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A COMPARISON OF VARIOUS FOAMS WHEN USED AGAINST LARGE SCALE PETROLEUM FIRES

BY

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ABSTRACT

During May and June 1992, a series of foam trials was carried out on a 56m² circular tray, using 1400 litres of petrol as fuel for each test. At least two manufacturers' versions of the foam types AFFF, AFFF-AR, FFFP, FFFP-AR, FP, protein (P) and synthetic (S) were applied to the test fires using standard fire service equipment and techniques.

All of the film forming foam concentrates (AFFF, AFFF-AR, FFFP, and FFFP-AR) gave quick and progressive knockdowns and virtual extinctions. With few exceptions, the non-film forming foam concentrates (FP, P and S) were significantly slower.

Both AFFF-AR, all three FP, one of the FFFP-AR and one of the P foam concentrates gave very good burnback performances. All of the AFFF, FFFP and S foam concentrates gave poor burnback performances. The burnback performances of all of the foam concentrate types were affected to some extent by fuel contamination.

In order to achieve optimum fire fighting performance, foam concentrates should always be used at the manufacturers recommended concentrations and at least the minimum application rates recommended in DCO Letter 10/91.

MANAGEMENT SUMMARY

Introduction

The Fire Experimental Unit (FEU) has been closely involved in the development of the proposed European (CEN) and International (ISO) standards for foam concentrates. The FEU work has been focused on the standards for low expansion foam concentrates because it is these foams that are most commonly used by the UK fire service.

The small pool fire tests contained within these standards have been under particular scrutiny because they are intended to be the main means of classifying foam concentrate performance.

FEU have carried out over 100 of these tests and some of the results have been disturbing. In particular, some good quality foam concentrates, which performed well during previous FEU large scale fire tests, have failed to extinguish the standard fire tests when used at full strength and so have not passed the standards.

In order to check that the results achieved by foam concentrates during the standard fire tests were reasonable, FEU carried out a series of large scale fire tests using petrol in a 56 square metre circular fire tray.

To make these large scale fire tests as realistic as possible, foam was applied to petrol fires by a firefighter using fire service equipment, tactics and recommended foam application rates.

This report details these large scale fire tests and provides results and conclusions on the performance of the various foam concentrates tested. The results of these tests are not compared here with those achieved during the standard fire tests.

Choice of Foam Concentrates and Application

Those foam concentrate types that are generally available to brigades were chosen for the tests. They were aqueous film forming foam (AFFF), alcohol resistant AFFF (AFFF-AR), protein (P), fluoroprotein (FP), film forming FP (FFFP), alcohol resistant FFFP (FFFP-AR) and synthetic (S). At least two manufacturers versions of each of these were used: in all 15 different foam concentrates were tested.

All of the foam concentrates were used at the concentration recommended by the manufacturer for petrol fires which was usually 3%. In addition, the effects of using weak foam concentrates on large fires were investigated with the film forming foam concentrates (AFFF, AFFF-AR, FFFP and FFFP-AR) being used at 2% and 1.5% concentrations.

During the majority of the fire tests, the foams were applied at the minimum rates recommended to the fire service. These are 4 lpm/m^2 for the film forming foam concentrates, 5 lpm/m^2 for FP and 6.5 lpm/m^2 for Protein. In addition, two of the FP foam concentrates were applied at 4 lpm/m^2 in order to directly compare the performance of FP with that of the film forming foam concentrates when used under the same conditions. There is no recommended UK fire service application rate for synthetic foam because it is not normally used in this country at low expansion. However, poor performance was anticipated and so it was applied at a rate of 6.5 lpm/m^2.

Commonly available fire service foam branchpipes were used for applying foam to the test fires. An Angus F225H branch was employed for the 4 and 5 lpm/m^2 tests and an Angus F450H was employed for the 6.5 lpm/m^2 tests.

Fire Test Procedure

The tests were carried out in a purpose-built 56m^2 circular tray with a concrete base and a metal rim. For most tests, the tray contained 1400 litres of lead-free petrol (with no oxygenates) floating on a water base. The petrol was ignited and allowed to burn for 1 minute before the foam stream was gently applied directly to the surface of the fuel by an experienced firefighter.

Five minutes after the fire had been extinguished, a burnback test was performed on the foam blanket to assess its resistance to flame.

Throughout the tests, observers noted the progress of the fire fighting, the times to 90% and 100% extinction, and the times to 25% and 100% burnback. Radiometers were used to measure heat radiation and all of the tests were recorded on colour video equipment.

The foam solution was produced using an in-line inductor as a convenient way of introducing foam concentrate in to the hoseline. The concentrate and solution flowrates were accurately monitored by the use of flowmeters and both could be controlled with the use of pumps.

Several burnback-only tests were also carried out during this trial. These tests were performed to experiment with a different burnback test where the burnback performance of a foam blanket was dependant on the foam characteristics and not influenced by the extinction performance. For each of these tests foam was gently applied directly to unignited petrol within the fire tray for either one or two minutes. After a five minute waiting period, the burnback flame was applied to the foam blanket as described above.

Results

During the analysis of the results, the following performance characteristics were isolated as being of most concern to the fire service when assessing the relative merits of firefighting foam concentrates:-

1. Knockdown
2. Virtual extinction
3. Burnback resistance
4. Flare resistance

Virtual extinction was defined by FEU as the point at which flames had been restricted to 5% or less of the tray side. 100% extinction times were not used because these were heavily dependant on the tactics employed by the firefighter after 99% extinction and appeared to have little to do with the properties of the foam concentrates used.

During many of the burnback tests, the foam blankets became involved in what FEU has called 'flare-ups'. A flare-up involves the foam blanket surface in flames which quickly escalate and then die down leaving the blanket intact. Flare-ups are probably due to the ignition of fuel picked-up by the foam blanket when the foam stream is applied to the fuel surface. The speed of escalation from the application of the burnback flame to a peak flare-up was unpredictable but many took place within 1 minute. The area of the foam blanket involved in large flames varied from less than 1% to more than 75%. In many cases, the fires were very severe but generally they quickly subsided, sometimes within seconds, often within 1 or 2 minutes.

Due to the spread of the results and the level of repeatability of the fire tests during this trial, a performance grading system was introduced. The results, employing this grading system, are given in Table MS1. For knockdown, virtual extinction, burnback resistance and flare resistance, the more symbols in the table, the better the performance.

Cost was also considered to be an important factor in selecting a foam concentrate and so this also has been included in Table MS1. In this case, the more £'s, the higher the cost of the foam concentrate required to achieve virtual extinction of the fire.

The burnback-only tests not only provided information on a different type of burnback test but also on the performance of some foams when used to provide protection on hydrocarbon spills.

Conclusions

It was only possible to test the foam concentrates against one Class B fuel in a controlled and almost ideal firefighting environment. Consequently, care must be taken in applying these conclusions to other circumstances.

In order to achieve optimum fire fighting performance, foam concentrates should always be used at the manufacturers recommended concentrations and at least the minimum application rates recommended in DCO Letter 10/91. The conclusions for foam concentrates used in this way are:-

1. All of the film forming foam concentrates (AFFF, AFFF-AR, FFFP and FFFP-AR) gave quick and progressive knockdowns and virtual extinctions. Quick knockdowns were also achieved by one of the synthetic and one of the FP foam concentrates tested.

2. Generally, the non-film forming foam concentrates (FP, P and synthetic) gave significantly slower knockdowns and virtual extinctions than achieved by the film forming foam concentrates.

3. All three FP, one of the FFFP-AR and one of the P foam concentrates gave very good burnback performances. Both AFFF-AR foam concentrates also gave very good burnback performances when their relatively short foam application times were taken into account.

4. All of the AFFF, FFFP and S foam concentrates, and one of the P foam concentrates gave poor burnback performances.

5. The burnback performances of all of the foam concentrate types tested were affected to some extent by fuel contamination. Foam must always be applied as gently as possible to minimise foam contamination.

Foam should be applied to hydrocarbon spills as gently as possible to prevent contamination of the foam blanket and should continue for as long as possible to produce a very thick protective foam layer. Precautions should be taken to ensure that any ignition source does not come into contact with the foam blanket. Should contaminated foam ignite, then large areas of the foam blanket are likely to be become involved in intense flames within seconds. The shorter and more forceful the foam application, the more severe any resulting flare-up is likely to be. FP gives much better burnback performance than AFFF or FFFP in such situations but is likely to become involved more quickly in a flare-up should one occur.

When foam concentrates were used at below their recommended concentrations or application rates, firefighting and burnback performances began to degrade. With some foam concentrates the degradation was not too significant, with others the effects were severe. The results of this trial indicate that safety factors are evident in both the recommended application rates and in the quality of foam concentrates. These safety factors ensure that, under severe firefighting conditions, the ability of foam concentrates to extinguish hydrocarbon fires is not seriously diminished. In general, the safety factor can expected to be higher for better quality foam concentrates.

Despite these tests only involving one firefighting situation, the results do at least provide the fire service with a basis for comparing the relative performance of various types of foam concentrate. The results also show that large variations in performance can be expected from different products of the same foam type.

FOAM TYPE AND USAGE CONC.	APP. RATE lpm/m^2	KNOCKDOWN GRADE	VIRTUAL EXT. GRADE	25% BURNBACK GRADES		COST TO VIRTUAL EXT.
				TIME	RATIO	
AFFF(1) 3%	4	□□□□□	■■■■■	♦♦	◇◇	££
AFFF(2) 3%	4	□□□□□	■■■■	♦♦	◇◇	£££
AFFF-AR(1) 3%	4	□□□□□	■■■■	♦♦♦	◇◇◇◇	£££
AFFF-AR(2) 3%	4	□□□□□	■■■■	♦♦♦	◇◇◇◇◇	£££
FFFP(1) 3%	4	□□□□□	■■■■■	♦♦	◇◇	££
FFFP(2) 3%	4	□□□□□	■■■■	♦♦	◇◇	£££
FFFP-AR(1) 3%	4	□□□□□	■■■■	♦♦♦	◇◇◇	£££
FFFP-AR(2) 3%	4	□□□□□	■■■■	♦♦♦♦	◇◇◇◇	£££
FP(1) 3%	5	□□□	■■	♦♦♦♦	◇◇◇◇	£££
FP(2) 3%	5	□□□□□	■■■	♦♦♦♦♦	◇◇◇◇	£
FP(3) 6%	5	□□	■■	♦♦♦♦♦	◇◇◇◇◇	-----[1]
P(1) 3%	6.5	□□	■	♦♦♦♦♦	◇◇◇◇	£££££
P(2) 3%	6.5	□	■	♦♦♦	◇◇	£££££
S(1) 3%	6.5	□□□□□	■■■	♦♦	◇◇	£££
S(2) 3%	6.5	□□□□	■	♦♦	◇◇	£££££

A difference in performance of one grade is not significant due to the tight cut off points between grades and the level of repeatability of the tests. However, where there is a difference in performance of two or more grades, the difference is significant.

