FIRE RESEARCH & DEVELOPMENT GROUP

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AN ASSESSMENT OF THE EFFECTIVENESS OF REMOVABLE PAVEMENT LIGHTS WHEN FIGHTING A BASEMENT FIRE

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FRDG Publication Number 6/95
ISBN 1-85893-546-6

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ABSTRACT

A series of trials were conducted to assess the effectiveness of removable or breakable pavement lights or stallboards in assisting a brigade in the event of a basement fire, in effect: "Are they necessary, or even helpful?"

All of the fire tests were conducted in the same basement, using a repeatable fire, and combinations of open light, closed light, and natural and forced ventilation were tried.

It is concluded that the use of a removable or breakable pavement light or stallboard can have a significant beneficial effect in improving the firefighting environment, particularly when forced ventilation is being used, and may increase a brigade's options as to how to proceed with firefighting.

MANAGEMENT SUMMARY

This report describes a series of trials designed to assess the effectiveness of removable or breakable pavement lights or stallboards, in the event of a basement fire. Fires in basements are notoriously difficult for brigades to combat because, generally, personnel need to descend from the building above into the basement through a layer of hot gases to carry out search and rescue or firefighting procedures.

The underlying question being asked was, in effect: "Are removable or breakable pavement lights or stallboards necessary, or even helpful, in firefighting operations?"

In these trials, use was made of the cellar in the Industrial "B" building on the Fire Service College fireground, which had a removable pavement light installed by FEU for the purpose. Four different scenarios were tested in the same basement:

a. Pavement light shut, natural ventilation, only.

b. Pavement light open, natural ventilation, only.

c. Pavement light shut, PPV fan in building doorway.

d. Pavement light open, PPV fan in building doorway.

The basement and stairwell were instrumented to record temperatures and smoke obscuration, at 1.8m. (6 feet) and 0.9m. (3 feet) levels, throughout the duration of each trial. Also, FEU's seconded fire officers remained in the basement for the duration of each trial, to give a subjective commentary upon the prevailing conditions.

Diesel fuel was used in the repeatable test fires, which produced dense black smoke. It was found that the greasy, sooty deposits from this smoke rendered the smoke obscuration meters inoperable, but the firefighters' commentaries gave a good indication of the degree of smokelogging, at all times, in the basement.

The results of the trials suggest that removing a pavement light can have a significant beneficial effect upon the firefighter's environment, particularly when forced ventilation is being used, thus aiding rapid searching and firefighting.

It is concluded that, from the point of view of the brigades, it is better to have removable or breakable pavement lights or stallboards than not to have them, since their existence gives a brigade an additional option which can give various benefits.

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APPENDIX

1. INTRODUCTION

Early in 1995 the Fire Services Division of the Home Office Fire & Emergency Planning Department requested the Fire Experimental Unit (FEU) at Moreton-in Marsh to undertake an assessment of the effect removable or breakable pavement lights or stallboards can have during and immediately after a basement fire. The FEU was able to make use of the cellar in the Industrial "B" building on the Fire Service College fireground, which had a removable pavement light installed for the purpose.

Pavement lights are, essentially, very strong horizontal glass windows built into a walkway or pavement to let daylight into the basements of the adjacent buildings. They consist, generally, of thick glass blocks, some 80mm-120mm square, set into a reinforced concrete or iron grille which is let into the pavement, flush. These grilles (termed 'lights' in this report) are, typically, some 1.3 metres long by some 0.7 metres wide. Some lights are designed so that they can be removed, by a brigade, in an emergency to assist firefighting and/or smoke clearance. Stallboards are similar in effect, but are mounted in a vertical wall. They may incorporate removable panels, or louvres which can be opened by a brigade. It was the effect of removing a pavement light during a fire in a basement that was to be assessed. The basic question to be addressed was: "Are removable or breakable pavement lights or stallboards necessary, or even helpful, in fighting a basement fire?"

2. BACKGROUND

Basement fires are notoriously difficult to fight. Often there is only a single stairwell, or open staircase, from the ground floor of the building into the basement. This means that in the event of a basement fire, where no removable or breakable pavement light or stallboard exists, firefighters can only gain access to the basement from above via the staircase, and since heat and smoke generated by the fire move upwards, this can be a difficult and hazardous undertaking.

If a removable or breakable pavement light, or stallboard is installed in or near the ceiling of the basement, firefighters can open this from the pavement above (obviously, extreme caution is required). This removal of a light will vent the basement to the outside atmosphere and, it would appear, give the following advantages.

a. Allow smoke to begin to escape, immediately into the atmosphere (possibly along with some flame), rather than being trapped in the basement and percolating up through the building.

b. Enable firefighters to assess the size, fierceness and nature of the fire from outside the building.

c. Make possible direct firefighting, from outside the building.

d. Eliminate, or at least reduce, the risk of a flashover or backdraught situation building up in the basement. (If a backdraught did occur when the light was removed, due to the fresh supply of oxygen available to the fire, the fireball would vent through the light opening into the open air, rather than into the building as it would if the door at the top of the basement stairs had been opened instead.)

In any event, it is clear that rapid smoke clearance from the basement is desirable since it enables firefighters to see what is happening, and get to grips with the fire quicker. Also the removal of smoke, and some heat, makes for a more tenable environment for firefighting or rescue operations, and would be expected to reduce the effects in the building above.

3. TRIALS DESIGN

3.1 General

It was decided at the outset that trials should be undertaken to assess any differences in fire and smoke behaviour in a basement, when:

a. a light was removed, and

b. no light was removed.

It was further decided to assess both of the above situations using:

a. natural ventilation, only, and

b. a positive pressure ventilation (PPV) fan.

It was decided that a total of four fire trials would be undertaken, with an identical fire in the basement, and the door at the top of he stairs open, in each case. These were:

a. Light shut, natural ventilation only.

b. Light open, natural ventilation only.

c. Light shut, PPV fan in shop doorway.

d. Light open, PPV fan in shop doorway.

3.2 The Building

Suitable buildings were sought for this work and, after an initial survey, it was decided to undertake trials in the basement of the 'Industrial B' building on the Fire Service College's fireground.

This basement was considered to be fairly typical of those below commercial premises. (See Figure 1). The ground floor, immediately above the basement was a simulated fish and chip shop, specially constructed to withstand hot, smoky, fires. A single standard sized door at the back of the shop gave access to a single stairwell which lead down into the cellar. There was no door at the bottom of these stairs, simply a doorway - width space giving entry into the basement.

Initially, this basement had three built in pavement lights along the front (pavement side), below the shop window, each 1.3 metres x 0.7 metres. These were permanently grouted in. FEU removed one of these lights, that furthest from the shop doorway and close to the corner of the basement, and replaced it with a steel grille which could be

blanked off. (See Figures 2, 3, and 4). This grille could be left blanked off, to simulate a basement with no removable light, or could be opened when required to simulate a removable light being removed, in the same basement. Vertical louvred panels immediately above the light were blanked off for the duration of the trials.

Each fire was instrumented to record smoke obscuration and 'air' temperatures at selected sites (the same sites throughout all trials). Also, FEU's seconded fire officers, suitably protected, remained in the basement for the duration of each trial and reported by radio what they could perceive happening. They had a charged hosereel with them throughout all trials, both for safety reasons and to be able to extinguish the fire, if necessary, or at the completion of each trial.

Sufficient time was allowed between trials for the air temperatures in the basement and stairwell to return to ambient temperature. The PPV fan was employed to assist this process, while the removable pavement light was opened between trials.

All trials were commenced with the pavement light closed.

3.3 The Fire

It was considered necessary to use a fire, for these trials, which would produce a large quantity of smoke and would also be a fairly 'hot' fire in order to reproduce reasonably authentic conditions. For this reason, diesel fuel was selected and the quantity burnt in each trial would be sufficient to completely smoke log the fish and chip shop and the cellar.

Initially the intention was to burn up to 18 litres of diesel fuel per trial, contained in a single sawn-off off 100 litre oil drum. This was subsequently changed to two such fires because the single fire, while producing sufficient smoke, did not raise the 'air' temperatures significantly.

These fires were initiated by being primed with a small quantity of petrol, gently poured onto the surface of the diesel fuel, and ignited by a long, handheld lance, by one of the firefighters.

The fire (and subsequently fires) was positioned approximately in the centre of the basement, but rather closer to the front wall, i.e. the pavement lights. (See Figure 1.).

3.4 Instrumentation

The basement and the stairwell leading down into it were instrumented to measure the degree of smoke obscuration, and the air temperatures. Both sets of instrumentation were used in conjunction with a datalogger, to continually monitor the basement environment during all trials. The trials were also recorded on video from outside the building.

Thermocouples were positioned as indicated in Figure 1. At the back of the basement, seven thermocouples were mounted vertically one above the other to record the temperatures between 0.6 metres (2 feet) and 2.4 metres (8 feet) from the floor, at 0.3 metres (1 foot) intervals. Also, three pairs of thermocouples were mounted on the stairwell adjacent to (but not touching) the outer wall, one pair at the top of the stairs, one half way down and one at the bottom of the stairs. Each pair had one thermocouple mounted at 0.9 metres (3 feet) and one at 1.8 metres (6 feet) above the adjacent stair tread.

Smoke obscuration meters, water cooled for this application, were positioned one in the basement and one half way up the stairs. The one in the basement was placed close to the back wall, immediately in front of the thermocouple array, approximately on the centreline of the basement, at a height of 1 metre (it afforded no protection to the thermocouples). The one on the stairs was positioned as close to the outer wall as possible (to allow access past it), half way up the stairs, and mounted horizontally to sample a 1 metre long space, its 'upper' end was effectively 1.3 metres above the adjacent stair tread.

All power supply and data transmission cabling was lead into the stairwell and basement from the top of the stairs and across the floor of the fish and chip shop. It emerged from the building through a small opening (approximately 0.1 metre diameter pipe) at the opposite side of the shop, near floor level. From here the cables ran to the FEU instrument pod sited alongside the building, upwind. All cables were protected from the environment within the building with a low conductivity 'thermal blanket' material and aluminium foil.

External to the building, some 12 metres from its SW corner, an air velocity (speed and direction) indicator was erected, at a height of 6 metres from the ground. This was used to measure and record the natural wind velocity throughout all trials, and the data was later plotted, and averaged, for use in analysing the trials results.

4. TRIALS PROCEDURE

4.1 General

In the event, five trials were completed. The first (Test 1) was undertaken to test that the proposed procedures would be satisfactory, that the proposed fire would produce sufficient smoke and temperature increase, and that all of the instrumentation would function in the intended manner. This preliminary trial was followed by the four trials during which data was recorded. These latter four trials were performed in the following order:

Test 2 Open light - natural ventilation only.

Test 3 Open light - PPV fan in shop doorway.

Test 4 Light closed - natural ventilation only.

Test 5 Light closed - PPV fan in shop doorway.

Throughout all of the trials all thermocouple readings were continuously monitored and recorded, the firefighters' commentary was recorded from before ignition until completion of the trial, and a video recording was made of the outside of the building throughout the trial. This latter showed the shop doorway and the removable pavement light.

The detailed procedure for each trial is given below.

4.2 Test 1: Open light - natural ventilation, only

The two firefighters, in full fire kit and self-contained breathing apparatus (BA) entered the basement, carrying the diesel fuel and a sealed plastic bottle containing 0.5 litre of petrol, and the shop door was closed behind them. A Diktron radio system was used to maintain communication between the firefighters and the researchers outside the building. The firefighters filled the firetray (a sawn-off oil drum) with diesel and carefully poured the petrol on top of the diesel. The plastic bottle was also put into the tray, for safety reasons.

At a given signal, a firefighter ignited the petrol, and thus the diesel oil, using a lance. The firefighters then took up their positions, low down near the foot of the stairwell, to give a commentary on what they perceived to be happening in the basement. (Recorded on video tape.)

The shop door was opened 12 minutes after ignition, and the pavement light was removed 30 seconds later. The fire was allowed to burn for a total period of 21½ minutes, after which it was extinguished by one of the firefighters, using a snuffer lid.

This trial proved two things:

1. The air temperature at 2 metres height only reached some 50°C, considered insufficient to replicate realistic conditions.

2. The lenses of the smoke obscuration meters became covered in thick, oily, soot which rendered them virtually useless, no reliable data on the decrease of the smokelogging being therefore available.

For these reasons, in the subsequent trials the burn-rate was doubled (two identical firetrays) and the smoke obscuration meters were ignored, so that the firefighters' commentary on their observations was the only available information upon the state of smoke logging in the basement, and stairs, at any time.

4.3 Test 2: Open light - natural ventilation only

The procedure, and timing, were identical to those stated for Test 1. (Section 4.2 above.) The shop door was fully opened at 12 minutes after ignition, when the basement and shop were thoroughly smoke logged, and the pavement light was removed at 12½ minutes after ignition. The fire was extinguished 22 minutes after ignition, the firefighters left the basement 25½ minutes after ignition, but temperatures were recorded until 27½ minutes.

4.4 Test 3: Open light - PPV fan in shop doorway

The basic procedure was identical to that for Test 2 until 21½ minutes after ignition. (Section 4.3, above) and the timing of events was kept the same as far as possible. The PPV fan (Tempest 24" power blower, with 5.0 HP Tecumseh petrol engine) was set up 2.5 metres from the shop doorway, where it appeared to 'seal' the doorway (no 'air' would come outwards through the doorway).

The shop door was opened 12 minutes after ignition, the pavement light removed at 12 minutes, 30 seconds after ignition, and the fan was started at 12 minutes, 40 seconds after ignition. The blanking plates over the vertical louvred panels immediately above the pavement lights were removed at 21½ minutes after ignition(this was not intended as part of the trial) and the fire was extinguished at 23½ minutes after ignition. Temperatures were recorded for a further 1½ minutes after this.

4.5 Test 4: Light closed - natural ventilation only

The basic procedure was identical to that of the previous trials. The shop door was fully opened 12 minutes after ignition, but no further action was taken. The fire was extinguished about 21½ minutes after ignition, the firefighters left the basement some 1½ minutes later and temperatures were recorded for a further 4 minutes after this.

