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HOME OFFICE

Additives for Hosereel Systems: Trials of Foam on Wooden Crib Fires

B P Johnson

FIRE RESEARCH & DEVELOPMENT GROUP

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F E P D

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ADDITIVES FOR HOSEREEL SYSTEMS :

TRIALS OF FOAM ON WOODEN CRIB FIRES

BY

B P JOHNSON

Home Office
Fire Research and Development Group
Fire and Emergency Planning Department (FEPD)
Horseferry House
Dean Ryle Street
LONDON SW1P 2AW

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ABSTRACT

Foam trials were carried out against small and large scale Class A fires involving British Standard wooden cribs. The large scale fires were carried out in a purpose built fire test room. The objective of the trials was to assess suitable additives for hosereel systems for control and extinction of Class A fires. A range of commercially available additives were tested.

In the large scale fire tests, the additives were supplied through a hosereel branch at a solution rate of 100 lpm and the branch was either hand-held or mounted on a remote firefighting rig. When using the branch at a spray setting and mounted on the remote rig, non-aspirated AFFF would allow a firefighter to enter the fire test room sooner than did any of the other additives tested, although not significantly quicker than when using water alone. Some additives gave worse performance than using water alone.

With the branch at a spray setting and mounted on the remote rig, Halofoam (now supplied as Pyrofoam), an expensive self-foaming additive, gave the best knockdown of the fire over the first 6 minutes of firefighting. This knockdown was significantly better than that achieved by non-aspirated AFFF, which in turn achieved a knockdown that was significantly better than that achieved by any of the other additives or by water. When the branch was hand-held and used on a jet setting, both aspirated and non-aspirated AFFF achieved similar knockdowns of the fire.

MANAGEMENT SUMMARY

As part of the Home Office Fire Research Programme, the Fire Experimental Unit (FEU) of the Fire Research and Development Group (FRDG) was requested to undertake a project to recommend a suitable additive or selection of additives for use in hosereel systems.

The work described in this report was carried out to assess which additives improve control and extinction of Class A fires. In order to achieve a standard, repeatable test fire, dry wood was used as the fuel throughout the trials.

The overall objective of this work was to select the most suitable additives for control and extinction of Class A fires. The work involved two series of small scale and one series of large scale fire trials. It was hoped that the small scale test method would provide a future means of additive selection without the need to carry out large scale fire trials.

Small scale trials

In each small scale trial, a fire in a single wooden crib was handfought by an experienced firefighter using either a small aspirating or a small non-aspirating nozzle delivering the additive solutions at 9 litres per minute. This is the typical flowrate of a hand-held fire extinguisher. The firefighter was allowed complete access to all sides of the burning crib.

The crib fire was started by igniting a quantity of Heptane, in trays, underneath the crib. The crib was allowed to burn for a total time of 8 minutes before firefighting commenced.

The following additives, in solution, were used :-

Fluoroprotein	FP
Alcohol Resistant FP	FP-AR
Film-forming FP	FFFP
Alcohol Resistant FFFP	FFFP-AR
Aqueous Film-forming Foam	AFFF
Alcohol Resistant AFFF	AFFF-AR
Synthetic	S
Wetting agent	
'Halofoam' (Now supplied as 'Pyrofoam')	
'Fireout'	

All of the above additives were applied aspirated and non-aspirated except for FP-AR which was applied aspirated only, and the wetting agent, Halofoam and Fireout which were applied non-aspirated only. Potable water, with no additives, was also used for comparison purposes.

The performance of each of the additives was measured in terms of the control time. This was defined as the time taken to knockdown all signs of flame with no immediate burnback.

The results of these small scale fire trials showed that Halofoam was the most successful of the additives tested (control in 1 minute 10 seconds), this was a significant improvement over the time to control achieved with water (control in 2 minutes 9 seconds).

Of the conventional "fire-fighting foam" additives, Synthetic gave the best control when both aspirated (1 minute 15 seconds) and non-aspirated (1 minute 40 seconds). Non-aspirated AFFF gave a very poor "time to control" (2 minutes 3 seconds).

In general, the aspirated versions of the additives tested showed an average 25% improvement in the time to control when compared with the corresponding non-aspirated versions.

The results of the small scale fire tests showed large variations in the relative effectiveness of the additives tested. None of these additives gave times to extinction that were significantly worse than water. It was for this reason that all of the additives tested here were selected for testing during the large scale Class A fire trials.

Large scale trials

The large scale Class A fire trials were performed at the fire test room facility in the Fire Experimental Unit's Hangar at Little Rissington. The room was constructed of brick with a flat reinforced concrete roof. It was 4.3 metres (14 feet) square, with an open doorway in the centre of one wall, and window openings in the two adjacent walls. The ceiling was 2.7 metres (9 feet) high and suitably protected. The fire test room was surmounted by a steel hood, designed to remove the combustion products from the Hangar.

The Class A fuel, wood, was systematically arranged in cribs around three sides of the room, approximately 0.5 tonne of it was used for each trial fire. The fire was started by igniting Heptane in trays beneath the cribs, using electrically triggered detonators.

The fire test room was fully instrumented to record temperature, both within the crib fires and the air within the room and around the doorway. Video cameras were also positioned outside the test room windows and low down in the doorway.

During the majority of the trials, an Angus Superfog hosereel branch was used to fight the crib fires. This branch was chosen because it is widely used in brigades and it had also been used in previous FEU trials.

For the non-aspirated trials, the branch was mounted on a rotatable rig. This rig enabled the fire to be fought in a repeatable way, thus avoiding any variations between trials due to human factors such as skill, etc. The branch was operated at a flowrate of 100 litres per minute and with an included spray cone angle of 26°. This allowed the spray to wet the front surfaces of the cribs over their entire height.

A branch could not be found that would produce an aspirated spray with an included angle of 26°. Consequently, comparison tests of aspirated against non-aspirated additives could not be made using the remote rig. Instead, several trials were performed where the fire was hand fought from the doorway using the Superfog branch, at 100 litres per minute, set to give a coherent jet of either aspirated AFFF (using its aspirator attachment), non-aspirated AFFF or water.

These trials gave an indication of the relative performance of aspirated against non-aspirated AFFF bearing in mind that the small scale tests indicated a 25% improvement when using aspirated additives.

In all trials, the fire was allowed to burn for 8 minutes by which time it was fully developed. When using the remote rig, the fire was first attacked from the doorway for a period of 2 minutes, the spray being systematically swept around the room. After 2 minutes, the rig was advanced into the centre of the room still sweeping and the attack continued from this position until the end of the trial. In the handfought trials, the firefighter commenced firefighting from the doorway at eight minutes and remained there throughout, systematically sweeping around the room.

In all of the fire trials, the fire was suppressed to some extent and contained by all of the additives (and water) tested, but none extinguished it completely.

During the analysis of the results it was found that the graphs of average crib temperature plotted against time gave a clear and accurate representation of the suppression of the crib fires. Also, the area under the curve gave an indication of the averaged temperature reduction of the fire during each of the tests. From these results, approximations of the percentage averaged temperature reduction of the fire during the first 30 seconds and 6 minutes of firefighting were made. Also, similar results were obtained from graphs of doorway air temperature plotted against time, for the averaged temperature reduction of the air at the doorway over the first 30 seconds. All of these results are presented within the report.

CONCLUSIONS

It was only possible to test the additives against one standard Class A fire, and care must be taken in applying the conclusions to other circumstances. Nevertheless, the work does provide a basis for comparing the relative performance of the various additives.

It was hoped that by performing the small scale fire trials, the results of the large scale trials could be predicted. This was not the case. This may be due to many factors, in particular, the variation of the degree of access allowed to the fires, the different characteristics of the firefighting branches used and the differences in the methods used to measure the performance of the additives.

The conclusions drawn from the large scale trials were as follows :-

1. The rate at which the air temperature in a room can be reduced will govern the time before a firefighter can enter and make a close range attack on the fire. Where water cannot be directed as a jet at the base of the fire, previous work has shown that a spray setting is best. In this current work, when using the branch at a spray setting none of the additives showed an appreciable improvement over the use of water alone in reducing the air temperature within the fire test room. AFFF was marginally the most effective, and Halofoam and AFFF-AR were worse than water alone.

2. The use of all additives, with the exception of Fireout, did make a positive contribution to reducing the severity of the test fire, when compared to the use of water alone, though some were far better than others. In general, AFFF and Halofoam were the most effective, with FFFP, AFFF-AR and Synthetic running second. The alcohol versions of AFFF and FFFP were both inferior to their standard versions.

3. The high cost of Halofoam would rule it out from all but special cases and, with Synthetic additive costing a third of the price of the more sophisticated AFFF and FFFP products, this has to be a factor to be considered.

4. Only a brief comparison between aspirated and non-aspirated application was made using AFFF from a hand-held branch at a jet setting. There was no significant difference in performance between the two applications. Also, water, when used under the same conditions, gave similar performance.

The best of the commonly used additives tested, AFFF, would reduce the duration of the control phase of firefighting but the overall saving in water and any reduction in fire damage would be small. The decision on whether to use this additive for domestic fires would therefore be based on operational considerations on the merits of a reduction in the time to get a room fire under control.

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1. INTRODUCTION

As part of the Home Office Fire Research Programme, the Fire Experimental Unit (FEU) of the Fire Research and Development Group (FRDG) was requested to undertake a project to recommend a suitable additive or selection of additives for use in fire appliance hosereel systems. This led to Fire Research Project F 23.05(85) (formerly F 4.7(85)).

The objectives of the project relate specifically to appliance hosereel systems and are as follows:-

1. To find which additives improve control and extinction of Class A fires.

2. To find the most suitable additives for the control and extinction of Class B fires and to evaluate burnback resistance.

3. To evaluate additive performance against non-standard fuels, for example: tyres, alcohols and polyurethane foam furniture.

4. To investigate the tactical variations possible when applying additives through hosereel systems, for example: aspirated/non-aspirated, high/low pressure, spray/jet, number of branches.

5. To study the chemical effects of additives on firefighters, fire appliances and associated equipment.

Background studies confirmed that these objectives could not be met by the use of existing knowledge and therefore further work was necessary.

This report describes the work carried out to assess which additives improve control and extinction of Class A fires.

Class A fires are defined as "Fires involving solid materials, usually of an organic nature (compounds of carbon), in which combustion normally takes place with the formation of glowing embers" (Reference 1). The Manual of Firemanship (Reference 2) states that "Class A fires are the most common, and the most effective extinguishing agent is generally water in the form of a jet or spray".

Class A fires occur in ordinary combustible materials including wood, paper, and rubber, as well as many other natural fibres. Class A fires require the use of a heat-absorbing extinguishing agent such as water, or an extinguishing agent that will interrupt the chemical chain reaction. A distinguishing characteristic of Class A fires is that they proceed from a flaming surface combustion to a deep-seated glowing combustion. The extinguishing agent must penetrate the burning material (Reference 3).

The work described in this report involved two series of small scale Class A fire trials followed by one series of large scale Class A fire trials. In the small and large scale Class A trials, additives in solution to the manufacturer's recommended concentration were applied to standard wooden crib fires (to BS 5423 Reference 4).

The objectives of the small scale Class A fire trials work were:-

a) To obtain small scale test data to assist in the selection of additives for large scale testing.

b) To develop a small scale test method for future selection of additives.

c) To provide small scale test results for correlation with large scale tests.

The objectives of the large scale Class A fire trials work were:-

a) To obtain Class A fire test data from realistically sized fires tackled with additives through fire service equipment.

b) To select the most suitable additives for control and extinction of Class A fires.

Many water additives for fire-fighting are available. A number fall within the definition "fire-fighting foam", but there are also wetting agents and novel additives. The additives considered were those in use or under evaluation by brigades, and any other novel types.

"Fire-fighting foam" additives are classified into various types e.g. FP, AFFF etc. and each type is available from several manufacturers. The objective of the work in this report is to compare types of additives and it is not intended to recommend one supplier or another.

The additive types selected for evaluation during this work were fluoroprotein (FP), alcohol resistant FP (FP-AR), film-forming fluoroprotein foam (FFFP), alcohol resistant FFFP (FFFP-AR), aqueous film-forming foam (AFFF), alcohol resistant AFFF (AFFF-AR), Synthetic (S), a wetting agent "Wetwater", a self-foaming additive "Halofoam" (now supplied as "Pyrofoam"), and "Fireout"[1] (Superscripts refer to the notes on page 35).

Generally, throughout the report, reference is made to the additive type only. However, when necessary the product is identified in the results tables. Table 1 gives full details of the additives used during this work.

The small scale Class A trials involved extinguishing fires in wooden cribs of size 13A and 27A (to BS 5423 Reference 4). During these trials, all of the selected additives were used both aspirated and non-aspirated except for FP-AR (aspirated only), "Halofoam", "Fireout" and the wetting agent (non-aspirated only). Water was also used during these trials.

In the large scale Class A trials, the FEU Fire Test Room facility at Hangar 97, RAF Little Rissington was used. The fire load here consisted of two 27A cribs and one 34A crib, disposed around three sides of the room. During these trials, the following additives were used non-aspirated :- AFFF, AFFF-AR, FFFP, FFFP-AR, S, "Wetwater", "Halofoam" and "Fireout", water was also used. Only AFFF was used aspirated during these trials.

A glossary of terms used in this report is given in Appendix A.

2. SMALL SCALE CLASS A FIRE TRIALS

2.1 General

The objectives of the small scale Class A fire trials were:-

a) To obtain small scale test data to assist in the selection of additives for large scale testing.

b) To develop a small scale test method for future selection of additives.

c) To provide small scale test results for correlation with large scale tests.

To meet these objectives, two series of small scale fire trials were undertaken by the Loss Prevention Council (LPC)[2] under contract to FRDG.

These fire trials were based upon BS 5423 (Reference 4), using wooden cribs as the Class A fuel.

The LPC reports on these trials are reproduced at Appendix B and Appendix C. The following sections summarise these reports.

2.2 Additives Tested

"Fire-fighting foam" additives are classified into various types e.g. FP, AFFF etc. and each type is available from several manufacturers. The objective of the work in this report is to compare types of additives; it is not intended to recommend one supplier or another.

The following additives, mixed to the stated concentrations in potable water, were used during these two series of small scale Class A fire trials :-

ADDITIVE	SOLUTION STRENGTH IN WATER
Fluoroprotein (FP)	3%
Alcohol resistant FP (FP-AR)	3%
Film-forming fluoroprotein foam (FFFP)	3%
Alcohol resistant FFFP (FFFP-AR)	3%
Aqueous film-forming foam (AFFF)	3%
Alcohol resistant AFFF (AFFF-AR)	3%
Synthetic (S)	3%
"Wetwater" (Type 2 with foam trace)	1%
"Halofoam"	15%
"Fireout"	0.2%

Potable water alone, with no additives, was also applied to the test fires for comparison purposes.

Some manufacturers state that their additives, when required as wetting agents for Class A fires, may be used at concentrations less than those used during these trials. Many of the above additives which were used at a concentration of 3% during these trials may be used at 1% with Class A fires while Halofoam may be used at 8%. More details on all of these additives are given in Table 1.

2.3 Equipment

The pre-mixed additive was applied to the test fire by means of a gear pump[3] feeding a 36.6m length of 19mm hose[4]. The hydraulic arrangement is shown in Figure 1. The hose was fitted with either an aspirating or a non-aspirating nozzle. The aspirating nozzle (Figure 2) was taken from a Thorn-EMI Protech[5] AFFF 9 litre foam extinguisher. The non-aspirating 'spray' nozzle (Figure 2) was a garden hose nozzle. This nozzle was set to give a coarse broken jet with a similar pattern to that of the aspirating nozzle.

The solution flowrate for the tests was standardised at 9 litres per minute. This is the nominal flowrate for an extinguisher when standard tested against this size of fire. The flowrate was adjusted using the gear pump and monitored by an electromagnetic flowmeter[6] connected to a digital display[7] which indicated the flowrate in litres per minute.

A pipe, with a thermocouple[8] fitted into a tapping, was also connected into the hoseline. The thermocouple was connected to a digital indicator[9] which displayed the temperature of the solution during fire-fighting.

For heat radiation measurements during the fire tests, two heat flux transducers[10] were used.

2.4 Fire Tests

In total, thirty four test fires were carried out, of these, twenty three used size 27A cribs and eleven used size 13A cribs (to BS 5423 see Reference 4).

Each test was conducted generally in accordance with Clause 26 of BS 5423 (Reference 4), with the exception that extinguishing efficiency was based upon flame knockdown and control, rather than upon total extinguishment and a subsequent 3 minute dormant period.

Each crib was ignited using a quantity of Heptane[11] that had been poured into trays situated underneath the crib. The Heptane was ignited using a flaming lance, and, after a 2 minute preburn, the trays were removed. The crib was then allowed to burn for a further 6 minutes, making a total preburn time of 8 minutes, after which time firefighting commenced.

Each fire was handfought by a fire fighter with many years experience of extinguishing crib fires to the requirements of BS 5423.

Measurements of foam quality were taken at the end of each fire test. Measurements were taken in respect of expansion ratio, drainage time and shear stress. These served as a general check on the quality of the additives and on the correct functioning of the branchpipes. Details of the test procedures and equipment used are given in Reference 5.

2.5 Results

Tests 1 to 14 were carried out during January 1986, and Tests 15 to 34 were carried out during October 1987. A summary of the results of these tests is given in Table 2.

2.5.1 13A Crib Fires

Tests 1 to 11 involved extinguishing fires in size 13A cribs. The additives used during these tests were FP, FFFP-AR, AFFF, "Fireout" and "Halofoam". FP, FFFP-AR and AFFF were applied both aspirated and non-aspirated. "Fireout" and "Halofoam" were applied non-aspirated only. Water was also used for comparison purposes.

The crib fire of Test 1 was extinguished using water only. This test was used to develop the test procedure and as such did not give a representative result. This test has therefore been ignored in the analysis of the results.

The firefighting technique adopted for the 13A Crib fires was to allow the firefighter to attack the fire as he wished. However, the firefighter was not allowed to fight the fire from above the crib.

One test was carried out for each additive condition (ie. aspirated or non-aspirated), and two tests were carried out using water.

The best control time of 25 seconds was achieved with non-aspirated "Halofoam" and the worst, with non-aspirated AFFF in a time of 48 seconds. Water achieved a control time of 36 seconds.

For those test fires using FP, FFFP-AR or AFFF, the aspirated version of each additive achieved a quicker time to control than the corresponding non-aspirated versions.

Non-aspirated FP, FFFP-AR, AFFF and "Fireout", and aspirated FFFP-AR, times to control were slower than that achieved with water.

2.5.2 27A Crib Fires

Test 12 to 34 involved extinguishing fires in size 27A cribs. These tests were carried out to give greater discrimination between the times to control for each additive. The additives used during these tests were FP, FP-AR, FFFP, FFFP-AR, AFFF, AFFF-AR, S, "Wetwater", "Fireout" and "Halofoam". FP, FFFP, FFFP-AR, AFFF, AFFF-AR and S were all applied both aspirated and non-aspirated. FP-AR, "Wetwater", "Fireout" and "Halofoam" were applied non-aspirated only. Water was also used for comparison purposes.

Tests 12, 13 and 14 were carried out to explore trials technique and have not been included in this analysis of the results. In Test 15, which used non-aspirated AFFF, the firefighter was allowed to attack the fire from the front face of the crib only. After 6 minutes 45 seconds of firefighting, knockdown of the fire had not been achieved and the crib had begun to collapse. This test was consequently abandoned.

Tests 16 to 34 employed the following modified firefighting technique:-

> "With the nozzle 1 metre from the front face of the burning crib, application of the additive solution commenced from the left hand end. A single pass was made along the front face of the crib. During this pass, the nozzle was moved rapidly up and down to wet as much of the crib as possible.
>
> A return pass was then made, maintaining the nozzle at a distance of 1 metre from the front face of the crib. The discharge was horizontal to the ground and at an angle relative to the vertical side sufficient to give optimum penetration without undue loss of additive solution through the fire. During this pass, additive solution was applied to each "pigeon hole" formed by the layers of sticks. Any re-ignition of the front face was dealt with during this process.
>
> When immediate re-ignition of the front face was considered unlikely, then a single rapid pass was made of the rear side of the crib (taking in first one end, followed by the long side, and then the other end). This was followed by applying agent to each "pigeon hole" as before until knockdown was achieved.
>
> A further application to prevent immediate re-ignition from major hotspots concluded the test. The firefighter was not allowed to alter the nozzle setting or to turn the nozzle off at any time"

One test was carried out for each additive condition (ie. aspirated or non-aspirated), and three tests were carried out using water.

The best control time of 1 minute 10 seconds was achieved with non-aspirated "Halofoam", and the worst, in a time of 2 minutes 9 seconds, was achieved by both water and non-aspirated FP (the time quoted for water is the mean of three tests).

For those test fires extinguished using FP, FFFP, AFFF, AFFF-AR and S, the aspirated version of each additive achieved a quicker time to control than the corresponding non-aspirated version. On average, aspirated versions were 30 seconds quicker to control the crib fire than non-aspirated versions (time to control reduced by 25%). FFFP-AR was the only additive where the non-aspirated version was quicker to control the crib fire, by 5 seconds, than the aspirated version. Of the aspirated versions of these additives, S gave the best time to control of 1 minute 14 seconds and FFFP-AR gave the worst time to control of 1 minute 45 seconds. Of the non-aspirated versions, S gave the best time to control of 1 minute 38 seconds and FP gave the worst time to control of 2 minutes 9 seconds.

Of the remaining wetting agents/novel additives, "Fireout" gave a time to control of 1 minute 57 seconds and "Wetwater" gave a time of 2 minutes and 2 seconds.

2.6 Discussion of Results

2.6.1 13A Crib Fires

The results of tests 1 to 11 have shown that a standard 13A crib fire can be quickly controlled with water or with any of the additive solutions tested when applied at 9 litre per minute. The times to control ranged between 25 and 48 seconds leaving little scope for determining the relative merits of each of the solutions. With such small differences in the time to control, and given the natural variations in the way the fires were fought, it is difficult to draw any valid conclusions on the relative effectiveness of each additive.

In order to obtain better discrimination between the results the larger 27A crib fires were performed. A different firefighting technique was also evolved during these tests.

2.6.2 27A Crib Fires

The firefighting technique used during the large scale Class A trials (see Section 4.2) was to attack the crib fire from the front face only. A simulation of this technique took place during Test 15. Unfortunately, the rear face of the crib continued to burn throughout the test and resulted in the crib collapsing before the fire had been controlled. Hence, this firefighting technique was considered unacceptable for use during the remaining small scale fire tests.

For Tests 16 to 34, the firefighting technique described in Section 2.5.2 was adopted. This new firefighting technique was strictly adhered to and led to a consistent firefighting method throughout these remaining tests.

The results of these tests showed an improved level of discrimination between various additives. The best time to control was 1 minute 10 seconds ("Halofoam"), and the worst, 2 minutes 9 seconds (Water).

The aspirated versions of the additives tested (except for AFFF-AR) showed an average 25% improvement in the time to control when compared with the corresponding non-aspirated versions.

"Halofoam" was the most successful of the additives tested (control in 1 minute 10 seconds), this was a 46% improvement in the "time to control" when compared with water (control in 2 minutes 9 seconds). Unfortunately, the thick foam blanket formed by Halofoam's self foaming action impeded the firefighters view of any flaming or hot spots within the crib. This made it difficult for the firefighter to be certain that he had controlled the fire.

Of the conventional "fire-fighting foam" additives, Synthetic gave the best control when both aspirated (1 minute 15 seconds) and non-aspirated (1 minute 40 seconds). The corresponding improvements in "time to control" when compared with water were 42% and 22% respectively. The manufacturer of the Synthetic additive tested does not suggest in sales literature that it may be used non-aspirated. Non-aspirated AFFF gave a very poor "time to control" (2 minutes 3 seconds) which was only a 5% improvement over that achieved by water.

2.7 Conclusions From Small Scale Tests

For small scale Class A fire tests extinguished with additive solutions applied at a rate of 9 litres per minute, size 27A cribs gave better comparisons of additive performance than size 13A cribs.

For 27A crib test fires, and an additive solution application rate of 9 litres per minute, it was found that:

1. Non-aspirated "Halofoam" gave the best "time to control". This was a 46% improvement over the time achieved by water.

2. Of the non-aspirated conventional "fire-fighting foam" additives, Synthetic gave the best time to control. This was a 42% improvement over the time achieved by water.

3. Of the aspirated conventional "fire-fighting foam" additives, Synthetic gave the best time to control, this was a 22% improvement over the time achieved by water.

4. The aspirated versions of additives (except for AFFF-AR) showed an average 25% improvement in the time to control when compared with the corresponding non-aspirated versions.

5. Non-aspirated AFFF achieved a poor time to control which was only 5% better than that achieved by water.

2.8 Selection of Additives For Large Scale Testing

One of the objectives of the small scale testing was to "..obtain small scale test data to assist in the selection of additives for large scale testing."

The results of the small scale fire tests have shown large variations in the relative effectiveness of the additives tested. None of these additives gave times to extinction that were significantly worse than water.

It was for this reason that all of the additives tested here were selected for testing during the large scale Class A fire tests.

3. LARGE SCALE CLASS A FIRE TRIALS

3.1 General

The objectives of the large scale Class A fire trials were:-

a) To obtain Class A fire test data from realistically sized fires tackled with additives through fire service equipment.

b) To select the most suitable additives for control and extinction of Class A fires.

To meet these objectives, a series of large scale fire trials were performed by the Fire Experimental Unit at its Fire Test Room facility, Hangar 97, RAF Little Rissington (Figure 3). This facility was originally constructed to enable large scale Class A fires to be carried out during project F 23.04, "The use of High Pressure and Low Pressure Pumps with Hosereel Systems" (Reference 6).

The fuel used during these Class A fire trials was wood built into cribs which conformed to BS 5423 (Reference 4).

3.2 Additives Tested

The following additives, mixed to the stated concentrations in potable water, were selected for use during this series of large scale Class A fire trials (see Section 2.8) :-

ADDITIVE	SOLUTION STRENGTH IN WATER
Fluoroprotein (FP)	3%
Film-forming FP (FFFP)	3%
Alcohol resistant FFFP (FFFP-AR)	3%
Aqueous film-forming foam (AFFF)	3%
Alcohol resistant AFFF (AFFF-AR)	3%
Synthetic (S)	3%
"Wetwater" (Type 2 with foam trace)	1%
"Halofoam"	15%
"Fireout"	0.2%

Potable water alone, with no additives, was also used for comparison purposes.

Some manufacturers state that their additives, when required as wetting agents for Class A fires, may be used at concentrations less than those used during these trials. Many of the above additives which were used at a concentration of 3% during these trials may be used at 1% with Class A fires while Halofoam may be used at 8%. More details on all of these additives are given in Table 1.

3.3 Description of the Fire Test Room

The following is a brief description of the Fire Test Room at Hangar 97. A more detailed description is given in Reference 6.

The design of the Fire Test Room is based upon that previously used by FRS during the 1950's. (See Reference 7).

The Fire Test Room at Hangar 97 is a 4.267m (14ft) square room, of internal height 2.745m (9ft) (See Figure 4). The walls are of brick construction, 0.33m (13") thick. The roof is made of 0.22m (9") thick reinforced concrete, and from this is suspended a special flame resistant "ceiling"[12]. The floor of the room is a concrete slab, cast in one piece, inside the brick walls.

The single doorway into the room is an opening positioned centrally in one wall and is 1.99m (6'6") high and 0.914m (3ft) wide. A reinforced concrete lintel spans the top of the doorway and is protected by flame resistant panels[13].

The room has two windows which are openings in the walls and are positioned centrally, one in each wall adjacent to the doorway wall (See Figure 4). These window openings are identical to each other and at opposite sides of the room. Each is 1.83m (6ft) long and 1.22m (4ft) high, with its lower sill 1.065m (3'6") above floor level. Reinforced concrete lintels span the tops of these openings and are protected by flame resistant panels.

All of the flame resistant panels are, because of their sacrificial nature, bolted into position so that panels can be replaced independently, as necessary.

A large steel smoke hood has been constructed over and around the fire test hood to channel all combustion products into a flue in the roof. The flue extends out through the Hangar roof and releases the combustion products into the atmosphere.

3.4 Fire Load

The trial fires took the form of wooden cribs which conformed to British Standard BS 5423 (Reference 4). These cribs were constructed from lengths of 38mm square sawn timber. The specified timber was Pinus Silvestris, with moisture content of between 12.5% and 17.5% by weight.

A total of three cribs were used within the room, two of size 27A and one of size 34A. The 34A crib was positioned along the back wall, and each of the 27A cribs was positioned under a window (Figure 4). Each crib was built upon a steel structure which providede a level horizontal support for the base of the cribs at a height of 0.25m above the floor. Steel trays were positioned beneath each crib structure (Figure 5). These trays contained Solvent 50[11] (Heptane) which was used to ignite the cribs. A total preburn time of eight minutes was allowed for the cribs before firefighting commenced.

A requirement of BS 5423 is that the solvent trays should be removed after a two minute preburn. Due to the design of the Fire Test Room, it was not possible to remove the trays during the pre-burn period. Therefore, an approximate preburn time of two minutes was achieved by pouring known quantities of Solvent 50 into each tray. Throughout the trials, Solvent 50 was poured onto the top of a water base within each of the trays.

A total of seven solvent trays were used within the Fire Test Room. In order to ignite the solvent, an electrically operated detonator[14] was placed within each tray, just above the surface of the fuel. These detonators were wired in parallel and fed back to the control room where they could be simultaneously fired when required by use of a firing box.

3.5 Instrumentation

3.5.1 Video

Fire trials within the Fire Test Room were recorded by using four video cameras. Two of the cameras were positioned low down in the doorway and the other two were positioned to view through the window openings.

The doorway cameras consisted of two CCD video cameras[15] each fitted with lenses[16] which gave a field of view of 110°. These cameras were positioned so that each viewed slightly more than half of the room interior. The cameras were contained in special housings[17] which were provided with both air and water cooling during fire trials.

The window cameras consisted of two video-8 camcorders positioned outside the Fire Test Room, one at either side, to view as much as possible of the cribs through the window openings.

A thermal image camera was used during each trial. This camera was positioned below the left hand window camera and gave a similar field of view.

For the duration of each trial, the signals from each of the four cameras and the thermal image camera were recorded onto video tape. These tapes were later analysed (see Section 6.1 and Appendix D). Also, the outputs from the cameras were available for the trials director to view during the fire trials.

All recorded video tapes had test time injected onto them during or after each fire trial to aid analysis. This test time was synchronised with a large digital clock[18], displaying minutes and seconds, which was sited near to the Fire Test Room. This clock was visible to all personal engaged in the conduct of the trial. The clocks were preset to 99 : 00 (min : sec) and were started when all preparations were complete. Ignition took place 1 minute after the clocks were started, at 00 : 00 indicated time. Thus the video tapes were accurately timed, and a means of co-ordination was provided for all involved with the trials.

