Fire Research Note

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FIRE PROBLEMS IN PEDESTRIAN PRECINCTS PART 4
EXPERIMENTS WITH A GLAZED SHOP FRONT

by

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SUMMARY

This note reports experimental fires in a compartment representing a shop with a glazed front. Even when a sprinkler system was installed to control the fire the glass cracked badly and in one case most of it fell out.

The experiments show that a drenching system wetting the inside of the glass, together with sprinklers, can effectively protect the window, but there must be a substantial flow of water over all the glass.

It is concluded that a conventionally glazed shop front could not be relied on to prevent the bulk flow of smoke into a covered pedestrian mall unless sprinklers and an effective drenching system were installed inside the shop.

DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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1. INTRODUCTION

It has been shown[1] that if a fire occurs in a shop opening on to a covered pedestrian mall there will be severe problems due to smoke and possibly flame passing into the mall and hindering escape. Shops will sometimes be open-fronted or merely protected by a security grille which affords no barrier to smoke and fire spread and is not intended to do so. Other shops may have a more conventional glazed front with door and display window. The question arises as to whether the shop front could form a barrier to smoke spread if fire breaks out behind it, particularly if sprinkler protection is provided in the shop. Without sprinklers it is regarded as almost certain that if a fire, other than a very small one, occurs in the shop, then the window will crack and some of the glass fall out to allow heat and smoke to escape into the arcade or covered mall. However, it was thought possible that sprinklers might control and cool a fire fast enough to prevent damage to the glass.

This note describes experiments made to determine what help is provided by sprinklers in this situation and also to assess the benefit of providing an internal drenching system which keeps the whole interior of the window wet if fire occurs.

2. EXPERIMENTAL ARRANGEMENTS

2.1. Arcade building

The tests were conducted in a building representing at full size a short length of a pedestrian precinct or arcade which has been described in earlier reports[2,3]. The fires were set in a compartment 7.7 m x 3.8m x 2.85 m high representing a shop giving on to an arcade 17.45 m long, 5.6-6.0 m wide and 3.1 m high. For the present series of tests the opening between the fire compartment and the arcade was fitted with a glazed shop front consisting of stout wooden framing with main window, door and fanlight over door (Fig.1). All three sections were glazed with 6 mm plate glass typical of that used in

shops installed by professional shopfitters. The glass was held in firmly by wood beading without putty or other mastic sealing compound, but was free to expand laterally by several mm.

The thermocouples installed for earlier tests in the plane of the fire compartment opening were removed because they would be unlikely to give meaningful readings in tests of this kind and also because they might hinder the glass from falling out during a test fire.

2.2. Sprinklers and drenching system

The fire compartment was fitted with sprinklers as described earlier[4] and for some of the tests the end of the sprinkler pipe was fitted with a tee piece holding a horizontal sparge pipe drilled with holes so as to provide jets for drenching the window from inside as a protection against heat. The pipe extended the full width of the glazing and was 25 mm external diameter (20 mm internal). A row of 2.4 mm diameter holes was drilled at 75 mm centres along the whole length of the pipe in a straight line. It was then mounted so that the holes were all 195 mm from the nearest point on the glass and orientated so that jets of water from the holes wetted the glass right to the top with water running down and covering the glass completely. Figure 2 shows details of this drenching system in vertical section and horizontal plan.

Earlier trials had shown that the sprinklers alone did not wet the upper 0.5 m of the glass adequately even with a water pressure of 240 kN/m^2 (35 lb/in^2, $\sim$ 2.4 bar).

It was calculated that the drencher would deliver about 0.55 l/s of water per metre width of glazing if the supply pressure was 124 kN/m^2 (18 lb/in^2, $\sim$ 1.24 bar) and the discharge coefficient for the holes in the drencher was taken to be 0.6.

Plate 1 shows the drencher effectively covering the window.

2.3. Fuel loading

A display rack used in some earlier tests[4] was located in the fire compartment leaving a 0.7 m gap between it and the window and also the side wall away from the shop door (Fig.3). The front sprinkler was directly over the longer side of the rack nearer the door.

Figure 4 shows how the rack was filled with combustibles to give a fuel load that would be easy to ignite and would spread fire rapidly and Plate 2 shows the rack loaded for a test.

The total weight of the wood cribs used was about 70 kg. There were also about 6 kg of polyurethane foam cushions, about 6 kg polystyrene and, to start the fire, 1 kg of wood wool shavings.

2.4. Test conditions

All the tests were carried out with the vent in the arcade and the shop door both closed and with the door at the rear of the fire compartment open to a width of 1 m to allow air to reach the fire. The top of the display rack was uncovered except for one test when a sheet of 5 mm hardboard 2.4 x 1.2 m was fitted as a canopy to see the effect of reducing the effectiveness of the sprinkler. This represents malpractice of a kind which does sometimes occur.

The water pressure at the first sprinkler was kept at 124 kN/m^2 (1.24 bar, 18 lb/in^2) in all the tests.

The tests were all done on days of fairly calm weather, with winds of velocity 0.5 to 1.5 m/s. The air temperature in the arcade at the start of each test varied from 7°C to 18°C.

2.5. Test procedure

The five tests listed in Table 1 below were carried out.

Table 1

Tests carried out

Test No.	Sprinklers	Window drencher	Canopy on display rack
121	Yes	No	No
122	Yes	Yes	No
123	Yes	Yes	Yes
124	No	Yes	No
130	Yes	No	No

Ignition of the display rack was always at the wood wool shavings on the lower shelf almost directly beneath the sprinkler (Fig.3). All events in the tests were timed from that moment. Visual observations were made both from the arcade and from outside the rear door of the fire compartment.