4.6 Test 5: Light closed - PPV fan in shop doorway

The basic procedure was again, identical to that of the previous trials. The shop door was fully opened 12 minutes after ignition, and the PPV fan started 15 seconds later. The fire was extinguished about 21½ minutes later and temperatures were recorded for a further 3 minutes.

5. TRIALS RESULTS

5.1 General

The first trial, Test 1, was undertaken to prove the procedure, and to determine what fire size and duration would be suitable to give sufficient smoke, and an adequate temperature rise, within the building to replicate a realistic basement fire situation. This trial showed that a larger fire would be necessary. The air temperature at the 1.85 metre level in the basement barely reached 50°C which was considered too low for a realistic trial. Also, the dense, greasy smoke produced sooted up the lenses of the smoke obscuration meters to such an extent that the readings reached 100% as expected, but did not reduce at all as the smoke cleared. Therefore, no results are given for this preliminary trial.

The size of the fire, i.e. the surface area of the burning fuel, was doubled for the subsequent trials (by adding a second, identical, fire tray) and the results of these - Tests 2 to 5, inclusive - are given below.

5.2 Cellar and stairwell temperatures

The temperatures recorded by all thermocouples were continuously recorded throughout all trials, from ignition (t=o) until some few minutes after the fires were extinguished (typically t=26 minutes). Temperature Vs. time plots are given in Figures 5-16 inc.

5.3 Smoke obscuration

Since the smoke obscuration meters could not cope with the sooty deposits from the burning diesel fuel, the firefighters' commentary from inside the basement was the only data available. For this reason, a precis of the commentary for each trial is given in the Appendix. Some of their comments have been excluded from these precis, for brevity, but the main, important, observations are given verbatim, with the time of each (in minutes and seconds) so that direct comparisons can be made from trial to trial.

Since the commentaries for all four trials were very similar to each other during the build-up stage, the complete commentary, from when the fires were lit, is given for Test 2, only. The commentaries for the subsequent trials are given from a stage just before the shop door was opened (the first action to be taken from above) in all cases.

It should be remembered that the firefighters were sitting with their backs against the wall separating the stairwell from the basement. Their eyes were, thus, about 0.9 metres from the floor.

5.4 Wind velocity data

The wind speeds and directions were recorded throughout all trials and were later plotted. Average velocities were calculated from these plots for each trial, over the period from the door of the building being opened until the fires were extinguished.

These average wind velocities, measured at a height of 6m. above ground, are given in Figure 17.

6. DISCUSSION ON TRIALS

6.1 General

To compare the effect of opening a pavement light with not doing so, while using natural ventilation only, the results of tests 2 and 4 (Figures 5, 6, 7 and 11, 12, 13) were compared.

To compare the effect of opening a pavement light with not doing so, while using a PPV fan at the front door in both cases, the results of tests 3 and 5 (Figures 8, 9, 10 and 14, 15,16) were compared.

To compare the effect of using PPV with that of natural ventilation, with a pavement light removed, the results of tests 2 and 3 (Figures 5, 6, 7 and 8, 9, 10) were compared.

To compare the effect of using PPV with that of natural ventilation, with no pavement light removed, the results of tests 4 and 5 (Figures 11, 12, 13 and 14, 15, 16) were compared.

These comparisons have been made by FEU and the overall conclusions are given in Section 7. However, a brief explanation of how the comparisons were made may be helpful. In each case, the recorded temperatures at all thermocouple positions were compared over the period from the door being opened to the fires being extinguished. Also, comparisons of the degree of smoke logging (or effectiveness of smoke clearance) over the same period were made by studying the subjective commentaries of the firefighters.

The prevailing wind conditions during the same period of each trial were also taken into account, although it was impossible to be certain what effects the differences in wind speed and, probably more importantly, wind direction may have had. These average wind velocities are indicated in Figure 17, and it is clear from these diagrams that a component of the wind would have been effectively pressurising the shop doorway (and possibly an open pavement light) during tests 4 and 5 and would have assisted the fan in test 5. The possible effect of the wind, or eddies, passing across the open light, in tests 2 and 3 are, however, not simple to assess.

It must be accepted that the temperatures experienced in these trials were not as high as might be encountered in a real basement fire. This was because the basement used was not protected by ceramic blocks, and it was feared that more severe fires than those used could have damaged the exposed concrete surfaces. However, the results from these trials are valid for the purposes of comparing one approach with another.

6.2 Observations on individual trials

The basic findings from the trials are summarised, very briefly, below. The changes in temperatures are given, at a few key times during each trial, and to give some idea of

any changes in the smokelogging, a few relevant comments are lifted from the firefighters' commentaries (given more fully in the Appendix).

6.2.1 Test 2: (Open light - natural ventilation only)

When the shop door was opened and the pavement light removed, the basement temperatures were 184°C at 6 feet and 98°C at 3 feet level. The temperature at both of these measuring positions remained essentially constant (fluctuating over about a 10°C range) until the fires were extinguished.

The temperatures measured at the top, middle and bottom of the stairs, at the 3 feet level, when the light was opened were 88°C, 66°C and 47°C respectively. Over the next one minute these fell to 54°C, 62°C and 46°C respectively. The top of the stairs then rose to 62°C, at extinction, while the other two remained essentially constant over the same period.

At the 6 feet level on the stairs, the temperatures measured at the top, middle and bottom when the light was opened were 97°C, 82°C and 76°C These temperatures remained fairly constant until the fires were extinguished, when they were 96°C, 83°C and 72°C respectively.

Selecting, and summarising, statements from the firefighter's commentaries [on page A3] which pertained to smokelogging (rather than the temperature) gave the following:-

13-00	(Half minute after the light was removed) "Can now see flames."
13-16	" Its beginning to clear. Can just make out Gary, next to me."
13-26	"Smoke definitely clearning quite rapidly now."
13-38	"Both fires visible now."
14-50	"Can't see 3 feet yet." (at waist height)
15-15	"Can just make Gary out."
18.00	"Smoke level definitely rising"
19-36	"Thickness of smoke not changing." (Equal smoke production and venting.)
	[Fires extinguished at 22-00.]
22-55	"Can now see my hand at arm's length with a torch."
23-09	"I'm 4 feet from smoke rig, but can't see it with my torch."

The above summary shows that the temperature did not alter significantly over the period from just before the door and light were opened until after the fires were

extinguished. The temperatures at the 3 feet height on the stairs did reduce somewhat and a slight improvement in visibility is evident, as described by the firfighter.

Outside the building, smoke was seen to be escaping from both the pavement light and the shop door but it would appear that this was being replaced by smoke being produced by the fires, resulting in a new equilibrium level of smoke in the basement.

6.2.2. Test 3 : (Open light, PPV fan in shop doorway)

The shop door was opened, the pavement light removed 30 seconds later and the PPV fan started 10 seconds later again. No changes were observed in any of the temperatures being recorded during this 40 second period. When the fan was started, the basement temperatures were 187°C at 6 feet and 112°C at 3 feet level. These temperatures dropped, after 1 minute, to 160°C and 89°C respectively and, after a further 1½ minutes, to 145°C and 76°C respectively. The temperature at the 6 feet level then increased slightly, to 156°C when the wall louvres were opened, while that at the 3 feet level remained essentially constant.

The temperatures measured at the top, middle and bottom of the stairs, at the 3 feet level, immediately before the fan started were 90°C, 70°C and 53°C respectively. Within one minute of the fan starting, all three had fallen significantly, to 33°C, 39°C and 39°C respectively. After a further minute they had reduced to 23°C, 25°C and 28°C respectively, and they had all fallen to about 20°C when the wall louvres were opened, some 6 minutes later.

At the 6 feet level on the stairs, the temperatures at the top, middle and bottom reduced in a broadly similar manner, being 103°C, 86°C and 82°C respectively when the fan was started. These temperatures (all three) fell to 49°C after one minute, and to 22°C, 25°C and 26°C respectively after a further one minute. They had all fallen to 17°C ~19°C when the louvres were opened, about 6 minutes later.

Selecting relevant comments from the firefighters' commentaries [on page A5] gave the following insight into the smoke clearance, over the same time period.

12-30	[Pavement light removed.]
12-40	[Fan started.]
12-48	"Making a big difference now, John. I can see the flames quite clearly."
13-12	"Becoming much clearer now."
13-33	"Flames spiralling."
14-02	"Visibility a good 4 feet at waist height."
16-30	"Can see to top of stairs easily."

16-50	"...Visibility is good...would make access particularly easy."
17-42	"...still a smoke layer at about head height."
18-05	"At waist height, you can see right across the room."

The above summary shows that the temperatures on the stairs were reduced significantly as soon as the fan was started, and continued to fall slowly. Also, the temperatures in the basement were reduced fairly significantly, to a level which the firefighters considered "reasonably comfortable", particularly at the 3 feet level. The degree of visibility in the basement appears to have improved markedly as soon as the fan was started, and this continued to improve (although the fires were seen to burn rather more fiercely). Also, the stairwell was relatively clear of smoke within 4 minutes of the fan being started. The firefighters commented that, as well as the improved visibility, they could feel the cooler air moving around them as soon as the fan was started, and that this was very welcome.

From outside the building, much smoke was seen to issue from the pavement light, though the volume appeared to tail off somewhat as the trial progressed. Virtually no smoke was seen to escape via the shop door, but the shop above the basement was seen to be virtually clear of smoke before the fires were extinguished. This implies that much of the smoke from the shop (it was heavily smokelogged when the door was opened) was carried back down into the basement and escaped through the pavement light.

6.2.3. Test 4: (Light closed, natural ventilation only)

In this trial the pavement light remained closed throughout, the shop door was opened and no further action was taken until the fires were extinguished. When the shop door was opened the basement temperatures were 152°C at 6 feet and 85°C at 3 feet Both of these temperatures increased slowly in a virtually linear manner, to 156°C and 98°C respectively when the first fire was extinguished.

The temperatures measured on the stairs, at the 3 feet level were 73°C at the top, 58°C at the middle and 43°C at the bottom, when the shop door was opened. The temperature at the top of the stairs reduced to some 50°C after one minute, and to 35°C when the first fire was extinguished. The other two remained essentially constant over the whole period from the door being opened until the fires were extinguished.

At the 6 feet level on the stairs there was little difference in any of the temperatures over the period from the door being opened until extinction: the top one increased from 86°C to 89°C, the middle one increased from 76°C to 79, and the bottom one remained virtually the same (although it fluctuated over a range of about 14°C.)

A study of the firefighters' commentaries [on page A7] between the times when the shop door was opened and the fires were extinguished reveals the following relevant comments:-

12-46	"...can see fires, solid flame."
13-52	"Bottom of smoke layer is rising, or thinning out slowly."
14-39	"Can see the outline of top of tray in silhouette against flames."
18-40	"The smoke seems to be thickening around the far tray...it may be a temporary swirling effect."
19-50	"Smoke slightly less thick, overall."

The above summary of results shows that the basement temperatures increased slightly during the trial, while the only position where the temperature decreased was at the top of the stairs, 3 feet from the floor. The smokelogging appears to have reduced very slightly during the trial, and some swirling is evidence (possibly due to the wind which was blowing into the shop doorway.

6.2.4. Test 5: (Light closed, PPV fan in shop doorway)

When the shop door was opened, and immediately before the fan was started, the basement temperatures were 157°C at 6 feet, and 95°C at 3 feet During the trial both temperatures increased, in a virtually linear manner, to 172°C and 108°C respectively, when the first fire was extinguished.

When the fan was started the temperatures on the stairs, at the 3 feet level, were 70°C at the top, 60°C in the middle and 48°C at the bottom. During the first minute after the fan was started these temperatures all fell to 32°C, 57°C and 42°C respectively, after which the top one remained essentially constant until extinguishment, while the middle and bottom ones rose steadily to 62°C and 48°C respectively.

At the 6 feet level on the stairs, the temperatures were 87°C at the top, 77°C in the middle and 67°C at the bottom. These three all increased fairly steadily until, when the first fire was extinguished they were 95°C 84°C and 68°C respectively.

With regard to the effect upon the smokelogging in the basement, selecting and summarising relevant comments from the firefighters' commentaries [on page A9] gives the following

12-15	[Start PPV fan]
12-40	"...fire becoming more visible."

15-45 "...still smoke down to the floor, but it's thicker above waist height."

17-38 "The base of the dense smoke is rising and falling by about 1 feet at about waist height."

19-33 "Still smoke to floor, the base of the dense smoke has dropped another foot...about 2 feet from the floor."

The above summary of results shows that, during the period from the fan being started until extinction, the temperatures in the basement rose steadily. On the stairs, the only position where the temperature reduced was at the top, at the 3 feet level. The temperatures at all other measuring positions on the stairs remained roughly the same.

The degree of smokelogging in the basement appears not to have improved perceptibly during the trial, an equilibrium position being reached where the base of the very dense smoke hovered from 2-3 feet from the floor, with somewhat thinner smoke below this extending to the floor.

During this trial it was apparent to observers outside the building that very little visible smoke was escaping from the end of the building involved in the trial. Several small leaks were apparent but it was realised that, with the fan effectively pressurising the shop, stairs and basement (the natural wind also was assisting in this) and the fires continually producing smoke, there must have been other, larger, though invisible (to the observers) leaks through which smoke was escaping through internal leaks from the shop and basement into the rest of the building. By the time the fires were extinguished the whole of the ground floor of the 'Industrial B' building (a volume of some 600m^3 plus the shop and basement) had been smokelogged.

This latter result confirms the danger of employing a PPV fan where adequate steps cannot be taken to control the air/smoke outlet/s from the building. In this trial air was forced in through the shop door and, with the pavement light closed, had 'nowhere to go'. In this situation the room inside the inlet doorway and adjoining rooms are pressurised and air (and smoke) will escape from them in any way it can, through all potential leaks however small, both out of, and into other parts of, the building.

6.3 Probable effects of the natural wind upon trials

As has been previously stated, during the first two trials (tests 2 and 3) the wind was blowing away from the shop doorway, probably causing a negative pressure in the doorway and above the light, whereas in tests 4 and 5, on the following day, the wind was blowing quite strongly towards the doorway.