3.5.2 Thermocouples

Thermocouples were used to measure crib and air temperatures during fire trials in the Fire Test Room.

3.5.2 (i) Temperatures Within the Cribs

A total of forty three thermocouples[19] were used to measure temperatures within the cribs. Seventeen thermocouples were positioned in the back crib, and thirteen in each of the side cribs, one in each alternate gap. Their positions within the Fire Test Room are shown in Figure 6. These thermocouples were mounted in 6mm diameter stainless steel tubes for protection, and fed through the walls of the Fire Test Room into the cribs. The thermocouples were fixed into the centre of these tubes at the hot junction end with fire cement, so that the hot junction (approximately 10mm of the thermocouple) protruded beyond the end of the tube. The position of the thermocouples within the cribs remained constant throughout the trials. This position was at the centre of the second gap in from the rear of the crib, in the third tier from the top (see Figure 7).

The signal cables from the forty three thermocouples were connected, in parallel, into ten groups of four or five adjacent thermocouples (Figure 6). There were three groups in each side crib and four groups in the rear crib. The data obtained from these groups of thermocouples gave an average temperature for that particular part of the crib in which the thermocouples were located.

During each trial, the outputs from the groups of thermocouples were recorded onto the main Orion data logger[20] and simultaneously displayed as a bar chart[21] on the computer[22] VDU in the control room. All data was stored for subsequent analysis.

During tests A5 to A19, a further thirteen thermocouples[23] were positioned within the left hand side crib. The sensing tips of these thermocouples were positioned adjacent to the thermocouples described above and were attached to the exterior of the stainless steel tubes. A second Orion data logger[20] was used to record the signals from these thermocouples during trials; again the data was stored for subsequent analysis.

These additional thirteen thermocouples were used to check the integrity of the data being recorded from the paralleled thermocouples and no results for these are given within this report although they are retained at FEU.

3.5.2 (ii) Air Temperatures

Air temperatures were measured using a similar type of thermocouple[19] to those used to measure crib temperatures (see above). Only two thermocouples were used, again these were mounted in stainless steel tubes for protection and extended 200mm into the room. One thermocouple measured the air temperature at the ceiling and the other measured the air temperature at the doorway, at approximately chest height (Figure 8).

During each trial, the outputs from these thermocouples were also recorded by the main Orion data logger and simultaneously displayed as a bar-chart on the computer VDU in the control room. All data was stored for subsequent analysis.

3.5.2 (iii) Checking Thermocouples Prior to Fire Tests

Prior to each fire test the thermocouples were checked to ensure that they were functioning correctly. To do this, the computer and data logger were initialised and the thermocouple bar-chart was displayed on the computer VDU. The thermocouples within the Fire Test Room were tested using a blowlamp as a heat source. One person played the blowlamp flame onto each of the thermocouples in turn while another checked their response on the VDU. Any damaged thermocouples were replaced and then re-checked.

3.5.3 Smoke Density Metering Equipment

Two smoke density meters[24] were employed during the fire tests. The sensing equipment of each meter consisted of a light projector and a photocell receiver. One set of sensing equipment was mounted onto stands at a height of approximately two metres. The stands were positioned outside of the room such that their optical path ran directly through the two windows of the room. The other set of sensing equipment was suspended from metal beams on the outside of the room and positioned level with the lower face of the concrete lintel of the right hand window. Their optical path ran along the face of the window at this height. Both the receiver and the projector were protected from direct flame impingement by the Fire Test Room walls. The associated electronics and indicators (calibrated in percentage obscuration) for both sets of sensing equipment were mounted in the mobile control room. Sensing equipment and indicators were connected by two cables. An analogue output corresponding to percentage obscuration, was provided by each indicator unit and was connected to the main Orion data logger.

The calibration of the smoke density measurement equipment was checked prior to each fire test. Neutral density filters were placed between the projector and receiver. The readings on the indicators and the data logger were recorded for each neutral density filter value.

3.5.4 Flowmeter and Associated Equipment

The flowrate of solution to the firefighting branch was monitored using an electromagnetic flowmeter[6] connected to a digital display[7] which indicated the flowrate in litres per minute (see Figure 9). An analogue output from the flowmeter was connected to the main Orion data logger to record flowrate during the tests.

A pipe, with two temperature transducers fitted into tappings, was also connected into the hoseline. One transducer[8] was connected into a digital indicator[9] and the other transducer[25] was connected to the main Orion data logger. Both thermocouples monitored the temperature of the solution being pumped to the branch.

A pressure tapping tube[26] was situated near to the branch to record branch inlet pressure. To this was connected a pressure gauge[27]. Connected in parallel with this pressure gauge was a pressure transducer[28], the output from which was fed to the main Orion data logger and also displayed on a digital indicator[29].

The flowmeter, pipe with temperature transducers, pressure gauges and associated indicators, were mounted on a trolley so that the pump operator could set and adjust the pump throttle while monitoring the flowrate and the pressure.

3.5.5 Relative Humidity

The relative humidity of the area around the Fire Test Room was measured immediately prior to each fire test. Two instruments were used, one a wet and dry bulb hygrometer[30] and the other a thermohygrometer[31] with a remote sensor. The wet and dry hygrometer and the remote sensor of the thermohygrometer were positioned in close proximity at a height of 2 metres above floor level. Both were attached to one of the stanchions of the Fire Test Room smoke hood.

The indicator for the thermohygrometer was located within the control room and gave a direct reading of relative humidity and air temperature. Relative humidity could be calculated from the wet and dry bulb hygrometer by the use of conversion tables.

3.5.6 Communications

Throughout the fire trials, a 2-way communication system[32] was used. This system enabled the trial director (in the control room), the pump operator and the firefighter to communicate with each other. All communications were recorded on an audio channel of each of the video recorders.

A public address system was also available for use from within the control room. This was used at the start of each trial to give an audible warning of the start of the countdown, but was provided essentially as a safety precaution.

3.5.7 Mobile Control Room

A mobile control room was utilised during this series of fire trials. Within it were contained necessary data logging, video and communication equipment. From the control room, the trial director was able to start the video and trial clocks, remotely fire the solvent detonators, select views from any of the video cameras, check the progress of the trial by reference to the computer generated bar-chart graphics and talk to essential staff via the communications equipment.

3.5.8 Data Logging, Processing and Presentation

In order to record the conditions within the Fire Test Room, and the operating conditions of the firefighting branch, the outputs of all thermocouples and other transducers were fed to the main Orion data logger. During a trial, all data was logged to magnetic disk within the data logger for subsequent processing. Also during each trial, thermocouple data was fed to the computer where it was displayed on a VDU, in real-time, in the form of a barchart.

After the completion of each trial, all of the data recorded by the data logger was transferred to the computer for processing and graph plotting[33].

4. TRIALS EQUIPMENT AND METHODS

4.1 Production of Foam Solution

A variety of hosereel induction systems were commercially available and many are in use within Brigades. Evaluations of some of these systems have been carried out by FEU (Reference 8). No system was available which would maintain the solution concentrations required and therefore a premix solution was used to ensure precise proportioning for each test.

4.2 Firefighting Branches

For the purposes of these trials, both aspirating and non-aspirating branchpipe(s) were required to operate on a remote firefighting rig under the following conditions :-

1. At a total flowrate of 100 litres per minute.
2. With a "spray" cone angle of 26° included.

A flowrate of 100 litres a minute was chosen because it could be obtained from most hosereel branches and it was a condition that had been used during previous FEU trials (see References 6 and 9).

A "spray" cone angle of 26° was required to just wet the entire height of the wood cribs, at their nearest point, with the nozzle at the crib centre line height and on the centre line of the Fire Test Room. This is the position of the nozzle when mounted on the remote firefighting rig (see Section 4.4).

For the non-aspirated tests an Elkhart Select-O-Flow hosereel gun[34] (Figure 10) was chosen. This Elkhart gun, operating with water, was the best of the branches tested against Class A fires during the high pressure fog/low pressure spray project (see Reference 6). It was decided that this branch would give a good indication of the merits, or otherwise, of using non-aspirated additives instead of water to fight Class A fires during this current work.

After the first two tests it was decided, for reasons discussed later (see Section 6.2), to use an Angus Superfog hosereel gun[35] (Figure 11) for all of the remaining non-aspirated tests.

For the aspirated tests, two Fire Research Station 50 litre per minute low expansion foam branchpipes[36] were chosen. These branches were mounted one above the other (Figure 12) onto the remote firefighting rig with the output from their nozzles interfering in order to obtain the required 26° "spray" cone angle.

After Test A3 it was decided, for reasons discussed later (see Section 6.3), to discontinue using the FRS branchpipes. For the remaining aspirated tests a hand-held Angus Superfog with an aspirator (Figure 13) was used.

Immediately after each fire test the foam quality of the branch/ aspirator/ additive combination used was checked.

4.3 High Pressure Hosereel

Lengths of 19mm bore high pressure 'hosereel' hose[4], connected via hermaphrodite couplings[37], were used throughout the trials. A single 3 metre length connected the high pressure hosereel outlet of FEU appliance ALT 469H to the inlet of the flowmeter. A single 18.3 metre length then connected the flowmeter outlet to a simple on/off valve. A pressure tapping tube was connected immediately into the downstream end of this valve. This tapping was connected to a pressure gauge mounted on the flowmeter trolley. A 3 metre length of hose connected the pressure tapping tube to the branch under test.

A schematic of this hydraulic arrangement is given at Figure 9.

4.4 Remote Firefighting Rig

A remotely operated rig to support and rotate the firefighting branches was used during the fire trials (Figure 14). This was used to remove any possibility of variations between one trial and another due to human expertise. In this context 'remote' simply means that the rig operator was positioned well back outside the Fire Test Room doorway, and was protected by a radiation shield built onto the rig. The operator, therefore, had no need to modify the method of 'remote' firefighting because of any danger to himself.

The rig was constructed such that the operator could cause the branch to sweep back and forth along the front faces of the cribs at a constant rate. The rig was mounted onto a four wheel trolley which enabled it to be moved into position when required.

During each fire test the branch (mounted on the rig) was moved into two positions within the room. The first position, taken up at test time 8 minutes, was with the branch just inside the doorway and on the centreline of the room. When at its extremes of sweep, the vertical centre line of the spray was allowed to impinge on the edge of the left or right hand crib nearest to the doorway. The second position, taken up at test time 10 minutes, was with the branch pushed into the centre of the room. Again, when at its extremes of sweep, the vertical centre line of the spray was allowed to impinge on the vertical edge of the left or right hand crib nearest to the doorway.

4.5 Manned Firefighting

During several of the fire tests, an experienced fire officer acted as the branchman. The fire officer was allowed to fight the fire from the doorway only in the following pre-determined systematic manner:-

1. Starting from the end of the left crib nearest to the doorway, sweep once around all three cribs in the room until reaching the end of the right crib nearest to the doorway.

2. Sweep along the right crib four times, then:-

3. Sweep along the centre crib three times, then:-

4. Sweep along the left crib four times, then:-

5. Sweep along the centre crib three times, then:-

6. Repeat steps 2 to 5 above until the end of the test.

   At no time was the fire officer allowed to attack the cribs from above, he was only allowed to hit the cribs from the front.

In order to maintain the application rate throughout the tests, the fire officer was not allowed to adjust the spray pattern or switch the branch off during the extinction phase. Firefighting commenced after a preburn time of 8 minutes.

4.6 Preburn

A preburn time of 8 minutes was allowed from the ignition of the solvent underneath the cribs until the commencement of firefighting. This preburn time is as specified in BS 5423 (Reference 4) and previous FEU trials (Reference 6) have shown this to be sufficient time for the crib fires to reach equilibrium.

5. EXPERIMENTAL PROCEDURE

5.1 Room Preparation

Prior to each test, the room, crib trays and stands were thoroughly cleaned using potable water. Care was taken to ensure that all additive solution from the previous test had been washed from the walls and floor. The crib trays and stands were checked for correct positioning and the thermocouples were positioned such that they would not be damaged during crib building.

5.2 Transfer of Wood to Fire Test Room

Lengths of wood were taken from the wood store and their moisture contents were measured. Each length within the 12.5% to 17.5% moisture content range was placed on a trolley ready for transfer to the Fire Test Room and the moisture content measurement was recorded. All other lengths were returned to the wood store. This process continued until the required number of each length of wood had been obtained.

The trolley was then moved to the Fire Test Room area.

5.3 Transfer of Priming Fuel to Fire Test Room

200 litre drums of Solvent 50 were stored in the flammable liquid store outside Hangar 97. For each test, fuel was transferred into three, 18 litre, flammable liquid containers by use of a hand pump[38]. These three containers were placed onto a trolley which was moved to a coned-off area in the centre of the Hangar.

The trolley was moved to the Fire Test Room area when required.

5.4 Detonator Preparation

The firing box was connected to the detonators by a system of two core cable and porcelain connector blocks. The detonators were connected in parallel. Each detonator was wired with a shorting link for safety. During all operations involving the detonators, the safety key for the firing box was removed.

5.5 Branch Preparation

For tests involving the remote firefighting rig, a wooden frame was placed within the first guide of the left hand side crib stand. The frame, when in this position, simulated the shape of the front face of a crib. The remote rig, with the branch attached, was pushed into its "10 minute" position within the room and operated at a flow rate of 100 litres per minute. The spray pattern was adjusted until the top and bottom portions of the spray cone just exceeded the top and bottom spars of the frame (equivalent to a spray cone angle of 26° included). The spray setting control of the branch was then locked in this position.

For tests involving manned fire fighting, the branch was hand-held by the fire officer and operated at 100 litres per minute. When used non-aspirated, the branch was adjusted and locked in a position which gave a coherent jet with slight feathering. When used aspirated, the branch was locked at its full jet setting.

5.6 Fire Tests - General Procedure

Prior to building of the cribs, all equipment was calibrated (where necessary) and checked for correct operation. The selected branch, with or without an aspirator, was connected to the hoseline and tested.

The cribs were built and all thermocouples were moved into their correct positions.

The premix solution was made up in a clean glass fibre tank. The tank was located on a platform scale to enable the required amount of water to be quickly weighed into the tank. Additive was measured into the tank by using calibrated containers and the premix was thoroughly mixed. For each test, 1500 litres of premix solution was made up. A fresh premix solution was made up for each test.

During the preparation of the premix the priming fuel was transferred from the trolley and into each of the seven solvent trays. The fuel temperature within the trays was then measured. Once this had been done, the detonators were placed into brackets within the trays and the shorting links were cut.

Relative humidity around the Fire Test Room was measured and recorded. Finally, when everyone was clear of the Fire Test Room, the safety key was inserted into the firing box. Video recorders and the data logger were set to record and all communications were checked.

After sounding the PA warning, the clocks (preset to 99 min : 00 sec) were started. One minute later, at 00 min : 00 sec indicated time, the detonators were fired.

An eight minute preburn was allowed before the firefighting commenced. During the final 90 seconds of the preburn, the pump was run up to the required operating condition (flowrate 100 litres per minute) and the branchman and pump operator ensured that the branch was operating correctly.

The pump operator monitored and recorded the flowrate and branch pressure throughout the test and adjusted when necessary. He also noted the maximum temperature displayed by the in-line temperature display. Flowrate, branch pressure and temperature were also monitored and recorded by the main Orion data logger.

Seven minutes 50 seconds after ignition the remote firefighting rig was moved into its initial position, just inside the doorway. At eight minutes, the on/off valve on the rig was opened and firefighting commenced. At ten minutes the rig was moved into its second position in the centre of the room. For a manned test, firefighting commenced at eight minutes, with the man remaining at the doorway throughout the test.

In general, the test was stopped after eight minutes of firefighting (16 minutes from ignition) and the rig or branchman was withdrawn from the room.

After foam application within the room had ceased, the branch was directed towards a foam collecting stand (Reference 5) and foam samples were collected.

Measurements were immediately made of foam quality in respect of expansion ratio, drainage time and shear stress. These served as a general check on the quality of the foam additives and on the correct functioning of the foam branchpipes. Both aspirated and non-aspirated foams were tested.

Air and foam temperatures were recorded using digital thermometers.

6. RESULTS OF LARGE SCALE CLASS A FIRE TRIALS

6.1 General

6.1.1 Presentation of Results

Examples of the graphical output produced by the computerised data logging system are given at Figures 15 and 16. Figure 15 shows the average crib temperature during a water test (Test A4), while Figure 16 shows the air temperature at the doorway during the same test.

During the analysis of the results, the following parameters were found to give an acceptable representation of the performance of each of the additives and firefighting tactics during the tests, these were:-

1. An indication of the percentage averaged temperature reduction of the air at the doorway during the first 30 seconds of firefighting for each test (see Section 6.1.2).

2. An indication of the percentage averaged temperature reduction within the fire during the first 30 seconds and the first six minutes of firefighting for each test (see Section 6.1.4).

The results of the tests are tabulated as follows:-

Table 3: Test conditions, including flow, pressure, relative humidity, wood moisture content and, solution, fuel and air temperatures for each test.

Table 4: Foam measurements, including expansion ratio, drainage time, and shear stress.

Table 5: Results of the percentage averaged temperature reduction of the doorway air, and of the fire, for each test.

Appendix D gives full details of the conduct of each test and was compiled from observers' notes and video records.

Due to the sheer bulk of data collected during each fire test, only a small proportion of the data appears in this report. However, all of the recorded data has been retained by FEU.

No results are given for the smoke density metering equipment (see Section 7.5).

6.1.2 Doorway Air Temperatures

During each test, a thermocouple was positioned at approximately chest height and adjacent to the doorway of the Fire Test Room. This thermocouple was employed to measure the temperatures likely to be experienced by a firefighter when standing at the doorway and also to measure the relative effectiveness of each firefighting solution at cooling the air in this position.

During the trials it was found that the air temperatures within the room after the 8 minute pre-burn were between 540°C and 624°C (mean = 567°C). Upon the first introduction of the firefighting solution into the room, the doorway air temperature increased to a peak of 61°C on average above the initial 8 minute temperature. Generally this peak occurred within the first 5 seconds of firefighting. This rise in the air temperature was assumed to be due to the flow of hot air and steam being displaced from the room, and the effect of the sweeping action of the firefighting tactics employed.

The rise in air temperature was immediately followed by a rapid decrease in temperature. 30 seconds after the start of the attack the air temperature had fallen to between 175°C and 315°C (mean = 231°C). After 8 minutes of firefighting the doorway air temperature had fallen to between 62°C and 177°C (mean = 113°C).

6.1.3 Averaged Temperature Reduction of the Air at the Doorway

During the analysis of the results it was found that the area under the graphs of doorway air temperature plotted against time gave an indication of the averaged temperature reduction of the air at the doorway during each of the tests. From these areas, approximations of the percentage averaged temperature reduction of the air at the doorway over the first 30 seconds of firefighting were made. These results are presented at Table 5 in chronological order.

The results give an indication of the relative efficiency of each firefighting solution in cooling the air at the doorway over the first 30 seconds of firefighting. The higher the percentage reduction, the sooner a firefighter could enter the Fire Test Room.

6.1.4 Crib Temperatures

Examination of the individual crib temperatures, (groups of 4 or 5 thermocouples within the cribs, Section 3.5.2), for the majority of tests showed that the temperature reductions within the cribs were not uniform. The following sections discusses the reductions achieved in each crib during the tests.

6.1.4 (i) Side Cribs

In both of the side cribs, the groups of thermocouples in those parts of the crib nearest to the doorway showed the most marked temperature reductions. All of these thermocouple groups showed a drop in temperature from a mean initial temperature of 807°C to below 100°C within 10 seconds of the commencement of firefighting.

The groups in the centres of these two cribs showed a smaller rate of temperature reduction, in general, these thermocouples indicated temperatures below 200°C within the first three minutes of firefighting.

Those thermocouples in the ends furthest from the doorway showed smaller rates of temperature reduction, or none at all. In general there was an initial reduction in temperature of between 50 and 350°C over the first 30 seconds of firefighting. Then, in all but the hand-held tests, and the Halofoam test, the temperature slowly increased. After 2 minutes of firefighting, when the branch was moved further into the room, generally, the temperatures measured had increased to within 100°C of those measured immediately prior to the commencement of firefighting. In the hand-held and the Halofoam tests the temperatures steadily fell throughout the tests.

6.1.4 (ii) Back Crib

In the back crib, the temperature reductions measured near the centre of the crib were always greater than those measured toward the ends of the crib, closer to the corners of the room. This effect was seen to be due to the geometrical arrangement of the cribs within the room and the arrangement of the fuel within the cribs.

In general, all of the thermocouples within the back crib showed a cooling of some 300 to 400°C within the first 30 seconds of firefighting. This was followed by either no further cooling, or by further cooling of the centre thermocouples only. After two minutes, when the remote rig had been advanced further into the room, the temperature in the centre of the crib fell, whereas the temperatures at the sides of the crib increased to the levels recorded immediately prior to firefighting. Exceptions to these generalisations were found in the hand-held firefighting tests. In tests A17, A18 and A19 all of the thermocouples showed a rapid reduction in temperature to below 100°C within the first minute. In Test A16 the temperatures dropped steadily to below 100°C after 6 minutes of fire fighting.

6.1.4 (iii) All Cribs

Overall, the temperatures were reduced markedly only in those parts of the cribs where the gaps between the short sticks were in line with the axis of the gun at some time as it swept around the room. The firefighting liquids could not penetrate through the cribs in other positions although some slight wetting of these areas of the cribs did occur due to airborne liquid droplets and deflected spray. It was evident that these parts of the trial fire (near the corners of the room, remote from the doorway), were unlikely to be completely extinguished by any of the firefighting solutions tested.

6.1.5 Averaged Temperature Reduction of the Fire

During the analysis of the results it was found that graphs of average crib temperature plotted against time gave a clear and accurate representation of the suppression of the crib fires. Also, the area under the curve gave an indication of the averaged temperature reduction of the fire during each of the tests. From these results, approximations of the percentage averaged temperature reduction of the fire during the first 30 seconds and 6 minutes of firefighting were made.

The results for the first 30 seconds and 6 minutes of firefighting are presented at Table 5 in chronological order.

6.2 Water. Remote Attack. Tests A1 and A2

The Elkhart Select-O-Flow hosereel gun, mounted onto the remote rig, was used during Tests A1 and A2. These tests were performed to assess the repeatibility of the trial and the reproducability of the results. They were also performed to give an indication of the performance of water against the test fire.

During Test A1 it was noted that some of the water spray produced by the branch was emerging from the side windows, also, the pump operator could not maintain a flowrate of 100 litres per minute to the branch. Consequently, the results from this test have been ignored.

After Test A1 and prior to Test A2, the pressure flow characteristics of the Branch were measured. Initially the branch did not perform in a consistent manner, but after flushing, the branch regained consistency and gave characteristics similar to those measured during previous work (Reference 6). For this reason it was decided to use this branch for Test A2. Also, to ensure that water only hit the front faces of the crib, the procedure described in Section 5.5 was adopted.

During Test A2, the pump operator could only maintain a flowrate of 90 litres per minute with a pressure of 33 bar at the branch. Again, because of the inconsistent performance of this branch, these results have been ignored.

At the end of Test A2, the branch was again flushed out and its pressure flow characteristics were checked. On this occasion the branch gave a flowrate of 100 litres per minute with a pump pressure of 26 bar. The inconsistent performance of this branch resulted in the selection of another branch, an Angus Superfog, for the remainder of the water and the non-aspirated trials.

6.3 Aspirated AFFF. Remote Attack. Test A3

The foam spray pattern produced by the 2 x 50 litre per minute branchpipe combination (See Section 4.2) gave the required 26° angle but proved to give a poor throw and poor penetration. This is not a direct criticism of the branches but of the methods used to produce the 26° spray cone. Consequently, approximately 20% of the front face of the rear crib and the far corners of the left and right cribs were untouched by foam throughout the test. The results of this test were as follows :-

Averaged temperature reduction of the air at the doorway during the first 30 seconds of firefighting = 27%.

Averaged temperature reduction of the fire during the first 30 seconds of firefighting = 26%.

Averaged temperature reduction of the fire during the first 6 minutes of firefighting = 47%.

Due to the poor performance of this branch configuration, these results are not presented in Table 5, where comparison with the other tests, using the Angus Superfog branch, would be inappropriate and misleading.

Although other methods of producing aspirated additives with a 26° cone angle were explored, none gave the required throw and penetration. For these reasons no further tests were carried out with aspirated additives using the remote attack method.

6.4 Non-aspirated. Remote Attack. Tests A4 to A15

The results of these tests, in descending order of effectiveness, are presented in the following tables :-

Table 6 : Averaged temperature reduction of the air at the doorway after the first thirty seconds of firefighting.

Table 7 : Averaged temperature reduction of the fire after the first thirty seconds of firefighting.

Table 8 : Averaged temperature reduction of the fire after the first six minutes of firefighting.

The Angus Superfog hosereel gun, mounted onto the remote firefighting rig was used throughout tests A4 to A15. Tests A4, A5 and A6 were performed with water to confirm the repeatibility of the trial configuration (see Reference 6). The results of these tests also indicated the fire extinguishing performance of water when used to fight the test fire.

Tests A7 to A15 used non-aspirated additive solutions to fight the test fires.

After the water test of Test A6, a bracket, which held the branch to the remote rig, was found to be loose. The branch, when in this position, gave a spray pattern that did not cover the tops of the front faces of the cribs. The branch may have slipped into this position during Test A6. For this reason, the results of Test A6 are presented in the tables but they have been ignored in any subsequent discussion (Section 7).

Test A10 was abandoned during the firefighting stage due to a leaky coupling. For this reason, the results of Test A10 have been ignored.

6.5 Hand-Held, Tests A16 to A19

As mentioned in Section 6.3, a branch could not be found that would produce an aspirated spray with an included angle of 26° suitable for use within the fire test room. Consequently, comparison tests of aspirated against non-aspirated additives could not be made using the remote rig. Instead, several trials were performed where the fire was hand fought from the doorway using the Angus Superfog branch, at 100 litres per minute, set to give a coherent jet of either aspirated AFFF (using an aspirator attachment), non-aspirated AFFF or water. AFFF was chosen for these tests because it performed better than any of the other standard additives during the remote tests.

These trials gave an indication of the relative performance of aspirated against non-aspirated AFFF bearing in mind that the small scale tests indicated a 25% improvement when using aspirated additives.

Test A16 used the Angus Superfog branch at a narrow spray setting. This gave a spray which lacked penetration when used from the doorway and gave a relatively poor result.

A summary of the results of the hand-held tests is given below :-

Firefighting Liquid	Test Number	Averaged Temperature Reduction		
		Of the Air at the Doorway	Of the Fire	
		1st 30 Secs	1st 30 Secs	1st 6 Mins
Non-aspirated AFFF (Narrow Spray)	A16	25%	26%	51%
Aspirated AFFF (jet)	A17	42%	45%	82%
Non-aspirated AFFF (jet)	A18	41%	46%	80%
Water (jet)	A19	30%	38%	75%

7. DISCUSSION

7.1 General

In order to compare the results from the tests by additive type, the following illustrations are given:-

Figure 17 : Average crib temperatures v's test time. The performance of each of the non-aspirated additives when used on the remote rig is represented by individual graphs (firefighting commenced at 8 minutes). For comparison purposes, the performances of water and of Halofoam (the additive which gave the best averaged temperature reduction of the fire over the first 6 minutes), have also been added to each graph. The performance of water has been derived

from the average of 2 of the water tests (Tests A4 and A5, Test A6 has not been used - see Section 6.4).

Figure 18 : Average crib temperatures v's test time. The performance of all of the hand-held tests is represented on a graph of average crib temperature against test time (firefighting commenced at 8 minutes).

It should be noted that, except for water, only one test was performed for each condition.

7.2 Averaged Temperature Reduction of the Air at the Doorway During the First 30 Seconds of Firefighting

7.2.1 Non-aspirated. Remote Attack. Tests A4 to A15

The results of the averaged temperature reduction of the air at the doorway during the first 30 seconds of firefighting ranged from 25% for AFFF-AR to 38% for AFFF. The water tests gave individual results of 34%, 29% and 35%. However, for reasons discussed in Section 6.4, the result of the water test, Test A6 (29%), has been ignored.

AFFF-AR (25%) and Halofoam (27%) gave reductions that were significantly less than the average 35% achieved by water. The remaining additives, AFFF (38%), Wetting Agent (37%), FFFP (35%), Fire-out (35%), FFFP-AR (31%) and Synthetic (31%) all gave results that were roughly similar to those achieved by water.

The results of these tests indicate that there is no significant advantage in using additives to cool the air at the doorway in order to gain quick access into the burning room. In fact, some additives, notably AFFF-AR and Halofoam, gave significantly less cooling of the air at the doorway than was achieved with water.

The alcohol resistant versions of FFFP and AFFF both gave reductions that were lower than the non-alcohol resistant versions of the same additives. With FFFP the difference was only 4% in terms of the averaged temperature reduction of the air at the doorway, ie 35% (FFFP) compared with 31% (FFFP-AR), whereas with AFFF there was a significant difference of 13%.

7.2.2 Hand-Held Attack. Tests A16 to A19

The hand-held attacks compared aspirated AFFF with non-aspirated AFFF and water when applied to the test fire as a jet. With the hosereel branch aspirators currently available, aspirated additives can normally only be applied as a solid foam jet.

The averaged temperature reductions of the air at the doorway during the first 30 seconds of firefighting achieved by aspirated (42%) and non-aspirated AFFF (41%) during the hand-held tests were greater than any of the reductions achieved during the remote rig tests. However, this was not significantly better than the 38% achieved with non-aspirated AFFF on the remote rig using a 26° spray angle.

At first sight these results may appear to be surprising in that a jet cools the air within the room at an equal or slightly greater rate than that achieved with a spray. However, in these tests, this may be due to the following factors :-

1. The high velocity of the jet provided quick delivery of large volumes of water to the hottest parts of the crib, this led to the production of large quantities of steam which quickly displaced the existing hot air in the room.

2. The high impact velocity of the jet on the cribs and on the walls behind the cribs caused the jet to break up and form a large quantity of "mist" within the room. The small liquid droplets within the "mist" quickly vaporized in the hot air of the room, cooling the surrounding air.

3. The spray issuing from the Angus Superfog branch during the remote tests appeared to contain liquid droplets that were significantly larger than those in the "mist". These larger droplets are less likely to vaporize during the time that it takes them to travel between the branch and the cribs. Also, the velocity of the spray appeared to be less than that of the jet and consequently lacked penetration.

The water jet gave a reduction of 30% which is roughly similar to its performance when used on the remote rig as a spray. However, there appears to be a significant improvement of 12%, in terms of the averaged temperature reduction of the air, when using aspirated or non-aspirated AFFF at a jet setting rather than water.