Data logger readings were taken as in earlier tests[2,3,4].

3. RESULTS

A log of events for each test is given in the Appendix. Table 2 compares the times for some main events in the tests, including damage to window.

The times of sprinkler operation are reasonably similar for all four tests where they were used, as also are the times at which flames from the rack reached the fire compartment ceiling. This shows that the display rack gave a fairly repeatable fire from test to test as regards rate of growth and heat output.

The glass remained uncracked only in those tests (122, 123) where both the sprinklers and window drencher were used. The results in Table 2 show that the window drencher is more effective than the sprinklers in delaying the cracking of the glass.

Plate 3 shows the early stages of test 121 with the cribs and polystyrene clearly visible on the display rack, the polyurethane cushions and the wood wool shavings beneath them well alight. Plate 4 shows the later stages of the same test with the sprinklers containing and even reducing the fire as well as wetting some of the glass. Two long cracks are visible on the left side.

Plate 5 shows the rack after test 122, the damage to the contents was never less than shown here in any of the other tests.

Plate 6 shows the rack after test 130, while Plate 7 shows the main window after the same test with over half the glass fallen out.

In test 124 the fire was unhindered by any sprinkler action and the radiation on to the window was high enough to cause the film of water running over the glass to become thin in places so that the water appeared to be mainly concentrated into discrete "streams" a few centimetres wide. Quite possibly the glass became completely dry in places but this could not be verified without approaching dangerously close to the glass and photographs taken at this time were not clear enough to be reproduced in this report.

Figure 5 compares temperature rises recorded beneath the fire compartment ceiling over the display rack for all the tests. The rises are reasonably similar for tests 121, 122 and 130 which would be expected since 121 and 130 are repeats and test 122 differs only in the addition of the drenching system. Test 123 gave lower temperatures because the canopy over the rack deflected the flames away from

Table 2

Test results compared

Visual observations with times in minutes and seconds

Event	Test 121 Sprinklers only	Test 122 Sprinklers and drencher	Test 123 Sprinklers and drencher, rack with canopy	Test 124 Drencher only	Test 130 repeat of 121 Sprinklers only
Flames reach ceiling	1.05	1.00	0.55	1.05	0.50
Front sprinkler operates	1.15	1.10	1.10	-	0.55
Rear sprinkler operates	1.40	1.40	1.30	-	1.45
First cracks in glass	2.15	-	-	3.30	2.00
Glass first falls away to leave an opening for smoke to pass through	2.50	-	-	None fell out before 14.00 but cracks bad enough to let some smoke through	3.05
Fire starting to decline	3.45	3.45	4.15	8.00	3.40 but subsequently increased, aided by big fall out of glass at 7.05. Final decline started at about 11.30

cont'd .....

Table 2 (cont'd)

Event	Test 121 Sprinklers only	Test 122 Sprinklers and drencher	Test 123 Sprinklers and drencher rack with canopy	Test 124 Drencher only	Test 130 repeat of 121 Sprinklers only
Fire extinguished by sprinklers	Almost by 11.00	Yes, by 7.30	Yes, by 15.00 except for few embers	-	Almost extinguished by 15.30
Condition of glazing after test	Door glass intact. extensive cracks elsewhere. c.0.05 m^2 glass fallen out	Uncracked	Uncracked	Very extensively cracked during test	Half fallen out, rest extensively cracked, door glass intact.
State of rack contents after test	Plastics nearly all burnt away. Cribs nearly all intact except near centre	Similar to test 121	More extensively burnt than in tests 121, 122	Mainly burnt out	More extensively burnt than in tests 121, 122 but similar to test 123

the ceiling thermocouple. Test 124, although giving a similar curve for the first two minutes, maintained higher temperatures later on because the rack contents burned away unhindered by any sprinklers.

4. DISCUSSION

The experiments carried out have demonstrated several important features of the behaviour of a window being heated by a fire and cooled by water.

Sprinklers alone will not usually reduce the fire at an early enough stage, or quickly enough, to prevent the glass cracking. Whilst the cracked glass will not necessarily fall out, it cannot be relied on to stay in position - in test 130 about half the area of the main pane fell out whereas in the nominally identical test 121 the glass cracked badly but largely remained in position.

When the window was provided with a drenching system, in addition to sprinklers, the glass survived intact, but the drencher alone, running at 0.55 l/s per metre width of window was insufficient to prevent damage to the glass. In the latter case the uniformity of water flow over the glass appeared to be interfered with by the strong heating, presumably mainly by radiation from the fire. Thus a system which gives a good flow of water over all parts of a window when tested in the absence of fire might yet not give enough protection with a severe fire. Even a system which might be shown to be adequate could be upset by obstruction of the drencher spray by articles close to the window.

5. CONCLUSIONS

(1) Although sprinklers considerably reduced the intensity of a wood and plastics fire they did not on their own save a glazed shop front near the fire from cracking and sometimes falling out.

(2) When a window-drenching system was used instead of sprinklers the damage to the glass was merely delayed.

(3) When both sprinklers and the window-drenching system were used the glass was undamaged.

(4) Whatever kind of window-drenching system is used it is essential that it wets completely the topmost parts of the glass where heating by a fire is most severe. The irregular functioning of either sprinklers or window-drencher is undesirable because it may result in an area of glass becoming dry and therefore overheated before being rewetted when it may well crack or shatter.

(5) Because the behaviour of glass is unpredictable as regards cracking and falling out it cannot be relied on to form a smoke barrier, without special protection.