In test 3, any wind which had some component towards the doorway would have, in effect, assisted the fan and would probably have improved the already impressive, performance of the fan in this trial. However, such a wind may also have impeded the outward airflow from the light to some extent.

During both tests 4 and 5, the wind was blowing quite strongly into the shop doorway. Resolving the average wind velocities (given in Figure 17) into components parallel with the wall of the building, and normal to it, gives average wind speeds of 4.7m/sec. in test 4, and 5.6 m/sec. in test 5, directly into the doorway. These natural wind components blowing into the shop doorway are, very roughly, equivalent to two thirds or three quarters of the average output velocity of the PPV fan (when measured at a realistic distance from the fan) in still air conditions.

It is therefore possible that, in test 4, when the light was kept closed, there may have been some smokelogging of the rest of the building, although none was detected. (It was not looked for). Also, in test 5, when the light was kept closed while the PPV was used, the actual average air velocity just outside the shop doorway may have reached virtually double that which the fan alone could produce in still air conditions. (This assumes that there was adequate means of escape for the air forced through the doorway, and it is more likely that the building was pressurised, thus preventing the full available airflow from entering the doorway).

Nevertheless, it is probable that this 'overpressurisation' of the doorway may have caused the slight changes in the basement, and the degree of smoke logging in the rest of the building to have been greater than they would have been on a still day.

In all cases, the geometry of the building meant that the doorway and pavement light were on the same side of the building. Ventilation is always more effective if the outlet vent (the pavement light or stallboard) is on the downwind side of the building and the inlet vent (the door) is on the upwind side. Ventilation is least effective if these conditions are reversed.

7. CONCLUSIONS

7.1 Natural ventilation

When natural ventilation only was used, there was some improvement in the visibility in the basement and stairwell when the single pavement light was removed, compared with when it was not. However,

it is possible that, if the wind had been blowing into the opened shop doorway when the light was removed, (as it was when the light was not removed) a greater improvement in smoke clearance may have been achieved.

The basement temperatures remained essentially constant when the light was removed, but increased slightly when it was not. On both occasions the temperature at the top of the stairs, at 3 feet from the floor was reduced somewhat, while the temperatures at other locations on the stairs stayed essentially constant. It is probable that the effect of natural ventilation would have been greater if the pavement light had been downwind, and the shop door upwind.

7.2 Use of a PPV fan

The differences in effect between opening a pavement light and not doing so were much more dramatic when a PPV fan was deployed at the shop doorway, both in terms of temperature reduction and visibility. When the light was opened, the temperatures in the basement were rapidly reduced, while when the light remained closed they increased. An even more dramatic rapid reduction in temperatures was achieved throughout the stairwell with the light removed, whereas when the light remained closed only that at the 3 feet level at the top of the stairs reduced significantly, while all others remained similar or increased somewhat.

The differences in smoke clearance were also very marked. With the light removed, visibility in the basement improved significantly within 1 minute of the fan starting, the stairwell was cleared within 4 minutes, and the firefighters could see right across the basement in about 5 minutes. When the light remained closed, the basement was not cleared of smoke, though some slight improvement in visibility at a very low level was noted. However, this trial proved that if a PPV fan is used to pressurise a basement (or any other room) without ensuring adequate means of egress for the gases and smoke, the whole of the building is likely to become smokelogged.

7.3 General conclusions

From the foregoing the underlying implication is that, from a fire brigade's standpoint, it is better to have a removable or breakable pavement light or stallboard installed in a basement than not to have one. Its existence gives firefighters an additional option which they would not otherwise have. It does not necessarily have to be used simply

because it is there: and if it is removed, and is then seen to be having an adverse effect upon the situation, it may be possible to replace it, or to blank it off.

In these trials, the removal of the light was seen to have a very slight beneficial effect with natural ventilation (although the benefit may have been more marked in different wind conditions).

However, when a PPV fan was deployed, the benefits accruing from the removal of the light were significant and almost immediate. The firefighters, in the basement throughout the trial, could detect some beneficial effect within 10 seconds of the fan being switched on. Visibility was improved within 1 minute, and they could feel the welcome effect of a cool airflow around them within 2 minutes.

The advantages of having a removable or breakable pavement light or stallboard in the event of a basement fire would appear to include:-

1. The ability to vent the fire without the need for smoke to have to permeate through the building above.

2. The (probable) reduction of temperatures in the basement and stairwell, aiding firefighting.

3. The reduction of smokelogging in the building as a whole.

4. The improvement in visibility in the basement, both by allowing smoke to escape, and by allowing some daylight (or artificial light) to enter into a, probably, smoke-blackened interior, aiding searching and firefighting.

5. It can allow firefighters to get an idea of what is happening in the basement, without the need to enter the building and descend to the basement.

6. It can allow direct firefighting from outside the building, making possible an early attack using water or high expansion foam.

In all cases, the use of a PPV fan can greatly accelerate venting.

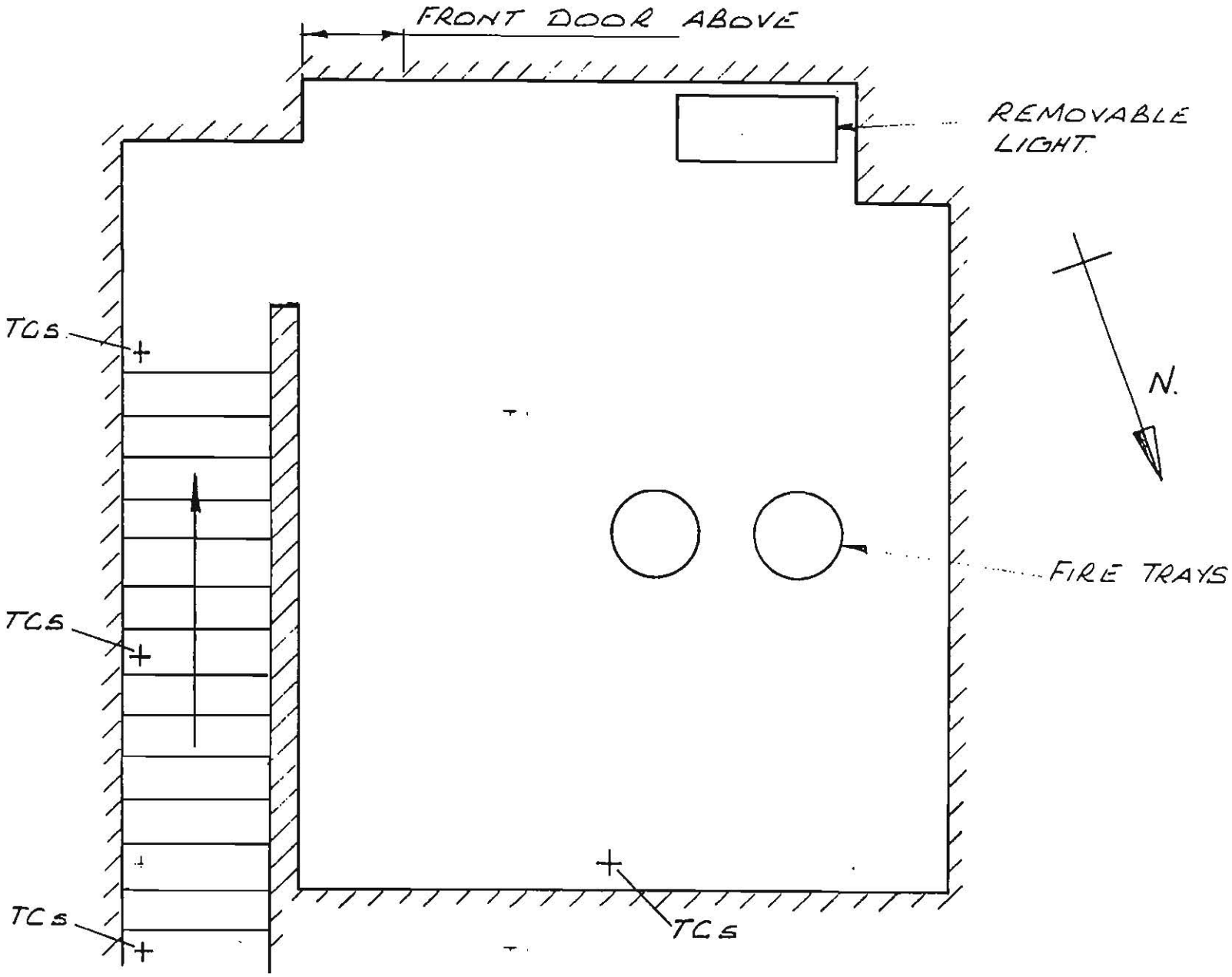

Figure 1. Plan view of basement.

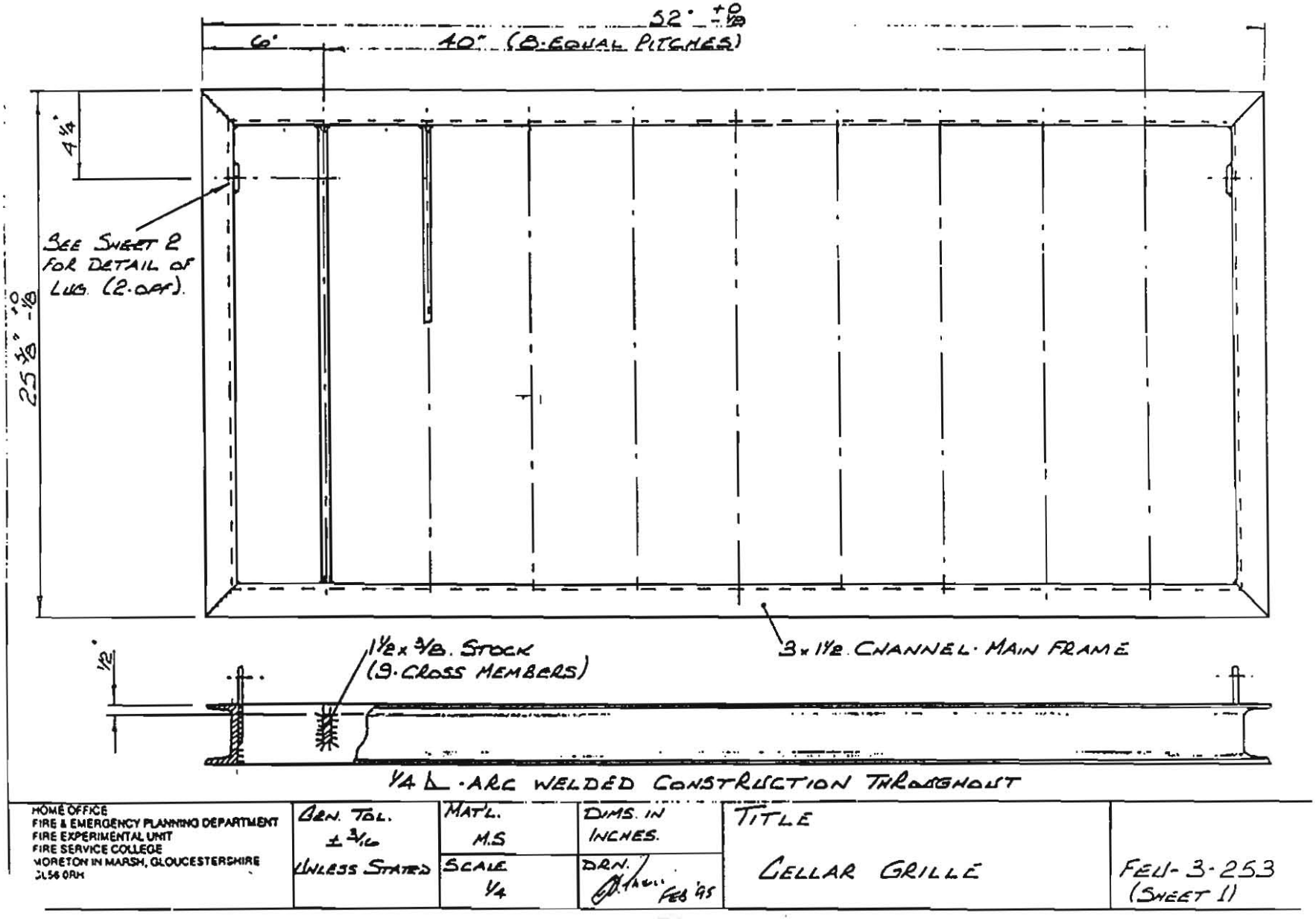

Figure 2. The removable pavement light - grille.