There is also a significant difference when comparing AFFF non-aspirated at jet (41%) and at half spray (25%). This is likely to be due to a low impact velocity from the half spray and consequently low penetration and little "mist" formation.

7.2.3 Summary

The results of the averaged temperature reduction of the air at the doorway over the first 30 seconds of firefighting can be summarised as follows :-

1. When applied from the remote rig at a spray cone angle of 26°, non-aspirated AFFF gave the greatest reduction of 38%. However, this was not significantly greater than that achieved by FFFP (35%) or water (35%) under the same conditions.

2. Some additives, notably non-aspirated AFFF-AR (25%) and Halofoam (27%), gave reductions that were significantly lower than that achieved by water when all were applied from the remote rig at a spray cone angle of 26°.

3. Both AFFF-AR (25%) and FFFP-AR (31%) gave reductions that were less than their associated AFFF (38%) and FFFP (35%) versions when all were applied from the remote rig at a spray cone angle of 26°.

4. Aspirated AFFF (42%) and non-aspirated AFFF (41%) gave similar reductions when both were applied as a jet and with the branch hand-held at the doorway. However these reductions were not significantly greater than those achieved by non-aspirated AFFF (38%), when applied from the remote rig at a spray cone angle of 26°.

5. Water (30%), when applied as a jet and with the branch hand held at the doorway, gave a reduction that was slightly less than that achieved when applied from the remote rig (35%) at a spray cone angle of 26°. However, the water jet result was significantly less than that achieved by aspirated AFFF (42%) and non-aspirated AFFF (41%) when both were applied as hand held jets.

7.3 Averaged Temperature Reduction of the Fire

7.3.1 Non-aspirated. Remote Attack. Tests A4 to A15

The averaged temperature reductions of the fire during the first 30 seconds of firefighting ranged from 26% with Fireout to 39% for both Halofoam and AFFF. The water tests gave individual results of 31%, 30% and 27%. However, the result of Test A6 (27%) has been ignored (see Section 6.4).

The largest averaged temperature reduction of the fire during the first 6 minutes of firefighting was achieved by Halofoam at 75% (see Section 7.4 regarding the cost of Halofoam). This was by far superior to the next best reduction achieved by AFFF of 63%. All of the other additives gave reductions of between 53% (FFFP) and 42% (Fireout), water gave an average reduction of 43%. The three water tests gave individual results of 44%, 41% and 44%. However the result of Test A6 (44%) has been ignored (see Section 6.4).

The graphs of Figure 17 show that, over the first six minutes of firefighting, Halofoam, AFFF and to some extent, FFFP, continued to reduce the average crib temperature steadily, with a rapid reduction during the first minute. For all of the other additives (including water), the average crib temperature dropped rapidly for the first 30 seconds to a minute, and then began to rise again until two minutes, the time at which the remote rig was pushed further into the room. This caused another reduction in temperature for the first 30 seconds to a minute, followed by little or no decrease in the temperature during the remaining period of firefighting.

Halofoam was the only additive solution tested that almost extinguished the test fire when operated from the remote rig, with only two small areas of flame remaining at the end of the test. This indicated that the spray produced by the test branch (Angus Superfog) could wet all of the burning cribs. With Halofoam, a self-foaming additive, any small droplets of solution reaching burning or glowing wood immediately foamed and hence reduced the intensity of the fire and also cooled the wood. The formation of foam allowed the solution to drain slowly out and to penetrate the wood. With many of the other additives, any small droplets of solution that landed on hot areas would immediately vaporise and only cool the burning area for a short period of time. No penetration of the wood was possible and the wood would again glow or burst into flame. Consequently the only areas of the burning cribs extinguished by the other additives were those hit by significant quantities of solution. Some penetration of the burning wood did occur with AFFF and FFFP, hence the lack of burnback occurring during the first two minutes of firefighting and the continuous cooling there-after.

Over the first six minutes of firefighting, the alcohol resistant versions of FFFP and AFFF both gave reductions that were significantly lower than those achieved by the non-alcohol resistant versions of the same additives. With FFFP the difference was 8% in terms of the averaged temperature reduction of the fire, ie 53% (FFFP) compared with 45% (FFFP-AR), whereas with AFFF there was a difference of 11%.

7.3.2 Hand-held Attack. Tests A16 to A19

With the firefighting branch hand-held at the doorway, the averaged temperature reduction of the fire during the first 30 seconds of firefighting was 46% using non-aspirated AFFF and by 45% using aspirated AFFF. A water jet achieved an averaged temperature reduction of 38% over the same period.

The averaged temperature reduction of the fire during the first 6 minutes of firefighting was 82% using aspirated AFFF and 80% using non-aspirated AFFF. A water jet achieved an averaged temperature reduction of 75% during the same period.

Both of these sets of results showed that when using the hand-held firefighting tactics of these tests, there was a slight advantage over water when using AFFF in the firefighting solution. Also, there was very little difference in the performance of aspirated AFFF when compared with non-aspirated AFFF.

The results of the non-aspirated AFFF with a narrow spray were very poor. The spray pattern used during this test was that of a low velocity jet in the centre of a 5° - 10° spray of very large water droplets. These droplets lacked sufficient velocity to penetrate the crib.

7.3.3 Summary

The results of the averaged temperature reductions of the fire can be summarised as follows:-

1. When the branch was mounted on the remote rig and with a spray angle of 26°, non-aspirated Halofoam (39%) and AFFF (39%) gave the greatest reductions over the first 30 seconds of firefighting. Both gave reductions that were marginally better than all of the other additives (except fire-out) and water (31%). Fire-out (26%) was significantly worse than the majority of additives tested.

2. When the branch was mounted on the remote rig and with a spray angle of 26°, non-aspirated Halofoam (75%) gave the greatest reduction over the first 6 minutes of firefighting. This reduction was significantly greater than that achieved by AFFF (63%). All of the other additives gave reductions of between 53% (FFFP) and 42% (Fireout). With the exception of fire-out (42%), all of the other additives gave slightly greater reductions than water (43%).

3. When the branch was hand-held at the doorway and on a jet setting, there was little difference in the reductions achieved by aspirated AFFF and non-aspirated AFFF. Both gave reductions that were slightly better than achieved with a hand-held water jet.

7.4 Costs

The following list summarises the total cost for the amount of additive required for 6 minutes of firefighting at 100 lpm. The costs given are at the rate charged to FEU (excluding VAT) during 1988 for the additives purchased for this series of trials. Also in the table is the concentration at which each of the additives was used :-

Concentrate	Cost of 6 minutes of firefighting	Concentration
AFFF	£42.66	3%
AFFF-AR	£41.76	3%
FFFP	£46.96	3%
FFFP-AR	£45.39	3%
Synthetic	£13.62	3%
Wetting Agent	N/A	1%
Fire-out	£2.90	0.2%
Halofoam	£704.70	15%

Some manufacturers state that their additives, when required as wetting agents for Class A fires, may be used at concentrations less than those used during these trials. All of the above additives used at a concentration of 3% during these trials may be used at 1% with Class A fires while Halofoam may be used at 8%.

7.5 Smoke Density Metering Equipment

The sensing equipments of the smoke density meters were positioned in such a way that smoke, steam, water spray and flame all passed through their optical paths. This interference with the optical paths led to erratic signals which could not be linked with events within the Fire Test Room. For this reason, no results of smoke density have been presented within this report.

7.6 Comparisons Between Large and Small Scale Tests

The results of the small scale tests are presented in Table 1 as time to 100% extinction. In the large scale tests, none of the additives extinguished the fire and so the results have been determined from measurements of doorway air temperatures and crib temperatures.

Both the small scale and large scale tests showed good crib fire suppression when using Halofoam and relatively poor crib suppression when using water and Fire-out. Other results did not show agreement between large and small scale tests. For instance, in the large scale tests non-aspirated spray AFFF gave good crib suppression while in the small scale tests, non-aspirated AFFF gave poor crib suppression.

In the small scale tests, the results indicated that there was a significant advantage in using aspirated additives instead of non-aspirated additives. In the large scale tests, a comparison between aspirated AFFF, non-aspirated AFFF and water was carried out with the branch on a jet setting. The results of these tests showed a very slight advantage when using aspirated AFFF instead of non-aspirated AFFF. Also, the advantage of using either aspirated or non-aspirated AFFF instead of water was not significant.

Overall, the results of the small scale tests could not be used to predict the results of the large scale tests. This may be due to many factors, in particular:-

1. In the small scale tests the firefighter was allowed complete access to all sides of the burning crib. In the large scale tests, firefighting could only take place from the front of the cribs.

2. The nozzles used in the small scale tests produced foams and spray patterns with different characteristics to those produced by the large scale nozzles.

3. In the small scale tests, performance of each additive was measured by time to extinction of the crib fire. In the large scale tests performance was measured by the ability of each additive to cool the doorway air temperature and the average crib temperature.

If any further small scale tests are to be performed then the test method should be modified to embrace the above comments. In this way it may be possible to predict the performance of each additive against Class A wooden crib fires without the expense of performing large scale fire tests.

7.7 Implications for the Fire Service

In the FEU report on the use of high pressure and low pressure hosereels (Reference 6), three phases of firefighting domestic room fires are identified: cooling the room prior to entry; controlling the fire; and extinguishing any residual hot spots.

During the initial phase, the use of additives would have a negligible effect on the reduction in the air temperature within the room.

During the second phase, the use of Halofoam or AFFF would make a contribution to the speed with which the fire was brought under control. Additives such as FFFP, AFFF-AR and Synthetic would have some effect.

During the final phase the firefighter is seeking to cool the contents of the room to temperatures where re-ignition is impossible. This is the least critical phase and is probably more a function of the amount of water used, rather than of any effect additives might have on the combustion process or penetration into materials.

Consequently, the decision on whether to use additives in tackling a typicaliy severe one-room domestic fire is governed by the importance attached to a reduction in the time to control a fire, the second phase in firefighting. The first phase lasts approximately thirty seconds, the duration of the second phase depends on the severity of the fire and the access to it, and the final phase lasts several times longer than this.

Thus the use of an additive would be justified for only part of the total duration of pumping. With most types of hosereel induction system, additive would still have to be used for the rest of the time, because the time taken for additive to feed through 55 metres of hoseline is significant when compared with the total time spent fighting a fire.

The best of the commonly used additives tested, AFFF, would significantly reduce the duration of the second phase but the overall saving in water would not be particularly large because of the amount of water still necessary for the final phase of firefighting. There might be a reduction in fire damage, but insurance claims after a fire are for smoke damage as well, and this would have been done before the fire service arrived.

The decision to use AFFF as an additive for domestic fires should therefore be based, not on the argument of a reduction in water consumption or fire damage, but on operational considerations of the merits of a reduction in the time to get a room fire under control.

8. CONCLUSIONS

It was only possible to test the additives against one standard Class A fire, and care must be taken in applying the conclusions to other circumstances. Nevertheless, the work does provide a basis for comparing the relative performance of the various additives.

It was hoped that by performing the small scale fire trials, the results of the large scale trials could be predicted. This was not the case. This may be due to many factors, in particular, the variation of the degree of access allowed to the fires, the different characteristics of the firefighting branches used and the differences in the methods used to measure the performance of the additives.

The conclusions drawn from the large scale trials were as follows:-

1. The rate at which the air temperature in a room can be reduced will govern the time elapsing before a firefighter can enter and make a close range attack on the fire. Where water cannot be directed as a jet at the base of the fire, previous work has shown that a spray setting is best. In this current work, when using the branch at a spray setting none of the additives showed an appreciable improvement over the use of water alone in reducing the air temperature within the fire test room. AFFF was marginally the most effective and Halofoam and AFFF-AR were worse than water alone.

2. The use of all additives, with the exception of Fireout, did make a positive contribution to reducing the severity of the test fire, when compared to the use of water alone, though some were far better than others. In general, AFFF and Halofoam were the most effective, with FFFP, AFFF-AR and Synthetic running second. The alcohol versions of AFFF and FFFP were both inferior to their standard versions.

3. The high cost of Halofoam would rule it out from all but special cases and, with Synthetic additive costing a third of the price of the more sophisticated AFFF and FFFP products, this has to be a factor to be considered.

4. Only a brief comparison between aspirated and non-aspirated application was made using AFFF from a hand-held branch at a jet setting. There was no significant difference in performance between the two applications. Water gave similar performance when used under the same conditions.

The best of the commonly used additives tested, AFFF, would reduce the duration of the control phase of firefighting but the overall saving in water and any reduction in fire damage would be small. The decision on whether to use this additive for domestic fires would therefore be based on operational considerations on the merits of a reduction in the time to get a room fire under control.

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NOTES

1. See Appendix A, Glossary of Terms, for details.

2. Loss Prevention Council, LPC, Melrose Avenue, Borehamwood, Herts, WD6 2BJ. Formerly the Fire Insurers Research and Testing Organisation, FIRTO.

3. Alpha Pumps, Ashford Road, Maidstone. Model GP 1/2/125/E.

4. Dunlop Limited, Hose Division (Midland Region), Building 33, Penareth Trading Estate, Kingswinford, West Midlands, DY6 7PD. Dunlop "Gacord-26", 19mm bore hose.

5. Thorn EMI Protech Limited, Hollins Road, Oldham, OL8 3DX. 9 litre foam fire extinguisher.

6. Kent Industrial Measurements Limited, Stonehouse, Glos. 15mm electromagnetic flowmeter, VTB 1129813049 with VKB converter.

7. Electroplan Limited, Orchard Road, Royston, Herts. SG8 5HH. Digital indicator DPM 2435.

8. T.C. Limited, P.O. Box 130, Longbridgeway, Uxbridge, UB8 2YS. K type thermocouple, 12K-100-118-3.0-2G-3.p.2-1mtr, -A.30K-4F7.

9. RS Components, Duddeston Mill Road, Saltley, Birmingham, B8 1BQ. Panel mounted digital temperature indicator, 257-284.

10. Paar Scientific Limited, 594 Kingston Road, Raynes Park, London SW20. Medtherm heat flux transducers, 64-10-20.

11. Exxon Chemicals Limited, Portland Terrace, Southampton, SO9 2GW. Solvent 50 - Heptane fuel.

12. Cape Durasteel Limited, Bradfield Road, Firedon Road Industrial Estate, Wellingborough NN8 4HB. Durasteel A60 panels.

13. Durasteel 6mm panels (as above).

14. Pains-Wessex Shermuly, High Post, Salisbury, Wilts SP4 6AS. Solvent Ignitor - Code Number 2015-01.

15. Sony (UK) Limited, Sony House, South Street, Staines, Middlesex, TW18 1BR. Sony DXC-102.P colour CCD video camera.

16. Pentax (UK) Limited, Pentax House, South Hill Avenue, South Harrow, Middlesex, HA2 0LT. Pentax 4.8mm f1.8.A1 lens.

17. Camera housing components manufactured 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.

18. Maine Engineering, Howe Park, Kings Longley, Herts, WD4 8RH. Model SD1200L.

19. T.C. Limited, P.O. Box 130, Longbridgeway, Uxbridge, UB8 2YS. 0.5mm sheath diameter (stainless steel), mineral insulated K type thermocouples 12-K-1000-125-0.5-21-3P2B-1Mtr C40K M11K attached, thermocouple length included pot seal. These were later replaced, on occasional failure (average 1 failure per test), with 12-K-1000-125-6.0-2I-3P6A reduced tip 0.5mm x 10mm, 1Mtr C40K, H22K, M11K attached, brazed spool type sheath/plug fixture required. These thermocouples were ready installed in a stainless steel tube which pushed directly through the existing stainless steel tubes and did not require fire cement to seal them.

20. Solatron Instruments, Victoria Road, Farnborough, Hampshire, GU14 7PW. Primary data logger : Orion Data Logger 3531D. Second data logger : Orion Data Logger 3530.

21. Solatron Instruments, Victoria Road, Farnborough, Hampshire, GU14 7PW. Solatron demonstration software.

22. IBM (UK) Limited, 414 Chiswick High Road, London W4 5TF. PS/2 Model 60 with colour display 8512 and 44MB hard disk.

23. H & B Sensors Limited, Heath Place, Ashgrove Industrial Park, Bognor Regis, PO22 9LS. K type mineral insulated thermocouples, 1.5mm diameter, length 1000mm, plain pot sealed solid with glass. 1000mm fibre glass stainless steel braid with mini plug.

24. Babcock-Bristol Limited, Power and Water Division, 218 Purley Way, Croydon. Smoke density metering equipment E66-50/5 with Industrial Control unit.

25. T.C. Limited, P.O. Box 130, Longbridgeway, Uxbridge, UB8 2YS. Platinum Resistance Thermometer.

26. Made by A W H Engineering, London Road, Moreton-in Marsh, Glos. To drawing No. FEU-0-009.

27. Budenburg Gauge Co. Limited, P.O. Box 5, Broad Heath, Altrincham, Cheshire WA14 4ER. 0-60 bar test pressure gauge.

28. Druck Limited, Fir Tree Lane, Groby, Leicestershire, LE6 0FH. Pressure Transducer PDCR60. Serial Number 106180.

29. Druck Limited, Fir Tree Lane, Groby, Leicestershire, LE6 0FH. Pressure Indicator DPI 203. Serial Number 203675.

30. Gallenkamp, Belton Road West, Loughborough, Leics. LE11 0TR. Wet and Dry Hygrometer, $-5^{\circ}C$ to $50^{\circ}C$ x $0.5^{\circ}C$, HYT-470-030F.

31. Lee-Integer Limited, Integer House, 1-3 Bowling Green Road, Kettering, Northants, NN15 7QW. DHL45 readout unit. CH15 I/4 Humidity probe with 30M extension cable.

32. Diktron Developments, Highgate Square, Birmingham, West Midlands, B12 0DT. Diktron line communication system with headset/microphone.

33. Lotus Developments (UK) Limited, Consort House, Victoria Street, Windsor, Berks SL4 1EX. Lotus 1-2-3, version 2.01.

34. Amendola Engineering Limited, 80 Hewell Road, Barnt Green, Birmingham B45 8NF. Elkhart Select-O-Flow, S.F.S.-G hosereel gun.

35. Angus Fire Armour Limited, Thame, Oxfordshire. Armourite Superfog gun Model ES4991 light alloy.

36. Details of the FRS 50 lpm branchpipes are given in Fire Research Note Number 1045, A 50 litre per minute Standard Foam Branchpipe, S P Benson and J G Corrie, April 1977.

37. Adflow International Limited, Bath Road, Woolhampton, Reading, Berks. 'C' type hermaphrodite coupling.

38. Plastic Pumps Limited, Hanworth Trading Estate, Feltham, Middlesex. Thermoplastic hand dispensing pump, HPN-3A.

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1. BS 4547 : 1972, Classification of Fires, BSI, London. 1972.

2. Home Office (Fire and Emergency Planning Department), Manual of Firemanship, Book 3, London : Her Majesty's Stationery Office. 1976.

3. NFPA, Fire Brigade Training Manual, David T Gold, National Fire Protection Association (USA). 1982

4. BS 5423 : 1987. Specification for Portable Fire Extinguishers. BSI, London. 1987.

5. SRDB Publication 9/87. Pilot Study on Low Expansion Foam-Making Branchpipes. B.P. Johnson and P.L. Parsons. Home Office Scientific Research and Development Branch. September 1986.

6. SRDB Publication 34/88. The Use of High Pressure and Low Pressure Pumps with Hosereel Systems, J. Rimen. Home Office Scientific Research and Development Branch. 1988.

7. Joint Fire Research Organisation Fire Research Note Number 342. The Use of High and Low Pressure Water Sprays Against Fully Developed Room Fires, D. Hird, R.W. Pickard, D.W. Fittes and P. Nash. Fire Research Station. 1958.

8. SRDB Publication 10/90. Equipment For the Induction of Additives Into Hosereel Systems, J.A. Foster and B.P. Johnson. Home Office Scientific Research and Development Branch. 1990.

9. JCFR Research Report Number 31. Additives For Hosereel Systems: Trials of Foam on $40m^2$ Petrol Fires. 1988.

TABLE 1 : DETAILS OF THE ADDITIVES USED DURING THIS WORK

Type	Conc.[1] %	Trade Name	Manufacturer/Supplier	Cost Per Litre[2] (£)
AFFF	3	Light Water	3M Chemicals Division Manchester	2.37
AFFF-AR	3	Light Water ATC	3M Chemicals Division Manchester	2.32
FFFP	3	Petroseal	Angus Fire Armour Limited Thame, Oxfordshire	2.61
FFFP-AR	3	Alcoseal	Angus Fire Armour Limited Thame, Oxfordshire	2.52
FP	3	FP70	Angus Fire Armour Limited Thame Oxfordshire	0.84
FP-AR	6	Fluoropolydol	Angus Fire Armour Limited Thame Oxfordshire	2.26
Synthetic	3	Expandol	Angus Fire Armour Limited Thame Oxfordshire	0.76
Halofoam	15	Halofoam[3]	Harrier Marketing Limited Wakefield	7.83
Fire-out	0.2	Fire-out	Traffic Safety Systems London WC2	2.42
Wetting Agent	1	Wetwater	Galena Limited London W6	N/A

NOTES TO TABLE 1 :

1. Concentration used during this work.
2. Cost per litre at the time of the Large Scale Class A Fires - July 1988. Not including VAT.
3. Now supplied as Pyrofoam.

TABLE 2 : SUMMARY OF THE RESULTS OF THE SMALL SCALE CLASS A FIRE TESTS

Test No.	Date	Additive	Nozzle Type	Crib Size	Temperature Air (°C)	Temperature Solution (°C)	Time to Control (Seconds)
1[1]	Jan 86	Water	Jet	13A	3	18	52
2	Jan 86	AFFF	N/Asp	13A	6	19	48
3	Jan 86	AFFF	Asp	13A	6	22	33
4	Jan 86	FP	Asp	13A	6	18	35
5	Jan 86	FP	N/Asp	13A	7	23	41
6	Jan 86	Halofoam	N/Asp	13A	7	19	25
7	Jan 86	Fire-out	N/Asp	13A	5	23	46
8	Jan 86	FFFP-AR	Asp	13A	3	21	40
9	Jan 86	FFFP-AR	N/Asp	13A	3	22	42
10	Jan 86	Water	N/Asp	13A	3	23	36
11	Jan 86	Water	N/Asp	13A	3	23	36
12[2]	Jan 86	Water	N/Asp	27A	4	24	125
13[2]	Jan 86	Halofoam	N/Asp	27A	4	18	76
14[2]	Jan 86	AFFF	Asp	27A	5	22	69
15[3]	Oct 87	AFFF	N/Asp	27A	13	16	—
16	Oct 87	AFFF	N/Asp	27A	15	16	123
17	Oct 87	Water	N/Asp	27A	14	21	140
18	Oct 87	Water	N/Asp	27A	14	18	130
19	Oct 87	AFFF	Asp	27A	17	17	87
20	Oct 87	FFFP-AR	Asp	27A	11	19	105
21	Oct 87	FFFP-AR	N/Asp	27A	12	19	101
22	Oct 87	Fire-out	N/Asp	27A	15	17	117
23	Oct 87	AFFF-AR	N/Asp	27A	13	19	114
24	Oct 87	AFFF-AR	Asp	27A	14	18	85
25	Oct 87	FP	Asp	27A	14	20	99
26	Oct 87	FFFP	Asp	27A	12	18	84
27	Oct 87	FFFP	N/Asp	27A	13	19	116
28	Oct 87	Wet Agt.	N/Asp	27A	14	19	122
29	Oct 87	Synth.	N/Asp	27A	13	19	98
30	Oct 87	Synth.	Asp	27A	13	19	74
31	Oct 87	Halofoam	N/Asp	27A	15	19	69
32	Oct 87	FP-AR	Asp	27A	13	19	101
33	Oct 87	FP	N/Asp	27A	13	19	129
34	Oct 87	Water	N/Asp	27A	14	19	116

NOTES TO TABLE 2 :

1. Test 1 was used to develop the test procedure. Tests 10 and 11 are more representative of the performance of water.

2. Tests 12, 13 and 14 were carried out to explore trials technique when fighting fires in size 27A cribs.

3. In Test 15, the firefighter was only allowed to attack the fire from one side of the crib. After 6 minutes 45 seconds of firefighting knockdown of the fire had not been achieved and the crib had begun to collapse. This test was consequently abandoned.

TABLE 3 : RESULTS OF LARGE SCALE CLASS A FIRE TESTS - TEST CONDITIONS

Test No.	Date	Firefighting Branch	Firefighting Solution	Application Method	Flow (LPM)	Pressure (bar)	Solution Temp. (°C)	Fuel Temp. (°C)	Air Temp. (°C)	Relative Humidity (%)	Wood Moisture Content (%)
A1	5/7/88	Elkhart	Water	Non-Aspirated	99.5	30.5	23	14	14	83	15
A2	8/7/88	Elkhart	Water	Non-Aspirated	90	32.8	25	13	12	86	17
A3	20/7/88	2xFRS 50 lpm	AFFF 3%	Aspirated	100	6.6[1]	21	16	18	75	17
A4	23/8/88	Superfog	Water	Non-Aspirated	100	18.1	22	14	16	74	16
A5	25/8/88	Superfog	Water	Non-Aspirated	100	18.2	21	14	14	71	15
A6	30/8/88	Superfog	Water	Non-Aspirated	100	18.3	21	13	14	81	15
A7	1/9/88	Superfog	AFFF 3%	Non-Aspirated	100	18.3	21	14	15	97	15
A8	8/9/88	Superfog	FFFP 3%	Non-Aspirated	100	18.2	21	15	18	78	15
A9	12/9/88	Superfog	FFFP-AR 3%	Non-Aspirated	100	18.2	20	14	14	81	15
A10[2]	27/9/88	Superfog	AFFF-AR 3%	Non-Aspirated	100	18.2	19	14	15	88	13
A11	30/9/88	Superfog	Synth. 3%	Non-Aspirated	100	19.0[3]	19	11	11	74	15
A12	3/10/88	Superfog	AFFF-AR 3%	Non-Aspirated	100	18.9	18	11	12	77	15
A13	5/10/88	Superfog	Fire-Out 0.2%	Non-Aspirated	100	19.0	18	12	13	83	16
A14	12/10/88	Superfog	Halofoam 15%	Non-Aspirated	100	19.2	18	10	10	87	14
A15	17/10/88	Superfog	Wet-Agent 1%	Non-Aspirated	100	18.7	17	11	12	88	14
A16	22/11/88	Superfog[4]	AFFF 3%	Non-Aspirated[5]	100	19.9	13	3	2	82	14
A17	23/11/88	Superfog[4]	AFFF 3%	Aspirated	100	19.5	14	5	4	92	15
A18	28/11/88	Superfog[4]	AFFF 3%	Non-Aspirated[6]	100	23.7	14	5	6	92	15
A19	2/12/88	Superfog[4]	Water	Non-Aspirated[6]	100	23.9	13	5	5	92	13

NOTES TO TABLE 3 :

1. This is the pressure recorded for eachof the two FRS 5 lpm branchpipes.
2. This is not a valid test due to the failure of a coupling at the branch at ten minutes which caused 20%-30% of the solution to be sprayed onto the fire test room floor instead of onto the burning cribs.
3. The couplings at the branch, and all other washers in the hosereel system, were changed prior to this test. This resulted in an increase in pressure of 0.8 bar when operating the branch at 100 lpm.
4. The branch was hand-held during this test.
5. The branch was operated at a narrow spray setting during this test.
6. The branch was operated at a jet setting during this test. The resulting jet pattern was similar to that obtained from the aspirating nozzle during Test A17.

TABLE 4 : RESULTS OF LARGE SCALE CLASS A FIRE TESTS - FOAM MEASUREMENTS

Test No.	Date	Firefighting Branch	Firefighting Solution	Application Method	Expansion Ratio	25% Drainage Time (Min-Sec)	Shear Stress (N/M^2)	Foam Temp (°C)
A1	5/7/88	Elkhart	Water	Non-Aspirated	—	—	-	—
A2	8/7/88	Elkhart	Water	Non-Aspirated	—	—	-	—
A3	20/7/88	2xFRS 50 1pm	AFFF 3%	Aspirated	7.6	4 - 26	4	19
A4	23/8/88	Superfog	Water	Non-Aspirated	—	—	-	—
A5	25/8/88	Superfog	Water	Non-Aspirated	—	—	-	—
A6	30/8/88	Superfog	Water	Non-Aspirated	—	—	-	—
A7	1/9/88	Superfog	AFFF 3%	Non-Aspirated	2.8	—[a]	1[b]	14
A8	8/9/88	Superfog	FFFP 3%	Non-Aspirated	3.1	—[a]	1[b]	19
A9	12/9/88	Superfog	FFFP-AR 3%	Non-Aspirated	1.8	—[a]	<1[b]	14
A10[c]	27/9/88	Superfog	AFFF-AR 3%	Non-Aspirated	2.2	—[a]	<1[b]	15
A11	30/9/88	Superfog	Synth. 3%	Non-Aspirated	2.4	—[a]	<1[b]	10
A12	3/10/88	Superfog	AFFF-AR 3%	Non-Aspirated	2.3	—[a]	1[b]	12
A13	5/10/88	Superfog	Fire-Out 0.2%	Non-Aspirated	1.1	—[a]	<1[b]	11
A14	12/10/88	Superfog	Halofoam 15%	Non-Aspirated	1.1	—[a]	<1[b]	9
A15	17/10/88	Superfog	Wet-Agent 1%	Non-Aspirated	1.1	—[a]	<1[b]	9
A16	22/11/88	Superfog[d]	AFFF 3%	Non-Aspirated[e]	2.2	—[a]	3	2
A17	23/11/88	Superfog[d]	AFFF 3%	Aspirated	7.4	5 - 34	3	8
A18	28/11/88	Superfog[d]	AFFF 3%	Non-Aspirated[f]	1.9	2 - 30	<1	7
A19	2/12/88	Superfog[d]	Water	Non-Aspirated[f]	—	—	-	-

NOTES TO TABLE 4 :

a. Due to the fast draining nature of non-aspirated additive solutions, drainage times could not be measured.
b. Viscometer pot contained a large volume of liquid during measurement.
c. This is not a valid test due to the failure of a coupling at the branch at ten minutes which caused 20%-30% of the solution to be sprayed onto the fire test room floor instead of onto the burning cribs.
d. The branch was hand-held during this test.
e. The branch was operated at a narrow spray setting during this test.
f. The branch was operated at a jet setting during this test. The resulting jet pattern was similar to that obtained from the aspirating nozzle during Test A17.