6. ACKNOWLEDGMENTS

The author would like to thank Mr A J M Heselden for advice and assistance with planning and carrying out the tests. Messrs P R Watts, S W Fink and N R Marshall also gave useful help during the experiments.

7. REFERENCES

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2. HESELDEN, A J M. Fire problems of pedestrian precincts - Part 1. The smoke production of various materials. Joint Fire Research Organisation Fire Research Note 856/1971.

3. HESELDEN, A J M, WRAIGHT, H G H and WATTS P R. Fire problems of pedestrian precincts - Part 2. Large-scale experiments with a shaft vent. Joint Fire Research Organisation Fire Research Note 954/1971.

4. HESELDEN, A J M, and WRAIGHT, H G H. Fire problems of pedestrian precincts - Part 3. The smoke production of sprinklered fires (low water pressure) Joint Fire Research Organisation Fire Research Memorandum No 98/1973.

APPENDIX

LOG OF EVENTS FOR EACH TEST

Test 121. With sprinklers, without window drencher, display rack without canopy.

Time (min s)	Event
00 00	Ignition of wood wool shavings in display rack.
00 25 to 00 30	Flames rising to upper shelf and igniting polyurethane foam cushions, smoke pouring steadily from upper half of rear opening in fire compartment.
00 50	Flames rising to top of display rack, smoke layer building up in fire compartment and reaching down to top of display rack.
01 05	Flames rising to ceiling.
01 15	Front sprinkler (nearer window) operates.
01 40	Rear sprinkler operates. Fire compartment almost filled with black smoke, obscuring vision, but vigorous flaming still visible in lower part of rack.
01 55	Slight clearance of smoke, revealing vigorous flames still reaching ceiling. Sprinkler seems to be preventing fire from spreading, but not reducing it.
02 15	First cracks appear in glazing at three widely separated points.
02 50	Further cracking, and small piece of glass (c. 0.3 m by 0.2 m) fell out from top of main window. One crack extends over full height of window. A little smoke now enters arcade. Less smoke, but some steam now emerging from rear.
03 45	Flames subsiding a little. No further glass cracking.
04 35	Flames rapidly decreasing.
05 30	Flames in rack now less than 0.5 m high.
c.11 00	Water off, fire almost out, and easily extinguished by hand with a little water. Glass extensively cracked and an area of about 0.05 m^2 of glass missing from top of main window. Glass in door intact.
After Test	Cribs on display rack wet and charred on their upper sides but very little wood burnt away. Polystyrene remained around the edge of both shelves. Wood shelving and sticks intact but charred in places. Fire had consumed the wood shavings and polyurethane cushions and also the polystyrene in the central part of both shelves.

Test 122. With sprinklers, and window drencher, display rack without canopy.

Time		Event
min	s	
00	00	Ignition as before. Drenching system operating.
00	30	Flames rising to top of rack.
00	45	Fire compartment completely filled with smoke.
01	00	Flames rising to ceiling and starting to spread beneath it.
01	10	Front sprinkler operates.
01	40	Rear sprinkler operates, then view into rear of fire compartment completely obscured by smoke.
02	05	Sprinkler appears to be just about containing fire.
02	55	Flames still reaching ceiling.
03	20	Now difficult to see flames through dense smoke.
03	45	Fire decreasing, flames less than 0.5 m high on both shelves.
04	15	Very little flame on lower shelf, more on upper shelf.
07	30	Fire appears to be out.
09	25	Water off.
After test		Sprinklers had extinguished fire. Glass was not cracked and was used again for test 123. State of display rack similar to test 121.

Test 123. With sprinklers and with drencher, display rack with canopy.

Time		Event
min	s	
00	00	Ignition as before. Drenching system operating.
00	15	Flames rising to upper shelf.
00	40	Flames rising to canopy.
00	55	Flames rising to ceiling.
01	10	Front sprinkler operatés. Flames directed by canopy towards glass but did not appear to touch it.
01	30	Rear sprinkler operates. Fire compartment now full of thick black smoke, making it difficult even to see the rack.
01	50	Some flame visible behind glass at top corner.
02	15	Flames spilling out from beneath canopy and reaching ceiling on both sides of it.
03	15	Smoke clearing slightly.
04	15	Flaming slightly reduced.
05	25	Fire on upper shelf nearly out. Body of flame some 0.6 m wide and high on lower shelf. Fire decreasing slowly.
11	10	Flaming ceased on upper shelf.
15	00	Fire out. Water off. A few glowing embers easily put out with a little water.
After test		Glass was not cracked and was used again for test 124. Contents of display rack more extensively damaged by fire than in previous tests. Almost all polystyrene gone and over half canopy burnt with remainder draped down across centre rail of rack.

Test 124. Without sprinklers, with window drencher, display rack without canopy.

Time		Event
min	s	
00	00	Ignition as before. Drenching system operating.
00	55	Flames rising to top of rack.
01	05	Flames rising to ceiling, fire compartment filling with smoke.
01	15	Column of flames nearly 1 m thick from floor to ceiling.
02	20	Fire compartment completely smoke-logged with black smoke.
03	30	First cracking of glass, down one side where water coverage was less. Smoke starting to clear.
03	50	Further cracking of glass on the same side of main window. Whole rack of fuel alight.
05	00	Drenching system not operating so well, giving irregular coverage with separate streams of water flowing down the glass.
05	50	Further glass cracking on same side. Some areas of glass not wetted.
06	25	Flames still reaching ceiling.
07	35	Cracking of glass in door.
08	00	Fire decreasing.
09	30	Water off, following by further glass cracking and some increase in burning on rack.
11	00	Flames from both shelves still over 1 m high.
13	45	Fire now much reduced.
14	10	Water turned on again slowly on to glass which 'crazes' where the water runs over it. A little later large areas of glass collapse.
18	30	Fire almost out.
After test		Glass cracked in fanlight and door, but largely fallen out elsewhere. Contents of rack mainly burnt out or heavily charred.