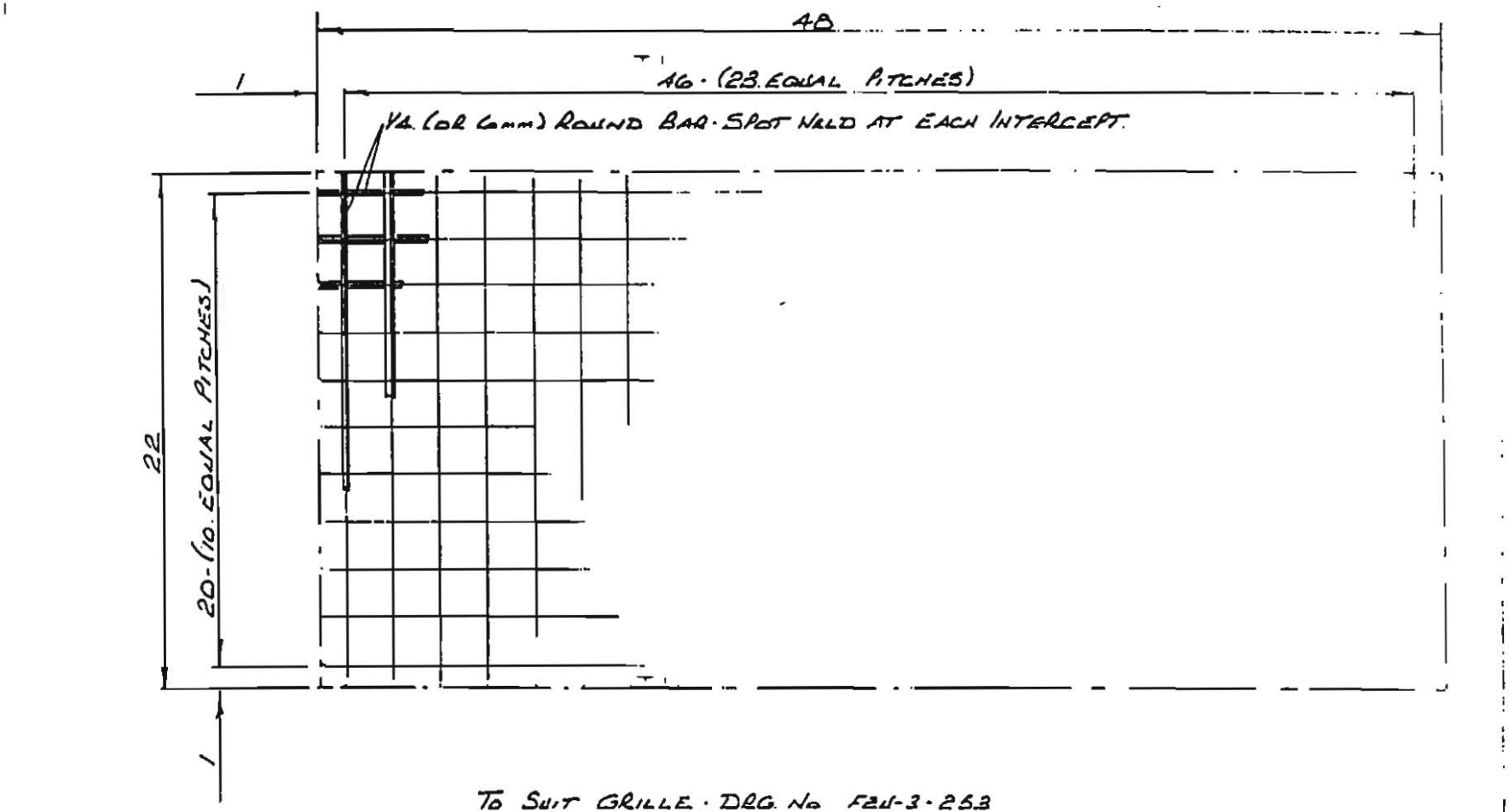

Figure 3. The removable pavement light - safety mesh.

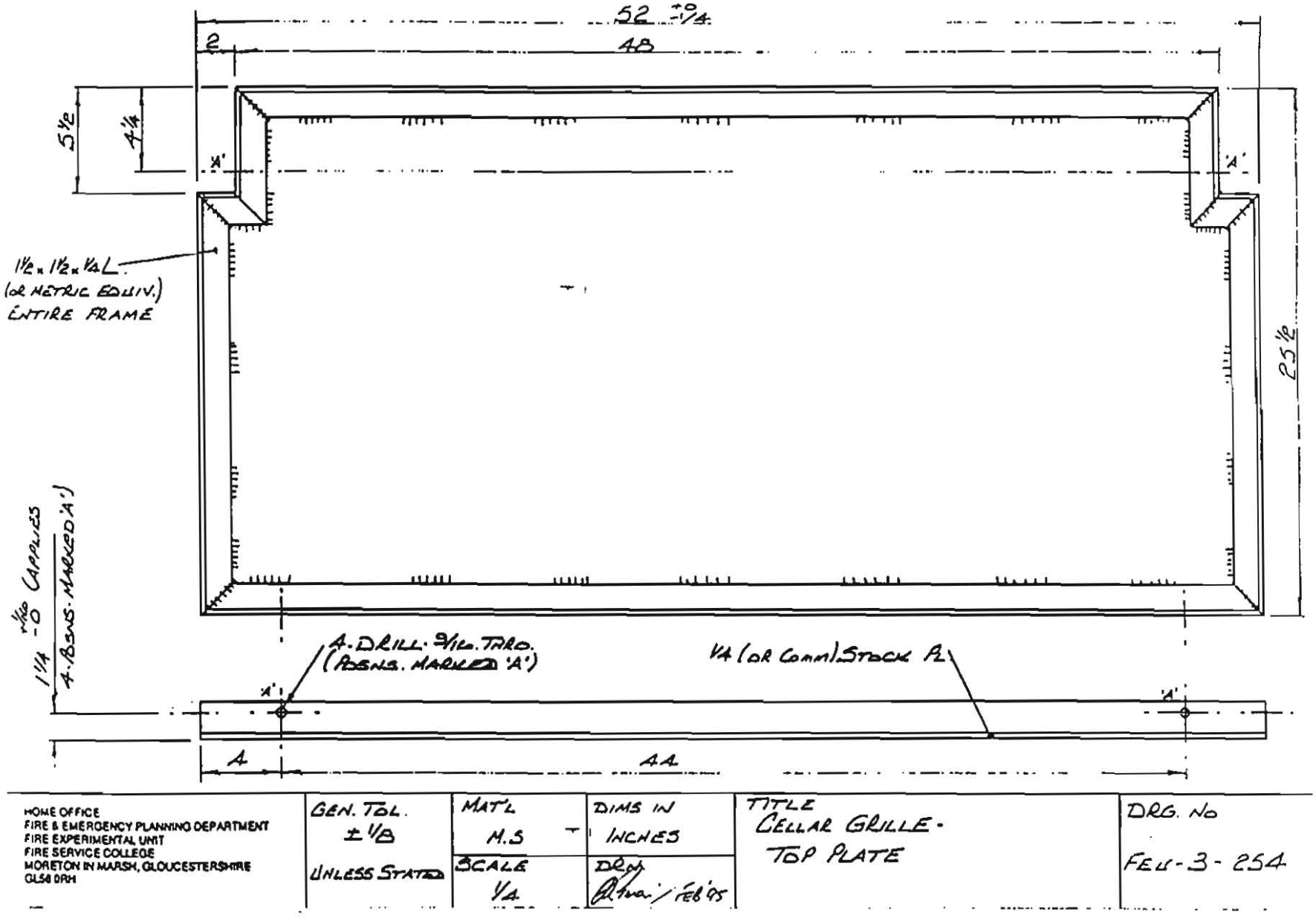

Figure 4. The removable pavement light - removable plate.

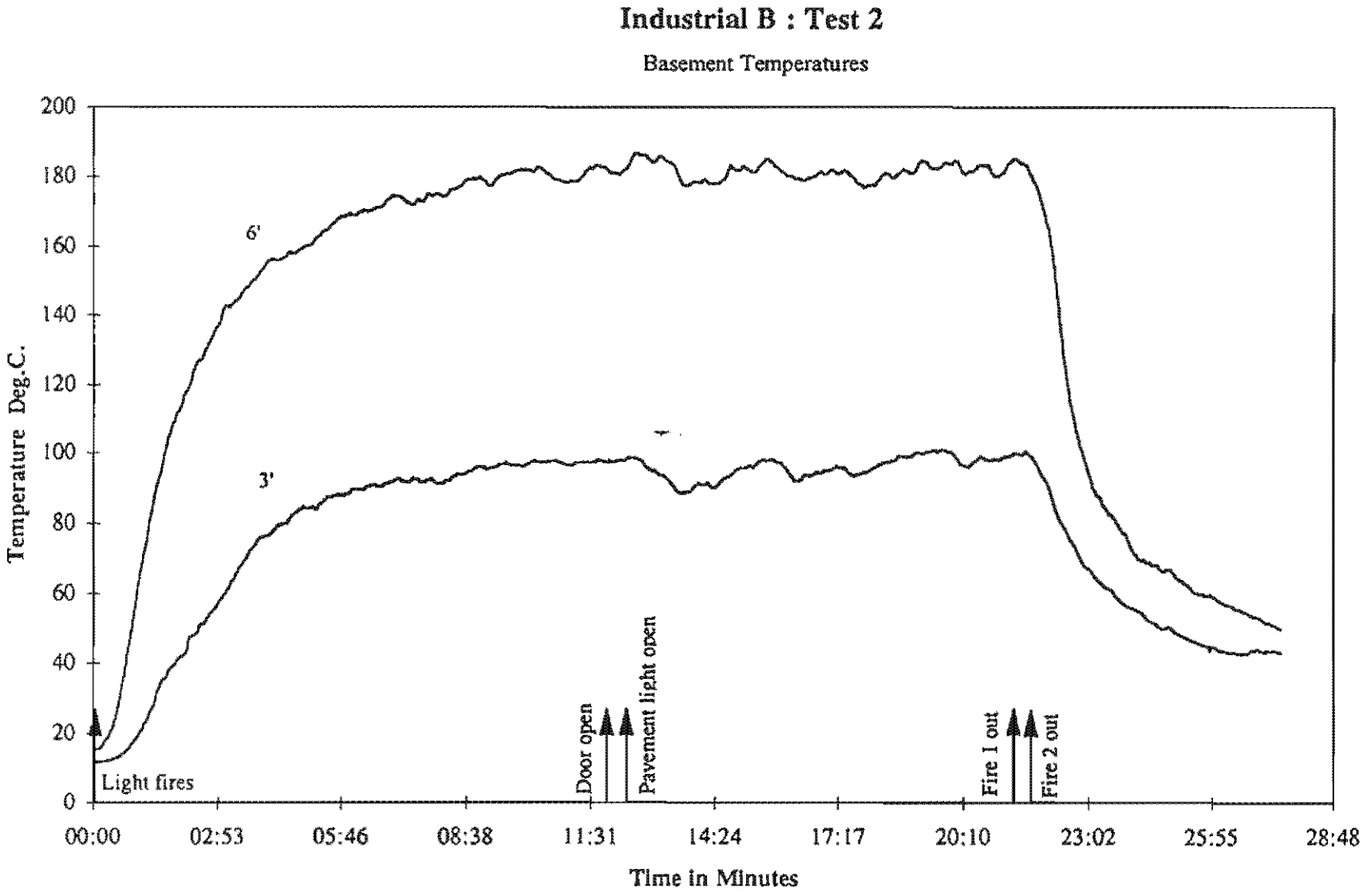

Figure 5. **Test 2 : Temperature Vs. Time, in basement, at 3 feet and 6 feet levels.**

