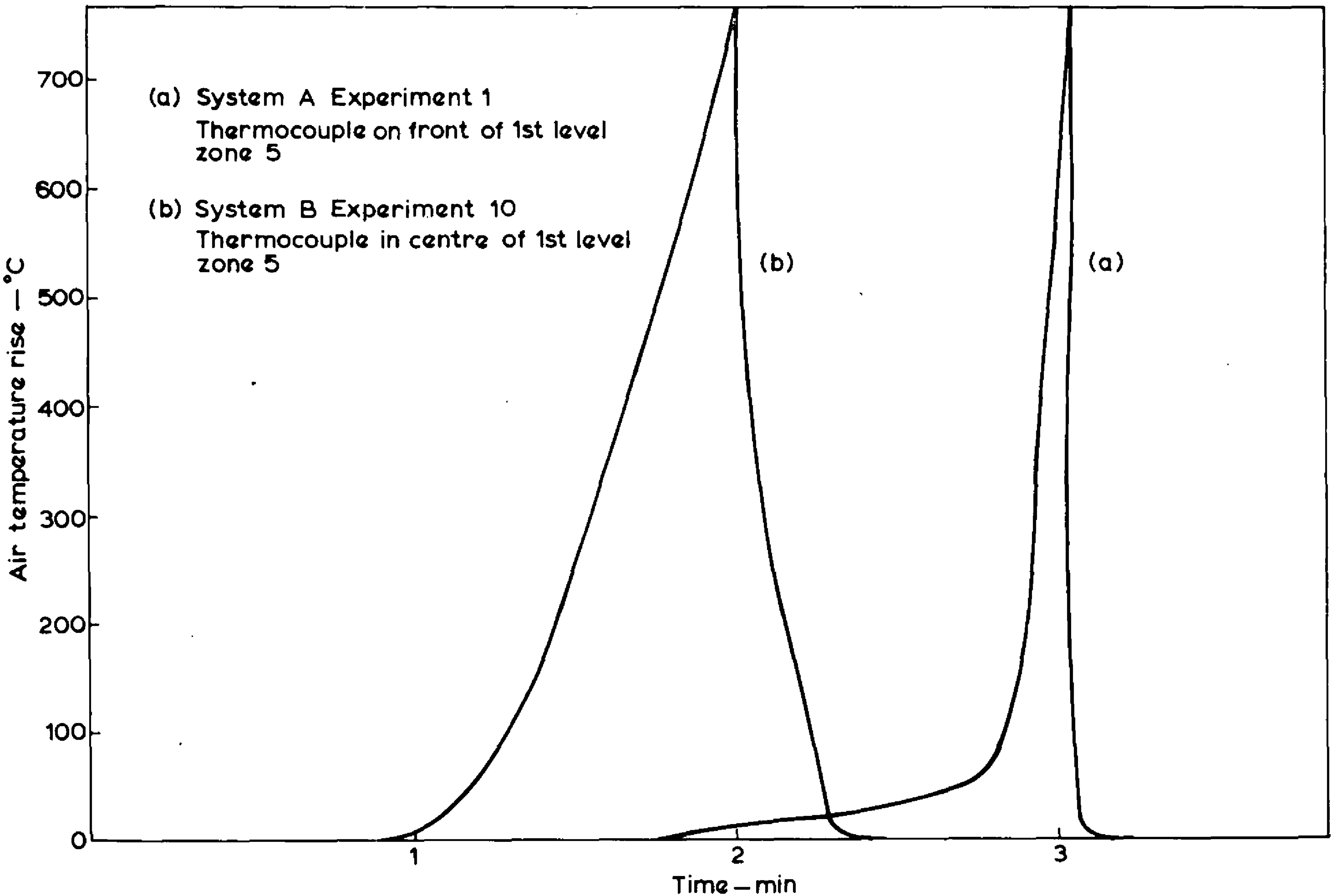


Figure 12 Air temperature graph

Printed in England for Her Majesty's Stationery Office by Studio Trade Plates Ltd.,