Test 130. With sprinklers, without window drencher (repeat of test 121) display rack without canopy

Time		Event
min	s	
00	00	Ignition as before.
00	30	Flames rising to top of display rack.
00	50	Flames rising to ceiling.
00	55	Front sprinkler operates.
01	15	Thick column of flame about 1 m wide reaching ceiling. Sprinkler seems to have little effect, but nearly all glass receiving water from it even at top.
01	45	Rear sprinkler operates.
02	00	First glass cracks, in fanlight.
02	15	Compartment filling with smoke.
02	30	Sprinklers just containing fire. Top 0.5 m of glass now dry. Smoke layer about 1 m deep flowing out through rear door.
03	05	Top of main window cracks and moves to leave an open slot a few centimetres wide along the top.
04	00	Flames still reaching ceiling. Large vertical crack near side of main window.
05	00	Some glass drops out.
05	45	Further cracking of glass.
07	05	About half the main window falls out and crashes to the floor.
07	25	Fire spreading back to upper shelf.
08	30	Flames still reaching ceiling.
09	00	Fire decreasing slightly.
10	00	Fire spreading in cribs towards window in spite of sprinklers.
15	30	Fire practically out.
After test		Glass in door intact, cracked in fanlight, at least half main window missing. Damage to rack contents greater than in test 121 with all the central parts burnt out on both shelves. Around the edges the cribs were undamaged and wet. A little polystyrene was left on these outer parts of the cribs.