Note:

1. This foam concentrate was produced by a foreign manufacturer and provided by a UK fire brigade, free of charge.

TABLE MS1 : Foam Concentrate Performance

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1. INTRODUCTION

At present there are no international standards for firefighting foams. Considerable effort has been put in over the years to develop firstly International Standards (ISO), and then subsequently European Standards (CEN)[1] (Superscripts refer to notes on page 42). These are now in their later stages and are either due to be published, or have been published, as drafts for public comment.

One of the concerns of the Fire Experimental Unit (FEU) is that the UK fire service should not experience a drop in the quality of its foam concentrates due to the introduction of these foam standards.

FEU has focused its foam work on the draft standards for low expansion foam concentrates for use on water immiscible fuels (References 1 and 2) because it is these foam concentrates that are most commonly used by the UK fire service. The pool fire tests contained within the standards have been under particular scrutiny because they are intended to be the main means of classifying foam concentrate performance.

The fire test method is essentially the same in both the International (ISO) and European Standards (CEN). The test consists of applying foam at 11.4 litres per minute through a standard branchpipe into a circular 4.5 m^2 fire tray. The tray contains 144 litres of burning heptane floating on a water base. For each test, foam application commences one minute after ignition of the fuel.

Two application methods are used, the first involves plunging the foam stream directly into the burning heptane for three minutes; the second involves applying the foam gently on to the surface of the burning fuel for five minutes via a backplate. Once the fire has been extinguished, a burnback test is performed by inserting a steel pot containing Heptane into the fire tray. This Heptane is ignited 5 minutes after the cessation of foam application.

Over 100 of these standard fire tests have been performed by FEU and some of the results have been disturbing. In particular, some good quality foam concentrates, which performed well during previous FEU large scale fire tests, have failed to extinguish the standard fire tests when used at full strength and so have not passed the standards.

In order to check that the results achieved by foam concentrates during the standard fire tests were reasonable, FEU carried out a series of large scale fire tests using petrol in a 56 square metre circular fire tray.

It was anticipated that the results from these large fires would indicate the level of confidence that brigades could have in the foam concentrates that meet the provisions of the ISO and CEN standards.

These large fire tests are of direct relevance to the UK fire service because they were hand-fought using standard fire service equipment (mainly 225 litre per minute branchpipes and inductors) at the minimum recommended fire service application rates. In addition, the foam stream was applied directly to the surface of the burning fuel. The high velocity at which the foam stream hits the surface of the fuel means that this is one of the severest application methods which may have to be used operationally.

The effects of watering down foam concentrates for application to large scale fires were investigated during this trial with the film forming foam concentrates (aqueous film forming foam (AFFF), alcohol resistant AFFF (AFFF-AR), film forming fluoroprotein foam (FFFP) and alcohol resistant FFFP (FFFP-AR)) being used at 2% and 1.5% concentrations as well as at their full strength concentrations of 3%. In addition, fluoroprotein (FP), protein (P) and synthetic (S) foam concentrates were tested at full strength. At least two manufacturers versions of each of the foam types were tested.

This report details these large scale fire tests and provides results and conclusions on the performance of the various foam concentrates tested. The results of these tests are not compared here with those achieved during the standard fire tests.

2. FACTORS AFFECTING TRIALS DESIGN

2.1 Choice of Foam Concentrates

At least two manufacturers versions of each of the following foam concentrate types were used during this trial:-

AFFF	Aqueous Film Forming Foam
AFFF-AR	Alcohol Resistant AFFF
P	Protein
FP	Fluoroprotein
FFFP	Film Forming FP
FFFP-AR	Alcohol Resistant FFFP
S	Synthetic

Full details, including cost per litre, are given in Table 1.

All of these foam concentrates, except for synthetic, are sold in large quantities to fire brigades within the UK for use at low expansion on Class B hydrocarbon fuels. Synthetic is used in the UK for the production of medium and high expansion foam and it is also used extensively abroad to produce low, medium and high expansion foam.

Protein foam concentrates, although stored in bulk by several brigades, are not generally recommended for use because of their inferior firefighting properties.

Although not extensively used for firefighting in the UK, both synthetic and protein foam concentrates are included within the draft ISO and CEN standards and so have been tested during this trial.

Many of these foam concentrates have been used during previous FEU fire tests and all have been tested during the standard ISO/CEN fire tests.

During this trial, all of the foam concentrates were used at the concentration recommended by the manufacturer for liquid hydrocarbon fuel fires which was generally 3%. However, during the ISO/CEN standard fire tests it was found that some of the foam concentrates gave similar performances when used at well below their recommended concentration. The effects of using foam concentrates at reduced concentration on large fires is investigated during this trial with the film forming foam concentrates being used at 2% and 1.5% concentrations as well as at their recommended use concentration of 3%.

2.2 Application Rate

Successful use of foam is dependent on the rate of application. Application rates are generally defined in terms of the amount of foam solution (not finished foam) in litres per minute expended on a 1 square metre area of the fuel surface (lpm/m^2).

There is a critical application rate below which the fire cannot be extinguished and above this there is a recommended rate which will vary depending on the method of application and the size of the fire.

The most recent Home Office guidance on application rates for the UK fire service was issued in a Dear Chief Officer letter number 10/91 (Reference 3) which supplemented information given in the Manual of Firemanship (Reference 4).

The majority of the tests during this trial involved spill fires of 1400 litres of petrol (25mm depth) floating on a 25mm deep water base. Fuel depths of up to 50mm with and without a water base were also used.

The following lists the fire service minimum foam application rates for hydrocarbon spill fires :-

Foam Concentrate	Application Rate (lpm/m^2)
AFFF	4
AFFF-AR	4
FFFP	4
FFFP-AR	4
FP	5
P	6.5
S	6.5*

* There is no recommended fire service minimum application rate for synthetic foam given in Reference 3. However, due to its poor performance during the CEN/ISO standard fire tests, the highest spill fire application rate of 6.5 lpm/m^2 was chosen for use during this trial.

Two of the three FP foam concentrates used during the trial were also applied at an application rate of 4 lpm/m^2 in order to directly compare the performance of FP with that of the film forming foam concentrates when used under the same conditions.

Previous FEU tests have used 2.5 lpm/m^2 (References 5 and 6), which was chosen because it was just above the critical application rate and it was hoped that this would differentiate between foam concentrates.

The objective of these present tests was to compare the performance of various foam concentrates when using standard fire service equipment and techniques. It was therefore appropriate to use the application rates currently recommended to the fire service.

2.3 Choice of Branchpipe

A pilot study on low expansion foam-making branchpipes was carried out by FEU in 1986 (Reference 7). For the purposes of the study, four branchpipes were chosen, all with flows of about 225 litres per minute. These were the Angus F225, the Angus F225H, the Chubb FB5X MKI and Chubb FB5X MKII. At the time, these branchpipes were the ones in most common use on first line appliances in the United Kingdom. The hydraulic characteristics of the branchpipes, the foam pattern, throw and the quality of the finished foam were measured during the pilot study.

The results indicated that the Chubb branchpipes gave a much shorter drainage time and more fluid foam, however the significance of this with regard to firefighting performance could not be fully assessed because comparative large scale fire tests were needed.

During September 1991, FEU carried out fire tests to investigate the effects of various formulations of lead-free petrol on the extinction performance of firefighting foams (Reference 8). The fire tests involved the same tray as used during the trial reported here.

These lead-free fire tests also allowed a brief comparison to be made of the effect of different foam-making branchpipes on the firefighting performance of the foam produced. Two of the four branchpipes assessed during the pilot study were used, these were the Angus F225H and the Chubb FB5X MKII branchpipes. The Angus F225 was rejected because of its short throw and the Chubb FB5X MKI because a later version was available.

The results of these tests showed that foams performed better when applied with the Angus F225H than when applied with the Chubb FB5X MKII. In addition, due to very poor performances during the trial, the Chubb branch could not be recommended for use with FP foam concentrates.

With the results of the lead-free fires in mind and because many foams types, including FP, were to be used, the Angus F225H branchpipe was chosen for use during this trial for the production of foams at the application rates of 4 and 5 lpm/m^2. These application rates required foam solution flow rates of 225 lpm and 281 lpm respectively.

For those foam concentrates requiring an application rate of 6.5 lpm/m^2, the required flow rate of 366 lpm could not be obtained through the Angus F225H. Foam could be produced at a flow rate of 366 lpm through foam-making branchpipes designed for optimum use at 450 lpm. In the absence of comparative foam quality data for 450 lpm branchpipes it was decided to use a branch which was of similar design to the Angus F225H branch and currently in use within the UK fire service. Consequently, an Angus F450H was used for those foams requiring an application rate of 6.5 lpm/m^2 during the present trial. The Angus F225H and F450H branchpipes are shown in Figure 1.

2.4 Preburn

A preburn time of 1 minute was allowed from ignition to the start of foam application. This was considered sufficient to allow the fire column to obtain equilibrium and for the burning rate to steady, while allowing reasonable economy in fuel costs.

The sealing qualities of the foams may not be fully tested with a one minute preburn because the steel rim of the tray will not be heated to significantly high temperatures.

2.5 Tactics of Foam Application

There are three ways in which a foam stream can be applied to a tray fire:-

1. Gentle surface application

   The foam stream is allowed to fall as gently as possible on to the fuel surface without allowing it to impact on the tray sides or any other object in or around the tray.

   Gentle surface application can be achieved without moving the branch or by moving the branch to produce a sweeping motion over the tray.

2. Forceful surface application

   The foam stream is directed forcefully into the fuel.

3. Gentle application, use of a backplate or front plate

   The foam stream is directed on to a plate above the fuel surface. This allows the foam to run gently on to the fuel surface, building up a blanket which can flow gently over the surface, so ensuring the minimum of disturbance. The tray sides can be treated as a backplate if there is enough metal above the fuel surface.

During the present trial, the branchman, an experienced Fire Officer, was asked to apply foam as gently as possible to the fuel surface without using the tray sides (ie. gentle surface application). No backplate was used because one may not always be available to a branchman at an operational incident.

For the majority of the tests, the initial attack involved the branch being directed so that the bulk foam stream hit the rear quarter of the left hand side of the tray.

The branchmen tried to keep the foam stream stationary for this phase. However, a clockwise foam motion (or foam swirl) was normally produced within the tray with the foam blanket flowing clockwise around the tray and over the fuel surface.

This gentle surface application technique was normally continued until virtual extinction[2] had been achieved and/or no further progress was being made in extinguishing the remaining flames. The branchman was then allowed to do any combination of the following to achieve a quick 100% extinction: change position; apply the foam stream directly to the remaining flames; feather the foam stream over the remaining flames.

2.6 Number of Test Fires

A minimum of three tests, under the same conditions, are preferable to assess repeatability. More tests are desirable but the size and cost of the these must impose limits.

During this trial, only one test per foam concentrate condition was normally performed with only three spare tests being available for repeats.

2.7 Production of Foam Solution

Brigades use in-line inductors or round-the-pump systems for the induction of foam concentrates on first-line appliances for main delivery foam-making branchpipes. Self inducting branchpipes are also used.

In this trial, an in-line inductor system was used in conjunction with a gear pump and flowmeters (see Section 3.4). This was a convenient means of introducing foam concentrate into the hoseline in a closely controlled manner.

The use of this arrangement also avoided foam solution passing through the appliance pump and the consequential need for thorough flushing of the pump after each test. It was also more economical on the use of foam concentrate over the alternative approach of using a premix solution. Premixing requires large volumes of solution to be available for the longest expected extinction times. When the concentrate is inducted, foam production can be terminated at the end of the test with only minimal wastage of foam concentrate.

2.8 Fuel

A fuel that was commonly encountered by the fire service and which would provide a realistic test of foam concentrates was required for this trial.

The fuel chosen was 95 octane premium lead-free petrol with no oxygenates. A total of 65,000 litres of it were used during the trial. The petrol was collected from the supplier[3] in two tankers[4], one of 29,000 litre capacity the other of 36,000 litre capacity. The petrol was supplied to the tankers simultaneously from a single storage tank. The tankers were stored in a locked compound at the Fire Service College (FSC) and were driven to the test site when required.

This particular lead-free petrol was similar to one of the fuels used successfully during a previous FEU trial which involved the use of foam against large scale petroleum fires involving lead-free petrol (Reference 7).

The results of this previous trial indicated that petrol containing oxygenates up to the maximum allowed in current European Directives and British Standards present a more challenging fire to some foam concentrates. However, lead-free petrol with oxygenates is not believed to be generally available in the UK at the present time and thus is extremely difficult to obtain. Consequently, it is unlikely that petrol containing oxygenates would be involved in an operational incident and so was not used here.

Although leaded petrol has been used during other FEU trials (References 5 and 6) it was felt that its use would further increase the pollution effects produced during a trial of this size. Also, lead-free petrol is considerably cheaper than leaded petrol.

2.9 Fire Tray

The area of the tray used for this trial (56.25 m^2) was dictated by the minimum application rate (4 lpm/m^2) and flowrate of the smallest branch selected (225 lpm).

The tray was originally built for the large scale lead-free petrol fire trial (Reference 7). The base, side walls and immediate surround were constructed of high temperature concrete. The 56.25m^2 area of the fire was defined by a steel ring which was encased in concrete and sealed at the edges by a high temperature mastic material. During tests, the trays outer channel contained water which prevented the steel rim from distorting. The sealant around the steel ring prevented fuel from flowing into the water in the surrounding channel. It also prevented water from flowing into the fuel. This was important during the previous trial where water soluble additives were used within the petrol.

There was a drain outlet from the base of the tray and an outlet from the outer channel. Both these outlets had valves which allowed the residue from the fire tests to be drained to a settlement and treatment system incorporated in the FSC fireground.

During the previous trial, it was found that the height of the steel tray wall was not sufficient to contain all of the foam applied during some tests. As a consequence of this, the height of the tray wall above the concrete base was increased from 165 mm to 315 mm.

A tray made entirely of steel was not used because of the problems of manufacture and of distortion of the base during fires.

2.10 Fuel Depth

At the beginning of this trial several preliminary tests were planned to assess the effects of different fuel depths, and the presence of a water base, on the firefighting performance of foam concentrates. The results of these tests would be used to specify the fuel/water configuration to be used for the remainder of the trial.

The amount of fuel used may affect the severity of the test fires and hence the extinction performance of foam concentrates. A water base is often necessary, especially when using relatively small fuel depths, to allow for any variations in tray level to be overcome by the water layer. This ensures an even depth of fuel across the whole of the tray surface.

The concrete base of the test tray used during this trial was uneven. About 1300 litres of liquid were required to ensure that the whole area of the test tray base was covered. This meant that in some areas the liquid depth reached 20mm before the whole of the tray base was completely covered. With or without a water base, 2800 litres of liquid, including at least 1400 litres of petrol, would be required to ensure a minimum 25mm depth of petrol within the test tray.

Three tests were allowed at the beginning of the trial to assess the following conditions:

- a 1400 litre water base covered by 1400 litres (25mm depth) of petrol
- a 1400 litre water base covered by 2800 litres (50mm depth) of petrol
- 2800 litres (50mm depth) of petrol with no water base

The results of these tests (see Section 5.2) indicated that the fuel depth and a water base had little effect on the firefighting performance of the foam concentrate used (AFFF(1)).

Consequently, for the remainder of the trial, each test fire involved a 1400 litre water base covered by 1400 litres of petrol. Assuming a free burning rate of 4 mm per minute, 1400 litres of petrol gives an estimated free burning time of 6 minutes 15 seconds.

2.11 Weather Conditions

The general guidelines used for weather conditions during this trial were that a test would not commence if there was any precipitation, or with wind speeds above 6 m/s.

Although desirable, it was not possible to control the air, fuel, water base or foam solution temperatures.

2.12 Burnback Test

A burnback test was required to assess the resistance of the foam blanket to flame. Burnback is also important in confirming that the fire has been extinguished by the application of foam and not because the fuel has burnt out.

The burnback apparatus used was a development of that described in Reference 6. This was a propane torch which was applied to the foam blanket approximately 0.5 metres from the edge of the tray.

Foam application was continued for a further 30 seconds after 100% extinction. This was intended to provide a standard blanket condition for the burnback test which could be regarded as representing practical circumstances of use in firefighting operations.

The burnback flame was applied to the foam surface 5 minutes after 100% extinction. The flame was left to play on the foam surface until the fire was well developed (about 1 m^2 of exposed petrol surface alight), the flame was then removed.

The above burnback method was used during the trials described in Reference 7. Although useful results were obtained from the burnback tests, it was found that the depth of the foam blanket affected the burnback time. Unfortunately, 100% extinction times and consequently foam blanket depth can vary considerably from one foam type to another and from one test to another during this type of large outdoor trial. It was therefore suggested that a different burnback test could be tried which would involve foam being applied to a fuel surface which had not been previously ignited. By controlling the foam solution flowrate and the time of foam application, a layer of foam could be built up which would be dependant on the foam characteristics and not influenced by the extinction performance.

To assess this new burnback test, four 'burnback-only' tests were carried out during this trial. For each of these tests foam was gently applied to unignited fuel within the fire tray for either one or two minutes. After a five minute waiting period, the burnback flame was applied to the foam blanket and the fire was left to develop as described above.

2.13 Safety

A safety procedure, including procedures for fuel transfers, was developed before the commencement of the trial and this was followed for each test. The procedure is given in Appendix A.

The fuel was ignited with an electrically fired cartridge[5] by an operator at a safe distance to avoid the risk of approaching the tray with a naked flame.

3. DESCRIPTION OF TRIALS SITE AND EQUIPMENT USED

3.1 General

Detailed descriptions of the equipment and procedures used are given in Appendix B. A summary of these descriptions follows.

3.2 Tray Site

The tray site was situated on the FSC fireground, Moreton-in-Marsh. Figure 2 shows a general view of the site. A more detailed description of the fire tray is given in Section 2.9.

3.3 Water Supply

Potable water was required for mixing with the foam concentrates for firefighting and for cleaning the tray. There was not an adequate potable water supply near the tray site and so two portable water dams[6] were positioned nearby but away from any danger from the fire. The dams each had a 24,000 litre capacity and were joined together with a length of suction hose.

The dams were filled overnight from a potable water supply available on the site by means of a small bore hose (19mm diameter) and an automatic control valve. If during a test day the water level became low, the dams were filled directly from the potable water supply via a larger bore (70mm diameter) hose.

A fire appliance adjacent to the dams was used to distribute potable water around the trials site (Figure 3).

FSC fireground hydrant water was used for cooling the concrete tray surround.

3.4 Instrumentation

Figure 4 is a block diagram of the typical layout of appliances and equipment. This shows the relative positions of instrumentation and other equipment when deployed for the trial. The hydraulic arrangement used during the fire tests is shown in Figure 5. Potable water from the pump was passed through a standard in-line inductor and an electromagnetic flowmeter[7], then through three 21.2 metre lengths of 70mm hose to the foam branchpipe.

The foam concentrate to be used was poured into an open drum. From here it was lifted by a small electrically driven gear-pump[8], through an orifice and then through a second electromagnetic flowmeter[9] before reaching the in-line inductor. The orifice was introduced to reduce variations in the concentrate flow. The gear pump was provided with an electrical variable speed drive control and both flowmeters were connected to digital displays. By adjusting the main pump throttle and the gear-pump control, the operator monitored and controlled the total liquid flow to the branchpipe and the correct percentage of foam concentrate. This arrangement ensured that the solution strength was accurately known and controlled.

The piezometer[10] tube housed a pressure transducer[11] and a temperature sensor[12]. Both these sensors were connected to digital displays[13,14] and these could be easily seen by the pump operator (Figure 6).

The temperature of the fuel in the tray was measured using a hand held intrinsically safe digital indicator and thermocouple probe[15].

The wind speed and direction was monitored using a wind station[16] mounted on a pole connected to the instrumentation van (Figure 7). A humidity probe and an air temperature sensor[17] were also mounted on the pole. These instruments were connected to readouts in the instrumentation van and their outputs were also recorded on a chart recorder[18] and a datalogger[19].

A wind sock[20] was mounted on a mast upwind of the tray to give a visual indication of the wind direction and a guide to the wind speed.

Each test was recorded using colour video equipment. A Skystalk mast[21] (Figure 8) with a colour video camera on top provided the primary view. This camera was mounted at a height of 20 metres for optimum viewing of the fire tray and could be remotely controlled from the instrumentation van. A second video camera[22] was mounted on top of the instrumentation van. Both cameras were connected to video recorders[23] in the instrumentation van. The direction of view of the Skystalk camera was approximately broad-side to the wind direction.

Two large synchronised digital clocks[24], displaying minutes and seconds, were sited near to the fire tray. These were in the field of view of the cameras and at least one was visible to all personnel engaged in the conduct of the trial.

The clocks were preset to 99 : 00 (min : sec) and started when all preparations were complete and the fuel had been transferred to the tray. Ignition took place 1 minute after the clocks were started, at zero indicated time. Thus the video records were accurately timed, and a means of co-ordination provided for all involved with the trial. The time on the clock is referred to as clock time in this report.

Records of the progress and timing of each fire were made by observers. They used the times from the large digital clocks but also had digital stopwatches available with split time facilities.

Two pairs of radiometers[25], were used to measure the radiated heat from the test fires. The radiometers were deployed mounted at a height of 3 metres on a mast (Figure 9), with one radiometer from each pair diametrically opposite the other. The pairs had different sensitivities. Each radiometer was cooled by circulating water from a tank using a pump[26].

The radiometers were positioned 15 metres from the tray and the radiometers on each side of the tray were sited 5 metres away from each other. The sensing faces of the radiometers were depressed by 10 degrees from the vertical. The signals from the radiometers were routed, via cables, to the instrumentation van where they were recorded on a datalogger and on a second chart recorder.

4. EXPERIMENTAL PROCEDURE

4.1 General

A detailed step by step experimental procedure is given in Appendix B. A summary of the experimental procedure follows.

4.2 Tray Preparation

Before each test, the tray was thoroughly cleaned out using yard brushes, wet vacuum cleaners, and potable water.

During the fire it was necessary to protect the concrete on the downwind side of the tray. This was done using ground monitors and "A" type nozzles, which were supplied with water from the FSC fireground hydrant supply. The nozzles were adjusted before each test to ensure that no spray entered the fire tray and that the spray adequately covered the downwind concrete area.

Sheet metal protection plates were placed over the outer concrete walls on the down wind side of the tray to prevent them from being damaged by flames. These plates extended around two-thirds of the circumference of the tray.

4.3 Fire Tests - General Procedure

Before the transfer of petrol to the tray, all equipment was operated to check correct functioning. The foam-making branchpipe was connected to the hoseline and tested. The wind direction and speed were monitored. The direction was checked to ensure that all vehicles and equipment were suitably deployed. The petrol tanker was then driven alongside the tray.

Whilst this was happening, the foam concentrate was poured into the open drum.

The tanker and the steel rim of the fire tray were connected to an earth spike and a length of petrol hose was connected from the tanker outlet to the tray. Local Authority firefighters were deployed as safety crews.

When all preparations were complete, petrol was transferred from the tanker to the tray by opening the tanker valve and allowing the petrol to be gravity fed in to the tray (Figure 10). The petrol tanker driver measured the quantity of petrol being delivered using a calibrated dipstick inserted into the top of the tank. When the required amount of petrol had been transferred the tanker valve was closed, the hose was underrun and the earth connection was removed from the tanker. The tanker was then driven away from the site. For some tests it was necessary to take petrol from more than one compartment of the tanker.

The aim was to carry out the tasks between fuel transfer to the tray and ignition, as quickly as possible to minimise fuel loss by vaporisation.

To ignite the petrol, two electrically fired cartridges were positioned, using metal straps, a few centimetres above the petrol surface, on the upwind side of the tray. Once the cartridges had been placed in position, the fuel temperature was measured and recorded.

Finally, when everyone was clear, the earth strap to the tray rim was disconnected.

The datalogger, chart recorders and video recorders were all set to record. Foam production from the firefighting branchpipe commenced and the cooling sprays were turned on.

The clocks (preset to 99 min : 00 sec) were started. One minute later, at zero indicated time, the cartridges were detonated using a safety firing box. A one minute preburn was allowed before firefighting commenced.

When the clocks were started the pump operator adjusted the flowrates to give the required conditions for the branchpipe. This ensured that the conditions were correct at the branch when firefighting commenced.

Figure 11 shows a general view of the fire during the preburn.

The pump operator monitored the flow rate throughout the test and adjusted when necessary. He also recorded the foam solution temperature from the display connected to the in-line temperature sensor.

At one minute after ignition, the foam stream was applied to the fire from the upwind side of the tray. The firefighter attempted to apply the foam gently to the fuel surface (Figure 12).

During the firefighting, four observers noted the progress made by the foam and in particular, the times to 90% and 100% extinction. 90% extinction was taken as the time at which 90% of the tray area was free from flames.

Application was continued for a further 30 seconds after 100% extinction of the fire.

At the end of foam application, the branchman directed the foam stream on to a foam collecting stand, containing a 1600ml collecting vessel, positioned 10 metres away from the branch (Figure 13). Once full of foam, the collecting vessel was taken to an instrument trailer where measurements were made of foam quality in respect of expansion ratio and 25% drainage time.

These served as a general check on the quality of the foam concentrate and on the correct functioning of the foam branchpipe. The foam quality measurement methods used are detailed in References 1 and 2.

Air and foam temperatures were recorded during the foam tests using digital thermometers.

Four minutes after 100% extinction the burnback flame was lit. Five minutes after 100% extinction the burnback flame was applied to the surface of the foam blanket, at a position approximately 0.5 metre from the edge of the tray (Figure 14).

The burnback flame was withdrawn from the tray when an area of approximately $1m^2$ of burning petrol had been established. The observers recorded the progress of the burnback including the times to 25% and 100% burnback[27].

For the last test only, where no water base was used, a pipe was positioned over the edge of the tray before the burnback flame was applied. This enabled water to be introduced into the tray when the burnback had developed to 75% to prevent damage to the base of the tray.

For the burnback-only tests, no firefighting took place although foam was applied gently to the fuel surface at zero indicated time for either one or two minutes. After a waiting period of five minutes, the burnback flame was applied to the foam blanket and the burnback was allowed to develop as described above.

4.4 Data Reduction of Radiometer Results

After the tests, the data recorded on the datalogger was transferred into a spreadsheet software package. The data was processed following the procedure given in the draft foam standards (References 1 and 2) to calculate the times for 90% extinction, 25% burnback[27] and 100% burnback[27] as well as other intermediate times.

Figure 15 shows an example of a radiometer record with the 90% extinction time and the 25% and 100% burnback times marked.

5. RESULTS

5.1 Presentation of Results

5.1.1 General

The results of the tests are tabulated as follows:-

Table 2: Extinction and burnback times for each test in chronological order. Air, water base and fuel temperatures are also given.

Table 3: Extinction and 25% burnback times for AFFF and AFFF-AR foam concentrates. Details of burnback flares are also given.

Table 4: Extinction and 25% burnback times for FFFP and FFFP-AR foam concentrates. Details of burnback flares are also given.

Table 5: Extinction and 25% burnback times for FP, Protein and Synthetic foam concentrates. Details of burnback flares are also given.

Table 6: Air, fuel and solution temperatures humidity, wind speed and wind direction for each test.

Table 7: Foam properties measured during the tests.

Times are measured from the first application of foam to the tray until 90%, 95%, virtual[2] and 100% extinction. Burnback times are measured from the first application of the burnback flame to the surface of the foam blanket[27].

The results of the flares observed during the burnback tests consist of the areas of the foam blanket involved in large flames at the peak of the flare and the times at which these occurred. The radiated heat intensity of the peak flare, as a proportion of the heat intensity of the fire when fully burning, is also given.

Appendix C gives details of extinction and burnback tests and was compiled from analysis of the radiometer records, observers' notes and video records. Graphical representations of the radiometer results are also included.

During the analysis of the results, the following performance characteristics were isolated as being of importance to the UK fire service when assessing the relative merits of firefighting foam concentrates:-

1. Knockdown
2. Virtual Extinction[2]
3. Burnback resistance
4 Flare resistance

However, due to the spread of the results and the level of repeatability of the fire tests during this trial (see Section 6.6), a performance grading system for the above results was introduced. The performance grading system is described in more detail in Section 5.1.2 below.

The performance gradings for the foam concentrates used during this trial are presented in the following tables:-

Table 8: Performance grading results for all foam concentrations. Costs to virtual extinction also included.

Table 9: Performance grading results for manufacturers recommended use concentrations only. Costs to virtual extinction also included.

Where more than one test has been carried out at any particular application rate and concentration, the average of these test results has been used in determining the performance grades given in Tables 8 and 9.

5.1.2 Performance Grades

During the analysis of the results a performance grading system was introduced in order to compare the knockdown, virtual extinction, burnback resistance and flare resistance performances of the foam concentrates tested. This was found necessary due to the spread of results experienced with repeated tests.

The performance grade results are presented in Tables 8 and 9. In general, a difference in performance of one grade is not regarded as significant due to the tight cut off points between grades. However, where there is a difference in performance of two or more grades, the difference can be regarded as significant (see Section 6.6).

The grading system is explained in detail in the following sections.

(i) Tests Not Used For Performance Grading

In producing the performance grade tables, the results of several tests were ignored.

Tests 1, 2, 38 and 43 involved the use AFFF(1) at 3% concentration. Tests 2 and 43 have been ignored when determining the performance grades for AFFF(1) because they involved the use of various water base/fuel volume combinations other than the usual 1400 litres of fuel and a 1400 litre water base (see Section 5.2).

Tests 8 and 22 involved the use of FFFP(1) at 3% concentration. Test 8 has been ignored when determining the performance grades for FFFP(1) because, for a significant period of the extinction test, much of the foam stream fell short of the fire tray.

Tests 34, 40, 41 and 42 were burnback-only tests and the results have not been given performance grades. The results of these tests are presented separately in Section 5.7.

(ii) Knockdown

The grades for knockdown are derived from the 90% extinction times and are as follows:-

Grade	**90% Extinction Time**
□□□□□	Less than or equal to 1 minute
□□□□	More than 1m but less than or equal to 1m 30s
□□□	More than 1m 30s but less than or equal to 2m
□□	More than 2m but less than or equal to 3m
□	More than 3 minutes

(iii) Virtual Extinction

These grades are based on virtual extinction[2] times.

Virtual extinction is the term used in the present report to describe the point in time at which the remaining flames, during the extinction phase of the fire test, were restricted to less than 5% of the tray edge. Complete extinction of these last few flames was shown during this trial to be due to the expertise of the firefighter and his tactics rather than any particular properties of the foams used.

Performance grades for virtual extinction are as follows:-

Grade	**Virtual Extinction Time**
■■■■■	Less than or equal to 1 minute 30 seconds
■■■■	More than 1m 30s but less than or equal to 2m
■■■	More than 2m but less than or equal to 3m
■■	More than 3m but less than or equal to 4m
■	More than 4 minutes

(iv) Burnback

The burnback resistance of the foam blankets is assessed in two ways. The first assessment is based on the 25% burnback time only and the second is based on what FEU has called the 25% burnback ratio (see below).

The performance grades for the 25% burnback times achieved by each of the foam concentrates used during this trial are as follows (the higher the 25% burnback time the better the performance):-

Grade	**25% Burnback Time**
◆◆◆◆◆	More than or equal to 12 minutes
◆◆◆◆	More than or equal to 9m but less than 12m
◆◆◆	More than or equal to 6m but less than 9m
◆◆	More than or equal to 3m but less than 6m
◆	Less than 3 minutes

The 25% burnback ratio method grades the ratio of the 25% burnback time to the foam application time, ie.

$$25\%\ \textit{burnback ratio} = \frac{25\%\ \textit{burnback time}}{\textit{total foam application time}}$$

The 25% burnback ratio method has been used because of the large variations in the foam application times during this trial, ranging from 2 minutes 2 seconds to 9 minutes 23 seconds. This allowed foam blankets of various depths to be built up (see Section 2.12).

Performance grades for 25% burnback ratio are as follows (the higher the ratio the better the performance):-

Grade	**25% Burnback Ratio**
◇◇◇◇◇	More than or equal to 2.5
◇◇◇◇	More than or equal to 2 but less than 2.5
◇◇◇	More than or equal to 1.5 but less than 2
◇◇	More than or equal to 0.75 but less than 1.5
◇	Less than 0.75

Flare-ups have not been taken into consideration for any of these burnback results. See Section (v) below.

(v) Flare Resistance

The flare resistance grades are based on the area of the foam blanket involved in a flare-up during the burnback test. A flare-up involves the foam blanket surface in flames which quickly escalate and then die down leaving the foam blanket intact. Flare-ups are probably due to the ignition of contaminated foam within the foam blankets.

Performance grades for flare resistance are as follows (the smaller the area of tray involved in flame the better the performance):-

Grade	Area of Tray Involved in Large Flare Flame
OOOOO	Less than 1%
OOOO	More than or equal to 1% but less than 5%
OOO	More than or equal to 5% but less than 15%
OO	More than or equal to 15% but less than 25%
O	More than or equal to 25%

5.1.3 Foam Concentrate Costs

Table 1 includes the cost per litre of each of the foam concentrates purchased by FEU during February 1992 for this trial. These costs exclude VAT and delivery charges.

Tables 8 and 9 contain summaries of the total cost of foam concentrates required to achieve virtual extinction. The following cost codes are used:-

GRADE	Cost of Foam Concentrate Required to Achieve Virtual Extinction
£	Less than or equal to £20
££	More than £20 but less than or equal to £30
£££	More than £30 but less than or equal to £40
££££	More than £40 but less than or equal to £50
£££££	More than £50

The time period from the first application of foam to virtual extinction is used along with the foam concentrate flow rate to calculate the amount of foam concentrate required.

5.2 Preliminary Tests

Preliminary tests (Tests 1 and 2) were carried out to indicate the effects of different fuel depths and the presence of a water base on the firefighting performance of foam concentrates (see Section 2.10).

Test 1 involved a 1400 litre water base covered by 1400 litres (25mm depth) of petrol and Test 2 involved a 1400 litre water base covered by 2800 litres (nominal 50mm depth) of petrol.

Both tests used the foam concentrates AFFF(1) at its recommended concentration of 3% and applied at an application rate of 4 lpm/m^2.

Tests 1 and 2 produced similar 90% extinction, 95% extinction and 25% burnback performances with AFFF(1). The virtual extinction times were 1 minute 10 seconds and 1 minute 29 seconds respectively. These results indicated that a doubling of the fuel depth, when floated on a water base, did not significantly effect the firefighting performance of AFFF(1). Consequently, all except one of the remaining tests (Test 43, see below) used a 1400 litre water base covered with 1400 litres of petrol.

A third test, involving 2800 litres of petrol with no water base, was planned at the beginning of the trial. This test was expected to indicate the effect of a water base on the firefighting performance of AFFF(1). However, due to some damage caused to the tray sealant during the first two fire tests, and the possible damage that could be caused by the absence of a water base, this test was not carried out until the end of the trial (Test 43).

Test 43 produced 90% extinction, 95% extinction and 25% burnback results that were similar to other tests that involved AFFF(1) with a water base. However, the virtual extinction time was slightly longer than previous AFFF(1) tests at 1m 39s.

These results indicated that the firefighting performance of AFFF(1) was not significantly affected by the use of a water base and confirmed the earlier decision to use a 1400 litre water base and 1400 litres of fuel for each test during the trial.

5.3 Knockdown Performance

5.3.1 Full Strength Foam Concentrates

FP(2), S(1), S(2) and all of the full strength film forming foam concentrates (AFFF, FFFP, AFFF-AR, FFFP-AR) gave quick knockdown performances during this trial. FP(1) gave a slightly slower knockdown with FP(3) and P(1) even slower still. P(2) gave a knockdown performance that was significantly worse than any of the other full strength foam concentrates tested.

Reducing the application rates for FP(1) and FP(2) did not significantly affect their knockdown performances.

Non-progressive knockdowns, that is where the area of the foam blanket failed to increase steadily and predictably with time, were noted for FP(3) and P(2) full strength foam concentrates. During these tests, the foam blanket was partially destroyed before control was re-established and knockdown achieved.

5.3.2 Reduced Strength Film Forming Foam Concentrates

The knockdown performances of all of the film forming foam concentrates did not significantly degrade when reducing the foam concentration from 3% to 2%. However, in almost all cases, knockdown times were longer.

When the usage concentration was reduced from 3% to 1.5%, the knockdown performances of AFFF(1), FFFP(1) and FFFP-AR(1) did not significantly degrade. However, the knockdown performances of AFFF(2), AFFF-AR(1), AFFF-AR(2), FFFP(2) and FFFP-AR(2) began to degrade significantly. The knockdown performances of AFFF(2) at 1.5% and AFFF-AR(2) at 1.5% were particularly poor. In all tests, the knockdown times were longer when the foam concentrates were used at 1.5% than when they were used at 3%.

Non-progressive knockdowns were noted for 1.5% concentrations of FFFP(2), AFFF(2), AFFF-AR(2), FFFP-AR(2) and the 2% concentration of FFFP(2).

5.4 Virtual Extinction Performance

5.4.1 Full Strength Foam Concentrates

All of the full strength film forming foam concentrates gave quick virtual extinction performances during this trial. FP(2) and S(1) produced slower virtual extinction performances than these. The virtual extinction performances of FP(1), FP(3), P(1), P(2) and S(2) were significantly worse than any of the film forming foam concentrates tested. P(1), P(2) and S(2) gave particularly poor virtual extinction performances.

Reducing the application rates for FP(1) and FP(2) did not significantly affect their virtual extinction performances. Non-progressive extinctions were noted for FP(3), P(2), S(1) and S(2) full strength foam concentrates.

5.4.2 Reduced Strength Film Forming Foam Concentrates

The virtual extinction performances of AFFF(1) and AFFF-AR(1) foam concentrates did not significantly degrade when reducing the foam concentration from 3% to 2%. However, the virtual extinction performances of all of the other film forming foam concentrates began to show signs of degradation. In almost all cases, the virtual extinction times of the foam concentrates at 3% were faster than those at 2%.

When the concentration of the film forming foam concentrates was reduced from 3% to 1.5%, their virtual extinction performances began to show signs of more significant degradation. The virtual extinction performances of AFFF(2) at 1.5% and AFFF-AR(2) at 1.5% were particularly poor. However, the virtual extinction performance of FFFP(2) was less affected by dilution than any of the other concentrates tested. In all cases, the virtual extinction times of the foam concentrates at 3% were faster than those at 1.5%.

Non-progressive extinctions were noted for AFFF-AR(2) and FFFP(2) at 2% and 1.5% concentrations, and for AFFF(2) and FFFP-AR(2) at 1.5% concentrations.

5.5 Burnback Performance

5.5.1 General

The burnback tests involving AFFF(2) at 2% and S(1) at 3% started prematurely when the test fuel reignited 1 minute 43 seconds and 1 minute 30 seconds respectively after extinction was believed to have been achieved; the burnback flame was not used.

Usually during this trial, the burnback test began 5 minutes after the end of extinction to enable the foam blanket to drain and so offer less burnback protection. With a shorter waiting time, as happened in the above tests, a better burnback resistance can be expected. However, even with this advantage, AFFF(2) at 2% and S(1) at 3% still achieved poor burnback performance grades.

FP(1), FP(2) (both applied at 4 lpm/m^2), S(1), S(2) and all of the film forming foam concentrates showed similar characteristics during the burnback tests. In almost all cases, within one minute of the application of the burnback flame to the foam blanket, small flames were seen ghosting from the burnback flame and across the surface of the foam blanket and around the tray edge. In many instances the flames on the foam surface increased in intensity to give flare-ups in areas away from the burnback flame. These flames then died down and sometimes self-extinguished. However, the main burnback, which involved exposing open areas of fuel, generally proceeded from the area around the burnback flame and occurred after the flare-up had subsided.

The foam blankets produced by the FP (all at an application rate of 5 lpm/m^2) and the P foam concentrates generally prevented the ignition of contaminated foam and hence the spread of small ghosting flames for longer than the other foam concentrates tested.

During all of the burnback tests, the flames spread very quickly once 25% burnback had been achieved.

5.5.2 25% Burnback Times

(i) Full Strength Foam Concentrates

FP(2), FP(3) and P(1) gave very good 25% burnback times closely followed by FFFP-AR(2) and FP(1). AFFF-AR(1), AFFF-AR(2), FFFP-AR(1) and P(2) gave slightly shorter 25% burnback times than these.

AFFF(1), AFFF(2), FFFP(1), FFFP(2), S(1) and S(2) all gave poor 25% burnback times.

Reducing the application rate of FP(1) did not effect its 25% burnback time. However, the 25% burnback time of FP(2) was significantly shorter when the application rate was reduced from 5 lpm/m^2 to 4 lpm/m^2.

(ii) Reduced Strength Film Forming Foam Concentrates

With the exception of FFFP-AR(2), the 25% burnback times of all of the film forming foam concentrates did not significantly degrade when their concentrations were reduced from 3% to 2% and 1.5%. The 25% burnback time of FFFP-AR(2) was significantly shorter when used at 2% and 1.5% when compared with its performance at 3%.

The 25% burnback time of AFFF-AR(2) was significantly longer when used at 1.5% concentration than when it was used at either 3% or 2% concentration.

The 25% burnback times of AFFF(1) were particularly poor at 2% and 1.5% concentrations.

5.5.3 25% Burnback Ratio

(i) Full Strength Foam Concentrates

AFFF-AR(2) and FP(3) gave the best 25% burnback ratio performances closely followed by AFFF-AR(1), FFFP-AR(2), FP(1), FP(2) and P(1). FFFP-AR(1) gave a slightly worse 25% burnback ratio performance than all of these.

AFFF(1), AFFF(2), FFFP(1), FFFP(2), P(2), S(1) and S(2) foam concentrates all gave poor 25% burnback ratio performances.

Reducing the application rates for FP(1) and FP(2) did not significantly affect their 25% burnback ratio performances.

(ii) Reduced Strength Film Forming Foam Concentrates

The 25% burnback ratios of AFFF(1), AFFF(2), FFFP(1), FFFP(2), and FFFP-AR(1) did not significantly degrade when their concentrations were reduced from 3% to 2% and 1.5%.

There were significant reductions in the 25% burnback ratios of AFFF-AR(1) and FFFP-AR(2) when they were used at 2% and 1.5% concentrations instead of their recommended 3% concentrations.

When the concentration of AFFF-AR(2) was reduced from 3% to 2%, its' 25% burnback ratio significantly degraded. However, when used at 1.5%, the 25% burnback ratio of AFFF-AR(2) returned back to the level it achieved at 3%.

5.6 Flare Resistance

5.6.1 General

Unfortunately, there were no signs of repeatability in the flare-up results of tests that were duplicated (AFFF(1) and AFFF(2) both at 3% concentration) and so these results must be viewed with caution.

Flare-ups commenced with small flames ghosting over the foam surface and around the edge of the tray. This spread of flames generally began within 1 minute of the burnback flame being applied to the foam surface although often it started as soon as the burnback flame was introduced. The speed of escalation of these small flames to peak flare-up was unpredictable. In some tests, peak flare-ups occurred within 30 seconds of the spread of small flames, in others it took more than 6 minutes. Generally, flare-ups quickly subsided, sometimes within seconds, often within 1 or 2 minutes.

At peak flare-up, the flame intensity indicated by the radiometer results was noticeably lower than expected for the area of the foam blanket involved in flame.

5.6.2 Full Strength Foam Concentrates

AFFF-AR(2), FFFP(2), FFFP-AR(1), FP(3), P(1) and P(2) were all only marginally affected by flare-ups during the burnback tests. However, AFFF(2), AFFF-AR(1), FP(1) and FP(2) were all badly affected by flares with over 25% of the surface of the foam blanket being involved in large flames soon after the burnback test commenced.

With FP(1), FP(2), FP(3) (all at an application rate of 5 lpm/m^2), P(1) and P(2) foam concentrates, flare-ups were very slow in developing and then self-extinguished before the burnback proper began.

FP(1) and FP(2) foam concentrates showed reductions in peak flare-up flame area with decreasing application rate.

5.6.3 Reduced Strength Film Forming Foam Concentrates

When the concentration of the film forming foam concentrates was reduced from 3% to 2%, AFFF(1), AFFF(2) and FFFP(1) became significantly more resistant to flare-ups. Conversely, AFFF-AR(2), FFFP(2) and FFFP-AR(2) became less resistant. AFFF(1), FFFP(1) and FFFP-AR(1) were only marginally affected by flares when applied at 2% concentration while AFFF-AR(1) and FFFP-AR(2) were badly affected by flare-ups.

When the concentration of the film forming foam concentrates was reduced from 3% to 1.5%, AFFF(1), AFFF(2), AFFF-AR(1) and FFFP(1) became significantly more resistant to flare-ups. AFFF-AR(2) and FFFP(2) became significantly less resistant to flare-ups. The resistance to flare-ups of FFFP-AR(1) and FFFP-AR(2) did not change with this reduction in foam concentration. AFFF(1), AFFF(2), FFFP(1) and FFFP-AR(1) were only marginally affected by flare-ups when used at 1.5% concentration, FFFP(2) was badly affected.

For the AFFF, AFFF-AR and FFFP(1) foam concentrates, there was a general trend of a reduction in flare-up area with reduction in foam concentration.

5.7 Burnback-Only Tests

Four burnback-only tests were performed. The results were as follows (a longer 25% burnback time indicates better burnback performance):-

Test No.	Foam Type	Application Period (Minutes)	25% Burnback Time (Min : Sec)
34	AFFF(1)	1	1 : 22
40	FP(1)	2	6 : 49
41	AFFF(1)	2	3 : 11
42	FFFP(1)	2	3 : 27

All of the above tests used the same application rate (4 lpm/m^2) in order that a direct comparison could be made between the burnback resistances of the foam blankets produced.

During Test 34, AFFF(1) was applied for only 1 minute and the resulting 25% burnback time was very short. Consequently, the foam application period was increased to two minutes for the remaining tests to enable longer burnback times to be achieved.

The flare-ups recorded during these tests were as follows (a smaller flare area indicates better performance):-

Test No.	Foam Type	Application Period (Minutes)	Maximum Flare Area	Time Flare Observed (Min : Sec)
34	AFFF(1)	1	75%	0 : 28
40	FP(1)	2	30%	0 : 17
41	AFFF(1)	2	35%	1 : 53
42	FFFP(1)	2	25%	1 : 00

In all of these tests, the flare-ups observed during these burnback-only tests were significantly greater and generally developed quicker than those experienced during burnbacks after the extinction tests.

5.8 Foam Properties

The foam expansion ratio and 25% drainage time results are given in Table 7. A summary of these foam properties is given below:-

Foam Type	Foam Branch	Flow	Expansion Ratio		25% Drainage Time	
			Average	Range	Average	Range
AFFF	F225H	225	15.7	12 - 17.6	2m 35s	2m - 3m 3s
AFFF-AR	F225H	225	13.4	11.9 - 14.8	6m 4s	5m 53s - 6m 15s
FFFP	F225H	225	12.2	11.6 - 12.8	2m 28s	1m 58s - 2m 41s
FFFP-AR	F225H	225	10.5	9.4 - 11.5	4m 20s	3m 30s - 5m 10s
FP	F225H	225	10.7	10.6 - 10.8	3m 29s	3m 25s - 3m 32s
FP	F225H	281	10.4	10.0 - 11.2	5m 6s	5m - 5m 15s
P	F450H	366	9.2	8.6 - 9.8	3m 1s	3m - 3m 2s
S	F450H	366	14.1	13.6 - 14.6	7m	5m - 9m

FP (1) and FP (2) foam concentrates were applied to the test fire at the recommended fire service minimum application rate of 5 lpm/m^2 and at the lower rate of 4 lpm/m^2. This lower rate of 4 lpm/m^2 was used to directly compare the performance of FP with that of the film forming foam concentrates when used under the same conditions. In order to achieve these application rates, it was necessary to increase the solution flow rate through the Angus F225H branchpipe from 225 lpm to 281 lpm. This increase in flow resulted in slightly lower expansion ratios and much longer 25% drainage times.

The P and S foam concentrates were applied to the test fire at an application rate of 6.5 lpm/m^2. In order to achieve this application rate an Angus F450H branchpipe was operated at 366 lpm instead of its recommended flow rate of 450 lpm. Consequently, the quality of the foam produced during this trial through the F450H is probably inferior to that which would have been produced had the branchpipe been operated at its recommended flow rate. This is not a criticism of the Angus F450H branchpipe but of the operating conditions that it was necessarily subjected to during this trial.

5.9 Temperatures

5.9.1 Fuel Temperature

The fuel was discharged from tankers which had been parked outdoors. The fuel temperature ranged from a maximum of 19°C to a minimum of 7°C. Although it is desirable to control the fuel temperature, this is very difficult to achieve with the large quantities of fuel used during these tests.

5.9.2 Water Base Temperature

The fire tray water base temperature ranged from a maximum of 30°C to a minimum of 17°C. The water base temperature was influenced by the temperature of the water in the water dams and the temperature of the pump through which the water was passed while being pumped to the tray.

5.9.3 Air Temperature

The air temperature ranged from a maximum of 23.2°C to a minimum of 12.5°C. These were relatively high for the UK and were due to the warm weather prevailing during most of the trials period.

5.9.4 Solution Temperature

The solution temperature ranged from a maximum of 21.2°C to a minimum of 16.4°C. The temperature being influenced by the temperature of the water in the appliance tank or water dams and the temperature of the pump through which the water passed.

5.10 Radiometers

The radiometer record from one pair of radiometers are given for each test in Appendix C. The second pair of radiometers gave similar results.

The 90% extinction, 95% extinction and burnback times quoted are generally those calculated from processing the radiometer results.

5.11 Wind Speeds

The average wind speeds during each test are given in Table 6. During all but one of the tests the average wind speed was less than 6 metres per second. During Test 3, the average wind speed was 6.3 metres per second.

6. DISCUSSION

6.1 Foam Concentrate Performance - Full Strength

6.1.1 Virtual Extinction Performance

All of the film forming foam concentrates gave quick and progressive knockdowns and virtual extinctions.

Quick knockdowns were also achieved by FP(2) and S(1). However, the virtual extinction times achieved by these and all of the other non-film forming foam concentrates were significantly slower than those achieved by the film-formers. Both of the protein foam concentrates and S(2) gave particularly slow virtual extinction times.

Reducing the application rates for FP(1) and FP(2) did not significantly affect their knockdown or virtual extinction performances.

In terms of foam concentrate costs in order to achieve virtual extinction, FP(2) was the cheapest, closely followed by AFFF(1) and FFFP(1). The remainder of the film-formers and S(1) were slightly more expensive. However, for FP(2) and S(1) to achieve this level of performance, they must be applied at higher application rates and for longer periods of time than the film forming foam concentrates. This will involve more water, higher flows, larger volumes of foam concentrate and more foam producing equipment than would be required for film forming foam concentrates.

The most expensive concentrates to use in order to achieve virtual extinction were P(1), P(2) and S(2).

6.1.2 Burnback Performance

(i) 25% Burnback Time

At an operational incident it is likely that foam would be applied to a hydrocarbon fire until the fire had been extinguished. Foam application would then continue for a short while to ensure that a coherent foam blanket had been formed. This is similar to the method employed during this trial where the foam was applied for a further 30 seconds after extinction to provide a standard blanket condition for the burnback test (see Section 2.12). As a result of this, the quality and depth of the foam blankets formed during these trials is likely to be similar to those produced at an operational incident. Consequently, the 25% burnback times recorded during this trial give an indication of the burnback performances that can be expected from foam concentrates used in similar operational conditions.

P(1), FFFP-AR(2) and all three of the FP foam concentrates gave very good 25% burnback times. However, the 25% burnback times of the AFFF, FFFP and S foam concentrates were particularly poor.

Reducing the application rate of FP(2) significantly deteriorated its 25% burnback time. The 25% burnback time of FP(1) was not affected by a reduction in the application rate.

(ii) Burnback Ratio

The results of 25% burnback time do not take into account the amount of time that foam was actually applied to the test fire. During this trial, due to the varying extinction performances of the foam concentrates used, foam application times varied from 2 minutes 2 seconds to 9 minutes 23 seconds. This allowed foam blankets of various depths to be built up. Consequently, those foam concentrates that achieved quick extinctions and hence short foam application times are heavily penalised during the burnback test because only a shallow foam blanket will have been formed. Conversely, those foam concentrates that gave poor extinction performance were able to build up deep foam blankets and so were at an advantage during the burnback tests.

The 25% burnback ratio takes into account the foam application time and provides results that indicate the burnback performance per minute of foam application.

For the 25% burnback ratio results, AFFF-AR(1), AFFF-AR(2), FFFP-AR(2), FP(1), FP(2), FP(3) and P(1) foam concentrates all showed very good resistance to burnback. However, the performances of the AFFF, FFFP, S and P(2) foam concentrates were particularly poor.

Reducing the application rates for FP(1) and FP(2) did not significantly affect their burnback performances.

(iii) Overall Burnback Performance

Overall, FFFP-AR(2), P(1) and all three FP foam concentrates gave good or very good 25% burnback times and 25% burnback ratios.

The foam application times for AFFF-AR(1) and AFFF-AR(2) were considerably shorter than the above foam concentrates. As a consequence of this, they gave good or very good 25% burnback ratios but their 25% burnback times were only average.

The burnback performances of the AFFF, FFFP and S foam concentrates were particularly poor.

6.1.3 Flare Resistance

AFFF-AR(2), FFFP(2), FFFP-AR(1), FP(3), P(1) and P(2) foam concentrates all showed good resistance to flare-ups with either no or only minor flames on the surface of the foam blanket during the burnback test. In contrast, AFFF(2), AFFF-AR(1), FP(1) and FP(2) all produced flare-ups which engulfed more than 25% of the foam surface in large flames during the burnback test.

6.2 Foam Concentrate Performance - Reduced Strength

6.2.1 Virtual Extinction Performance

Only the film forming foam concentrates were used at reduced strength during this trial (see Section 2.1). In almost all cases, using these foams at below the concentration recommended by the manufacturer resulted in longer times to knockdown and virtual extinction.

The virtual extinction performances of some of the foam concentrates appeared to degrade significantly more than others when used at reduced strength. For instance, with AFFF(2) and AFFF-AR(2) the reduction of foam concentration from 3% to 1.5% resulted in extremely poor virtual extinction performances that were no better than those achieved by the protein foam concentrates. In other cases, such as with FFFP(1), knockdown and virtual extinction times did not degrade significantly with the reduction in foam concentrate strength.

6.2.2 Burnback Performance

(i) 25% Burnback Time

There were no improvements in the 25% burnback times of any of the foam concentrates with dilution except for AFFF-AR(2) which gave a very long 25% burnback time when used at 1.5%. The 25% burnback time of FFFP-AR(2) became significantly shorter with dilution. For the remaining foam concentrates, their 25% burnback times did not significantly degrade with dilution.

(ii) 25% Burnback Ratio

There were no improvements in the 25% burnback ratios of any of the foam concentrates with dilution. The 25% burnback ratios of AFFF-AR(1) and FFFP-AR(2) significantly degraded with dilution. For the remaining foam concentrates, their 25% burnback ratios did not significantly degrade with dilution.

(iii) Overall Burnback Performance

Overall, with the exception of AFFF-AR(2), there were no improvements with dilution in the 25% burnback times and 25% burnback ratios of all of the foam concentrates tested. AFFF-AR(2) gave an exceptionally long 25% burnback time when used at

1.5% concentration however its 25% burnback ratio remained similar at 3% and 1.5% concentrations. This was due to the foam application period at 1.5% being twice as long as it was at 3%. These results indicate that the burnback resistance of the AFFF-AR(2) foam blanket was not significantly affected by dilution but by the amount of foam applied to the fire.

The 25% burnback times and 25% burnback ratios of FFFP-AR(2) significantly degraded with dilution. In addition, the 25% burnback ratio of AFFF-AR(1) significantly degraded with dilution. This indicated that the burnback resistance of the foam blanket of AFFF-AR(1) is significantly affected by dilution but increased foam application masked this drop in performance in the 25% burnback times.

The 25% burnback times and 25% burnback ratios of the remaining foam concentrates did not significantly degrade with dilution.

6.2.3 Flare Resistance

When diluted, the resistance to flare-ups of AFFF(1), AFFF(2), FFFP(1) and AFFF-AR(1) all increased while those of AFFF-AR(2) and FFFP(2) decreased. The resistance to flare-ups of FFFP-AR(1) and FFFP-AR(2) did not change.

6.3 Severity of Tests

It is understood that 'safety factors' are built into both the quality of foam concentrates and foam application rates. For foam concentrates, the safety factor may involve the addition of more of the active ingredients than the minimum required to achieve a quick extinction of most hydrocarbon fuel fires. Minimum application rates may involve a safety factor that makes them significantly higher than the critical application rate (see Section 2.2).

These safety factors help to ensure that under severe firefighting conditions the ability of the foam concentrates to extinguish hydrocarbon fires is not seriously affected.

During this trial, care was taken to ensure that almost ideal firefighting conditions were maintained throughout. This involved the use of a symmetrical (round) test tray with no internal obstructions containing a fixed depth of non-flowing fuel, a pre-conceived firefighting tactic carried out by an experienced firefighter, correct application rates with all of the foam produced going on to the test fire, reasonably controlled weather conditions and firefighting equipment operated under closely controlled flow and pressure conditions. All of these controls were necessary to ensure that the primary objective of this trial was met, that was to compare the performance of various foam concentrates when using standard fire service equipment and techniques. Consequently, during this trial the firefighting abilities of some of the foam concentrates (particularly the film formers), when used at full strength, were not severely tested.

The use of foam concentrates at below their recommended concentrations and application rates does, however, begin to closely examine the abilities of foam concentrates under difficult conditions.

Testing foam concentrates at reduced concentration was mainly carried out during this trial to provide large scale fire tests data that could be compared with results from the ISO and CEN fire tests (see Section 2.1).

Testing foam concentrates at reduced application rates was only carried out with FP(1) and FP(2) foam concentrates.

The results of the reduced concentration tests show that generally, firefighting and burnback performance degrades with dilution. With some foam concentrates this degradation is not too significant, with others the effects are severe.

The results of the lower application rates for FP(1) indicated only relatively minor differences in performance, with the performance at 4 lpm/m^2 being only slightly worse than applied at 5 lpm/m^2. However, for FP(2) the 25% burnback time achieved at 4 lpm/m^2 was greatly inferior to that achieved when the foam was applied at 5 lpm/m^2. This may be partially due to the fact that foam was applied for 30% longer during the higher application rate test. The 25% burnback ratio results indicate similar burnback performance at both application rates.

In addition, the differences in foam quality caused by the changes in branchpipe operating conditions necessary to achieve these application rates may be a factor in the performances of the FP foam concentrates (see section 6.8).

Although these results appear to suggest that some foam concentrates can be used at reduced concentrations or application rates, it should be remembered that these fire tests were carried out in almost perfect firefighting conditions. At an operational incident, where there are many unknowns and barely controllable circumstances, firefighting can be considerably more difficult. Consequently, to ensure that the apparent safety factors shown during these tests come in to play, foam must always be applied at the recommended application rates and at the recommended concentration.

6.4 Burnback-Only Tests

The results on the burnback-only tests provide valuable information on the performance of foams when used to provide protection of hydrocarbon spills where fire is not involved. During these tests, foam was applied gently to the surface of the test fuel. However, the results indicate that a considerable amount of contamination of the foam blankets occurred for each of the foam concentrates tested.

During each test, within 10 seconds of the burnback torch being applied to the foam surface, small flames began to spread around the tray edge and over the surface of the foam blanket.

For AFFF(1) where foam was applied to the fuel surface for 1 minute only, over 75% of the foam blanket area was involved in large flames within 28 seconds of the burnback flame being applied. This was a very severe fire but involved only the foam surface, none of the test fuel had been exposed. If this occurred at an operational incident, such as at a road traffic accident where a spill had been covered with foam, the quick escalation of such of fire could easily lead to injury and loss of life. The ignition source at such an incident could be anything from a hot object to sparks from vehicle electrical equipment.

For AFFF(1), FFFP(1) and FP(1) where foam was applied for 2 minutes, the areas of foam blanket involved in flare-ups were between 25% and 35% of the tray area. However, these were still severe fires.

Doubling the application time for AFFF(1) resulted in a halving of the area involved in a flare-up and greatly increased the time before the flare occurred.

FP(1) gave a burnback time that was twice that of AFFF(1) and FFFP(1). The 25% burnback time for AFFF(1) after 2 minutes of foam application was more than twice the time it achieved after 1 minute of foam application.

These results indicate that doubling the foam application time to a hydrocarbon spill may as much as double the burnback resistance, decrease the intensity of a flare-up and increase the time between any ignition of the contaminated foam surface and a peak flare up. FP offered much better burnback resistance than AFFF and FFFP, however a peak flare occurred much sooner on the surface of the FP foam blanket than on the others.

Although not investigated during this trial, it is likely that gentle application of foam other than directly to the surface of a hydrocarbon spill would result in less contamination of the foam blanket and consequently better flare resistance and burnback resistance. At an operational incident, this should be the preferred method of foam application.

When comparing the results of the burnback-only test with those of the usual FEU burnback test performed after extinction, the 25% burnback ratio results give similar but generally slightly improved burnback performances for the foam concentrates during the burnback-only tests. However, the 25% burnback times achieved during the burnback-only tests are slightly shorter. These differences in results are probably due to the shorter foam application times used during the burnback-only tests.

Burnback-only tests would effectively double the number of tests carried out during large scale fire tests if both extinction and burnback performance assessments needed to be made. However, the indications are that the results achieved during these trials for burnback were similar from both burnback methods when assessed using either the 25% burnback time or 25% burnback ratio determinations. Further burnback-only tests are required to further assess the merits of this method (if any) over the existing FEU method.

6.5 Comparison of Burnback Assessment Methods

Two methods of assessing the burnback performances of the foam concentrates were used during this trial. These were 25% burnback time and 25% burnback ratio. Generally, the graded results from the two methods agreed very closely. The only noticeable exception to this was AFFF-AR(2) at 3% which achieved an average 25% burnback time but a very good 25% burnback ratio. The extinction time and hence the foam application time for this test was relatively short and so only a thin foam blanket was formed. Consequently, the 25% burnback time result penalises AFFF-AR(2) for its quick extinction whereas the 25% burnback ratio takes this into account.

When comparing the results of the burnback-only test with those of the usual FEU burnback test performed after extinction, the 25% burnback ratio results give similar but generally slightly improved burnback performances for the foam concentrates during the burnback-only tests. However, the 25% burnback times achieved during the burnback-only tests are slightly shorter. These differences in results are probably due to the shorter foam application times used during the burnback-only tests (see Section 6.4).

The 25% burnback time results provide information on the burnback performances that can be expected from foam concentrates used in operational conditions where foam application ceases soon after extinction or once a coherent foam blanket has been formed on a spill. However, the 25% burnback ratios provide results that indicate the burnback performance per minute of foam application and so give an absolute comparison of burnback only. Consequently, both assessment methods provide valuable information on two different aspects of the burnback performances of foam concentrates.

6.6 Repeatability of Tests

Where tests have been repeated with the same branchpipe, foam concentrate and foam application rate, there were variations in the results. A minimum of three tests employing the same conditions is ideally required to assess repeatability, although more are desirable. However, the size and cost of the test impose practical limits. When planning this trial, it was decided that, due to the number of foam concentrate type/foam concentration/application rate combinations that required investigation, only one test could be carried out for each condition. Three additional tests were reserved for tests of repeatability.

Wherever possible, test conditions and procedures were standardised. However, in large scale outdoor tests of this kind, temperatures and wind conditions cannot be controlled and these contribute to the variability of the test results.

Analysis of the results of the repeated tests revealed that the 100% extinction times and the burnback times varied greatly. 100% extinction times were heavily dependant on the tactics employed by the firefighter after 99% extinction and appeared to have little to do with the properties of the foam concentrates used. Some of the burnback times appeared to be heavily influenced by the foam application time during the extinction phase of the test.

Consequently, virtual extinction times, 25% burnback times and 25% burnback ratios were used along with performance gradings to compare the results of these tests. Using these, results of repeated tests fell within either the same or adjacent performance grades to produce a reasonable level of repeatability. This was also true of the 90% extinction results which were used to produce knockdown performance gradings.

The results for flare resistance were not as repeatable. Results for each repeated test vary greatly. For AFFF(2) for instance, when repeated the first test resulted in a burnback with no flares, the second test resulted in a flare that covered 50% of the foam blanket. However, the foam application period for the first test was more than twice as long as that for the second test. As discussed in Section 6.4, a longer application time appears to result in reduced burnback flares.

6.7 Tactics of Foam Application

During this trial, foam was applied directly to the fuel surface as gently as possible without the use of a frontplate or backplate. Direct application is the most testing condition likely to be experienced operationally because, in practice, there may be surfaces on to which the foam stream can be directed so that the foam flows more gently on to the fuel surface.

As discussed in Section 6.6, 100% extinction was influenced more by the tactics of the firefighter after 99% extinction had been achieved than by the properties of the foam tested. Generally, the last remaining flames were along the edge of the tray nearest to the firefighter. Due to the height of the tray sides, the firefighter either had to feather the foam just over the tray edge or move around the tray in order to apply foam directly to the remaining flames. In such circumstances, the use of medium expansion foam with its gentler application and lower flow rate may be of benefit in extinguishing these final flames.

During this trial, a commercially available combined low and medium expansion foam branchpipe was used to extinguish one of the fires at the end of a burnback test. However, the poor quality of the foam produced by it, especially the low expansion foam, resulted in very poor firefighting performance and did not adequately demonstrate the possible advantages of using medium expansion at the later stages. Due to the poor performance of this branch, the results of the above test are not discussed further in this report and a full fire test was not carried out with it. The foam branchpipe used has now been withdrawn from sale by the manufacturers. FEU are currently investigating the possibility of designing and producing a combined low and medium expansion branchpipe.

6.8 Branchpipes

Comparisons of the foam quality of FP(1) and FP(2) foam concentrates used through the F225H branch at 225 lpm and 281 lpm show that the increase in flow resulted in a slightly lower expansion ratio and a much longer drainage time. It is difficult to assess the effects that this change in foam quality had on the extinction performances of these foams because the application rates necessarily changed as well.

The F450H produced foam that appeared to be of reasonable quality, however, FEU have not previously carried out any comparison tests involving this branch.

6.9 Use of a Water Base and Various Fuel Depths

Three tests were carried out to briefly investigate the effects of fuel depth and the presence of a water base on firefighting performance. Only one test was carried out for each water base fuel depth combination using just one foam concentrate, AFFF(1).

From these results it was tentatively concluded that the firefighting performance of AFFF(1) was not significantly affected by the use of a water base or by the depth of fuel. Consequently, 1400 litres of petrol floating on a 1400 litre water base was used for each test.

The results of these three tests must, however, be treated with caution. It should not be concluded that a water base or depth of fuel have no effects on firefighting foam performance. Only one foam concentrate was considered for these preliminary tests and as such the above conclusion can only be valid for AFFF(1) and only for fuel depths up to 50mm. It may be that had another concentrate been used for these tests, such as a fluoroprotein, then the results may have been very different. Unfortunately, there was no time to investigate the effects of water bases or depths of fuel on the firefighting performances of other foam types during this trial.

6.10 Discussion of Equipment and Trials Technique

6.10.1 Tray Design

The tray design and the modifications made to the height of the tray walls were satisfactory. However, there was some damage to the sealant used between the steel rim and the tray base which required replacement after the trial.

The increase in the tray height prevented almost all washout of fuel and foam during foam application. It also prevented the foam applied into the tray overflowing into the surrounding bund.

6.10.2 Instrumentation

The instrumentation proved to be satisfactory. However, the problem of the background level of the radiometers changing with ambient light reoccurred (see Reference 8). The use of sapphire windows to eliminate these variations in background levels needs to be investigated.

The radiometers, water pumps, water tanks, metal radiation shields, associated cables and mounting poles required repositioning regularly with changes in wind direction. This became a laborious task requiring the trials to be delayed for long periods of time while the equipment was dismantled, reassembled and tested. It is desirable that the whole of the above radiometer system be mounted on to two trolleys (one trolley for each set of two radiometers) to allow repositioning to be carried out quickly and easily. Also, to save time in winding in and letting out signal cables to the radiometers, a telemetry system would be advantageous and should be investigated.

6.10.3 Video Equipment

As in previous trials (Reference 8), the use of the Skystalk camera proved the most useful camera angle for data analysis. However the second camera, which was mounted on the roof of the instrumentation van, gave a less useful camera angle due to it being situated considerably nearer to the ground than the Skystalk. The positioning of this second camera was also restricted by the need for the instrumentation van to be situated on the hard standing to the upwind side of the fire tray.

Ideally, the view from the skystalk should be supplemented by a second camera at a similar height and with a field of view to cover the opposite side of the tray.

7. CONCLUSIONS

It was only possible to test each of the foam concentrates against one Class B fuel in a controlled and almost ideal firefighting environment. Consequently, care must be taken in applying these conclusions to other circumstances.

In order to achieve optimum fire fighting performance, foam concentrates should always be used at the manufacturers recommended concentrations and at least the minimum application rates recommended in DCO Letter 10/91. The conclusions for foam concentrates used in this way are:-

1. All of the film forming foam concentrates (AFFF, AFFF-AR, FFFP and FFFP-AR) gave quick and progressive knockdowns and virtual extinctions. Quick knockdowns were also achieved by one of the synthetic and one of the FP foam concentrates tested.

2. Generally, the non-film forming foam concentrates (FP, P and synthetic) gave significantly slower knockdowns and virtual extinctions than achieved by the film forming foam concentrates.

3. All three FP, one of the FFFP-AR and one of the P foam concentrates gave very good burnback performances. Both AFFF-AR foam concentrates also gave very good burnback performances when their relatively short foam application times were taken into account.

4. All of the AFFF, FFFP and S foam concentrates gave poor burnback performances.

5. The burnback performances of all of the foam concentrate types tested were affected to some extent by fuel contamination. Foam must always be applied as gently as possible to minimise foam contamination.

Foam should be applied to hydrocarbon spills as gently as possible to prevent contamination of the foam blanket and should continue for as long as possible to produce a very thick protective foam layer. Precautions should be taken to ensure that any ignition source does not come into contact with the foam blanket. Should contaminated foam ignite, then large areas of the foam blanket are likely to be become involved in intense flames within seconds. The shorter and more forceful the foam application, the more severe any resulting flare-up is likely to be. FP gives much better burnback performance than AFFF or FFFP in such situations but is likely to become involved more quickly in a flare-up should one occur.

When foam concentrates were used at below their recommended concentrations or application rates, firefighting and burnback performances began to degrade. With some foam concentrates the degradation was not too significant, with others the effects were severe. The results of this trial indicate that safety factors are evident in both the recommended application rates and in the quality of foam concentrates. These safety factors ensure that, under severe firefighting conditions, the ability of foam concentrates to extinguish hydrocarbon fires is not seriously diminished. In general, the safety factor can expected to be higher for better quality foam concentrates.

Despite these tests only involving one firefighting situation, the results do at least provide the fire service with a basis for comparing the relative performance of various types of foam concentrate. The results also show that large variations in performance can be expected from different products of the same foam type.

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3. Dear Chief Officer Letter 10/91, Firefighting Foam: Foam Application Rates. Home Office, 1991.

4. Home Office (Fire Dept), Manual of Firemanship, Book 3, Her Majesty's Stationery Office, 1990.

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6. SRDB Publication 40/87, Additives for Hose Reel Systems: Trials of Foam on 40 m^2 Petrol Fires, J A Foster, 1987.

7. FRDG Publication 5/92, The Use of Foam Against Large Scale Petroleum Fires Involving Lead-Free Petrol, J A Foster, 1992, ISBN 0-86252-701-5.

8. SRDB Publication 9/87, Pilot Study on low Expansion Foam-making Branchpipes, B P Johnson and P L Parsons, Sept. 1986.

NOTES

1. The foam standards being produced by both ISO and CEN are as follows:-

   - Specification for low expansion foam concentrates for top application to water-immiscible liquids.

   - Specifications for medium and high expansion foam concentrates.

   - Specification for low expansion foam concentrates for top application to water-miscible liquids.

2. Virtual extinction is the term used by FEU to describe the point in time at which the remaining flames had been restricted to 5% or less of the tray side. In addition, very small areas of flame on the foam surface elsewhere in the tray were allowed if it was considered that these would have been easily extinguished by a quick change of tactic as occurred during some of the later tests.

   After virtual extinction had been achieved, complete extinction of the remaining flames was shown during this trial to be due to the expertise of the firefighter and his tactics rather than any particular properties of the foams used.

3. Mobil Oil Company Limited, Coryton Terminal, Stanford-le-Hope, Essex.

4. P&O Roadtanks Limited, Victoria Road, Stanford-le-Hope, Essex, SS17 0JB.

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

6. J W Automarine, Hempstead Road, Holt, Norfolk. 24,000 Litre Flexi-dam, Model Number SP24000FD.

7. Endress and Hauser Limited, Ledson Road, Manchester. 80mm electromagnetic flowmeter - Type Pulsmag V.

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

9. Endress and Hauser Limited, Ledson Road, Manchester. 15mm electromagnetic flowmeter - Type Picomag.

10. Piezometer tube constructed to FEU requirements.

11. RS Components Limited, Corby, Northants.
    Pressure sensor, RKC model PRT/AF4.

12. TC Limited, PO Box 130, Cowley Mill Trading Estate, Longbridge Way, Uxbridge, UB8 2YS. Temperature sensor 16-1-3-100-CE4L-R100-1/5-2 MTR.

13. TC Limited, PO BOX 130, Cowley Mill Trading Estate, Longbridge Way, Uxbridge UB8 2YS. Digital temperature indicator AF4NR-MA5.

14. RS Components Limited, Corby, Northants. Digital pressure indicator type 646-763.

15. Comark, Rustington, Sussex. Intrinsically safe Ni-Cr/Ni-Al thermometer, Type 3006.

16. Vector Instruments Limited, Marsh Road, Rhyl, Clywd. Wind speed and direction indicator D600/120.

17. Skye Instruments Limited, Unit 5, Dbole Industrial Estate, Llandrindrod Wells, Powys, LD1 6DF. Air temperature and humidity sensor SKH 2013.

18. Rickadinki Mitsui Electronics (UK) Limited, Oakcroft Road, Chessington, Surrey, KT9 1SA. Multipen recorder type R-300 series, Model 83.

19. Solatron Instruments, Victoria Road, Farnborough, Hampshire. Orion data logger Type 3531D.

20. Met-check, PO Box 284, Bletchley, