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ABSTRACT

This report describes fire trials carried out in Industrial B building at the Fire Service College in November 1995. The building was instrumented to obtain experimental data which included gas temperatures, heat flux, smoke density and gas velocities. A total of 8 tests were carried out in which a heptane fire was allowed to burn for 5 minutes before ventilation commenced. Ventilation conditions were varied by using different combinations of two roof vents and two doors in the building. One test used a PPV fan mounted in a doorway.

The work was carried out in support of computer modelling studies and the experimental data will be compared with that predicted from the model. The results of trials are given in this report but the predictions of the computer model and comparisons with the experimental results will be the subject of a later report

The comparison of the effectiveness of the various ventilation options used are discussed briefly.

MANAGEMENT SUMMARY

Introduction

A programme of work is being undertaken by the Home Office to undertake a theoretical study of the effects of tactical ventilation. This theoretical study will make use of computer modelling to develop an understanding of the processes involved, with the intention of developing practical guidance for the fire service in terms that would be of use on the fireground. It is necessary, at an early stage in the work, to validate the computer models by means of experimental fires. The computer modelling is being carried out by AEA Technology under contract to the Home Office.

This report describes the validation trials carried out in the Industrial B Building at the Fire Service College during the week commencing 20 November 1995. A total of 8 tests were undertaken.

The Trials

The trials were carried out the Industrial B Building at the Fire Service College. This building has a relatively large open room (17m x 9m) on the first floor with two external doors and a pitched roof. There are four roof vents in the building although only two vents were used in the tests. This arrangement gave the opportunity to explore the effects of various combinations of roof vents and doors.

The fuel used was 95% n-heptane which was poured onto a water base in three rectangular trays to give a fire of 3.9m ^{2} (only 1.3 m^2 in test 1). This was considered to be as large a fire as possible whilst paying due regard to safety and to minimising the risk of damage to the building.

The fire was ignited remotely and allowed to burn for 5 minutes before ventilation. The fuel volume was estimated to allow a 10 minute burn period in the open air.

One test was carried out with a PPV fan fitted into one of the doors. Although it was not physically possible to deploy the fan in the appropriate position for accepted PPV methods, a test with a fan was included to give experience of its use in a large building.

Instrumentation

The building was instrumented to measure the following:

Gas Temperatures

Gas temperatures were measured by using vertical temperature trees of 4 and 5 metres in height at four positions in the building.

Gas Velocity

The velocity of the gases through one open vent and one door were measured at a number of points using bi-directional probes in conjunction with sensitive micromanometers. The temperatures at each of the probes were also measured using thermocouples as near to the probe as possible but without affecting the performance. Some probes were dedicated to micromanometers and others were selected using scanning boxes.

Smoke Density

Smoke density was measured at one position but two heights using equipment which consisted of a light projector and photocell.

Surface Temperatures

Measurements of the surface temperature of the walls were required to assist with assessing the energy transfer into the walls. These measurements were obtained by fitting a thermocouple into a surface tile and insulating the tile so that the only path for heat transfer was from the front surface. Four tiles were used, positioned on two of the thermocouple trees, the floor and near to an internal wall by the fire.

Heat Flux

Heat flux was measured with four radiometers:

- one facing the roof
- one facing the floor
- two facing the fire

Wind Speed and Direction

Throughout the tests the wind speed and direction were recorded at heights of 1 and 7 metres.

Fuel depth

The depth of the fuel in one tray was measured using an ultrasonic depth gauge. The gauge measured the depth in a small tray connected to the fuel tray and acting as a hydraulic balance. This technique did not prove successful.

Static Pressure

Static pressure was measured inside the building and at a number of points outside using a sensitive micromanometer.

Fire Spread

In realistic fires, ventilation can result in fire spread. Fire spread was not possible because the fuel was contained in trays and the building was lined with refractory tiles. However fire spread is a major factor in real fires and some indication of fire spread was required for future modelling work.

To explore fire spread, pieces of wood were mounted on wooden poles and examined for signs of charring. In the later tests thermocouples were mounted above some of the wooden pieces and the temperature logged. The idea was that flaming would be accompanied by a rapid rise in the local temperature and this would be indicated by the thermocouple readings.

Video Record

All the tests were recorded using colour video equipment from cameras in the following positions:

- high level external camera (at 20 metres) showing the whole building
- wide angle camera inside the fire room
- cameras viewing the external doors.

Datalogger

All the data was recorded on a datalogger for processing after the trials .

Results

The results of the trials are given in the report but the predictions of the computer model and comparisons with the experimental results will be the subject of a later report.

The results are presented as graphs although all the data is available on computer spreadsheet files. A graph showing typical results from four temperature trees is shown in Figure MS1.

Discussion

The instrumentation performed satisfactorily although possible improvements have been identified for future work and are discussed. The measurement of fuel regression rate proved unreliable.

The various tactical venting options used in the tests were compared by producing a figure of merit for the temperature changes after ventilation. There were no surprises in the results and the ranking order would no doubt have been predicted by experienced firefighters.

The most effective ventilation was with one door and two roof vents open. The least effective was the cross-ventilation case with two doors open and no roof vents open.

When one roof vent and one door were used, then an upwind door and a downwind vent was the best. A door and vent at opposite ends of the building were more effective than a door and vent at the same end.

The fire became ventilation limited after the first minute until ventilation took place at five minutes. The fire was still ventilation limited after venting unless an upwind door and at least one roof vent was open.

The PPV fan mounted into a doorway produced very similar results to natural ventilation. The comparison was made with very similar wind conditions where the wind was blowing directly into the door.

Conclusions

The tests carried out provided valid data for comparison with predictions from the computer model.

The tests demonstrated the advantages of venting a building at high level.

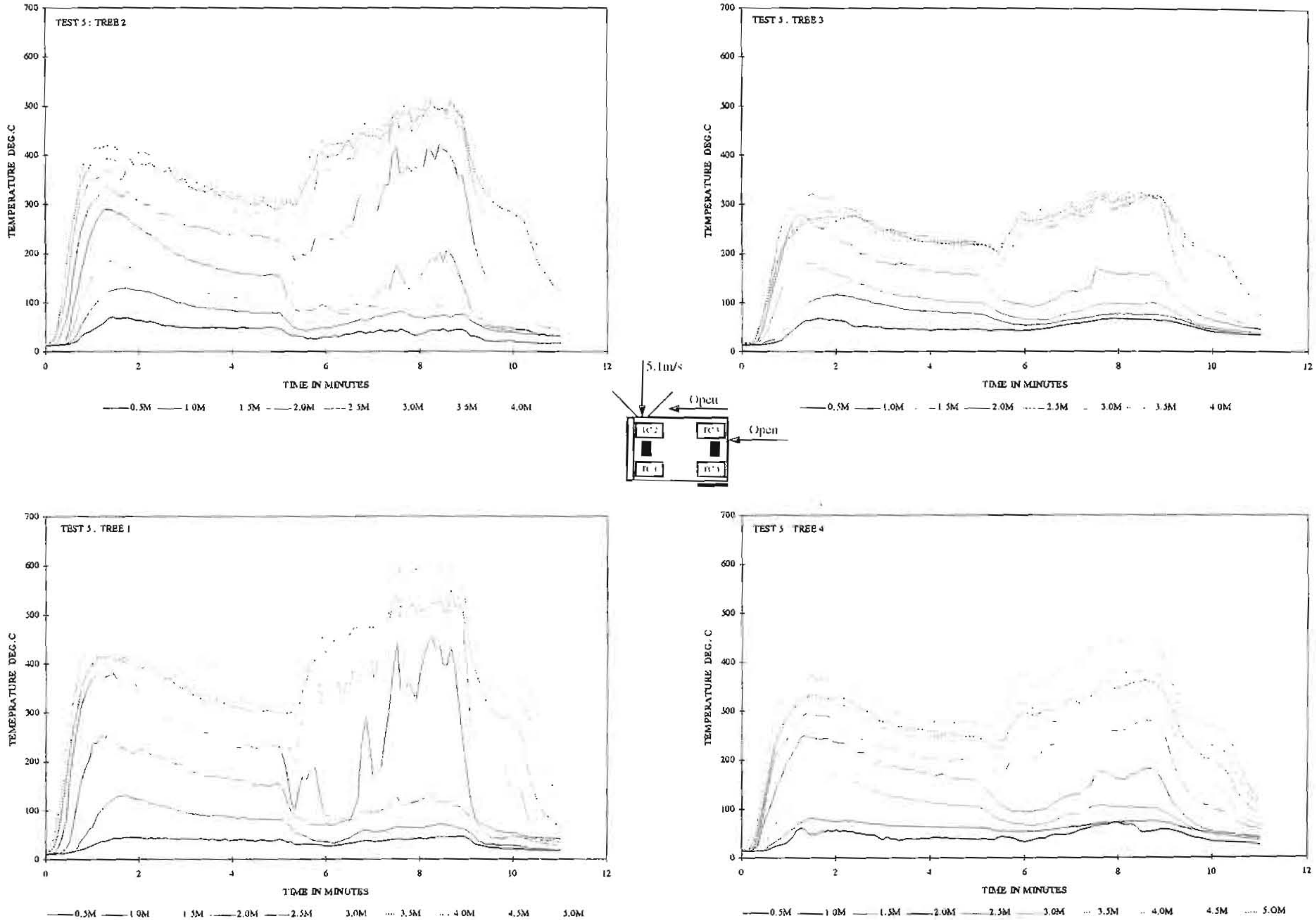

Figure MS1 : Test 5. Typical Gas Temperature Results

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1. INTRODUCTION

The fire service have a requirement to assess the merits of venting as a firefighting tactic and to compare this tactic with existing practices. The Fire Experimental Unit (FEU) of the Home Office Fire Research and Development Group (FRDG) have been tasked to undertake research into this area. As a first step, a survey of the field of venting of fires to determine the true state of the art has been carried out for FEU by a contractor (Reference 1). The consultants carrying out the survey concluded that there was scope for the more extensive application of ventilation tactics in the UK. They considered that there was a need for further research, aimed at assessing the effectiveness of various tactics and developing safe working practices.

A further programme of work is now being carried out by the Home Office to undertake a theoretical exploration of the effects of tactical ventilation in a number of scenarios. This theoretical study will make use of computer modelling to develop an understanding of the processes involved, with the intention of developing practical guidance for the fire service in terms which would be of use on the fireground. Such theoretical studies will have to be validated by means of experimental test fires. Ultimately these may be followed by large scale tests to determine the relative merits of tactical ventilation and other firefighting techniques.

A contract has been placed with AEA Technology to carry out computer modelling of large fires. It is hoped that the modelling will predict the effects of various tactical venting options without the need for expensive large scale test fires. However it is necessary to validate the modelling at an early stage in this work and this report describes the validation trials carried out in the Industrial B building at the Fire Service College during the week commencing the 20th November 1995. The results of the trials are given but the predictions of the computer modelling and comparisons with the experimental results are not considered and will be the subject of a later report.

2. TRIALS PLANNING

2.1 The Building

The trials were carried out in the Industrial B building at the Fire Service College. Figures 1 and 2 show general views of the building from the south-east and north-west. This building has a relatively large open room (17m x 9m) on the first floor with two external doors and a pitched roof. There are four roof vents although only two were used in the tests. This arrangement gave the opportunity to explore the effects of various combinations of roof vents and doors although, for the tests, only two of the roof vents and the two external doors were used for ventilation. The room has a small extension in the south-west corner with a conventional ceiling 3.3m high. To simplify the computer model, this room was partitioned off using metal sheeting for these trials. There was an internal door at the south end that was closed throughout the tests.

Doors at the south-west and north-east corners of the room connect onto the surrounding balcony and the windows along the two long sides are glazed. The upper part of the windows can be opened but remained closed during the tests. Drenchers were already installed in the building to protect the windows during fires and these were turned on for the duration of the tests.

Figure 3 is a floor plan of the room. There were internal partition walls to a height of 1.8m in the building as shown in the figure.

2.2 The Fire Source

The fuel used was Norpar 7[1] which is 95% n-heptane . Superscripts refer Notes on page 23. This fuel was preferred to the cheaper alternative of Solvent 50 used in other FEU trials because Norpar 7 was purer in composition and simpler to define in the computer model.

The fuel was poured onto a water base in up to three rectangular trays and was ignited remotely with an electrically fired cartridge positioned in each tray.

Rectangular trays (each 1.70m x 0.77m) were preferred by the computer modellers and as far as possible the size and position of the trays were selected to locate within the mesh lines of the Computational Fluid Dynamics (CFD) grid. Three trays were manufactured to give the options of various fire sizes by using one, two or three trays. The position of the trays is shown in Figures 3 and 4.

The aim was to have as large a fire as possible in the building whilst paying due regard to safety and to minimizing the risk of damage to the building.

A Safety Procedure (given in Appendix A), was developed before the commencement of the trials and this was followed for each test. This included procedures for fuel transfers.

2.3 Test Plan

A test plan of ventilation options was developed prior to the tests which included the two extreme combinations in terms of expected effectiveness to ventilate the room. The best combination was expected to be a downwind vent open together with an upwind door. The worst combination expected was an upwind vent open with a downwind door or a downwind vent with a downwind door.

The first test was carried out with a single tray in order to develop procedures and assess the effect of the fire in the building. Subsequent tests were carried out with three trays (each 1.7 m x 0.77m) which gave a total area of $3.9m^2$.

The fire was allowed to burn for 5 minutes before ventilation. The fuel volume in the tray was estimated to allow a 10 minute burn period.

One test was carried out using a PPV fan fitted into one of the doors. Although it was not possible to deploy the fan in the appropriate position for accepted PPV methods, a test with a fan was included to give experience of its use in a large building. This was in support of another FEU project on PPV.

3. INSTRUMENTATION

3.1 Gas Temperature Measurements

Vertical gas temperature profiles were measured at four positions by 0.3mm diameter thermocouples[2] with bare wire welded junctions. The temperature trees were located as shown in Figure 3. The thermocouples were at height intervals of 0.5m up to a height of 5m on the two columns towards the east of the room but because of the sloping roof the other two columns were restricted to 4m high.

The trees were mounted onto tripods and could be lowered to allow checking of the thermocouples before each test.

The thermocouples were connected to the data logger via termination panels using multicore compensating thermocouple extension cables[3]. Each thermocouple was logged every 5 seconds.

3.2 Gas Velocity

3.2.1 General

The velocity of the gases through one open vent or one door was measured at a number of points in the openings using bi-directional probes[4] in conjunction with sensitive micromanometers[5]. The temperatures at each of the probes were measured using welded tip thermocouples[2] as near as possible to the probes without affecting their performance.

The probes used were McCaffrey probes (Ref. 2) which were constructed of stainless steel. When positioned in a gas flow, a McCaffrey probe produces a differential pressure which can be converted to velocity using the relationship given below.

$$u = \sqrt{\Delta P / K\rho}$$

where u = fluid velocity

ΔP = pressure difference across the probe in pascals (measured by the micromanometer)

K is a calibration factor which was determined for each probe using standard calibration techniques[6]

ρ is the fluid density. To calculate the density it is necessary to know the temperature at the probe.

The differential pressure was measured using a sensitive calibrated micromanometer. The micromanometer produced an output voltage proportional to the differential pressure and this voltage was recorded on a data logger.

It was not practical to dedicate a micromanometer to each probe because of the cost of these instruments, and therefore scanning boxes[7] were used to select one of ten probes for reading by a single micromanometer. It was essential that there was no doubt in associating the data recorded with the appropriate micromanometer channel and therefore a unique code for each probe was recorded from the scanning box using an interface unit. The channel to be read was selected from the scanning box by operating in a mode which allowed sequential scanning at a rate controlled from the scanning box front panel.

3.2.2 Installation in vent openings

Twelve probes were mounted in frames in the south and north vents of Industrial B. The stainless steel connection pipes from the probes were bent to a cooler position where connections could be made to the flexible tubing. Figure 5 shows the McCaffrey probes in the vent opening. It was hoped that this number of probes would allow the variation of gas flow within the vent area to be explored. The probes were positioned as near as possible to the centre of each cell in the CFD mesh at one height in the vent.

As explained above, it was not possible to monitor each probe with a dedicated micromanometer so the arrangement below was used. Positions designated M1 and M2 were connected to dedicated micromanometers and were logged every second when the vents were open. The other ten positions S1 to S10 were logged by scanning each in turn using a scanning box. When selected, each probe was logged at 1 second intervals for 10 seconds. The temperature at each point of measurement was monitored with a K type thermocouple[2] fixed to each probe with soft iron wire. The temperature was recorded at 1 second intervals during the venting period .

S1	S2	S3
S4	M1	S5
S6	M2	S7
S8	S9	S10

Probe positions in vents (viewed from the top)

The McCaffrey probes were connected to the micromanometers[5] or scanning box by silicone tubing[8] . It was preferable to keep the lengths of these tubes as short as possible to minimise temperature effects in the tubing and keep the response time as short as possible. Therefore the micromanometers and scanning boxes were housed in a heated wooden box on the roof to afford weather protection (Figure 6). The box contained the electrical connections to the data logger for the gas velocity measurements and the extension cables for the thermocouples. Only one housing was manufactured for the roof area although probes and thermocouples were installed in both the south and north vents. Only the north vent was monitored during the tests and therefore the housing was positioned near to this vent. If the south vent had been monitored then the housing would have been moved.

A scaffolding platform was erected around the two roof vents to give safe access to the instrumentation.

3.2.3 Installation in the doors.

A frame housing 18 McCaffery probes had been produced for the FEU project on PPV. This was modified so that it conformed more closely with the CFD grid for the door. Only one frame was available so that this was moved from the SW door to the NW door as required for the tests. Figure 7 shows the frame installed in a doorway. The positions for probes are shown below.

S1		S2	
	M4		S3
S4	S5		
		M5	S6
S7		S8	
	M6		
S9			S10

Probe positions in the door (viewed from outside)

Three probes M4, M5 and M6 were logged at 1 second intervals through dedicated micromanometers. The others S1-S10 were selected by a scanning box in turn and when each probe was selected it was logged at one second intervals for 10 seconds.

The temperature at each point of measurement was monitored with a K type thermocouple[2] and the temperature was recorded at 1 second intervals during the venting period .

3.3 Smoke Density

Optical smoke density was measured at heights of 0.91m (3ft) and 1.82m (6ft) in one location near to the west wall. The equipment[9] consisted of a light projector and photocell (one metre apart) that were mounted in independent water cooled protective housings (Figure 8). An air blower system was used to reduce the possibility of smoke deposits forming on the front covers of the housing

It was not possible to record the progress of the smoke layering throughout the building with only two smoke density meters. However it was hoped that the temperature trees would give additional information on the hot layering.

3.4 Surface Temperature Measurements

Measurements of the surface temperature of the walls were required to assist with assessing the energy transfer into the walls. The method used was to obtain four of the lining tiles used in the building and drill a small hole from the rear of the tile to a distance of 1.5mm from the front surface. A thermocouple was positioned at this point and the hole filled with fire cement. Insulation was positioned around the tiles so that the only path for heat transfer into the tiles was from the front surface. Four tiles were used, with two positioned on two of the thermocouple trees, one on the floor of the building near a radiometer and one on the floor by an internal wall near to the fire.

3.5 Heat Flux

Heat flux was measured using Medtherm Radiometers[10] (114 kW/m^2 max. range) at the following positions:

One facing the roof (adjacent to a tile fitted with thermocouple to measure surface temperature)

One facing the floor

Two directed at the fire

The radiometers were cooled throughout the tests by circulating water by means of a pump from a tank outside the building.

Figure 9 shows a radiometer mounted on a frame.

3.6 Wind Speed and Direction

The wind speed and direction throughout the tests were logged at 1 second intervals from sensors[11] on the upwind side of the building at heights of 1 metre and 7 metres above the ground. The 1 metre height was included because the wind near to the ground was of interest to the computer modellers.

The wind direction sensor was aligned to magnetic north using a compass. The bearing of the building in relation to this magnetic north was also measured.

A wind sock[12] was mounted on a mast upwind of the building to give a visual indication of the wind direction and a guide to the wind speed.

Figures 10 and 11 show the wind sensors and wind sock.

3.7 Depth of Fuel Measurement

It was desirable to record the rate of change of the fuel level in the tray. The method used was to have a pipe of 25mm connected from the bottom of the tray to a smaller tray containing water. The levels in the two trays balanced hydraulically.

An ultrasonic level gauge[13] was positioned above the smaller tray and an output from the gauge connected to the datalogger (Figure B1). The waterbase level was recorded before the fuel was added and during analysis corrections were applied to the water level readings for the relative densities of water and the fuel.

In the later tests, a thermocouple tree was also positioned in the centre of one of the trays. This comprised of 6 thermocouples[14] at height intervals of 2.5mm and it was hoped that this would provide additional information on the change in fuel level throughout the tests. The thermocouple outputs were recorded on the datalogger.

3.8 Video Record (inside and outside building)

Each test was recorded using colour video equipment. A Skystalk mast[15] with a colour video camera on top provided the primary view. This camera was mounted at a height of 20 metres for optimum viewing of the building and could be remotely controlled from the instrumentation van. The Skystalk mast was used to record the smoke movement from the building. A CCD video camera[16] with a wide angle lens (110°)[17] was positioned inside the building to view the fire trays. The camera was contained in a special housing[18] which was cooled by circulating cold air from a blower unit outside the building. This camera was connected to the instrumentation pod and was used to observe the fire development and smoke movement during the tests.

One or two additional video cameras were positioned on the first floor balcony to observe smoke movement at the door or doors used in each test.

For the duration of the tests the signals from all the video cameras were monitored and recorded in the instrumentation control van. After the tests these records were available for analysis of the trials. All line communications during the trial were recorded on the audio track of all the video recorders.

3.9 Pressures Inside and Outside the Building

The static pressure inside and outside the building was measured at 6 positions using a single sensitive micromanometer[5] together with a scanning box[7].

Four sensors were positioned on the outside of the balcony walls and an additional sensor was mounted on the side of the roof vent which was being opened. A single position was monitored inside the building.

The sensor was a 150mm x 150mm piece of plywood with a central hole into which a stainless steel pipe was fitted flush to the front surface. The sensors were connected to a scanning box using clear PVC tubing[19] which was routed around the building as rigidly as was possible to minimise the effects of movement of the tubing. Figure 12 shows a sensor mounted on the balcony.

The probe inside the building was logged for the first minute and then the other probes scanned for a period during the first five minutes of the fire. The probe to be logged was selected manually from the instrument pod.

3.10 Communications

Throughout the trials a two way communication[20] system was used. This system enabled the trial director (in the instrument pod), the persons opening the doors and vents and other observers to communicate with each other. All line communications during the trial were recorded.

A public address system was also available for use from the instrument pod. This was used to give an audible warning of the start of the test and the time for the vents to be opened.

3.11 Air Temperature and Humidity

A humidity probe and air temperature sensor[21] were mounted on a pole on the instrument pod and connected to readouts in the pod. These were not connected to the datalogger but were manually recorded during each test.

3.12 Datalogger

The datalogger[22] was located in the instrumentation pod. All cables from the transducers in and around the building were fed into connection panels in the pod and then connected into the datalogger. Care was taken to ensure that connections were made as reliably as possible and that all connections were clearly labelled.

The datalogger was connected to a computer which was programmed using commercial software[23] to display essential monitoring data on the monitor screen. The data from the trial was recorded on the computer's hard disk and also as a back-up, summary information was recorded on the disc drive of the data logger.

In total, over 120 channels were logged and it was necessary to select the data rates and prioritise data recording to ensure reliability. The details of the channel allocations and the logging program are given in Appendix B. Appendix B has also been used to record other details that do not necessarily fit into other areas of the text.

3.13 Weather Forecast

The wind speed and direction were the major factors in deciding on the venting conditions for each test. To assist with planning, local weather forecasts were obtained twice daily from the meteorological office at RAF Brize Norton.

3.14 Instrumentation Pod.

An instrumentation pod was utilised during the trials which contained the necessary datalogging, video and communications equipment. The pod also served as the trial control room. From the pod the trial director was able to supervise the instrumentation , remotely fire the detonators to ignite the fire and talk to essential staff via the communications equipment. The progress of the trial could also be monitored by reference to the computer screen, instrument displays and video monitors.

The cabling inside the building was routed in cable trunking wherever possible and covered with felt insulation[24] and aluminium foil.

3.15 Measurements of Building Integrity.

Measurements were undertaken by BSRIA[25] to determine the air leakage from the fire compartment. The method is summarised below.

A double fanblower system was installed in the north-east door opening with the remaining area of the door opening blocked off (Figure 13). The vents, internal door and SW door were closed as they were for the trials. The building had a large number of 150mm circular holes along 3 sides which could be closed or partly closed by a sliding door on the inside. The tests were carried out with the holes covered in the same way as they were in the actual tests.

The air-flow rate through the fans and the resulting pressure differentials were measured for a range of flow rates. Throughout the tests the internal and external air temperatures were measured using thermistor probes.

The air-flow rate and pressure differential is related by the equation:

$$Q = k.(dp)^n$$

Where	Q = air-flow rate supplied to the compartment	$m^3 s^{-1}$
	dp = pressure differential across compartment	Pa
	k = the air leakage coefficient	$m^3 s^{-1} Pa^{-n}$
	n = an exponent normally between 0.5 and 1.0	

From the results, the air leakage coefficient and exponent were determined.

3.16 Fire Spread

For realistic fires, ventilation can result in fire spread. The tray fires and building construction in these tests did not allow fire spread to take place but some indication of fire spread was required for future modelling work.

Pieces of wood were mounted on wooden poles and examined after the test for signs of charring. In the later tests thermocouples were mounted above some of the wooden pieces and the temperatures logged. The idea was that flaming would be detected by a rapid rise in the temperature indicated by the thermocouple.

4. EXPERIMENTAL PROCEDURE

A summary of the experimental procedure is given below. The Safety Procedure which covers fuel handling, ignition of the fuel, and fire safety during the tests is given in Appendix A.

The fuel (Norpar 7) was stored in drums at a compound on the Fire Service College fireground. Before each test, fifty litres of fuel for each tray was measured out (using a calibrated dipstick) into 200 litre drums (one drum per tray) at the fuel store. The drums were then transported to Industrial B building and hoisted to the first floor (Figure 14).

All instrumentation was calibrated before the test period and checked for correct functioning before each test. Each sensor was checked by one person at the sensor applying a test condition while another person checked the response at the datalogger. The methods used are summarised below.

Instrument/sensor	Check Method
Thermocouples	Each thermocouple was touched with a hot object[26]
Radiometers	A calibrated light source was switched on at a fixed position in front of each radiometer.
Smoke density meters	Neutral density filters[27] were positioned between the light source and the detector.
Gas velocity probes	Air was blown into each probe.
Micromanometers	A known pressure was applied to each instrument using a calibrator[28]

The water base levels and temperatures in the trays were recorded using a dipstick and intrinsically safe digital thermometer respectively. The detonators[29] were then connected ready for use.

When all the preparations were complete, the fuel was transferred to the trays and the fuel levels and temperatures recorded. The aim was to carry out the tasks between fuel transfer to the tray and ignition as quickly as possible so as to minimise fuel loss by evaporation.

Just prior to ignition the window drenchers were turned on and all the doors to the building closed. The datalogger and video recorders were all set to record data and then the fuel was ignited using the electrical detonators. Figure 15 shows the fire seen from outside the building during a test and this figure also shows the instrument pod.

At 5 minutes after ignition of the fire, ventilation was commenced using the vents and doors required for the selected test conditions. The roof vents were normally held closed by a retaining catch which was released by pulling a handle at first floor level (Figure 16). The vents then opened by the effect of gravity on the counterbalance weights (Figure 17). The doors were opened by fire officers or FEU staff wearing suitable protective clothing.

The test was terminated after all the fuel had burnt out. After the test, the data recorded from the data logger was transferred into a spreadsheet software package[30] and processed to graphical output.

The ventilation conditions are given in Table 1. All the tests used natural ventilation except Test 4 which used a PPV fan[31] installed in a wooden panel in the SW doorway (Figure 18). The door was sealed for the first five minutes with the panel and then a small panel was removed to leave a hole into which the fan was moved. This test was carried out to explore the use of a fan in a large building, although the fan was not used in the accepted PPV role in which it would be some distance from an open door.

5. RESULTS

A plethora of data was collected during the trials which has been processed into Excel[30] spreadsheets and this data can be made available on disk on request from those interested.

The results are presented in graphical form with an appendix (C-J) being allocated to each test.

Table 1 gives the ventilation and wind conditions for each test and serves as an index for the appendices

The first page in the appendices (C-J) gives the following information:

- comments from the video record
- water base/ fuel depths and temperatures
- air temperature/humidity for each test.
- any instrument problems or changes.

The format of each appendix follows the list given in Table 2. Graphs have been combined on to one sheet wherever this simplifies the analysis of the data. For example, Figure 1 in each Appendix shows a graph for each of the temperature trees including a small diagram of the building which indicates the positions of the trees and the wind speed and direction. The graphs in this figure are positioned on the page relative to their location in the building.

Tabular data is also included in the appendices where this supports the graphs.

The wind speed and direction and the gas velocities have been smoothed by using a 9 point moving average. The raw and smoothed data are presented.

Not all the results from the scanning channels of gas velocities and static pressures have been processed. The computer modelling concentrated on Tests 5 and 7 and for these tests all the data is presented.

There are some tests where not all the parameters were recorded. However, to preserve the index system, there are gaps in the figure numbers as shown in Table 3.

5.2 Video Recordings

Table 4 lists the tape numbers (in the FEU Video reference system) for each camera view used.

From the internal CCD camera, still frame images have been produced from the recording of Test 5. These are included as Figures 19 and 20 and show how the fire grows initially , then becomes ventilation limited until the door and vent are opened at 5 minutes when the fire grows again. The visibility of the windows on the right hand side of the images gives a guide to the obscuration throughout the sequence.

5.3 Measurements of the building integrity

As noted in Section 3.16, the air flowrates and pressure differential is related by the equation:

$$Q = k.(dp)^n$$

Where	Q = airflowrate supplied to the compartment	$m^3 s^{-1}$
	dp = pressure differential across compartment	Pa
	k = the air leakage coefficient	$m^3 s^{-1} Pa^{-n}$
	n = an exponent normally between 0.5 and 1.0	

The results of the leakage measurements carried out by BSIRA (Reference 2) were

Air leakage coefficient $k = 0.55\ m^3.\ s^{-1}\ Pa^{-n}$

exponent $n = 0.6607$

Air flow rate at 50 pascals was given as 7.3 m^3/s

Further leakage measurements are planned for summer 96.

6. DISCUSSION

6.1 Instrumentation

6.1.1 General

Generally the instrumentation operated satisfactorily during the tests. Reliable data was obtained of the gas temperatures, heat flux, gas velocities (from dedicated probes), static pressure in the building, surface temperatures and smoke density (after Test 4). Smoke density results for Tests 1 to 4 were not reliable because the blower, designed to prevent smoke deposits on the instrument windows, was wrongly connected. This resulted in deposits forming on the instrument glasses thus invalidating the readings.

Comments are given below on other instruments including changes that would be made if additional trials were carried out.

The trials used more instruments than any other FEU trials and the installation of all the instruments and cables in the short time available was only possible after careful planning and hard work by FEU staff. It would not be possible to sustain trials of this type for a longer period than a week without a break to analyse the results, fully check the instrumentation and rectify any instrumentation problems. Where there were problems identified, there was not the time to address these during the trials period.

6.1.2 Gas velocities

The dedicated probes gave reliable results. The probes which were scanned were not as effective and future trials would use additional micromanometers with more dedicated probes rather than use the scanning boxes. The use of scanning boxes required a settling time for the conditions to stabilise in the tubing between the probes and the scanning box before steady data was recorded. The data reduction was also very time consuming from the scanned probes.

Data reduction for the scanning probes is not reported for all of the tests.

Further precautions would be taken to address the problem of the silicone tubing being prone to kinking, particularly when the probes or micromanometers/scanning boxes were moved. Either a different type of tubing or further protection would be investigated.

6.1.3 Gas temperatures

The thermocouples on the temperature trees were positioned a height intervals of 0.5 metre. Thermocouples at one metre height intervals would provide adequate data on the temperature height profile. A faster logging rate (an interval of less than 5 seconds) would be preferred to record any fluctuations in the temperatures more closely.

6.1.4 Static pressure.

The most useful measurement point for static pressure was inside the building. This was scanned along with the other static pressure probes around the balcony. The data from around the balcony was not of interest to FEU but could be of use to the computer modellers to check their predictions of the effect of the wind around the building. Further investigation is required into the location of the reference probe for the differential pressure measurement.

6.1.5 Fuel regression rate.

The results from the fuel regression rate do not always show a continuous reduction in the fuel level. The explanation for this is thought to be distortion in the tray due to the heat from the fire and this could be overcome by welding steel beam sections to the base of the tray or using concrete trays. The other possibility is that the ultrasonic probe is affected by temperature, although it was protected with insulation and should not have exceeded its operating limits.

The thermocouple tree placed in the tray does not give step changes to allow accurate measurements.

Further investigation of both these techniques is required but the alternative approach of using load cells under the trays would be favoured in future.

Fuel regression rate is a useful parameter to measure in fire trials and its measurement is worthy of further research.

6.1.6 Heat Flux

The results from the radiometers do show some negative values. The instruments were calibrated at heat fluxes between 1.5 and 10 kW m^2 and a curve fitted over this range. Where the instrument operates outside these values either a different type of radiometer or calibration over a lower range would be preferential.

6.1 7 Fire Spread.

Observations on the damage to the wood have been included in the Appendices I and J. Different damage did occur in the various positions used and such samples could be used for qualitative assessment of fire spread. The thermocouples positioned above the wood did not indicate high enough temperatures for flaming to have taken place and further work with observation of the samples using video cameras would be required.

6.2 Comparison of Tactics

Although the objective of the trials was to obtain experimental data for comparison with predictions from the computer model, a limited range of tactical options was explored in the wind conditions at the time of the tests.

Some simple analysis has been carried out to compare the effectiveness of the options in terms of temperature changes in the building. Temperatures on all the temperature trees at 1m, and 2 m were compared by calculating the sum of all the temperature values recorded from 5 minutes to 8 minutes and then dividing this total by the temperature for each position at 5 minutes. This gives a number which is a guide to the temperature change. This number was then subtracted from a constant to give figure of merit such that the greater the number, the better the performance.

The temperatures at 1m and 2m have been used for the comparison because these are most relevant to the firefighter who is entering a building to effect rescue and fight a fire.

The period 5 to 8 minutes was selected to ensure that all three trays were still burning.

The percentage burnback has been calculated. This is peak of the fire after ventilation as a percentage of the peak fire in the first 5 minutes as calculated from the heat flux measurements.

Figure 21 shows the results of these comparison presented in the order of improved performance. The venting and wind conditions are also shown in the figure.

It can be seen from the burnback results given in Figure 21 that the fire growth was still ventilation limited unless an upwind door and a downwind vent were opened. In the other cases the fire never reached the same size as in the initial period.

There are no surprises in the results and the ranking order would no doubt be predicted by experienced firefighters. The tests do however provide experimental data to support experience. Care should be taken with applying these results to other buildings which may not behave in the same way.

The most effective ventilation was with one door and two roof vents open. The least effective was the cross-ventilation case with two doors open and no roof vents.

When one roof vent and one door were used, then:

- an upwind door and a downwind vent are the best
- a door and vent at opposite ends of the building are more effective than a door and vent at the same end.

Tests 4 and 5 were carried out in similar wind conditions (speed 5.1 m/s and direction 287/300 degrees) and after five minutes the SW door and the N vent were opened. The difference between them was that Test 5 was with natural ventilation and Test 4 used a PPV fan positioned in the doorway.

The figures of merit were calculated and showed little difference overall but the gas temperatures were lower on the tree near to the fan at the lower heights when the fan was used.

CONCLUSIONS

The tests carried out provided valid data for comparison with predictions from the computer model. Reliable data was recorded on gas temperatures, heat flux, surface temperatures and gas velocities at points in the open doors and vents. Other data was less reliable.

The tests demonstrated the advantages of venting a building at high level.

ACKNOWLEDGEMENTS

Acknowledgements are due to the Commandant and fireground staff at the Fire Service College.

The assistance of FEU staff is also gratefully acknowledged.

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1. FRDG Publication 6/94, A Survey of Fire Ventilation, Dr A Hay (Warrington Fire Research), 1994.

2. BSRIA, Report 12563/1, Envelope Integrity Measurements of a Fire Compartment, Moreton-in-Marsh, January 1996.

NOTES

[1] Chemitrade , Station House, 81-83 Fulham High Street, London SW6 3JW. Chemitrade supplied Norpar 7 to thier specification dated November 4 1991. Norpar 7 is one of the range of Exxon Chemicals products.
[2] Minta Instrumentation Limited, Caddick Road, Knowsley Industrial Park(South), Knowsley, Prescot, Merseyside. L349HP. Type K glass/glass extension thermocouples, 7/0.2mm flat twin cable, hot junctioned complete with mini plug.
[3] Minta Instrumentation Limited, Caddick Road, Knowsley Industrial Park(South), Knowsley, Prescot, Merseyside. L349HP. Type K thermocouple Extension Cable PVC coated. Cable fitted with mini K type plugs and sockets. Cable 16/0.2VX screened drain. 300mmm tails each end. Lengths of 30 metres and 60 metres. Extension cables from other suppliers but with similar specifications were also used
[4] McCaffrey Probes manufactured to FEU drawing based on refernce "A Robust Bidirectional Low velocity probe for flame and fire application" by B J McCAffrey and G Heskestad. Published in "Combustion and Flame " 26, 125-127(1976). FEU probes produced by FRS and BMD Engineering
[5] Furness Controls Limited, Beeching Road, Bexhill, East Sussex, TN39 3LJ. FCO14 3 Range Analogue Micromanometers - Model 2 Ranges ± 1/10/100 Pascals 0-12 m/s
[6] Building Research Establishment Fire Research Station, Garston, Watford, Herts. WD2 7JR. 10 point calibration.
[7] Furness Controls Limited, Beeching Road, Bexhill, East Sussex, TN39 3LJ.FCO91 Series Scanning Box. 10 pairs of differential inputs.
[8] Primasil Limited, Kington Road, Weobley, Herefordshire HR4 8QU. Silicone Double Tube Product Code HOME6348, Special Product.
[9] Skil Controls Limited, Greenhey Place, East Gillibrands, Skelmersdale, Lancs. Visible Emission Monitor Model 250.
[10] Parr Scientific Limited, 594 Kingston Road, Rayens Park, London. Metherm Heat Flux Transducers types, 64-10-20.
[11] Vector Instruments Limited, Marsh Road, Rhyl,Clwyd. Wind Speed and direction indicator D600/120.
[12] Met-check, PO Box 284, Bletchley, Milton Keynes, MK17 0QD. Wind Sock 4ft polyurethane.
[13] Hawker Electronics Limited, 43Melchett Road, Kings Norton Business Centre, Kings Norton, Birmingham, B30 3HP. Hawkersonda Ultrasonic Level Transmitter
[14] TC Ltd, PO Box 130, Uxbridge. UB8 2YS. Mineral insulated thermocouples. Order code 12-K-1000-125-0.5-2I-3P2BL-1mtr-C60KX-F11KX
[15] Cloud Nine (Photographic Services) Limited, Unit 9, Old Great North Road, Sutton-on-Trent, Newark, Notts, NG23 6QS. Skystalk Mast.
[16] Sony (UK) Limited, Sony House, South Street, Staines, Middlesex, TW18 1BR. Sony DXC-102.P colour CCD video camera.
[17] Pentax (UK) Limited, South Hill Avenue, South Harrow, Middlesex, HA2 0LT. Pentax 4.8mm f1.8 A1 lens.
[18] Camera housing components manufactured in 1987 by P J Hare, Great Western Road, Cheltenham Glos, GL50 3QW. To FEU drawing No. FEU-1-102, and associated drawings. Commissioned and assembled by FEU.
[19] Flexible Hose Supplies Ltd. 140,Edinburgh Avenue, Slough, Berks. SL1 4VA. Clear PVC Tubing 3mm i/d.

NOTES

[20] Diktron Developments, Highgate Squre, Birmingham, West Midlands, B12 0DT. Diktron Line Communication system with headset/microphone.
[21] Skye Instruments Limited, Unit 5, Dbole Industrial Estate, Llandrinrod Wells, Powys, LD1 6DF. Air temperature and humidity sensor SKH2013.
[22] Solatron Instruments, Victoria Road, Farnborough, Hampshire, GU14 7PW Scorpio Data Logger SI3535D
[23] Solatron Instruments, Victoria Road, Farnborough, Hampshire, GU14 7PW. Scorpio Software.
[24] Warren Bestobell, Unit 11 Severside Trading Estate, Textilose Road, Trafford Park, Manchester, M17 1LL. Lo-Con Felt insulation 12.7mm thick (96kg/m^3).
[25] The Building Services Research and Information Association (BSRIA), Old Bracknell Lane West, Bracknell, Berkshire RG12 7AH.
[26] Braun (UK) Ltd, Dolphin Estate, Windmill Road, Sunbury-On-Thames, Middlesex. Braun Style'n Go styling tong Type 4560.
[27] Jessop of Leicester Ltd, Jessop House, Scudamore Road, Leicester. LE3 1TZ. Kodak wratten filters. Neutral densities of 0.1, 0.5, 0.6, 0.9, 1.0, 2.0.
[28] Furness Controls Limited, Beeching Road, Bexhill, East Sussex, TN39 3LJ. PPC500 Pressure calibrator. Range 0-2kPa..
[29] Le Maitre (Sales) Ltd, 6 Forval Close, Wandle Way, Mitcham, Surrey. CR4 4NE. 2 Second Gerb Heptane Igniters
[30] Microsoft Coporation. Excel v5.0c.
[31] Tempest, 24" Power Blower with 5.0 HP Tecumseh petrol engine.

Test No.	Date	Fire size	Appendix for results	Doors opened at 5 mins.	Vents opened at 5 mins.	Wind speed at 7 m m/s		Wind Speed at 1m m/s		Wind Direction at 7m		Wind Direction at 1m	
						Avg.	Std Dev	Avg.	Std Dev	Avg.	Std Dev	Avg.	Std Dev
1	20 Nov.	1 tray	B	SW	N	4.7	1.0	3.4	.8	167	10.4	171	12.6
2	21 Nov.	3 trays	C	SW	S & N	4.6	.9	3.5	.8	179	7.6	183	10.5
3	21 Nov.	3 trays	D	None	S & N	3.0	.5	2.1	.5	190	10.3	197	13.1
4	22 Nov.	3 trays	E	PPV fan at SW door	N	5.1	1.9	4.1	.9	287	9.8	295	11.1
5	22 Nov.	3 trays	F	SW	N	5.1	.8	4.2	1.0	300	5.5	306	10.3
6	23 Nov.	3 trays	G	NE	N	5.4	2.9	4.0	1.0	215	12.1	223	14.8
7	23 Nov.	3 trays	H	SW & NE	None	6.4	1.2	4.7	1.1	206	14.6	211	17.3
8	24 Nov.	3 trays	I	NE	S	7.9	1.5	6.0	1.3	183	9.8	187	12.7

Table 1: Test details including wind speed and direction

Figure number in Appendix	Parameter	Content of page	Details
Figure 1	Gas temperatures for the 4 temperature trees	Graph 1	Tree 2
		Graph 2	Tree 3
		Graph 3	Tree 1
		Graph 4	Tree 4
Figure 2	Wind Speed and Direction	Graph 1	Wind speed at 7m and 1m
		Graph 2	1 Wind speed at 7m and 1m - data smoothed 9 point moving average.
		Graph 3	Wind direction at 7m and 1 m
		Graph 4	Wind direction at 7m and 1 m - data smoothed 9 point moving average
		Table	Table of averages and standard deviation of speed and direction at 2 heights for time periods 0-5 ins, 5-10 ins and 0-10 ins.
Figure 3	Smoke Obscuration and Heat Flux	Graph 1	Smoke obscuration at .91 m (3ft) and 1.82 (6ft) in one position
		Graph 2	Heat flux from 4 radiometers
Figure 4	Gas velocities in doorway - dedicated probes	Graph 1	Door velocities from dedicated probes in doorway
		Graph 2	Door velocities from dedicated probes in doorway data smoothed 5 point moving average
	Gas velocities from scanned probes	Table	Average values from scanned gas velocity probes
Figure 5	Gas velocities in roof vent - dedicated probes	Graph 1	Gas velocities from dedicated probes in roof vent
		Graph 2	Gas velocities from dedicated probes in roof vent data smoothed 5 point moving average
	Gas velocities from scanned probes	Table	Average values from scanned gas velocity probes in roof vent
Figure 6	Static pressures	Graph 1	Static pressure inside building for initial ignition period
Figure 7	Surface temperature	Graph 1	Surface temperature measured in wall tiles
Figure 8	Fuel Depth		Depth from ultrasonic depth gauge
			Temperatures from thermocouple tree in fuel
Figure 9	Flame spread		Temperatures measured above wood flame spread

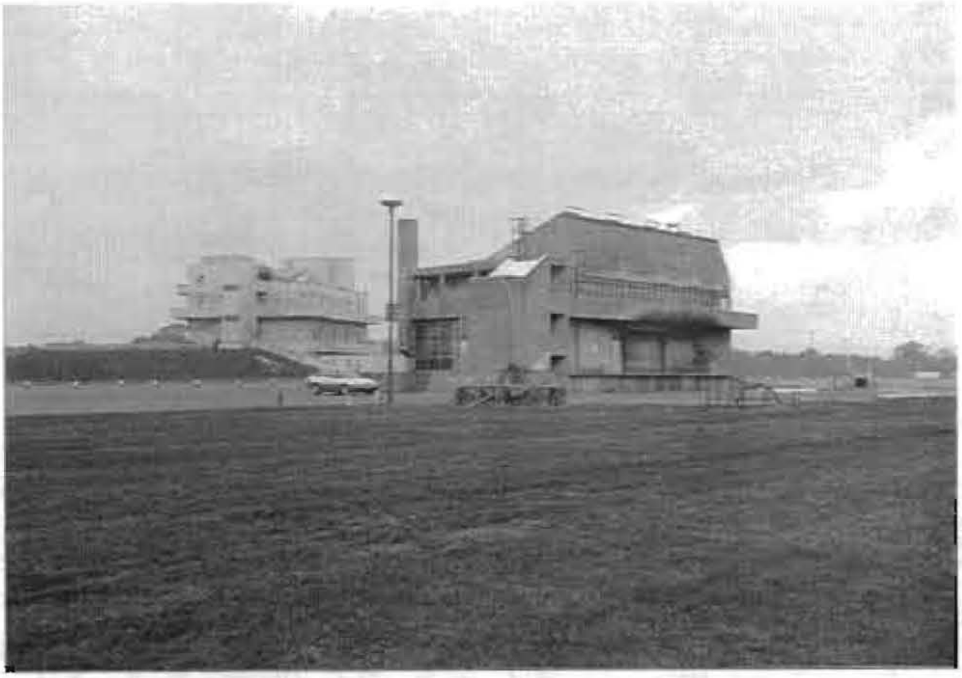
Table 2 : Details of results presented in each Appendix

		Test Number							
Appendix Fig. No		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Gas Temperatures	C1	D1	E1	F1	G1	H1	I1	J1
2	Wind speed and direction	C2	D2	E2	F2	G2	H2	I2	J2
3	Smoke Obscuration and heat flux	C3	D3	E3	F3	G3	H3	I3	J3
4	Gas velocities in doorway	C4	D4	None	None	G4	H4	I4	J4
5	Gas velocities in roof	C5	D5	E5	F5	G5	H5	None	None
6	Static pressures	C6	None	E6	F6	G6	H6	I6	J6
7	Surface Temperature	C7	D7	E7	F7	G7	H7	I7	J7
8	Fuel depth	C8	D8	E8	F8	G8	H8	I8	J8
9	Flame spread	None	None	None	None	None	None	I9	J9

Table 3: Index to Graphs in the Appendices.