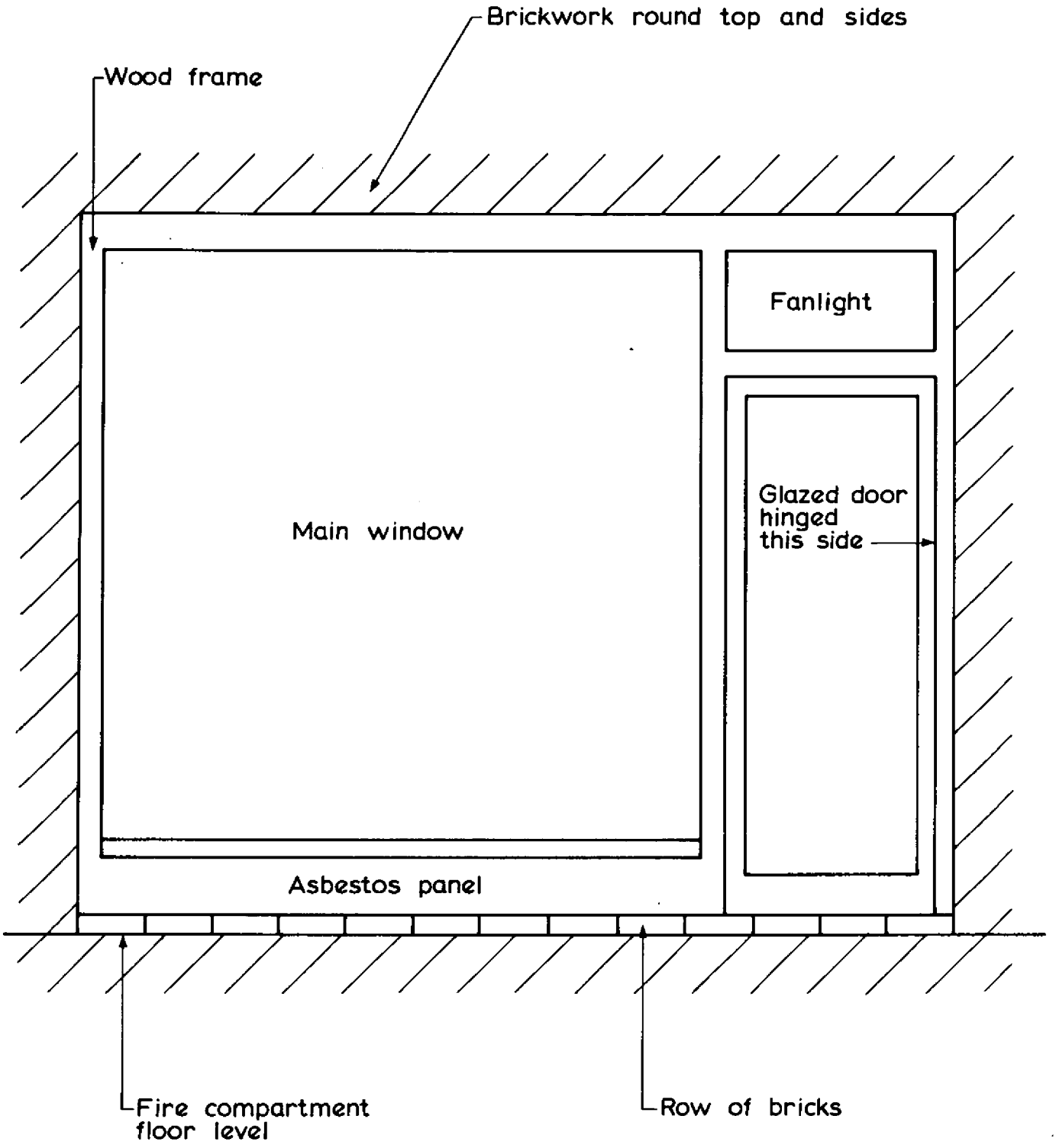
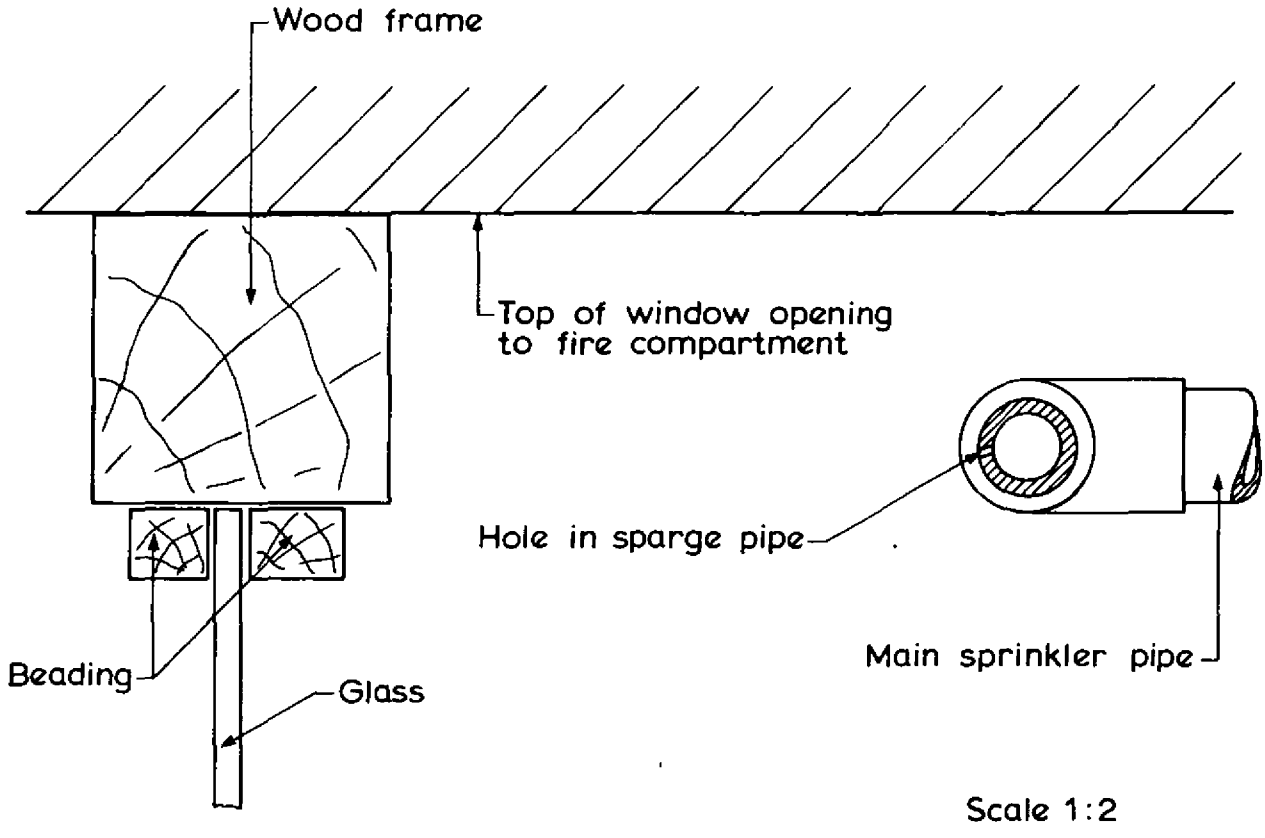