TABLE 5 : RESULTS OF LARGE CLASS A FIRE TESTS - AVERAGED TEMPERATURE REDUCTIONS

Test Number	Firefighting Liquid	Application Method	Tactic	Branch Setting	Averaged Temperature Reduction		
					Of the Doorway Air	Of the Fire	
					(First 30 Seconds)	(First 30 Seconds)	(First 6 Minutes)
A4	Water		Remote	Spray	34%	31%	44%
A5	Water		Remote	Spray	35%	30%	41%
A6	Water		Remote	Spray	29%	27%	44%
A7	AFFF	Non-Aspirated	Remote	Spray	38%	39%	63%
A8	FFFP	Non-aspirated	Remote	Spray	35%	34%	53%
A9	FFFP-AR	Non-aspirated	Remote	Spray	31%	32%	45%
A11	Synthetic	Non-aspirated	Remote	Spray	31%	35%	50%
A12	AFFF-AR	Non-Aspirated	Remote	Spray	25%	33%	52%
A13	Fire-out	Non-aspirated	Remote	Spray	35%	26%	42%
A14	Halofoam	Non-aspirated	Remote	Spray	27%	39%	75%
A15	Wetting Agent	Non-aspirated	Remote	Spray	37%	30%	48%
A16	AFFF	Non-aspirated	Hand-held	Narrow spray	25%	26%	51%
A17	AFFF	Aspirated	Hand-held	Jet	42%	45%	82%
A18	AFFF	Non-aspirated	Hand-held	Jet	41%	46%	80%
A19	Water		Hand held	Jet	30%	38%	75%

TABLE 6 : NON-ASPIRATED , REMOTE ATTACK, TESTS A4 TO A15, AVERAGED TEMPERATURE REDUCTION OF THE AIR AT THE DOORWAY DURING THE FIRST 30 SECONDS OF FIREFIGHTING

Test No.	Firefighting Liquid (Non-aspirated)	Averaged Temperature Reduction of the Air (First 30 Seconds)
A7	AFFF	38%
A15	Wetting Agent	37%
A5	Water	35%
A8	FFFP	35%
A13	Fire-out	35%
A4	Water	34%
A9	FFFP-AR	31%
A11	Synthetic	31%
A6[1]	Water[1]	29%[1]
A14	Halofoam	27%
A12	AFFF-AR	25%

TABLE 7 : NON-ASPIRATED, REMOTE ATTACK, TESTS A4 TO A15, AVERAGED TEMPERATURE REDUCTION OF THE FIRE DURING THE FIRST 30 SECONDS OF FIREFIGHTING

Test No.	Firefighting Liquid (Non-aspirated)	Averaged Temperature Reduction of the Fire (First 30 Seconds)
A7	AFFF	39%
A14	Halofoam	39%
A11	Synthetic	35%
A8	FFFP	34%
A12	AFFF-AR	33%
A9	FFFP-AR	32%
A4	Water	31%
A15	Wetting Agent	30%
A5	Water	30%
A6[1]	Water[1]	27%[1]
A13	Fire-out	26%

TABLE 8 : NON-ASPIRATED, REMOTE ATTACK, TESTS A4 TO A15, AVERAGED TEMPERATURE REDUCTION OF THE FIRE DURING THE FIRST SIX MINUTES OF FIREFIGHTING

Test No.	Firefighting (Non-aspirated)	Averaged Temperature Reduction of the Fire (First 6 minutes)
A14	Halofoam	75%
A7	AFFF	63%
A8	FFFP	53%
A12	AFFF-AR	52%
A11	Synthetic	50%
A15	Wetting Agent	48%
A9	FFFP-AR	45%
A4	Water	44%
A6[1]	Water[1]	44%[1]
A13	Fire-out	42%
A5	Water	41%

NOTE TO TABLES 6, 7 and 8 :

1. The water spray used during this test did not cover the tops of the front faces of the cribs. See section 6.4 for more details.

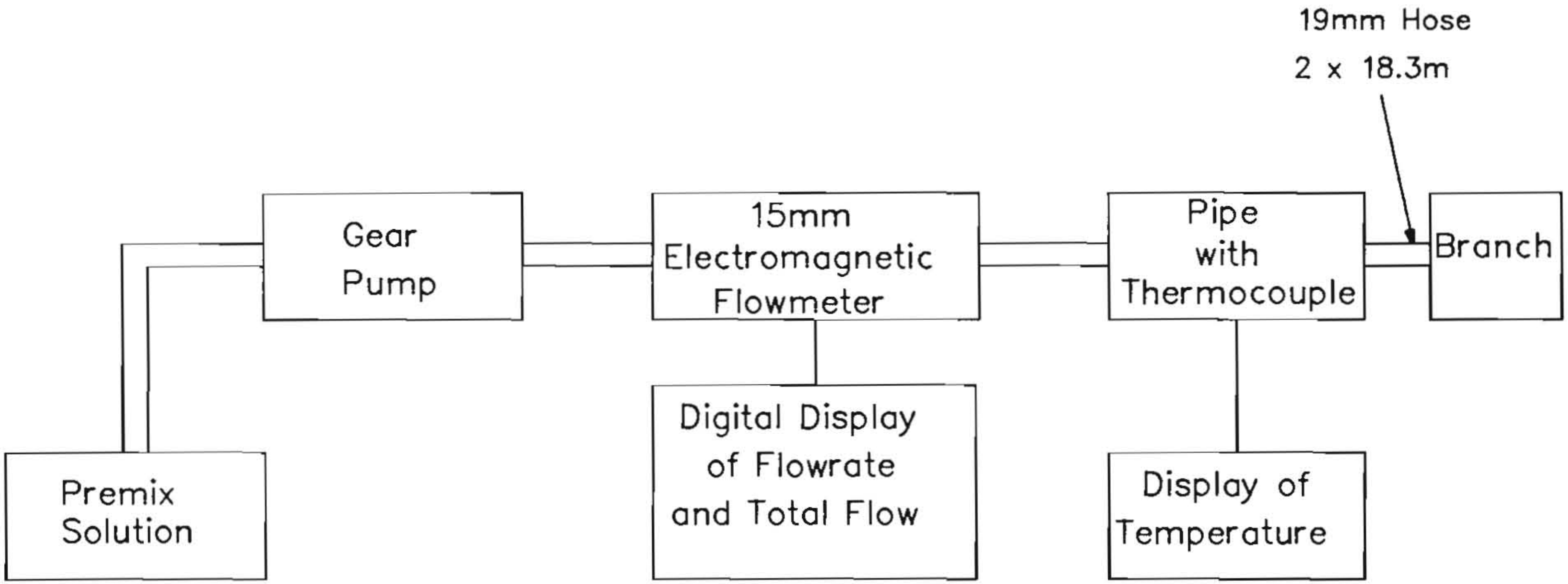


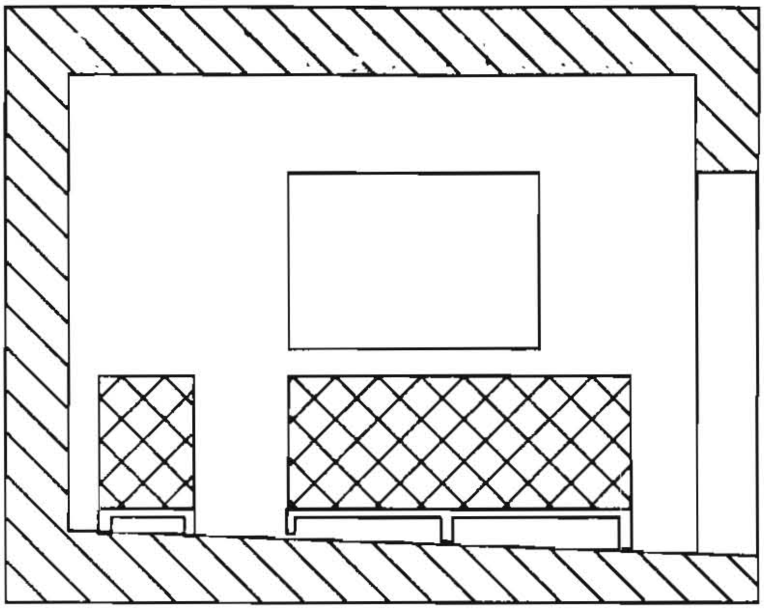
Figure 1. Hydraulic Arrangement For Small Scale Class A Fire Tests

C/139/87

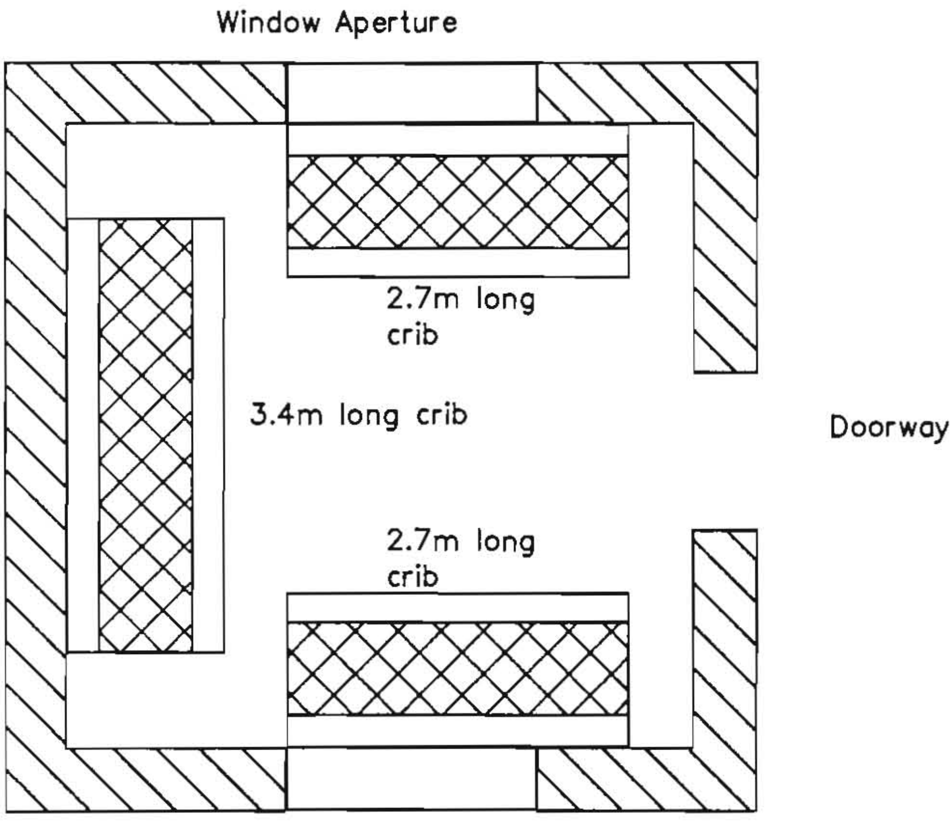
Figure 2 : Two Nozzles Used for Extinguishing Small Scale Class A Fires
(Upper : Non-aspirating, Lower : aspirating)

S/317/87

Figure 3 : The Fire Test Room at Hangar 97



Cross Section on Room Centreline



Plan View (roof removed)

Figure 4 : Fire Test Room — Internal Layout

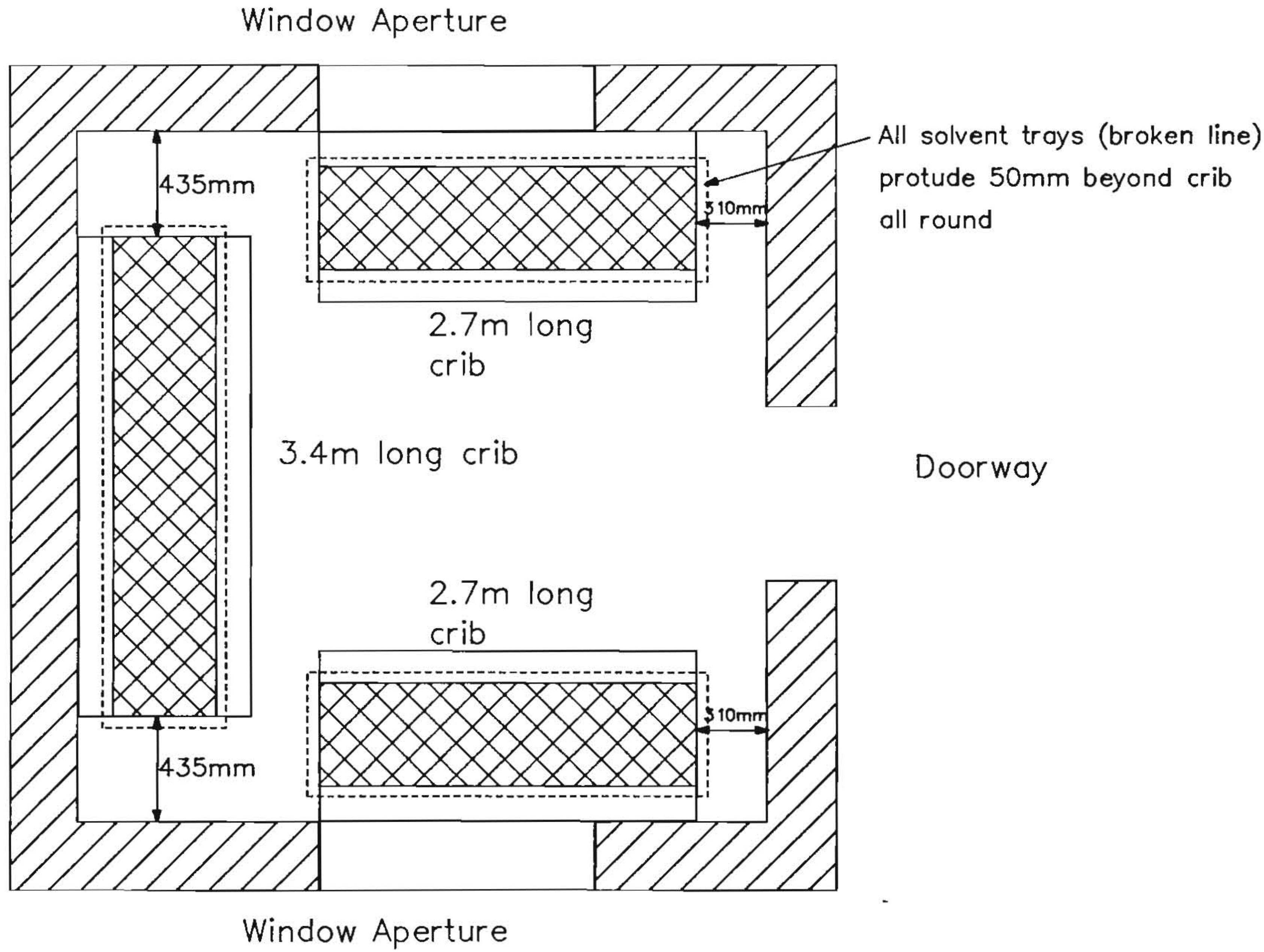


Figure 5 : Arrangement of Solvent Trays Beneath Cribs

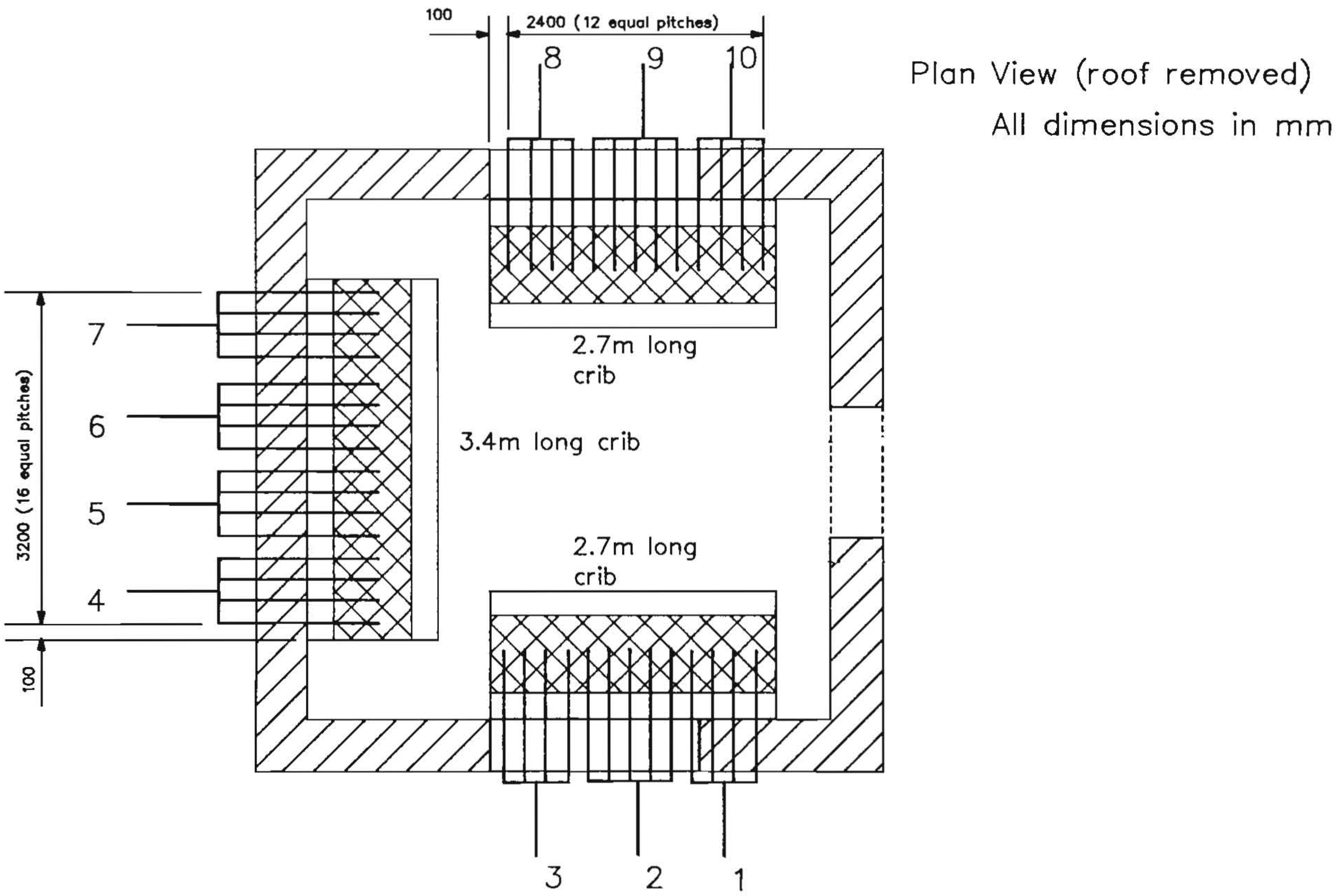


Figure 6 : Positions and Groupings of Thermocouples within the Cribs

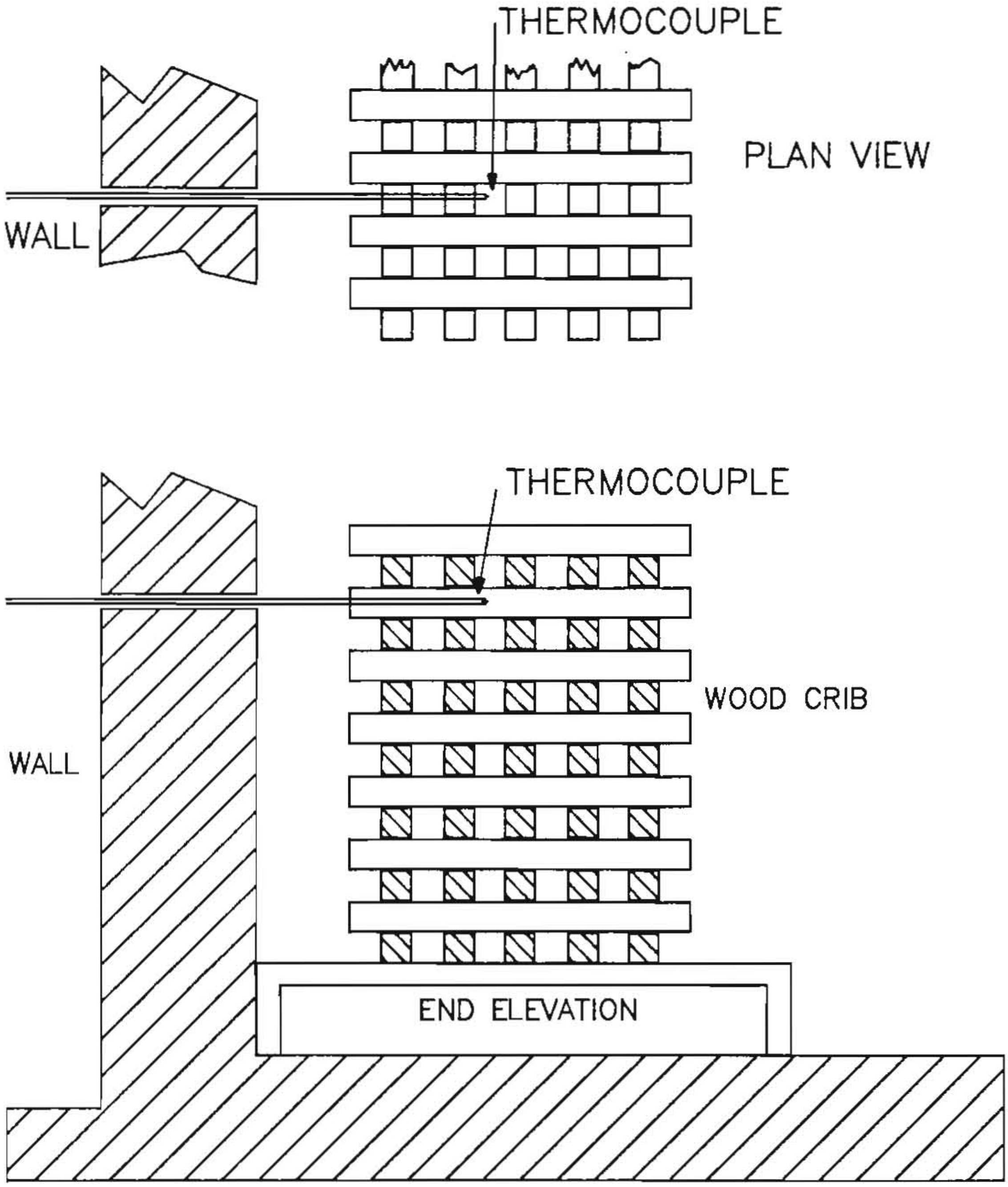


Figure 7 : Longitudinal Position of a Thermocouple Within a Crib

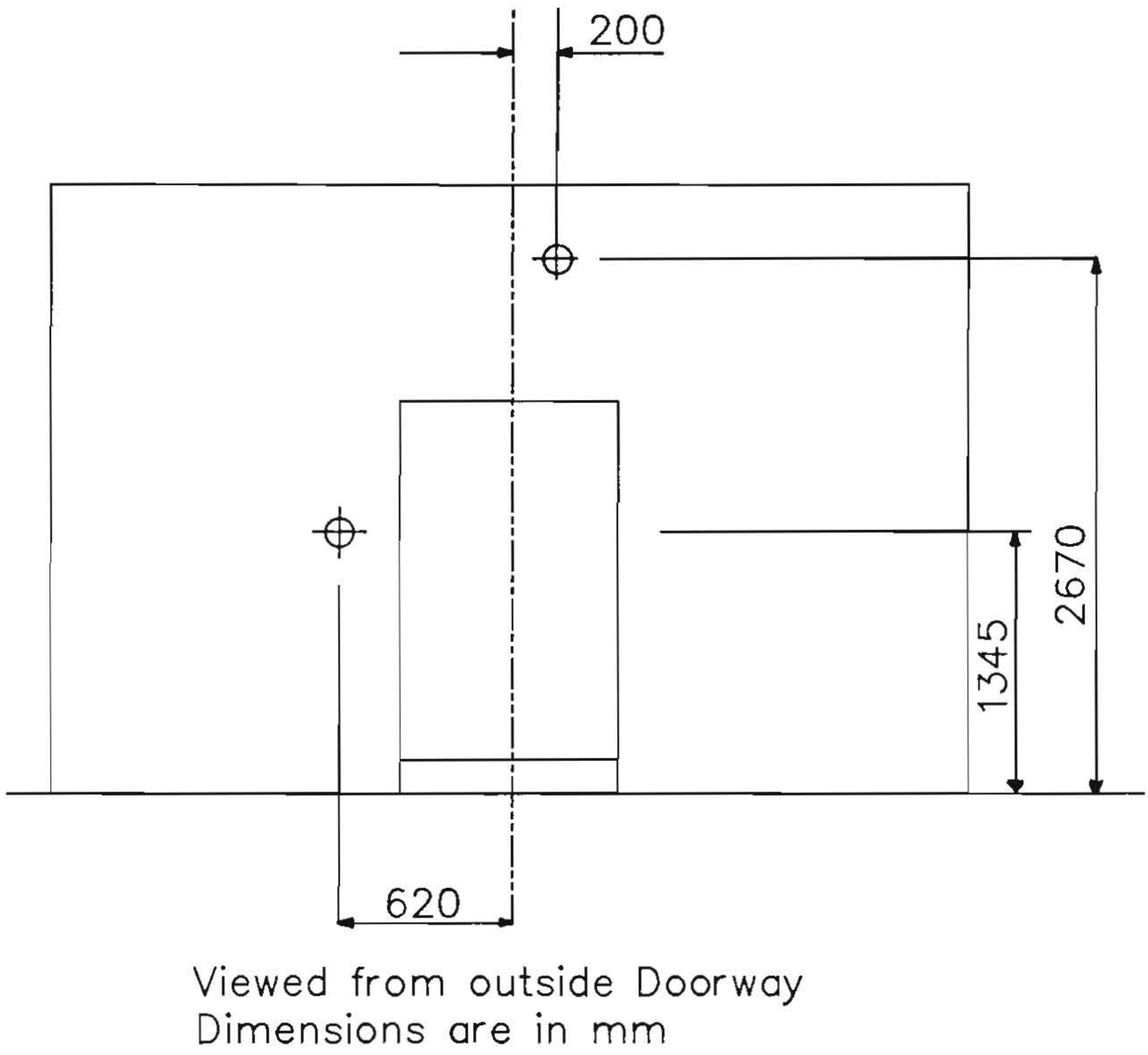


Figure 8 : Positions of Thermocouples around the Doorway

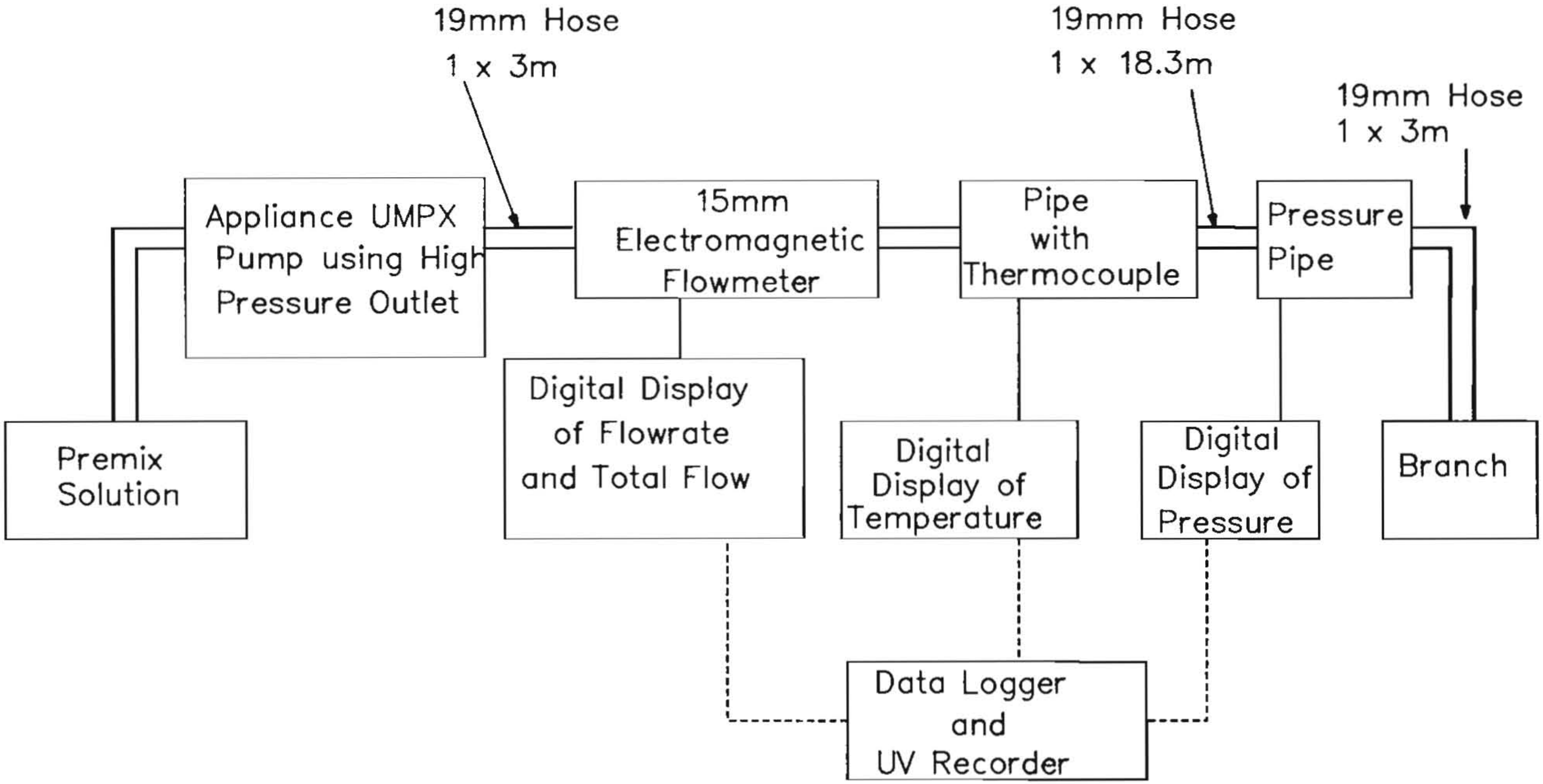


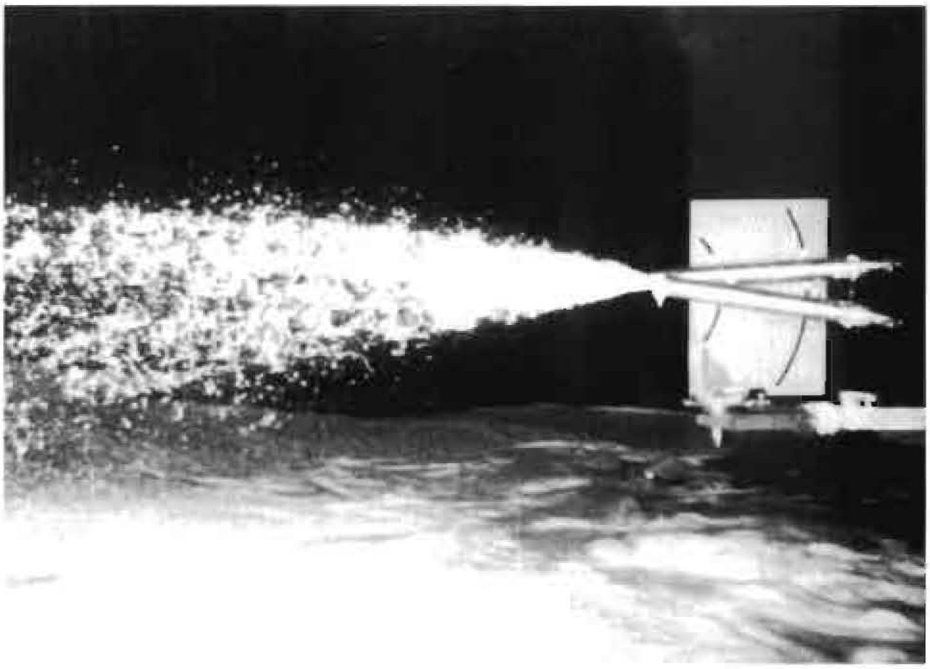
Figure 9. Hydraulic Arrangement for Large Scale Class A Fire Tests

C/692/84

Figure 10 : Elkhart Select-O-Flow Hosereel Branch

C/456/86

Figure 11 : Angus Superfog Hosereel Branch



B/353/90

Figure 12 : FRS 50 lpm Branches, Mounted for Use During Test A3

C/459/86

Figure 13 : Angus Superfog Hosereel Branch Fitted With Aspirator

C/365/88

Figure 14 : Remote Firefighting Rig

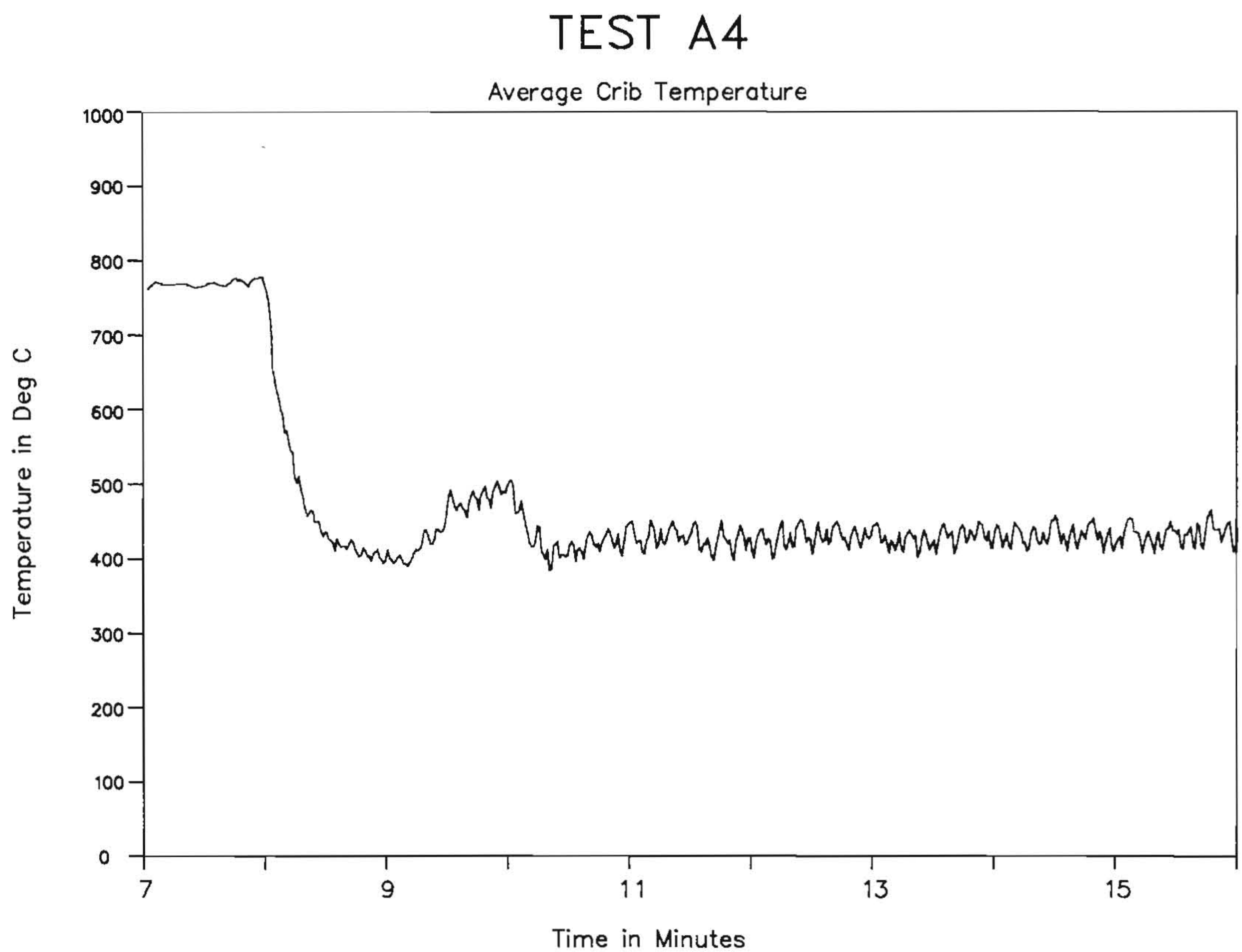


Figure 15 : Graph of Overall Average Crib Temperature Vs Time, Test A4 (Water)

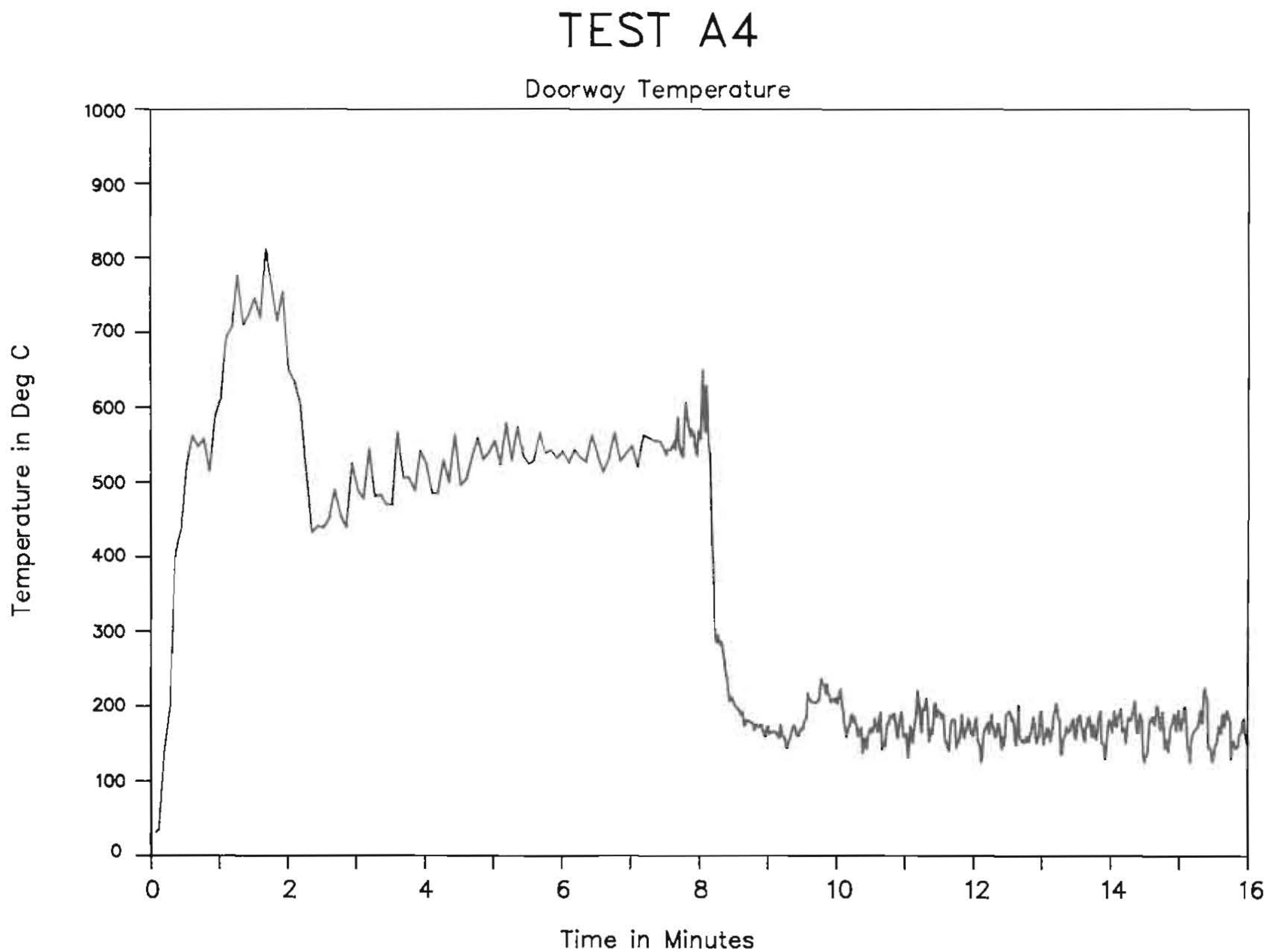


Figure 16 : Graph of Air Temperature Measured at Doorway, Test A4 (Water)

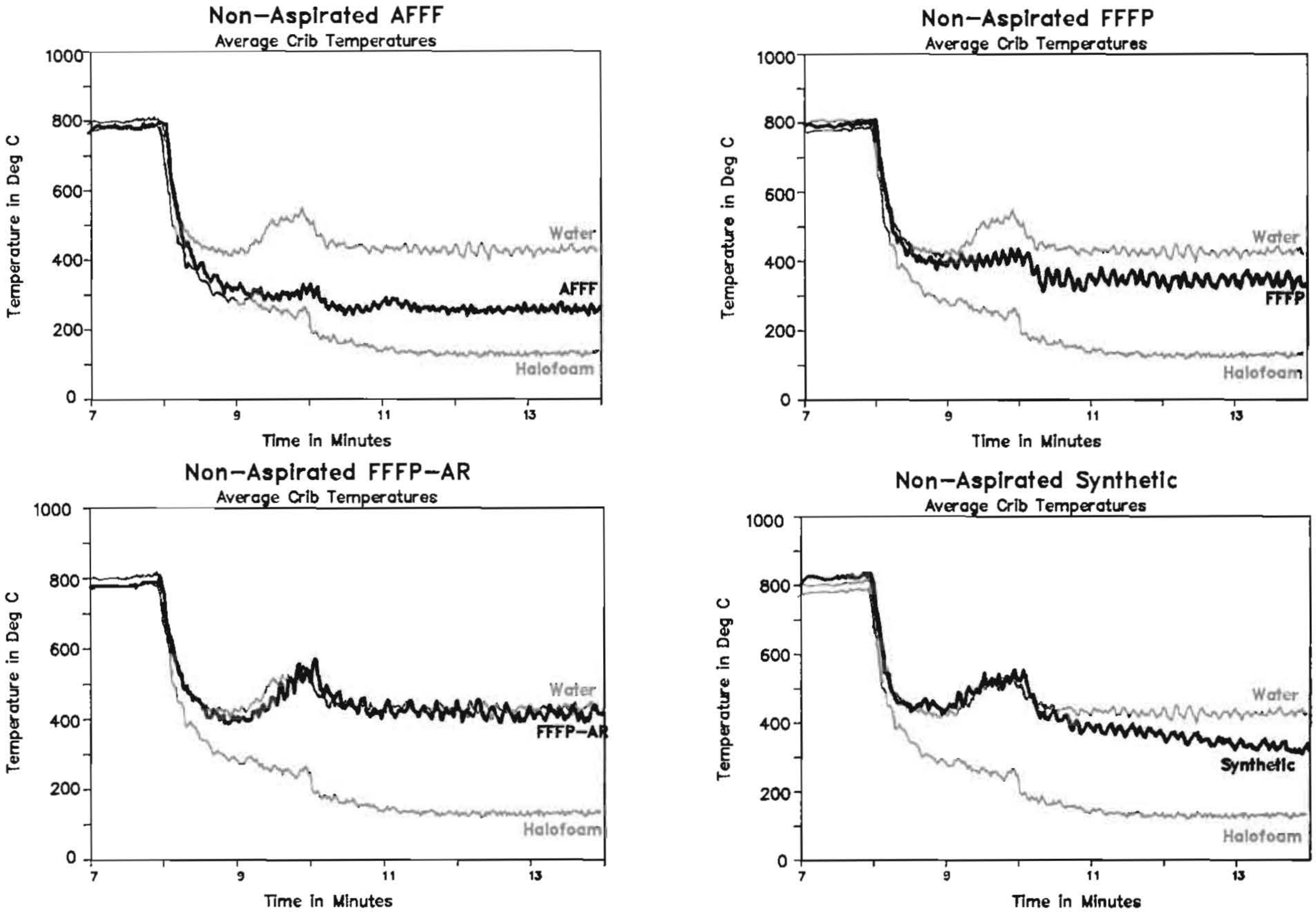


Figure 17 : Graphs of Average Crib Temperatures Vs Time for all Remote Tests (Non-aspirated)

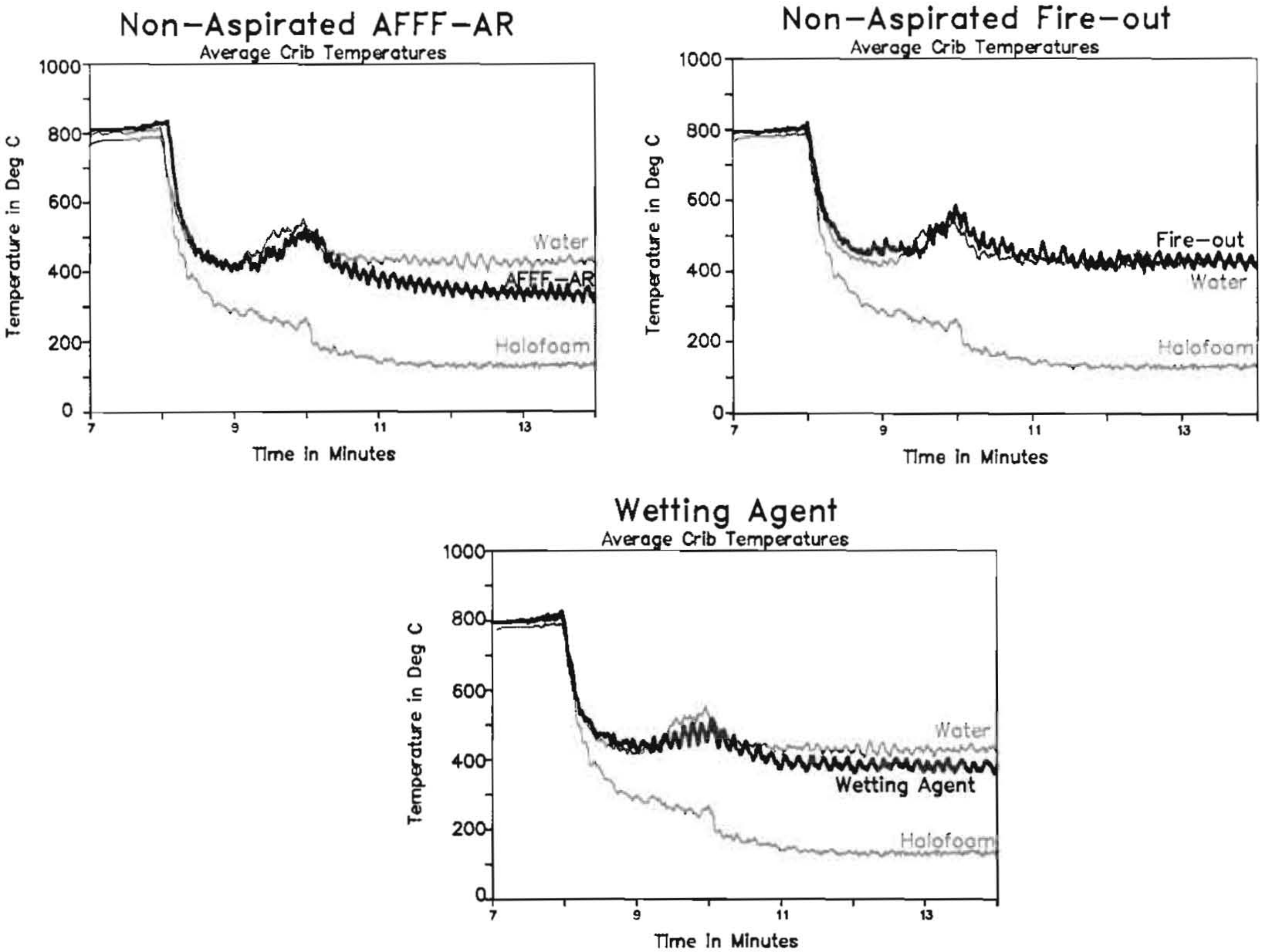


Figure 17 : Graphs of Average Crib Temperature Vs Time For All Remote Tests (Non-aspirated) (CONTINUED)

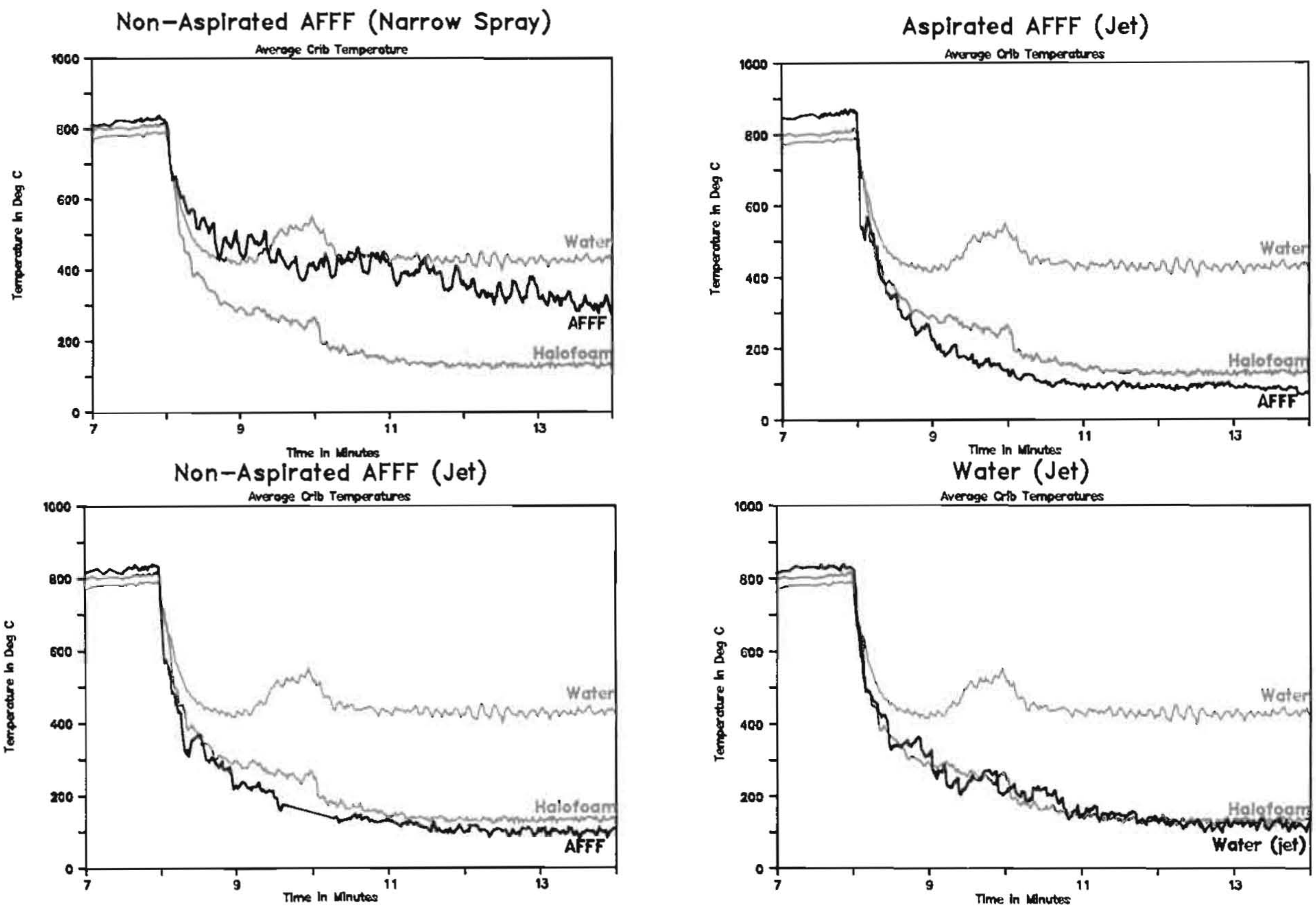


Figure 18 : Graphs of Average Crib Temperature Vs Time
For All Hand Held Tests

APPENDIX A : GLOSSARY OF TERMS USED IN THIS REPORT

Alcohol resistant (AR) additives

These are formulated for use on water miscible liquids; the foams produced are more resistant than ordinary foams to breakdown by the liquid. They may be of any of the classes of foam additives e.g. AFFF-AR, FFFP-AR. Film forming foams do not form films on water miscible liquids.

Generally used at 6% concentration on water miscible fuels and 3% on hydrocarbon fuels.

Aqueous film-forming foam (AFFF) additives

These are generally based upon mixtures of hydrocarbon and fluorinated hydrocarbon surface active agents. Foam solutions made from fluorochemical additives are film forming on some liquid hydrocarbon fuel surfaces. Generally used at 1%, 3% or 6% concentration.

To achieve effective performance, the premix or induction system must take account of the additive used. For each 100 litres of solution the additive must be mixed as follows :-

Concentration	Volume of Additive litres	Volume of Water litres	Volume of Solution litres
1%	1	99	100
3%	3	97	100
6%	6	94	100

Aspirator

An attachment to a hosereel branchpipe in which foam solution is mixed with air to form foam.

Averaged temperature reduction

During the analysis of the results of this work it was found that the area under the curves of crib and air temperatures plotted against time gave an indication of the averaged temperature reduction of the air and the fire during each of the tests. The results are presented as percentage averaged temperature reductions.

The areas under the curves were calculated using a Simpsons rule application from a computer software package (@STATS, 4-5-6 World) with raw data in a Lotus 1-2-3 spreadsheet file. This area was then subtracted from the probable area under the curve if no firefighting had occurred (this assumed that the temperature at eight minutes continued over the period of interest). The result is presented in the report as the percentage averaged temperature reduction.

Concentration

The ratio of foam additive in the foam solution usually expressed as a percentage, vol/vol.

Drainage time

The time for a defined percentage of the liquid content (25% in this work) of a foam to drain out under specified conditions.

Expansion ratio

The ratio of the volume of aerated foam to the volume of foam solution from which it was made.

Film-forming

The characteristics of a foam, foam solution or foam additive forming an aqueous film on some hydrocarbon liquids.

Film-forming fluoroprotein (FFFP) foam additives

These will generally be film-forming fluoroprotein foam concentrates which are protein foam concentrates with added fluorinated surface active agents. The foams are more fluid than both protein and standard fluoroprotein foams. The foam is resistant to contamination by hydrocarbon liquids. The solution is film forming on some hydrocarbon liquids and is generally used at 3% to 6% concentration.

Fireout

This is an additive of which few details are given in the manufacturers literature, but more information is given in United States Patent 4,398,605 dated August 16th 1983.

The abstract from this patent states; "The firefighting composition is formed from a concentrate comprising of one or more non-ionic surfactants having a combined cloud point of 68°F - 212°F and sufficient water to form a concentrate solution of not greater than 30% by weight of the surfactant".

Fireout is claimed by the manufacturers to have a water cooling efficiency of up to 40 times that of water.

Fluoroprotein (FP) foam additives

These are protein foam additives with added fluorinated surface active agents. The foam is generally more fluid than protein foam, gives faster control and extinction of the fire, and has a greater ability to reseal if the foam blanket is disturbed. The foam is more resistant than protein to contamination by hydrocarbon liquids. Generally used at 3% or 6% concentration.

Foam

The result of mixing foam additives, water and air to produce bubbles.

Foam additive

Foam additives are liquids, usually aqueous solutions, which are mixed with water to produce the foam solution used to make foam.

Foam solution

A solution of foam additive in water at the appropriate concentration.

Halofoam

Halofoam is an additive that combines AFFF with halon compounds. In a solution of Halofoam, emulsified halons are released by the heat of the fire and as they expand, they foam the AFFF solution. Halofoam is applied non-aspirated and claimed to produce an aspirated finished foam. The manufacturers state that "there is virtually no air trapped within the foam cells which could feed re-ignition or even explosion".

Halofoam is currently being marketed as Pyrofoam.

Shear stress

The measurement of the stiffness of a foam sample when measured with a foam viscometer. Units of measurement are newtons per square metre (N/M^2).

Surface active agents

Foam is stabilised by the addition of surface active agents (or surfactants) which promote air/water stability by reducing the liquids surface tension. Most surface active agents are organic in nature and common examples are soaps and detergents.

Wetting agent

A wetting agent is a chemical compound which, when added to water in correct proportions, materially reduces its surface tension, increases its penetrating and spreading abilities and may also provide foaming characteristics.

APPENDIX B : FIRTO REPORT CONTAINING THE RESULTS OF THE FIRST SERIES OF SMALL SCALE CLASS A FIRE TESTS - JANUARY 1986

February 1986

Fire extinguishing tests

Home Office Fire Experimental Unit

FIRTO

Technical Evaluation

Report for Home Office, Scientific Research and Development Branch, Fire Experimental Unit, c/o Fire Service College, Moreton-in-Marsh, Gloucestershire, GL56 ORH.

Fire extinguishing tests using water with and without various water additives or foam concentrates.

FIRE INSURERS' RESEARCH AND TESTING ORGANISATION
Melrose Avenue, Borehamwood, Hertfordshire, WD6 2BJ

1 INTRODUCTION

This report describes a series of fire extinguishing tests conducted jointly with the Home Office Fire Experimental Unit (H.O.F.E.U.).

The tests involved the use of water with and without various water additives or foam concentrates as extinguishing agents and were preliminary to a more comprehensive H.O.F.E.U. project investigating the properties and use of water additives and foam concentrates for Fire Brigade purposes.

Participation in this phase of the project was requested by the H.O.F.E.U., order numbers SRDB M454 and SRDP M455, dated 25 November 1985.

2 EQUIPMENT AND EXTINGUISHING AGENTS SUPPLIED

2.1 Equipment

Extinguishing agent was applied to the test fire by means of a geared pump feeding a 36.6m length of 19.05mm bore hose fitted with either an aspirated or non-aspirated nozzle.

The pump was arranged to give a selectable, variable flow at a constant pressure. The pressures measured at the delivery end of the hose were:

Aspirated nozzle at 9L/min	- 2.7bar
at 11L/min	- 4.0bar
Non-aspirated nozzle (spray) at 11L/min	- 4.0bar
Non-aspirated nozzle (jet) at 9L/min	- 2.6bar
at 11L/min	- 4.0bar

The aspirated nozzle used was from a proprietary portable fire extinguisher (reference Thorn-EMI Protech 9L AFFF).

The non-aspirated nozzle was a standard, adjustable, garden-hose nozzle. For the tests described in this report two settings were selected. One setting (designated Jetspray) gave a hollow-cone spray pattern with a small droplet size. The other (designated Jet) delivered a coarse broken jet.

The delivery end of the hose was equipped with a device to interrupt discharge.

All extinguishing agents were pumped from an open reservoir.

For the 'burn-back' phase of the Class B test fire series a propane gas/air blowtorch was used, arranged to apply the flame to the surface of the foam at a fixed distance in from the edge of the test tray.

2.2 Extinguishing agents

The following extinguishing agents were used:

- Water
- Angus 'Alcoseal' (3%)
- Angus FP70 (3%)
- Macron 'Fire-out' (0.2%)
- 3M AFFF (3%)
- RTG 'Halofoam' (15%)

Figures in parenthesis indicate solution strength in water.

3 TEST PROGRAMME

3.1 General

The series of tests were undertaken in three phases:

Class A test fires
Class B indicative test fires
Class B test fires

Throughout the series of tests all aspects of test fire preparation, fire-fighting and data recording were the responsibility of FIRTO. Staff from the Fire Experimental Unit prepared each extinguishing agent for test, operated the delivery pump, took video recordings of each test and acted as observers.

3.2 Class A test fires

The Class A test fires were generally conducted in accordance with Clause 26 of B.S. 5423 : 1980[1], with the exception that extinguishing efficiency was based upon flame knockdown, rather than upon total extinguishment and subsequent 3 minute dormant period. The objective therefore was not to achieve a test rating but to use the test fire configuration in order to determine comparative extinguishing efficiency between water and the various additives and foam solutions. The extinguishing technique involved a continuous application of agent to achieve knockdown and, if necessary, additional cooling to prevent instant re-ignition.

3.3 Class B indicative test fires

The Class B indicative test fires were generally conducted in accordance with Clause 27 of B.S. 5423 : 1980[1] using a size 34B test tray. The object being to determine whether certain additives, of which little was known, were suitable for testing on larger-size test fires. Again water was used for datum purposes. Application of the extinguishing agent was on a continuous basis.

3.4 Class B test fires

The Class B test fires were also conducted generally in accordance with Clause 27 of B.S. 5423 : 1980[1] with the exception that following complete extinguishment a burn-back test was conducted. In general, extinguishing agent was applied to the fire continuously until effective knockdown was achieved and then on at a reduced rate for spotting purposes. This latter phase was either continuous or intermittent at the discretion of the fire-fighter.

The burn-back test involved applying a flame to the surface of the foam blanket, using the apparatus described in Section 2 until the fuel re-ignited and the fire became sustained, and then timing the period to 100% re-involvement.

3.5 Instrumentation

Apart from the instrumentation required to carry out the tests in accordance with the appropriate British Standard test method, the flow of extinguishing agent and radiation from the test fire were also monitored.

For radiation monitoring, two heat flux transducers were used, positioned as shown in Figures 1 and 2. All subsequent chart recordings were used by the Fire Experimental Unit for graphical representation of fire development and do not form part of this report.

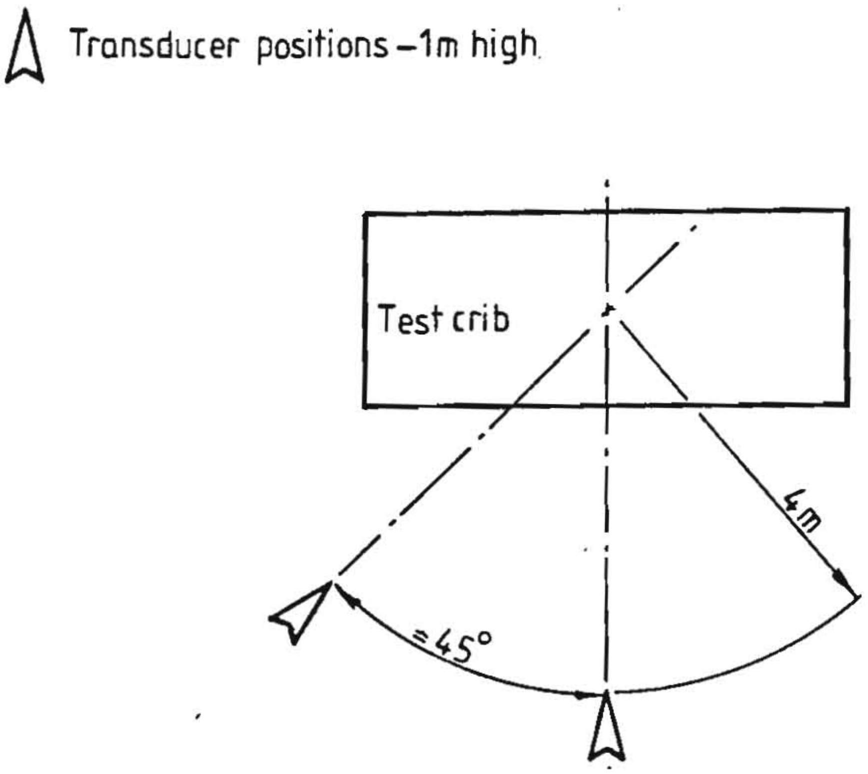


Figure 1 Position of heat flux transducers for Class A fire tests

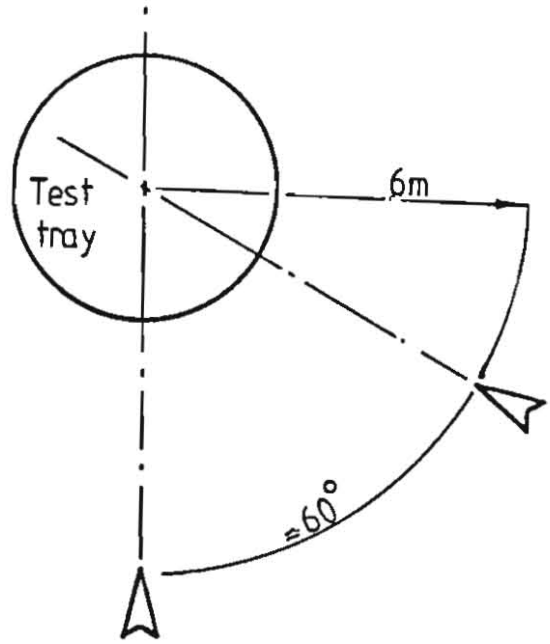


Figure 2 Position of heat flux transducers for Class B fire tests

4 RESULTS

4.1 Class A test fires

The results are summarized in Table 1.

Test Number :	1A
Extinguishing agent :	Water
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	18.0
Ambient temperature (°C) :	2.7
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:52
Quantity of agent used (L) :	7.8
Time to knockdown (min:s) :	0:52

Comments/observations

This test was to some degree exploratory since the datum point for knockdown had not been predetermined.

It was considered that tests 10A and 11A were more representative and that for this test a greater quantity of extinguishing agent may have been used unnecessarily in order to achieve the same end results. It was also noticeable that the heart of the test crib after extinguishing was cooler and exhibited less hot-spots than the corresponding test cribs of tests 10A and 11A.

X X X

Test Number :	2A
Extinguishing agent :	AFFF
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	18.6
Ambient temperature (°C) :	5.9
Fire size :	13A
Rate of application (L/min) :	9.1
Application time (min:s) :	0:48
Quantity of agent used (L) :	7.3
Time to knockdown (min:s) :	0:48

Comments/observations

It was noticeable that the foam reduced the effective penetration of the jet and that the heart of the test crib was hotter than the corresponding crib of test 1A.

Test Number :	3A
Extinguishing agent :	AFFF
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	22.0
Ambient temperature (°C) :	6.1
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:33
Quantity of agent used (L) :	5.0
Time to knockdown (min:s) :	0:33

Comments/observations

Although the heart of the test crib after extinguishing was cooler than that of test 2A (non-aspirated AFFF), it still exhibited more hot-spots than test 1A (Water).

X X X

Test Number :	4A
Extinguishing agent :	FP70
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	18.0
Ambient temperature (°C) :	6.0
Fire size :	13A
Rate of application (L/min) :	9.2
Application time (min:s) :	0:35
Quantity of agent used (L) :	5.4
Time to knockdown (min:s) :	0:35

Comments/observations

The incidence of hot-spots at the heart of the test crib after extinguishing was similar to test 3A (aspirated AFFF).

X X X

Test Number :	5A
Extinguishing agent :	FP70
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	22.5
Ambient temperature (°C) :	6.7
Fire size :	13A
Rate of application (L/min) :	8.9
Application time (min:s) :	0:41
Quantity of agent used (L) :	6.1
Time to knockdown (min:s) :	0:41

Comments/observations

The incidence of hot-spots at the heart of the test crib after extinguishing was similar to test 2A (non-aspirated AFFF).

Test Number :	6A
Extinguishing agent :	Halofoam
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	18.9
Ambient temperature (°C) :	6.5
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:25
Quantity of agent used (L) :	3.8
Time to knockdown (min:s) :	0:25

Comments/observations

The point of knockdown was difficult to determine as the centre of the test crib was obscured by the foaming action of the extinguishing agent.

Because no allowance was made for the on-going reaction of Halofoam, extinguishing agent may have been applied to excess.

At the conclusion of the test the crib was totally extinguished with no hot-spots in evidence.

X X X

Test Number :	7A
Extinguishing agent :	Fire-out
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	22.6
Ambient temperature (°C) :	5.4
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:46
Quantity of agent used (L) :	6.9
Time to knockdown (min:s) :	0:46

Comments/observations

No significant differences when compared with the performance of water.

X X X

Test Number :	8A
Extinguishing agent :	Alcoseal
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	21.0
Ambient temperature (°C) :	2.9
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:40
Quantity of agent used (L) :	6.0
Time to knockdown (min:s) :	0:40

Comments/observations

Penetration of foam and subsequent crib hot-spots were similar to tests 3A (aspirated AFFF) and test 4A (aspirated FP70).

Test Number :	9A
Extinguishing agent :	Alcoseal
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	22.2
Ambient temperature (°C) :	2.7
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:42
Quantity of agent used (L) :	6.3
Time to knockdown (min:s) :	0:42

Comments/observations

No significant differences when compared with aspirated Alcoseal.

X X X

Test Number :	10A
Extinguishing agent :	Water
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	23.4
Ambient temperature (°C) :	2.7
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:36
Quantity of agent used (L) :	5.4
Time to knockdown (min:s) :	0:36

Comments/observations

Knockdown datum re-established, less extinguishing agent used.

X X X

Test Number :	11A
Extinguishing agent :	Water
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	23.3
Ambient temperature (°C) :	2.7
Fire size :	13A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:36
Quantity of agent used (L) :	5.4
Time to knockdown (min:s) :	0:36

Comments/observations

Confirmation of test 10A result.

Test Number :	12A
Extinguishing agent :	Water
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	24.0
Ambient temperature (°C) :	4.0
Fire size :	27A
Rate of application (L/min) :	9.0
Application time (min:s) :	2:05
Quantity of agent used (L) :	18.8
Time to knockdown (min:s) :	2:05

Comments/observations

The doubling of the fire load did not yield a corresponding linear extinguishing efficiency owing to the increase in length of the crib which resulted in reduced penetration to the heart of the crib.

A secondary objective of this test and the following two tests was to compare the resistance to re-ignition and subsequent spread of flame.

Re-ignition occurred at one point, 50s after knockout followed by re-ignition at other points and gradual spread of flame.

X X X

Test Number :	13A
Extinguishing agent :	Halofoam
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	17.6
Ambient temperature (°C) :	4.3
Fire size :	27A
Rate of application (L/min) :	9.0
Application time (min:s) :	0:56 + 0:20
Quantity of agent used (L) :	8.4 + 3.0
Time to knockdown (min:s) :	0:56 + 0:20

Comments/observations

As in test 6A vision of the crib heart was obscured by the foaming action of the agent, consequently knockdown was not completely successful at the first attempt and re-ignition occurred practically simultaneously with cessation of agent application.

Further extinguishing agent was therefore applied 15s later in order to achieve knockdown. Subsequent re-ignition occurred at a single point at the heart of the test crib 35s later with a gradual spread of flame at a rate slower than that of the previous test for water.

Test Number : 14A
Extinguishing agent : AFFF
Nozzle type : Aspirated
Extinguishing agent temperature (°C) : 22.2
Ambient temperature (°C) : 5.1
Fire size : 27A
Rate of application (L/min) : 9.0
Application time (min:s) : 1:09
Quantity of agent used (L) : 10.4
Time to knockdown (min:s) : 1:09

Comments/observations

Re-ignition of the test crib occurred at a number of different points, 15s after extinguishing agent had ceased to be applied.

The subsequent involvement of flame was more intense than for the previous two tests for a similar time period, indicating a lower resistance to burnback than that of water and Halofoam.

Table 1 Summary of results of Class A test fires

Fire size	Agent	Nozzle	Application time/ time to knockdown min:s	Agent used L	Test number
13A	Water	Jet	0:52 0:36 0:36	7.8 5.4 5.4	1A 10A 11A
	AFFF	Jet Aspirated	0:48 0:33	7.3 5.0	2A 3A
	FP70	Jet Aspirated	0:41 0:35	6.1 5.4	5A 4A
	Halofoam	Jet	0:25	3.8	6A
	Fire-out	Jet	0:46	6.9	7A
	Alcoseal	Jet Aspirated	0:42 0:40	6.3 6.0	9A 8A
27A	Water	Jet	2:05	18.8	12A
	Halofoam	Jet	0:56 + 0:20	8.4 + 3.0	13A
	AFFF	Aspirated	1:09	10.4	14A

4.2 Class B indicative test fires

The results are summarized in Table 2.

Test Number :		1B
Extinguishing agent :		Water
Nozzle type :		Jetspray
Extinguishing agent temperature (°C) :		25.0
Ambient temperature (°C) :		6.5
Fire size :		34B
Rate of application	a) continuous (L/min) :	11.0
	b) spotting (L/min) :	-
Application time - continuous (min:s) :		1:00
Quantity of agent used (L) :		11.0
Time to 90% extinction (min:s) :		-
Time to 100% extinction (min:s) :		-

Comments/observations

Test fire not extinguished, extinguishing agent had little effect, therefore the test was terminated.

X X X

Test Number :		2B
Extinguishing agent :		Fire-out
Nozzle type :		Jetspray
Extinguishing agent temperature (°C) :		25.0
Ambient temperature (°C) :		6.7
Fire size :		34B
Rate of application	a) continuous (L/min) :	10.8
	b) spotting (L/min) :	-
Application time - continuous (min:s) :		1:00
Quantity of agent used (L) :		10.8
Time to 90% extinction (min:s) :		-
Time to 100% extinction (min:s) :		-

Comments/observations

Test fire not extinguished, extinguishing agent had little effect, therefore the test was terminated.

No significant difference when compared with the performance of water.

Test Number :	3B
Extinguishing agent :	Halofoam
Nozzle type :	Jetspray
Extinguishing agent temperature (°C) :	25.0
Ambient temperature (°C) :	7.2
Fire size :	34B
Rate of application a) continuous (L/min) :	11.1
b) spotting (L/min) :	-
Application time - continuous (min:s) :	0:43
Quantity of agent used (L) :	8.0
Time to 90% extinction (min:s) :	0:38
Time to 100% extinction (min:s) :	0:43

Comments/observations

Owing to the spray pattern of the jet, a quantity of agent fell short of the test tray during initial application. As a result it was considered that extinguishing time and quantity of agent used could have been reduced.

It was also considered that the fine spray generated by the nozzle setting was detrimental to extinguishing efficiency and that a coarser jet would have been more efficient.

4.3 Class B test fires

The results are summarized in Table 2.

Test Number :	4B
Extinguishing agent :	FP70
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	23.5
Ambient temperature (°C) :	7.8
Fire size :	144B
Rate of application a) continuous (L/min) :	10.7
b) spotting (L/min) :	7.8
Application time - continuous (min:s) :	1:40
Quantity of agent used (L) :	43.8
Time to 90% extinction (min:s) :	1:00
Time to 100% extinction (min:s) :	--

Comments/observations

Test fire not extinguished. Subsequent to initial knockdown the impact force of the jet destroyed the integrity of the foam blanket lying on the surface of the fuel. Little recovery was apparent and the fire gradually re-developed.

It was considered that improved performance could be obtained with a more efficient application technique.

Test Number :	5B
Extinguishing agent :	FP70
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	24.2
Ambient temperature (°C) :	7.3
Fire size :	144B
Rate of application a) continuous (L/min) :	11.2
b) spotting (L/min) :	4.7
Application time - continuous (min:s) :	1:34
Quantity of agent used (L) :	23.0
Time to 90% extinction (min:s) :	1:05
Time to 100% extinction (min:s) :	9:10

Comments/observations

Generally similar to previous test (4B) but revised technique and reduced flow during the spotting phase permitted extinguishing albeit protracted.

Burn-back characteristics:

Time to application of flame (min:s) :	3:40
Application time of flame (min:s) :	2:40
Time to 25% burn-back (min:s) :	1:25
Time to 50% burn-back (min:s) :	1:40
Time to 100% burn-back (min:s) :	2:10

X X X

Test Number :	6B
Extinguishing agent :	Alcoseal
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	25.5
Ambient temperature (°C) :	4.6
Fire size :	144B
Rate of application a) continuous (L/min) :	11.4
b) spotting (L/min) :	6.0 - continuous
Application time - continuous (min:s) :	1:25
Quantity of agent used (L) :	20.6
Time to 90% extinction (min:s) :	1:10
Time to 100% extinction (min:s) :	2:10

Comments/observations

Better flow characteristics resulted in more efficient extinguishing than that of FP70 (test 5B).

Burn-back characteristics:

Time to application of flame (min:s) :	4:43
Application time of flame (min:s) :	2:22
Time to 25% burn-back (min:s) :	0:50
Time to 50% burn-back (min:s) :	1:15
Time to 100% burn-back (min:s) :	1:25

Test Number :	7B
Extinguishing agent :	Alcoseal
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	21.0
Ambient temperature (°C) :	5.5
Fire size :	144B
Rate of application a) continuous (L/min) :	11.3
b) spotting (L/min) :	-
Application time - continuous (min:s) :	1:14
Quantity of agent used (L) :	28.0
Time to 90% extinction (min:s) :	1:10
Time to 100% extinction (min:s) :	2:55

Comments/observations

Repeat of test 6B owing to malfunction of monitoring instrumentation.

Extinguishing characteristics similar to previous test but restriction in hose during the spotting phase caused protracted extinguishing time.

Burn-back characteristics:

Time to application of flame (min:s) :	2:00
Application time of flame (min:s) :	2:42
Time to 25% burn-back (min:s) :	0:40
Time to 50% burn-back (min:s) :	1:10
Time to 100% burn-back (min:s) :	1:30

X X X

Test Number :	8B
Extinguishing agent :	Alcoseal
Nozzle type :	Jetspray
Extinguishing agent temperature (°C) :	24.0
Ambient temperature (°C) :	5.8
Fire size :	144B
Rate of application a) continuous (L/min) :	11.1
b) spotting (L/min) :	-
Application time - continuous (min:s) :	3:35
Quantity of agent used (L) :	39.8
Time to 90% extinction (min:s) :	-
Time to 100% extinction (min:s) :	-

Comments/observations

Test fire not extinguished.

A thin foam film formed on the surface of the fuel during initial application. This film proved to be inadequate and was subsequently broken down allowing the fire to re-establish.

It was considered that the fine spray generated by the nozzle again contributed to inefficient extinguishing.

Test Number :	9B
Extinguishing agent :	AFFF
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	24.0
Ambient temperature (°C) :	6.6
Fire size :	144B
Rate of application a) continuous (L/min) :	11.3
b) spotting (L/min) :	6.3 - continuous
Application time - continuous (min:s) :	0:55
Quantity of agent used (L) :	11.8
Time to 90% extinction (min:s) :	0:40
Time to 100% extinction (min:s) :	1:09

Comments/observations

Good knockdown and flow characteristics resulted in highly efficient extinguishing.

Burn-back characteristics:

Time to application of flame (min:s) :	2:00
Application time of flame (min:s) :	2:55
Time to 25% burn-back (min:s) :	1:35
Time to 50% burn-back (min:s) :	2:25
Time to 100% burn-back (min:s) :	2:44

X X X

Test Number :	10B
Extinguishing agent :	AFFF
Nozzle type :	Jetspray
Extinguishing agent temperature (°C) :	25.0
Ambient temperature (°C) :	7.0
Fire size :	144B
Rate of application a) continuous (L/min) :	11.3
b) spotting (L/min) :	-
Application time - continuous (min:s) :	2:55
Quantity of agent used (L) :	33.0
Time to 90% extinction (min:s) :	-
Time to 100% extinction (min:s) :	-

Comments/observations

Test fire not extinguished.

Apart from the formation of a fine film on the surface of the fuel the extinguishing agent had little effect.

Again the fine spray generated by the nozzle was considered to be a major contributory factor.

Test Number :	11B
Extinguishing agent :	Halofoam
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	17.4
Ambient temperature (°C) :	7.2
Fire size :	144B
Rate of application a) continuous (L/min) :	11.3
b) spotting (L/min) :	-
Application time - continuous (min:s) :	1:14
Quantity of agent used (L) :	13.9
Time to 90% extinction (min:s) :	0:55
Time to 100% extinction (min:s) :	1:14

Comments/observations

The action of the foam was such that no spotting was required.

Burn-back characteristics:

Time to application of flame (min:s) :	2:00
Application time of flame (min:s) :	4:03
Time to 25% burn-back (min:s) :	2:30
Time to 50% burn-back (min:s) :	3:00
Time to 100% burn-back (min:s) :	3:10

During burn-back the foam continued to react, extinguishing isolated areas of flame and resisting its spread.

X X X

Test Number :	12B
Extinguishing agent :	AFFF
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	20.4
Ambient temperature (°C) :	5.6
Fire size :	144B
Rate of application a) continuous (L/min) :	11.3
b) spotting (L/min) :	5.8 - continuous
Application time - continuous (min:s) :	2:35
Quantity of agent used (L) :	37.1
Time to 90% extinction (min:s) :	2:30
Time to 100% extinction (min:s) :	3:57

Comments/observations

Repeat of test 10B but with the alternative nozzle setting giving a broken jet instead of a fine spray.

Burn-back characteristics:

Time to application of flame (min:s) :	2:00
Application time of flame (min:s) :	1:30
Time to 25% burn-back (min:s) :	0:35
Time to 50% burn-back (min:s) :	0:50
Time to 100% burn-back (min:s) :	1:20

Test Number :	13B
Extinguishing agent :	Alcoseal
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	21.8
Ambient temperature (°C) :	6.3
Fire size :	144B
Rate of application a) continuous (L/min) :	11.3
b) spotting (L/min) :	-
Application time - continuous (min:s) :	3:15
Quantity of agent used (L) :	36.7
Time to 90% extinction (min:s) :	-
Time to 100% extinction (min:s) :	-

Comments/observations

Test fire not extinguished.

Repeat of test 8B but with the alternative nozzle setting giving a broken jet instead of a fine spray.

No significant difference in result between this and the previous corresponding test.

X X X

Test Number :	14B
Extinguishing agent :	Halofoam
Nozzle type :	Jet
Extinguishing agent temperature (°C) :	24.4
Ambient temperature (°C) :	6.1
Fire size :	183B
Rate of application a) continuous (L/min) :	11.8
b) spotting (L/min) :	-
Application time - continuous (min:s) :	1:25
Quantity of agent used (L) :	24.0
Time to 90% extinction (min:s) :	1:20
Time to 100% extinction (min:s) :	2:00

Comments/observations

The increased surface area of test fire did not affect extinguishing efficiency.

Burn-back characteristics:

Time to application of flame (min:s) :	2:00
Application time of flame (min:s) :	2:00
Time to 25% burn-back (min:s) :	4:30
Time to 50% burn-back (min:s) :	5:05
Time to 100% burn-back (min:s) :	5:20

A secondary objective of this test and the following test was to compare burn-back resistance and subsequent fire re-involvement under the same conditions.

Test Number :	15B
Extinguishing agent :	AFFF
Nozzle type :	Aspirated
Extinguishing agent temperature (°C) :	21.0
Ambient temperature (°C) :	6.6
Fire size :	183B
Rate of application a) continuous (L/min) :	11.8
b) spotting (L/min) :	-
Application time - continuous (min:s) :	1:04
Quantity of agent used (L) :	18.7
Time to 90% extinction (min:s) :	0:55
Time to 100% extinction (min:s) :	1:35

Comments/observations

The increased surface area of test fire did not affect extinguishing efficiency.

Burn-back characteristics:

Time to application of flame (min:s) :	2:00
Application time of flame (min:s) :	2:00
Time to 25% burn-back (min:s) :	3:30
Time to 50% burn-back (min:s) :	3:50
Time to 100% burn-back (min:s) :	4:00

Table 2 Summary of results of Class B test fires

Fire size	Agent	Nozzle	Application time continuous min:s	Time to extinction 90% min:s	Time to extinction 100% min:s	Agent used L	Burn-back flame application time min:s	Burn-back time 25%	Burn-back time 50%	Burn-back time 100%	Test number
34B	Water	Jetspray	1:00	-	-	11.0	-	-	-	-	1B
	Fireout	Jetspray	1:00	-	-	10.8	-	-	-	-	2B
	Halofoam	Jetspray	0:43	0:38	0:43	8.0	-	-	-	-	3B
144B	FP70	Aspirated	1:40	1:00	-	43.8	-	-	-	-	4B
		Aspirated	1:34	1:05	9:10	23.0	2:40	1:25	1:40	2:10	5B
	Alcoseal	Aspirated	1:25	1:10	2:10	20.6	2:22	0:50	1:15	1:25	6B
		Aspirated	1:14	1:10	2:55	28.0	2:42	0:40	1:10	1:30	7B
		Jetspray	3:35	-	-	39.8	-	-	-	-	8B
		Jet	3:15	-	-	36.7	-	-	-	-	13B
	AFFF	Aspirated	0:55	0:40	1:09	11.8	2:55	1:35	2:25	2:44	9B
		Jetspray	2:55	-	-	33.0	-	-	-	-	10B
		Jet	2:35	2:30	3:57	37.1	1:30	0:35	0:50	1:20	12B
	Halofoam	Jet	1:14	0:55	1:14	13.9	4:03	2:30	3:00	3:10	11B
183B	Halofoam	Jet	1:25	1:20	2:00	24.0	2:00	4:30	5:05	5:20	14B
	AFFF	Aspirated	1:04	0:55	1:35	18.7	2:00	3:30	3:50	4:00	15B

5 CONCLUSION

No definitive conclusions can be drawn from the tests described in this report since the test programme was compiled as a fact-finding exercise. The data derived being a preliminary contribution to an on-going more comprehensive Fire Experimental Unit project.

It should be noted that the aspirated nozzle used was designed for optimum performance with AFFF in a portable fire extinguisher. When used as described in this report, with both AFFF and other foam solutions, it was possible that optimum performance may not have been attained.

Because of the manner in which Halofoam performed, it may be advantageous to conduct further tests with weaker solutions as it is considered that comparable performance could be achieved more economically.

It is also conceivable that enhanced performances may also be obtained using the various foam concentrates at different solution strengths.

Tests by:
A.R. Tompkins
G. Selfe
R. Bushell
F.E.U. Staff

Report by:

A.R. Tompkins
Head of Extinguishers and
Systems Section

Approved by:

S.T. Evans

S.T. Evans
Division Head - Appliances

R.W. Pickard

R.W. Pickard
Executive Director

ART/ASF
18 February 1986

APPENDIX C : FIRTO REPORT CONTAINING THE RESULTS OF THE SECOND SERIES OF SMALL SCALE CLASS A FIRE TESTS - OCTOBER 1987

THE LOSS PREVENTION COUNCIL

FIRTO Technical Evaluation

TE 30260

Class A fire extinguishing tests using water with and without various water additives or foam concentrates

Home Office, Scientific Research and Development Branch, Fire Experimental Unit, c/o Fire Service College, Moreton-in-Marsh, Gloucestershire, GL56 0RH

November 1987

The Technical Centre, Melrose Avenue, Borehamwood, Hertfordshire, WD6 2BJ
Telephone: 01-207 2345 Telex: 291835 Fax: 01-207 6305

1 INTRODUCTION

1.1 Object

The object of this evaluation was to provide the Home Office Fire Experimental Unit (H.O.F.E.U.) with data on the comparative efficiency of various extinguishing agents comprising water with and without various additives or foam concentrates when applied to a 27A test fire.

1.2 Origin of request

Participation in the tests was requested by the H.O.F.E.U., order number SRDB M1081, dated 27 July 1987.

1.3 Background

The H.O.F.E.U. is investigating the use of water additives and foam concentrates for fire brigade use. The tests in this evaluation were conducted jointly with the H.O.F.E.U. and are complementary to a previous evaluation carried out in conjunction with the H.O.F.E.U. by the Fire Insurers' Research and Testing Organisation, details of which are given in report FIRTO TE 2226[1].

2 EQUIPMENT AND EXTINGUISHING AGENTS SUPPLIED

2.1 Equipment

Extinguishing agent was applied to the test fire by means of a geared pump feeding a 36.6m length of 19.05mm-bore hose fitted with either an aspirated or non-aspirated nozzle.

The pump was arranged to give a ~~selectable flow at~~ a constant ~~pressure.~~ flow. The pressures at the delivery end of the hose for a flow of 9L/min were:

Aspirated nozzle - 2.7bar.
Non-aspirated nozzle - 2.6bar.

The aspirated nozzle used was from a proprietary portable fire extinguisher (reference Thorn - EMI Protech 9L AFFF).

The non-aspirated nozzle was a standard, adjustable, garden hose nozzle giving a coarse broken jet.

There was no means of interrupting the discharge from either device.

All extinguishing agents were pumped from an open reservoir.

2.2 Extinguishing agents

The following extinguishing agents were used:

- Water
- Angus 'Alcoseal' (3%)
- Angus 'Expandol' (3%)
- Angus 'Fluoropolydol' (6%)
- Angus FP70 (3%)
- Angus 'Petroseal' (3%)
- Galena 'Wetwater' (1%) - Type 2 with foam trace
- Macron 'Fire-out' (0.2%)
- 3M AFFF (3%)
- 3M AFFF-AR (3%)
- RTG 'Halofoam' (15%)

Figures in parenthesis indicate solution strength in water.

3 TEST PROGRAMME

3.1 General

Throughout the series of tests all aspects of test fire preparation, fire fighting and data-recording were the responsibility of The Loss Prevention Council. Staff from the Home Office Fire Experimental Unit prepared each extinguishing agent for test, operated the delivery pump, took video recordings of each test, measured shear strength, expansion ratio and drainage times of each foam, and acted as observers.

3.2 Test fires

Twenty size 27A test fires to B.S. 5423: 1980[2] were carried out.

Each test was generally conducted in accordance with Clause 26 of B.S. 5423: 1980[2], with the exception that extinguishing efficiency was based upon flame knockdown and control, rather than upon total extinguishment and subsequent 3min dormant period. At the conclusion of application of extinguishing agent the test fire was allowed to re-ignite and burn back to full development before being finally extinguished with the agent. The objective therefore was not to achieve a test fire rating but to use the test to compare the extinguishing efficiency of water and the various additives and foam solutions together with an indication of their effect on burnback resistance.

For each test the rate of application of extinguishing agent was nominally 9L/min unless otherwise specified.

3.3 Extinguishing technique

3.3.1 Test 1

For this test the extinguishing technique involved continuous application of agent to only one of the long sides of the test fire. As total flame knockdown could not be achieved by this method it was abandoned for the subsequent tests.

3.3.2 Tests 2 to 20

With the discharge nozzle approximately 1m from the test fire, application of agent commenced from the left-hand end with a single rapid pass over the vertical face of one long side in order to quell flame intensity. During this pass the nozzle was moved rapidly up and down to wet as much of the fire as possible.

A return pass was then made maintaining the nozzle at a distance of 1m and with the discharge horizontal to the ground and at an angle relative to the vertical side sufficient to given optimum penetration without undue loss of agent through the fire. During this pass agent was applied to each "pigeon hole" formed by the layers of sticks. Any re-ignition of the fire on that face was dealt with during this process.

When immediate re-ignition of that face was considered unlikely (reference time a), a single rapid pass as before was made taking in first one end, then the opposite long side, and finally the other end. This was followed by a return pass applying agent to each "pigeon hole" as before until knockdown was achieved (reference time b).

A further application to prevent immediate re-ignition from major hot spots concluded the exercise (reference time c).

3.4 Instrumentation

Apart from monitoring the instrumentation required to carry out the tests in accordance with the British Standard test method, the flow of extinguishing agent and radiation from the test fire were also monitored. For radiation measurement, two heat flux transducers were used, positioned as shown in Figure 1. Radiation measurements, observations of burnback resistance and measurements of foam characteristics were undertaken by the Fire Experimental Unit staff and do not form part of this report.

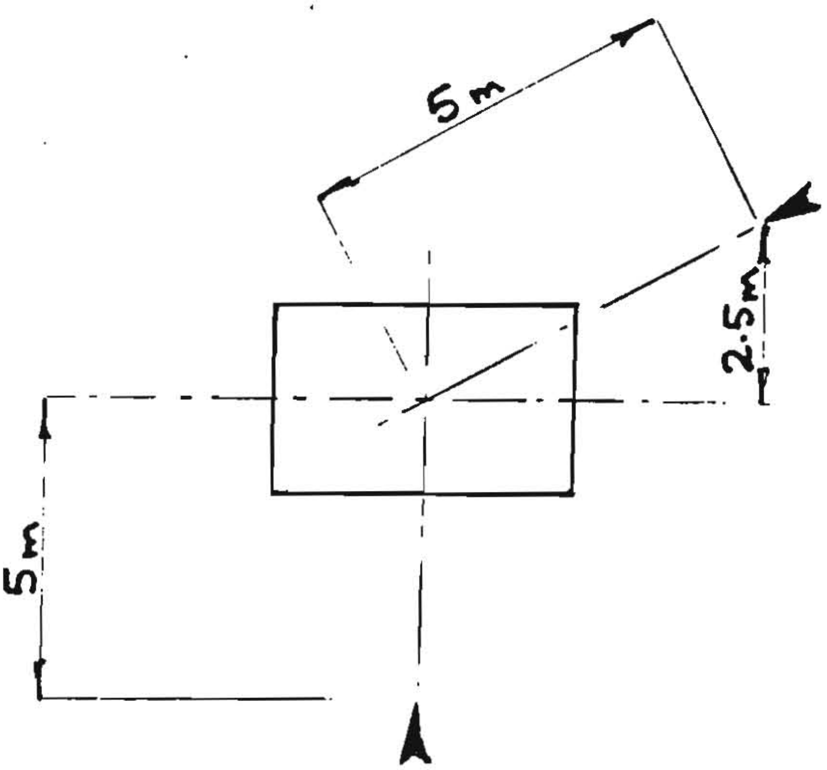


Figure 1 Position of heat flux transducers

4 RESULTS

Table 1 Summary of data

Test No.	Extinguishing agent	Nozzle type	Temperature Ambient °C	Temperature Agent °C	Time to knockdown and control Ref. a min:s	Ref b min:s	Ref c min:s
1*	AFFF	Non-aspirated	13	16	-	-	-
2	AFFF	Non-aspirated	15	16	1:05	1:25	2:03
3	Water	Non-aspirated	14	21	0:55	2:00	2:20
4	Water	Non-aspirated	14	18	1:00	1:45	2:10
5	AFFF	Aspirated	17	17	0:50	1:05	1:27
6	Alcoseal	Aspirated	11	19	1:05	1:27	1:45
7	Alcoseal	Non-aspirated	12	19	0:57	1:25	1:40
8	Fire-out	Non-aspirated	15	17	0:58	1:47	1:55
9	AFFF-AR	Non-aspirated	13	19	1:00	1:42	1:55
10	AFFF-AR	Aspirated	14	18	0:48	1:05	1:25
11	FP-70	Aspirated	14	20	0:45	1:10	1:40
12	Petroseal	Aspirated	12	18	0:45	0:58	1:25
13	Petroseal	Non-aspirated	13	19	0:55	1:45	1:57
14	Wetwater	Non-aspirated	14	19	0:55	1:35	2:03
15	Expandol	Non-aspirated	13	19	0:47	1:25	1:40
16	Expandol	Aspirated	13	19	0:30	1:05	1:15
17	Halofoam	Non-aspirated	15	19	0:30	1:02	1:10
18	Fluoropolydol	Aspirated	13	19	0:50	1:15	1:42
19+	FP-70	Non-aspirated	13	19	1:00	1:45	2:08
20	Water	Non-aspirated	14	19	0:58	1:37	1:56

* Application to only one side of fire. Knockdown and control not achieved, test terminated at 6min 30s.

\+ Rate of agent application 8.9L/min.

5 EVALUATION COMMENTS

It should be noted that the control time for Halofoam could be deceptive as it was difficult for the fire-fighter to determine the condition of the test fire centre owing to obscuration by the foaming action of the extinguishing agent.

In addition when Halofoam was applied to the test fire following burnback considerable time elapsed before the agent had any effect on the fire, unlike its performance in its initial application.

6 REFERENCES

1 Fire extinguishing tests using water with and without various water additives or foam concentrates. FIRTO TE 2226. Fire Insurers' Research and Testing Organisation, Borehamwood, 1986.

2 Specification for portable fire extinguishers. British Standard 5423: 1980. British Standards Institution, London, 1980. Including amendments up to April 1984.

Report by:

A.R. Tompkins
Head of Extinguishing
Systems Section

Approved by:

S.T. Evans
Division Head - Appliances

ART/VW
26 November 1987

APPENDIX D - DETAILED NOTES ON LARGE SCALE CLASS A FIRE TESTS

Test Number : A1 **Date** : 5/7/88 **Additive** : WATER, NON-ASPIRATED **Conc.** : -

Branch : Elkhart **Flowrate** : 99.5 lpm

Branch Pressure : 30.5 bar

Air temperature : 14°C **Fuel temperature** : 14°C **Solution temperature** : 23°C
Foam temperature : -

Relative Humidity : 83 % **Average wood moisture content** : 15 %

Expansion ratio : - **Drainage time** : - min - sec **Shear Stress** : -

GENERAL NOTES

1. Elkhart Gun used (best performer in John Rimens High Pressure Fog / Low Pressure Spray work). Gun positioned horizontally and set, using angle measuring rig, to give a spray angle of 13° from the horizontal to the upper edge of the cone. The angle from the horizontal to the lower edge of the spray cone was estimated to be 11°. The gun was set in the first spray notch and the 10GPM notch. This spray setting was not checked within the room.

2. With the above setting it was noticed that during the test some spray emerged from the left and right hand side windows.

3. Extinction of the fire commenced from the right hand crib.

PREBURN

Time from ignition (min : sec)	Observations
0 : 0	Ignition.
2 : 24	Priming fuel burnt out.
3 : 23	Front faces of all cribs alight.
7 : 56	Rotating rig entered room.

FIREFIGHTING

Time from ignition (min : sec)	Observations
8 : 00	Extinction commenced from the corner of the right hand crib nearest to the door, with the first sweep towards the centre crib.
8 : 02	All of the right crib appeared to be extinguished.
8 : 04	All of the centre crib appeared to be extinguished. Flames re-appeared at the rear of the right crib.
8 : 06	All of the left crib appeared to be extinguished.

8 : 08	Flames re-appeared at the rear of the left crib.
8 : 11	First "double" sweep of the room completed.
8 : 14	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and steam.
8 : 25	Opposite cribs obscured from the window cameras by smoke and steam.
9 : 58	Rig moved into the centre of the room.
10 : 06	Rig in position in the centre of the room. Smoke and steam production increased, visibility poor.
10 : 29	Flames in the centre crib were visible from the doorway cameras for the first time since 8:13. 65% of the rear of the centre crib well alight (35% gap at the centre of the crib). Flames in the left and right cribs restricted to 25% of the rear of the cribs nearest to the centre crib.
10 : 46	Opposite cribs visible from the window cameras.
10 : 53	Flames in the centre crib reaching the roof of the fire test room. Visibility fair.
11 : 00	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 65% of the rear of the centre crib well alight (35% gap at the centre of the crib). Flames in left and right cribs restricted to 25% of the rear of the cribs nearest to the centre crib.
16 : 00	Firefighting ceased. Flames visible at the rear corners of the side cribs nearest to the centre crib. 65% of the rear of the centre crib remained alight (35% gap at the centre of the crib) and 30% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

NOTE

1. Flames at the rear of the left and right cribs were visible from the doorway cameras throughout the test.

Test Number : A2 **Date** : 8/7/88 **Additive** : WATER, NON-ASPIRATED **Conc.** : -

Branch : Elkhart **Flowrate** : 90 lpm

Branch Pressure : 32.8 bar

Air temperature : 12°C **Fuel temperature** : 13°C **Solution temperature** : 25°C
Foam temperature : -

Relative Humidity : 86 % **Average wood moisture content** : 17%

Expansion ratio : - **Drainage time** : - min - sec **Shear Stress** : -

GENERAL NOTES

1. Pressure flow characteristics of the Elkhart branch were measured prior to Test A2. These showed that the branch did not perform in a consistent manner initially. Eventually the branch appeared to gain some consistency and so it was decided to use it for Test A2.

2. On the day before Test A2 the branch was set up in the Fire Test Room using wood guides in the crib holders to mark out the top and bottom of the cribs. The spray was set to just go over the top guide and just under the bottom guide. Spray set on left hand side crib only. With guides also placed in the other two cribs the branch was rotated while operating at 100LPM to check general pattern around room. Spray found to just miss top guide of centre crib and to be below top guide of right crib. The gun was set in the first spray notch and the 10 GPM notch, the nozzle was pointing some 10° downwards.

3. On the day of the test, the branch was again checked within the room and found to be performing acceptably, Pressure 30.5 bar, flow 100 lpm. Unfortunately, during the test the maximum achievable was only 90 lpm at a pressure of 32.8 bar.

4. The "mushroom" within the branch nozzle was jammed after this test. Freeing the "mushroom" resulted in the appearance of a white solid substance around its' rim.

5. After Test A2 the Elkhart branch was thouroughly flushed through, this resulted in a flow of 100 lpm with a pressure of 25.7 bar. The inconsistency of this branch resulted in the selection of another branch, an Angus Superfog, for the remainder of the non-aspirated trials.

6. Extinction of the fire commenced from the right hand crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 18	Priming fuel burnt out.

4 : 34	Front faces of all cribs alight.
7 : 59	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the corner of the right crib nearest to the door, with the first sweep towards the centre crib.
8 : 01	Rotating rig in position.
8 : 02	All of the right crib appeared to be extinguished.
8 : 03	Flames re-appeared at the rear of the right crib.
8 : 04	All of the centre crib appeared to be extinguished.
8 : 05	All of the left crib appeared to be extinguished.
8 : 08	Flames re-appeared at the rear of the left crib.
8 : 11	First "double" sweep of the room completed.
8 : 14	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and steam.
8 : 20	Opposite cribs obscured from the window cameras by smoke and steam.
9 : 49	Opposite cribs visible from the window cameras.
9 : 59	Rig moved into the centre of the room.
10 : 04	Rig in position in the centre of the room. Smoke and steam production increased, visibility poor.
10 : 08	Opposite cribs again obscured from the window cameras by smoke and steam.
11 : 41	Flames in the centre crib visible from the doorway cameras for first time since 8:04. 50% of the rear of the centre crib alight (50% gap at the centre of the crib). Flames in the left and right cribs restricted to 40% of the rear of the cribs nearest to the centre crib. Visibility poor.
11 : 59	Opposite cribs visible from the window cameras.
12 : 30	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 60% of the rear of the centre crib well alight (15% gap at the centre of the crib). Flames in the left and the right cribs restricted to 50% of the rear of the cribs nearest to the centre crib.
13 : 10	Flames in the centre crib reaching the roof of the fire test room.
16 : 00	Large flames visible at the rear corners of the side cribs nearest to the centre crib. 65% of the rear of the centre crib remained alight (35% gap at the centre of the crib) and 50% of the rear of each of the side cribs remains alight.
20 : 00	Firefighting ceased. Large flames visible at the rear corners of the side cribs nearest to the centre crib. 60% of the rear of the centre crib remained alight (40% gap at the centre of the crib) and 40% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

Test Number : A3 **Date** : 20/7/88 **Additive** : AFFF, ASPIRATED **Conc.** : 3%

Branch : 2 x FRS 50 lpm **Flowrate** : 100 lpm

Branch Pressure : 6.6 bar (each)

Air temperature : 18^oC **Fuel temperature** : 16^oC **Solution temperature** : 21^oC
Foam temperature : 19^oC

Relative Humidity : 75 % **Average wood moisture content** : 17%

Expansion ratio : 7.6 **Drainage time** : 4 min 26 sec **Shear Stress** : 4 N/M

GENERAL NOTES

1. This test employed 2 x FRS 50 lpm branches mounted on to a purpose built rotating rig. This rig enabled the branches to be held in a position which gave a total foam spray angle of 26^o, although each branch gave a total spray angle of 13^o only.

2. The branches were set up in the room as described in the General Notes for Test A2.

3. The initial position (8 to 10 minute position) of the rig in the room was changed from Tests A1, A2 and the high pressure fog low pressure spray work. The rig was allowed to go further into the room to enable the branches to rotate without them fouling the doorway and also to enable the Angus Superfog gun with aspirator to be used if required. This position was adopted as standard for all of the remaining tests.

4. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 23	Priming fuel burnt out.
3 : 26	Front faces of all cribs alight.
7 : 57	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib, with the first sweep towards the left crib. Rig not in position at

	this point.
8 : 02	50% of the centre crib appeared to be extinguished.
8 : 03	Rig in position. Incomplete first sweep to the left crib, only 25% of the left crib extinguished, rig then swept back across the centre crib to the right crib.
8 : 04	All of the centre crib appeared to be extinguished.
8 : 05	All of the right crib appeared to be extinguished except for 75% of the rear top of the crib.
8 : 10	All of the left crib appeared to be extinguished except for 75% of the rear top of the crib.
8 : 12	First "double" sweep of the room completed.
8 : 14	Some flames visible from approximately 1% of the rear right of the centre crib.
8 : 17	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and steam.
9 : 00	Flames in the centre crib were visible from the doorway cameras for first time since 8:08. 5% of the rear right of the centre crib alight. Flames in the left and right cribs were restricted to 50% of the rear of the cribs nearest to the centre crib, these areas were well alight with flames reaching the roof. Visibility good, all cribs clearly visible from the doorway cameras.
9 : 45	Flames in the centre crib reaching the roof of the fire test room.
9 : 59	Rig moved into the centre of the room.
10 : 02	Flaming in the rear left of the centre crib for the first time since 8:08.
10 : 05	Rig in position in the centre of the room. Smoke and steam production increased, visibility fair.
10 : 40	30% of the rear of the centre crib alight (70% gap at the centre of the crib). Flames in the left and right cribs restricted to 30% of the rear of the cribs nearest to the centre crib.
12 : 40	Room almost totally clear of smoke and steam. 40% of the rear of the centre crib well alight (60% gap at the centre of the crib). Flames in the left and right cribs restricted to 30% of the rear of the cribs nearest to the centre crib.
18 : 00	Firefighting ceased. Large flames were visible at the rear corners of the side cribs nearest to the centre crib. 40% of the rear of the centre crib remained alight (60% gap at the centre of the crib) and 25% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the last 4 minutes of the test, this is probably due to fuel starvation.

NOTES

1. Sustained flaming in the corners of the left and right cribs nearest to the centre crib throughout the whole test.
2. Opposite cribs visible from window cameras throughout whole test.

Test Number : A4 **Date** : 23/8/88 **Additive** : WATER, NON-ASPIRATED **Conc.** : -

Branch : Angus Superfog **Flowrate** : 100 lpm

Branch Pressure : 18.1 bar

Air temperature : 16°C **Fuel temperature** : 14°C **Solution temperature** : 22°C
Foam temperature : -°C

Relative Humidity : 74 % **Average wood moisture content** : 16 %

Expansion ratio : - **Drainage time** : - min - sec **Shear Stress** : - N/M

GENERAL NOTES

1. The branch was set up in the room as described in section 2 of the General Notes of Test A3.

2. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 01	Front faces of all cribs alight.
2 : 34	Priming fuel burnt out.
7 : 50	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the left of the centre crib, with the first sweep towards the right crib. The rig was not in position at this point.
8 : 02	95% of the centre crib appeared to be knocked down but glowing embers could be seen through 50% of the crib.
8 : 04	All of the right crib appeared to be extinguished. Rig in position.
8 : 07	Flames re-appeared at the rear of the right crib.
8 : 08	All of the centre crib appeared to be extinguished.
8 : 11	All of the left crib appeared to be extinguished.
8 : 13	First "double" sweep of the room completed.
8 : 15	Flames re-appeared at the rear of the left crib.
8 : 16	Opposite cribs obscured from the window cameras by smoke and steam.
8 : 18	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and

steam.

9 : 19	Flames in the rear right hand corner of the left crib were visible from the doorway cameras for the first time since 8:19.
9 : 23	Flames in the rear left hand corner of the right crib visible from the doorway cameras for the first time since 8:15.
9 : 36	Flames in the centre crib were visible from the doorway cameras for the first time since 8:12.
9 : 37	Opposite cribs visible from the window cameras.
9 : 45	Flames in the centre crib reaching the roof of the fire test room. Visibility fair.
9 : 59	Rig moved into the centre of the room.
10 : 02	Rig in position in the centre of room. Smoke and steam production increased, visibility fair to poor.
11 : 25	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 70% of the rear of the centre crib well alight (30% gap at the centre of the crib). Flames in the left and right cribs restricted to 35% of the rear of the cribs nearest to the centre crib.
17 : 13	Firefighting ceased. Large flames visible at the rear corners of the side cribs nearest to the centre crib. 75% of the rear of the centre crib remained alight (25% gap at the centre of the crib) and 50% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

Test Number : A5 **Date** : 25/8/88 **Additive** : WATER, NON-ASPIRATED **Conc.** : -

Branch : Angus Superfog **Flowrate** : 100 lpm

Branch Pressure : 18.2 bar

Air temperature : 14^{o}C **Fuel temperature** : 14^{o}C **Solution temperature** : 21^{o}C
Foam temperature : -^{o}C

Relative Humidity : 71 % **Average wood moisture content** : 15 %

Expansion ratio : - **Drainage time** : - min - sec **Shear Stress** : - N/M

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that originally set for Test A5 except that the branch was tilted slightly downwards.

2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

3. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 23	Priming fuel burnt out.
3 : 30	Front faces of all cribs alight.
7 : 54	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib, with the first sweep towards the right crib.
8 : 02	75% of the centre crib appeared to be knocked down but glowing embers could be seen through all areas of the crib.
8 : 06	All of the right crib appeared to be extinguished.
8 : 10	All of the centre crib appeared to be extinguished.
8 : 11	Flames re-appeared at the rear of the right crib.
8 : 13	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and steam.
8 : 14	All of the left crib appeared to be extinguished.

8 : 16	First "double" sweep of the room completed.
8 : 18	Opposite cribs obscured from the window cameras by smoke and steam.
8 : 20	Flames re-appeared at the rear of the left crib.
9 : 05	Flames in the rear right hand corner of the left crib were visible from the doorway cameras for the first time since 8:21.
9 : 12	Flames in the rear left hand corner of the right crib were visible from the door cameras for the first time since 8:29.
9 : 21	Opposite cribs visible from the window cameras.
9 : 25	Flames in the centre crib were visible from the doorway cameras for the first time since 8:10. 95% of the rear of the centre crib well alight (5% gap at the centre of the crib). Flames in the left and right cribs restricted to 40% of the rear of the cribs nearest to the centre crib.
9 : 42	Flames in the centre crib reaching the roof of the fire test room. Visibility fair.
9 : 59	Rig moved into the centre of the room.
10 : 03	Rig in position in the centre of the room. Smoke and steam production increased slightly, visibility fair.
11 : 00	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 85% of the rear of the centre crib well alight (15% gap at the centre of the crib). Flames in the left and right cribs restricted to 40% of the rear of the cribs nearest to the centre crib.
17 : 02	Firefighting ceased. Large flames visible at the rear corners of the side cribs nearest to the centre crib. 95% of the rear of the centre crib remained alight (5% gap at the centre of the crib) and 40% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

Test Number : A6 **Date** : 30/8/88 **Additive** : WATER, NON-ASPIRATED **Conc.** : -

Branch : Angus Superfog **Flowrate** : 100 lpm

Branch Pressure : 18.3 bar

Air temperature : 14°C **Fuel temperature** : 13°C **Solution temperature** : 21°C
Foam temperature : -°C

Relative Humidity : 81 % **Average wood moisture content** : 15 %

Expansion ratio : - **Drainage time** : - min - sec **Shear Stress** : - N/M

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that originally set for Test A5
2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.
3. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition (min : sec)	Observations
0 : 0	Ignition.
1 : 33	Front faces of all cribs alight.
2 : 24	Priming fuel burnt out.
7 : 58	Rotating rig entered room.

FIREFIGHTING

Time from ignition (min : sec)	Observations
8 : 00	Extinction commenced from the middle of the centre crib, with the first sweep towards the left crib. The rig was still moving into position at this point.
8 : 01	60% of the centre crib appeared to be knocked down but glowing embers could be seen through all areas of the crib.
8 : 03	All of the left crib appeared to be extinguished.
8 : 05	Rotating rig in position.
8 : 08	All of the centre crib appeared to be extinguished.
8 : 09	Left, right and centre cribs were not visible from the cameras the in doorway due to obscuration caused by smoke and steam. Flames re-appeared at the rear of the left crib.
8 : 10	All of the right crib appeared to be extinguished.
8 : 13	First "double" sweep of the room completed.

8 : 16	Flames re-appeared at the rear of the right crib.
8 : 17	Opposite cribs obscured from the window cameras by smoke and steam.
8 : 55	Flames in the rear right hand corner of the left crib were visible from the door cameras for the first time since 8:22.
9 : 24	Flames in the centre crib were visible from the doorway cameras for the first time since 8:09. 95% of the rear of the centre crib was well alight (5% gap at the centre of the crib). Flames in the left and right cribs were restricted to 40% of the rear of the cribs nearest to the centre crib.
9 : 25	Opposite cribs were visible from the window cameras.
9 : 36	Flames in the rear left hand corner of the right crib were visible from the doorway cameras for the first time since 8:29.
9 : 40	Flames in the centre crib reached the roof of the fire test room. Visibility fair.
10 : 00	Rig moved into the centre of the room.
10 : 04	Rig in position in the centre of the room. Smoke and steam production increased slightly, visibility fair.
11 : 00	Room almost totally clear of smoke and steam. Fire appears to have stabilised
17 : 03	Firefighting ceased. Large flames were visible at the rear corners of the side cribs nearest to the centre crib. 80% of the rear of the centre crib remained alight (20% gap at the centre of the crib) and 40% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

Test Number : A7 **Date** : 1/9/88 **Additive** : AFFF, NON-ASPIRATED **Conc.** : 3%

Branch : Angus Superfog **Flowrate** : 100 lpm

Branch Pressure : 18.3 bar

Air temperature : 15°C **Fuel temperature** : 14°C **Solution temperature** : 21°C
Foam temperature : 14 °C

Relative Humidity : 97 % **Average wood moisture content** : 15 %

Expansion ratio : 2.8 **Drainage time** : - min - sec **Shear Stress** : 1.5 N/M (Mostly Liquid)

GENERAL NOTES

1. Brackets holding the branch onto the metal holding plate had worked themselves loose prior to this test. These brackets were tightened and an extra washer put in to lower the nozzle slightly in order to acheive the same spray position as in the previous tests, this was checked in the room by the method described in the general notes of test A2. The spray pattern of the branch WAS NOT CHANGED.

2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

3. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 25	Priming fuel burnt out.
4 : 59	Front faces of all cribs alight.
7 : 56	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib, with first sweep towards the right crib.
8 : 02	All of the centre crib appeared to be extinguished. (25% appeared to be extinguished without any contact with the firefighting spray).
8 : 04	All of the right crib appeared to be extinguished.
8 : 08	The centre crib was not visible from the cameras in the doorway due to obscuration caused by thick black smoke and steam. The side cribs were not visible except for flaming

	only.
8 : 09	Flames re-appeared at the rear of the right crib.
8 : 10	All of the left crib appeared to be extinguished.
8 : 13	First "double" sweep of the room completed. Opposite cribs obscured from the window cameras by smoke and steam.
8 : 15	Flames re-appeared at the rear of the left crib.
8 : 37	Flames restricted to a small area (3%) of the rear left hand corner of the right crib.
8 : 40	Flames restricted to a small area (5%) of the rear right hand corner of the left crib.
9 : 10	Flames in the rear right hand corner of left crib visible from the doorway cameras for the first time since 8:22.
9 : 57	Flames in the rear left hand corner of the right crib visible from the doorway cameras for the first time since 8:17.
10 : 00	Rig moved into the centre of the room.
10 : 03	Rig in position in the centre of the room. Smoke and steam production increased, visibility poor.
10 : 50	Flames in the centre crib visible from the doorway cameras for the first time since 8:02. 30% of the rear of the centre crib well alight (corners only). Flames in the left and right cribs restricted to a small area of the rear corners nearest to the centre crib.
11 : 04	Improved visibility in the room. Centre crib visible from the from the cameras in the doorway.
11 : 10	Opposite cribs visible from the window cameras. Fire appears to have stabilised.
11 : 40	Room almost totally clear of smoke and steam.
13 : 00	Foam layer visible along the rear wall of the room to a height of 1.5 metres.
17 : 00	Firefighting ceased. Small flames visible at the rear corners of the side cribs nearest to the centre crib. 40% of the rear of the centre crib (corners only) remained alight.

Test Number : A8 **Date :** 8/9/88 **Additive :** FFFP, NON-ASPIRATED **Conc. :** 3%

Branch : Angus Superfog **Flowrate :** 100 lpm

Branch Pressure : 18.2 bar

Air temperature : 18°C **Fuel temperature :** 15°C **Solution temperature :** 21°C
Foam temperature : 19 °C

Relative Humidity : 78 % **Average wood moisture content :** 15 %

Expansion ratio : 3.1 **Drainage time :** - min - sec **Shear Stress :** 1.0 N/M (Mostly Liquid)

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that originally set for Test A5
2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.
3. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 08	Front faces of all cribs alight.
2 : 21	Priming fuel burnt out.
7 : 55	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib, with the first sweep towards the left crib.
8 : 01	75% of the centre crib appeared to be completly extiguished.
8 : 03	All of the left crib appeared to be extinguished.
8 : 08	All of the centre crib appeared to be extinguished.
8 : 09	Flames re-appeared at the rear of the right hand corner of the left crib.
8 : 10	Centre crib not visible from the cameras in the doorway due to smoke and steam.
8 : 11	All of the right crib appeared to be extinguished except for "glowing" at the rear of the left hand corner.

8	: 15	First "double" sweep of the room completed. Opposite cribs obscured from the window cameras by smoke and steam.
8	: 16	Flames re-appeared at the rear of the left hand corner of the right crib.
9	: 45	Improved visibility in the room.
10	: 00	Rig moved into the centre of the room.
10	: 03	Rig in position in the centre of the room. Smoke and steam production increased, visibility poor.
11	: 13	Opposite cribs were visible from the window cameras.
11	: 15	Improved visibility in the room, the centre crib was visible from the cameras in the doorway.
11	: 22	Corners and 60% of the rear of the centre crib were well alight.
11	: 35	Flames in the side cribs restricted to a small area of the rear corners nearest to the centre crib.
11	: 44	Room almost totally clear of smoke and steam. Fire appears to have stabilised.
13	: 21	Foam layer on top of the cribs clearly visible to the firefighter. Foam over half of the crib width only (from the front of the crib).
14	: 00	Foam layer visible at the rear corners of the room to a height of 2 metres.
16	: 10	Firefighting ceased. Small flames visible at the rear corners of the side cribs nearest to the centre crib. 60% of the rear of the centre crib remained well alight.

Test Number : A9 **Date :** 12/9/88 **Additive :** FFFP-AR, NON-ASPIRATED **Conc. :** 3%

Branch : Angus Superfog **Flowrate :** 100 lpm

Branch Pressure : 18.2 bar

Air temperature : 14°C **Fuel temperature :** 14°C **Solution temperature :** 20°C
Foam temperature : 14 °C

Relative Humidity : 81 % **Average wood moisture content :** 15 %

Expansion ratio : 1.8 **Drainage time :** - min - sec **Shear Stress :** 0.4 N/M (Mostly Liquid)

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that originally set for Test A5
2. Difficulty was experienced in completely mixing the AFFF-AR additive with the water in the premix tank. Consequently, at the end of the test, a thin layer of unmixed additive was observed at the bottom of the tank.
3. "Through room" smoke density meter dismantled prior to this test.
4. Second data logger used to log data from individual thermocouples within the left hand crib during this test.
5. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 35	Priming fuel burnt out.
2 : 49	Front faces of all cribs alight.
7 : 55	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib, with the first sweep towards the left crib.
8 : 01	60% of the centre crib appeared to be completly extiguished.
8 : 03	All of the left hand crib appeared to be extinguished.
8 : 08	All of the centre crib appeared to be extinguished. Flames re-

	appeared at the rear of the right hand corner of the left crib. The centre crib was not visible from the cameras in the doorway due to smoke and steam.
8 : 10	All of the right hand crib appeared to be extinguished.
8 : 11	None of the cribs were visible from the doorway cameras.
8 : 14	Flames re-appeared at the rear of the left hand corner of the right crib
8 : 15	First "double" sweep of the room completed.
8 : 24	Opposite cribs obscured from the window cameras by smoke and steam.
9 : 38	Opposite cribs were visible from the window cameras.
9 : 46	Improved visibility in the room. Visibility fair. 50% of the rear of the left crib nearest to the centre crib well alight. 75% of the rear of the right nearest to the centre crib well alight. 95% of the rear of the the centre crib well alight (5% gap at the centre of the crib).
9 : 59	Rig moved into the centre of the room.
10 : 02	Rig in position in the centre of the room. Smoke and steam production increased, visibility poor.
11 : 30	80% of the rear of the centre crib well alight (20% gap at the centre of the crib). 75% of the rear of the right crib nearest to the centre crib well alight. 50% of the rear of the left crib nearest to the centre crib well alight.
11 : 44	Room almost totally clear of smoke and steam. Fire appears to have stabilised.
14 : 00	Thin foam layer visible on the rear wall of the room to a height of 1.5 metres.
16 : 05	Firefighting ceased. 80% of the rear of the centre crib remained well alight (20% gap at the centre of the crib). 75% of the rear of the right crib nearest to the centre crib well alight. 50% of the rear of the left crib nearest to the centre crib well alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

INVALID TEST

Test Number : A10 **Date** : 28/9/88 **Additive** : AFFF-AR, NON-ASPIRATED **Conc.** : 3%

Branch : Angus Superfog **Flowrate** : 100 lpm

Branch Pressure : 18.2 bar

Air temperature : 15°C **Fuel temperature** : 14°C **Solution temperature** : 19°C
Foam temperature : 15 °C

Relative Humidity : 88 % **Average wood moisture content** : 13 %

Expansion ratio : 2.2 **Drainage time** : - min - sec **Shear Stress** : 0.3 N/M (Mostly Liquid)

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that originally set for Test A5

2. This additive appeared to mix easier than the FFFP-AR used in the previous test. Only a very thin, yellow, skin was left in the bottom of the pre-mix tank.

3. Second data logger used to log data from individual thermocouples within the left hand crib during this test (results not processed).

4. Extinction of the fire commenced from the centre crib.

5. At approximately 10 minutes into the test, the washer in the branch coupling came away and lodged itself in the on/off valve of the branch. This led to between 20% and 30% of the foam solution being lost onto the fire test room floor and a dramatic change in the pressure/flow characteristics of the branch. Although the test continued until 16 minutes, the results of this test are not valid due to the problems experienced with the branch coupling

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 51	Front faces of all cribs alight.
2 : 33	Priming fuel burnt out.
7 : 59	Rotating rig entered room.

FIREFIGHTING

Time from ignition **Observations**

min : sec	
8 : 00	Extinction commenced from the middle of the centre crib, with the first sweep towards the right crib.
8 : 02	Rig in position. 75% of the centre crib appeared to be completly extiguished. Foam clearly visible on the front face of the crib.
8 : 04	All of the right crib appeared to be extinguished.
8 : 08	All of the centre crib appeared to be extinguished. Flames re-appeared at the rear of the left hand corner of the right crib.
8 : 09	The centre crib was not visible from the cameras in the doorway due to smoke and steam.
9 : 10	Opposite cribs were visible from the window cameras.
8 : 11	All of the left crib appeared to be extinguished.
8 : 12	First "double" sweep of the room completed. All of the cribs were obscured from the doorway cameras by smoke and steam.
8 : 13	Flames re-appeared at the rear of the right hand corner of the left crib.
8 : 18	Visibility extremely poor.
8 : 24	Opposite cribs obscured from window cameras by smoke and steam.
9 : 14	Flames in the centre crib were visible from the cameras in the doorway for the first time since 8:08.
9 : 22	Foam layer visible on the rear wall of the room to a height of 1.5 metre.
9 : 34	95% of the rear of the centre crib well alight (5% gap at the centre of the crib). 75% of the rear of the left and right cribs well alight, severe flaming at the rear corners of these cribs nearest to the centre crib.
9 : 40	Improved visibility in the room, the centre crib was visible from the cameras in the doorway. Visibility fair.
9 : 58	Rig moved into the centre of the room.
10 : 02	Rig in position in the centre of the room. Smoke and steam production slightly increased, visibility poor to fair.
10 : 15	Coupling at branch began to leak, pressure flow characteristics changed.
11 : 20	Room almost totally clear of smoke and steam. Fire appears to have stabilised.
11 : 30	80% of the rear of the centre crib well alight (20% gap at the centre of the crib). 60% of the rear of the left and right cribs well alight, severe flaming at the rear corners of these cribs nearest to the centre crib.
16 : 00	Firefighting ceased, 95% of the rear of the centre crib alight (5% gap at the centre of the crib). Flames in left and right cribs restricted to 50% of the rear of the cribs nearest to the centre crib.

Test Number : A11 **Date** : 29/9/88 **Additive** : SYNTHETIC, NON-ASPIRATED **Conc.**: 3%

Branch : Angus Superfog **Flowrate** : 100 lpm

Branch Pressure : 19.0 bar

Air temperature : 11°C **Fuel temperature** : 11°C **Solution temperature** : 19°C
Foam temperature : 10 °C

Relative Humidity : 74 % **Average wood moisture content** : 15 %

Expansion ratio : 2.4 **Drainage time** : - min - sec **Shear Stress** : ˜1.0 N/M (Mostly Liquid)

GENERAL NOTES

1. The coupling at the branch and all of the rubber washers in the hosereel system were changed prior to this test. This resulted in an increase in pressure of 0.8 bar when operating the branch at 100 lpm.

2. Due to a washer in the coupling at the branch being dislodged during test A10, the branch had to be dismantled. The washer was found in the on/off valve of the branch. On re-assembling the branch, it was operated in the room and slightly adjusted to give a spray pattern similar to those used in tests A4 to A9 inclusive.

4. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

5. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
1 : 52	Front faces of all cribs alight.
2 : 18	Priming fuel burnt out.
7 : 56	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib, with the first sweep towards the left crib.
8 : 01	60% of the centre crib appeared to be knocked down. Foam clearly visible on the front face of the centre crib.

8 : 03	All of the left crib appeared to be extinguished.
8 : 06	All of the centre crib appeared to be extinguished. Flames re-appeared at the rear of the left crib.
8 : 08	Flames re-appeared at the rear of the centre crib.
8 : 11	All of the right crib appeared to be extinguished.
8 : 12	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and steam. Flames re-appeared at the rear of the right crib.
8 : 13	First "double" sweep of the room completed.
8 : 17	Opposite cribs obscured from the window cameras by smoke and steam.
8 : 45	Opposite cribs visible from the window cameras.
8 : 48	Flames in the centre crib were visible from the doorway cameras for first time since 8:12. 85% of the rear of the centre crib well alight (15% gap in the centre of the crib). Flames in the left and right cribs restricted to 40% of the rear of the cribs nearest to the centre crib. Foam did not appear to be adhering to the back wall.
9 : 30	All of the cribs clearly visible from the doorway cameras. Visibility good.
9 : 50	Flames in the centre crib reached the roof of the fire test room. Visibility good.
9 : 59	Rig moved into the centre of the room.
10 : 02	Rig in position in the centre of the room. Smoke and steam production increased slightly, visibility fair to good.
11 : 00	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 65% of the rear of the centre crib well alight (35% gap at the centre of the crib). Flames in the left and right cribs restricted to 40% of the rear of the cribs nearest to the centre crib.
11 : 40	Foam on top of the cribs only adhering to half of the cribs' width nearest to the front face.
16 : 04	Firefighting ceased. Flames visible at the rear corners of the side cribs nearest to the centre crib. 65% of the rear of the centre crib remained alight (35% gap at the centre of the crib) and 30% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation. Some foam adhered to back wall but mainly in rear corners to a height of 1.5 metres.

NOTES :

1. Flames in the rear of the left and right cribs were visible throughout the whole test from the cameras in the doorway.

Test Number : A12 **Date** : 3/10/88 **Additive** : AFFF-AR, NON-ASPIRATED **Conc.**: 3%

Branch : Angus Superfog **Flowrate** : 100 lpm

Branch Pressure : 18.9 bar

Air temperature : 12°C **Fuel temperature** : 11°C **Solution temperature** : 18°C
Foam temperature : 12 °C

Relative Humidity : 77 % **Average wood moisture content** : 15 %

Expansion ratio : 2.3 **Drainage time** : - min - sec **Shear Stress** : 1.0 N/M (Mostly Liquid)

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that set for Test A11.

2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

3. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 00	Front faces of all cribs alight.
2 : 18	Priming fuel burnt out.
8 : 05	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 07	Extinction commenced from the middle of the centre crib.
8 : 09	Rig in position, first sweep commenced towards the left crib.
8 : 10	50% of the centre crib appeared to be knocked down. Foam was clearly visible on the front face of the crib.
8 : 11	All of the left crib appeared to be extinguished.
8 : 14	All of the centre crib appeared to be extinguished.
8 : 15	Flames re-appeared at the rear of the centre crib.
8 : 16	Flames re-appeared at the rear of the left crib.
8 : 18	All of the right crib appeared to be extinguished.
8 : 19	First "double" sweep of the room completed. Flames re-appeared at the rear of the right crib.
8 : 20	Left, right and centre cribs were not visible from the

cameras in the doorway due to obscuration caused by smoke and steam.

8 : 30	Opposite cribs were obscured from the window cameras by smoke and steam.
9 : 12	Flames in the centre crib were visible from the doorway cameras for first time since 8:19. 85% of the rear of the centre crib well alight (15% gap at the centre of the crib). Flames in the left and right cribs restricted to 50% of the rear of the cribs nearest to the centre crib, with the rear corners well alight. Visibility good.
9 : 20	Opposite cribs were visible from the window cameras.
9 : 59	Flames in the centre crib reaching the roof of the fire test room. Visibility good.
10 : 07	Rig moved into the centre of the room.
10 : 11	Rig in position in the centre of the room. Smoke and steam production increased slightly, visibility fair.
10 : 15	Foam adhering to a height of 1.5 metre on the rear wall, coverage patchy.
11 : 30	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 75% of the rear of the centre crib well alight (15% gap at the centre of the crib). Flames in the left and right cribs restricted to 30% of the rear of the cribs nearest to the centre crib.
16 : 10	Firefighting ceased. Large flames were visible at the rear corners of the side cribs nearest to the centre crib. 65% of the rear of the centre crib remained alight (35% gap at the centre of the crib) and 35% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

NOTE

1. Flames in the left and right cribs were visible from the doorway cameras throughout the test.

Test Number: A13 **Date :** 5/10/88 **Additive :** FIRE-OUT, NON-ASPIRATED **Conc.:** 0.2%

Branch : Angus Superfog **Flowrate :** 100 lpm

Branch Pressure : 19.0 bar

Air temperature : 13°C **Fuel temperature :** 12°C **Solution temperature :** 18°C
Foam temperature : 11 °C

Relative Humidity : 83 % **Average wood moisture content :** 16 %

Expansion ratio : 1.1 **Drainage time :** - min - sec **Shear Stress :** ~1.0 N/M (Mostly Liquid)

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that set for Test A11.
2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.
3. Extinction of the fire commenced from the centre crib.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 10	Front faces of all cribs alight.
2 : 30	Priming fuel burnt out.
7 : 58	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib with the first sweep towards the left crib.
8 : 02	50% of the centre crib appeared to be knocked down although glowing embers could be seen through the crib.
8 : 03	All of the left crib appeared to be extinguished.
8 : 07	All of the centre crib appeared to be extinguished.
8 : 08	Flames re-appeared at the rear of the left crib.
8 : 11	All of the right crib appeared to be extinguished.
8 : 12	First "double" sweep of the room completed.
8 : 13	Flames re-appeared at the rear of the right crib.
8 : 14	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and

	steam.
8 : 19	Opposite cribs were obscured from the window cameras by smoke and steam.
9 : 15	Flames in the left crib were visible from the doorway cameras for the first time since 9:15.
9 : 39	Flames in the centre crib were visible from the doorway cameras for first time since 8:07. 100% of the rear of the centre crib well alight. Flames in the left and right cribs restricted to 75% of the rear of the cribs nearest to the centre crib, with the rear corners well alight. Visibility good to fair.
9 : 40	Opposite cribs were visible from the window cameras.
9 : 50	Flames in the centre crib reaching the roof of the fire test room.
9 : 55	All cribs were clearly visible from the doorway cameras. Visibility good.
10 : 00	Rig moved into the centre of the room.
10 : 03	Rig in position in the centre of the room. Smoke and steam production increased slightly, visibility fair.
12 : 15	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 90% of the rear of the centre crib well alight (10% gap at the centre of the crib). Flames in the left and right cribs restricted to 50% of the rear of the cribs nearest to the centre crib.
16 : 03	Firefighting ceased. Large flames were visible at the rear corners of the side cribs nearest to the centre crib. 85% of the rear of the centre crib remained alight (15% gap at the centre of the crib) and 50% of the rear of each of the side cribs remained well alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

NOTE

1. Flames in the right crib were visible from the doorway cameras throughout the test.

Test Number: A14 **Date :** 12/10/88 **Additive :** HALOFOAM, NON-ASPIRATED **Conc.:** 15%

Branch : Angus Superfog **Flowrate :** 100 lpm

Branch Pressure : 19.2 bar

Air temperature : 10°C **Fuel temperature :** 10°C **Solution temperature :** 19°C
Foam temperature : 9 °C

Relative Humidity : 87 % **Average wood moisture content :** 14 %

Expansion ratio : 1.1 **Drainage time :** - min - sec **Shear Stress :** ~1.0 N/M (Mostly Liquid)

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that set for Test A11.

2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

3. Extinction of the fire commenced from the centre crib.

4. Pouring and mixing the additive proved difficult due to its' high viscosity. At the end of the test, a residue, several mm thick , was left at the bottom of the premix tank.

5. This was by far the best of the additives tested to date under these particular test conditions. The fire was almost completely extinguished except for two small areas of flame, one at the left hand rear corner of the centre crib and the other at left hand rear corner of the right crib.

6. At the end of the test, the floor within the fire test room was extremely slippy. This is the only test so far where FEU staff could walk into the room immediately the test had finished without further cooling of the room or cribs.

7. The coverage of the foam was very even over all except the burning areas of the cribs, a thick foam layer had also adhered to the inside wall of the fire test room to a height of at least 1.5m. The formation of foam bubbles continued for at least 15 minutes after the end of the test. The burning areas of the cribs were extinguished with water at the end of the test.

PREBURN

Time from ignition (min : sec)	Observations
0 : 0	Ignition.
2 : 22	Priming fuel burnt out.
2 : 50	Front faces of all cribs alight.

7 : 55	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib with the first sweep towards the left crib.
8 : 02	50% of the centre crib appeared to be knocked down. Foam clearly visible on the front face of the crib.
8 : 04	All of the left crib appeared to be extinguished.
8 : 08	All of the centre crib appeared to be extinguished.
8 : 10	Flames re-appeared at the rear of the centre crib. Flames re-appeared at the rear of the left crib. All of the right crib appeared to be extinguished.
8 : 12	Left, right and centre cribs were not visible from the cameras in the doorway due to obscuration caused by smoke and steam.
8 : 13	First "double" sweep of the room completed.
8 : 14	Flames re-appeared at the rear of the right crib.
8 : 15	Opposite cribs obscured from the window cameras by smoke and steam.
9 : 12	Flames in the centre crib were visible from the doorway cameras for first time since 8:14. 10% of the rear left of the centre crib was alight. There were no flames in the left crib. 3% of the rear corner of the right crib nearest the centre crib was alight.
9 : 14	Flames in the right crib visible from the doorway cameras for the first time since 8:17.
9 : 59	Rig moved into the centre of the room.
10 : 02	Rig in position in the centre of the room. Smoke and steam production increased, visibility poor.
11 : 19	Opposite cribs were visible from the window cameras. 10% of the rear left of the centre crib was alight. There were no flames in the left crib. 3% of the rear corner of the right crib nearest the centre crib was alight. Fire appears to have stabilised.
11 : 30	Thick layer of foam adhering to a height of 1.75 metre along the rear and side walls, foam layer touching the ceiling of the room at the rear corners.
13 : 00	All of the cribs were visible from the doorway cameras. Visibility fair.
14 : 40	Room almost totally clear of smoke and steam. 10% of the rear left of the centre crib was alight. There were no flames in the left crib. 3% of the rear corner of the right crib nearest the centre crib was alight.
16 : 08	Firefighting ceased. 10% of the rear left of the centre crib was alight. There were no flames in the left crib. 3% of the rear corner of the right crib nearest the centre crib was alight.

Test Number: A15 **Date :** 17/10/88 **Additive :** WETTING AGENT, NON-ASPIRATED
Conc.: 1%

Branch : Angus Superfog **Flowrate :** 100 lpm

Branch Pressure : 18.7 bar

Air temperature : 12°C **Fuel temperature :** 11°C **Solution temperature :** 17°C
Foam temperature : 9 °C

Relative Humidity : 88 % **Average wood moisture content :** 14 %

Expansion ratio : 1.1 **Drainage time :** - min - sec **Shear Stress :** ~1.0 N/M (Mostly Liquid)

GENERAL NOTES

1. The branch was operated in the room prior to the test. The setting remained at that set for Test A11.
2. Second data logger used to log data from individual thermocouples within the left hand crib during this test.
3. Extinction of the fire commenced from the centre crib.
4. During the test, it was noticed that the spray pattern was slightly lower than in previous tests.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 20	Priming fuel burnt out.
2 : 50	Front faces of all cribs alight.
8 : 05	Rotating rig entered room.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from the middle of the centre crib with the first sweep towards the left crib.
8 : 01	60% of the centre crib appeared to be knocked down.
8 : 03	All of the left crib appeared to be extinguished. Glowing embers could be seen through the knocked-down part of the centre crib.
8 : 08	All of the centre crib appeared to be extinguished. Flames re-appeared at the rear of the left crib.

8 : 10	All of the right crib appeared to be extinguished.
8 : 14	First "double" sweep of the room completed. Flames re-appeared at the rear of the right crib. Left, right and centre cribs not visible from the cameras in the doorway due to obscuration caused by smoke and steam.
8 : 17	Opposite cribs obscured from the window cameras by smoke and steam.
9 : 17	Opposite cribs were visible from the window cameras.
9 : 19	Flames in the centre crib were visible from the doorway cameras for the first time since 8:07.
9 : 30	60% of the rear of the centre crib was well alight (40% gap at the centre of the crib). Flames in the left and right cribs were restricted to 70% of the rear of the cribs nearest to the centre crib, with the rear corners well alight. Visibility good to fair.
9 : 46	Flames in the centre crib reached the roof of the fire test room. Visibility good.
9 : 50	All of the cribs were visible from the doorway cameras.
9 : 59	Rig moved into the centre of the room.
10 : 02	Rig in position in the centre of the room. Smoke and steam production increased slightly, visibility fair.
11 : 30	Room almost totally clear of smoke and steam. Fire appears to have stabilised. 60% of the rear of the centre crib well alight (40% gap at the centre of the crib). Flames in the left and right cribs were restricted to 50% of the rear of the cribs nearest to the centre crib, with severe flaming in these corners.
16 : 07	Firefighting ceased. Large flames were visible at the rear corners of the side cribs nearest to the centre crib. 80% of the rear of the centre crib remained alight (20% gap at the centre of the crib) and 50% of the rear of each of the side cribs remained alight. Flames have gradually reduced in height throughout the test, this is probably due to fuel starvation.

Test Number: A16 **Date :** 22/11/88 **Additive :** AFFF, NON-ASPIRATED **Conc.:** 3%

Branch : Angus Superfog, Narrow spray, Hand-held **Flowrate :** 100 lpm

Branch Pressure : 19.9 bar

Air temperature : 2°C **Fuel temperature :** 3°C **Solution temperature :** 13°C
Foam temperature : 2°C

Relative Humidity : 82 % **Average wood moisture content :** 14 %

Expansion ratio : 2.2 **Drainage time :** - min - sec **Shear Stress :** 3.0 N/M

GENERAL NOTES

1. This fire test was hand fought by seconded fire officer D.O. Richard Lock from the room doorway. The fire officer was not allowed to advance into the room at any time during the test.

2. The branch was operated by the fire officer prior to the test. The branch was set to give a narrow angle spray (total included angle approximately 16°).

3. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

4. Extinction of the fire commenced from the left crib.

5. The tactics used by the fire officer were as follows:-

   a. Starting from the end of the left crib nearest to the doorway, sweep once around all three cribs in the room until reaching the end of the right crib nearest to the doorway.

   b. Sweep along the right crib four times, then:-

   c. Sweep along the centre crib three times, then:-

   d. Sweep along the left crib four times, then:-

   e. Sweep along the centre crib three times, then:-

   f. Repeat points b. to e. above until the end of the test.

   At no time was the fire officer allowed to attack the cribs from above, he was only allowed to hit the cribs from the front.

PREBURN

Time from ignition (min : sec)	**Observations**
0 : 0	Ignition.
2 : 29	Priming fuel burnt out.
4 : 05	Front faces of all cribs alight.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from end of the left crib nearest to the doorway with the first sweep towards the centre crib.
8 : 01	90% of the left crib appeared to be knocked down, with the top layer well alight. Foam clearly visible on the front face of the crib.
8 : 02	Bottom half of the centre crib, where struck by spray, appeared to be extinguished with foam clearly visible. Top half of the crib well alight.
8 : 03	First complete sweep of room complete (left to right crib), 75% of the rear of the right crib well alight.
8 : 06	First four sweeps of right crib complete, crib extinguished except for 50 % of top layer.
8 : 08	First three sweeps of centre crib complete, crib appears to be extinguished.
8 : 12	First four sweeps of left crib complete, 5% of rear of crib alight.
8 : 30	75% of the top layers of the left and right cribs well alight.
8 : 57	Flames in rear crib visible from doorway cameras for the first time since 8:15. Visibility fair.
9 : 20	75% of the top layer of the right crib well alight, flames in the left crib restricted to 50% of the rear of the crib nearest to the centre crib.
9 : 25	Visibility good to fair.
10 : 30	70% of the rear of the centre crib alight, 100% of the top of the right crib well alight, 40% of the rear of the left crib well alight. Visibility good.
11 : 20	"Wall of foam" reaches doorway cameras.
12 : 00	20% of the rear of the centre crib alight (very small flames), 100% of the top of the right crib well alight, 40% of the rear of the left crib well alight.
13 : 14	View from the camera in the left hand side of the doorway obscured by foam on the lens.
14 : 00	Centre crib extinguished. 100 % of the top of the right crib well alight, 40% of the rear of the left crib well alight.
15 : 01	View from the camera in the right hand side of the doorway obscured by foam on the lens.
16 : 00	50% of the rear of the right crib alight, 20% of the rear of the centre crib alight.

Test Number: A17 **Date :** 23/11/88 **Additive :** AFFF, ASPIRATED **Conc.:** 3%

Branch : Angus Superfog with aspirator, Hand-held **Flowrate :** 100 lpm

Branch Pressure : 19.5 bar

Air temperature : 4°C **Fuel temperature :** 5°C **Solution temperature :** 14°C
Foam temperature : 8°C

Relative Humidity : 92 % **Average wood moisture content :** 15 %

Expansion ratio : 7.4 **Drainage time :** 5 min 34 sec **Shear Stress :** 3.0 N/M

GENERAL NOTES

1. This fire test was hand fought by the seconded fire officer D.O. Richard Lock from the room doorway. The fire officer was not allowed to advance into the room at any time during the test.

2. The branch was operated by the fire officer prior to the test. The branch gave a narrow aspirated jet.

3. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

4. Extinction of the fire commenced from the left crib.

5. The tactics used by the fire officer were as follows:-

   a. Starting from the end of the left crib nearest to the doorway, sweep once around all three cribs in the room until reaching the end of the right crib nearest to the doorway.

   b. Sweep along the right crib four times, then:-

   c. Sweep along the centre crib three times, then:-

   d. Sweep along the left crib four times, then:-

   e. Sweep along the centre crib three times, then:-

   f. Repeat points b. to e. above until the end of the test.

   At no time was the fire officer allowed to attack the cribs from above, he was only allowed to attack the cribs from the front.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 19	Priming fuel burnt out.
3 : 26	Front faces of all cribs alight.

FIREFIGHTING

Time from ignition min : sec	Observations
7 : 59	Extinction commenced from end of the left crib nearest to the doorway with the first sweep towards the centre crib.
8 : 01	95% of the left crib appeared to be knocked down, with only the corner nearest the rear crib alight. Foam clearly visible on the front face of the crib.
8 : 03	80% of the centre crib, where struck by the foam, appeared to be extinguished with foam clearly visible. The 20% of the crib not struck by foam (lower layers) well alight.
8 : 05	First complete sweep of room complete (left to right crib), 100% of the rear of the right crib and left cribs well alight. The 20% of the crib not struck by foam (lower layers) well alight.
8 : 09	First four sweeps of right crib complete, crib extinguished except for 50 % of the rear of the crib nearest to the centre crib.
8 : 11	Left, right and centre cribs were not visible from the doorway cameras due to obscuration caused by smoke and steam.
8 : 13	First three sweeps of centre crib complete, crib appears to be extinguished. Centre crib not visible from window cameras.
8 : 14	Opposite cribs not visible from window cameras.
8 : 19	First four sweeps of left crib complete, 10% of rear of crib alight.
8 : 30	10% of the rear of the left and right cribs nearest to the centre crib well alight.
8 : 52	Flames in the right crib visible from the doorway cameras for the first time since 8:12.
8 : 55	Left and right cribs visible from the doorway cameras for the first time since 8:11. Visibility poor.
9 : 00	5% of the rear of the left and right cribs nearest to centre crib alight.
9 : 01	Flames in the left crib visible from the doorway cameras for the first time since 8:12.
11 : 48	"Wall of foam" reaches doorway cameras.
12 : 00	Centre crib visible from window cameras for the first time since 8:14. Centre crib extinguished. 5% of the rear of the left and right cribs alight. Visibility fair.
12 : 23	Opposite cribs visible from window cameras for the first time since 8:14.
12 : 43	Centre crib visible from the doorway cameras for the first time since 8:11. Visibility fair to good.
14 : 00	Centre crib extinguished. Less than 5% of the rear of the right and left cribs alight.
16 : 00	Centre crib extinguished. Less than 5% of the rear of the right and left cribs alight.
16 : 03	Firefighting ceased.

Test Number: A18 **Date :** 28/11/88 **Additive :** AFFF, NON-ASPIRATED **Conc.:** 3%

Branch : Angus Superfog, Jet, Hand-held **Flowrate :** 100 lpm

Branch Pressure : 23.7 bar

Air temperature : 6°C **Fuel temperature :** 5°C **Solution temperature :** 14°C
Foam temperature : 7°C

Relative Humidity : 92 % **Average wood moisture content :** 15 %

Expansion ratio : 1.9 **Drainage time :** 2 min 30 sec **Shear Stress :** ˆ1.0 N/M

GENERAL NOTES

1. This fire test was hand fought by the seconded fire officer D.O. Richard Lock from the room doorway. The fire officer was not allowed to advance into the room at any time during the test.

2. The branch was operated by the fire officer prior to the test. The branch was set to give a coherent jet.

3. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

4. Extinction of the fire commenced from the centre crib.

5. The tactics used by the fire officer were as follows:-

   a. Starting from the end of the left crib nearest to the doorway, sweep once around all three cribs in the room until reaching the end of the right crib nearest to the doorway.

   b. Sweep along the right crib four times, then:-

   c. Sweep along the centre crib three times, then:-

   d. Sweep along the left crib four times, then:-

   e. Sweep along the centre crib three times, then:-

   f. Repeat points b. to e. above until the end of the test.

   At no time was the fire officer allowed to attack the cribs from above, he was only allowed to hit the cribs from the front.

PREBURN

Time from ignition min : sec	Observations
0 : 0	Ignition.
2 : 21	Priming fuel burnt out.
3 : 32	Front faces of all cribs alight.

FIREFIGHTING

Time from ignition min : sec	Observations
7 : 59	Extinction commenced from end of the left crib nearest to the doorway with the first sweep towards the centre crib.
8 : 01	95% of the left crib appeared to be knocked down, with the only visible flame at the bottom front face of the crib nearest to the centre crib, where no foam had struck. Foam clearly visible on the front face of the crib.
8 : 02	80% of the centre crib, where struck by the foam, appeared to be extinguished with foam clearly visible. The 20% of the crib not struck by foam (lower layers) well alight. 50% of the left crib nearest to the centre crib now well alight.
8 : 03	First complete sweep of room complete (left to right crib), 50% of the right and left cribs well alight. The 30% of the right crib not struck by foam (lower layers) well alight also rear of the right crib well alight.
8 : 06	First four sweeps of right crib complete, crib extinguished except for 30 % of the rear of the crib nearest to the centre crib.
8 : 09	First three sweeps of centre crib complete, crib appears to be extinguished. Centre crib not visible from window cameras.
8 : 13	Opposite cribs not visible from window cameras. First four sweeps of left crib complete and appears to be extinguished.
8 : 15	Left, right and centre cribs were not visible from the doorway cameras due to obscuration caused by smoke and steam.
8 : 17	Left crib re-ignites.
8 : 30	Less than 5% of the rear of the left crib and 10 % of the rear of the right crib nearest to the centre crib well alight.
8 : 54	Flames in the right crib visible from the doorway cameras for the first time since 8:18.
8 : 57	Flames in the left crib visible from the doorway cameras for the first time since 8:14.
9 : 00	5% of the rear of the left and right cribs nearest to centre crib alight.
9 : 16	Left and right cribs visible from the doorway cameras for the first time since 8:15. Visibility poor.
12 : 00	Centre crib extinguished. 5% of the rear of the left and right cribs alight. Visibility fair.
12 : 14	"Wall of foam" reaches doorway cameras.
12 : 23	All cribs visible from window cameras for the first time since 8:15.
12 : 50	Centre crib visible from the doorway cameras for the first time since 8:15. Visibility fair to good.
14 : 00	Centre crib extinguished. 5% of the rear of the right and left cribs alight.
16 : 00	Centre crib extinguished. 5% of the rear of the right and left cribs alight.
16 : 05	Firefighting ceased.

Test Number: A19 **Date :** 2/12/88 **Additive :** WATER **Conc.:** -

Branch : Angus Superfog, Jet, Hand-held **Flowrate :** 100 lpm

Branch Pressure : 23.9 bar

Air temperature : 5°C **Fuel temperature :** 5°C **Solution temperature :** 13°C
Foam temperature : -°C

Relative Humidity : 92 % **Average wood moisture content :** 13 %

Expansion ratio : - **Drainage time :** - **Shear Stress :** -

GENERAL NOTES

1. This fire test was hand fought by the seconded fire officer D.O. Richard Lock from the room doorway. The fire officer was not allowed to advance into the room at any time during the test.

2. The branch was operated by the fire officer prior to the test. The branch was set to give a coherent jet.

3. Second data logger used to log data from individual thermocouples within the left hand crib during this test.

4. Extinction of the fire commenced from the left crib.

5. The tactics used by the fire officer were as follows:-

   a. Starting from the end of the left crib nearest to the doorway, sweep once around all three cribs in the room until reaching the end of the right crib nearest to the doorway.

   b. Sweep along the right crib two times, then:-

   c. Sweep along the centre crib three times, then:-

   d. Sweep along the left crib two times, then:-

   e. Sweep along the centre crib three times, then:-

   f. Repeat points b. to e. above until the end of the test.

   At no time was the fire officer allowed to attack the cribs from above, he was only allowed to hit the cribs from the front.

PREBURN

Time from ignition (min : sec)	Observations
0 : 0	Ignition.
2 : 23	Priming fuel burnt out.
3 : 10	Front faces of all cribs alight.

FIREFIGHTING

Time from ignition min : sec	Observations
8 : 00	Extinction commenced from end of the left crib nearest to the doorway with the first sweep towards the centre crib.
8 : 01	95% of the left crib appeared to be knocked down, with the only visible flame on the rear top layer of the crib.
8 : 02	85% of the centre crib appeared to be extinguished. Top layer of the crib well alight.
8 : 03	First complete sweep of room complete (left to right crib), top layers of left and right cribs well alight.
8 : 04	First two sweeps of right crib complete, top layer and rear of crib well alight.
8 : 07	First three sweeps of centre crib complete, crib appears to be extinguished. Centre crib not visible from door cameras.
8 : 09	First two sweeps of left crib complete and appears to be extinguished.
8 : 10	Centre crib not visible from window cameras.
8 : 11	Flames reappear at the rear of the left crib.
8 : 16	Left, right and centre cribs were not visible from the doorway cameras due to obscuration caused by smoke and steam.
8 : 20	Opposite cribs not visible from window cameras.
8 : 30	Less than 5% of the rear of the left crib and of the rear of the right crib nearest to the centre crib alight.
8 : 53	Flames in the right crib visible from the doorway cameras for the first time since 8:28.
9 : 00	5% of the rear of the left crib and 30% of the rear of the right crib nearest to centre crib alight.
9 : 03	Flames in the left crib visible from the doorway cameras for the first time since 8:20.
9 : 48	Opposite cribs visible from the window cameras for the first time since 8:20. Centre crib appears to be extinguished.
10 : 00	Left and right cribs visible from the doorway cameras for the first time since 8:16. Visibility poor.
12 : 00	5% of the rear of the left and right cribs alight. Visibility fair.
13 : 14	All cribs visible from window cameras for the first time since 8:15.
13 : 00	Centre crib visible from the doorway cameras for the first time since 8:07. Visibility fair to good.
14 : 00	Centre crib extinguished. 5% of the rear of the right and left cribs alight.
16 : 00	Centre crib extinguished. 5% of the rear of the right and left cribs alight.
16 : 06	Firefighting ceased.