Test	Camera			
	Skystalk	CCD	W Side	E Side
1	-	71/95	70/95	-
2	-	71/95	70/95	-
3	72/95	71/95	70/95	-
4	72/95	71/95	70/95	-
5	75/95	74/95	73/95	-
6	75/95	74/95	73/95	76/95
7	75/95	74/95	73/95	76/95
8	79/95	74/95	77/95	

Table 4 : Video Tape References



C1065/94

Figure 1 : Industrial B building from the south-east

C987/95

Figure 2 : Industrial B building from the north-west

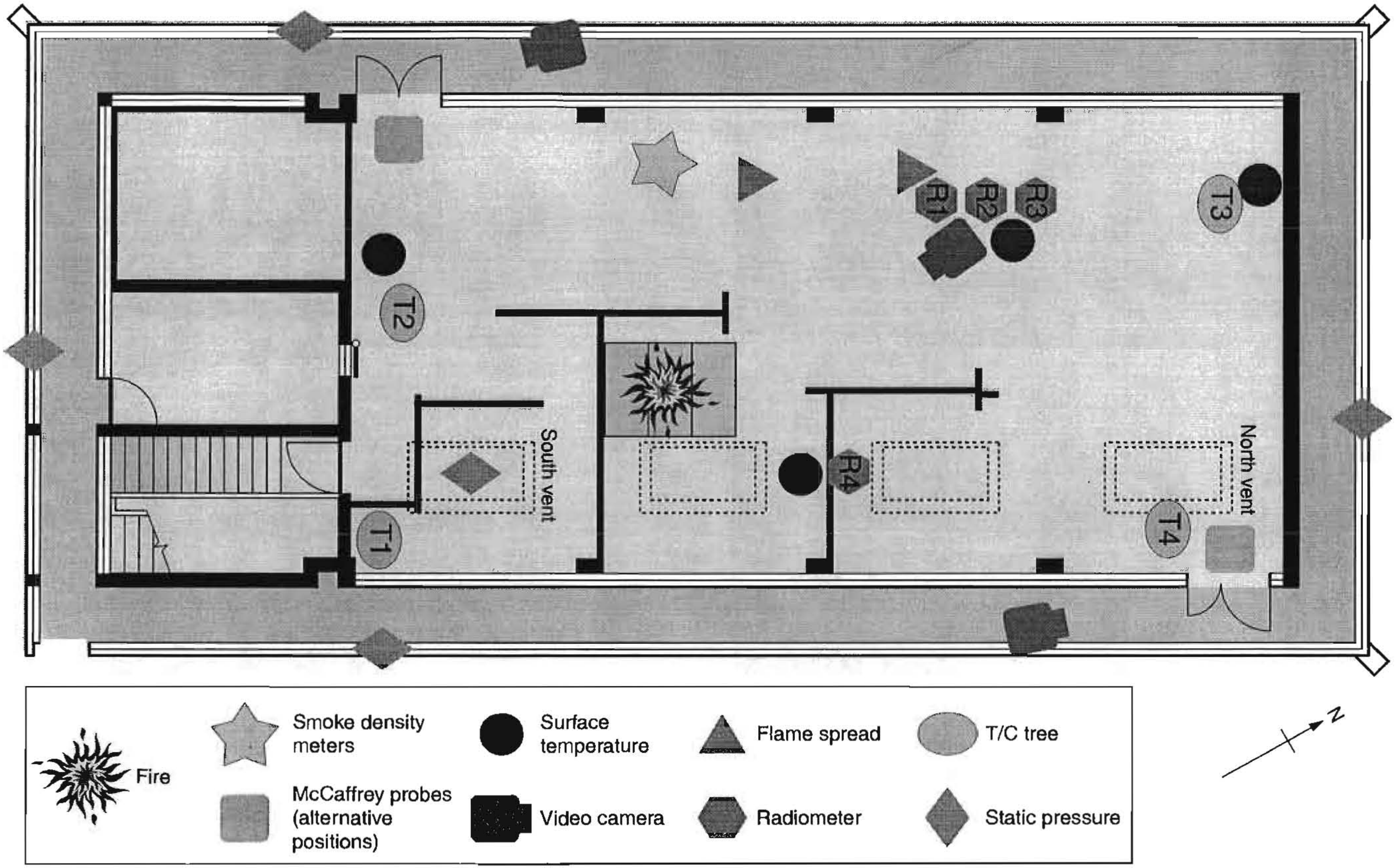
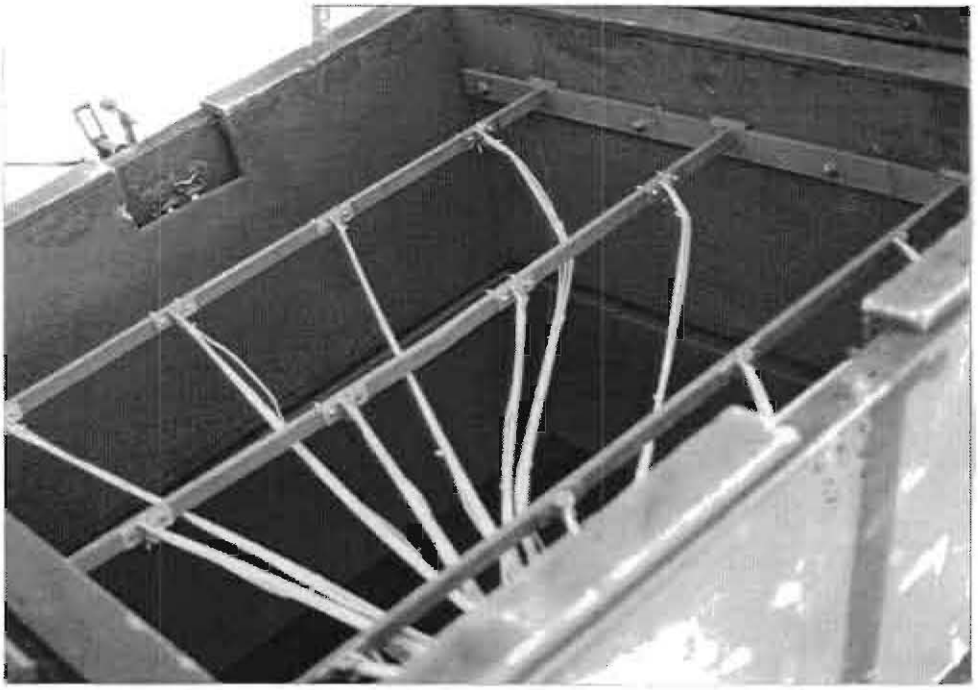


Figure 3 : Schematic of instrumentation layout

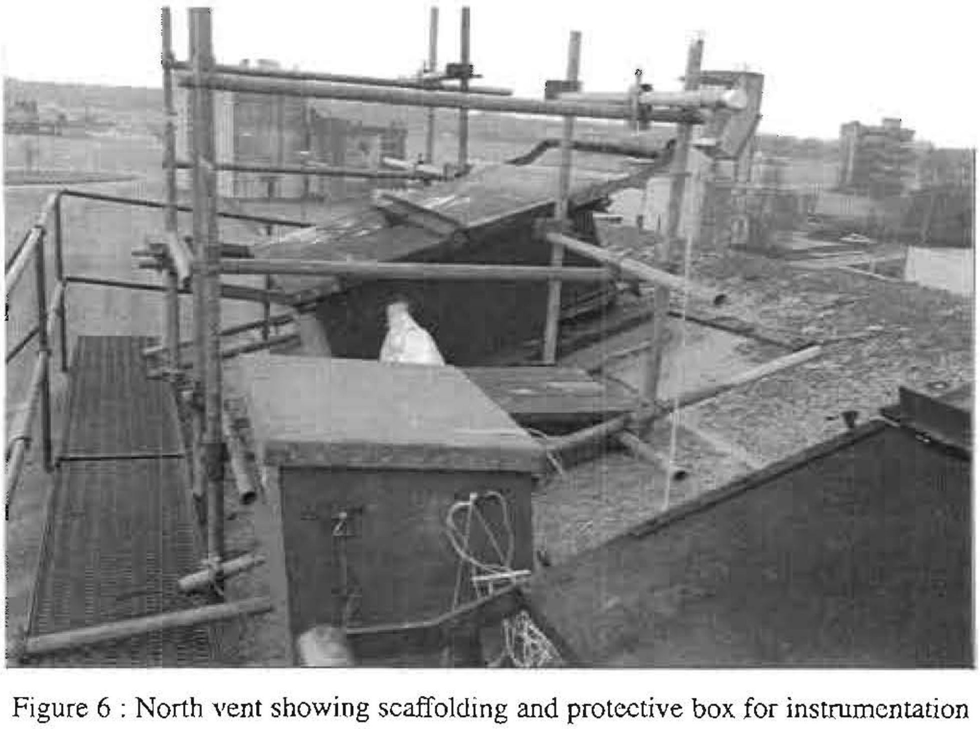
S522/95

Figure 4 : Position of rectangular trays



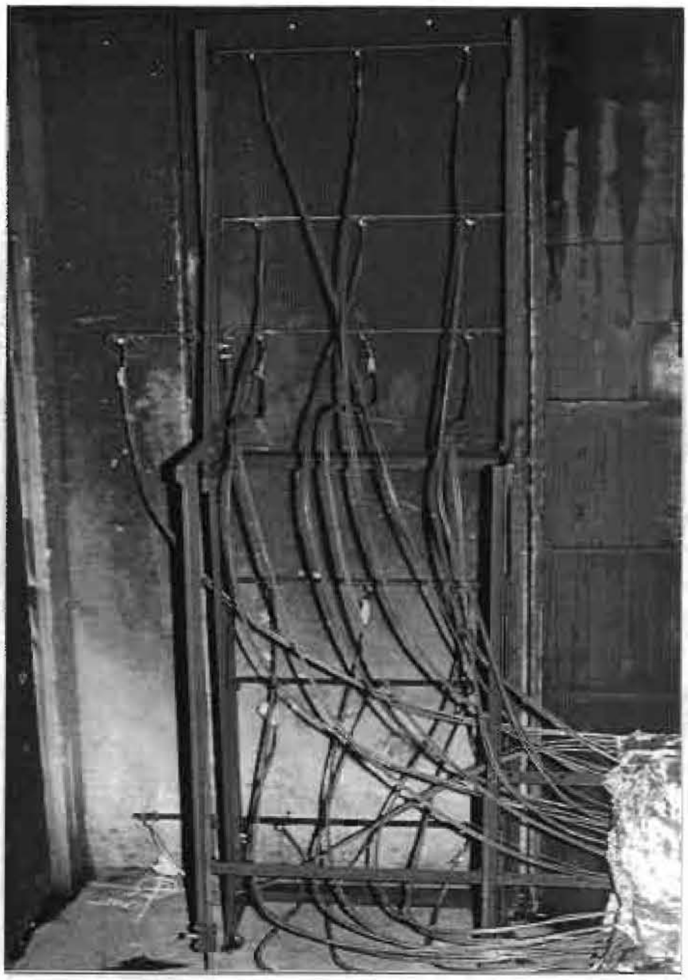
S484/95

Figure 5 : McCaffrey probes installed in the north roof vent



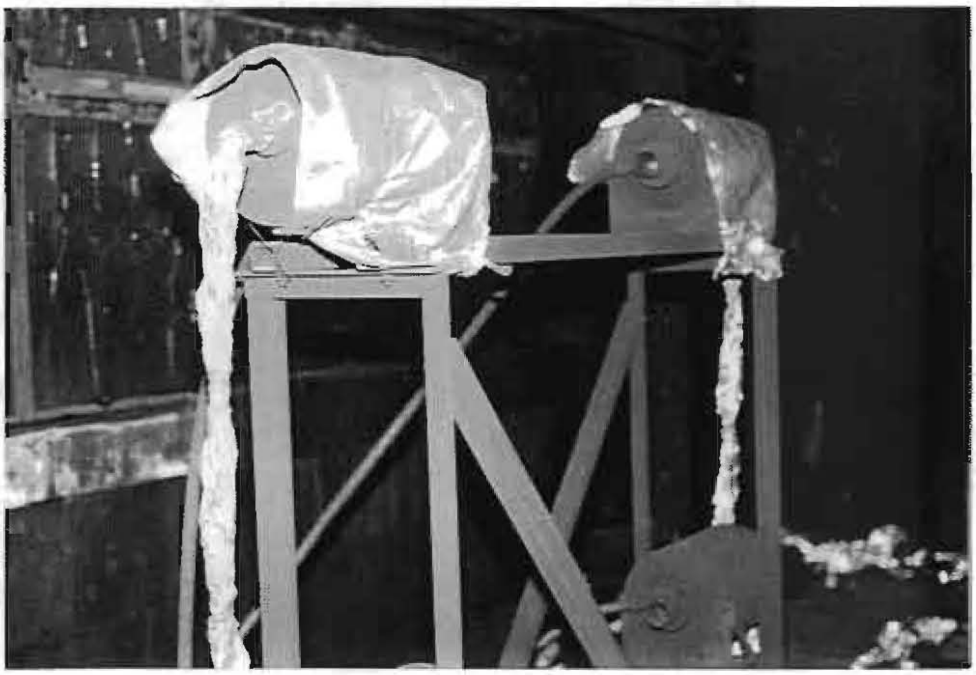
C923/95

Figure 6 : North vent showing scaffolding and protective box for instrumentation



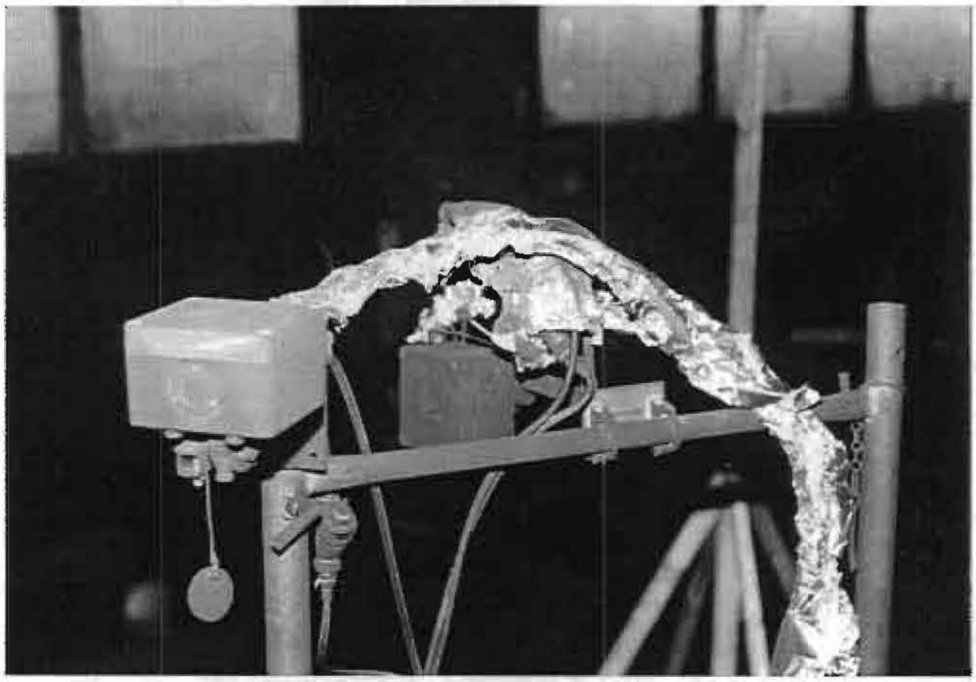
S526/95

Figure 7 : McCaffrey probe frame installed in a doorway



S521/95

Figure 8 : Smoke density meters

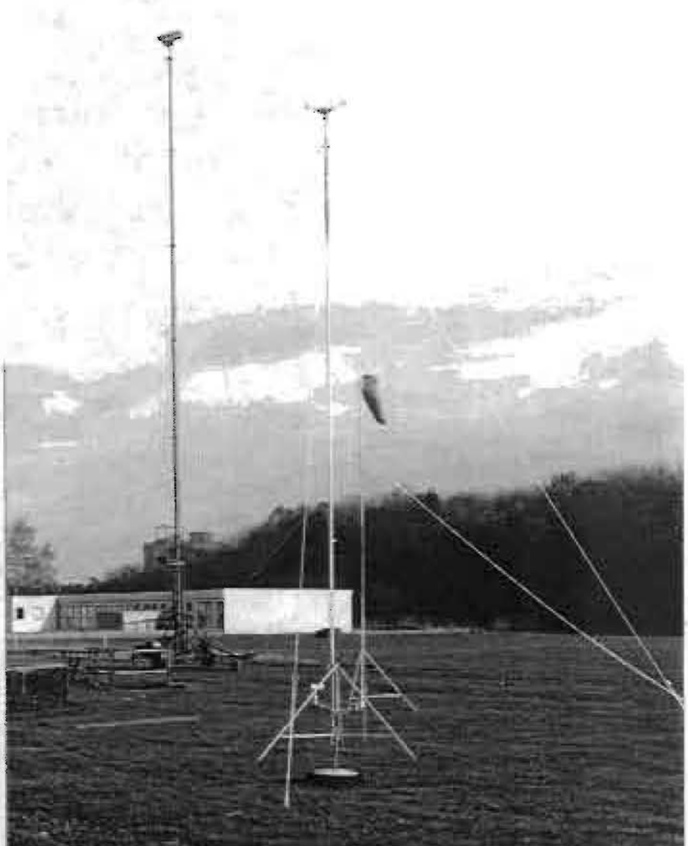


S453/95

Figure 9 : Radiometer mounted on a frame

S434/95

Figure 10 : Wind sensors mounted at 1m



S436/95

Figure 10 : Wind sensors at 1m and 7m with wind sock in the background

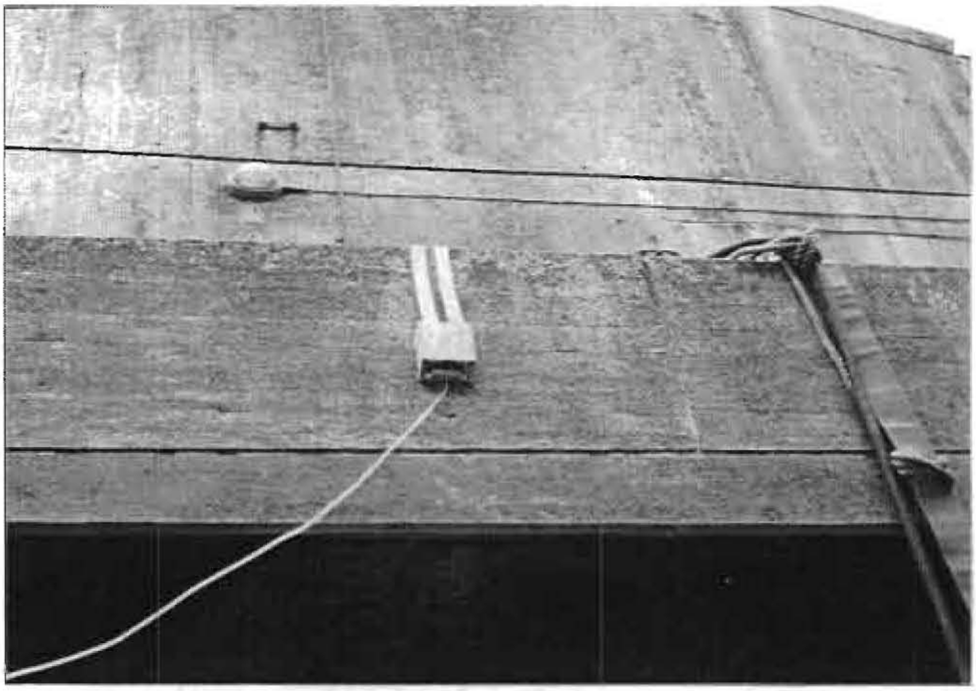


Figure 12 : Static pressure sensor mounted on the balcony

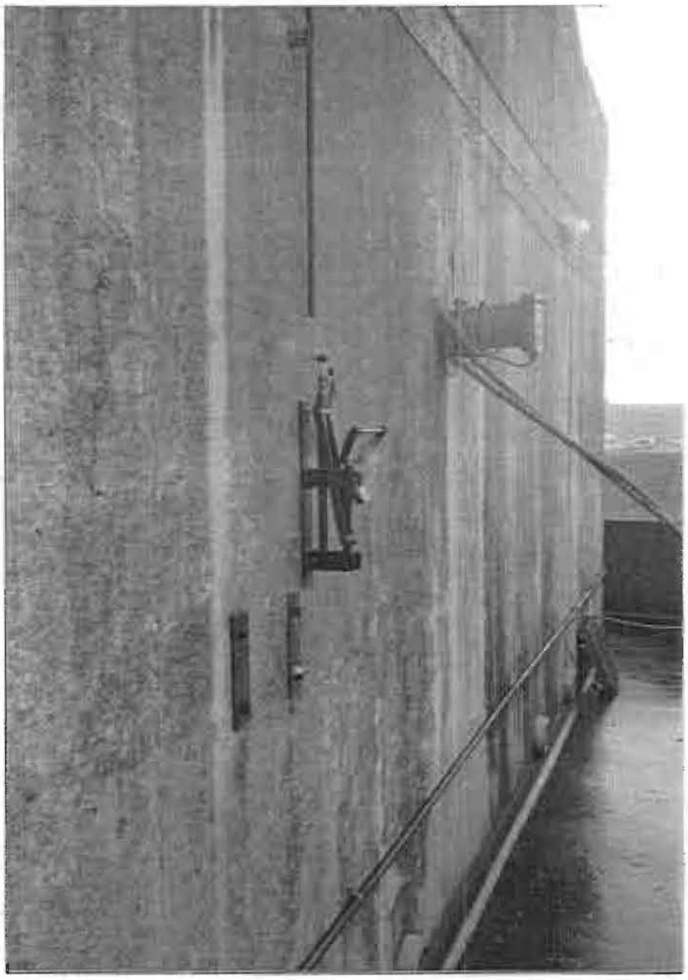
Figure 13 : Double fanblower system used for air leakage measurements

S469/95

Figure 14 : Fuel being hoisted to the first floor

S420/95

Figure 15 : View of fire from outside the building

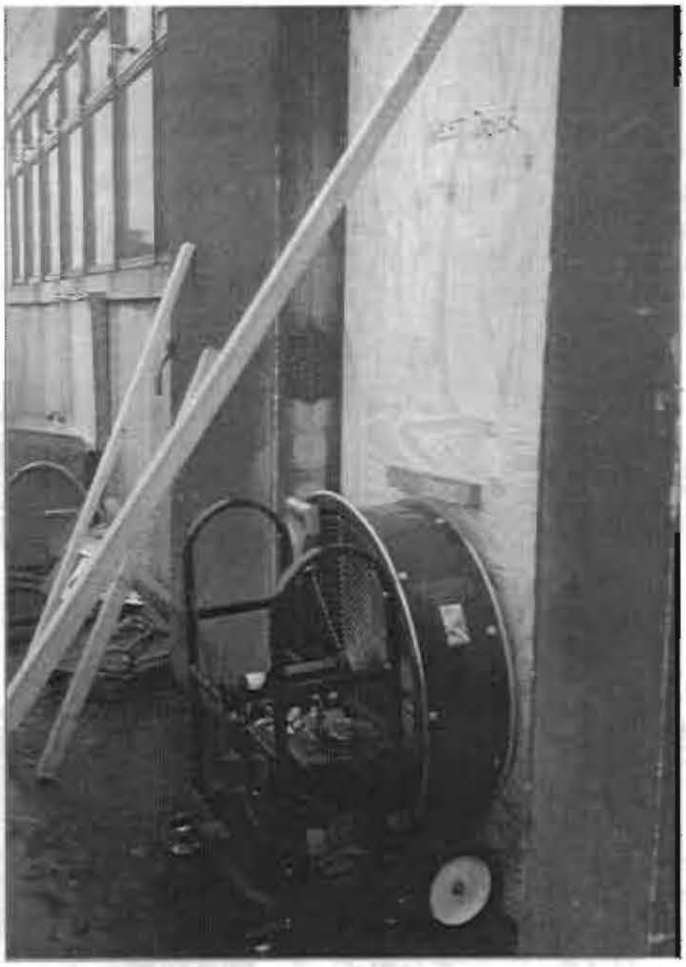


C972/95

Figure 16 : Handle for opening the roof vents

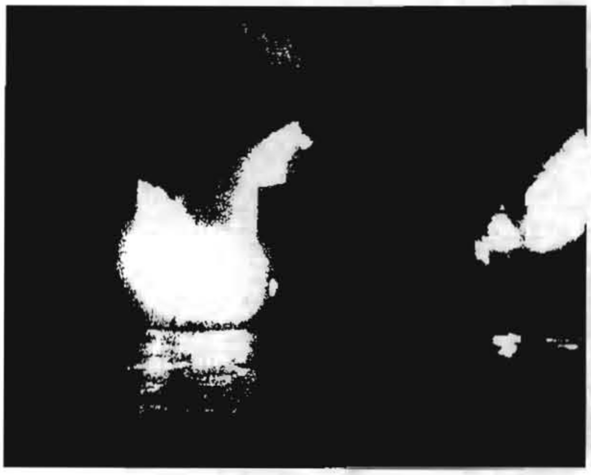
C994/95

Figure 17 : North roof vent (open)

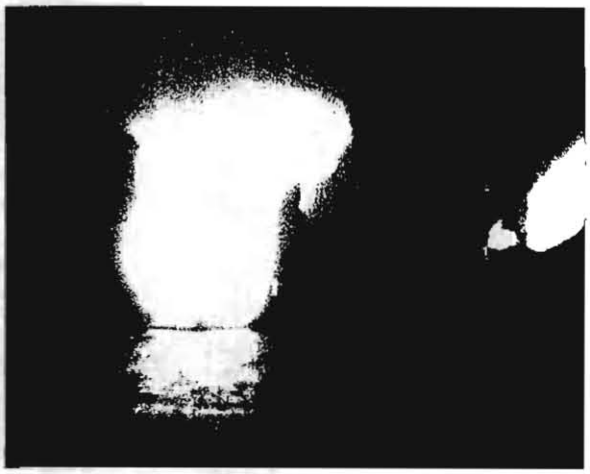


C939/95

Figure 18 : PPV fan installed in the south-west doorway

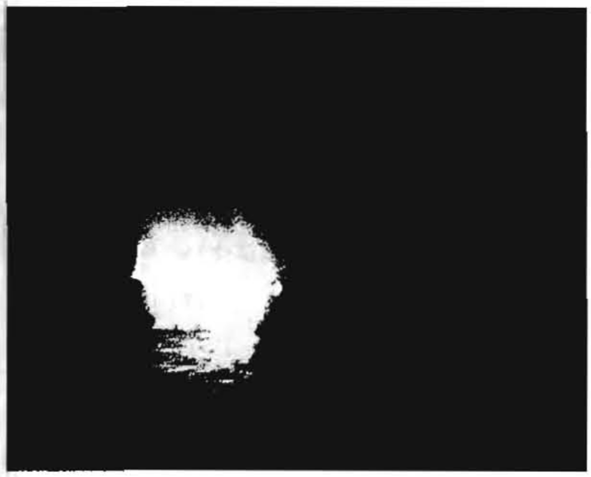


10 Seconds

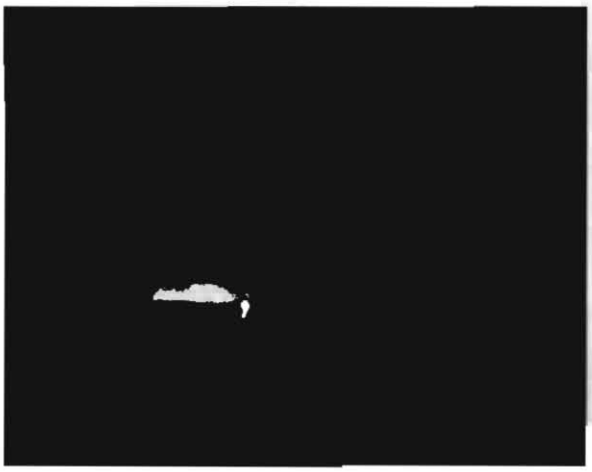


30 Seconds

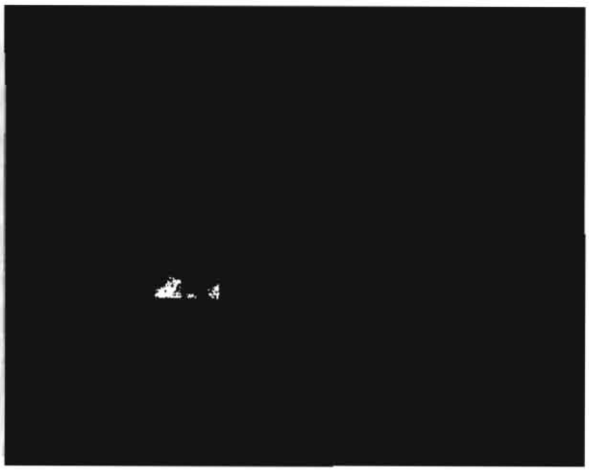
45 Seconds



1 Minute

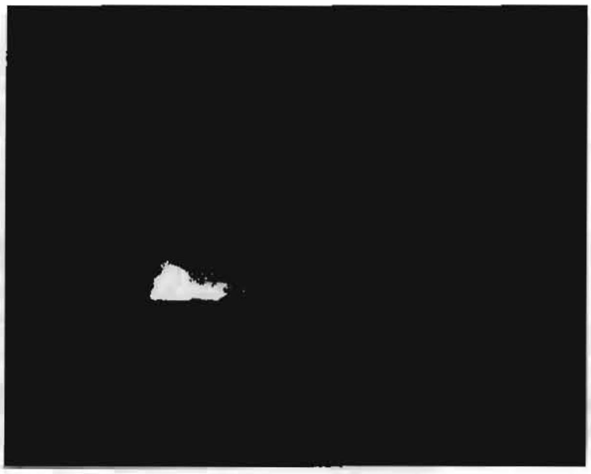


2 Minutes

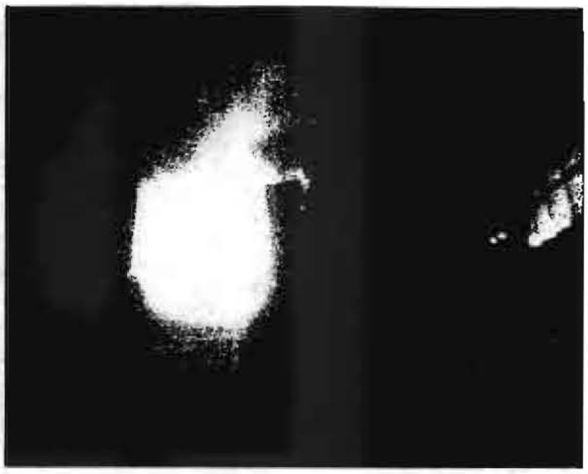


4 Minutes 30 Seconds

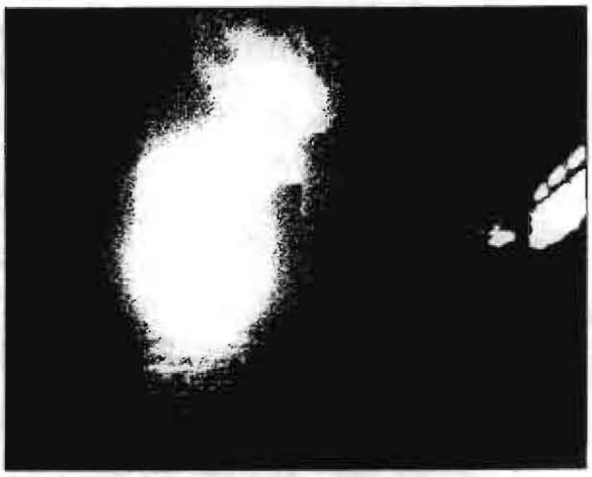
Figure 19 Still frame images from Test 5 Up to 4 minutes 30 seconds



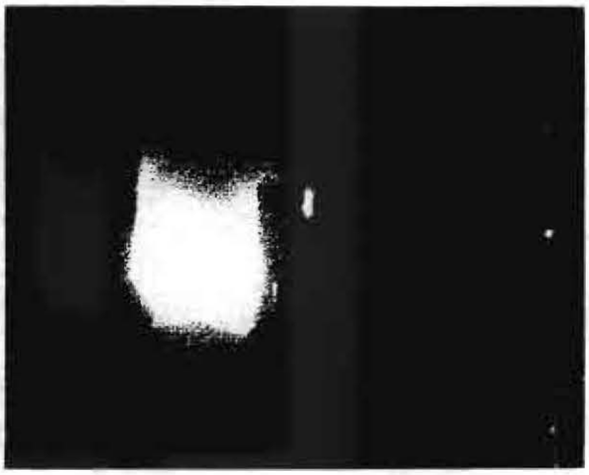
5 Minutes



5 Minutes 30 Seconds



6 Minutes



8 Minutes

9 Minutes

Figure 20 Still frame images from Test 5 5 - 9 minutes

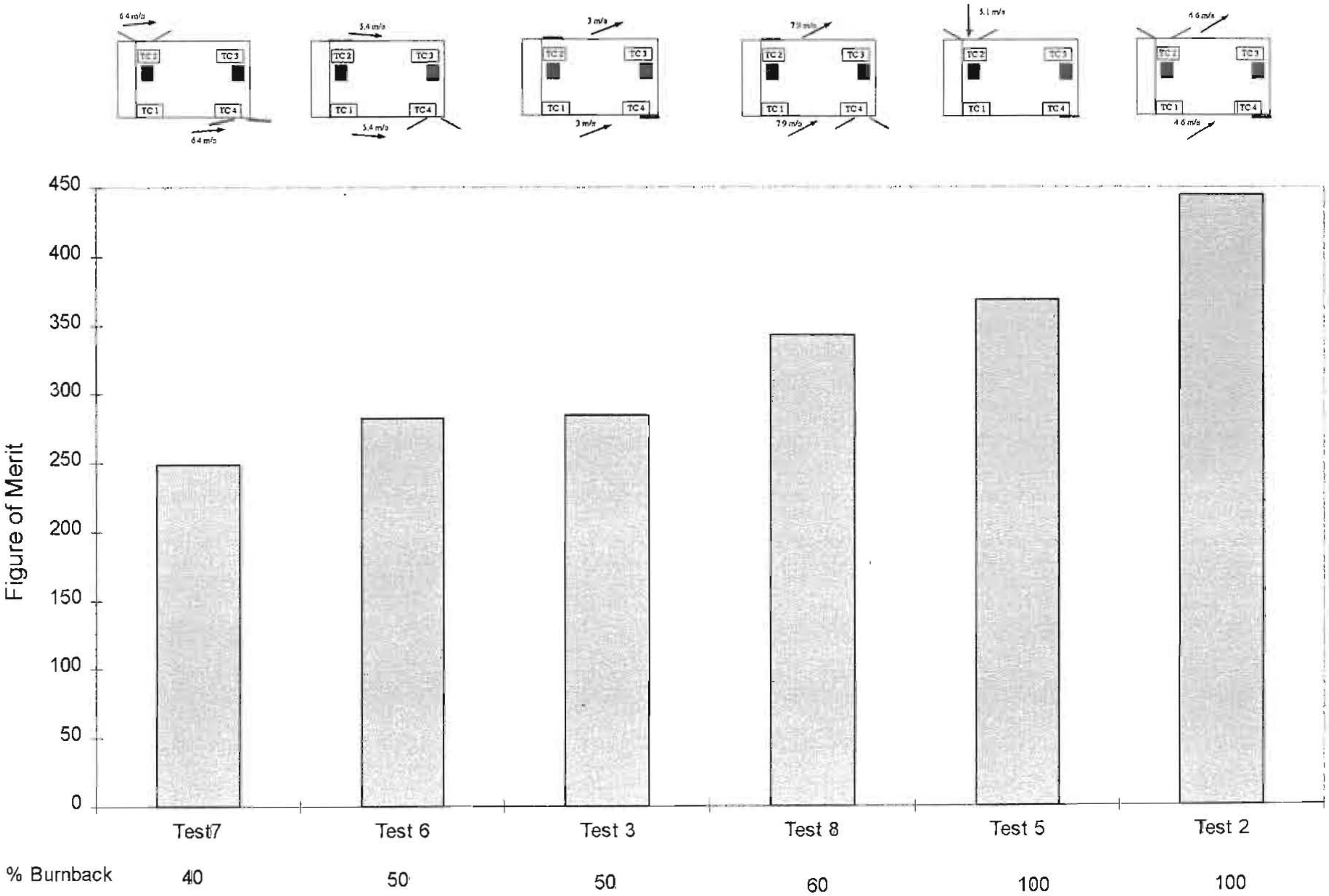


Figure 21 : Figure of merit from temperature trees

Appendix A : Safety Notes

Safety Notes

VALIDATION FIRE TESTS - Industrial B, November 1995

Introduction

A series of trials are to be carried out in the Industrial B building of the Fire Service College. Approximately 10 tests are planned in total.

The following instructions concern the safety aspects of these tests. These instructions must be adhered to throughout.

YOUR ATTENTION IS DRAWN TO THE CONTENTS OF THE FEU INSTRUCTIONS FOR HEALTH AND SAFETY AT WORK WHICH SHOULD BE READ IN CONJUNCTION WITH THIS DOCUMENT

Safety Helmets and safety shoes or boots will be worn at all times on the FSC fireground and inside the fireground buildings.

Safety Instructions

Personnel Directly Involved in the Fire Tests

John Foster - Project Officer, Instrumentation and Observer.

Guy Roberts - Instrumentation.

Bryan Johnson - Fuel handler, igniters and instrumentation

Kirsty Bosley - Video, instrumentation and fuel handler

SO Gary Pearson - Safety cover, observer.

DO Peter Snowden - Senior Fire Officer, Safety Cover and observer

John Price - Pump operator, instrumentation.

Dr M Thomas - Head of Unit, door/vent opener and observer.

J Rimen - Instrumentation, door/vent opener and observer.

The above allocation of duties are provisional and may be changed as the trials procedure develops. The trials will be conducted with the minimum number of personnel required to carry out the necessary tasks safely.

Casual observers

These are personnel who are not directly involved in the fire tests. These people may or may not be members of the Fire Experimental Unit. In all cases, they MUST read these safety notes before being allowed to observe a fire test. They must also sign a copy of the visitors form attached to this note. Visitors must not enter the Pod without permission.

Visitors must remain in the area designated for visitors at ground level and away from the building. They must not enter the building without the agreement of the Project Officer for each occasion of entry. Only instrumentation and video operators will be allowed in the Instrumentation Pod during the tests.

Project Officer

1 The project officer responsible for this work is John Foster. In the first instance, all matters of safety during these fire tests are his responsibility.

No Smoking

2. No smoking will be allowed around the trials site, in the instrumentation pod or in Industrial B.

Fuel

3. The following fuel will be used during these trials :-

Heptane (Norpar 7) in volumes up to 200 Litres of fuel will be required for each fire test. The Health and Safety Data Sheets for Norpar 7 can be found in the Health and Safety Data Sheet Library (in the Information Desk). ALL PERSONNEL INVOLVED IN THIS TRIAL SHOULD CAREFULLY READ THESE SAFETY DATA SHEETS

4. All fuel and fuel waste containers will be correctly labelled indicating their contents.

Foam Concentrates

5. The following types of foam concentrates may be used during these fire tests for safety cover:-

Type of Concentrate
Film Forming FP (FFFP)
Alcohol Resistant FFFP (FFFP-AR)
Aqueous Film Forming Foam (AFFF)
Alcohol Resistant AFFF (AFFF-AR)

The Health and Safety Data Sheets for these foam concentrates can be found in the Health and Safety Data Sheet Library (in the Information Desk). ALL PERSONNEL INVOLVED IN THIS TRIAL SHOULD CAREFULLY READ THESE SAFETY DATA SHEETS. In particular, gloves and goggles should be worn when pouring out and handling these foam concentrates.

Fuel Handling

6. The drums of Norpar 7 will be stored in the Car Compound of the Fire Service College. The quantities of fuel required for the tests will be transferred from the full drums at this site.

7. Several AFFF and dry powder extinguishers will be positioned around the fire test area prior to each test. Extinguishers will be located at the car compound to cover the fuel handling operations.

8. The person handling or measuring out fuels will be dressed in a Fleet Suit or A26 tunic and leggings, safety fire boots and wearing a protective helmet with integral face visor and flame resistant protective gloves. All operations which involve the handling of fuels will be overseen by a second person standing at a safe distance and holding a fully charged dry powder fire extinguisher and with access to a foam

extinguisher. This second person will be dressed in non-flammable clothing and have experience in the use of fire extinguishers. When fuel is being poured into the fire tray, two people will handle the drum and pour the fuel while two fire officers oversee them with firefighting equipment.

9. All fuel operations which involve the removal of caps from flammable liquid containers will be carried out with the protection specified in 6. above.

10. Where possible, the correct drum handling equipment should be used for moving fuel drums. Pushing drums along the ground should be avoided.

11. When fuel is being measured out, the fuel drums involved must be connected to an earth spike in the ground.

12. Measurement of fuel temperatures will only be carried out with an intrinsically safe thermocouple/indicator.

Fuel Ignition and Igniter Checking

13. The fuel will be ignited with electric igniters.

14. The igniters will be locked in a metal toolbox and placed in an empty locker of the trials appliance. This box will only be opened when connection of the igniters is due to take place. Only enough igniters for one days trials will be contained in the box at any one time. Up to three igniters will be used for each test.

15. Before each test the lead from the Instrumentation Pod DC supply will be connected to the igniter connector block. The lead and the connector block will be checked for damage and to ensure that it is long enough to reach the tray/trays.

16. With the DC supply switched on and the Safety Key inserted, the switch on the igniter control box will be pushed to the ON position. One operator will check the connections to the connector block adjacent to the fire tray using a multimeter. The multimeter should read approximately 14 volts DC. After the check the key will be removed and given to the person nominated to install the igniters. A short-out lead will be connected at the connector block on wiring the igniters. Ensure that the location of the clips for the igniters is known before the fuel is dispensed.

Electrical Equipment

17. All electrical equipment, plugs, sockets, distribution boards etc. will be lifted off the floor and positioned to prevent the ingress of liquid.

18. Only 110v equipment shall be used around the trials area. 240v transformers may be used inside Industrial B. 240v equipment may be used within the instrumentation pod via the cabins own 240v supply.

Additional Fire Cover

19. A fire appliance will be positioned adjacent to Industrial B with a full tank of water. This will be equipped with at least a diffuser branch, a foam inductor, foam branchpipe and a supply of foam concentrate. The pump will be running and manned at times during the transfer of fuel to the tray and the fire tests. The foam branches will be tested before any of these operations commence by producing foam.

The fire appliance will also have two dry powder extinguishers, a leather fire blanket and a first aid kit stowed in a locker.
The appliance will be started and warmed up before each test to ensure it functions correctly.

20 A main line will be connected directly to the appliance with sufficient hose length to allow it to be used to cover all fuel operations within Industrial B and cover any other area as directed by the Senior FEU Seconded Fire Officer. The appliance tank will be filled with potable water

Emergency Procedures

21. A portable telephone will be available in the Instrumentation Pod to summon assistance if required. In an emergency, the portable phone will be used to Dial 999 and request the appropriate service. The College Switchboard will then be contacted (01608-650831) to inform them of the emergency, request assistance and ensure that the gate are aware of the location of the emergency at Industrial B building . If a member of the FEU staff can be spared, he/she will be sent to the main gate to escort the emergency services to the scene.

22. A filtered air supply will be available to the pump operator. This will be used if it becomes necessary to operate the pump in smoke for a short period.

Notification to FSC

23. The FSC Switchboard, Appliance Bay (FSC Ambulance Station) and Medical centre will be informed that tests are in progress from the 20th to the 25th November..

Special Precautions

24. These trials will be carried out during November when the weather could be wintry. There may be icy conditions on the ground, particularly in the early morning period.

It will be necessary to access the roof area of the building to check and move the air velocity probes and associated equipment. Only climb the vertical ladders and access the roof area if you are confident to do this in the conditions at the time. Never do this unless a second person is in the immediate area of the roof.

A scaffolding safety platform will be erected around the vent area. Only work within the area of the safety platform and catwalk at roof level.

25. There may be occasions with high winds or slippery conditions when a decision will be made not to access this area. If in any doubt do not climb onto the roof area and consult the Project Officer.

26. Take particular care when climbing the vertical ladders.

27. It will be necessary to open and close the two roof vents at the north and south end of the building. The opening will be carried out from the first floor level using cables or pulleys. Ensure that no person is working near to the vents before they are opened. The opening sections of the vents are heavy and will have to be closed from the roof area. Ensure that the closing procedure is clear to all carrying out this task and fingers etc. are not in positions where they could be trapped.

28. Take care when entering the Pod and other vehicles in wet, frosty conditions or high winds.

Procedure for the trials

29. The quantities of fuel required for each test will be transferred into three drums in the car compound. The level in each drum will be measured using a calibrated dipstick. The safety precautions for fuel handling will be observed throughout.

30. The drums required for the next test, will be transported to the trials site in the tail lift vehicle. The vehicle will be parked in an area marked with flammable liquid signs until the fuel is required.

31. During final preparations for a test, the drums will be hoisted to the first floor and stored round the southern balcony in a marked area. The electric hoist installed in the building will be used together with the drum lifting attachment. If the hoist is not working then it will be necessary to lift the drums up the stairs. The drums shall be sealed and not vented during these operations.

32. When all the instrumentation has been checked and final preparations made for the test, the Project Officer will request the fuel to be transferred to the tray or trays. The fuel will be poured onto a water base in the tray. The fuel drum and tray should be connected together with an earthing cable during the transfer of fuel. Safety cover will be given for this operation as stated above. When the fuel has been poured into the trays, all but one member of staff and safety cover will leave the building.

33. The fuel temperature in each tray will be measured with an intrinsically safe thermocouple/indicator.

34. The igniters will be positioned in the clips at the edge of each tray.

35. On the instruction of the project officer, the shorting links on the igniters will be removed. All staff will leave the building and close all doors. The igniters will be initiated from the Pod using the safety switch.

36. If the fuel fails to ignite, then a Fire Officer with safety cover, will ignite the trays with a lance. The lance will be located on the first floor . Only 1 litre of fuel will be placed in a measuring cylinder for use with the lance. This measuring cylinder will be placed within a metal tray in a safe area on the first floor balcony. This fuel must be transferred to a safety container at the end of each working day.

37. The lance must be extinguished immediately after use.

38. The plan is for the fuel to burn for 5 minutes before the building is vented by opening a combination of vents and doors. These operations will be carried out from the first floor on the direction of the Project Officer.

39. It is possible that the fire could become oxygen starved during the 5 minute burn period. It is probable the fire will decrease in intensity and it is possible that it may go out. If extinction does occur then the building will be vented and no-one will enter until time has been allowed for all flammable vapours to have left the building.

40. Because of the conditions described above the doors should be opened with extreme care. The possibility of flames coming out of the door or vents cannot be excluded. The doors will be opened by personnel in protective clothing and covered by a fire officer with a branch. Where ever possible the doors will be opened using a length of wire so that the person opening the door will not be directly in front of the door.

41. When the fuel has burnt out the building will be allowed to clear of smoke and cool before entry.

42. It is not proposed to have observers in the building for the initial tests. If observers are required they will be trained firefighters wearing BA.

43. If it necessary to extinguish the fire, this will be carried out by trained firefighters under the command of the senior FEU Seconded Fire Officer present.

44. If access to the building is required during a test, the Fire Officers must note that one door may have air velocity instrumentation inside the door.

45. After the test is completed, the trays will be checked by a fire officer with a lance to ensure that no fuel remains. If no fuel remains then the waste will be pumped outside. If small quantities of fuel remain, then it will be burnt off in the tray. If the fire has been extinguished and significant quantities of fuel remain then it may be pumped into drums at ground level. The drums will then be taken onto an area of the fire ground and the fuel allowed to burn off. The precautions given above for fuel handling, safety cover and protective clothing will apply during these operations.

Use of Lifting Tackle

46. There is an electric hoist on the west side of the building, which will be used for hoisting the partly filled drums of fuel to the first floor. Only lifting tackle which

has been inspected and certified within the last 12 months must be used. No personnel must stand below the hoist when lifting is in progress.

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Additional Safety Instructions.

The vents at the south and north end of Industrial B have now been modified for the trials.

To open the vents the following must be carried out

A safety retaining screw must be removed from each vent at roof level. (Keep the screw in a safe place because it will be needed to secure the vent after closing).

The padlock on the appropriate release lever on the first floor must be unlocked and removed. The lever for the south vent is at the south end of the east 1st floor balcony and the lever for the north vent is on the east end of the north balcony.

The lever is then pulled down. The action of pulling the lever down releases a catch and the counter weights on the vents then open the vents quickly.

Before going on to roof level to work ensure that either:

the vents are padlocked in the closed position and the safety screws are in position on the vents.

or

the vents are open. For checking the instrumentation, the vents will need to be open.

It will obviously be necessary to go to roof level to remove the securing bolt. When carrying out this task, check the safety catch is engaged and be prepared for the vents to open if the safety catch is not properly secured.

No-one must unlock the padlock without the agreement of the Project Officer J Foster. J Foster will ensure that no-one is working near or under the vents before they are opened.

The vents must be closed from roof level but to do this the lever on the first floor must be in the closed position. Two strong persons are required to close the vents.

A scaffolding platform has been erected around both the vents. Keep within the safety rails of the platforms.

Before working on the probes and thermocouples in the vents, cone off the area on the first floor below the vents in case tools etc. are dropped.

Ensure that no-one is below the vents before they are opened or closed. The lining material of the vent cover can be dislodged during these operations.

Appendix B : Details of datalogger program and channel allocations

Instruments	Comment	Height/s m	Positions (m)		
Temperatures	Column 1	1m,2m,3m,4m,5m	1.29 from S wall	0.83 from E wall	
	Column 2	1m,2m,3m,4m	1.14 from S wall	3.75 from W wall	
	Column 3	1m,2m,3m,4m	1.08 from N wall	2.21 from W wall	
	Column 4	1m,2m,3m,4m,5m	0.85 from E wall	2.40 from N wall	
Smoke density		091m and 1.82m	5.50 from S wall	1.28 from W wall	
Radiometers	View of fire	1.36	5.97 from N wall	2.40 from W wall	
	View of ceiling	.23	4.78 from N wall	2.38 from W wall	
	View of floor	1.5	5.40 from N wall	1.97 from W wall	
Static pressure		0.4	2.0 from S wall	2.0 from E wall	
Temp at roof vents		165mm from top of vents	Position shown in figure		
Flame spread 1		2m and 3m	7.5 from S wall	1.28 M from W wall	
Flame spread 2		2m and 3m	6.5 M from N wall	1.28 M from W wall	

Table B1 : Locations of instrumentation

TASK 1

Title
Function Off

TASK 2

Title	
Function	Scan
Trigger	Timer
Delay	00-00:00:00:0
Scans *	
Scan	Interval
Interval	00-00:00:02.0
Channels	001-002, 004-006,
013, 022,	
	071, 073, 077, 081,
093	
Rate	100/s
Processing	Off
Data to be logged	All
Header	LogData
Output Device	Disk
Format	Compact
Tasks triggered	0
Tasks aborted	0

TASK 3

Title	
Function	Scan
Trigger	Timer
Delay	00-00:00:00.0
Scans *	
Scan	Interval
Interval	00-00:00:30.0
Channels	106-110
Rate	100/s
Processing	Off
Data to be logged	All
Header	LogData
Output Device	GPIB
Format	Compact
Tasks triggered	0
Tasks aborted	0

TASK 4

Title	
Function	Scan
Trigger	Task
Delay	00-00:00:00.0
Scans *	
Scan	Interval
Interval	00-00:00:01.0
Channels	003-006, 021, 083-
105,	
	121, 126
Rate	100/s
Processing	Off
Data to be logged	All
Header	LogData
Output Device	GPIB
Format	Compact
Tasks triggered	0
Tasks aborted	0

TASK 5

Title	
Function	Scan
Trigger	Timer
Delay	00-00:00:00.0
Scans *	
Scan	Interval
Interval	00-00:00:02.0
Channels	028
Rate	100/s
Processing	Off
Data to be logged	None
Header	LogData
Output Device	GPIB
Format	Compact
Tasks triggered	Triggered 4
Tasks aborted	0

TASK 6

Title	SMOKE
Function	Scan
Trigger	Timer
Delay	00-00:00:00.0
Scans *	
Scan	Interval
Interval	00-00:00:05.0
Channels	007-008, 014-019,
	041-050, 053-060,
063-080	
Rate	100/s
Processing	Off
Data to be logged	All
Header	LogData
Output Device	GPIB
Format	Compact
Tasks triggered	0
Tasks aborted	0

Table B2 : Datalogger Program

TASK 7

Title	
Function	Scan
Trigger	Timer
Delay	00-00:00:00.0
Scans *	
Scan	Interval
Interval	00-00:00:02.0
Channels	013, 022-025, 111-
116	
Rate	100/s
Processing	Off
Data to be logged	All
Header	LogData
Output Device	GPIB
Format	Compact
Tasks triggered	0
Tasks aborted	0

TASK 8

Title	
Function	Scan
Trigger	Timer
Delay	00-00:00:00.0
Scans *	
Scan	Interval
Interval	00-00:00:01.0
Channels	001-002, 009-012,
	029-030, 081-082,
131	
Rate	100/s
Processing	Off
Data to be logged	All
Header	LogData
Output Device	GPIB
Format	Compact
Tasks triggered	0
Tasks aborted	0

Table B2 : Datalogger Program (continued)

Data logger Channel Number	Instrument/ transducer	Location of instrument/ transducer	Height m	Logging rate vent closed	Logging rate vent open	Task
1	Micromanometer 1	Roof (Dedicated)		1	1	8
2	Micromanometer 2	Roof (Dedicated)		1	1	8
3	Micromanometer 3	Roof (Scan 1)			1	4
4	Micromanometer 4	Door (Dedicated)			1	4
5	Micromanometer 5	Door (Dedicated)			1	4
6	Micromanometer 6	Door (Dedicated)			1	4
7	Smoke Density 1	1st Floor	0.91	5	5	6
8	Smoke density 2	1st Floor	1.82	5	5	6
9	Wind speed 7m	7m		1	1	8
10	Wind Direction 7m	7m		1	1	8
11	Wind Speed 1m	1m		1	1	8
12	Wind Direction 1m	1m		1	1	8
13	Ultrasonic	1st Floor		2	2	7
14	Fire spread	2m (nr fire)	2	5	5	6
15	Fire spread	3m(nr fire)	3	5	5	6
16	Fire spread	2m(nr rads)	2	5	5	6
17	Fire spread	3m(nr rads)	3	5	5	6
21	Micromanometer 7	Door (Scan 2)			1	4
22	Radiometer 1 10	Towards Roof	0.23	2	2	7
23	Radiometer 2 10	Towards Floor	1.5	2	2	7
24	Radiometer 3 10	Towards Fire	1.36	2	2	7
25	Radiometer 4 10	Towards Fire	1.92	2	2	7
28	Switch	Pod 3				5
29	Micromanometer 8	Control Room		1	1	8
30	Event	Pod 3		1	1	8
41	Air temps 1st floor	T1	0.5	5	5	6
42	Air temps 1st floor	T1	1.0	5	5	6
43	Air temps 1st floor	T1	1.5	5	5	6
44	Air temps 1st floor	T1	2.0	5	5	6
45	Air temps 1st floor	T1	2.5	5	5	6
46	Air temps 1st floor	T1	3.0	5	5	6
47	Air temps 1st floor	T1	3.5	5	5	6
48	Air temps 1st floor	T1	4.0	5	5	6
49	Air temps 1st floor	T1	4.5	5	5	6
50	Air temps 1st floor	T1	5.0	5	5	6
53	Air temps 1st floor	T2	0.5	5	5	6
54	Air temps 1st floor	T2	1.0	5	5	6
55	Air temps 1st floor	T2	1.5	5	5	6
56	Air temps 1st floor	T2	2.0	5	5	6
57	Air temps 1st floor	T2	2.5	5	5	6
58	Air temps 1st floor	T2	3.0	5	5	6
59	Air temps 1st floor	T2	3.5	5	5	6
60	Air temps 1st floor	T2	4.0	5	5	6
63	Air temps 1st floor	T3	0.5	5	5	6
64	Air temps 1st floor	T3	1.0	5	5	6
65	Air temps 1st floor	T3	1.5	5	5	6
66	Air temps 1st floor	T3	2.0	5	5	6
67	Air temps 1st floor	T3	2.5	5	5	6
68	Air temps 1st floor	T3	3.0	5	5	6

Table B3 : Datalogger Channel Allocations

Data logger Channel Number	Instrument/ transducer	Location of instrument/ transducer	Height m	Logging rate vent closed	Logging rate vent open	Task
69	Air temps 1st floor	T3	3.5	5	5	6
70	Air temps 1st floor	T3	4.0	5	5	6
71	Air temps 1st floor	T4	0.5	5	5	6
72	Air temps 1st floor	T4	1.0	5	5	6
73	Air temps 1st floor	T4	1.5	5	5	6
74	Air temps 1st floor	T4	2.0	5	5	6
75	Air temps 1st floor	T4	2.5	5	5	6
76	Air temps 1st floor	T4	3.0	5	5	6
77	Air temps 1st floor	T4	3.5	5	5	6
78	Air temps 1st floor	T4	4.0	5	5	6
79	Air temps 1st floor	T4	4.5	5	5	6
80	Air temps 1st floor	T4	5.0	5	5	6
81	T/C airflow	Roof RM1	165mm from top of vent	5	5	8
82	T/C airflow	Roof RM2	"	5	5	8
83	T/C airflow	Roof RS1	"		1	4
84	T/C airflow	Roof RS2	"		1	4
85	T/C airflow	Roof RS3	"		1	4
86	T/C airflow	Roof RS4	"		1	4
87	T/C airflow	Roof RS5	"		1	4
88	T/C airflow	Roof RS6	"		1	4
89	T/C airflow	Roof RS7	"		1	4
90	T/C airflow	Roof RS8	"		1	4
91	T/C airflow	Roof RS9	"		1	4
92	T/C airflow	Roof RS10	"		1	4
93	T/C airflow	Door DM1			1	4
94	T/C airflow	Door DM2			1	4
95	T/C airflow	Door DM3			1	4
96	T/C airflow	Door DS1			1	4
97	T/C airflow	Door DS2			1	4
98	T/C airflow	Door DS3			1	4
99	T/C airflow	Door DS4			1	4
100	T/C airflow	Door DS5			1	4
101	T/C airflow	Door DS6			1	4
102	T/C airflow	Door DS7			1	4
103	T/C airflow	Door DS8			1	4
104	T/C airflow	Door DS9			1	4
105	T/C airflow	Door DS10			1	4
106	Surface Temp	On TC Tree 2		30	30	3
107	Surface Temp	On floor (Nr rads)		30	30	3
108	Surface Temp	On TC Tree 3		30	30	3
109	Surface Temp	On floor (Nr fire)		30	30	3
111	Rate Of Burn T/C	1st Floor		2	2	7
112	Rate Of Burn T/C	1st Floor		2	2	7
113	Rate Of Burn T/C	1st Floor		2	2	7
114	Rate Of Burn T/C	1st Floor		2	2	7
115	Rate Of Burn T/C	1st Floor		2	2	7
116	Rate Of Burn T/C	1st Floor		2	2	7
121	BCD IN	Scan 1			1	4
122	BCD IN	Scan 1			1	4

Table B3 : Datalogger Channel Allocations (continued)

Data logger Channel Number	Instrument/ transducer	Location of instrument/ transducer	Height m	Logging rate vent closed	Logging rate vent open	Task
123	BCD IN	Scan 1			1	4
124	BCD IN	Scan 1			1	4
125	BCD IN	Scan 1			1	4
126	BCD IN	Scan 2			1	4
127	BCD IN	Scan 2			1	4
128	BCD IN	Scan 2			1	4
129	BCD IN	Scan 2			1	4
130	BCD IN	Scan 2			1	4
131	BCD IN	Scan 2		1	1	8
132	BCD IN	Scan 3		1	1	8
133	BCD IN	Scan 3		1	1	8
134	BCD IN	Scan 3		1	1	8
135	BCD IN	Scan 3		1	1	8

Table B3 : Datalogger Channel Allocations (continued)

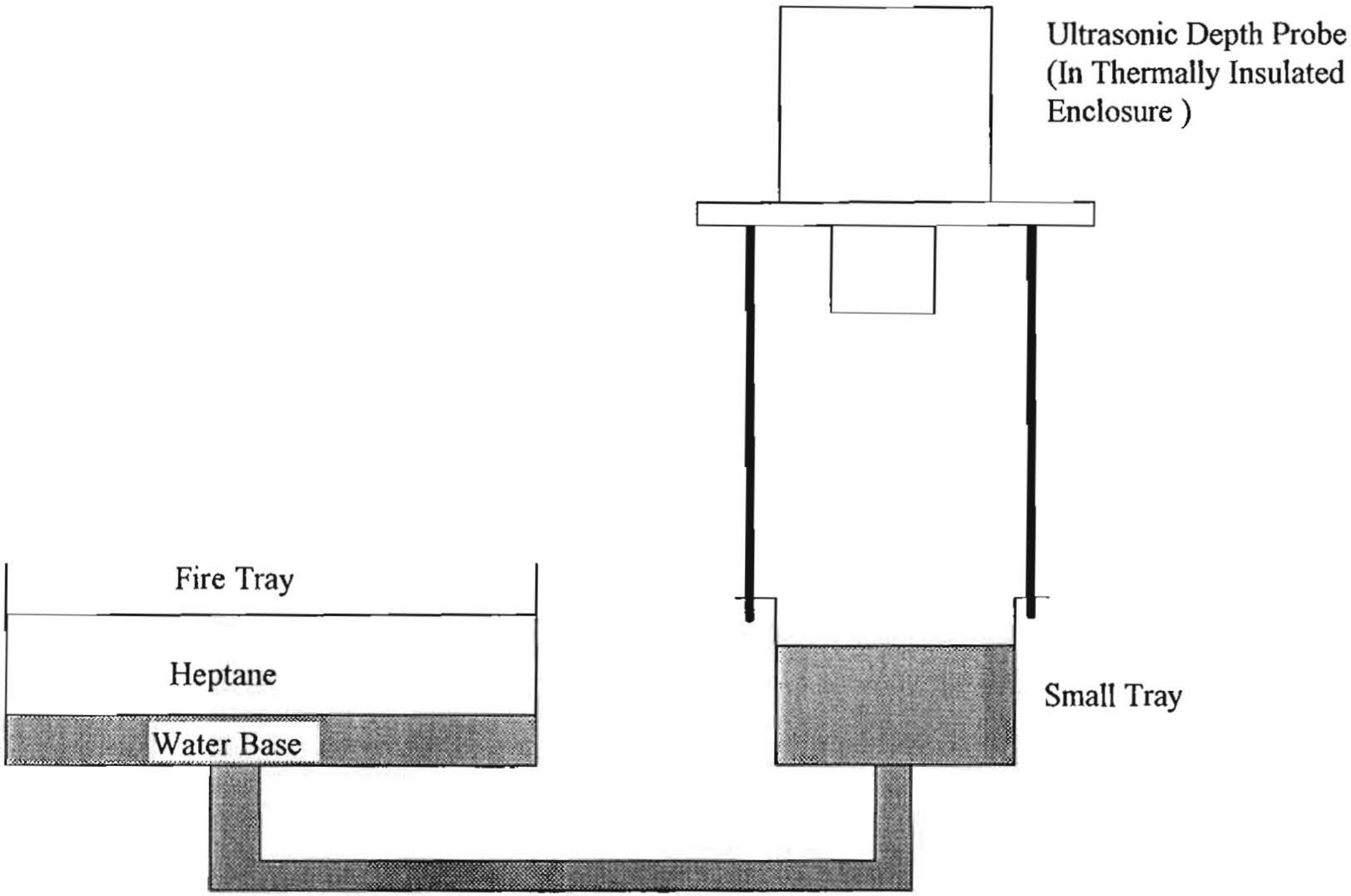


Figure B 1 : Schematic Diagram of Fuel Depth Measurement System

Appendix C : Results of Test 1.

Test 1

Date 20 November 1995
Weather Cloudy

North vent and SW door opened at 5 minutes

Air Temperature 7.0 ° C

Relative Humidity 86.4%

Tray 1	
Water depth -mm	32
Fuel depth-mm	30
Water Temp-°C	12.2
Fuel Temp- °C	8

Time from ignition	Observations
2:00	Fire still visible and burning well
5:05	SW Door (North half) open to 90 degrees
5:15	Other half of door open No smoke from SW door
9:36	Main fire out
10:30	Fire out

Notes on instrumentation

No Skystalk video record
Smoke density meter results unreliable because air flow to keep front glass clear was reversed.

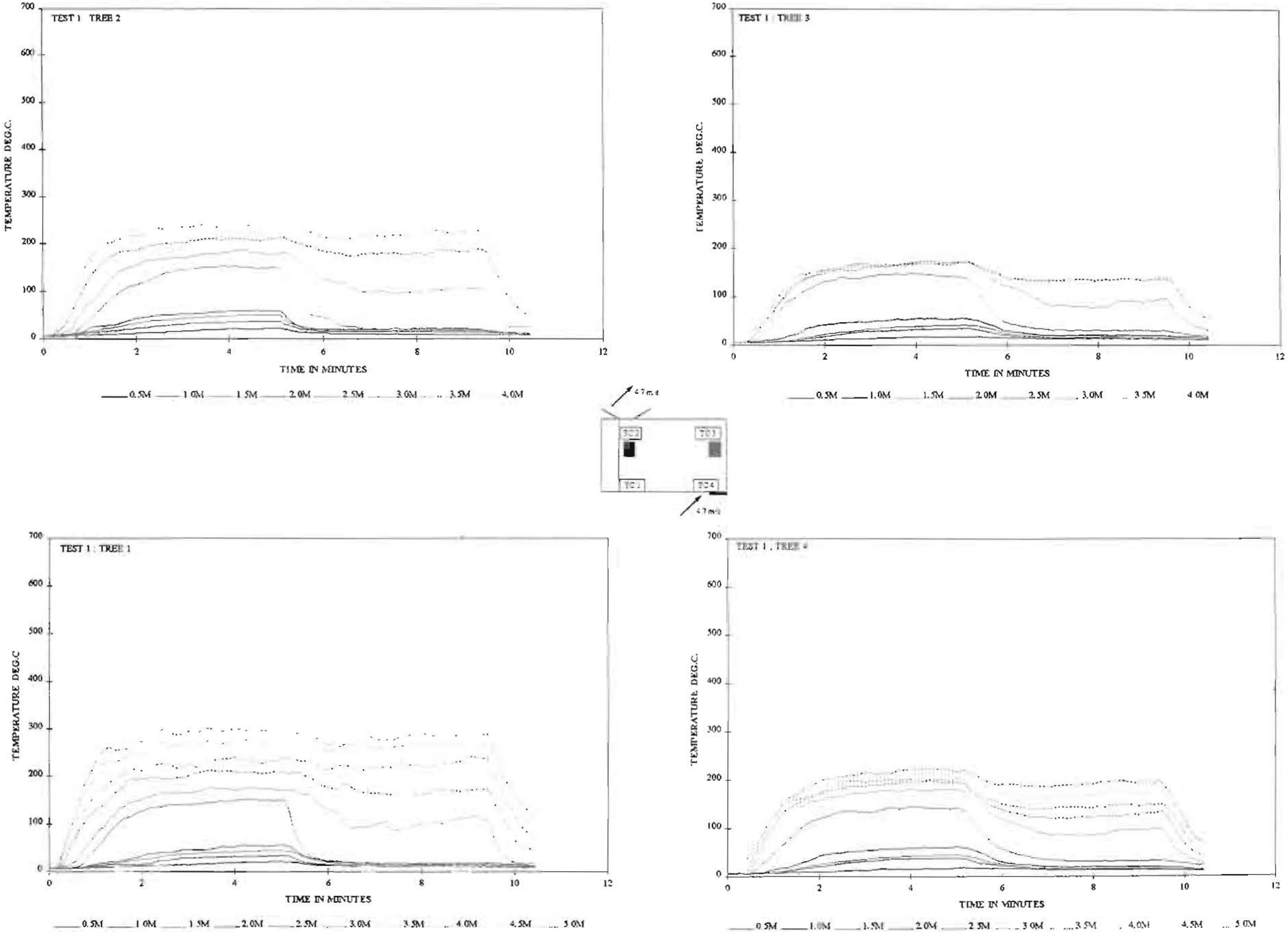
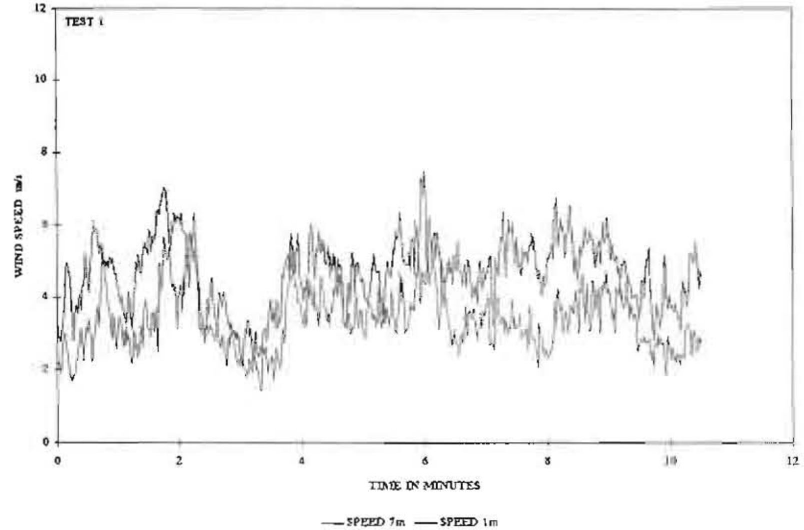
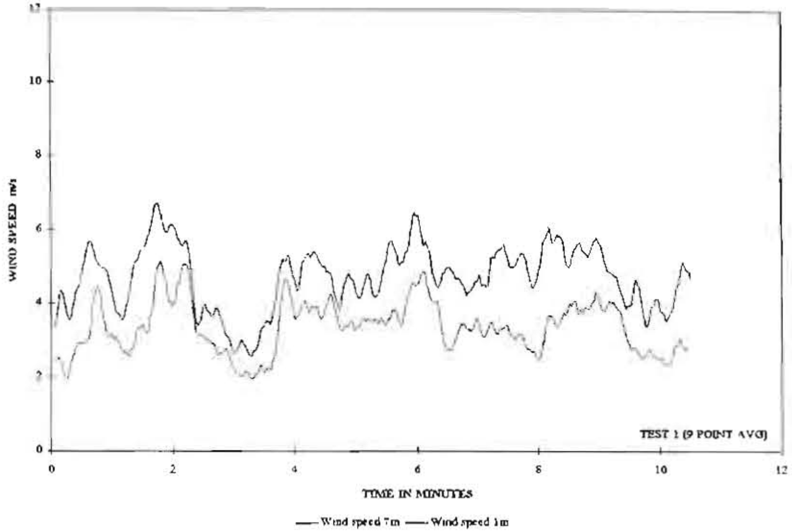
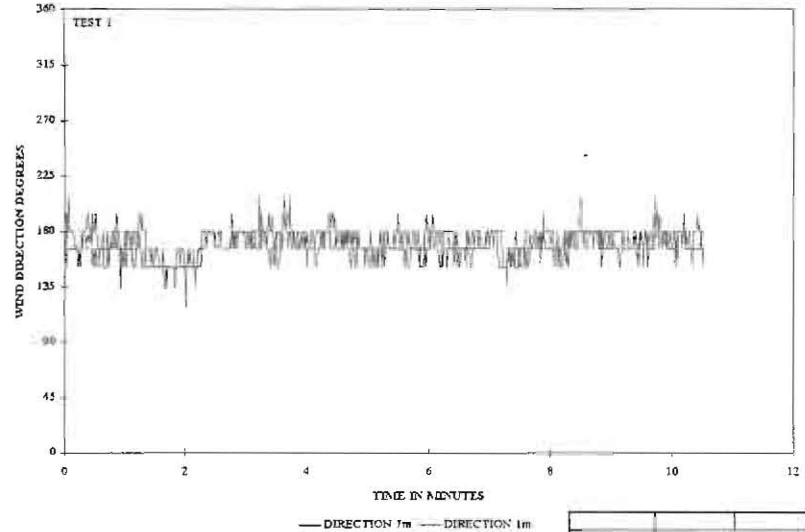
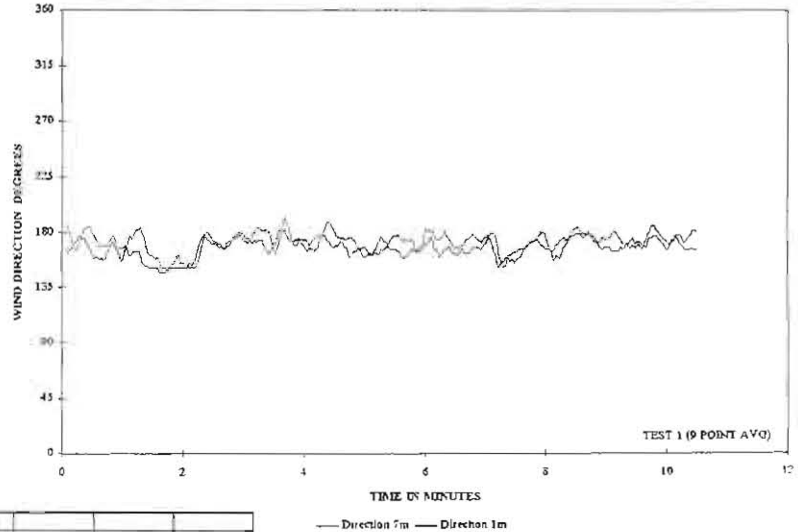


Figure C1 : Test 1. Gas Temperatures from Temperature Trees



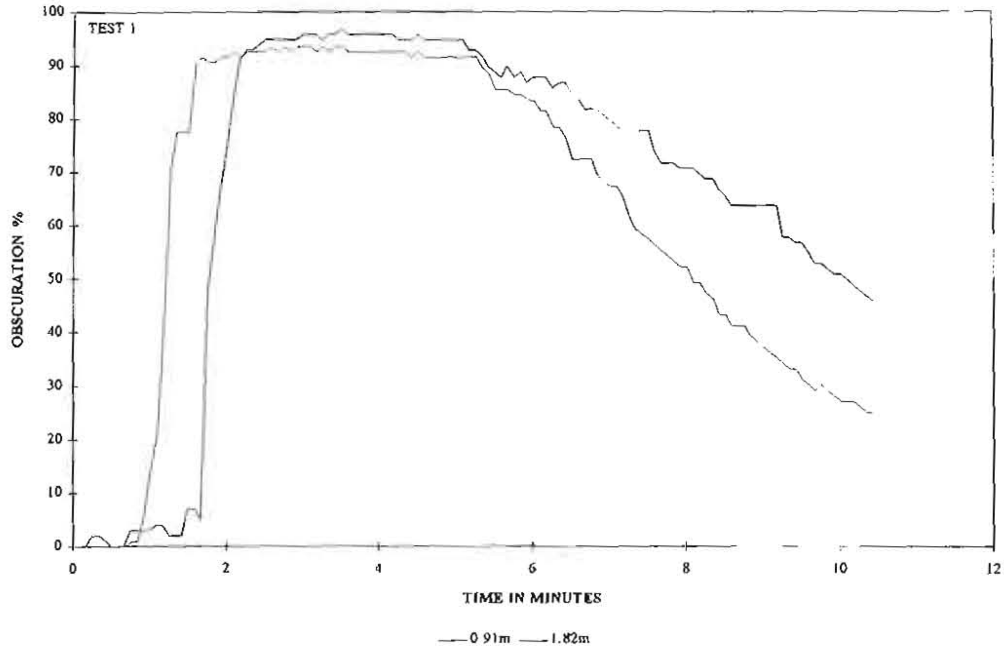






			TEST 1				
			WIND SPEED & DIRECTION				
7m				1m			
SPEED	0-5 MINS	5-10 MINS	0-10 MINS	SPEED	0-5 MINS	5-10 MINS	0-10 MINS
AVG	4.469677741	4.9515814	4.710956705	AVG	3.273619934	3.449751475	3.362122463
STD	[illegible]	[illegible]	[illegible]	STD	0.934544676	0.667083531	0.816612272
7m				1m			
DIRECTION				DIRECTION			
AVG	[illegible]	[illegible]	167.0564518	AVG	170.6875207	171.3211439	171.0125734
STD	11.38970713	9.23198806	10.37660737	STD	13.58423514	11.55206312	12.61148751

Figure C2 : Test 1. Wind Speed & Direction



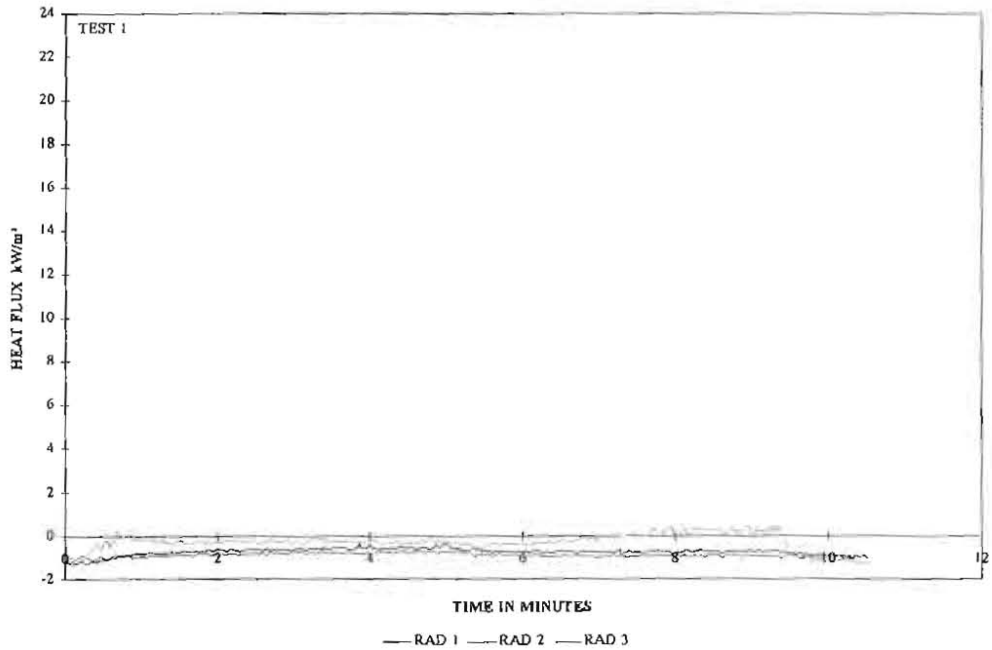
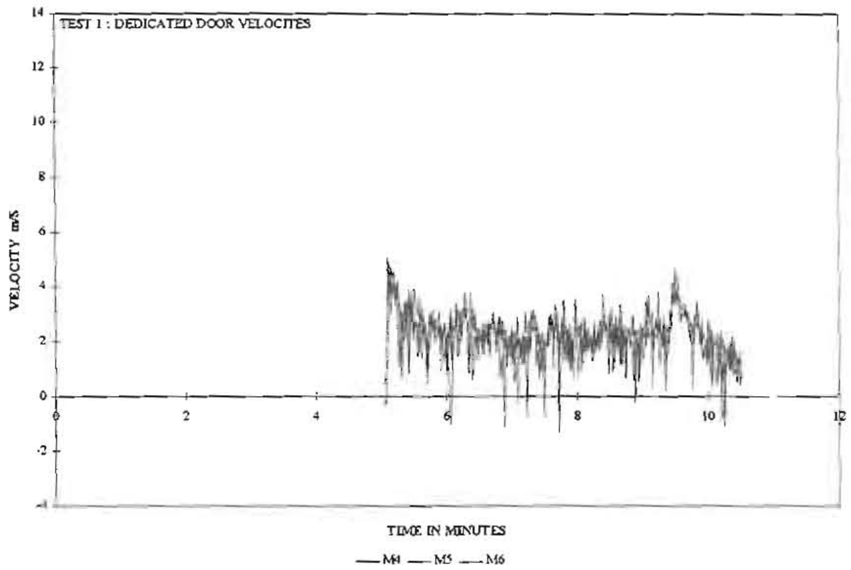


Figure C3 : Test 1. Smoke Obscuration & Heat Flux



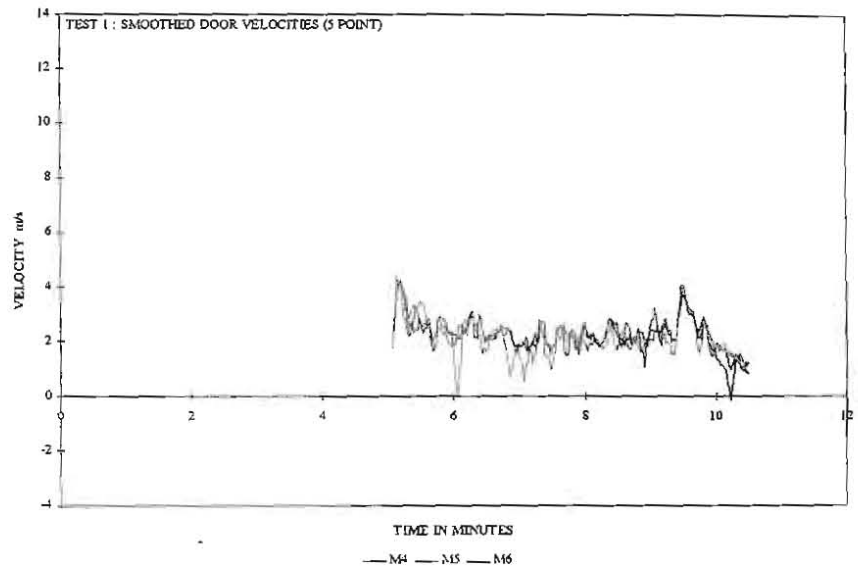


Figure C4 : Test 1.Gas Velocities in Doorway

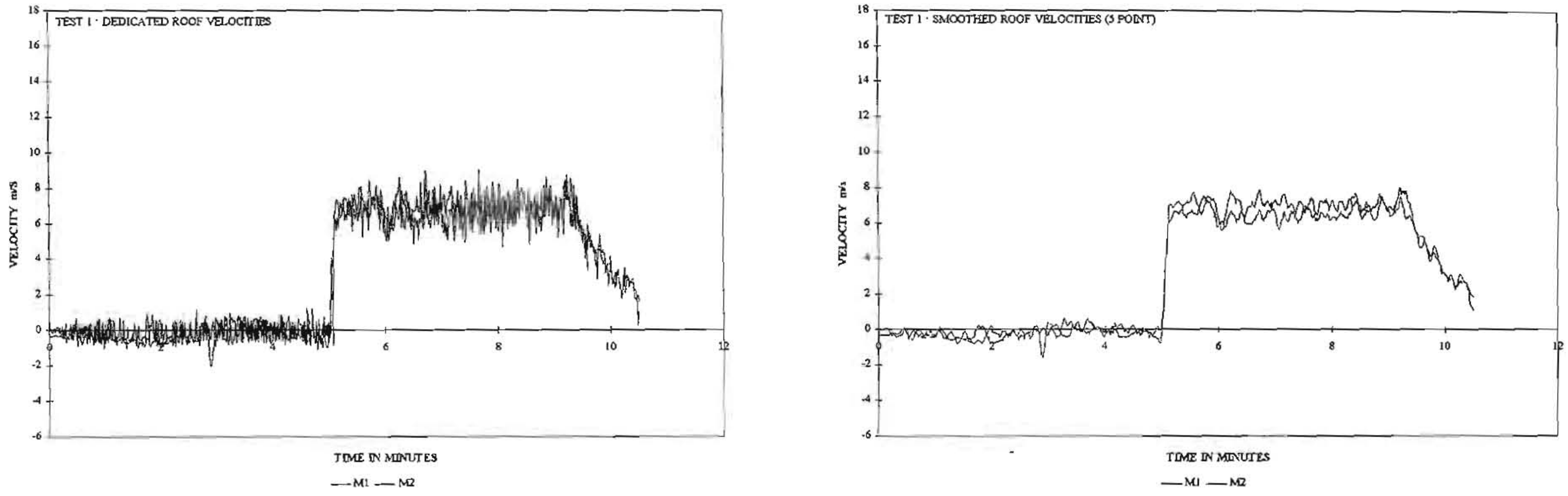


Figure C5 : Test 1.Gas Velocities in Roof Vent

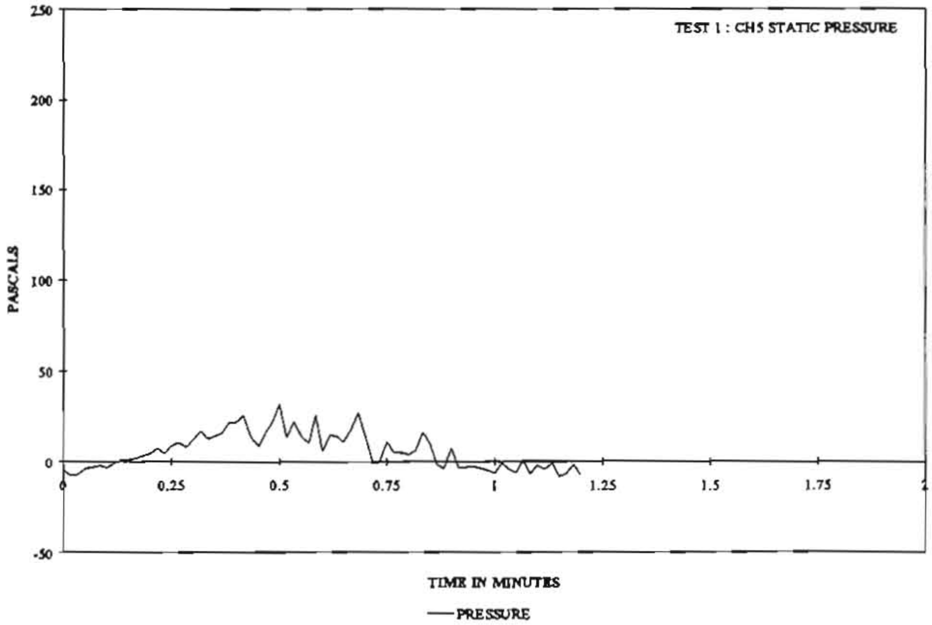


Figure C6 : Test 1. Static Pressure

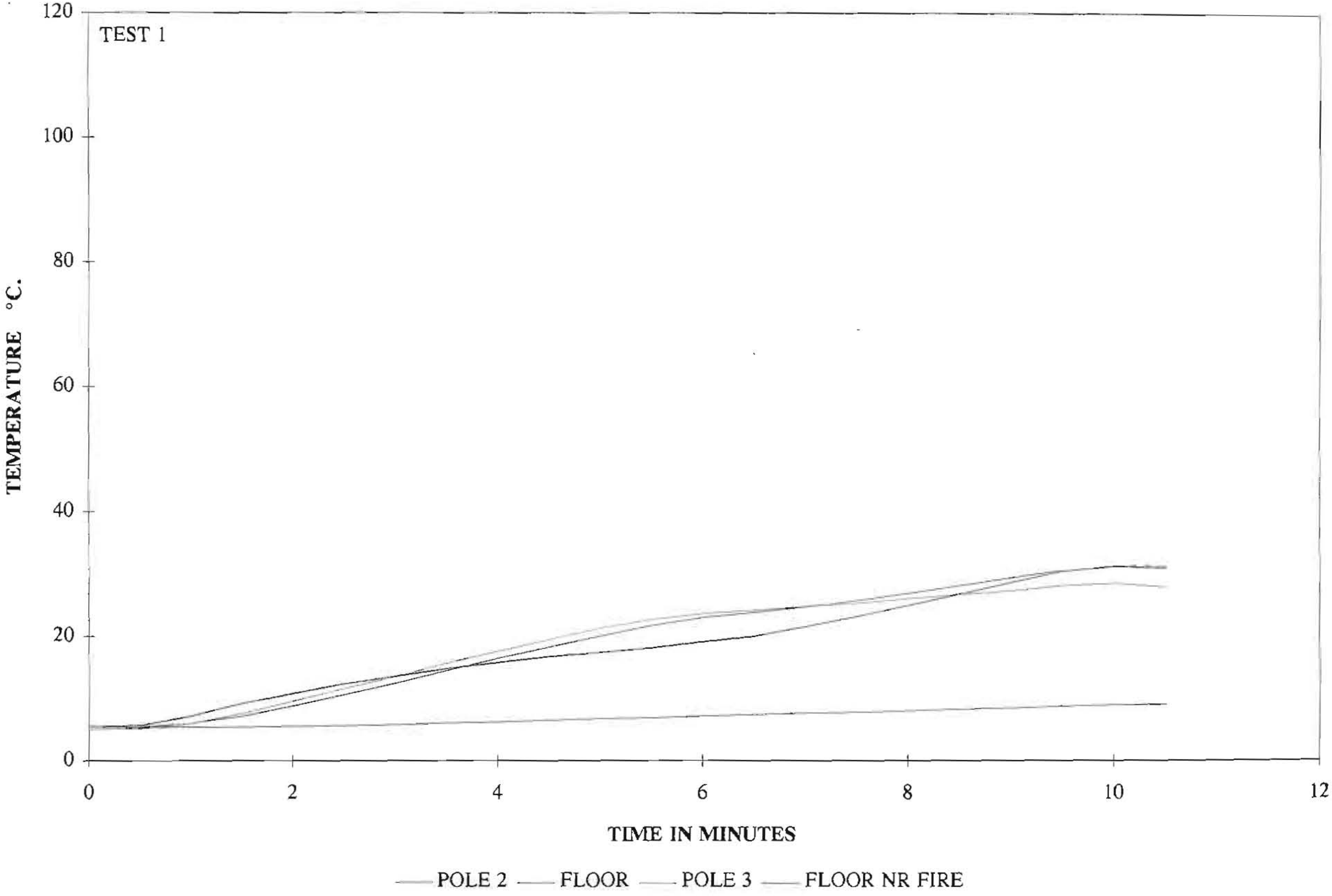


Figure C7 : Test 1. Surface Temperatures

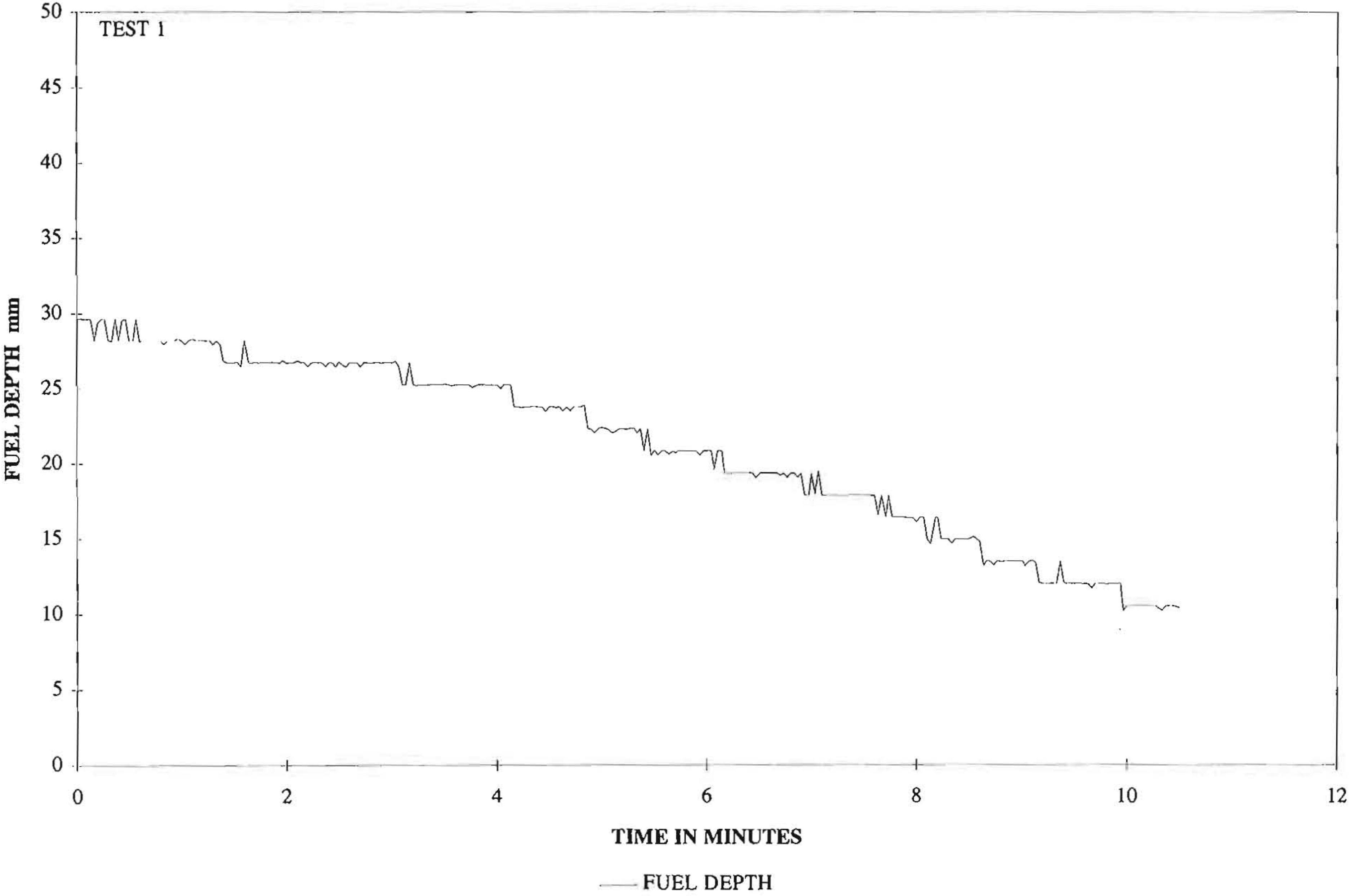


Figure C8 : Test 1. Fuel Depth

Appendix D : Results of Test 2.