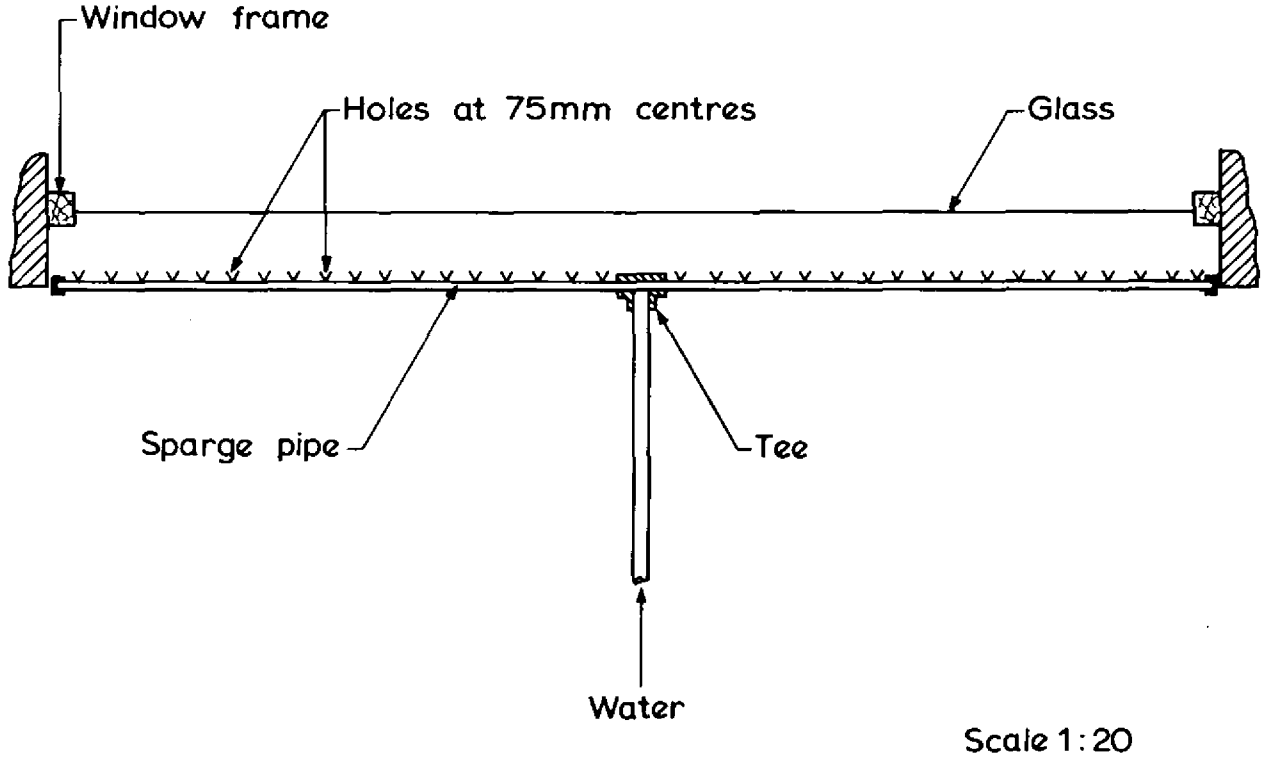


Figure 1 Shop front elevation



Vertical section



Horizontal section

Figure 2 Window drenching system

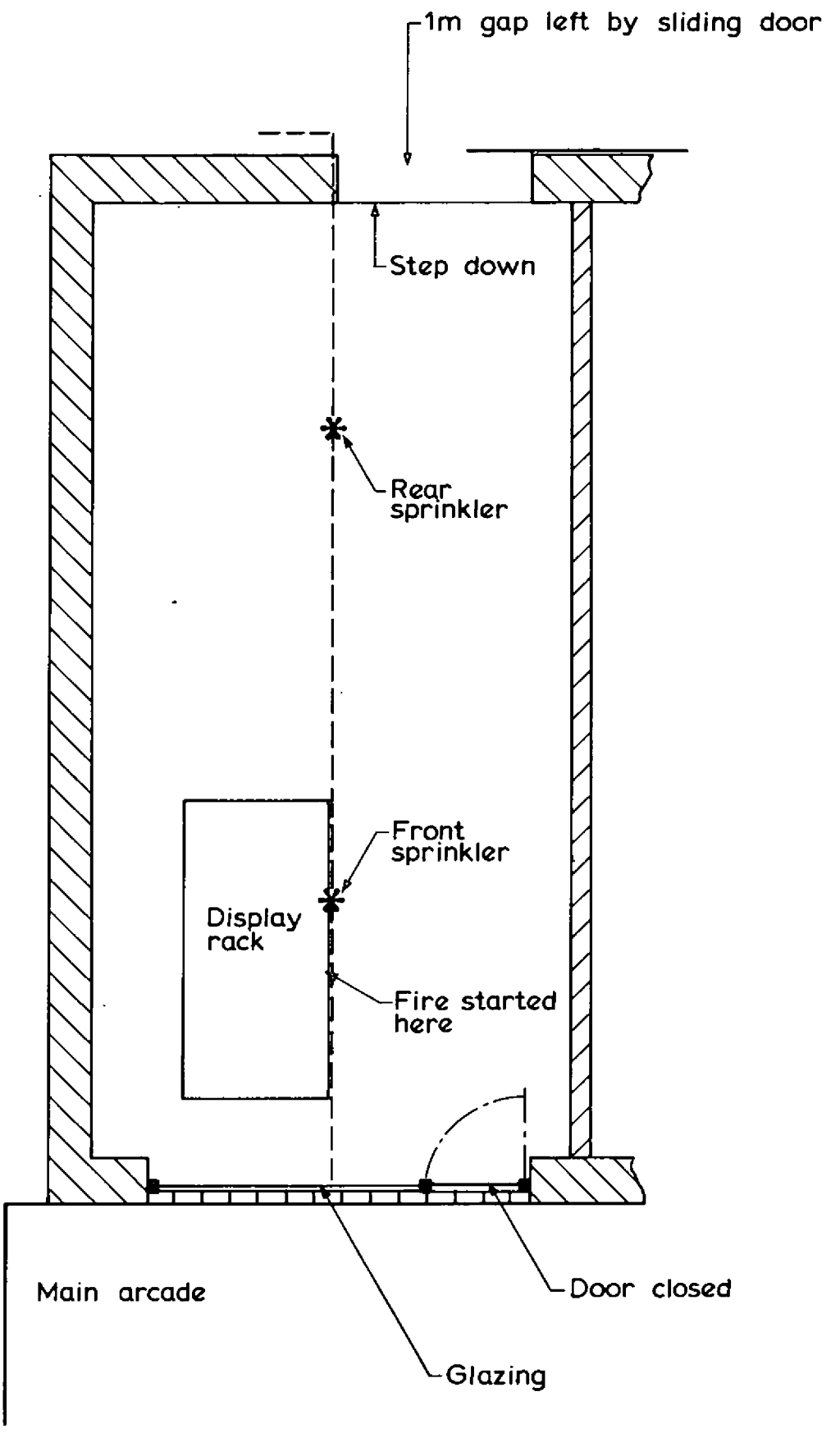
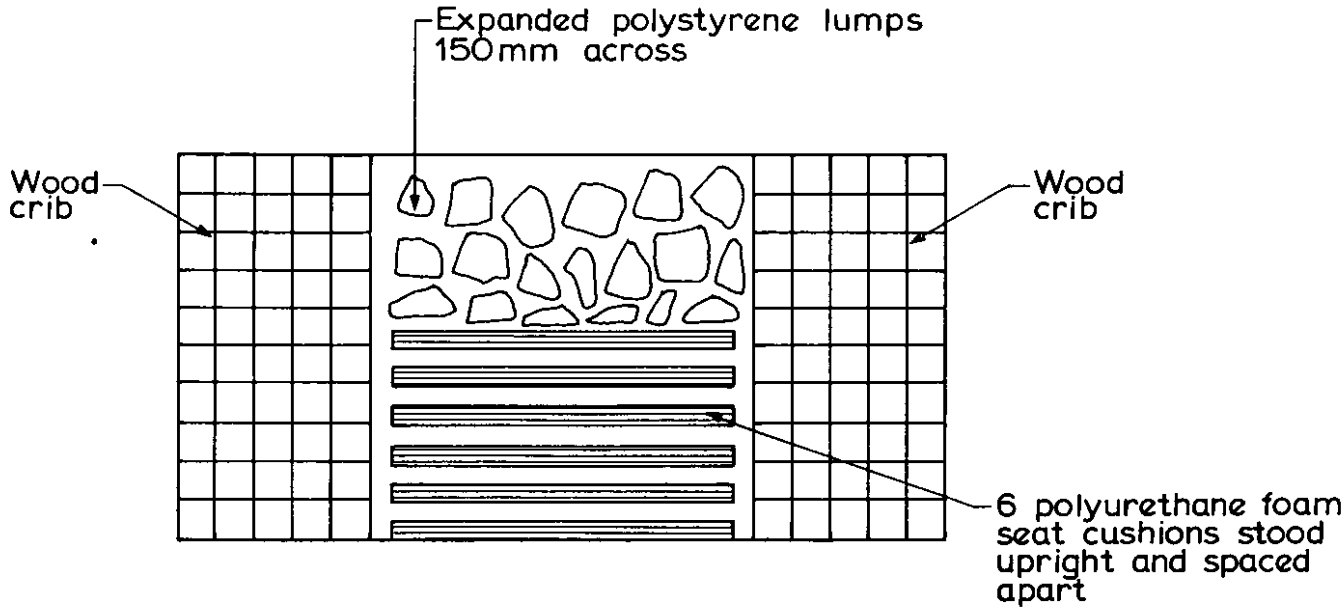
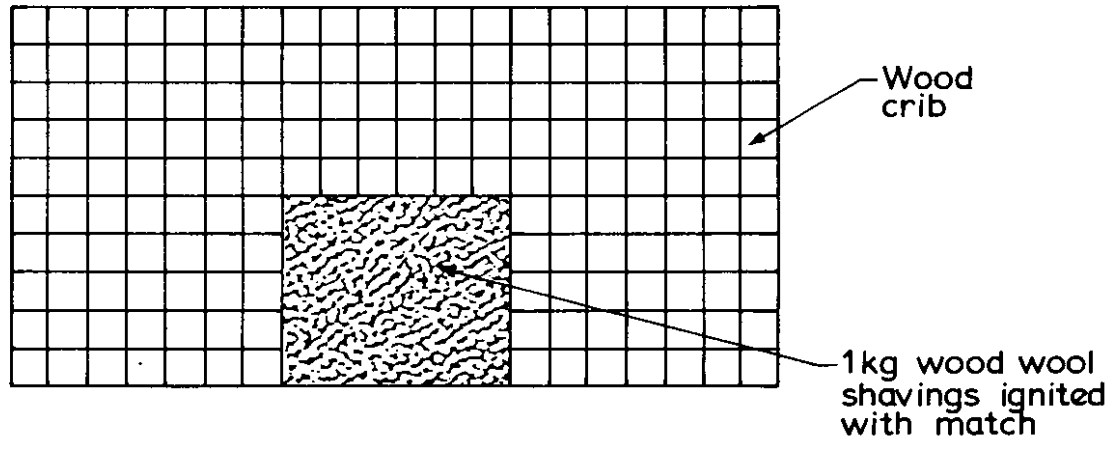