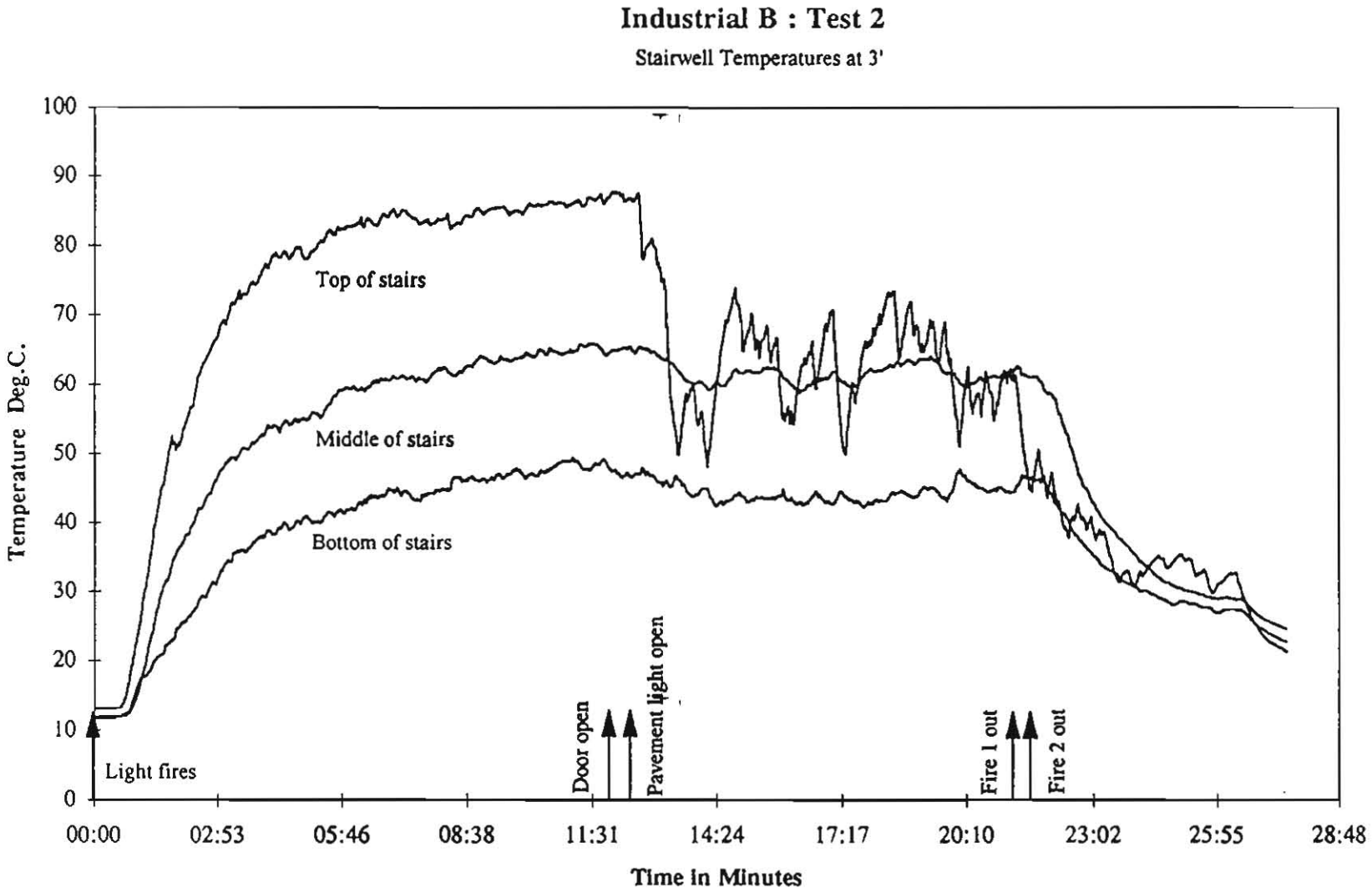

Figure 6. **Test 2 : Temperature Vs. Time, on stairs, at 3 feet above treads .**

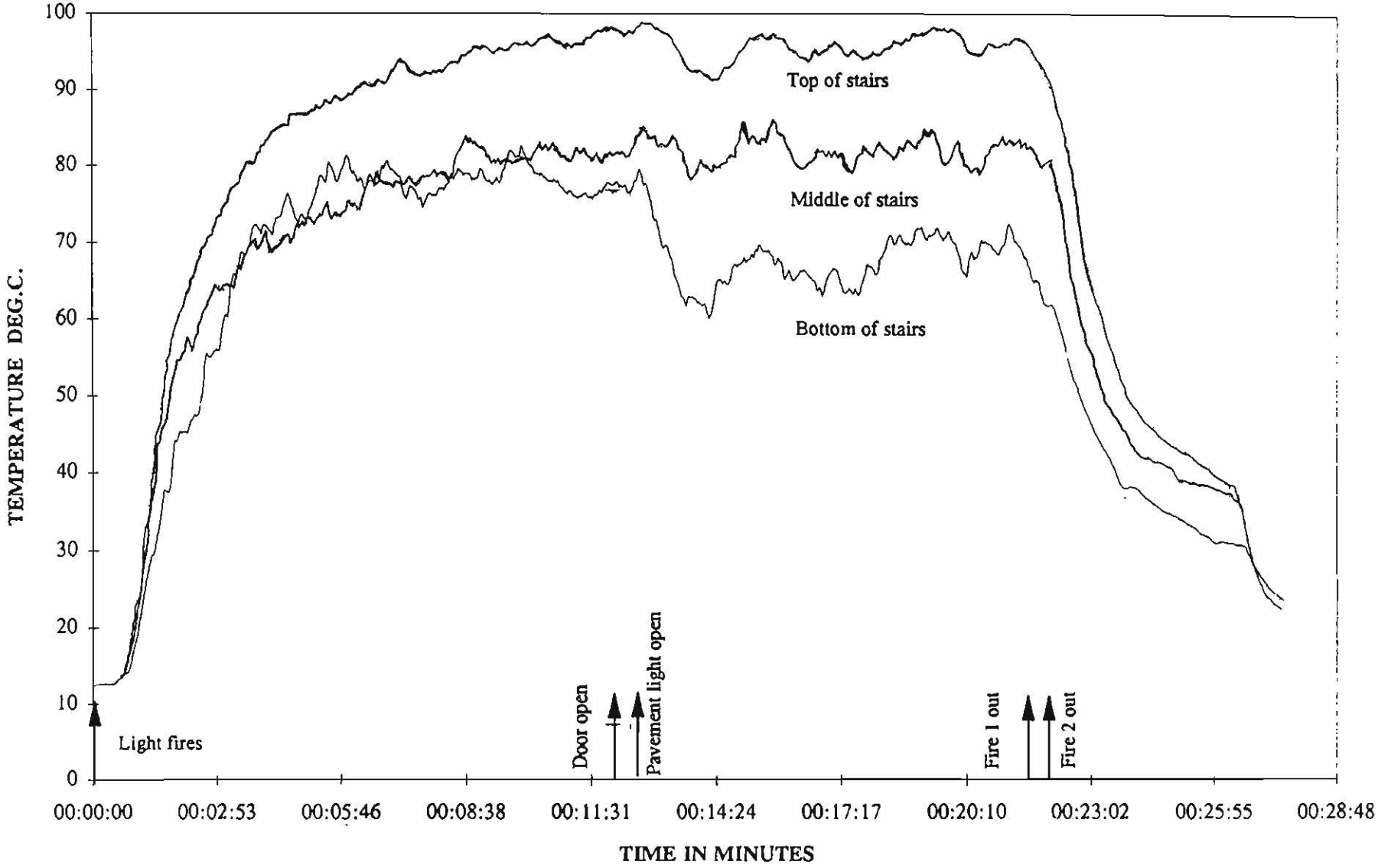

Figure 7. **Test 2 : Temperature Vs. Time on stairs, at 6 feet above treads.**

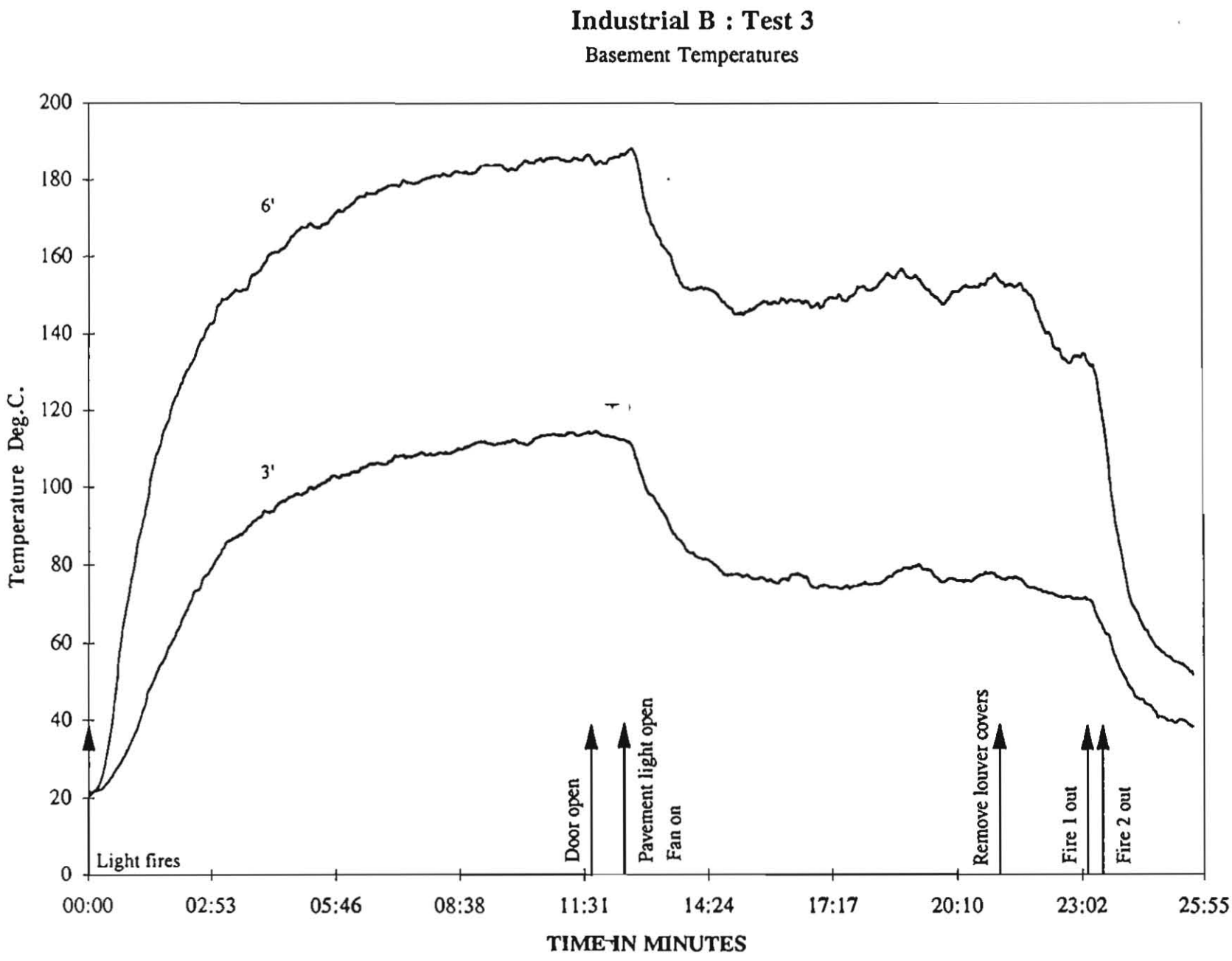

Figure 8.

Test 3 : Temperature Vs. Time, in basement, at 3 feet and 6 feet levels.