Test 2

Date 21 November 1995
Weather Rain

North vent, south vent and SW door opened at 5 minutes

Air Temperature 7.2 ° C   Relative Humidity 91.9%

Tray 1	
Water depth -mm	33
Fuel depth-mm	34
Water Temp-°C	7
Fuel Temp- °C	6.6
Tray 2	
Water depth -mm	29
Fuel depth-mm	41
Water Temp-°C	8.6
Fuel Temp- °C	7.6
Tray 3	
Water depth -mm	26
Fuel depth-mm	37
Water Temp-°C	9.9
Fuel Temp- °C	8.2

Time from ignition	**Observations**
0:10	Door blew open
	Smoke at South vent
	No smoke from low vents
3:15	Some pulsing from doors & low vents
5:00	South vent open
5:03	Door open to 90 degrees
5:21	Door fully open
	No smoke issuing from south door.
	Fire grows
10:08	Main fire out

Observations (JR)

JR observed flames from south vent on seven occasions at about 6 minutes. The flames were 1m in length.
There was no charring on the wood near to the radiometers.

Smoke density meter results unreliable because air flow to keep front glass clear was reversed.

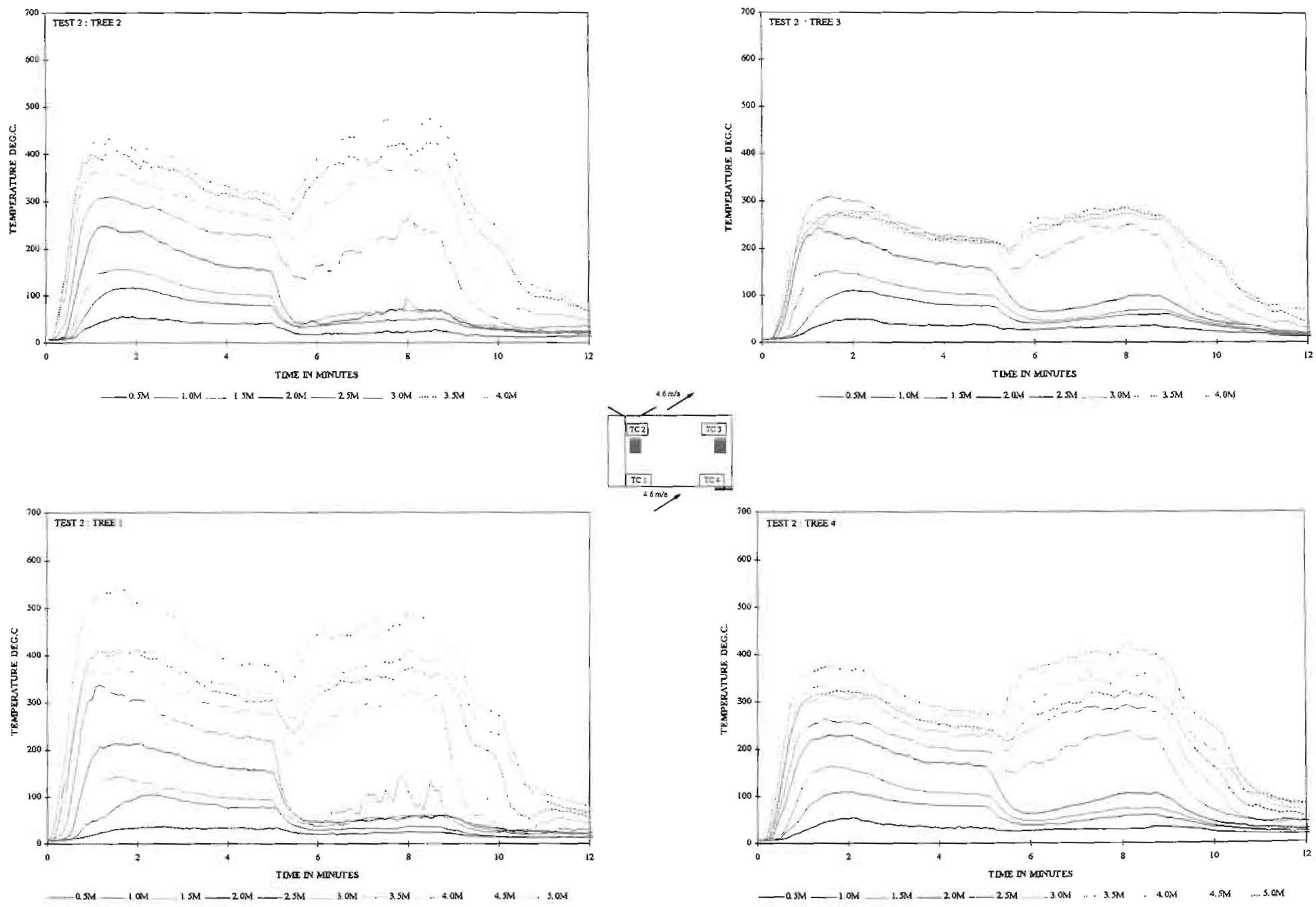
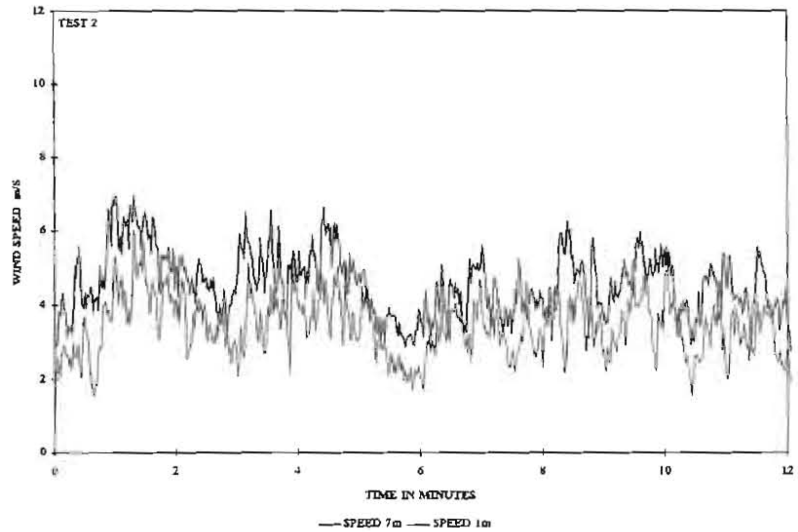
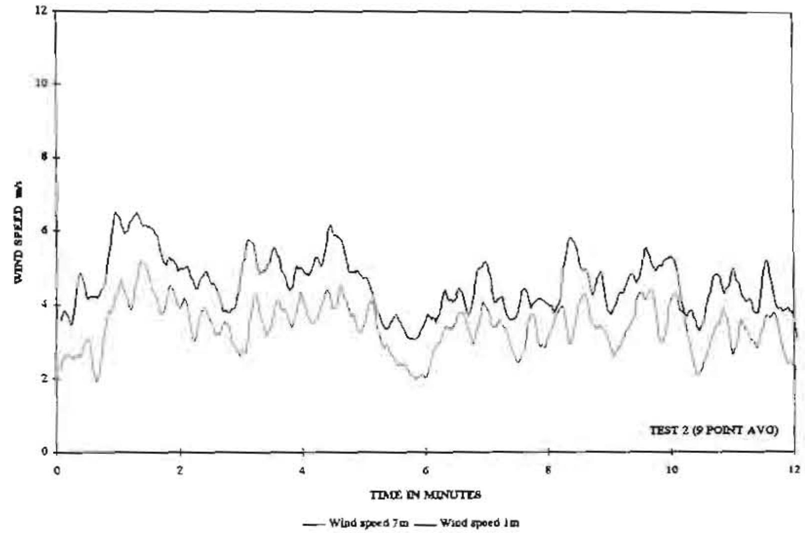
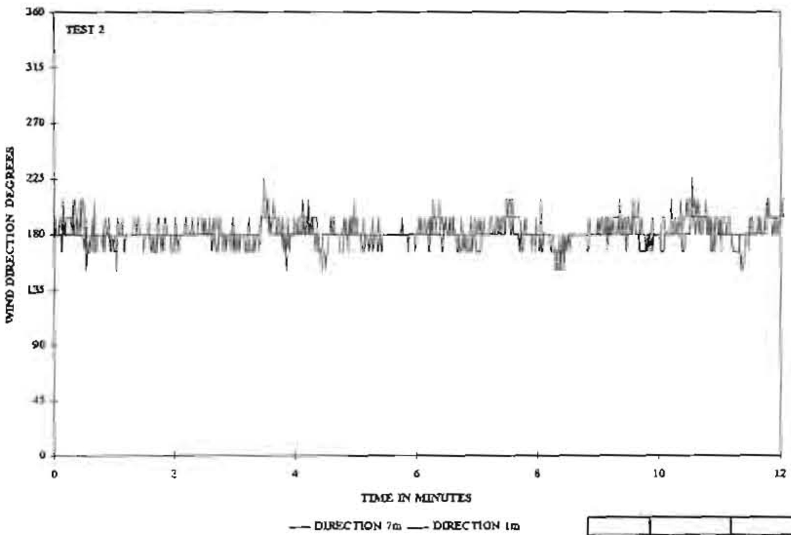
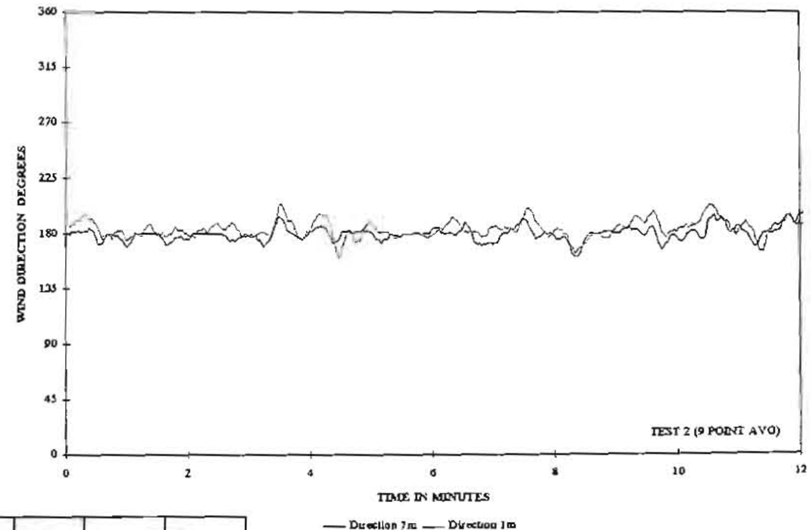


Figure D1 : Test 2. Gas Temperatures from Temperature Trees



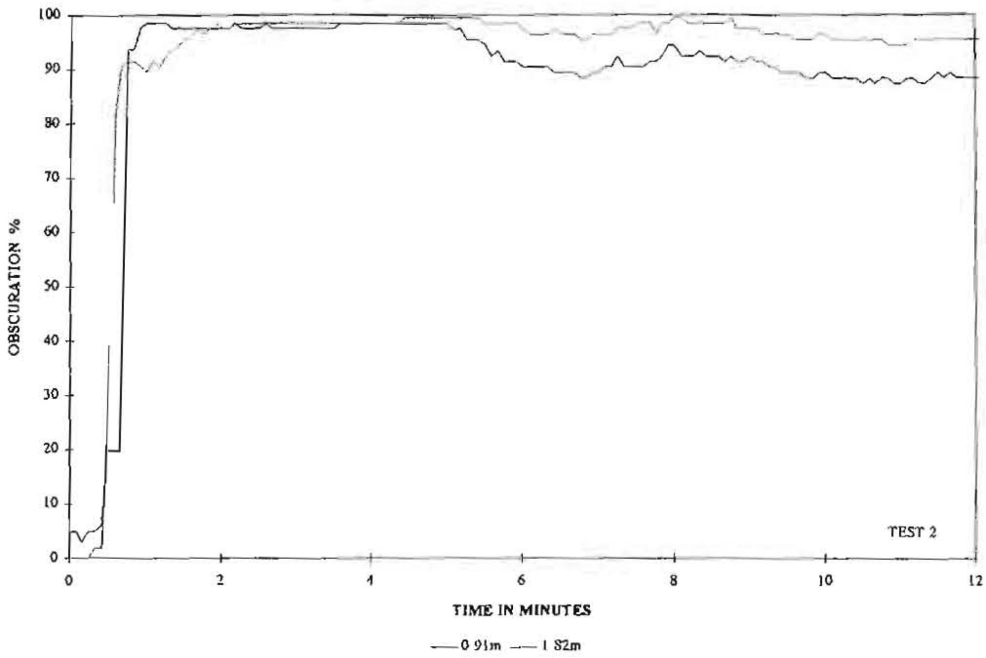






			TEST 2				
	WIND SPEED & DIRECTION						
7m				1m			
SPEED	0-5 MINS	5-10 MINS	0-10 MINS	SPEED	0-5 MINS	5-10 MINS	0-10 MINS
AVG	5.011813953	4.280299003	4.645750416	AVG	3.6567083	3.285717608	3.471838935
STD	0.867953654	0.766101497	0.896825232	STD	0.8290092	0.715780495	0.796295119
7m				1m			
DIRECTION				DIRECTION			
AVG	178.8679272	178.5523997	178.7074558	AVG	183.4768	183.1204234	183.3040808
STD	7.206170074	8.008951429	7.619491236	STD	11.371436	9.663066501	10.55253679

Figure D2 : Test 2. Wind Speed & Direction



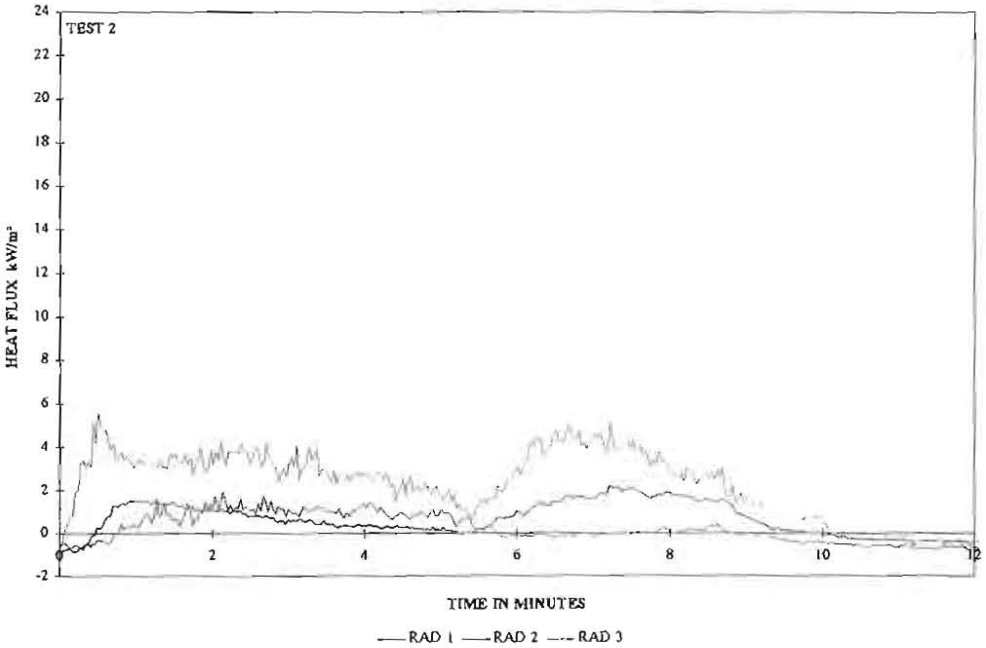
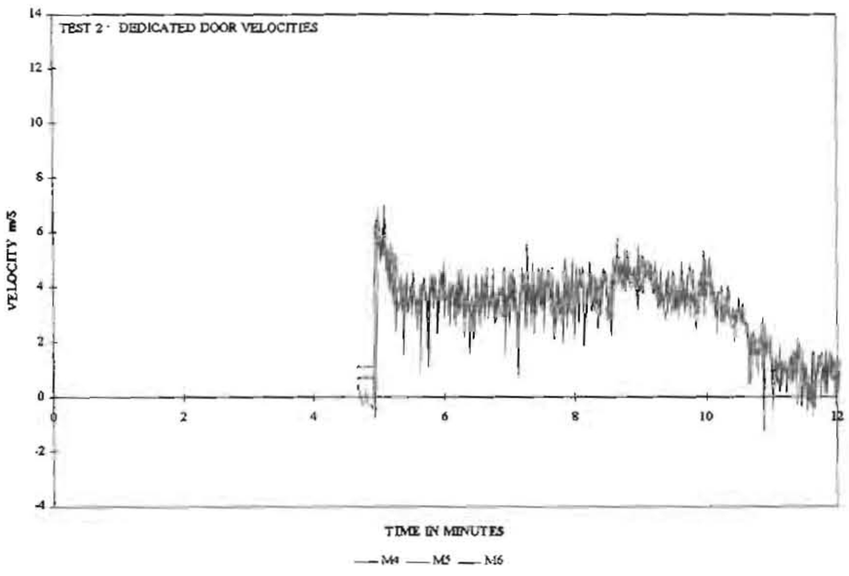


Figure D3 : Test 2. Smoke Obscuration & Heat Flux



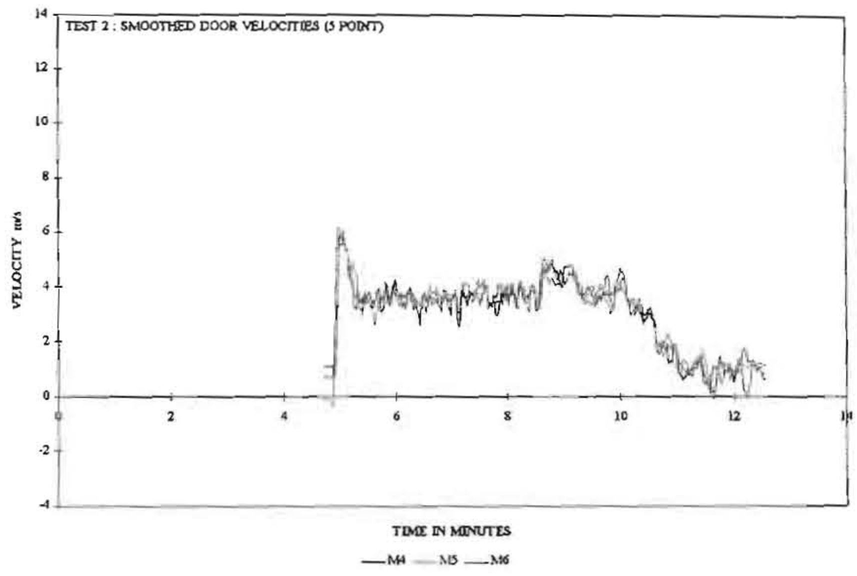
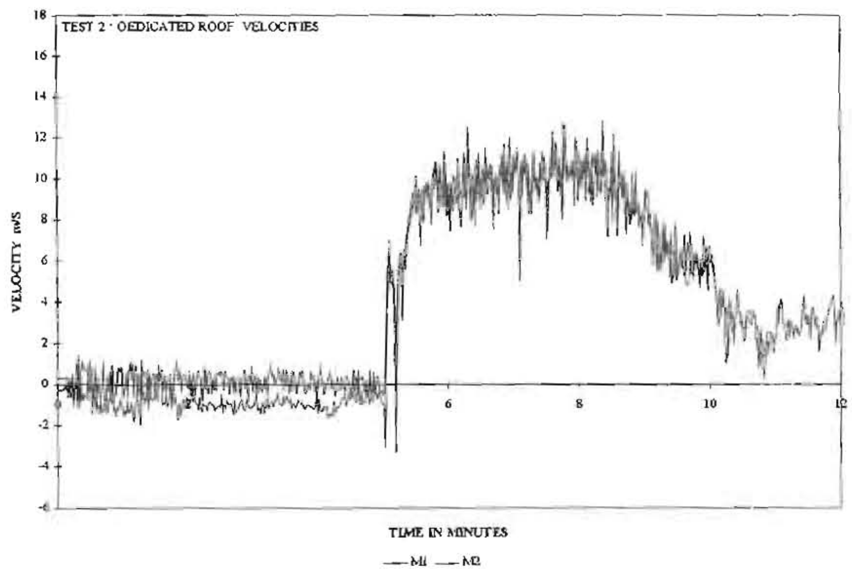


Figure D4 : Test 2. Gas Velocities in Doorway



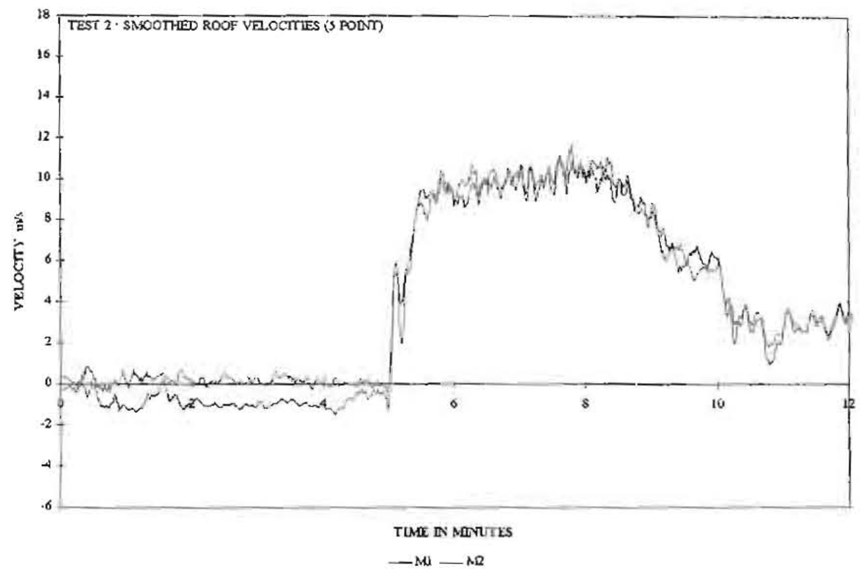


Figure D5 : Test 2 Gas Velocities in Roof Vent

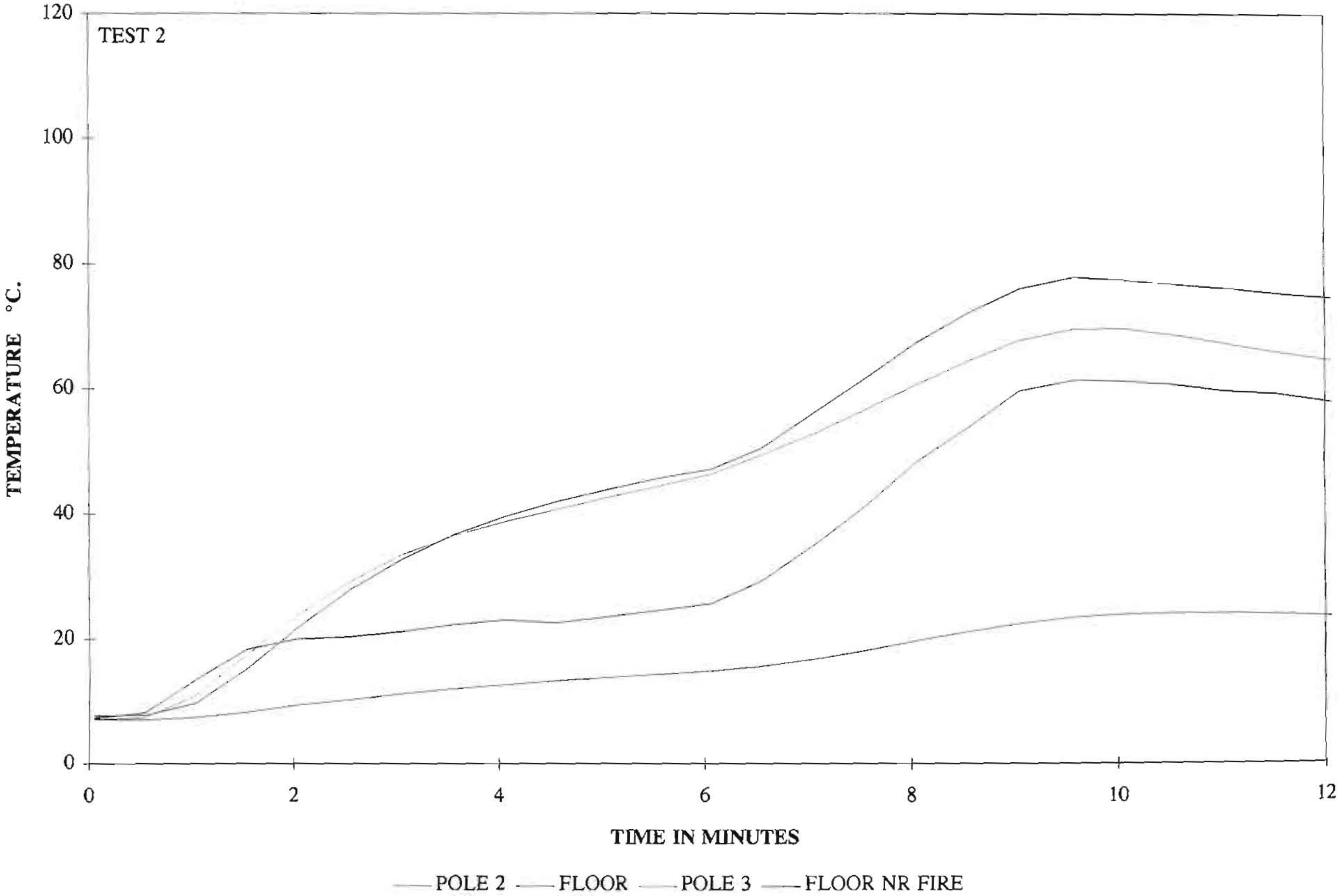


Figure D7 : Test 2. Surface Temperatures

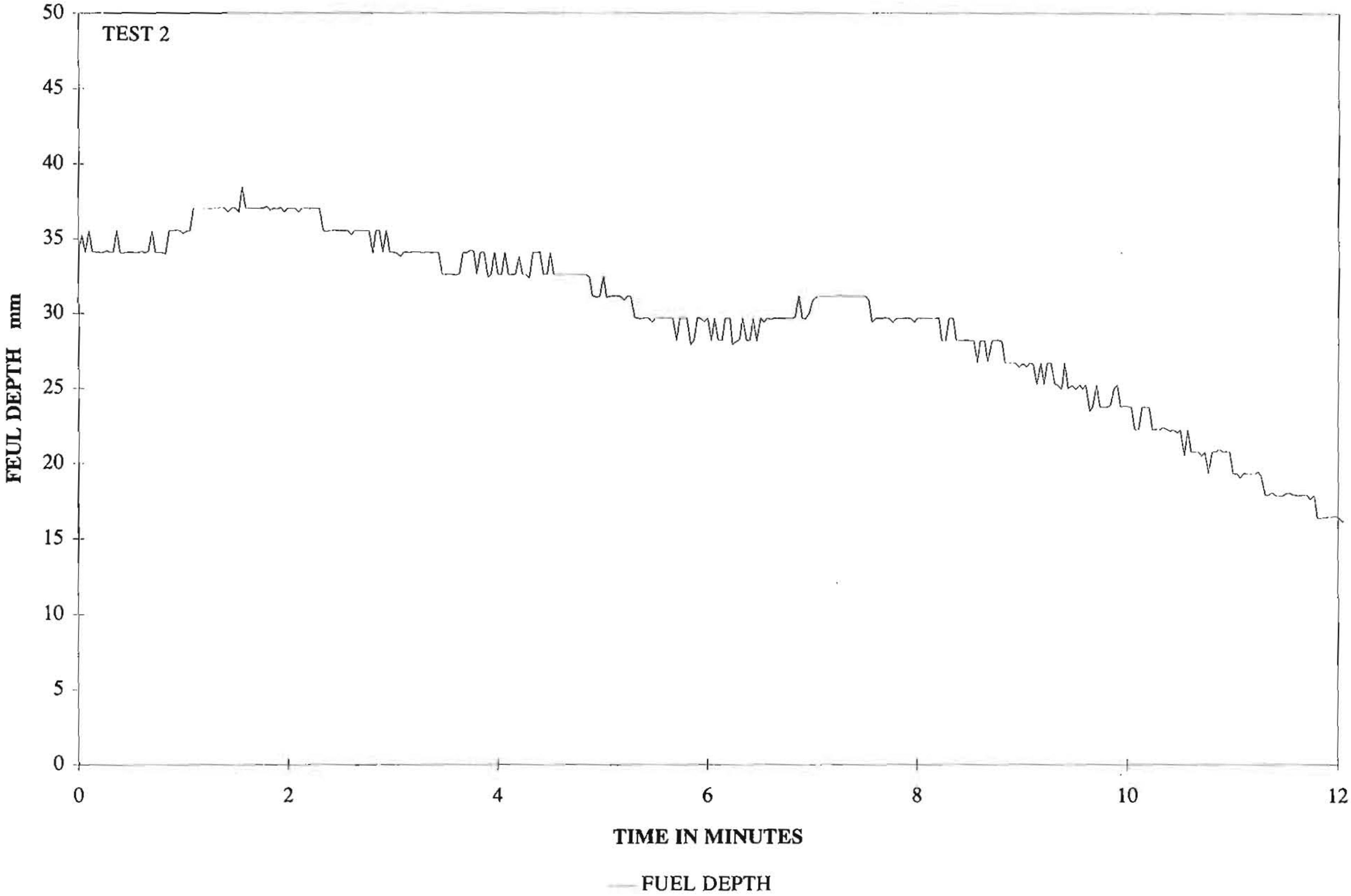


Figure D8 : Test 2. Fuel Depth

Appendix E : Results of Test 3.

Test 3

Date 21 November 1995
Weather Cloudy

North vent and south vent opened at 5 minutes

Air Temperature 8.1 ° C Relative Humidity 95.9%

Tray 1	
Water depth -mm	26
Fuel depth-mm	35
Water Temp-°C	18.7
Fuel Temp- °C	14.2
Tray 2	
Water depth -mm	28
Fuel depth-mm	40
Water Temp-°C	17.7
Fuel Temp- °C	13.8
Tray 3	
Water depth -mm	25
Fuel depth-mm	38
Water Temp-°C	16.6
Fuel Temp- °C	12.5

Time from ignition	Observations
0:23	Buzzing noise from NE door Lazy smoke from roof
1:10	Puffing at floor level on E side
5:02	Both vents open
6:02	More smoke vertical from S vent
6:40	More smoke from N vent and smoke blacker.
7:13	Flames from south vent
7:30	Blacker smoke exiting faster from N vent
9:50	No visible signs of flame

Smoke density meter results unreliable because air flow to keep front glass clear was reversed.

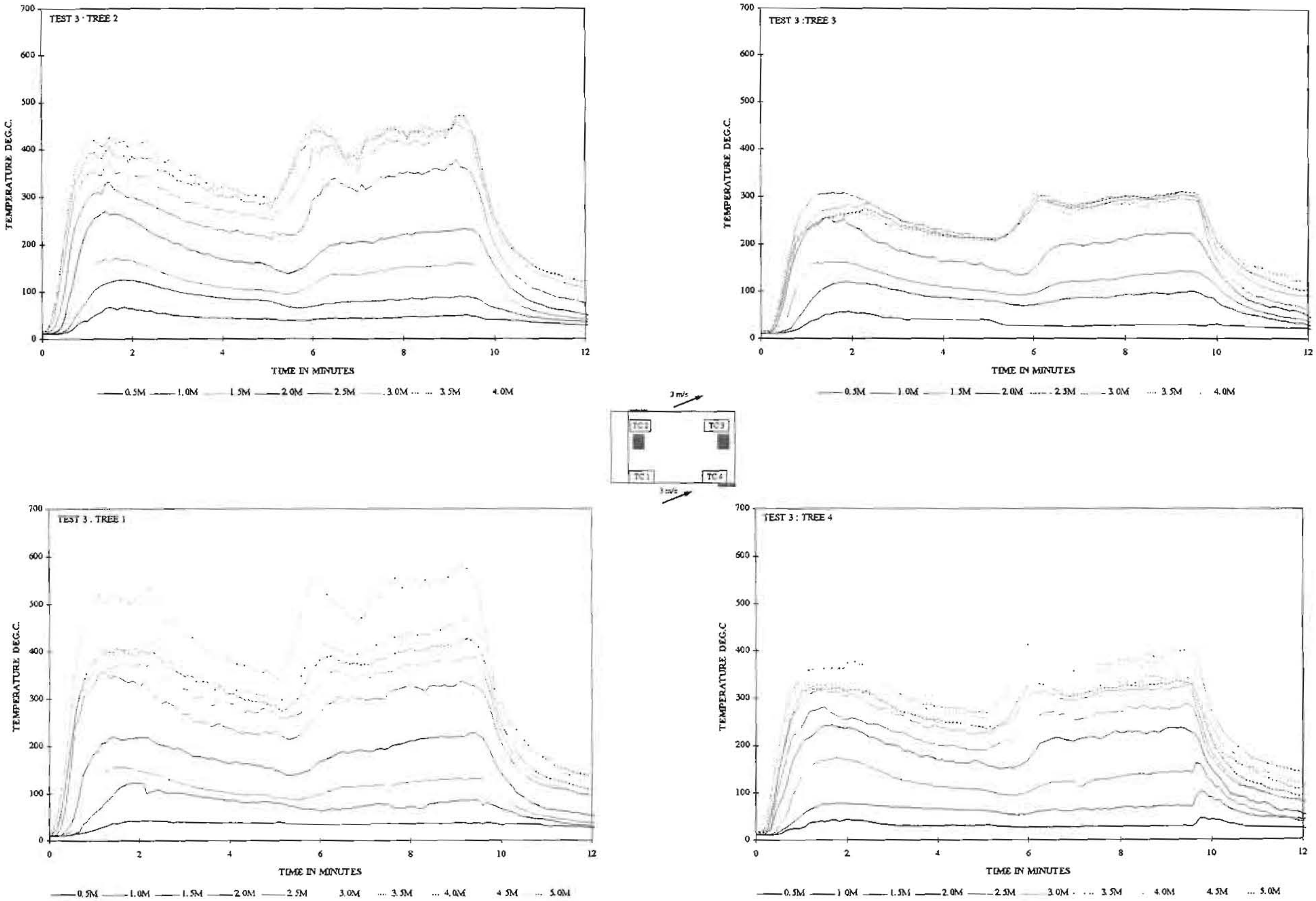
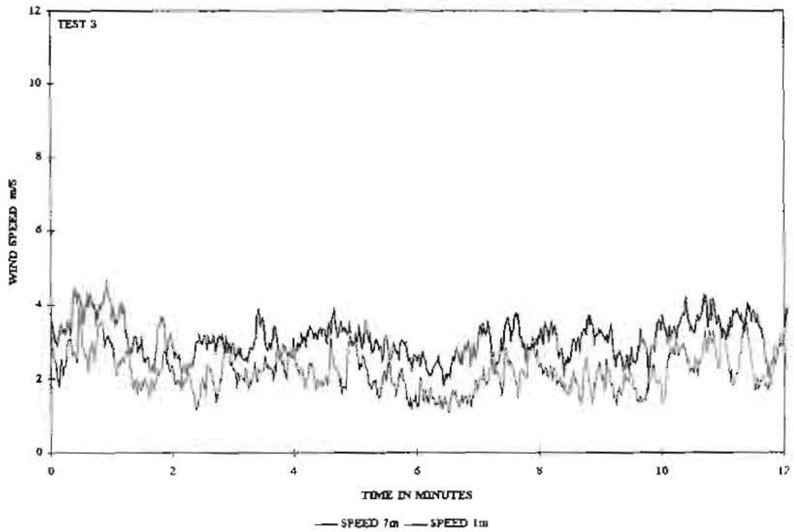
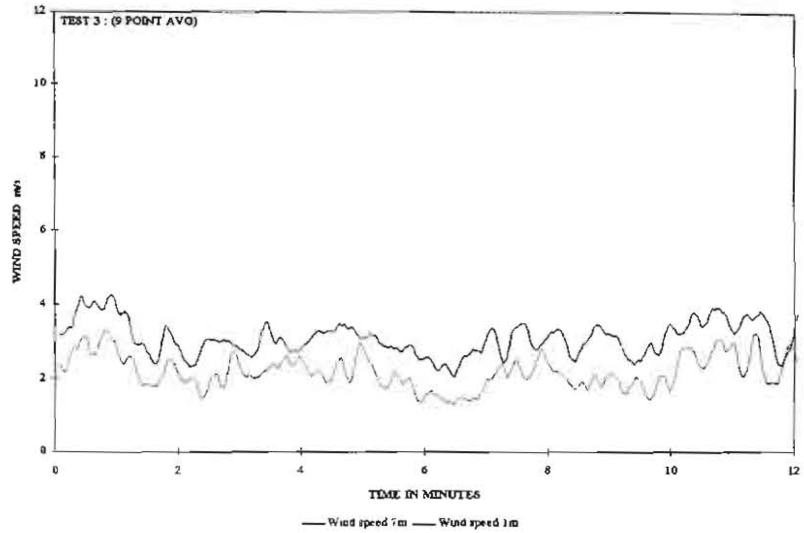
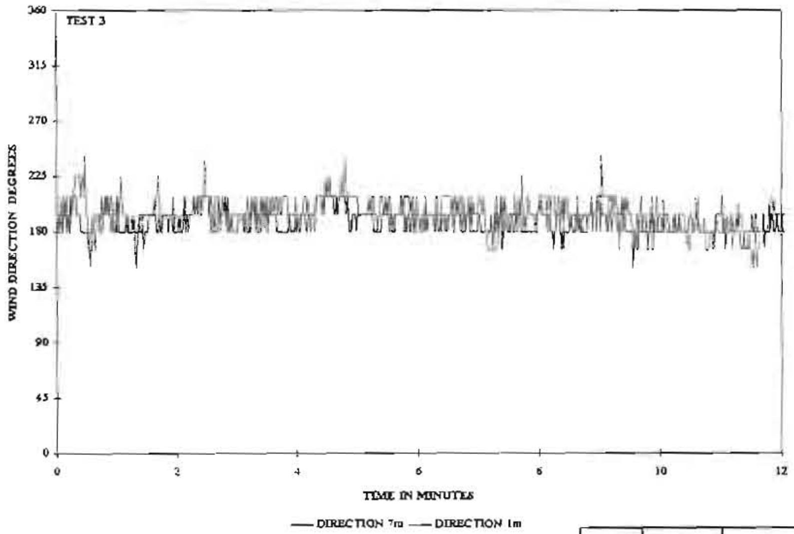
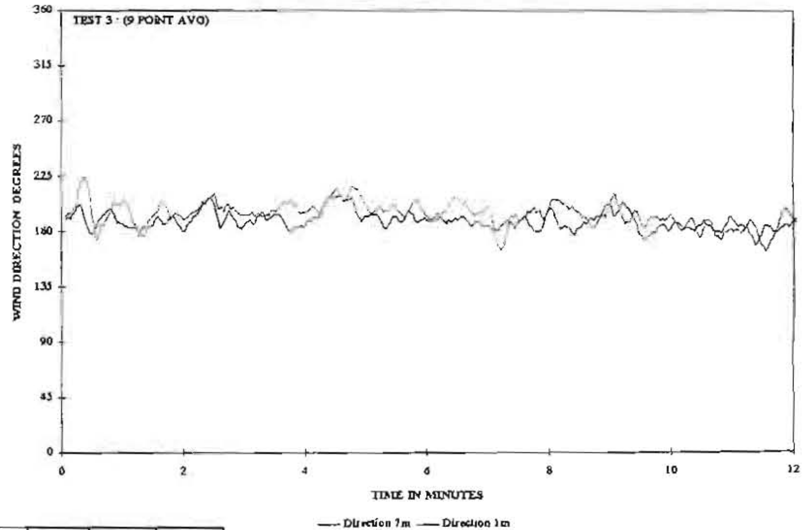


Figure E1 : Test 3. Gas Temperatures From Temperature Trees



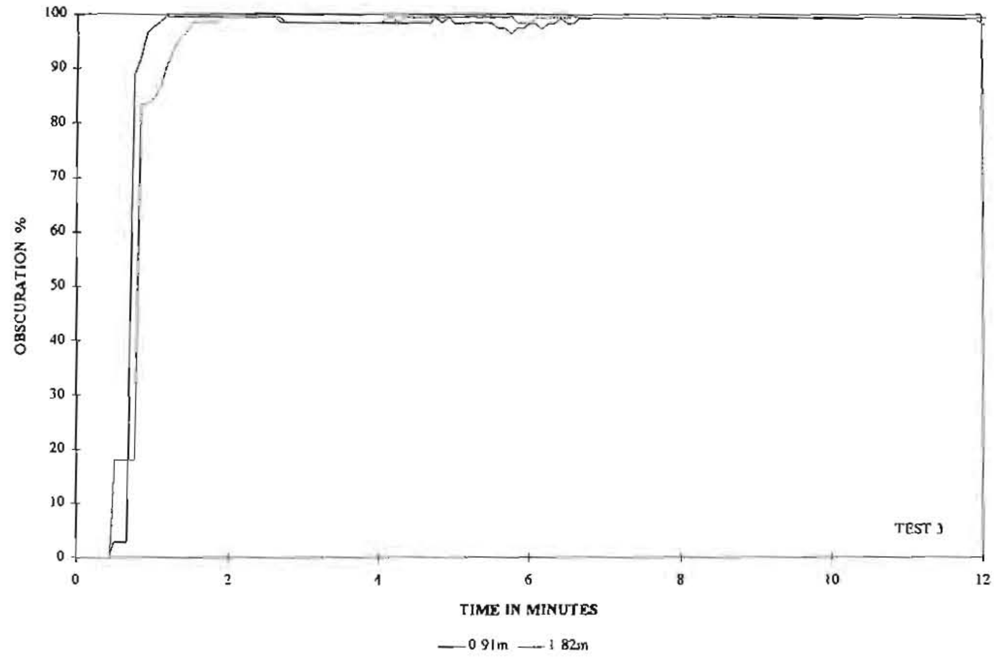






			TEST 3				
			WIND SPEED & DIRECTION				
7m				1m			
SPEED	0-5 Mins	5-10 Mins	0-10 Mins	SPEED	0-5 Mins	5-10 Mins	0-10 Mins
AVG	3.162142857	2.864448505	3.012923461	AVG	2.327019	1.9206664	2.1222584
STD	0.517519742	0.419331176	0.493941745	STD	0.48165	0.4196824	0.4939276
7m				1m			
DIRECTION				DIRECTION			
AVG	191.2117603	188.1849177	189.6913466	AVG	198.9447	194.90537	196.90446
STD	10.72495551	9.532968059	10.25766399	STD	13.57168	12.309586	13.103261

Figure E2 : Test 3. Wind Speed & Direction



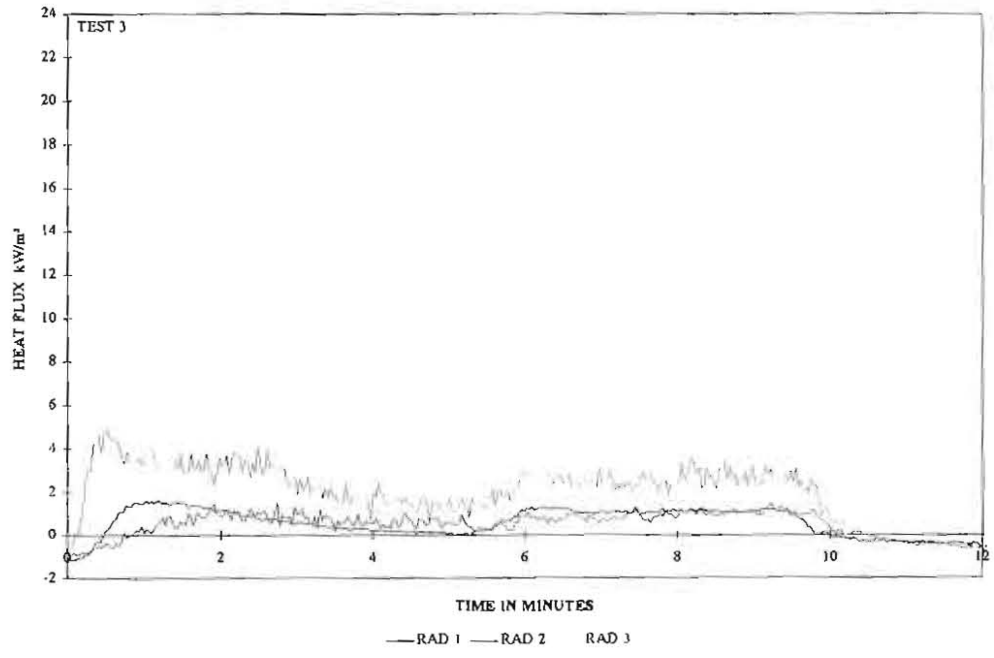
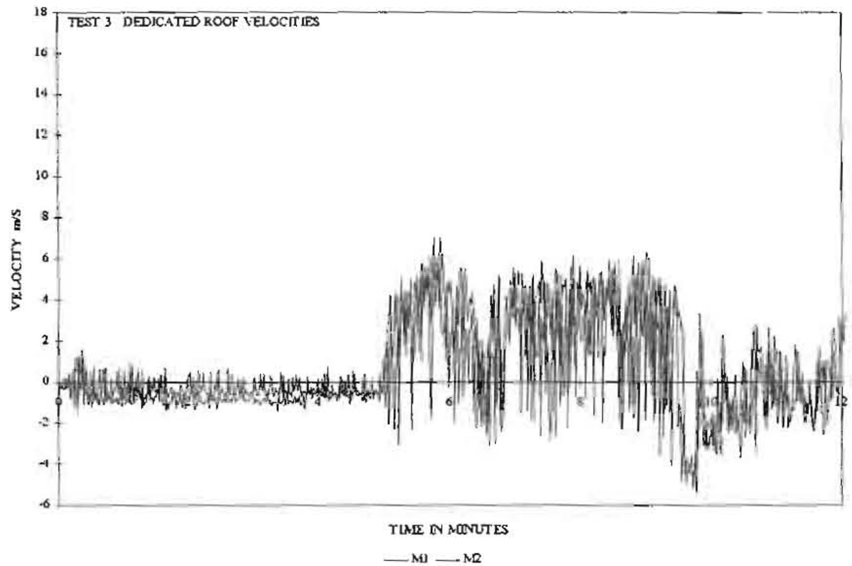


Figure E3 : Test 3. Smoke Obscuration & Heat Flux



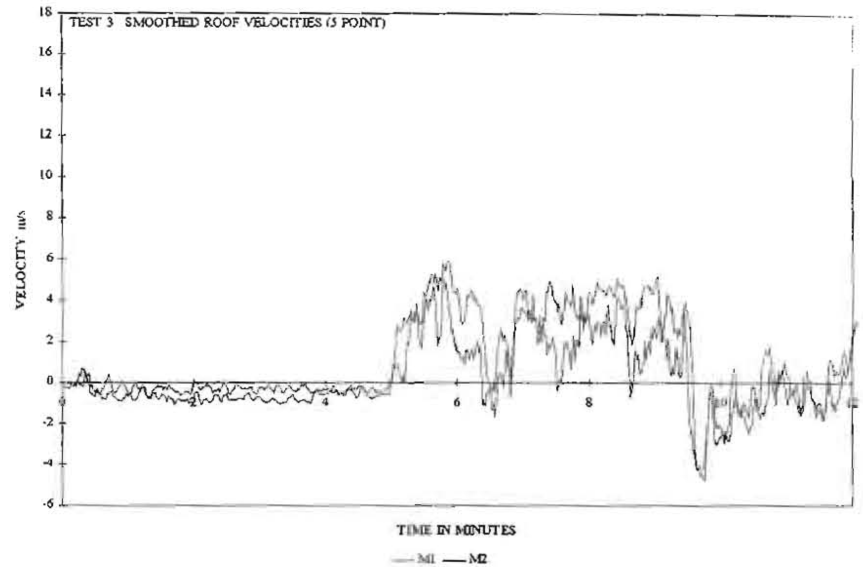


Figure E5 : Test 3. Gas Velocities in Roof Vent

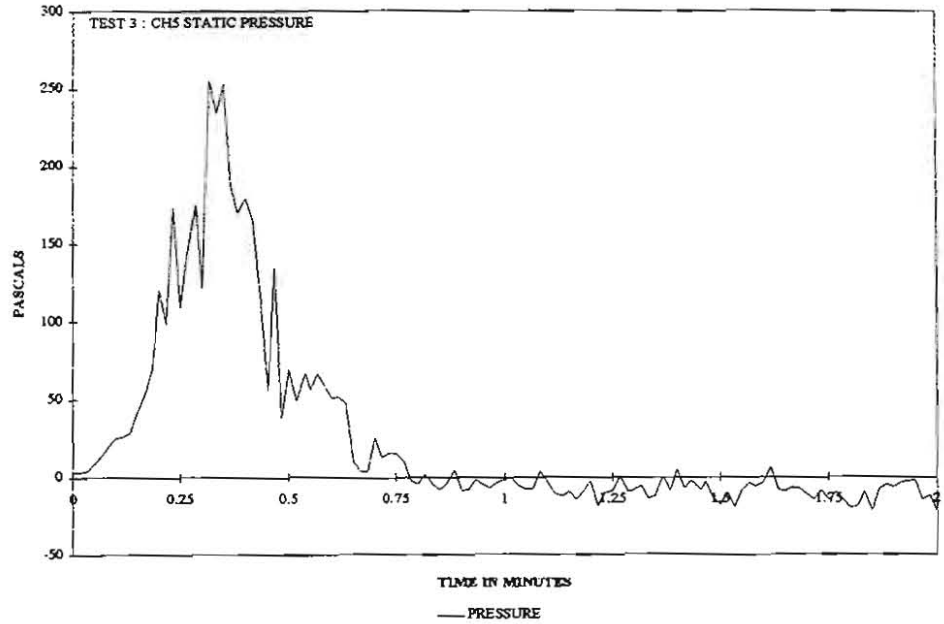


Figure E6 : Test 3. Static Pressure

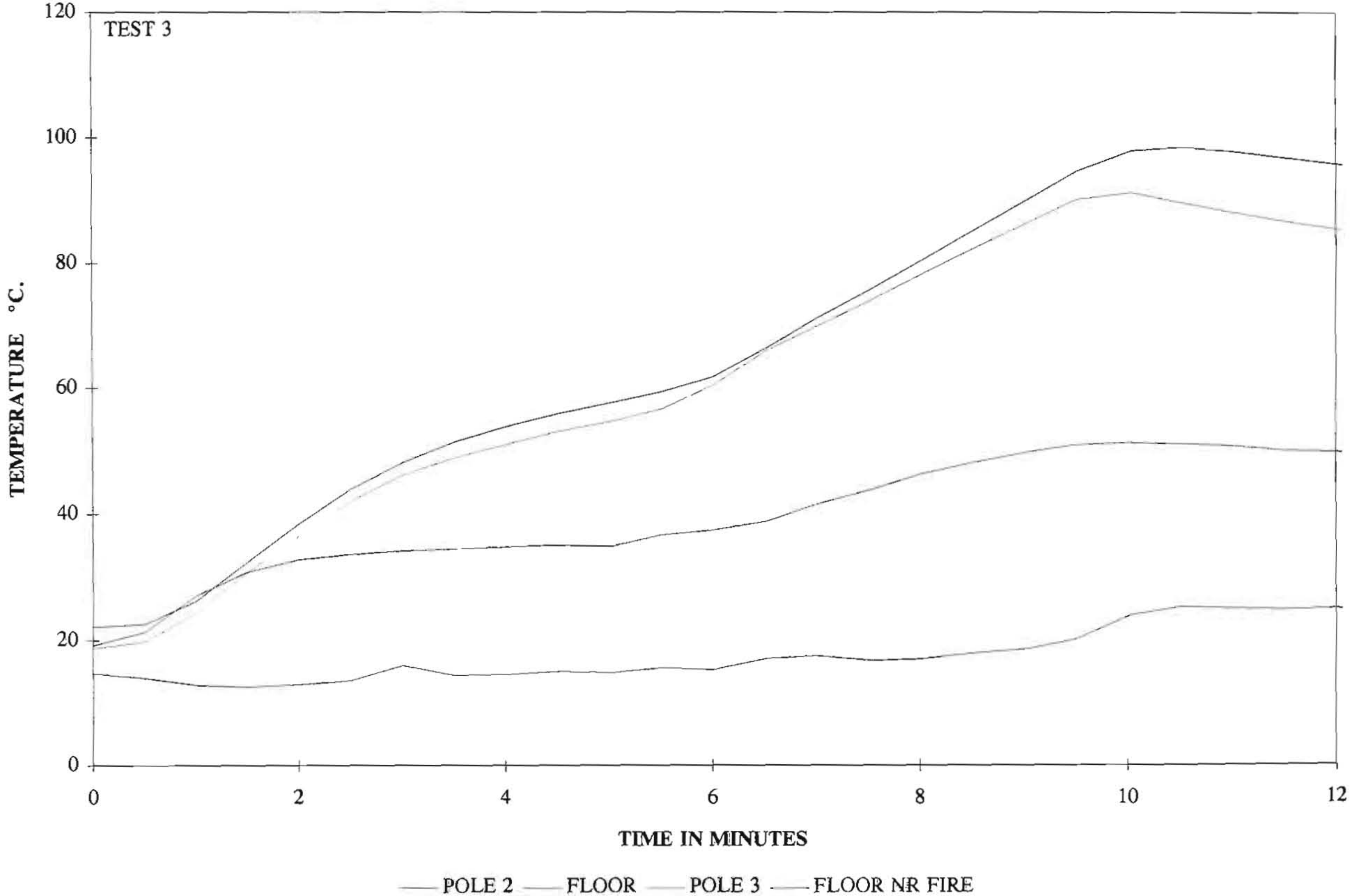


Figure E7 : Test 3. Surface Temperatures

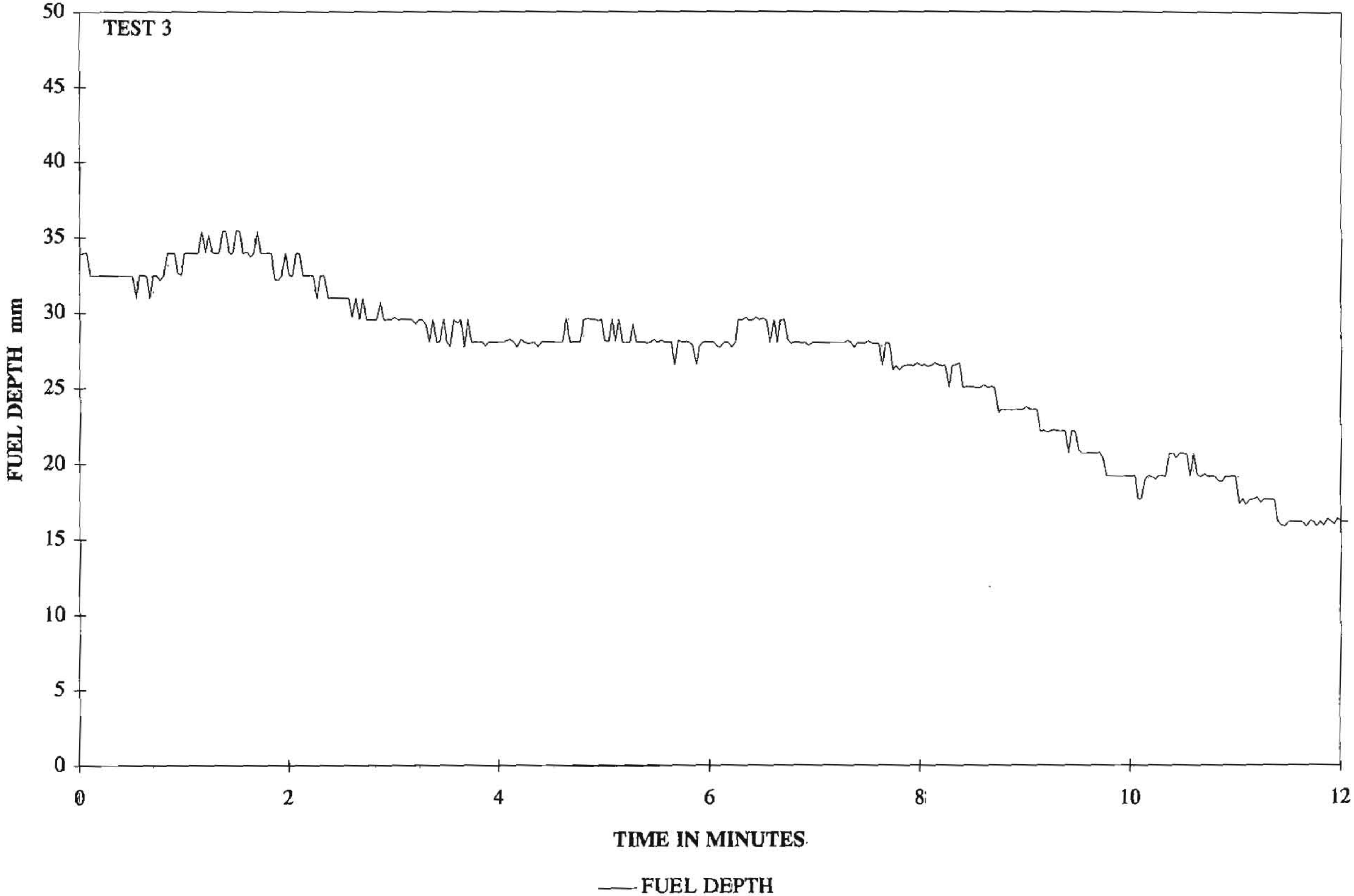


Figure E8: Test 3. Fuel Depth

Appendix F : Results of Test 4.

Test 4

Date 22 November 1995
Weather Cloudy

North vent and SW door opened at 5 minutes

Air Temperature 12.2 ° C Relative Humidity 87%

Tray 1	
Water depth -mm	31
Fuel depth-mm	33
Water Temp-°C	11.9
Fuel Temp- °C	11.3
Tray 2	
Water depth -mm	30
Fuel depth-mm	37
Water Temp-°C	11.8
Fuel Temp- °C	10.6
Tray 3	
Water depth -mm	29
Fuel depth-mm	35
Water Temp-°C	12.1
Fuel Temp- °C	10.5

Time from ignition	**Observations**
0:28	Small window opens
1:08	Small window shut
1:18	Puffing of smoke
2:51	Puffing at ground level stops
3:47	Pulsing of smoke
5:00	Fan on
10:06	Fire out

Smoke density meter results unreliable because air flow to keep front glass clear was reversed.

Extra radiometer introduced near internal wall.
Thermocouple tree 1 not raised (results not used).
Ultrasonic probe not covered on top with thermal insulation.
This test used a PPV fan placed in the doorway.

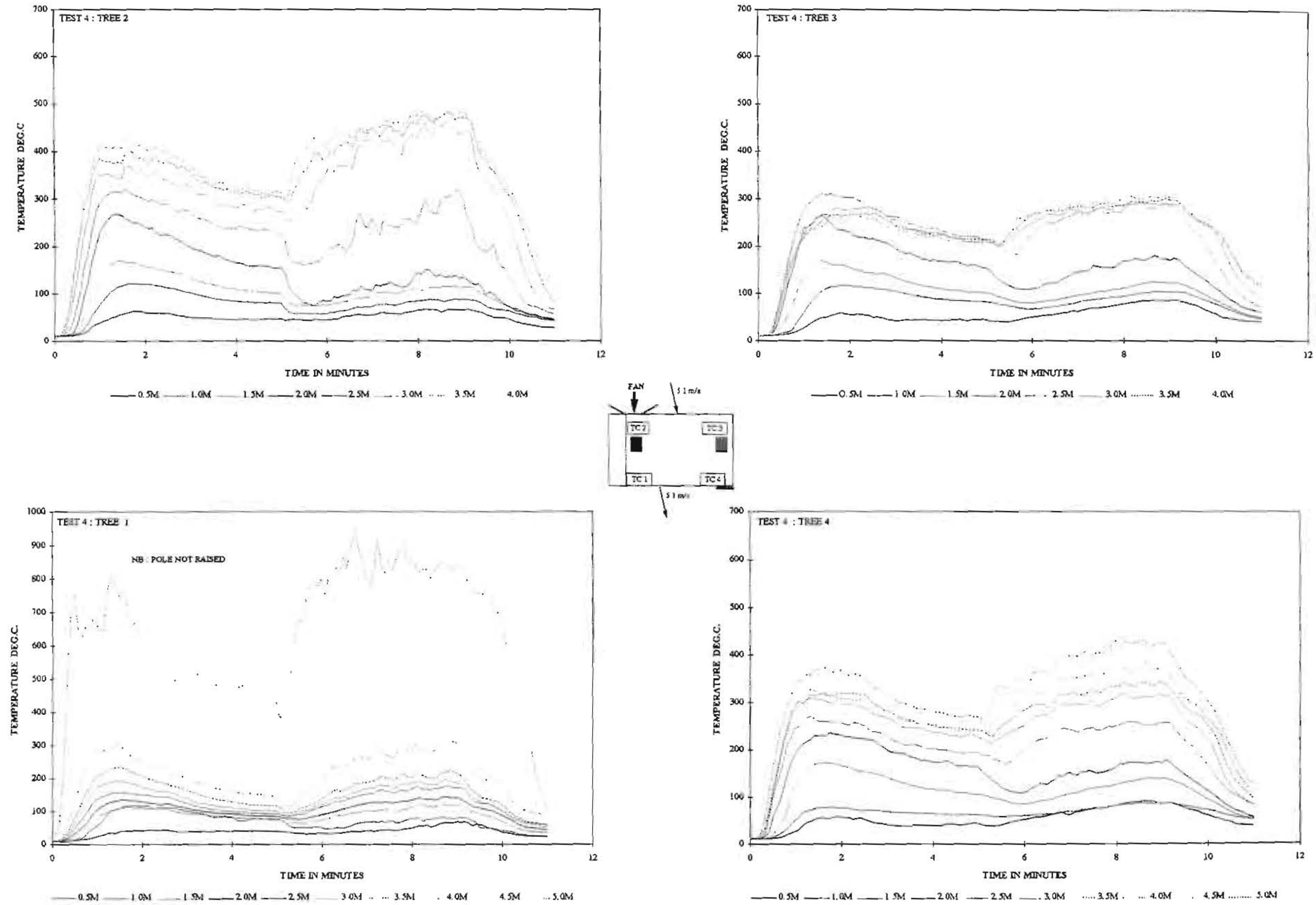
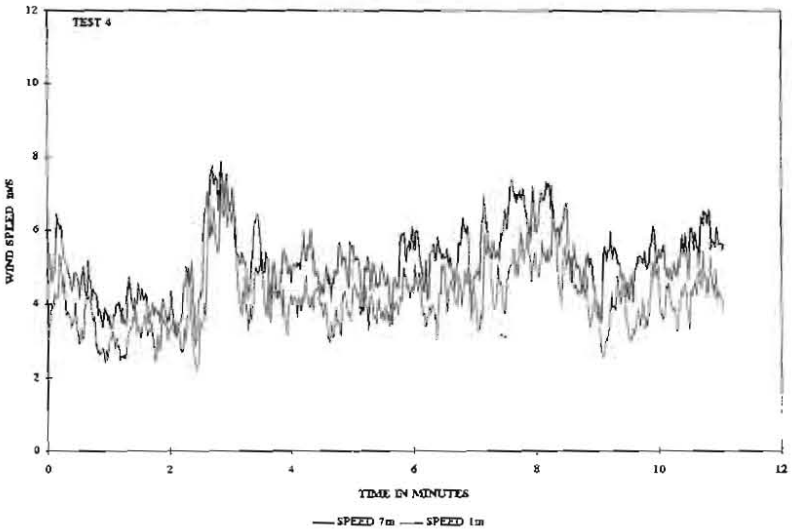
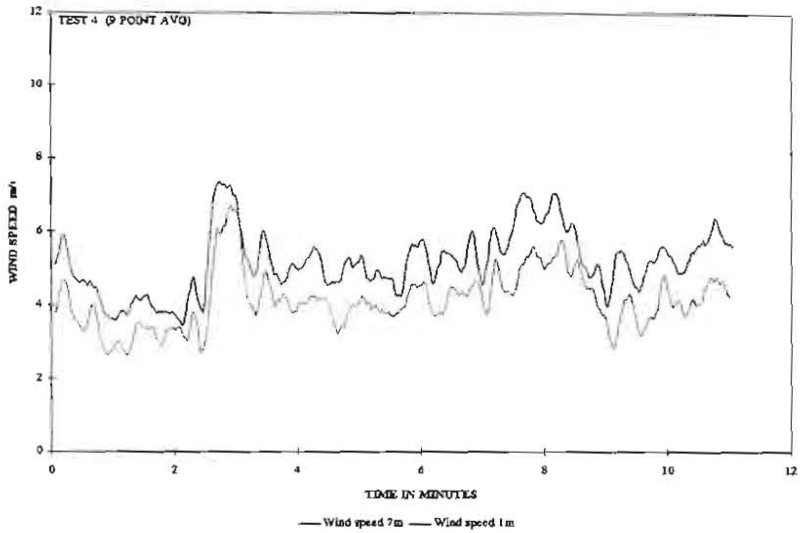
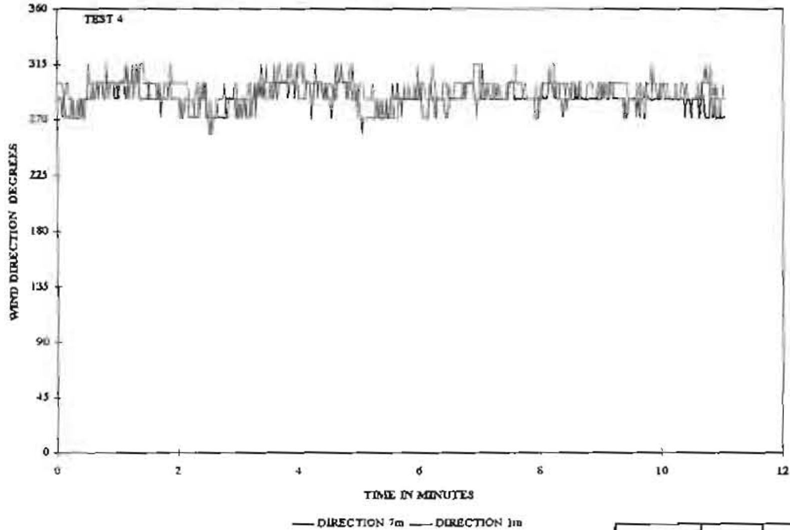
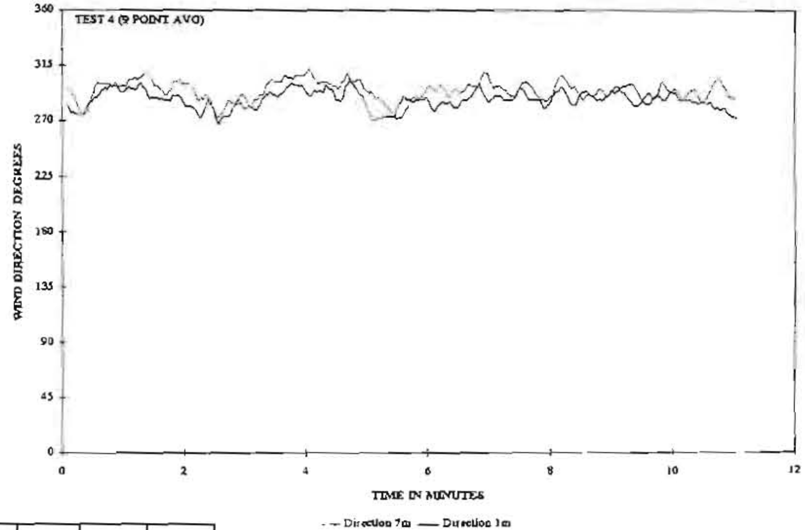


Figure F1 : Test 4. Gas Temperatures from Temperature Trees



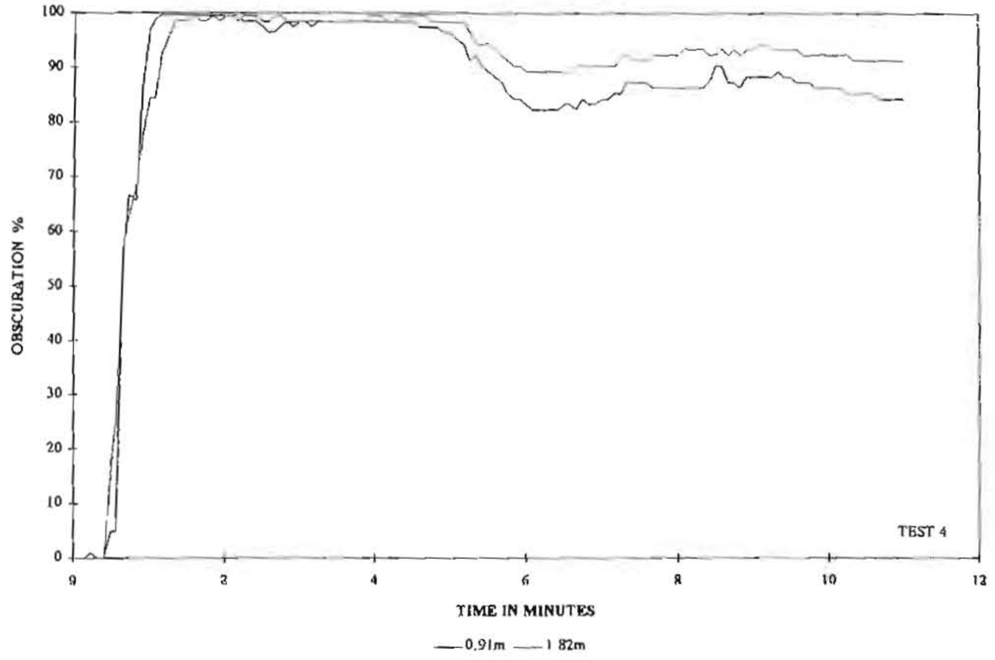






			TEST 4				
		WIND SPEED & DIRECTION					
7m				1m			
SPEED	0-5 Mins	5-10 Mins	0-10 Mins	SPEED	0-5 Mins	5-10 Mins	0-10 Mins
AVG	4.844874	5.40578073	5.124506	AVG	3.90912	4.3456013	4.1273178
STD	1.032799	0.83785582	0.981248	STD	1.006844	0.7348561	0.9081084
7m				1m			
DIRECTION				DIRECTION			
AVG	288.1601	286.470618	287.3154	AVG	296.4492	293.51346	294.97282
STD	10.79047	8.60966275	9.797766	STD	11.77845	10.127112	11.079861

Figure F2 : Test 4. Wind Speed & Direction



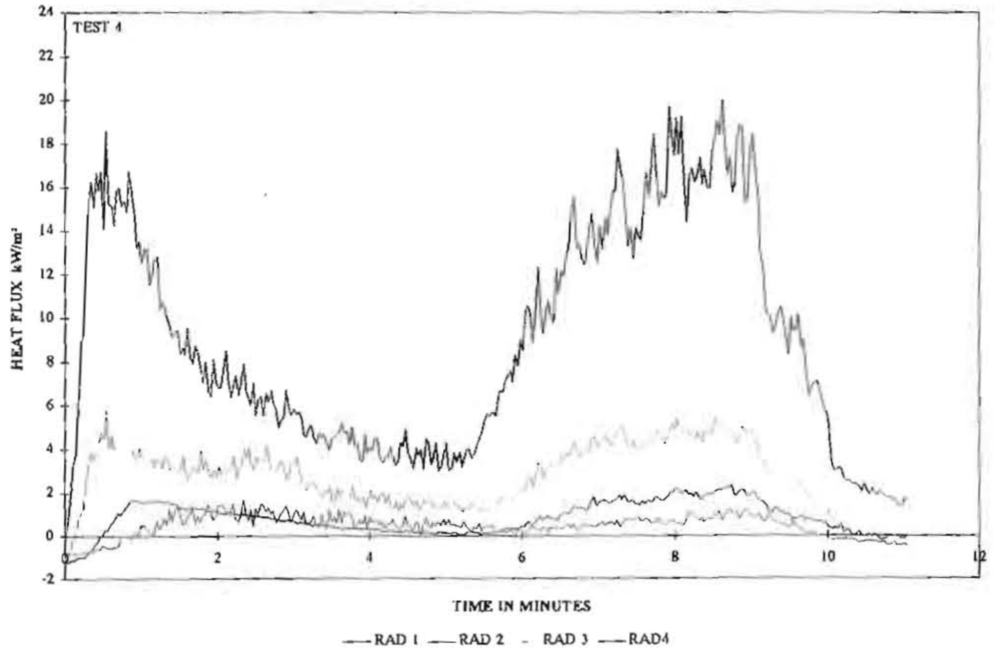


Figure F3 : Test 4. Smoke Obscuration & Heat Flux

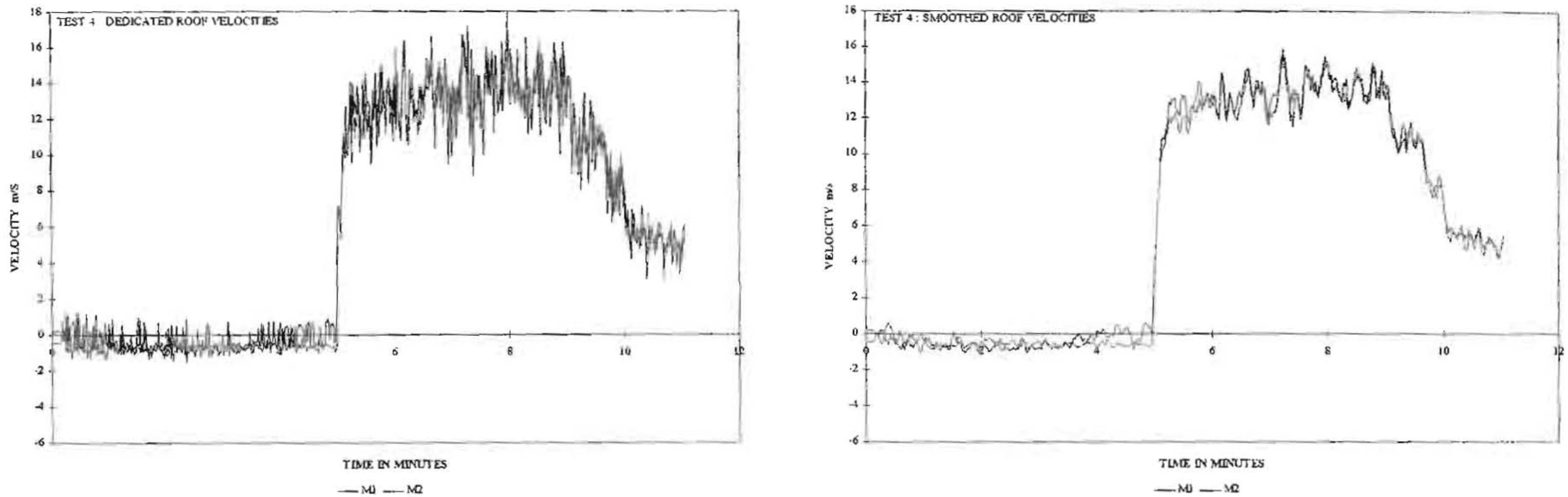


Figure F5 : Test 4. Gas Velocities in Roof Vent

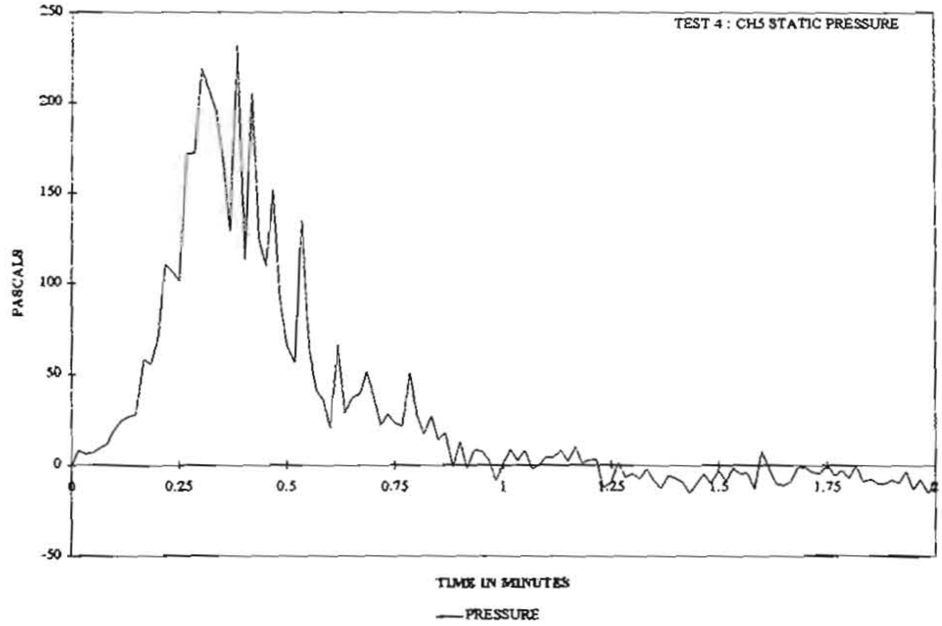


Figure F6 : Test 4. Static Pressure

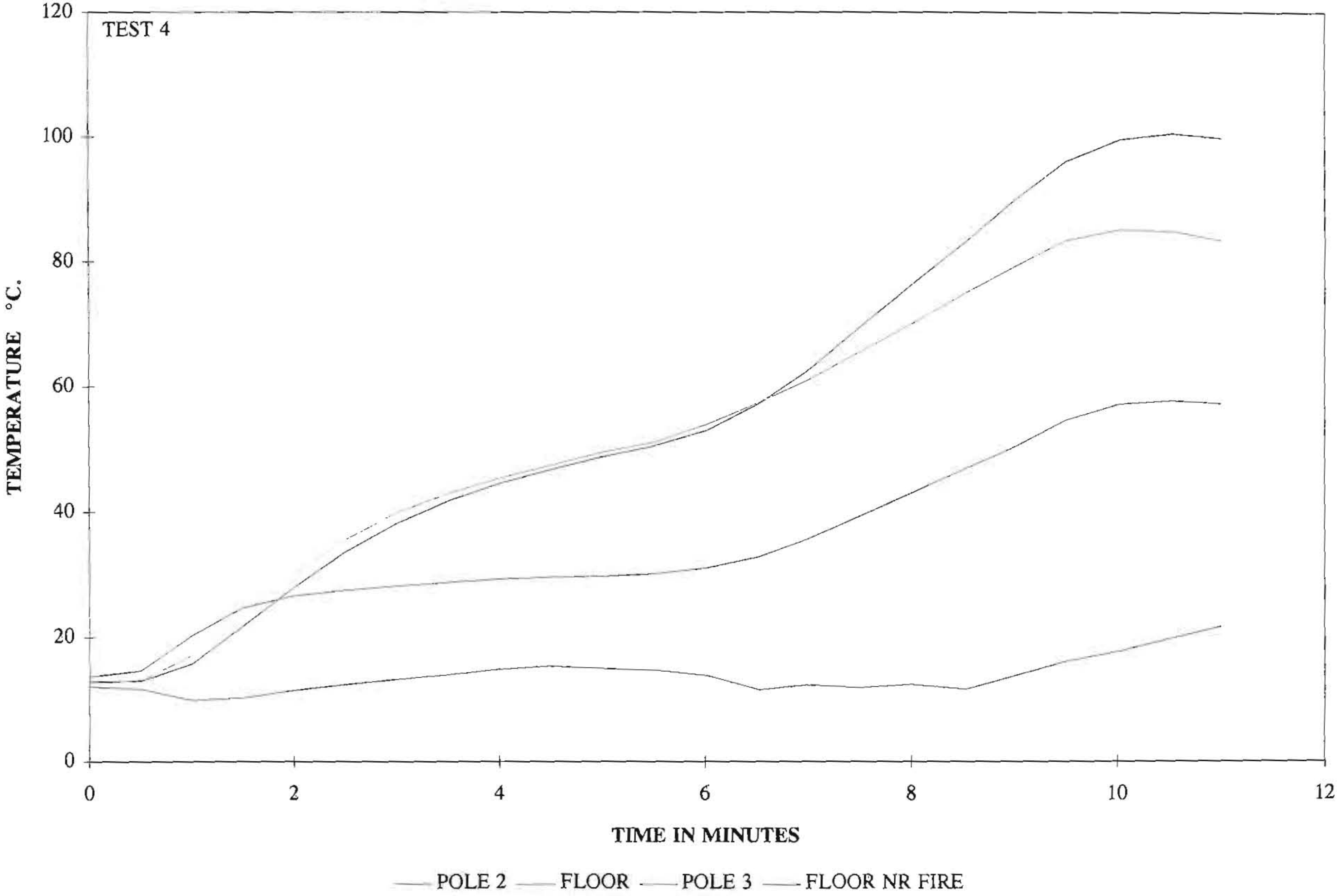


Figure F7 : Test 4. Surface Temperatures

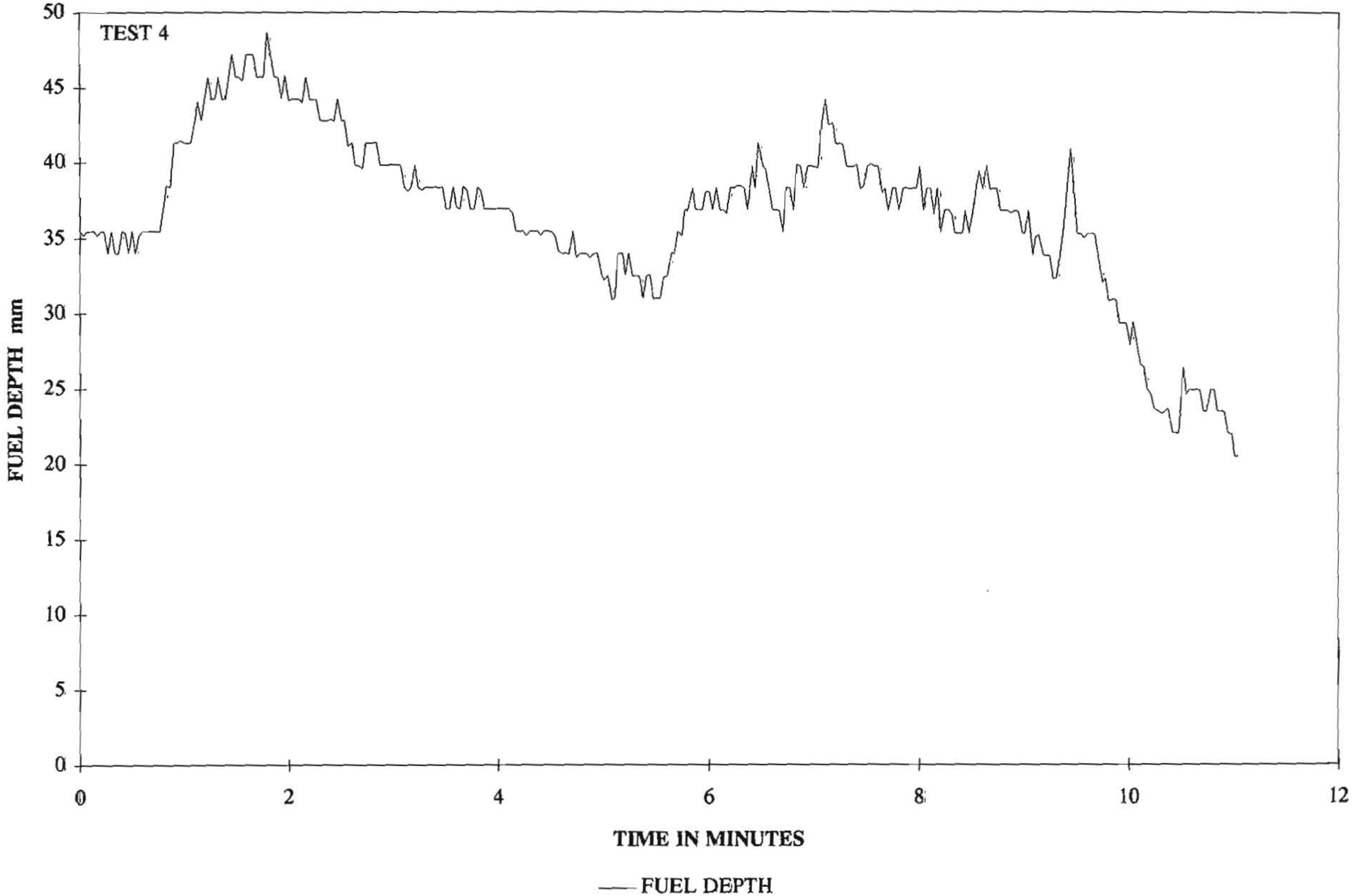


Figure F8 : Test 4. Fuel Depth

Appendix G : Results of Test 5.

Test 5

Date 22 November 1995
Weather Sunny. 4/8 cloud cover

North vent and SW door opened at 5 minutes

Air Temperature 12.3° C Relative Humidity 79.6%

Tray 1	
Water depth -mm	33
Fuel depth-mm	34
Water Temp-°C	21.3
Fuel Temp- °C	17.5
Tray 2	
Water depth -mm	30
Fuel depth-mm	38
Water Temp-°C	21.4
Fuel Temp- °C	17
Tray 3	
Water depth -mm	27
Fuel depth-mm	40
Water Temp-°C	21.4
Fuel Temp- °C	16.9

Time from ignition	**Observations**
0.08	Small upper window forced open
0.15	Small upper window closed
0.25	Some smoke around west door
0:40	Door shaking
1.00	Smoke puffs around door
5.01	North half of SW door open to 90 degrees
5.10	North door right back
5.10	South half of door opened No smoke from door
5.25	Puff of smoke from door
6.09	Puff of smoke at high level in door Occasional puffs
7.25	Large puff of smoke from door
8.57	N tray goes out
10.14	fire out

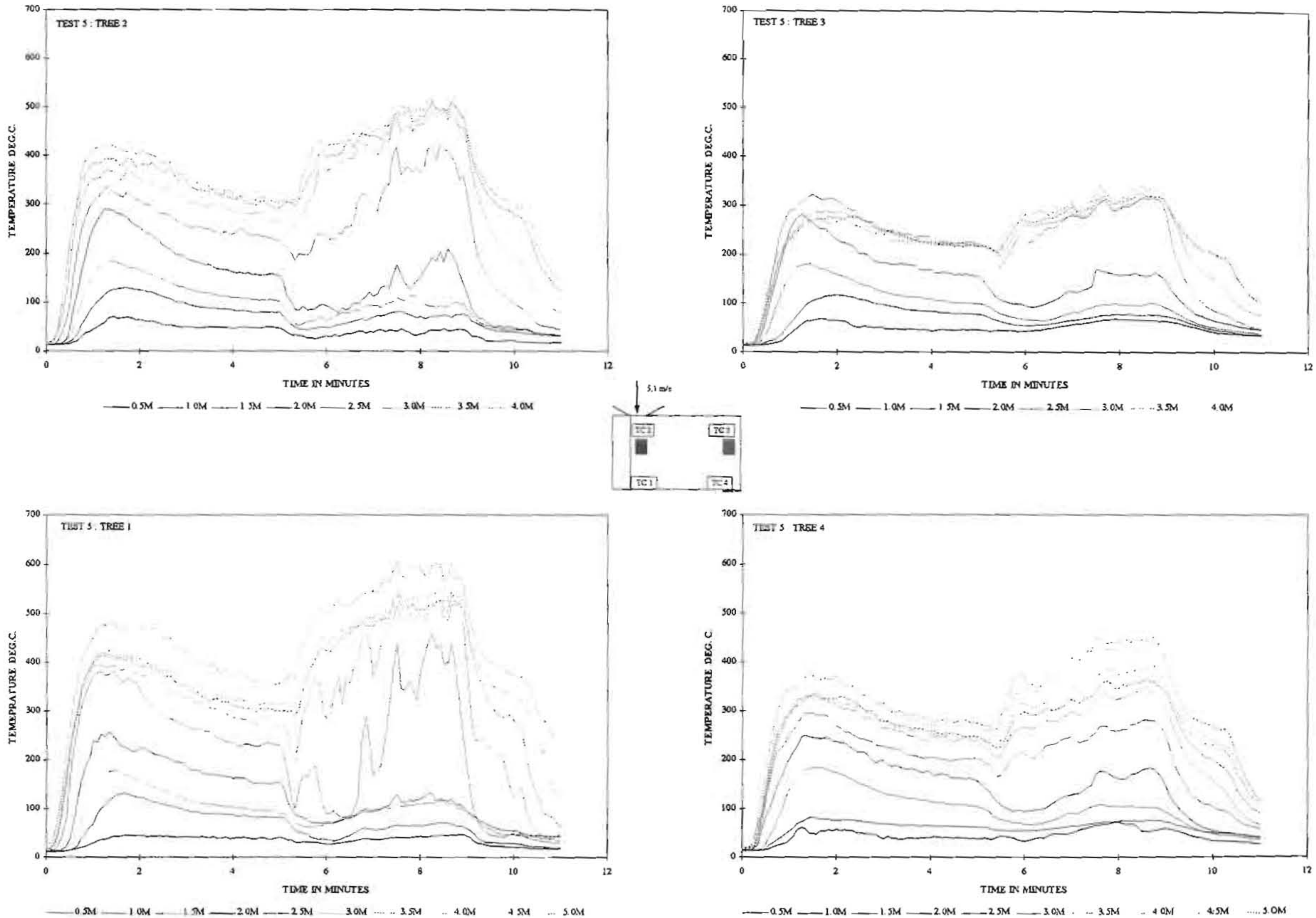
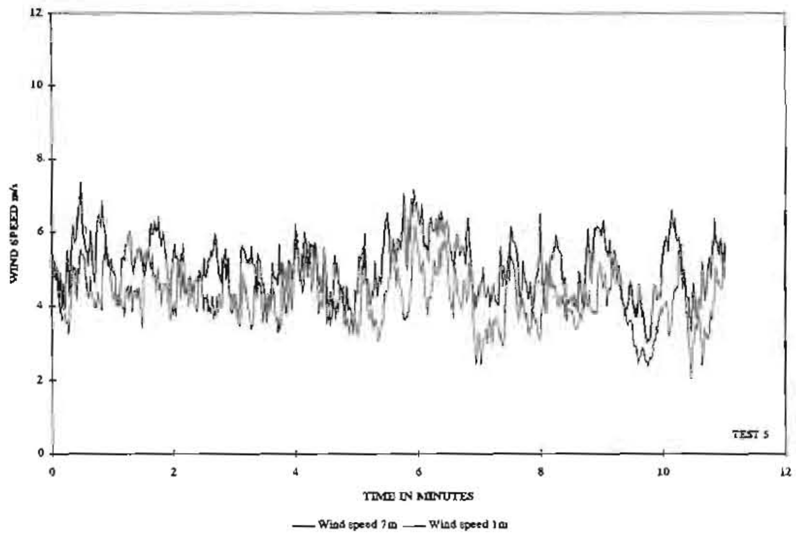
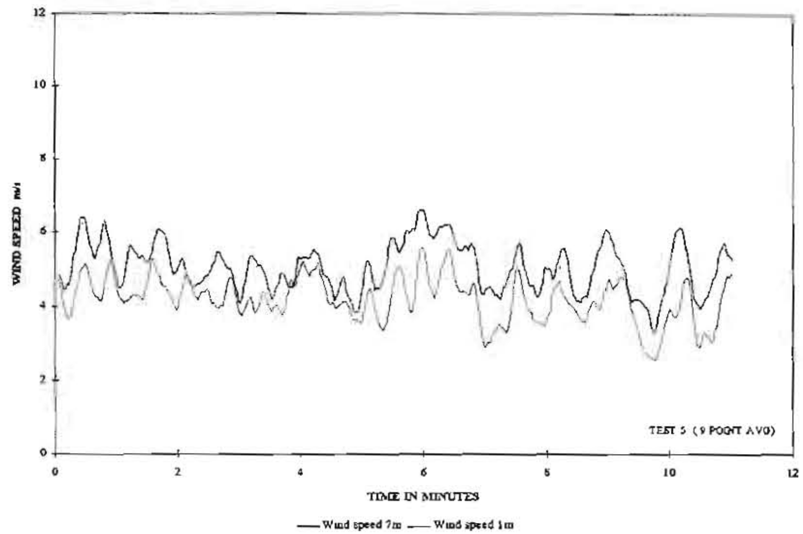
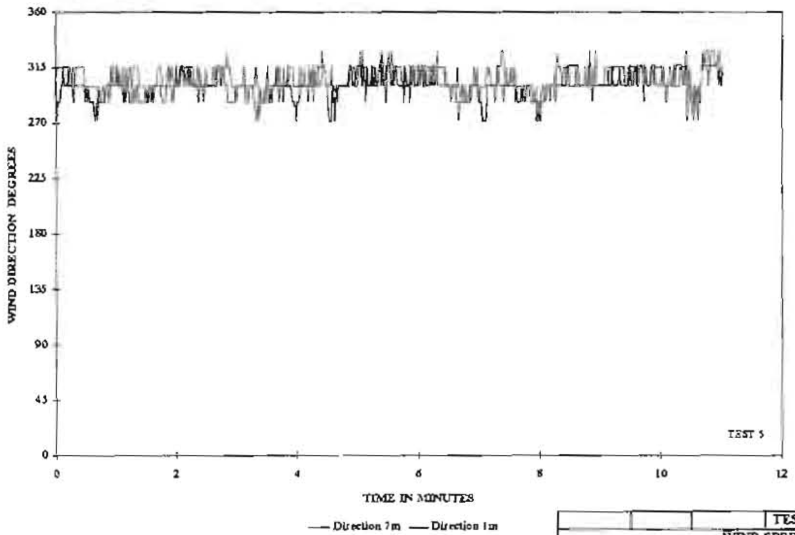
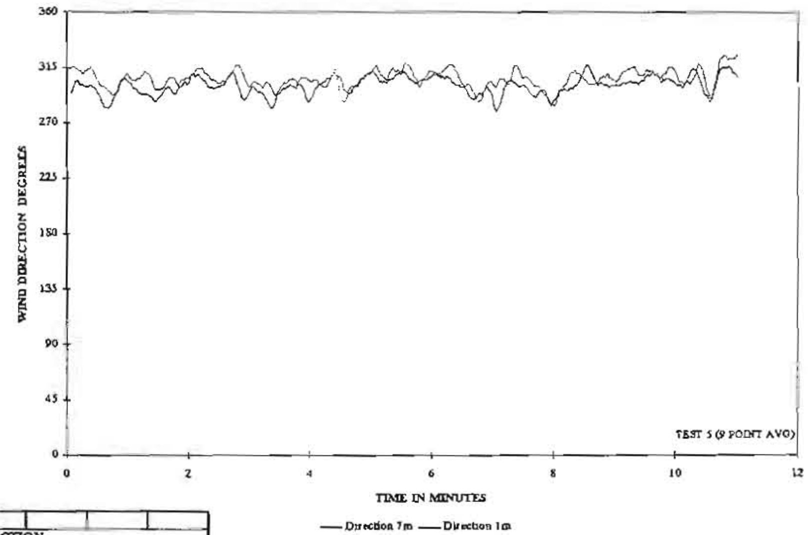


Figure G1 : Test 5. Gas Temperatures from Temperature Trees



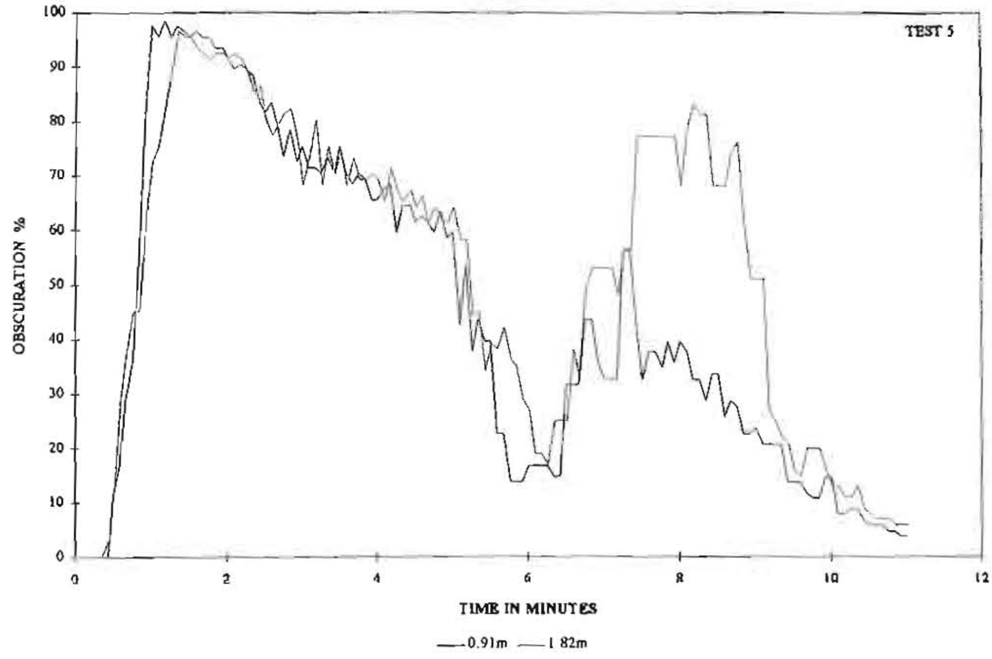






			TEST 5				
		WIND SPEED & DIRECTION					
7m				1m			
SPEED	0-5 Mins	5-10 Mins	0-10 Mins	SPEED	0-5 Mins	5-10 Mins	0-10 Mins
AVG	5.042349	5.07162791	5.05815	AVG	4.382611	4.089316	4.237101
STD	0.705599	0.863463364	0.788113	STD	0.58608	0.806073	0.719318
7m				1m			
DIRECTION				DIRECTION			
AVG	297.9413	301.389927	299.6376	AVG	304.912	306.7601	305.8456
STD	10.18625	9.88540896	10.16127	STD	9.511822	10.98797	10.31537

Figure G2 : Test 5. Wind speed & Direction



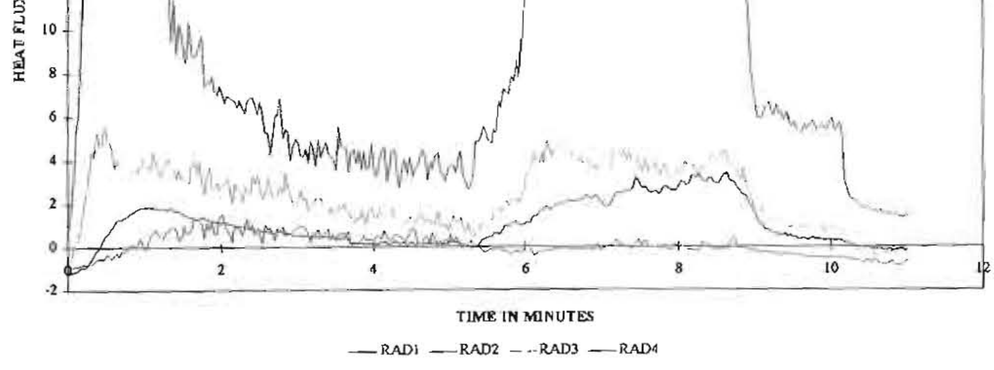
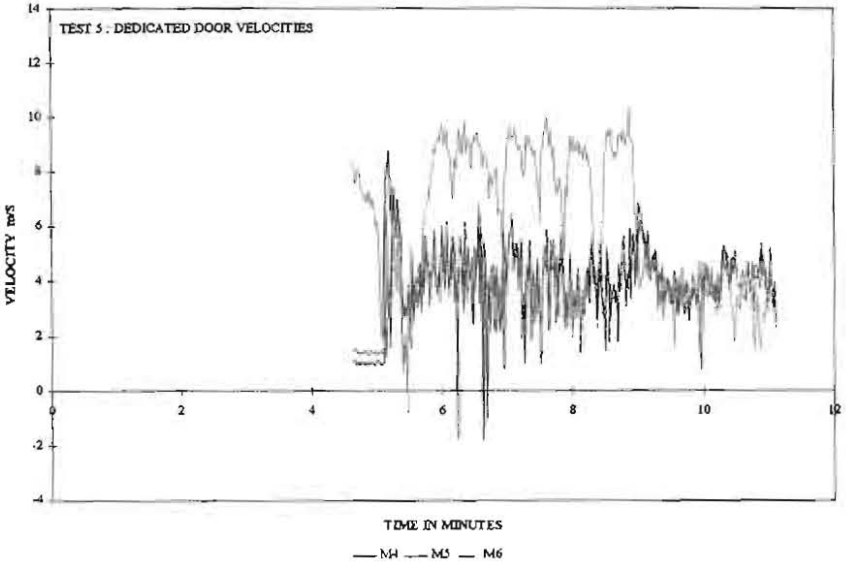
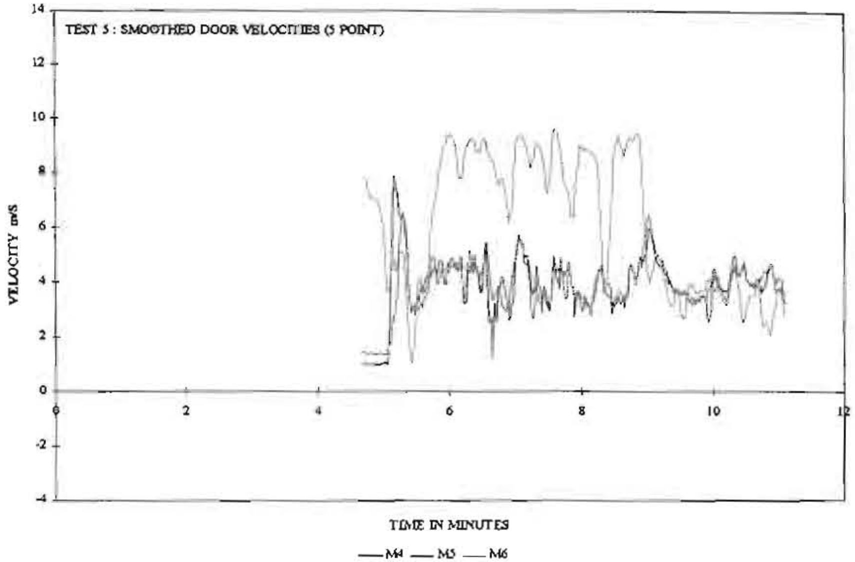


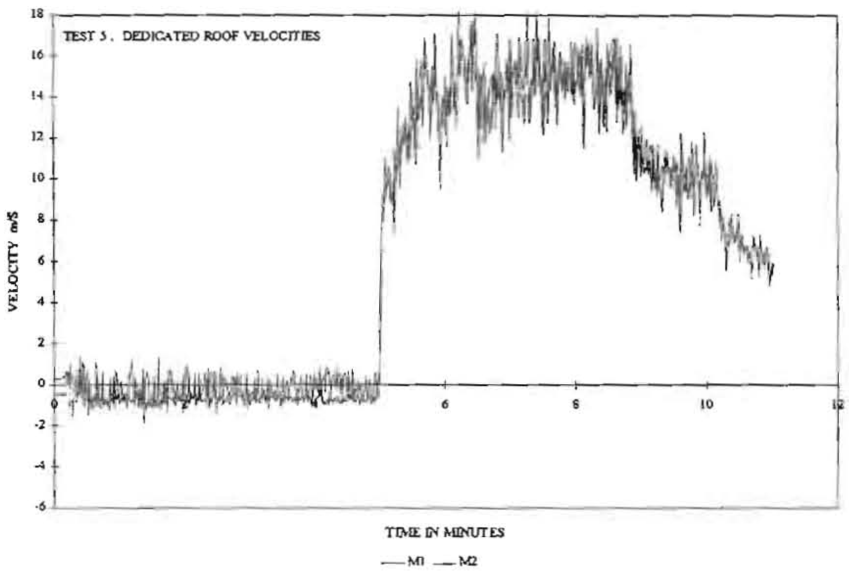
Figure G3 : Test 5. Smoke Obscuration & Heat Flux

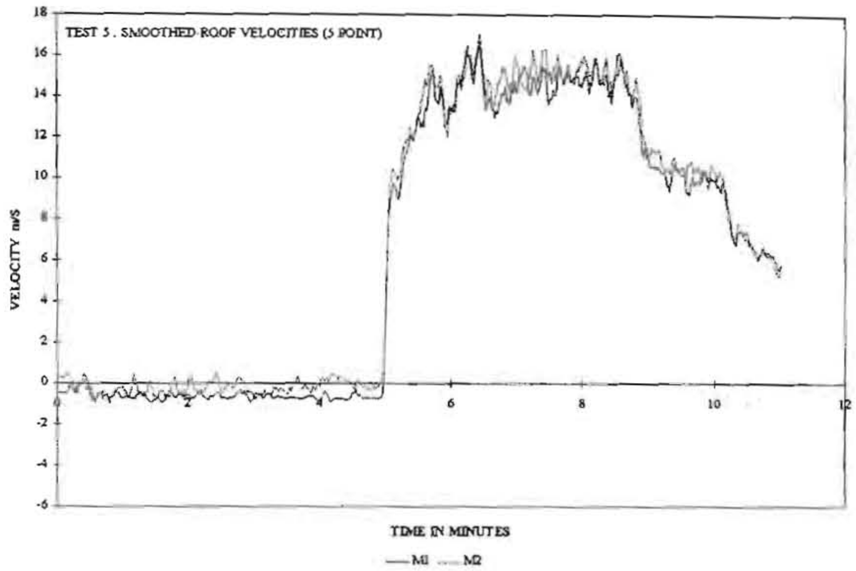




DOOR	TIME		AVG	
CHANNEL	MINUTES		VELOCITY	STD
S No.	START	FINISH	m/s	DEV
1	5.50	5.65	-7.9	1.3
1	7.47	7.62	-11.5	1.5
1	9.43	9.58	7.9	0.5
2	5.67	5.82	4.4	0.8
2	7.65	7.80	4.0	1.7
2	9.62	9.75	1.9	1.3
3	5.85	6.02	3.1	1.8
3	7.82	7.98	3.6	1.6
3	9.77	9.93	2.2	2.0
4	6.03	6.18	4.5	0.8
4	8.00	8.17	3.0	0.6
4	9.97	10.12	3.9	0.5
5	6.20	6.37	4.3	1.7
5	8.18	8.33	4.0	0.6
5	10.13	10.30	4.0	0.8
6	6.38	6.55	4.7	1.0
6	8.35	8.50	3.6	0.9
6	10.32	10.48	4.5	0.6
7	4.63	4.77	-0.4	0.1
7	6.56	6.72	1.2	2.0
7	8.52	8.68	1.8	2.1
7	10.50	10.67	2.3	1.4
8	4.78	4.93	-0.1	0.3
8	6.73	6.90	2.3	0.5
8	8.70	8.87	3.7	1.0
8	10.68	10.85	2.7	0.9
9	4.95	5.10	-0.2	2.0
9	6.92	7.07	9.6	0.8
9	8.90	9.05	13.3	0.0
9	10.87	11.02	-8.5	0.2
10	5.13	5.30	0.8	1.5
10	7.08	7.27	2.3	1.6
10	9.08	9.23	3.9	0.9
10	11.03	11.10	3.6	0.8

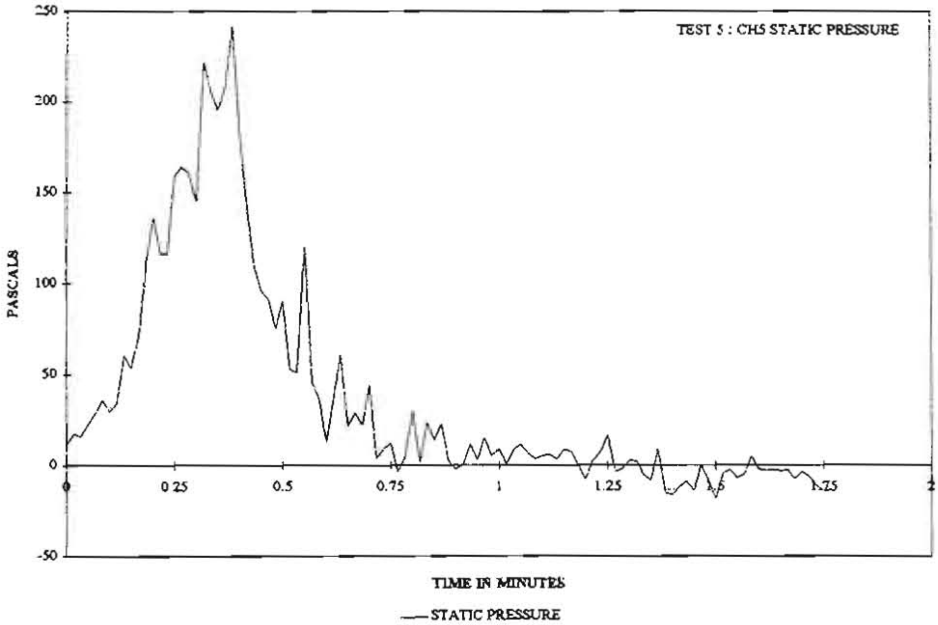
Figure G4 : Test 5 Gas Velocities in Doorway





ROOF	TIME		AVG	
CHANNEL	MINUTES		VELOCITY	STD
S No.	START	FINISH	m/s	DEV
1	4.63	4.78	0.7	0.2
1	6.80	6.98	13.5	1.4
1	9.00	9.17	10.6	0.9
2	4.80	4.98	0.6	0.5
2	7.00	7.17	16.1	1.3
2	9.18	9.38	11.3	1.0
3	5.00	5.15	1.3	1.5
3	7.22	7.38	-3.1	2.1
3	9.40	9.58	0.4	2.8
4	5.22	5.40	9.4	1.3
4	7.42	7.60	13.1	1.1
4	9.62	9.77	9.0	0.4
5	5.42	5.58	4.7	2.1
5	7.62	7.79	3.0	3.9
5	9.80	9.98	2.9	3.5
6	5.62	5.80	14.1	1.0
6	7.82	7.98	13.3	1.1
6	10.00	10.18	9.9	1.1
7	5.82	6.00	4.8	4.1
7	8.02	8.18	2.2	5.0
7	10.20	10.38	1.1	3.5
8	6.02	6.18	12.5	3.0
8	8.22	8.38	14.2	2.3
8	10.40	10.58	5.8	1.9
9	6.20	6.40	16.6	0.9
9	8.42	8.58	15.0	1.5
9	10.60	10.78	6.1	0.7
10	6.47	6.60	-3.4	1.9
10	8.64	8.78	-3.5	1.3
10	10.81	10.95	0.3	1.9

Figure G5 : Test 5. Gas Velocities in Roof Vent



	TIME		AVG	
CHANNEL	MINUTES		PRESSURE	STD
S No.	START	FINISH	PASCALS	DEV
1	2.20	2.43	-0.4	1.2
1	8.65	11.02	-2.0	1.9
2	2.45	2.73	16.2	4.6
2	8.38	8.62	8.4	2.2
3	2.75	3.03	-6.1	2.0
3	8.17	8.37	-0.8	1.0
4	3.05	3.45	-2.2	1.4
4	7.68	8.15	-3.6	1.0
5	0.00	1.77	36.8	61.1
5	3.47	3.87	-2.0	5.5
5	7.45	7.67	2.0	3.7
6	1.78	2.15	-2.8	2.2
6	3.88	7.23	-0.5	4.9
7	7.25	7.43	-0.1	0.0

Figure G6 : Test 5. Static Pressures

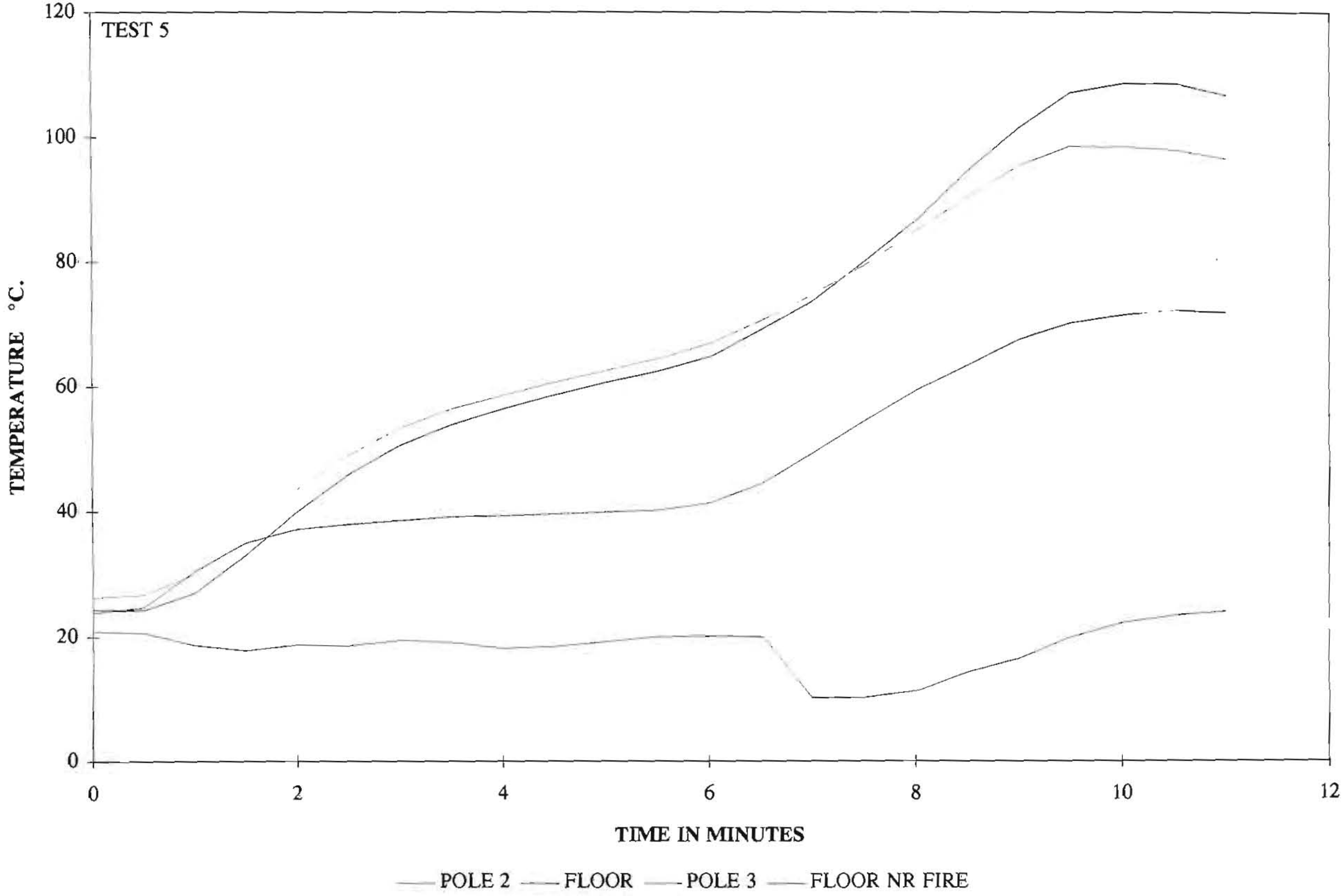


Figure G7 : Test 5 Surface Temperatures

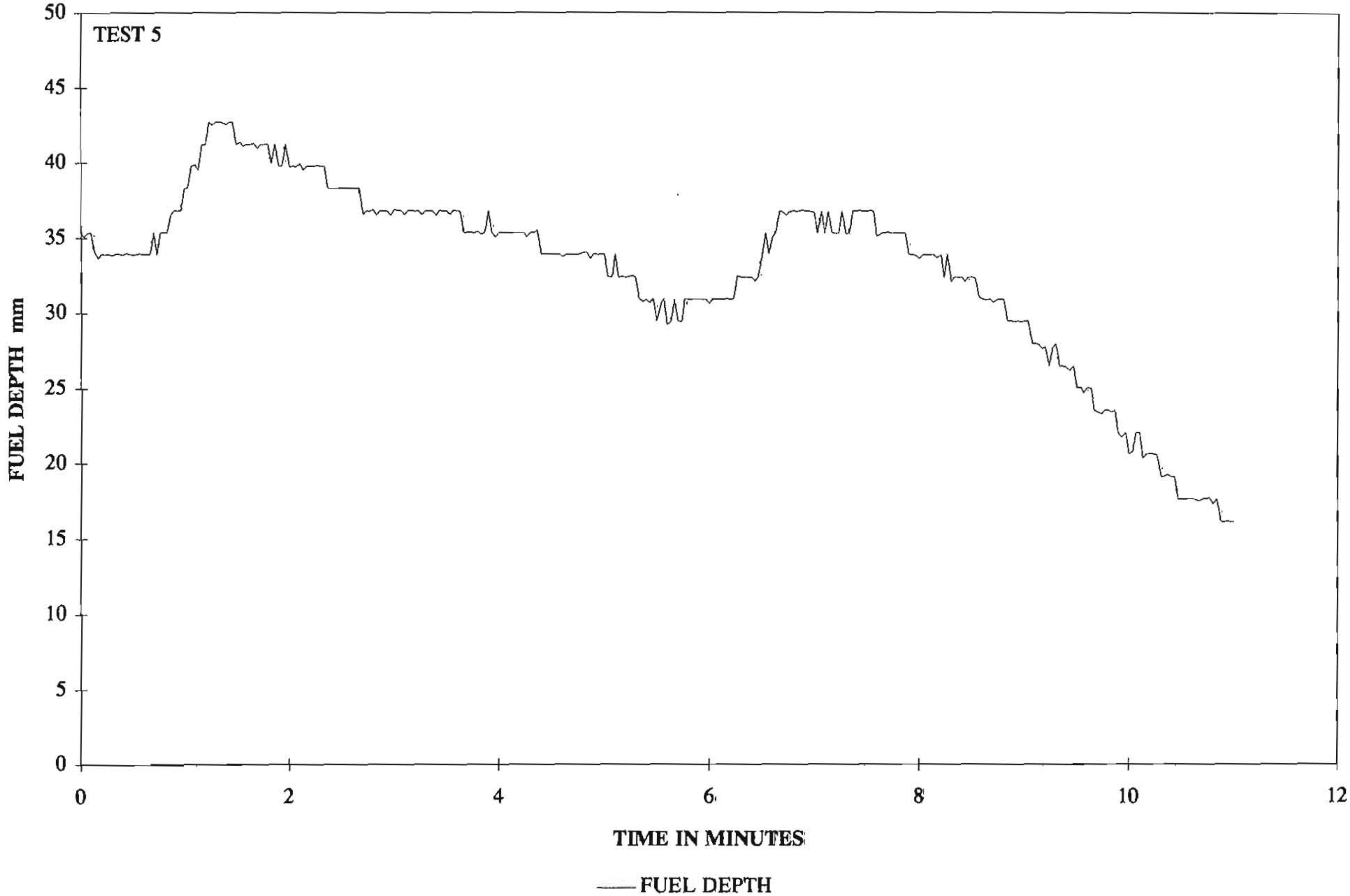


Figure G8 : Test 5. Fuel Depth

Appendix H : Results of Test 6.

Test 6

Date 23 November 1995
Weather Sunny and dry. 6/8 cloud cover

North vent and NE door opened at 5 minutes

Air Temperature 9.7° C   Relative Humidity 87.0%

Tray 1	
Water depth -mm	29
Fuel depth-mm	37
Water Temp-°C	10.8
Fuel Temp- °C	9.4
Tray 2	
Water depth -mm	24
Fuel depth-mm	36
Water Temp-°C	10.8
Fuel Temp- °C	9.7
Tray 3	
Water depth -mm	22
Fuel depth-mm	42
Water Temp-°C	11.2
Fuel Temp- °C	9.4

Time from ignition	Observations
0:50	Fire dying down
1.30	Lazy smoke along building
2:20	No visible fire in the building as seen from Skystalk
4:26	CCD camera record ends
5;02	S LH door open to 90 degrees
5:12	Both doors open
5:13	First smoke from top of E door
5:28	Puff from E door
5:46	Swirling from door
7:14	Pulsing at north door
9:00	Fire not visible

Fuel thermocouple tree added
Micromanometer M3 on door changed to position of probe S8
Some evidence of wood charring.

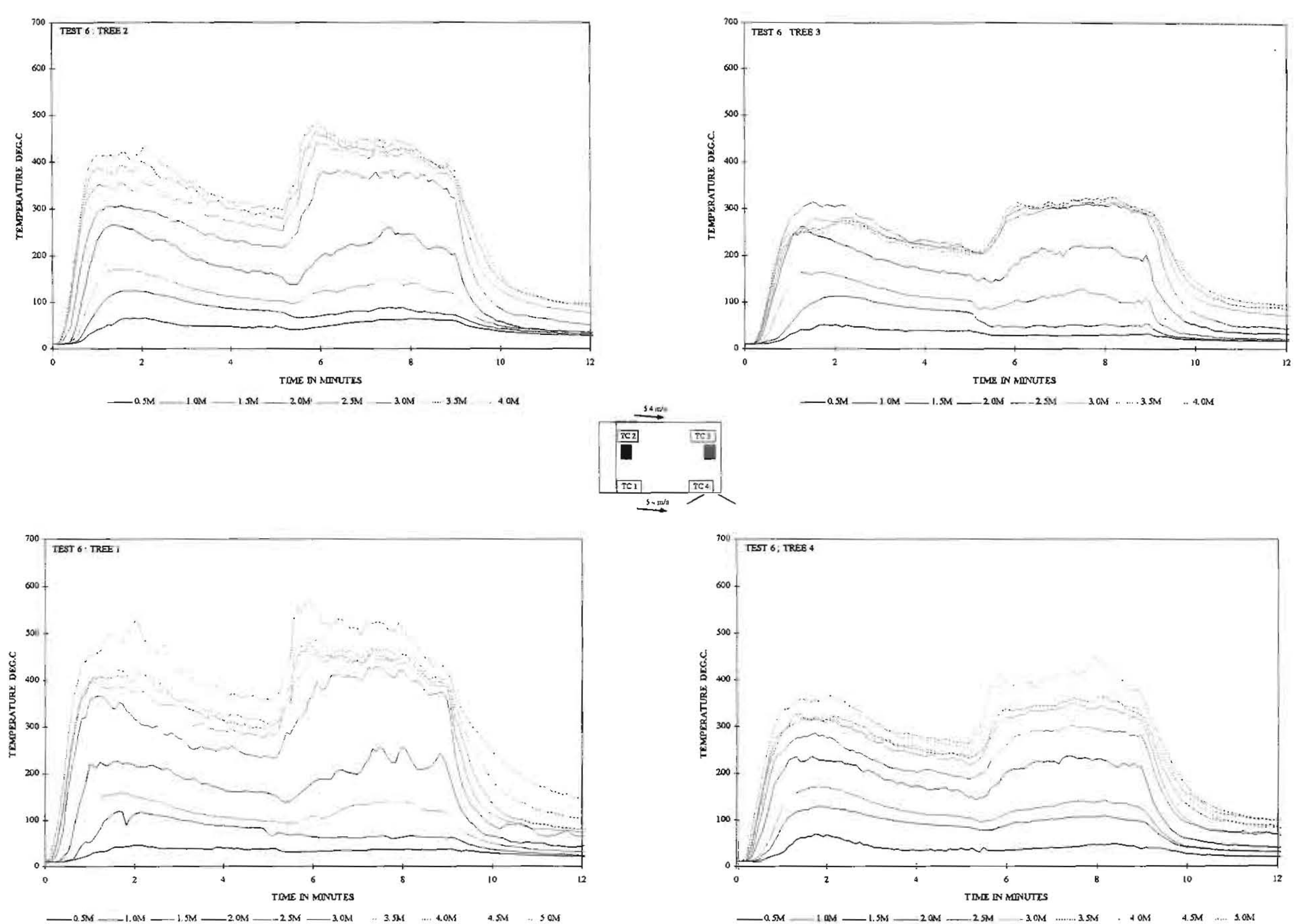
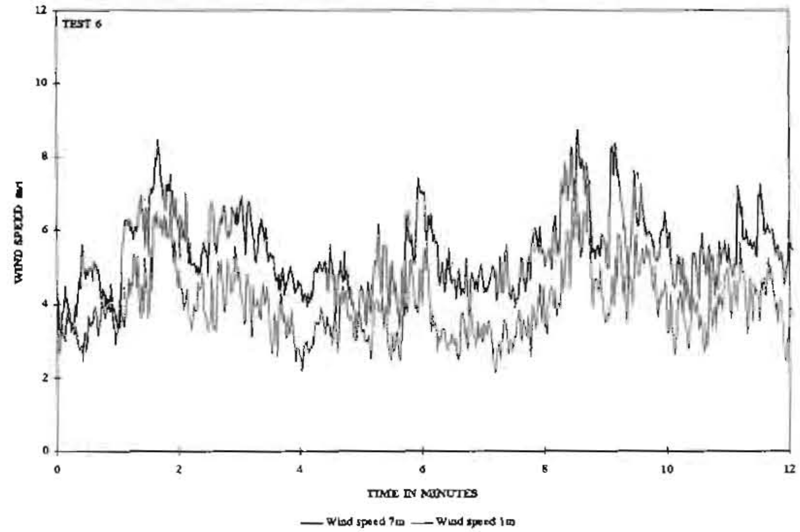
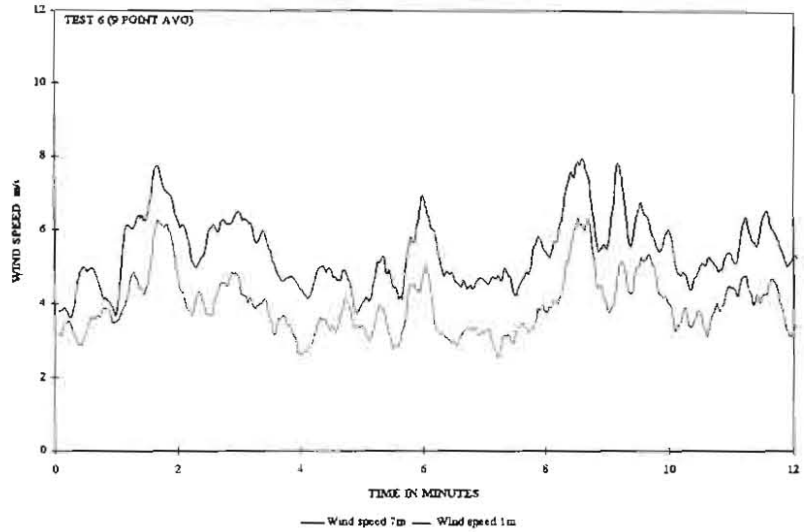
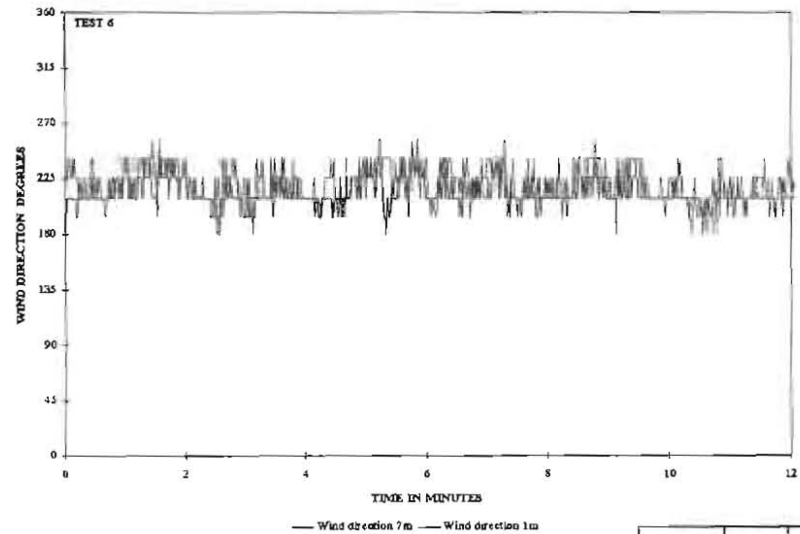
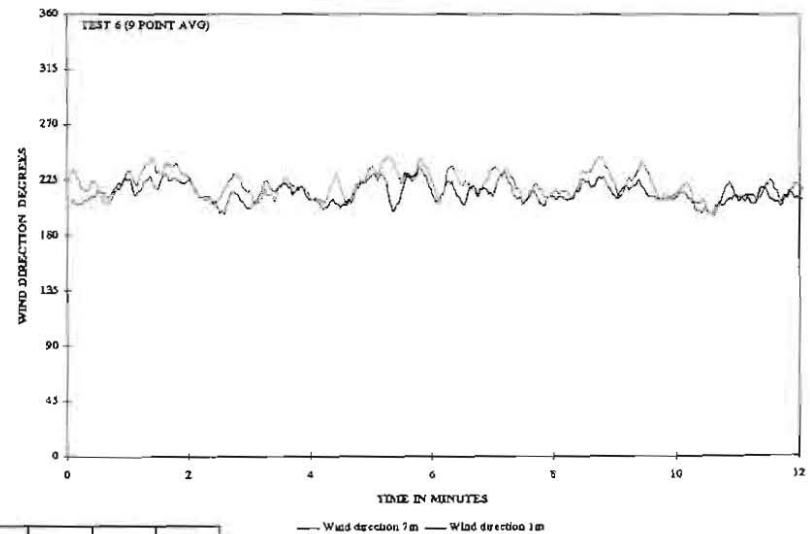


Figure H1 : Test 6. Gas Temperatures from Temperature Trees



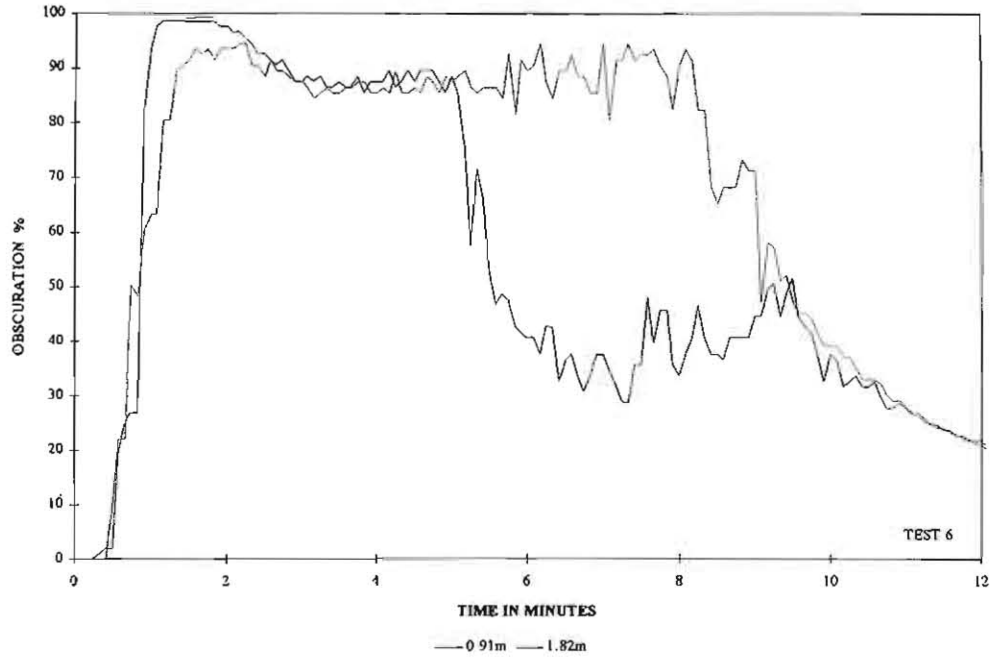






			TEST 6				
		WIND SPEED & DIRECTION					
7m				1m			
SPEED	0-5 Mins	5-10 Mins	0-10 Mins	SPEED	0-5 Mins	5-10 Mins	0-10 Mins
AVG	5.280551	5.52618272	5.40485	AVG	3.955605	3.994449	3.975651
STD	1.091327	1.13783805	1.121001	STD	0.894258	1.032327	0.965837
7m.				1m			
DIRECTION				DIRECTION			
AVG	214.1901	216.334923	215.2724	AVG	220.5366	224.7023	222.5869
STD	11.41146	12.6217926	12.07727	STD	14.19197	15.123	14.791

Figure H2 : Test 6. Wind Speed & Direction



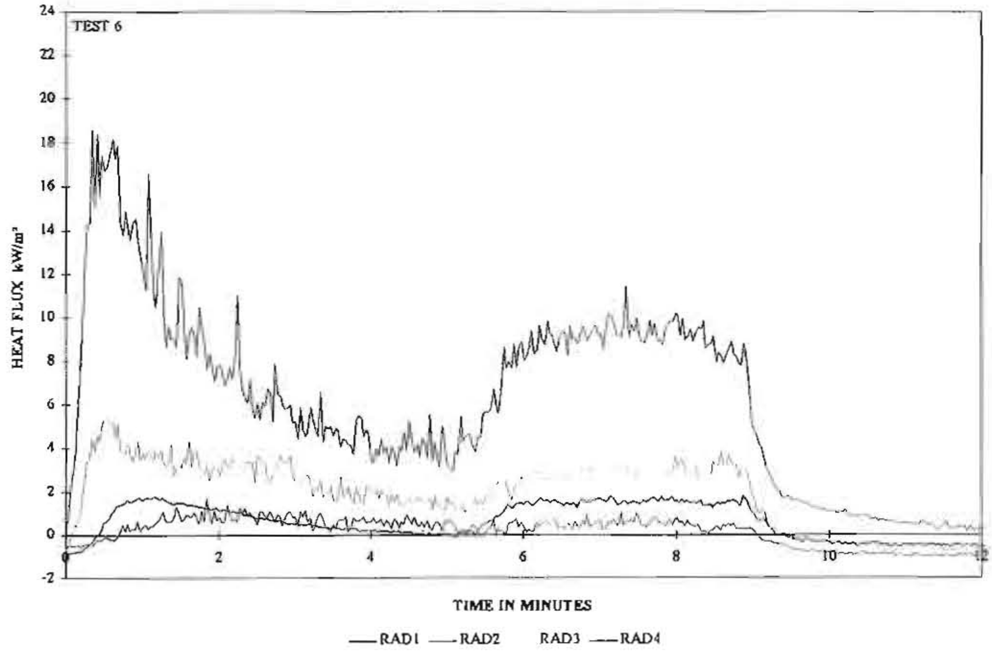
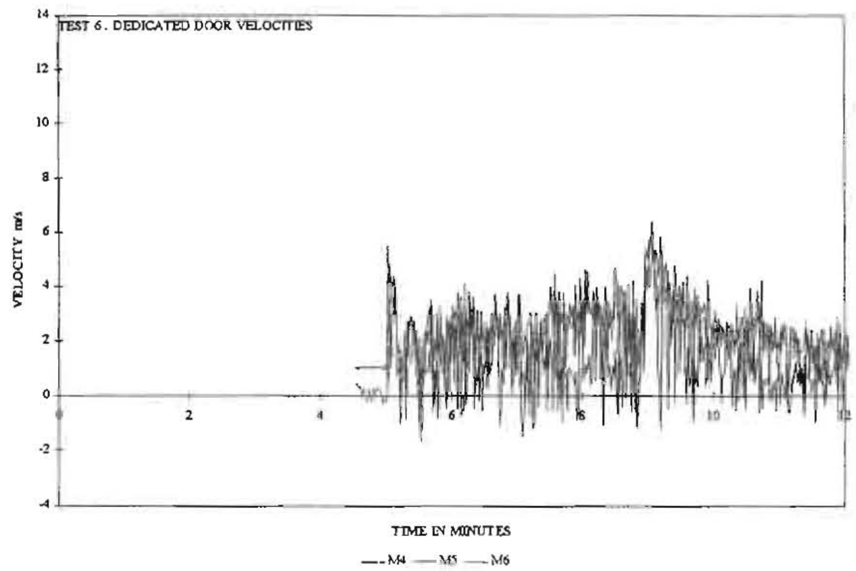


Figure H3 : Test 6. Smoke Obscuration & Heat Flux



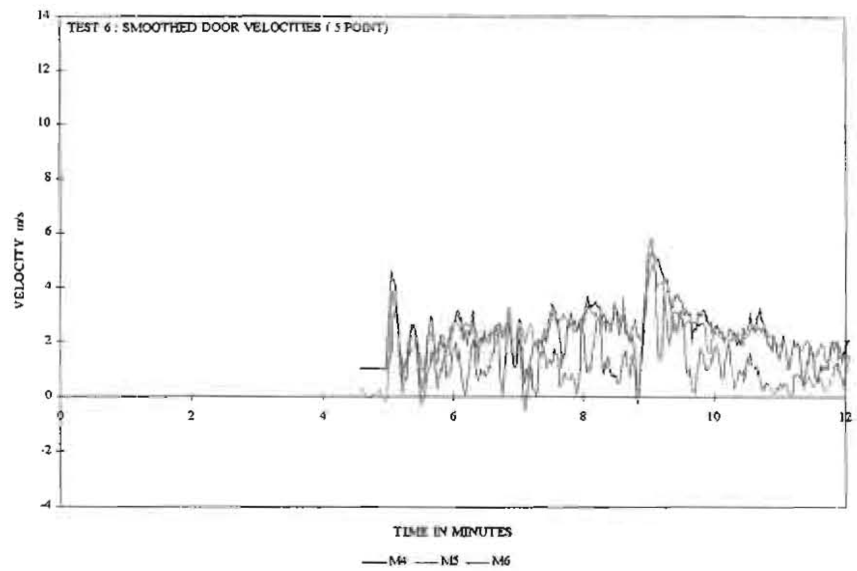
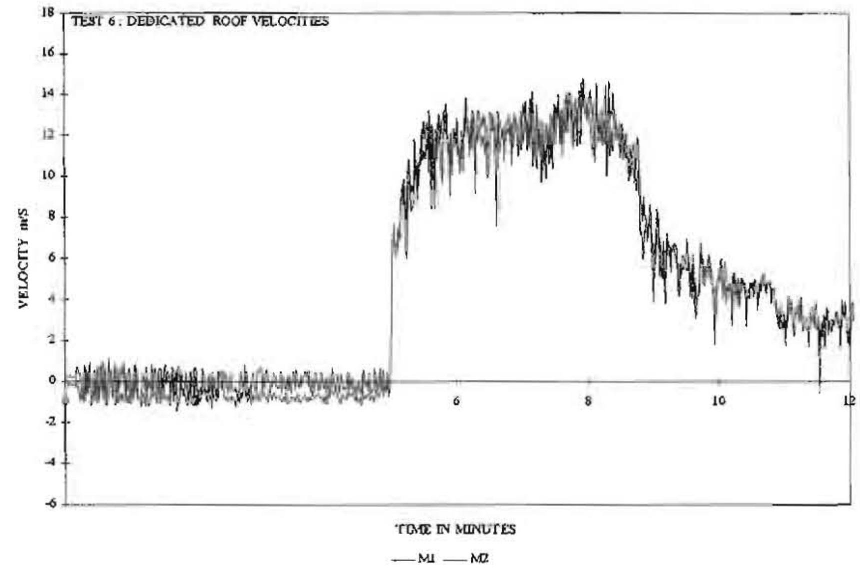


Figure H4 : Test 6. Gas Velocities in Doorway



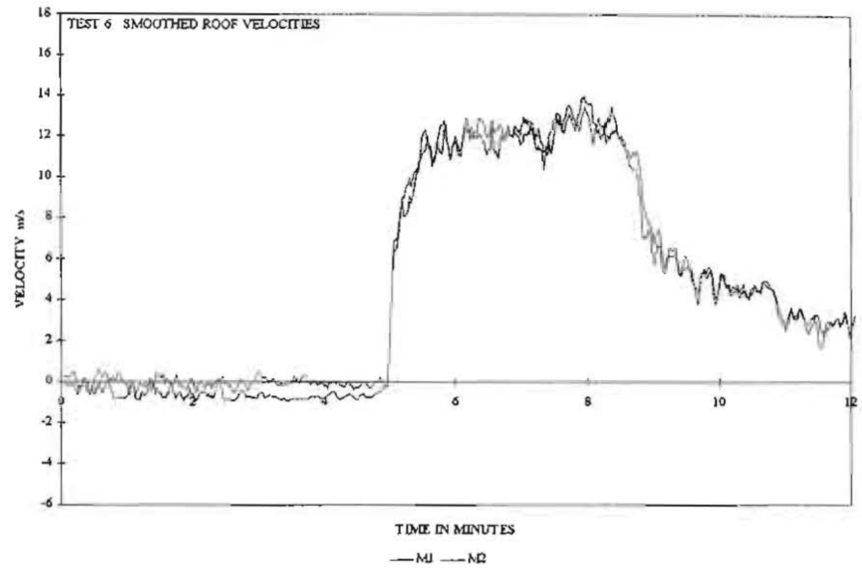


Figure H5 : Test 6. Gas Velocities in Roof Vent

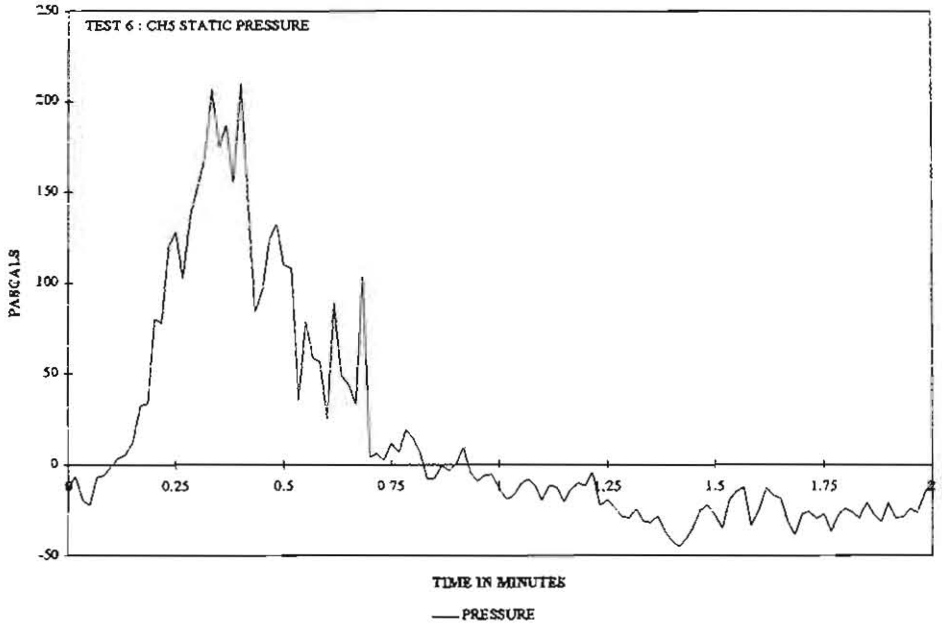


Figure H6 : Test 6. Static Pressure

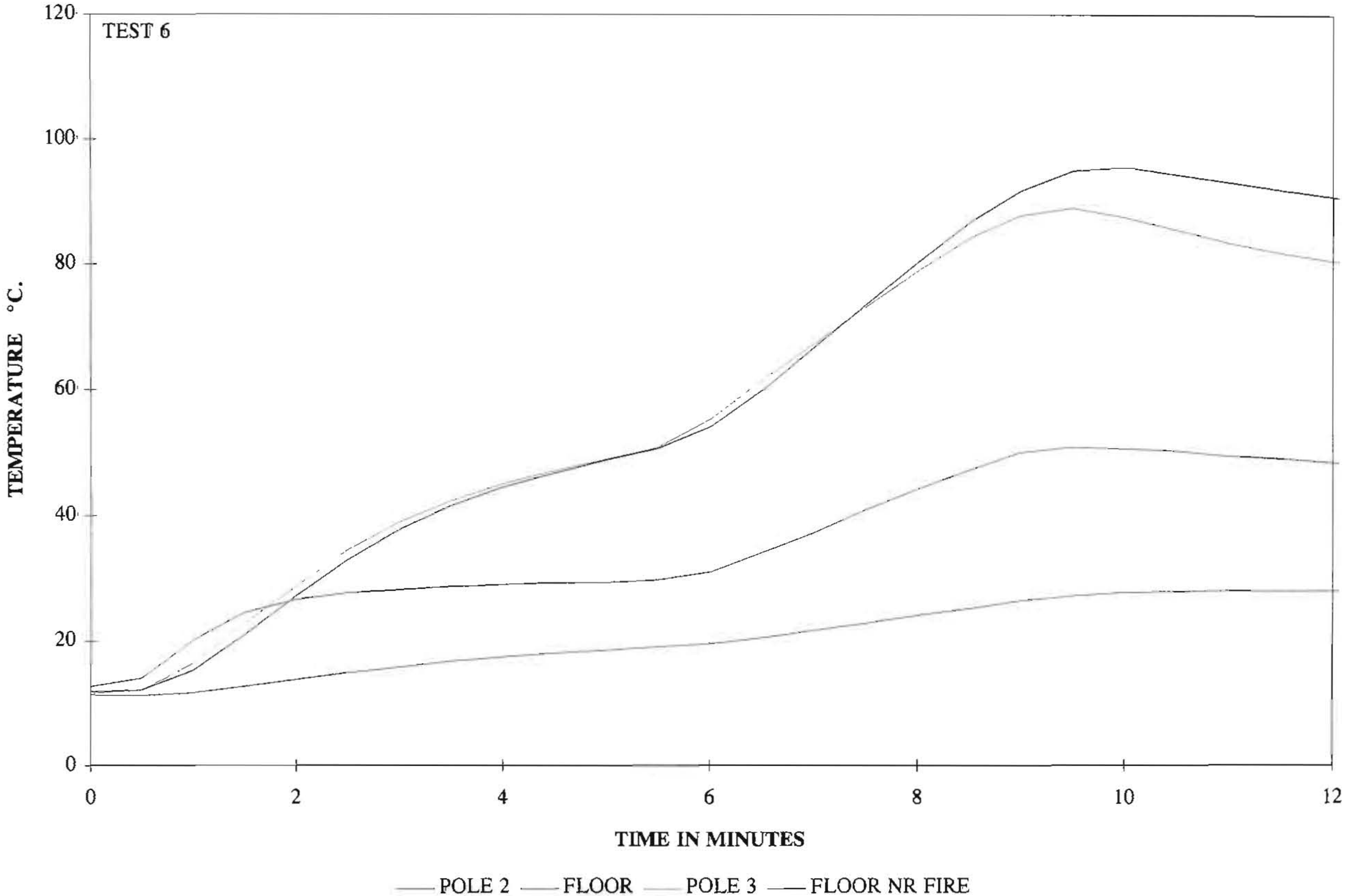
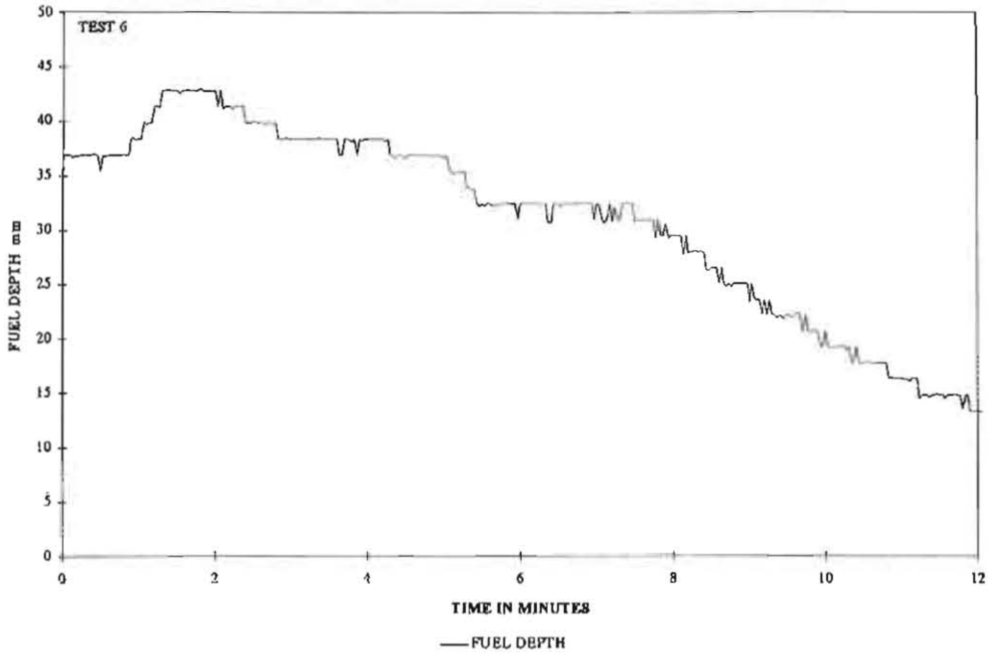


Figure H7 : Test 6. Surface Temperatures



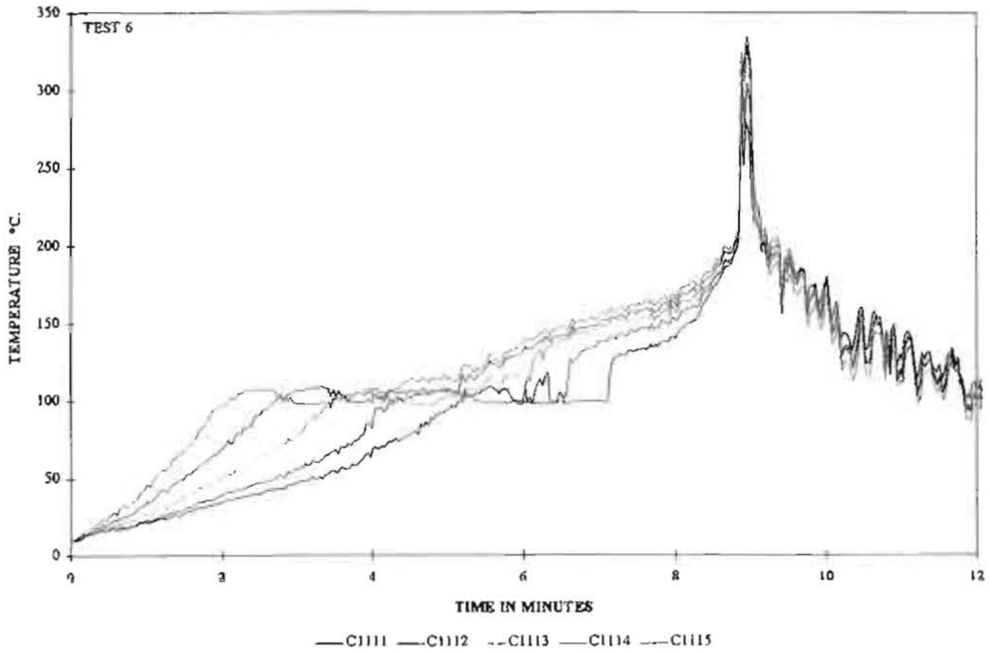


Figure H8 : Test 6. Fuel Depth & TC Tree

Appendix I : Results of Test 7.

Test 7

Date 23 November 1995
Weather Overcast

NE door and SW door opened at 5 minutes

Air Temperature 11.0° C Relative Humidity 82.0%

Tray 1	
Water depth -mm	31
Fuel depth-mm	34
Water Temp-°C	19.9
Fuel Temp- °C	15.8
Tray 2	
Water depth -mm	33
Fuel depth-mm	36
Water Temp-°C	17.8
Fuel Temp- °C	14.6
Tray 3	
Water depth -mm	29
Fuel depth-mm	38
Water Temp-°C	18.8
Fuel Temp- °C	14.4

Time from ignition	**Observations**
0:13	NE door open
0:20	Door closed
	Some pulsing
	Lazy smoke from roof vents
	Not much smoke on E side
5:02	LH side of SW door open to 90 degrees
5:11	LH door fully back
	Smoke lazy out of top of door
5:10	South half of door to 90 degrees
5:17	N door half opened
5:20	South door fully open
5:27	Other door open
	Smoke from lower level vents in last 5 minutes
	More smoke from each vent than from NE door
10:00	Fire out

Flame spread poles added at 2m and 3m.
Fire Spread Test 7

	2 m	3 m
Fire Spread Tree 1	No charring, surface blackened	Charring to 4mm deep on top and surface facing fire.
Fire Spread 2	No charring surface blackened	Light charring to 1 mm deep,,

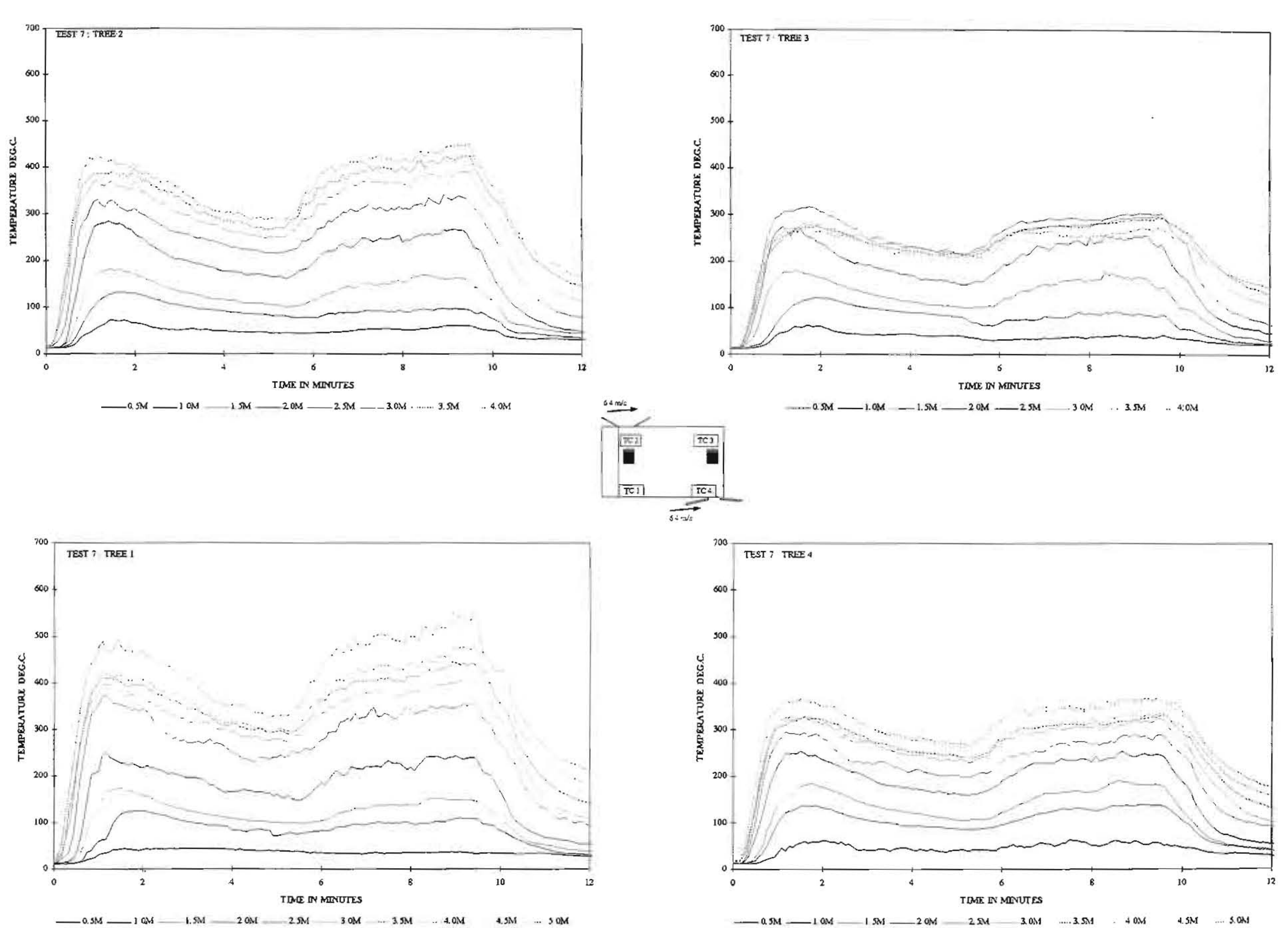
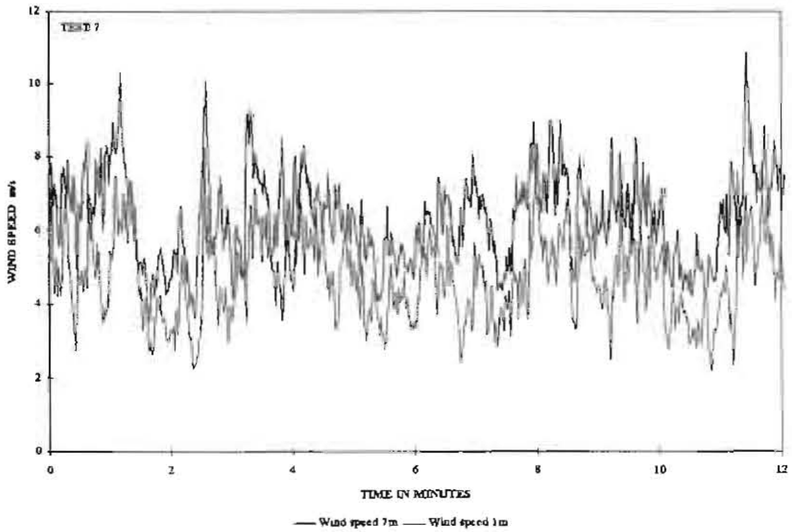
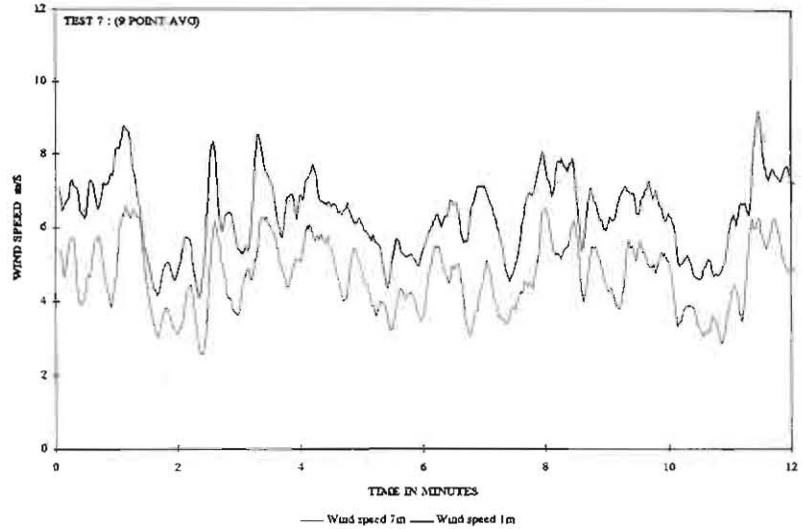
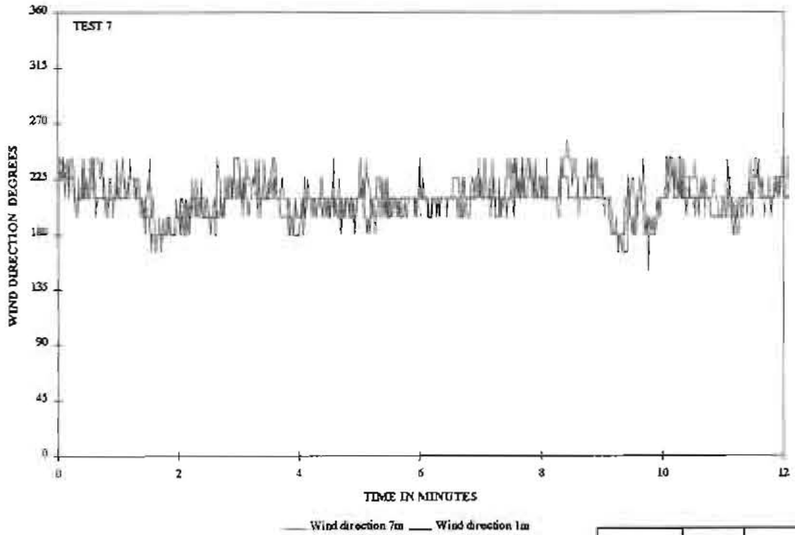
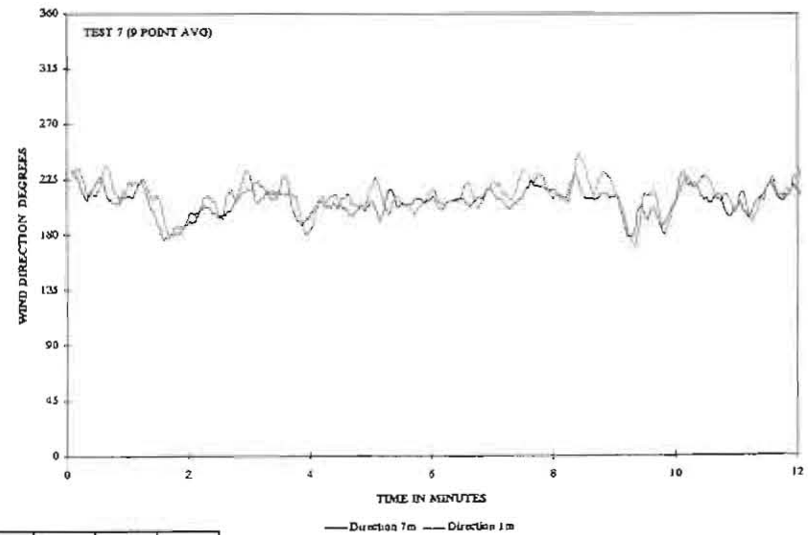


Figure I1: Test 7. Gas Temperatures from Temperature Trees



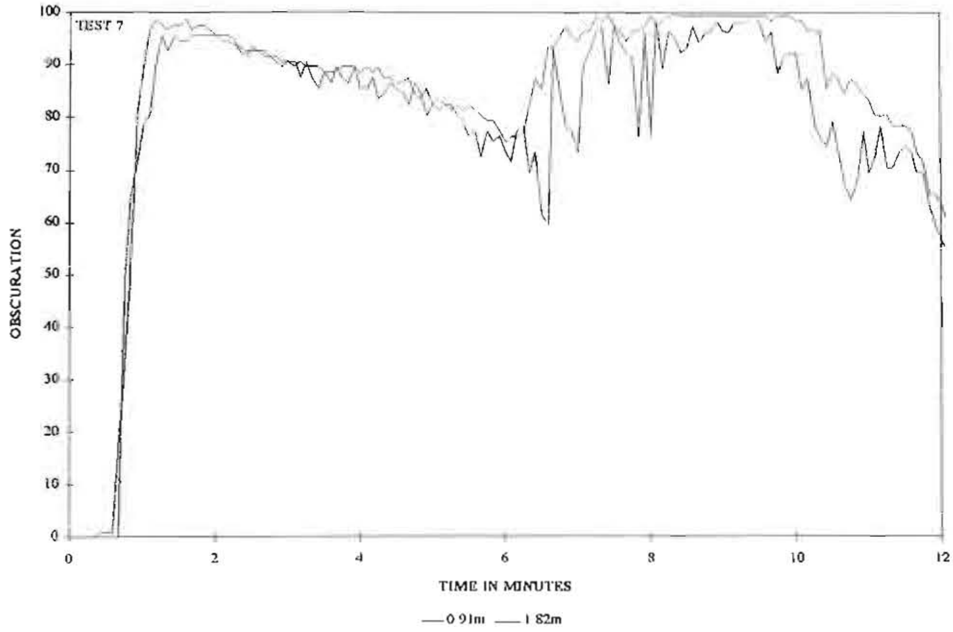






			TEST 7			
		WIND SPEED & DIRECTION				
7m			1m			
SPEED	0-5 Mins	5-10 Mins	0-10 Mins	SPEED	0-5 Mins	5-10 Mins	0-10 Mins
AVG	6.471884	6.29366777	6.382657	AVG	4.852236	4.621731	4.736293
STD	1.299797	1.03713766	1.179204	STD	1.188657	0.987988	1.098887
7m				1m			
DIRECTION				DIRECTION			
AVG	205.0112	206.82349	205.9112	AVG	210.2957	212.1664	211.2341
STD	16.10115	12.7526697	14.55128	STD	16.72981	17.74367	17.26946

Figure I2 : Test 7. Wind Speed & Direction



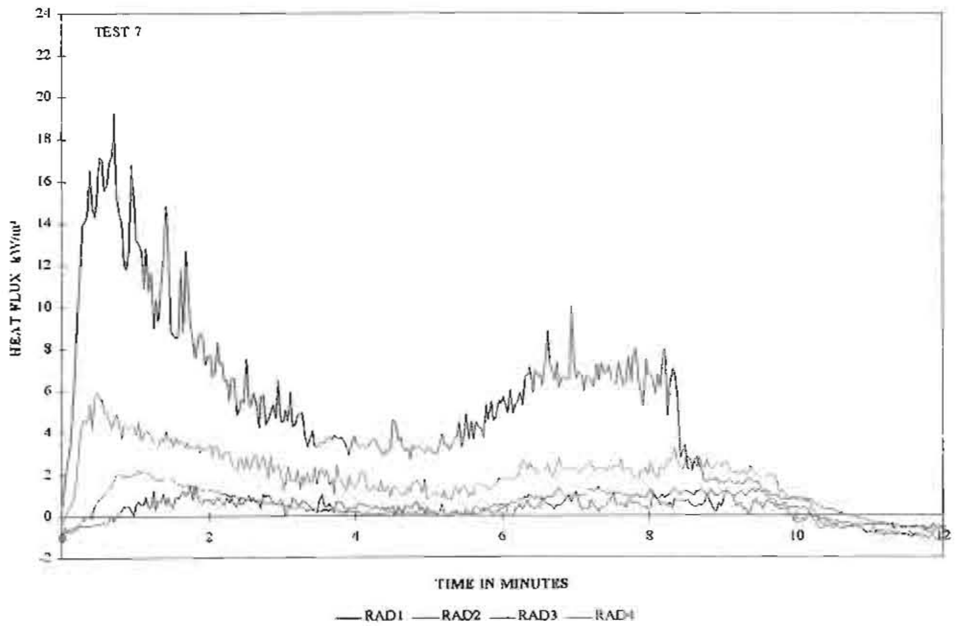
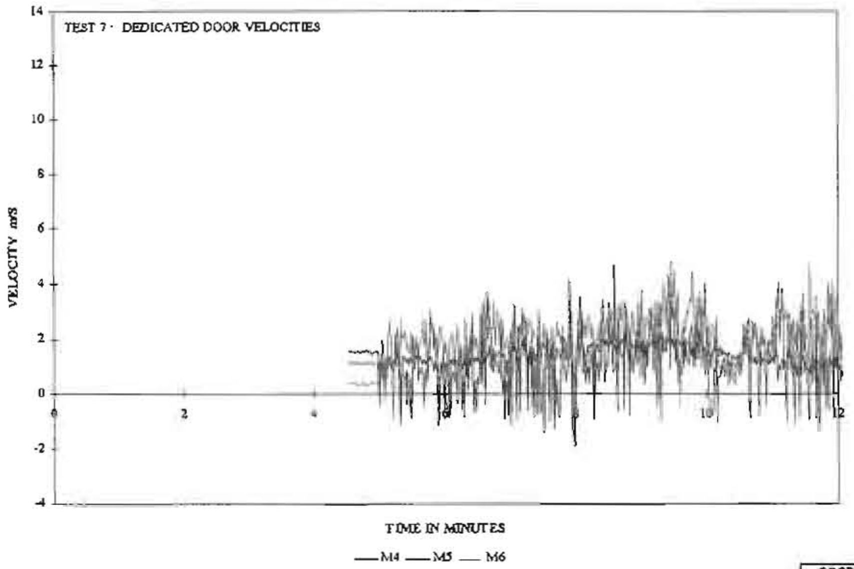
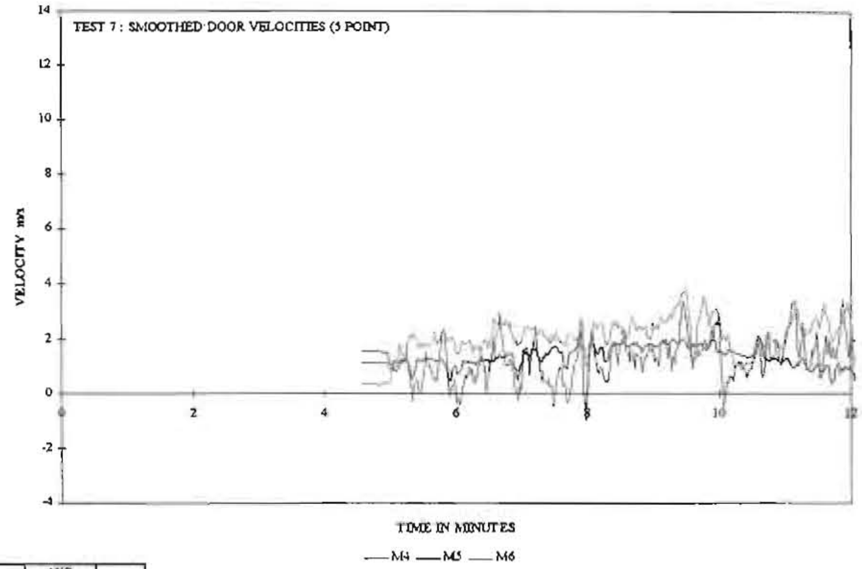


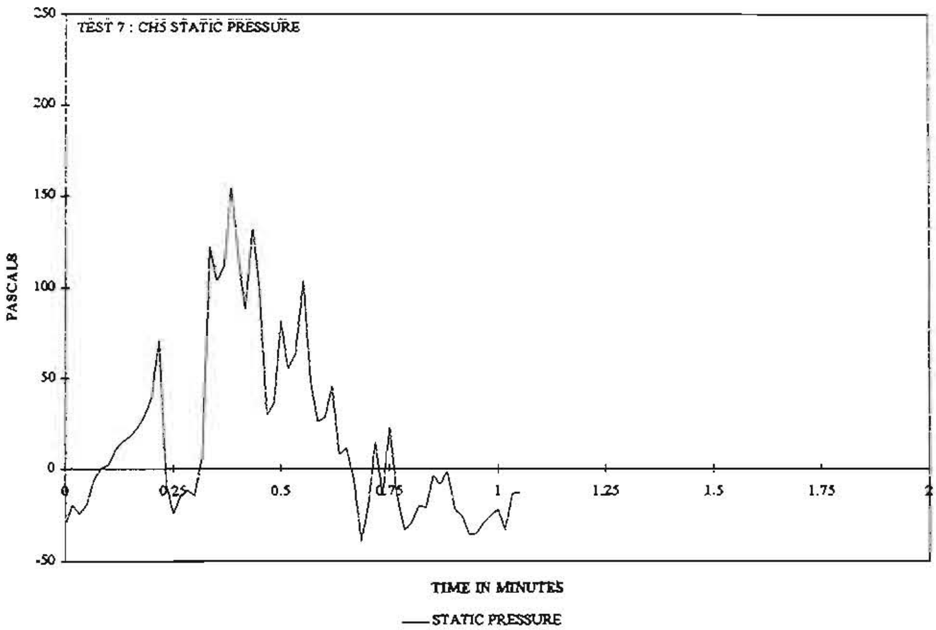
Figure 13 : Test 7. Smoke Obscuration & Heat Flux





DOOR CHANNEL	TIME MINUTES		AVG VELOCITY	STD
5 No.	START	FINISH	m/s	DEV
1	[illegible]	6.23	[illegible]	1.9
1	[illegible]	8.22	-6.48	0.9
1	[illegible]	10.17	5.23	0.4
1	12.01	12.17	6.52	0.9
1	13.98	14.14	8.89	1.1
2	6.27	6.40	[illegible]	0.5
2	8.25	8.40	[illegible]	1.2
2	10.22	10.38	-0.12	0.6
2	12.18	12.33	0.79	1.2
2	14.17	14.33	0.54	0.4
3	4.56	4.60	0.74	[illegible]
3	8.42	8.60	-0.95	0.8
3	8.44	8.57	-0.49	1.1
3	10.37	10.55	-0.23	0.7
3	12.37	12.52	7.08	0.9
4	4.62	4.77	1.30	0.2
4	5.62	6.77	1.39	0.7
4	8.60	8.75	1.60	0.3
4	10.57	10.73	1.45	0.8
4	12.53	12.70	1.35	0.9
5	4.78	4.93	1.08	0.0
5	6.78	6.93	0.60	0.6
5	8.82	8.93	0.79	0.6
5	10.81	10.90	0.54	0.2
5	12.72	12.90	0.81	1.0
6	4.98	5.17	0.93	0.2
6	6.97	7.14	2.67	1.1
6	8.95	9.10	2.35	1.1
6	10.93	11.08	3.06	0.7
6	12.90	13.08	2.12	0.7
7	5.18	5.35	1.74	0.8
7	7.17	7.32	1.44	0.6
7	9.14	9.28	0.57	0.4
7	11.12	11.27	-0.19	0.7
7	13.08	13.23	1.66	0.7
8	5.35	5.52	0.51	0.0
8	7.33	7.48	0.51	0.0
8	9.31	9.48	0.51	0.0
8	11.28	11.44	0.47	0.1
8	13.27	13.42	0.51	0.0
9	5.55	5.68	-4.27	0.2
9	7.52	7.67	5.79	0.4
9	9.50	9.65	10.22	0.2
9	11.47	11.60	6.14	0.2
9	13.45	13.60	-7.93	0.2
10	5.72	5.85	2.81	0.7
10	7.70	7.83	2.36	0.3
10	9.68	9.83	3.33	0.6
10	11.65	11.78	2.44	0.6
10	13.65	13.77	1.48	0.5

Figure I4 : Test 7. Gas Velocities in Doorway



	TIME		AVG	
CHANNEL	MINUTES		PRESSURE	STD
S No.	START	FINISH	PASCALS	DEV
1	1.10	1.40	-12.7	9.5
2	1.42	1.57	-36.4	7.3
3	1.62	1.95	-7.4	1.9
4	1.97	2.08	-5.6	2.2
5	0.00	1.05	16.9	48.9
5	2.10	2.38	-24.7	4.7
5	3.12	4.07	-29.5	8.6
6	2.40	3.10	-8.4	9.5
6	4.08	14.35	-8.7	9.8

Figure I6 : Test 7. Static Pressures

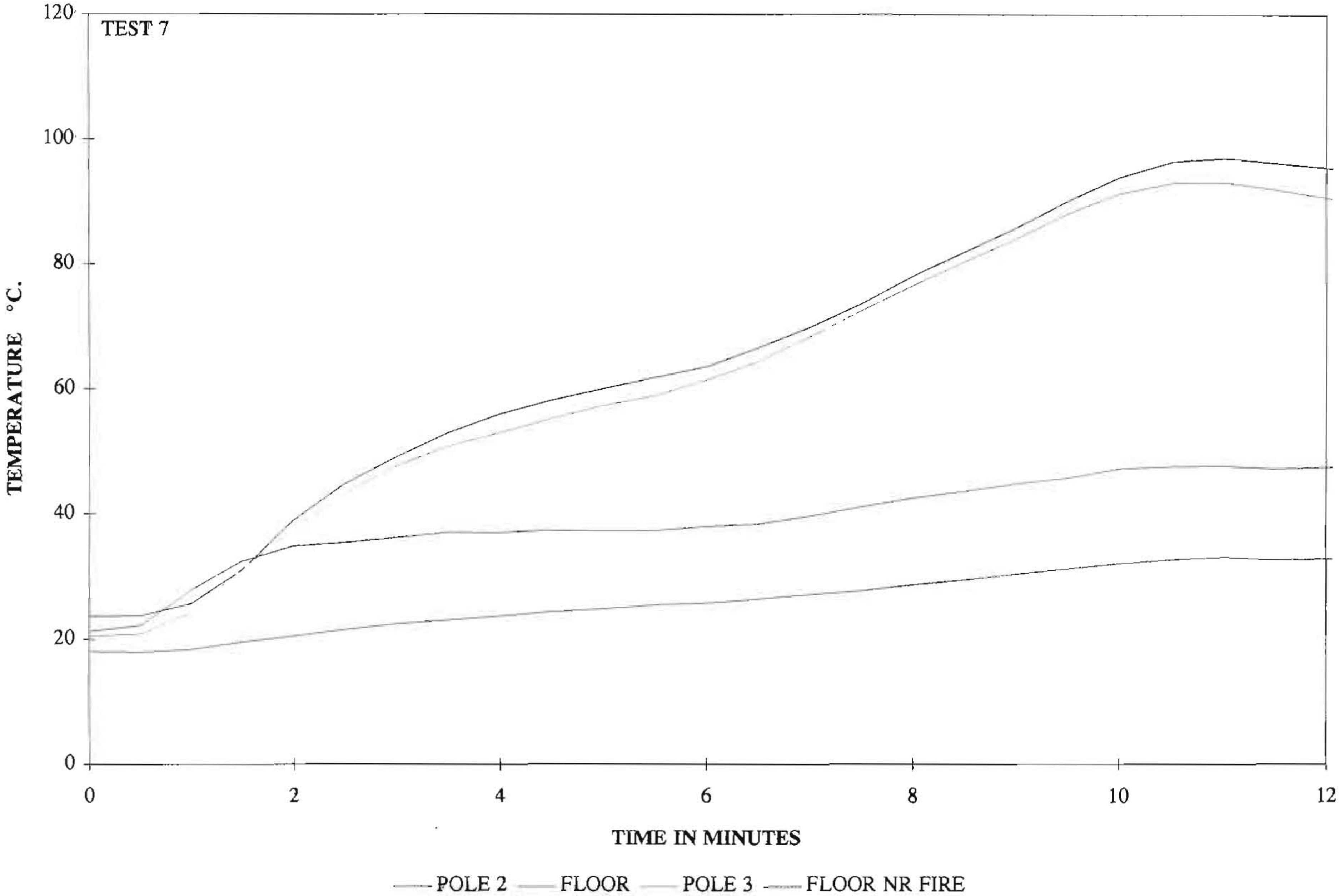
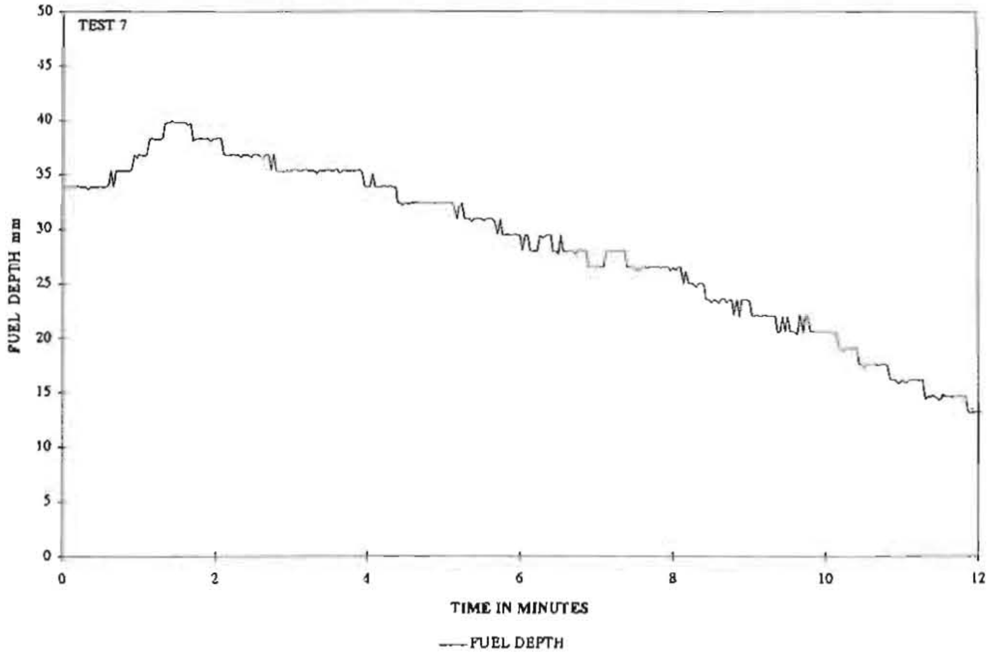


Figure I7 : Test 7. Surface Temperatures



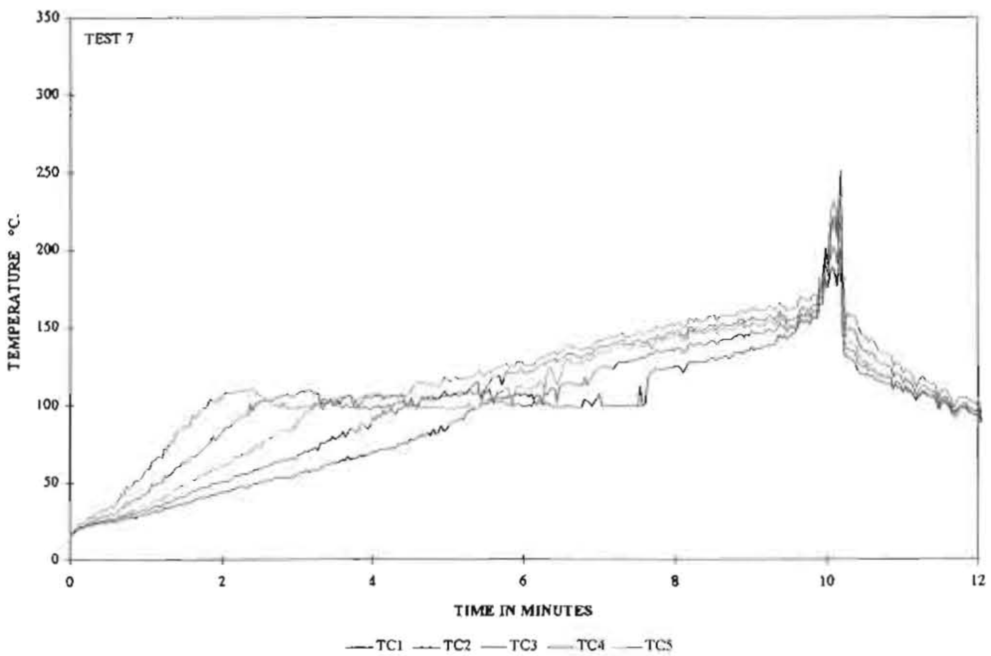


Figure I8 : Test 7. Fuel Depth & TC Tree

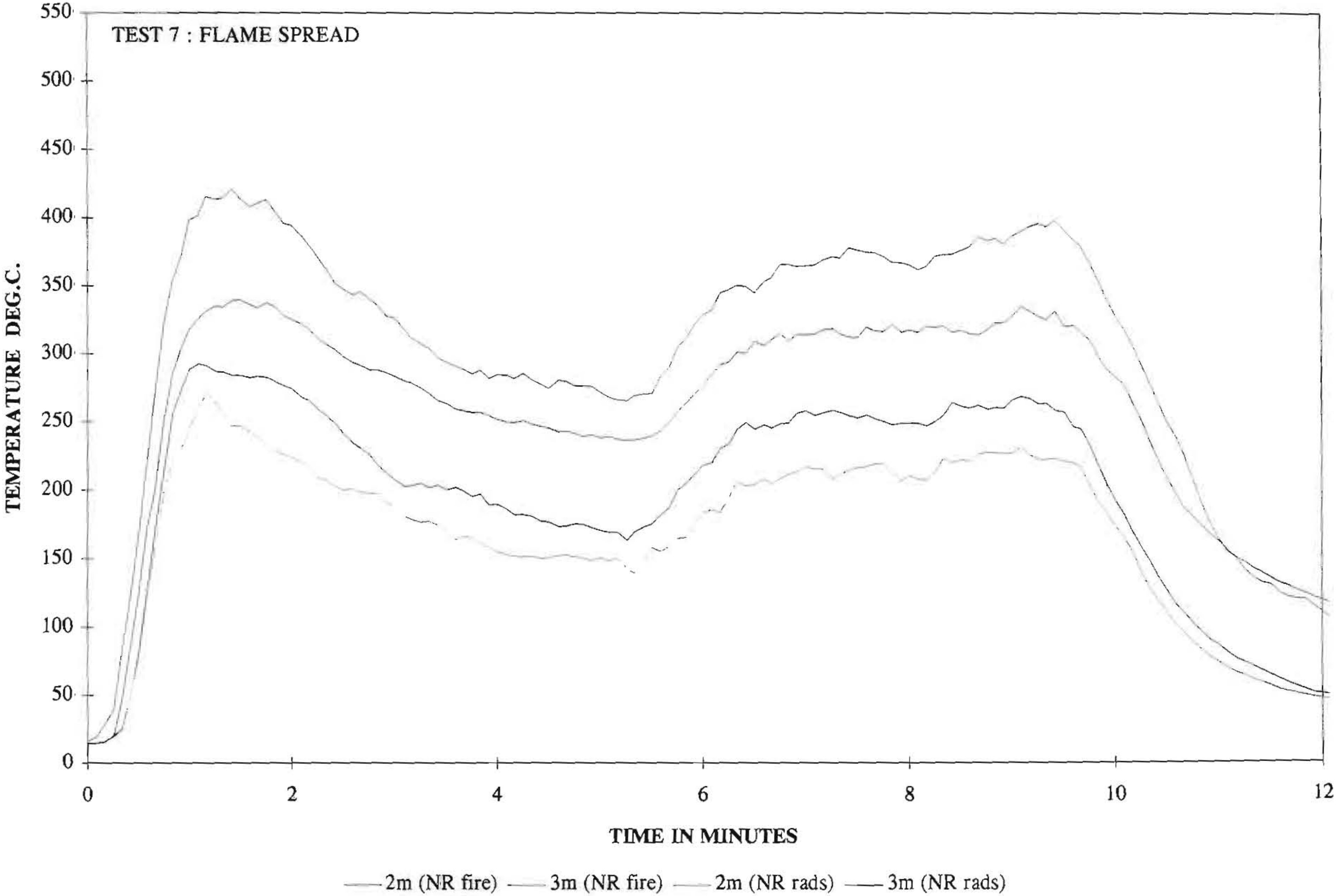


Figure I9 : Test 7. Flame Spread TC's

Appendix J: Results of Test 8

Test 8

Date 24 November 1995
Weather Windy and overcast

North vent and SW door opened at 5 minutes

Air Temperature 11.3° C Relative Humidity 85.8%

Tray 1	
Water depth -mm	23
Fuel depth-mm	38
Water Temp-°C	12.7
Fuel Temp- °C	11.3
Tray 2	
Water depth -mm	23
Fuel depth-mm	40
Water Temp-°C	12.7
Fuel Temp- °C	11.4
Tray 3	
Water depth -mm	27
Fuel depth-mm	41
Water Temp-°C	13
Fuel Temp- °C	11.5

Time from ignition	**Observations**
	Most smoke from Number 2 vent
	Smoke swirls around E door south side
5:01	Vent open
5:02	Door S half open to 90 degrees.
5:12	Door back to wall
5:20	Other half of door open
	Very little smoke from NE door. Some swirling around south side of the door
9:42	Fire Out

Fire Spread

	2 m	3 m
Fire Spread Tree 1	No charring, surface blackened	All surfaces charred. Top surface and surface facing fire to 6mm, other surfaces to 2mm.deep
Fire Spread Tree 2	No charring surface blackened	Light charring to 1mm deep on top and

surface facing fire.

All pieces of wood were pine 358mm x 36mm x 36mm.

In addition to the trees with thermocouples fitted, other pieces of wood were positioned on top of the 1.8 metres wall to the west of the fire trays The moisture content of all the samples was in the range 12-14%.

Ref.	**Position**	**Observations**
Sample 1 (Ref. SF1)	On top of internal wall opposite tray 1	Deep charring to 4mm on top and surface facing fire.
Sample 2 (SF2)	On top of internal walls opposite tray 3	Deep charring 5mm deep on top and side facing fire.
Sample 3 (Ref. SF3)	On top of wall adjacent to radiometer 4	Slight charring (depth 1mm) on top corner facing fire

No roof McCaffery probes.

Radiometer 4 gave approximately half its normal output on calibration.

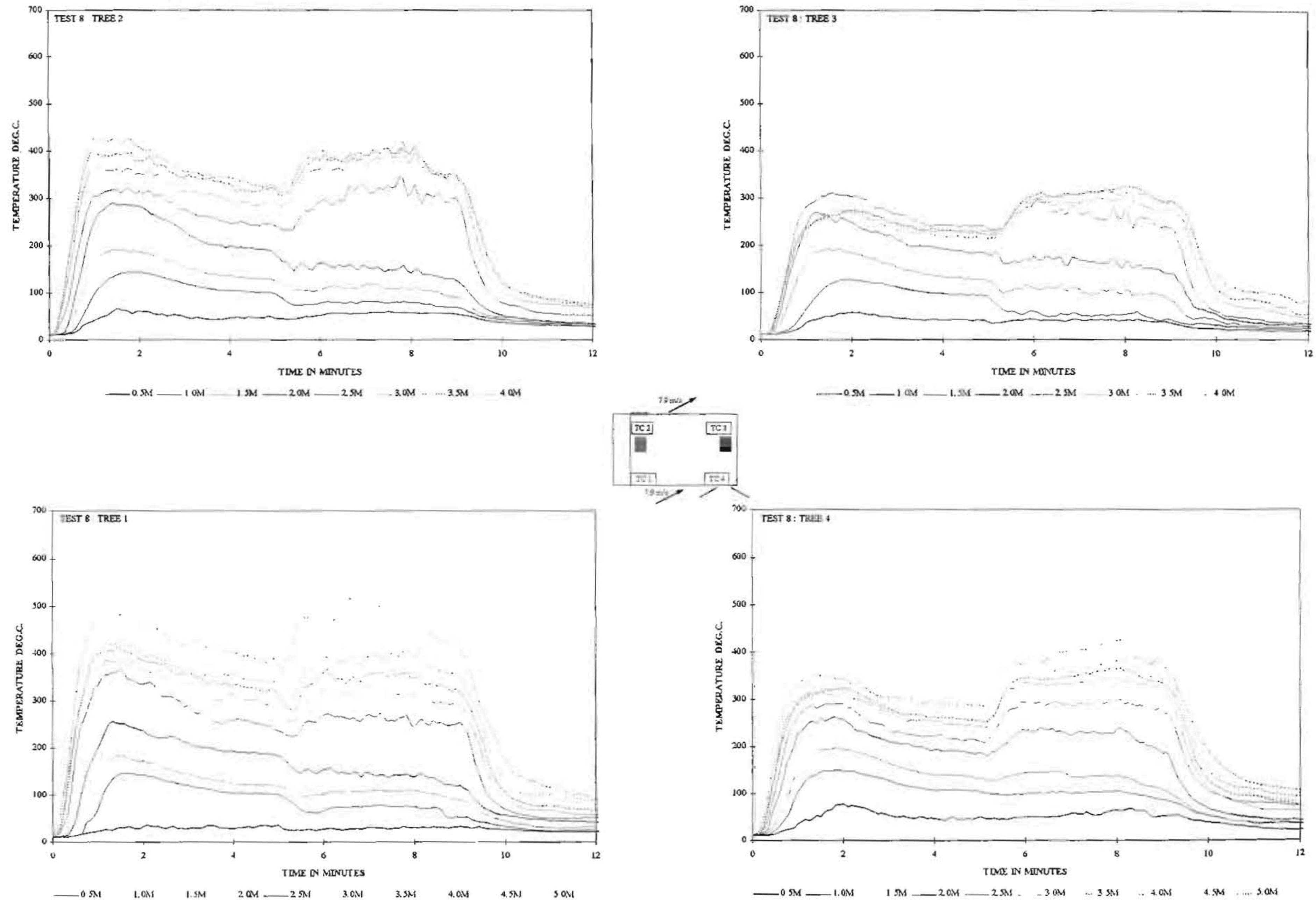
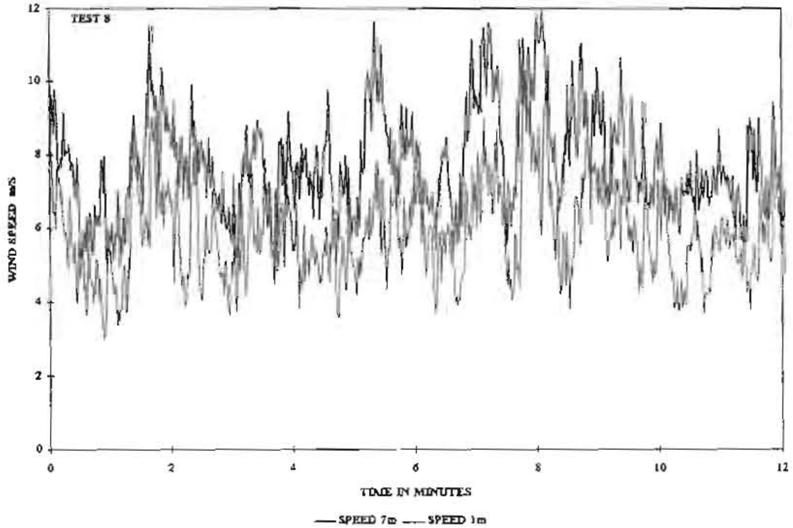
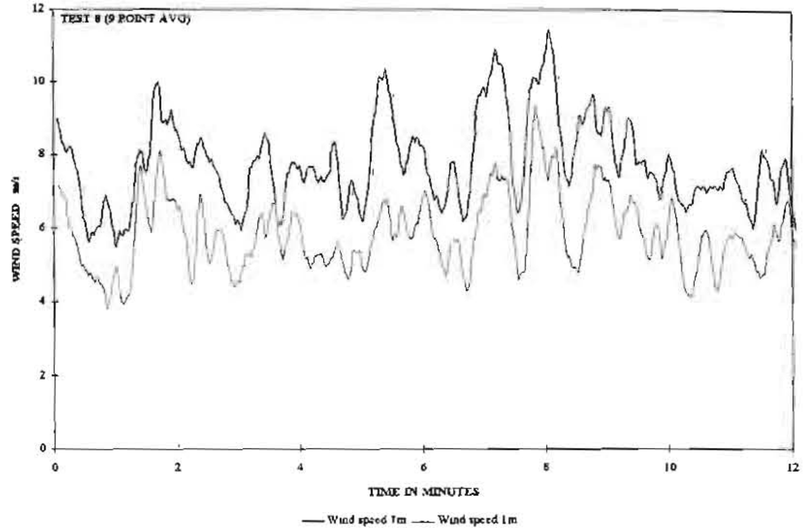
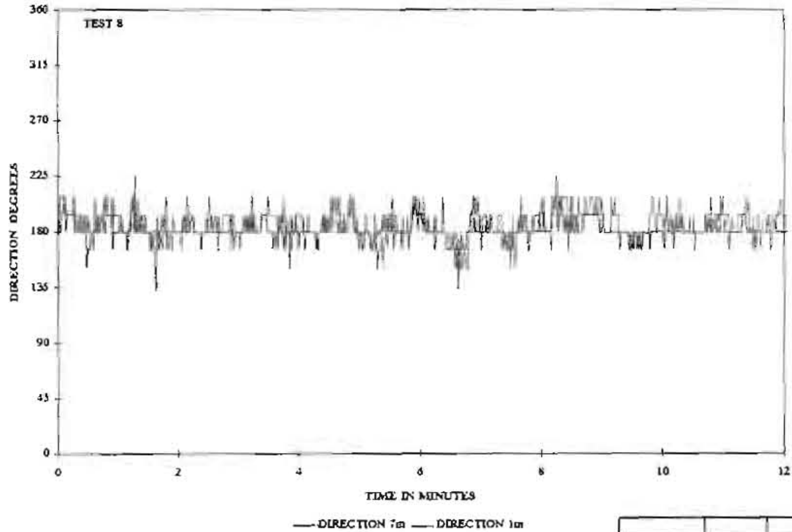
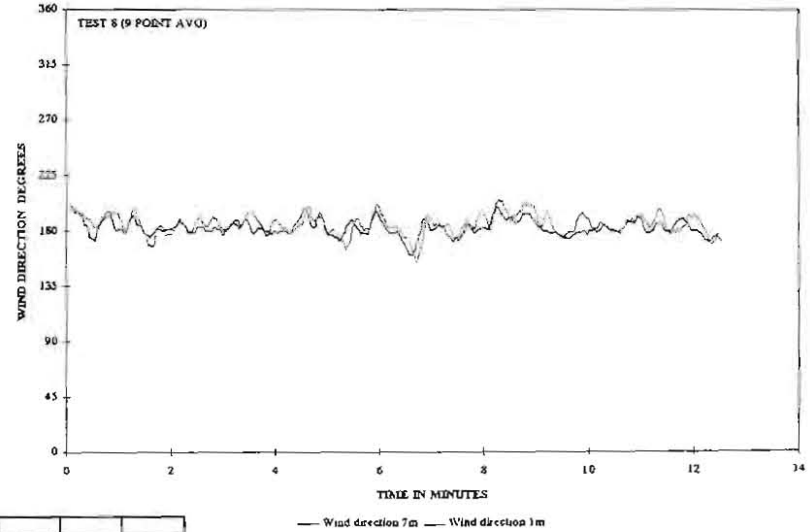


Figure J1 : Test 8. Gas Temperatures from Temperature Trees



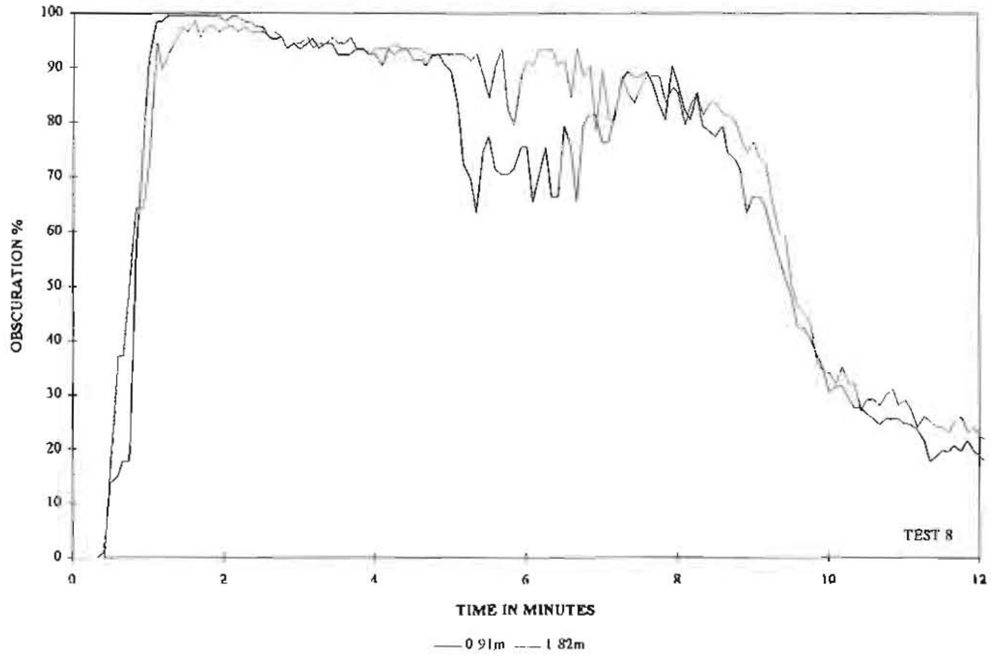






		TEST 8					
		WIND SPEED & DIRECTION					
7m				1m			
SPEED	0-5 Mins	5-10 Mins	0-10 Mins	SPEED	0-5 Mins	5-10 Mins	0-10 Mins
AVG	7.400153	8.427511628	7.916483	AVG	5.626734	6.273551	5.951689
STD	1.232334	1.518128564	1.473836	STD	1.20646	1.30655	1.298011
7m				1m			
DIRECTION				DIRECTION			
AVG	183.9607	181.3143476	182.6415	AVG	187.4	186.0543	186.7383
STD	9.843669	10.44954015	9.843669	STD	11.36812	13.90389	12.71436

Figure J2 : Test 8. Wind Speed & Direction



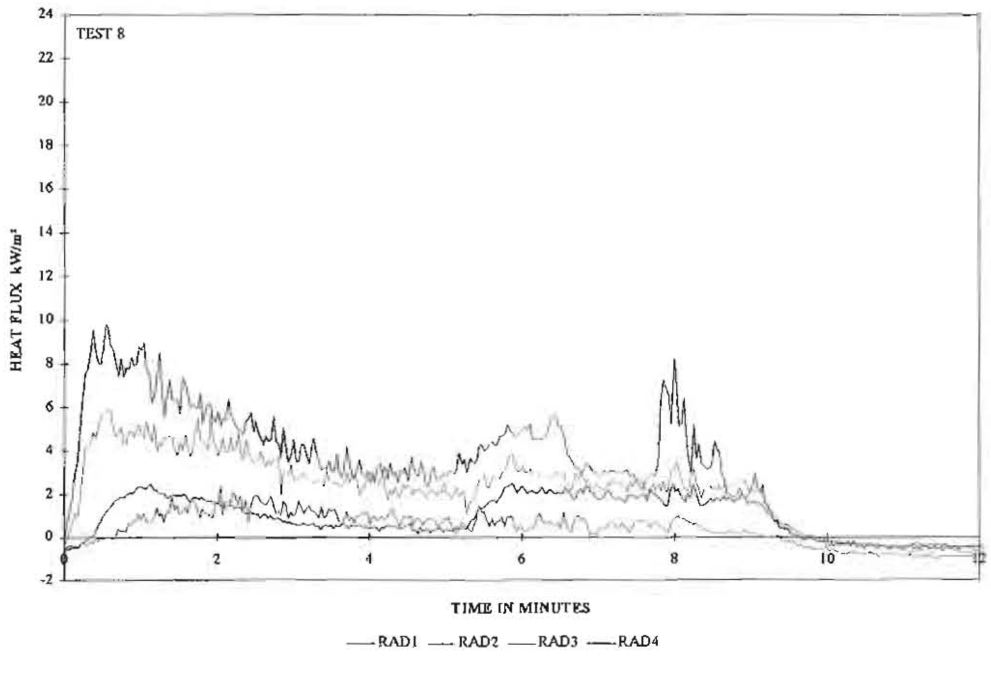
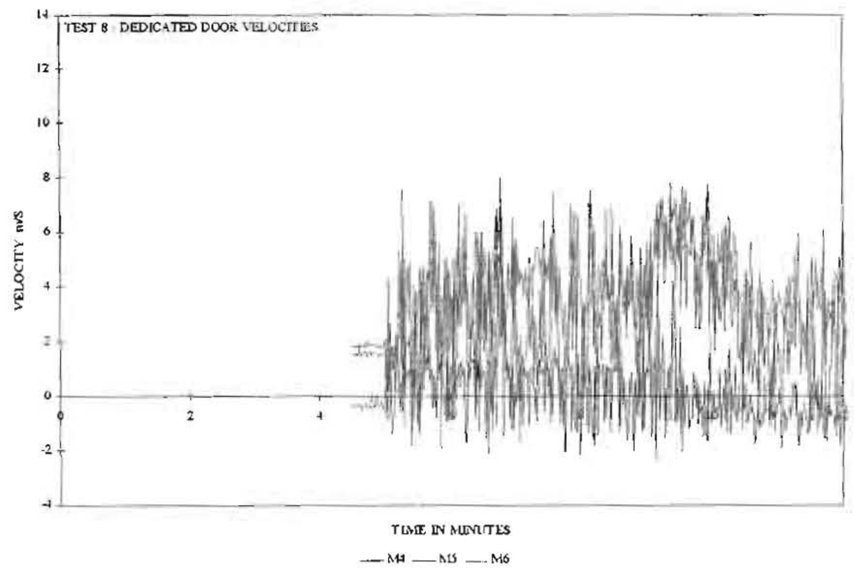


Figure J3 : Test 8. Smoke Obscuration & Heat Flux



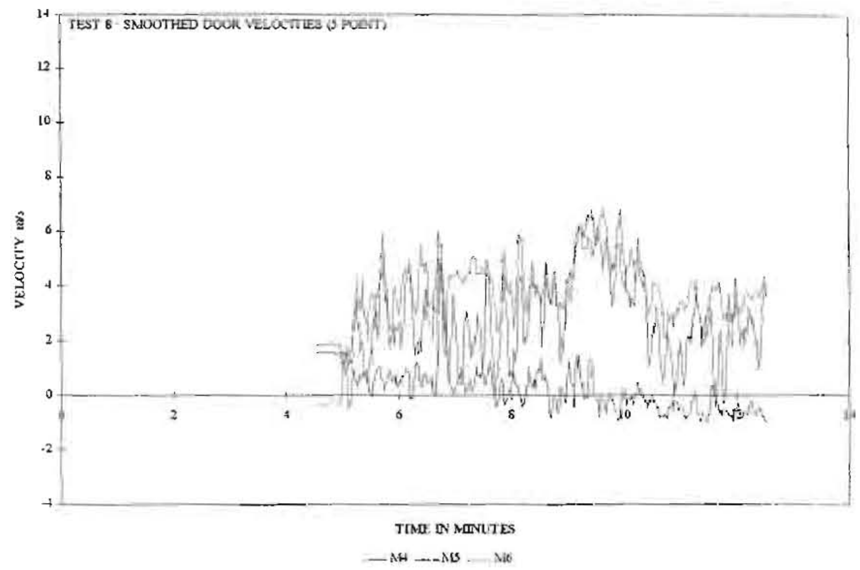


Figure J4 Test 8. Gas Velocities in Doorway

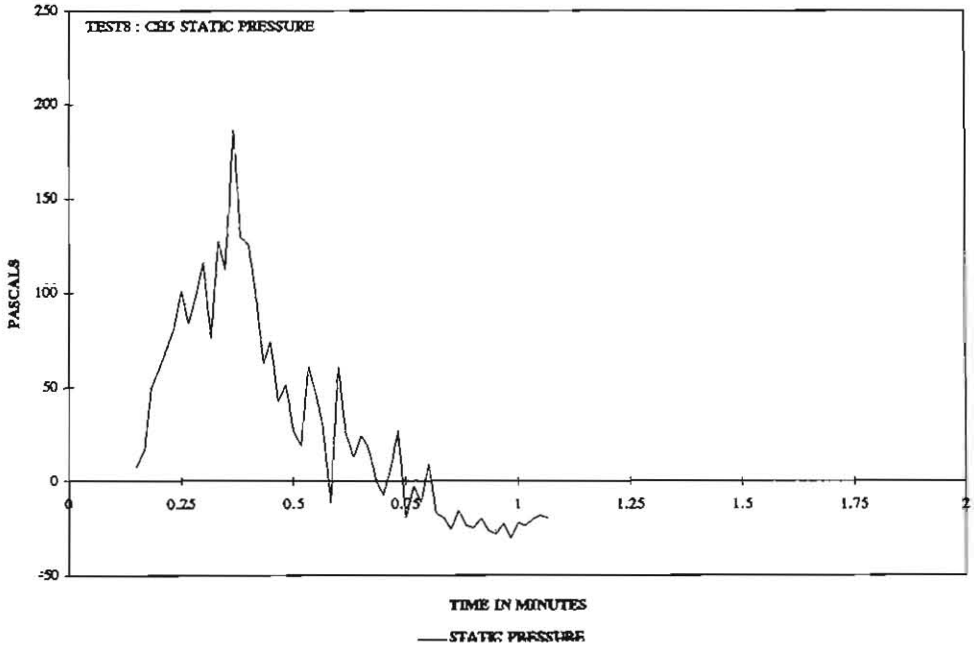


Figure J6 : Test 8. Static Pressure

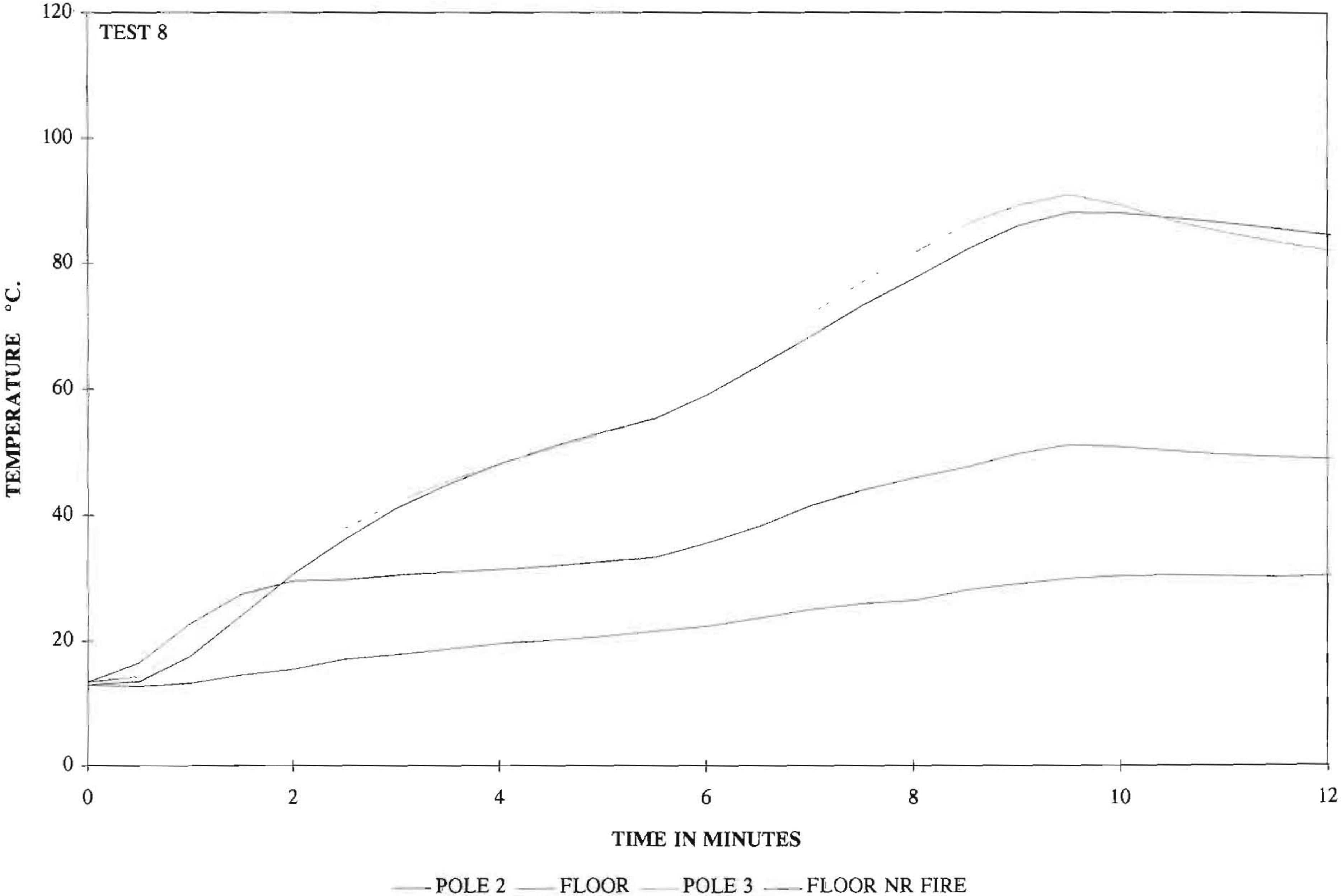
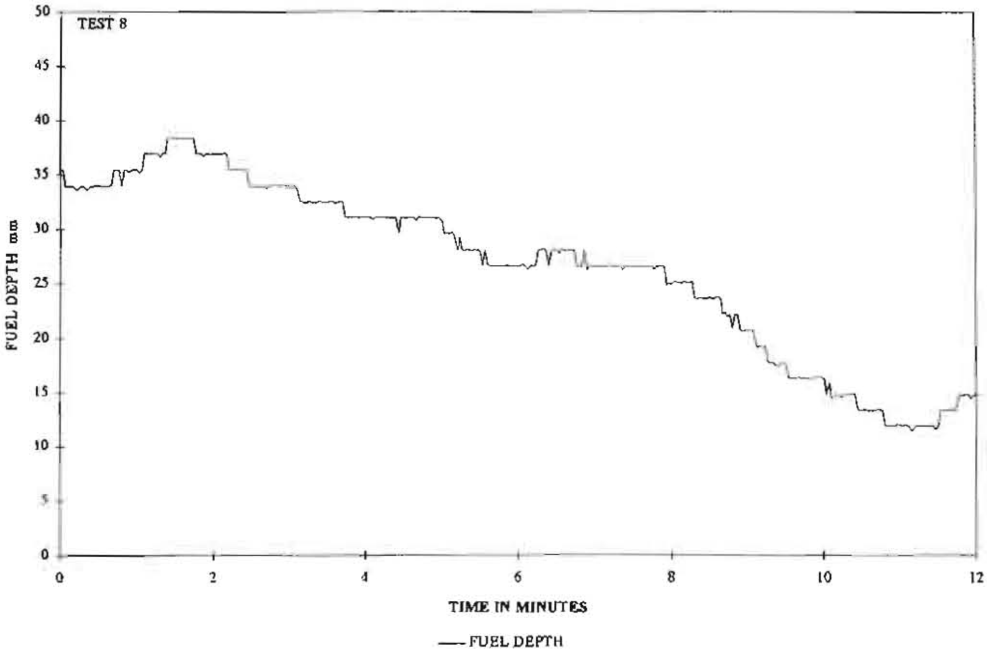


Figure J7 : Test 8. Surface Temperatures



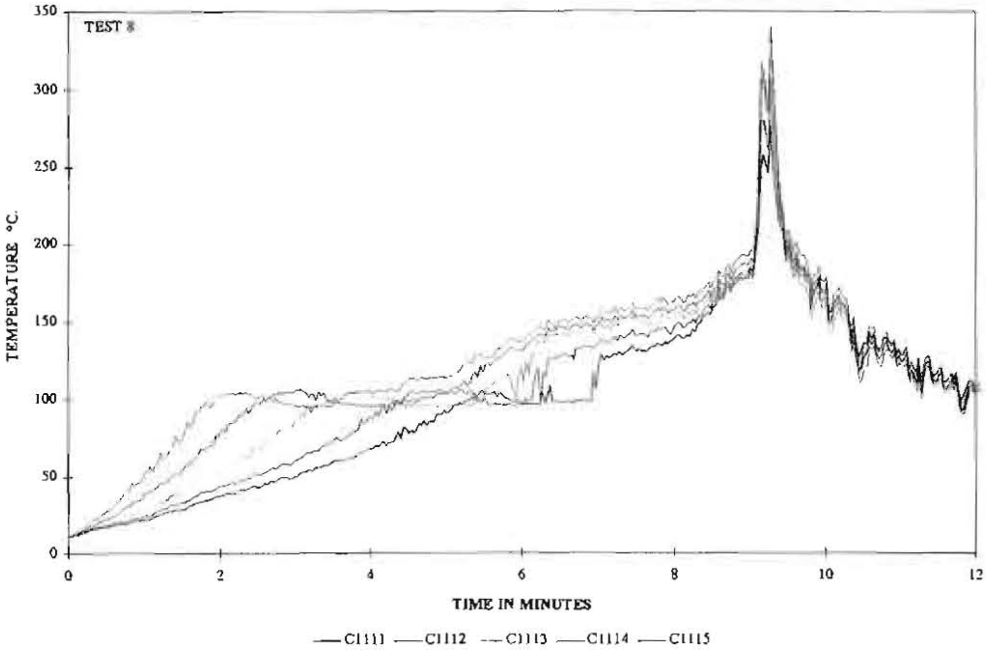


Figure J8 : Test 8. Fuel Depth & TC Tree

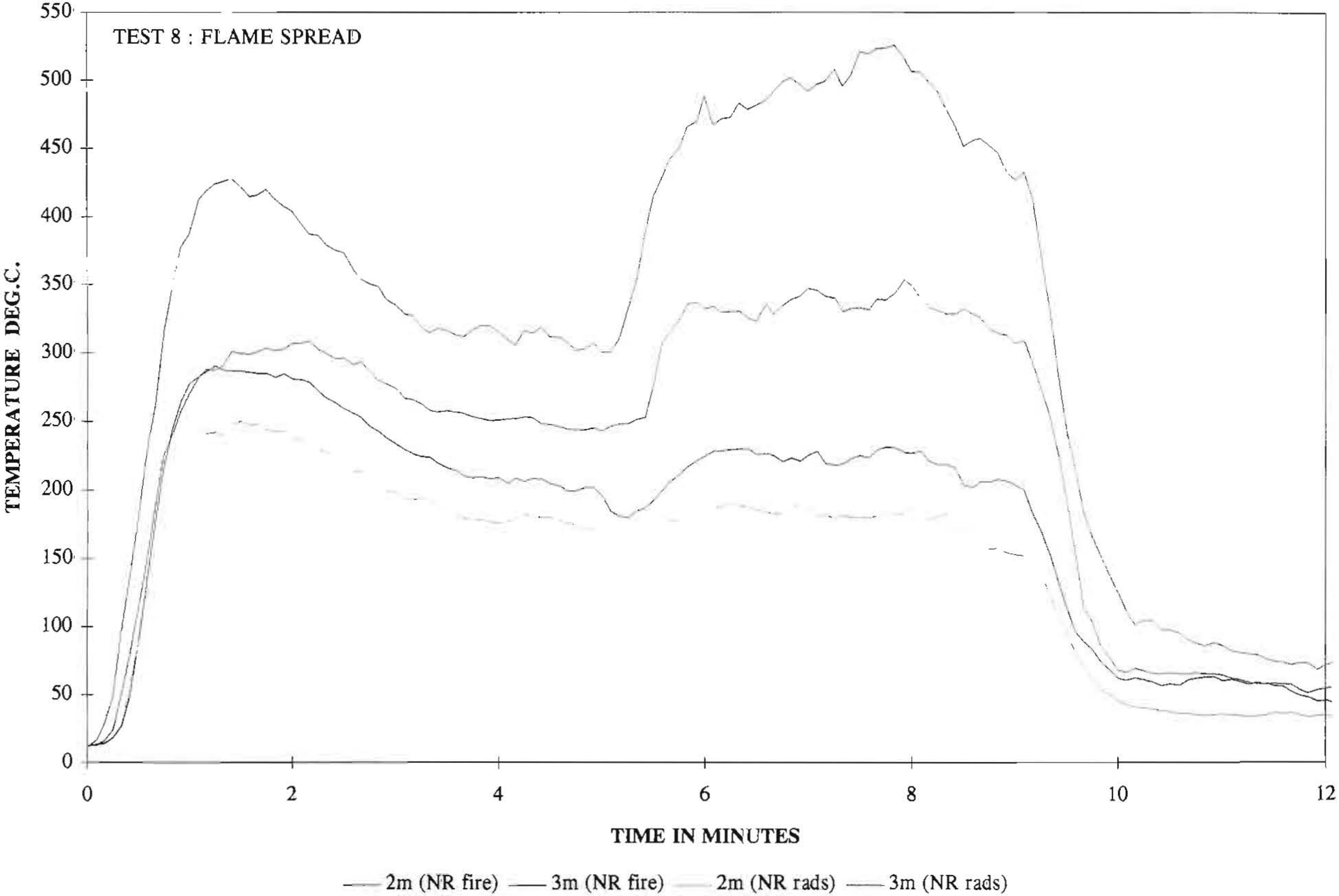


Figure J9 : Test 8. Flame Spread TC's