Figure 3 Plan of fire compartment set for test



Upper shelf of 23 45mm wood sticks laid at approximately 100mm parallel centres



Lower shelf of 15 - 20mm plywood

All cribs built of 25mm square sticks running parallel at 100mm centres and 6 layers of sticks (150mm total height) at right angles to those in adjacent layers

All cribs covered with expanded polystyrene lumps to a depth 150 - 300mm

Figure 4 Arrangement of fuel on display rack (plan of shelves)

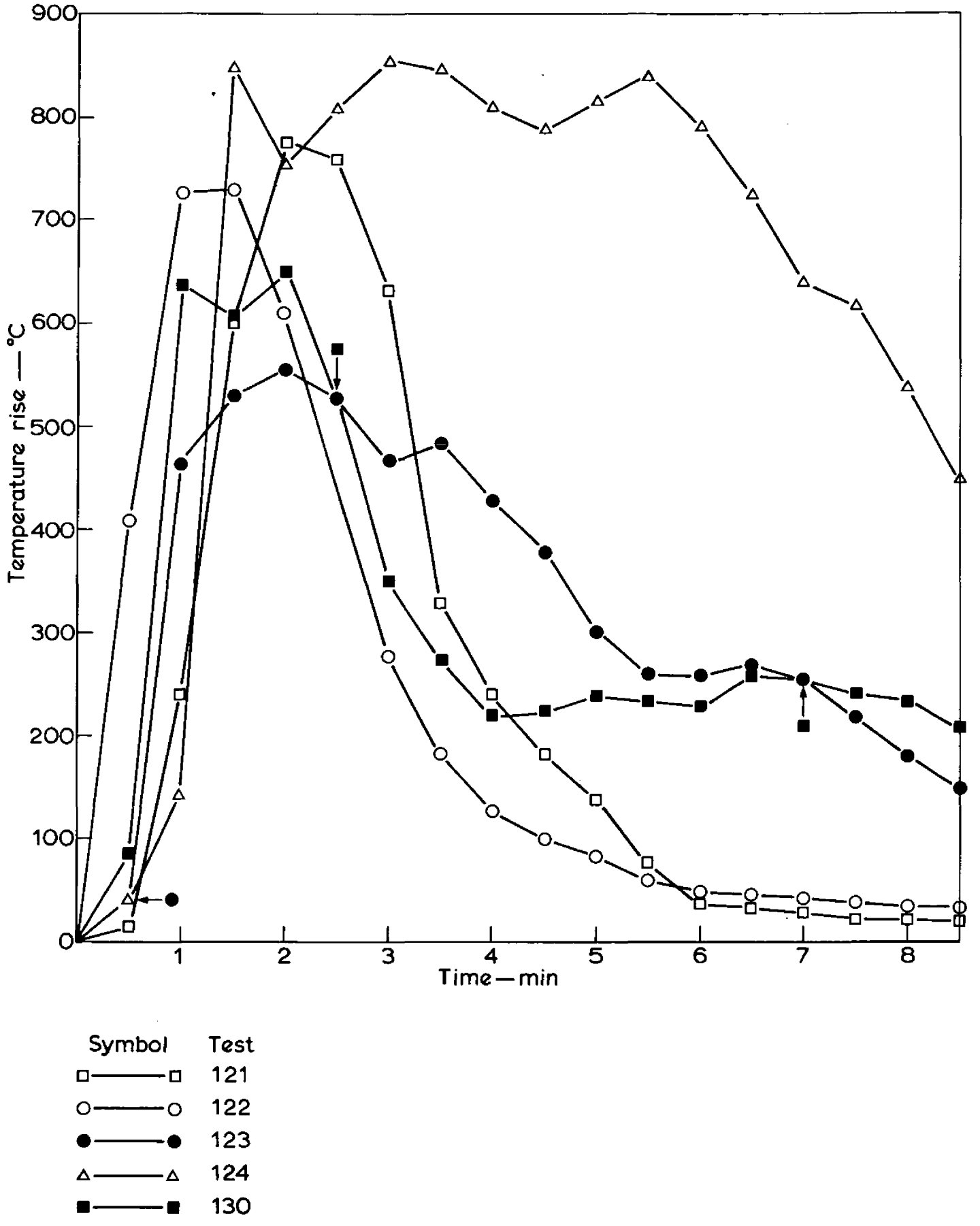


Figure 5 Temperature rise near fire compartment ceiling over display rack

PLATE 1. SPARGE PIPE DRENCHING INSIDE OF SHOP FRONT BEFORE TEST 122

PLATE 2. DISPLAY RACK LOADED BEFORE A TEST (130)

PLATE 3. EARLY STAGES OF TEST 121, 55 SEC FROM IGNITION

PLATE 4. LATER STAGES OF TEST 121, 4 MIN 35 SEC

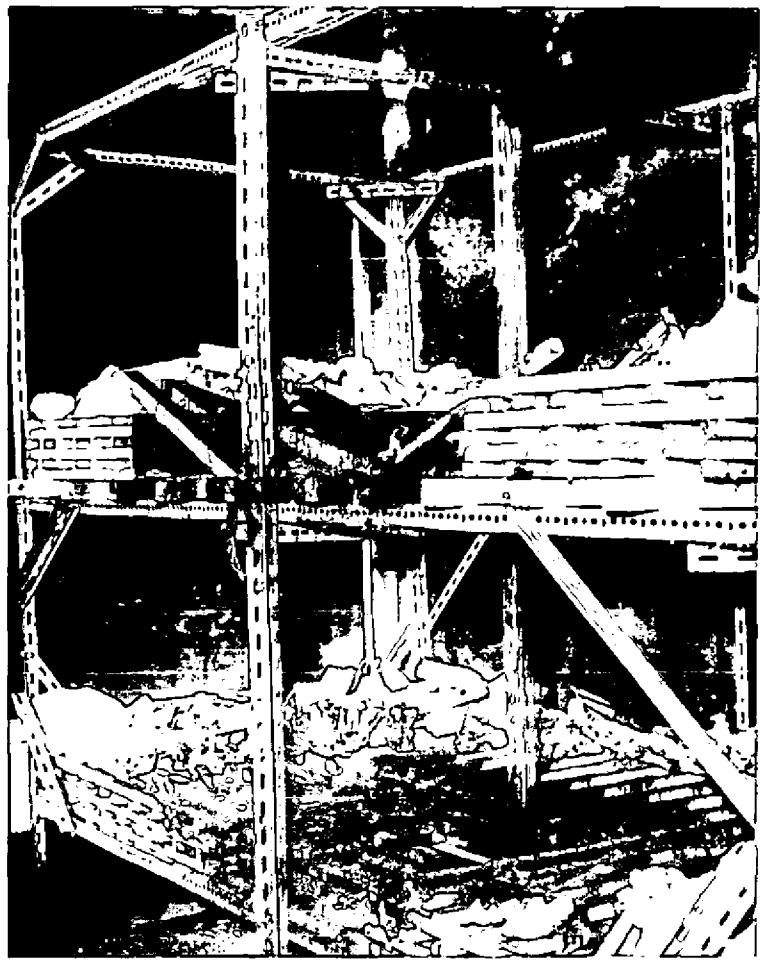


PLATE 5. TEST 122 AFTER SPRINKLERS HAD EXTINGUISHED THE FIRE

PLATE 6. AFTER TEST 130

PLATE 7. MAIN WINDOW AFTER TEST 130