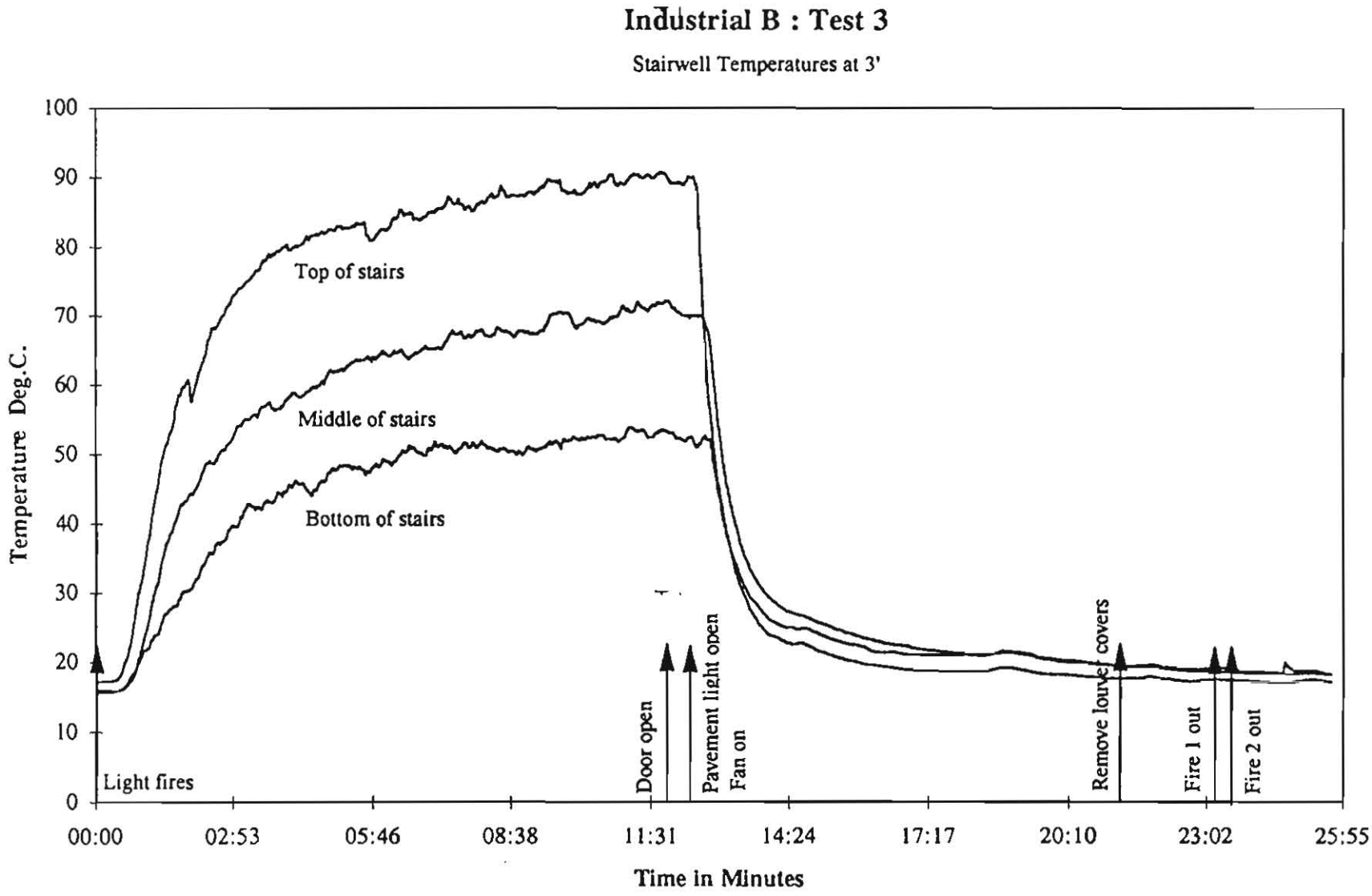

Figure 9. **Test 3 : Temperature Vs. Time on stairs, at 3 feet above treads.**

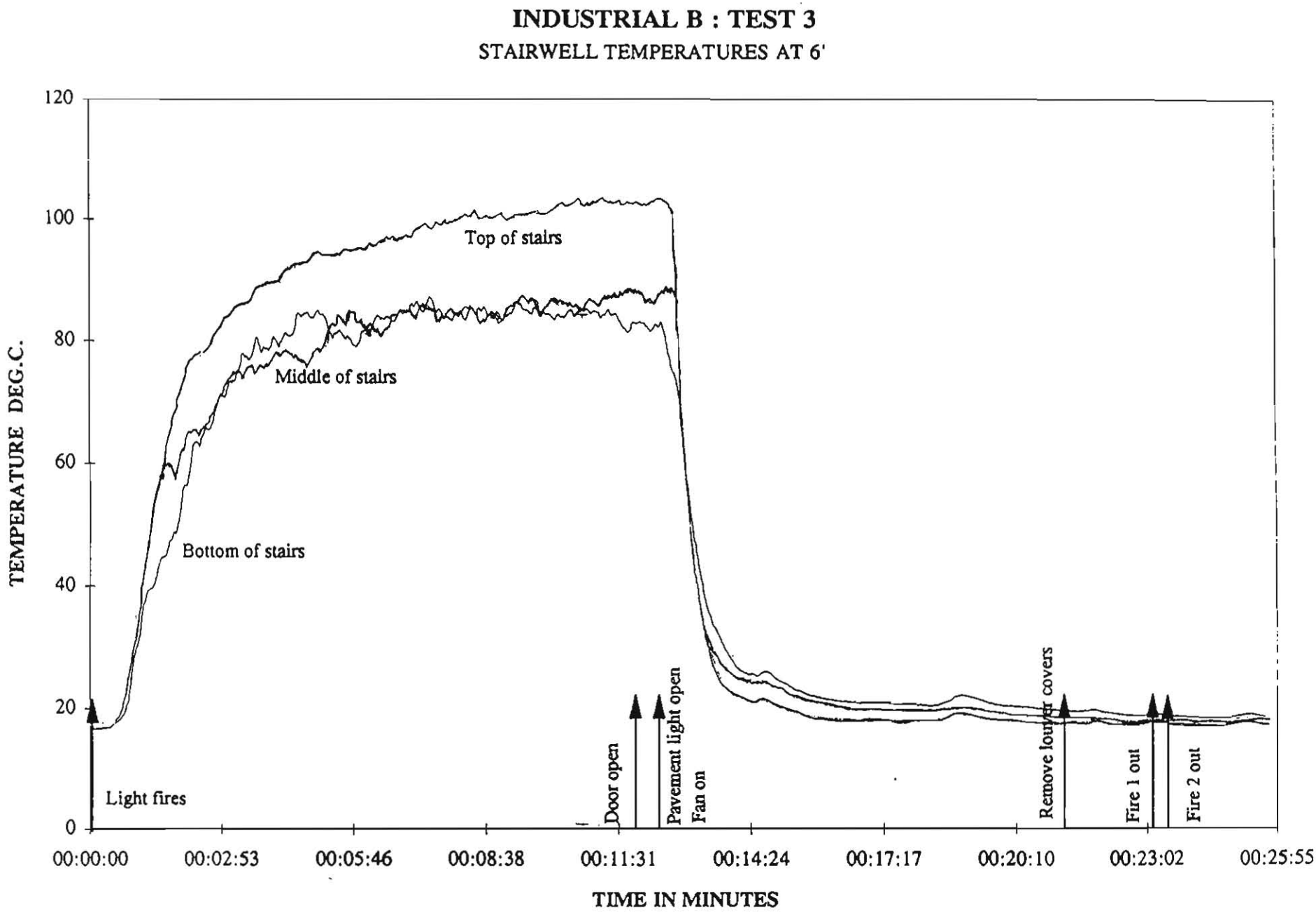

Figure 10. **Test 3 : Temperature Vs. Time, on stairs, at 6 feet above treads.**

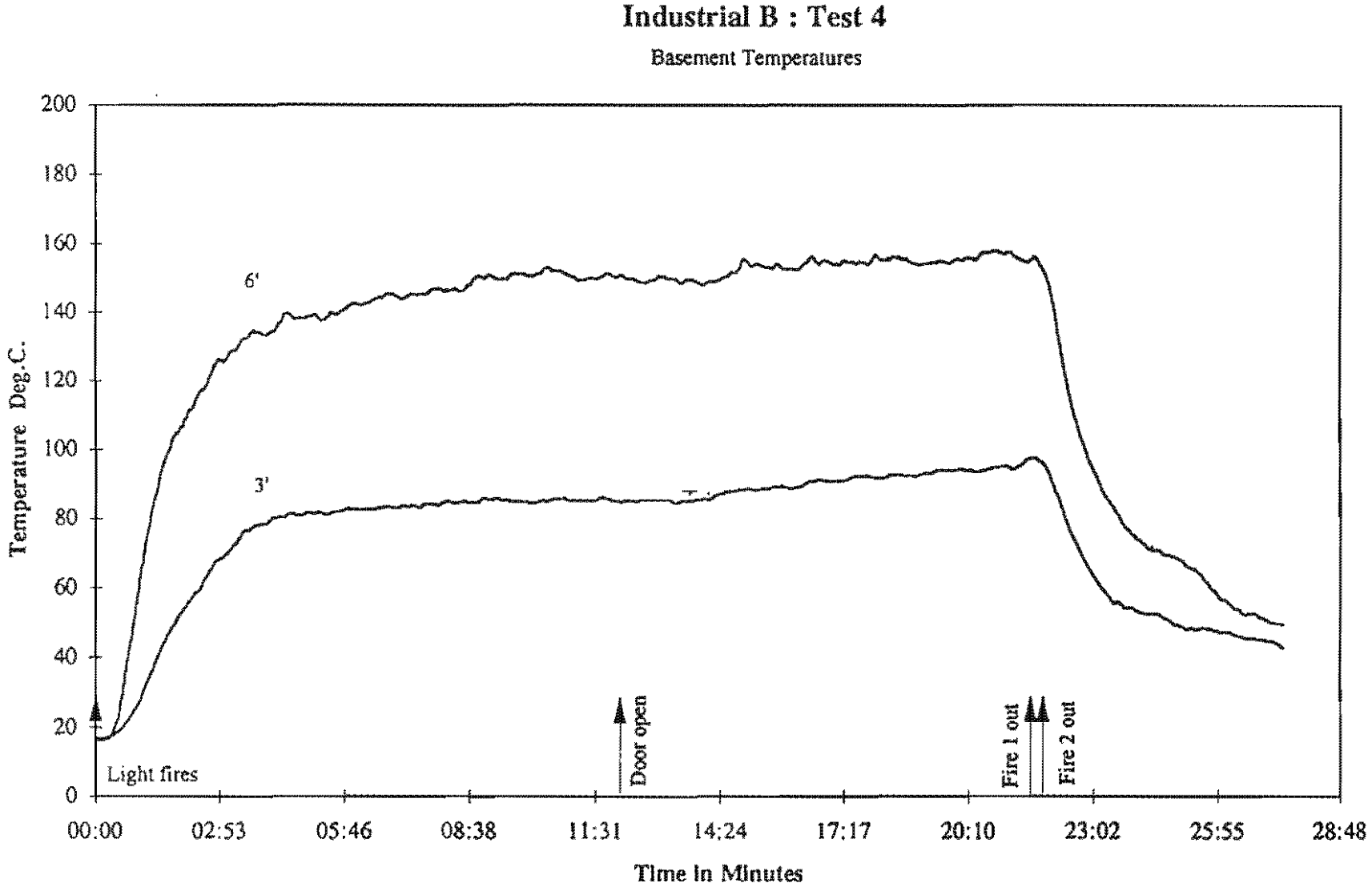

Figure 11. **Test 4 : Temperature Vs. Time, in basement, at 3 feet and 6 feet levels.**

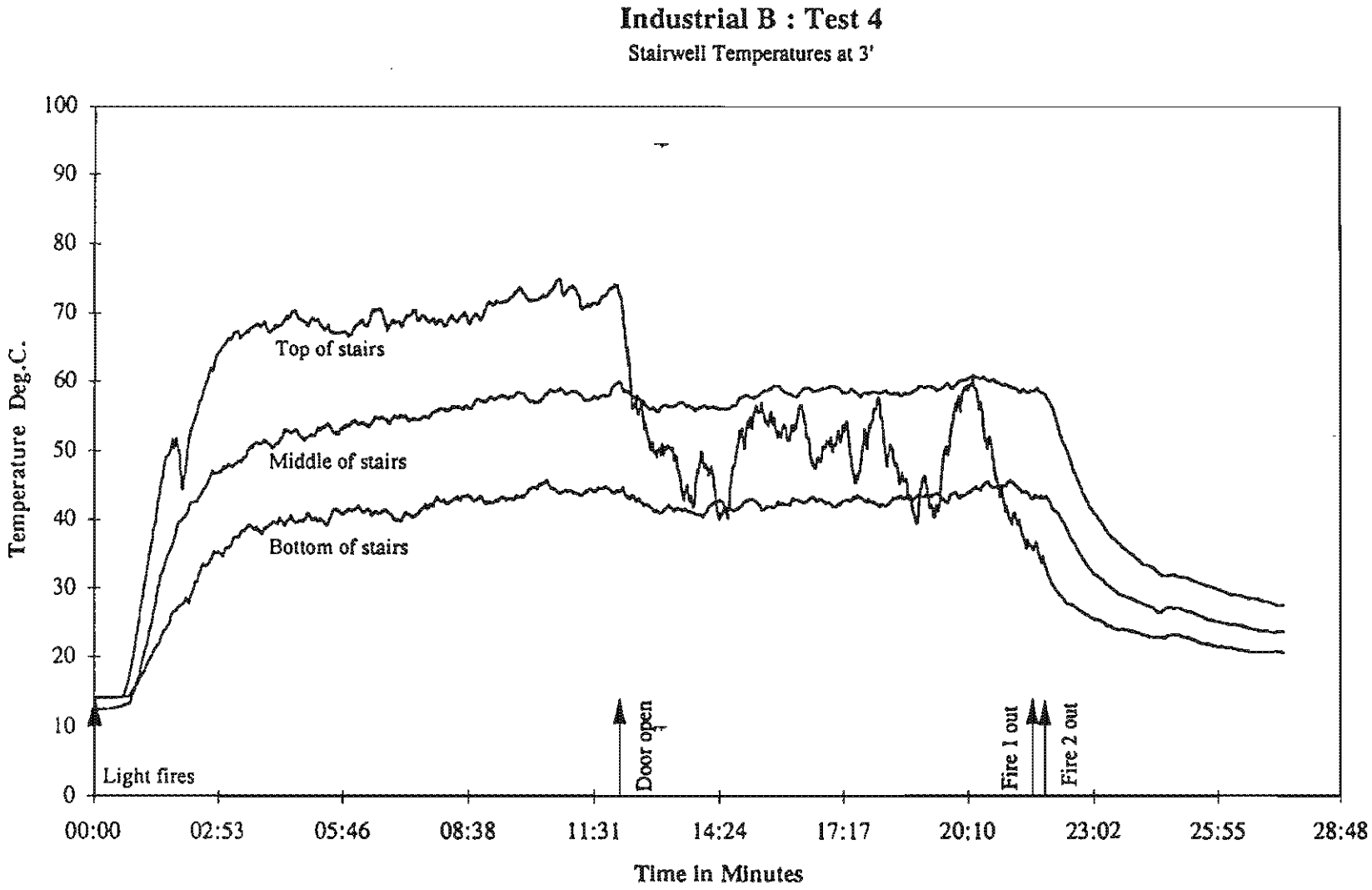

Figure 12. Test 4 : Temperature Vs. Time on stairs, at 3 feet above treads.

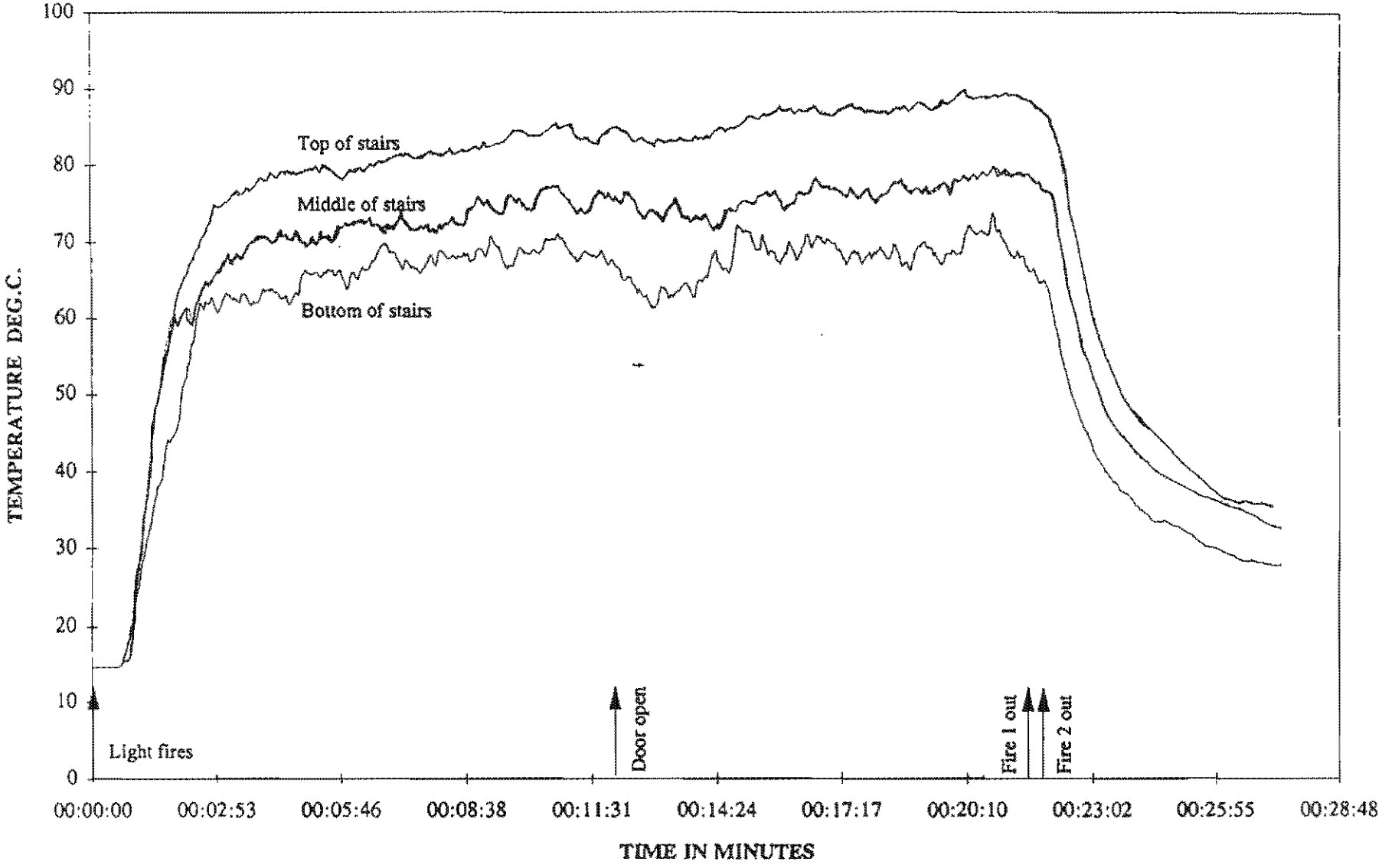

Figure 13. **Test 4 : Temperature Vs. Time,on stairs, at 6 feet above treads.**

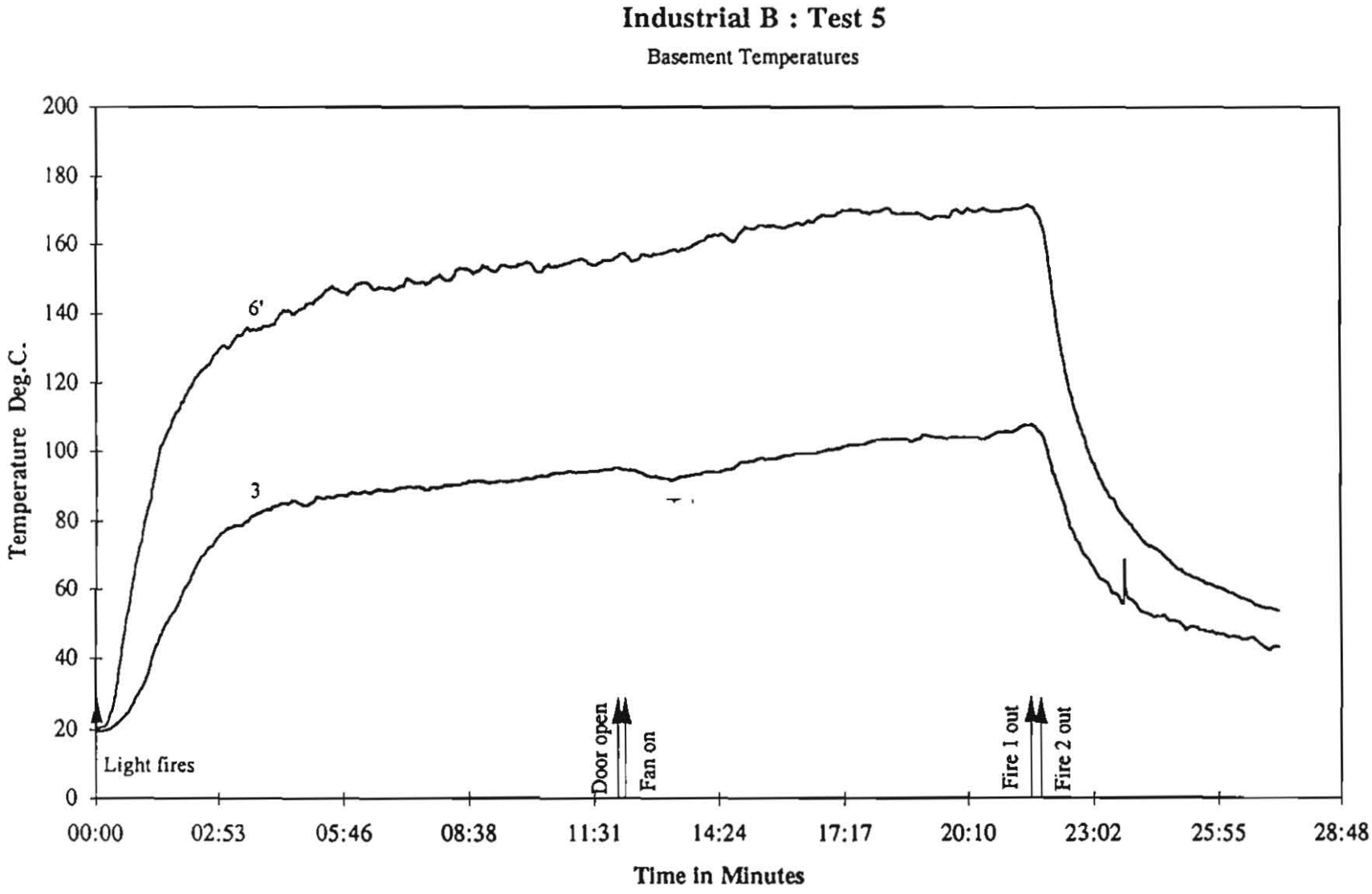

Figure 14.

Test 5 : Temperature Vs. Time, in basement, at 3 feet and 6 feet levels.

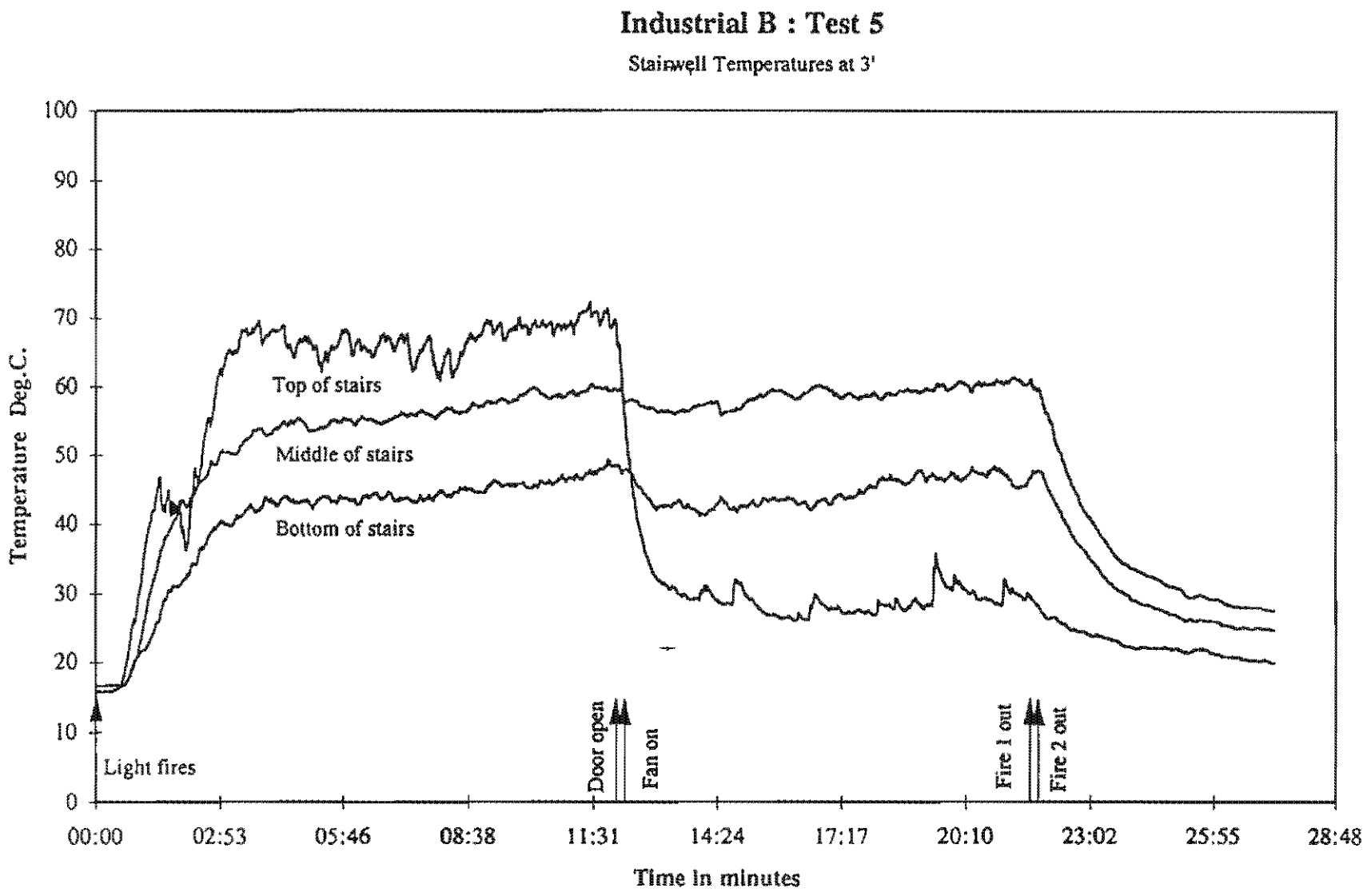

Figure 15. **Test 5 : Temperature Vs. Time, on stairs, at 3 feet above treads.**

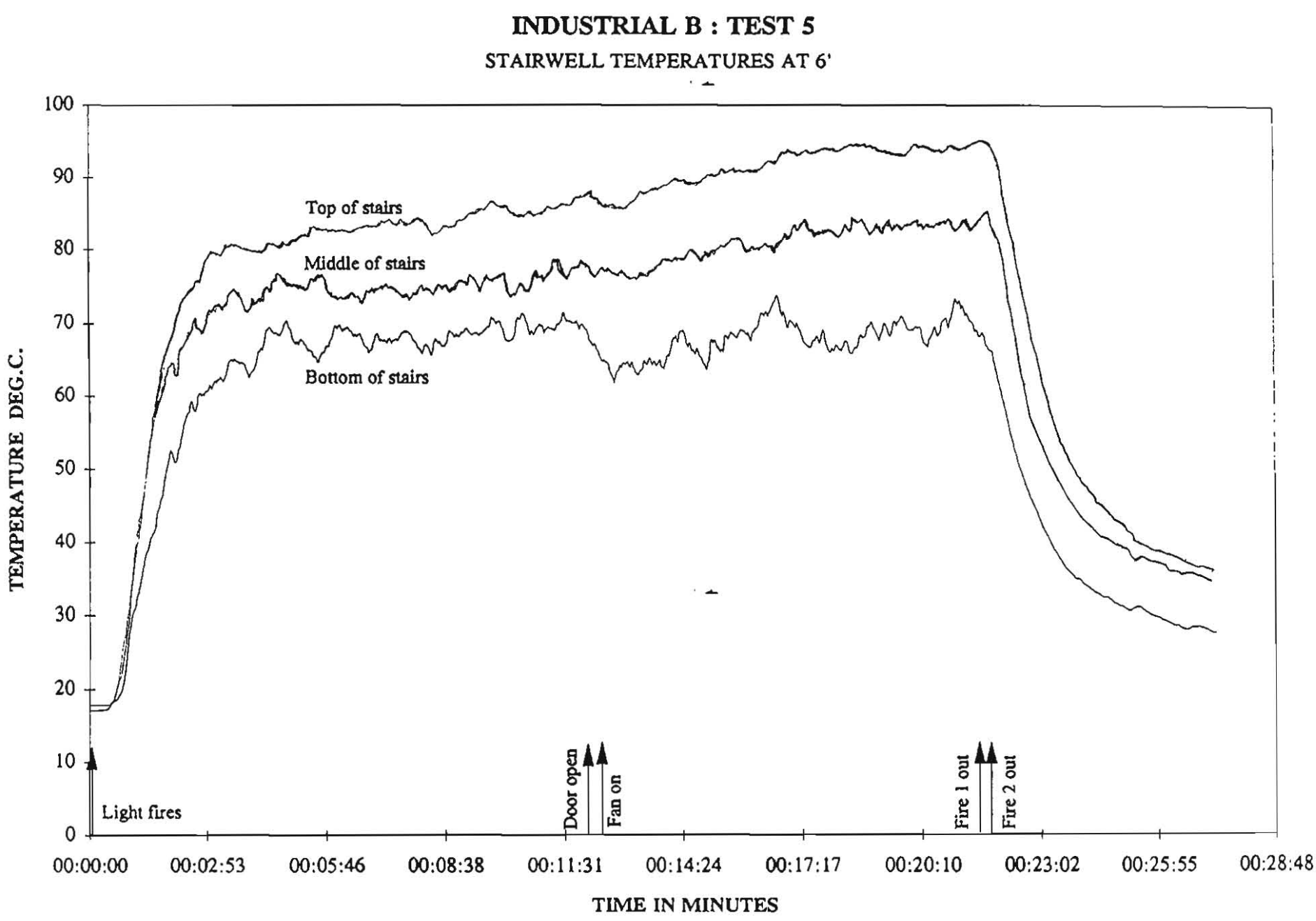

Figure 16. **Test 5 : Temperature Vs. Time,on stairs, at 6 feet above treads.**

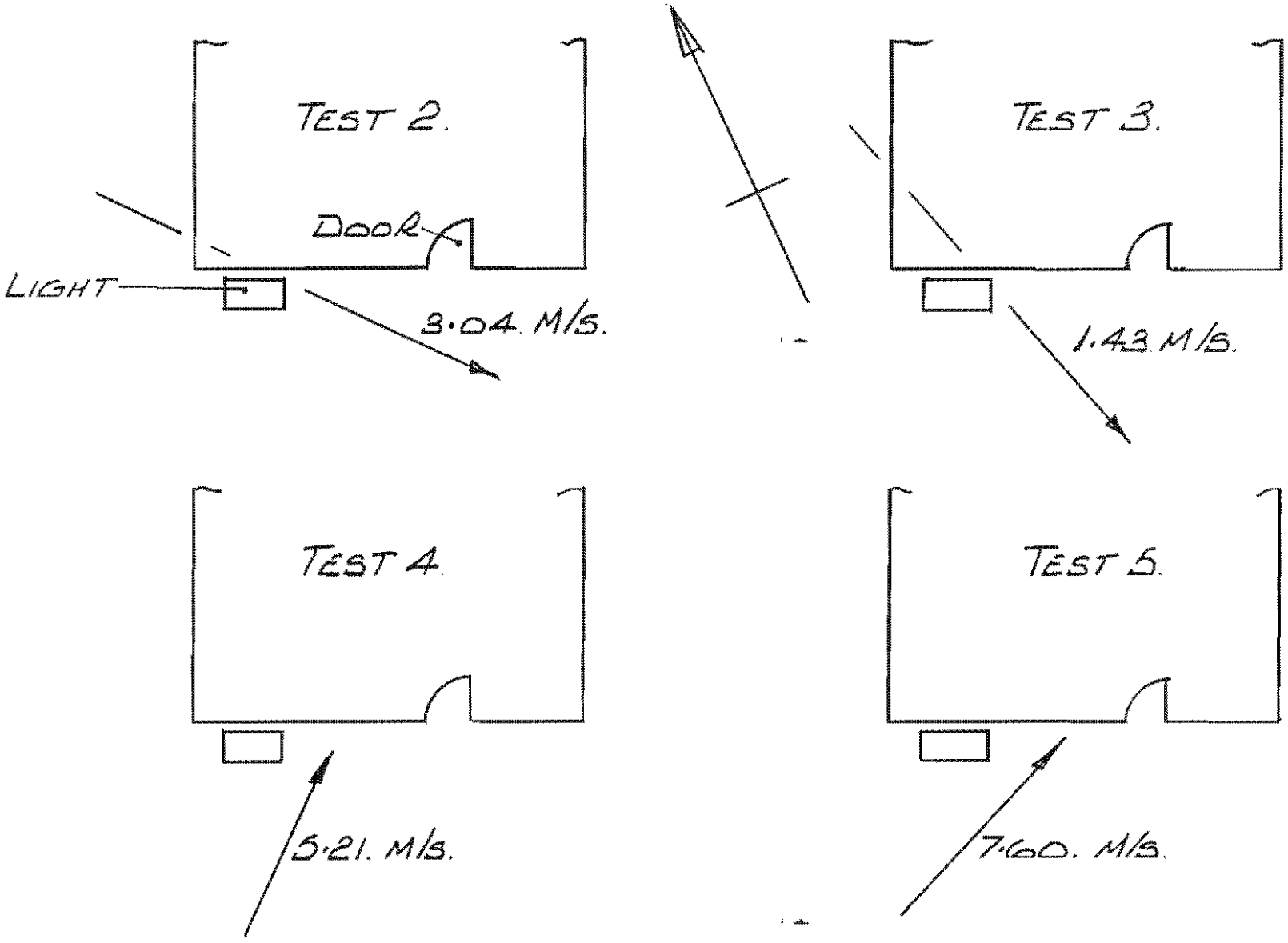

Figure 17. Average wind velocities during trials (between door opening and extinguishment).

APPENDIX 1

FIREFIGHTERS' COMMENTARIES FROM THE BASEMENT

Test 2: commentary from basement

t=o	"1st tray lit."
0-02	"2nd tray lit."
0-22	"Both going well."
1-40	"Temperature building up."
2-00	"Can just about see far corner of room now."
2-06	"Can now no longer see the crib about 15 feet away."
2-23	"Can just about make out the outline of the smoke meter."
2-35	"Smoke base at about head height (about waist high, standing) the shop must be smoke logged by now".
2-46	"Smoke level coming down quickly."
3-02	"Flame height approximately 3-4 feet"
3-28	"Can no longer see smoke meter."
3-50	"Peter and me are sitting with elbows virtually touching and all I can see of him is his visor."
4-13	"With my torch, I can make him out quite clearly - not visible without."
4-40	"Heat barrier now coming down to my waist level, if I was standing."
4-50	"Fire still burning fiercely."
5-05	"With glove removed, heat barrier is now 2-3 feet from the floor."
5-18	"It's hot, putting glove back on."
5.30	"Smoke barrier now much lower and much denser."
5-40	"Now getting to the stage were I can only just see a little of the flame from the second drum."
5-55	"I'm sitting about 4 feet from the nearest drum, I can barely see the flames from the second drum, but it is still burning quite fiercely."

6-10	"If anything, the flame height has increased from the first ignition, 4 feet at least."
6-30	"Can now only see the glow from Gary's torch - can't see him at all; elbows still touching."
7-35	"Reasonable difference in the heat output - I would think at the top of the stairs the heat barrier would be quite high now."
8-26	"Smoke now all the way down to the floor."
8-36	"Fire trays are not visible."
8-45	"Can't see anything except a slight glow from Gary's torch."
8-55	"Can see it now - he's turned it round to shine it at me."
9-50	"Visibility virtually nil - just a dull glow from the fires."
11-00	"No change down here - it doesn't seem to be getting any hotter, and the smoke doesn't seem to be getting any more dense."
11-10	"But it is very dense. If I shine my torch, I can't make out my hand at arm's length now."
[12-00	SHOP DOOR OPENED]
[12-30	PAVEMENT LIGHT REMOVED]
12-48	"The fire is increasing or the smoke is clearing - one or the other."
13-00	"Can now see flames above the lips of the trays."
13-16	"It's beginning to clear - I can just make out Gary sitting next to me now."
13-26	"Smoke definitely clearing quite rapidly now - you can see the glow of the second [furthest] fire."
13-38	"Both fires visible now."
14-10	"Gary is standing immediately adjacent to me - I can just make him out."
14-15	"It is really quite warm standing up - your ears really do detect the difference don't they?"
	"Yes!"

14-30	"There is a big difference now between waist height and head height."
14-50	"Still can't see more than about 3 feet now!"
15-15	"Can make out Gary now - just about."
15-52	"I can't see any light from the pavement light, as yet."
18-00	"Smoke level is definitely rising - becoming clearer - still can see the smoke meter though, but that could be because it's now black with soot deposits."
	[In fact, it was: matt black.]
19-00	"Quite warm still, but I think it's just radiant heat from the fire because my back's not hot, just my front."
19-20	[Firefighters preparing to extinguish fires.]
19-36	"I think the smoke production has reached a sort of equilibrium with the ventilation. Don't seem to be getting any better vision at all, but it's not getting any worse."
21-40 to 22-04	[Extinguishing fires]
22-10	"Can now see the cellar light - we're standing [near the fire trays] and it's quite warm standing - we'll sit down and let a little bit of the heat dissipate."
22-40	"we're back on our seats."
22-55	"Smoke is certainly clearing - if I hold my hand out, I can see it by the light of my torch."
23-09	"I'm about 4 feet from the smoke rig and I still can't see it, even with the light from my torch."
23-46	"It's clearing now and getting appreciably cooler."
24-00	"Taken my glove off, putting my hand up, yes the heat's gone."
24-41	"We're cooling down the firetrays and their lids now with the hosereel."
24-50	"Just a bit of steam, now."
25-20	"We're about to unplug [communications] and make our way out."

Test 3: Commentary from basement

t=12-00	[Shop door opened]
12-26	"The glow from the flames is just beginning to become visible to me."
12-30	[Pavement light removed.]
12-40	[PPV fan started.]
12-48	"Making a big difference now, John - I can see flames quite clearly."
13-03	"The flames are quite high now and are becoming clearer."
13-12	"Becoming much clearer, now."
13-25	"Can actually see the flames, now, they are increasing in intensity."
13-33	"..and the breeze seems to be having an effect on them - they appear to be going in a sort of a spiral...probably the air current."
13-45	"Burning quite well now, it's certainly make a difference to the supply of oxygen."
13-54	"The smoke is also clearing ...becoming quite clear, I can see Gary fairly well."
14-02	"I would say visibility is a good 4 feet at waist height now."
14-16	"Gary is now going to the base of the stairs to see if he can feel the air flow."
14-31	"He's been to the base of the stairs, I could see him all the time."
14-35	"You can certainly feel the flow of the air."
14-54	"I'll have a feel for the heat barrier now."
15-00	"The heat barrier in the basement begins at about head height now...before it was down at knee height."
15-45	"Heat barrier is approximately head height."
16-00	"Going to the stairs to feel the draught coming down."
16-10	"I've taken my glove off and it's cold air coming down the stairs ...I'm at the bottom of the stairs and I've now got a current of cold air sweeping around me..."

16-22 "...and it's very cold and very comfortable."

16-30 "I can also see to the top of the stairs quit easily."

16-50 "We are standing...the fire is burning fiercely, of course, but visibility is good."

17-00 "There would be no doubt that putting the PPV fan on in a situation like this would make access particularly easy."

17-42 "There is still a smoke layer at about head height."

18-05 "At waist height you can see right across the room."

18-31 "Making a big difference all round, the fires are burning well, of course...but it's certainly done a good job."

18-53 "The top of the stairs is still easily visible."

21-19 [Commence removing vertical louvres - NOT ORIGINALLY INTENDED, second removed at 21-27, third removed at 21-58.]

22-12 "Very good visibility at waist height."

22-20 [Observation from outside, above:- "There is some smoke from the recently opened barriers, but very little...it's mostly belching out of the light, still."]

23-13 "OK, we'll extinguish."

23-26 "That's one."

23-42 "That's two covered."

23-52 "We'll put the hosereel on them now...cool them down."

24-26 "There's no smoke in here now, it's clear."

Test 4: Commentary from basement

t=12-00	[Shop door opened.]
12-29	"No change yet...a faint glow 1or 2 feet above the rim of the tray...2-3 feet above that is a pulsing flame."
12-46	"Starting to become more distinct now...slowly becoming more solid flame as opposed to a pulsating flame."
13-30	"The fire is slowly and slightly increasing in its burning rate - there is a lessening of the pulsing effect and increasing the solid flame."
13-52	"I can't detect any difference in temperature, but the smoke does seem to be clearing, or shall we say the bottom of the smoke layer is rising, or thinning out, slowly."
14-24	"The outline of the furthest tray from me is now becoming quite distinct."
14-39	"That's the flames I can see, I can see the silhouette of the tray against the flames, and not the tray itself. That's all...a distance of 6-7 feet"
15-10	"There is definite change, albeit it's been a gradual one, the fires are now burning much more as they were during the first half of the burn. They are steadier, more consistent flames - still a little bit 'flickery' but the pulsing effect has almost disappeared now."
16-00	"It appears that the base of the flames - at the tray rim is now pulsing as a whole, as though cool air from the ground floor is arriving in bursts."
16-30	[Comment from outside building;- "We don't see any sign of the smoke pulsing out of doorway. What sort of frequency are the pulses?]
16-42	"I'll try and call them out: pulse - pulse - pulse - pulse - pulse - pulse [indicating about 1 second intervals]
17-19	"Still don't detect any great difference in the temperature on the heat banding, albeit that at the very lowest level things do seem to be getting a little bit cooler."
17-48	"Pete's just reported that with his glove off, he doesn't really get any sensation of heat until up to about knee height. You start to feel the heat then. From about waist height upwards, it starts to become uncomfortable."

18-40 "The fire is still exhibiting the same characteristics...slow pulsing at the rim of the tray, flame flickering throughout its height....if anything, the smoke now seems to be thickening towards the second [furthest] tray...it may be a temporary swirling effect."

19-50 "We seem to have reached a state of equilibrium, since the door was opened...it's burning fairly steadily. Since having the door open, it's altered the bottom of the heat barrier slightly, lessened the smoke slightly and given a few extra feet of visibility...it's still quite uncomfortable at waist to chest height as far as temperature goes."

21-38 "Extinguish first tray now."

21-56 "Extinguish second tray now."

22-19 "Relatively comfortable sitting down, standing up is uncomfortable."

23-00 "We are going to disconnect communications, and come up to feel the heat barrier."

[The firefighters emerged from the shop door at t=25-00 and went back in at t=37-04.]

38-30 "Just a quick impression on the way in, much clearer of smoke on the ground floor, visibility much improved, a lot cooler."

38-55 "The staircase was appreciably cooler, you could actually see your feet."

39-10 "Peter and I are in the basement and it is markedly cooler. The visibility is improved but standing in my normal position, or sitting, I can't yet see any part of the smoke meter without a torch - I'm about 4 feet from the nearest part. With the torch on, it's very distinct."

[It was dark in the basement.]

40-32 "Peter and I are standing at opposite sides of the room without the torch. We can't see each other. With the torch I can see him very clearly...very little smoke at head height."

41-10 "Looking up towards the ceiling, there is still smoke at that level."

[Trial completed at t=42-40.]

Test 5: Commentary from basement

11-16	"Conditions comparable to the last three trials...visibility even at floor level very, very limited. Can see the floor if I shine my torch directly onto it from about six inches away, but no higher."
12-00	[Shop door opened.]
12-15	[PPV fan started.]
12-25	"Height of the glow from the flames has increased."
12-40	"The second [furthest] fire is becoming much more visible to me...I believe that's as much to do with the clearing of the smoke as with any increase in the fire."
12-55	"The fires have both gone back to their state before pulsing, their flame height is consistent with what it was before. The furthest fire from me seems to be burning with a greater intensity and with more spiralling than the one nearer to the cellar steps...that's because the airflow is moving down into the corner beneath the pavement lights and coming back, creating a vortex around it."
13-36	"The fire nearer the cellar steps is certainly displaying a different characteristic to that further away, it is still very much a circular, solid cone...the pulsing has almost disappeared...relatively slow burning rate."
13-55	"The one furthest from us has got a definite spiralling effect and increased intensity...the flame height of the furthest fire is about a foot higher than the nearest one."
14-22	"The temperature seems to be increasing slightly."
14-52	Peter reports that an ungloved hand can be held at, seated, head height for 10-15 seconds.
15-15	"The sensation I get is of increased heat...it's radiated heat, as the fires themselves have increased. I'm sitting a little bit closer than Pete, so I'm feeling more radiation than he is."
15-45	The actual smoke layer...the smoke is still down to the floor but the thick, dense, smoke...the bottom layer of that is now raised up to our seated head height, whereas previously it was at our seated waist height, so this layer has raised by 3 feet easily."
16-50	"The radiant heat from the fires has definitely increased. The bottom of the smoke layer has raised, conditions below the thick smoke layer have eased slightly."

17-38 "With the increased burning rate, we think the base of the dense black layer is dropping again. After the initial raising it seems to be alternately rising and falling slightly, at around the height of our seated head height, moving about 1 feet up and down."

18-07 "Radiant heat from the fire has increased significantly."

18-45 Pete has just reported that, with his ungloved hand, the heat at knee level is comfortable, at shoulder height he starts to feel the warmth, at head height it's just about OK. Above head height, it goes into a sharply increasing temperature.

19-17 "Peter has confirmed that the smoke level - dense smoke level - is dropping nearer to the ground."

19-33 "...It has dropped about another foot since we last spoke. There is still smoke below what I call the bottom of the thick smoke layer, but it is a lot lighter."

19-46 "The smoke barrier is still lowering back towards the ground."

19-52 "The fires are burning with a good ferocity, the fire furthest from the staircase seems to be burning at a far greater rate than the one closer to it. The closer one is burning quite steadily and consistently, the one furthest from us is burning fiercely and with a distinct spiralling effect."

21-06 "Standing up, preparing to extinguish...a lot more uncomfortable standing up." [Due to the higher temperature at the higher level.]

21-35 "Tray one is now extinguished."

21-50 "Tray two is now extinguished."

22-40 "About to apply a small amount of water now to the tray lids."

22-48 "Water is going on now...just to cool the rim."

23-23 "We've finished applying water now."

23-50 "Just going to disconnect communication."

The firefighters emerged from the building at t=25-20.

[During this trial, the whole of the ground floor of the Industrial 'B' building had become smokelogged.]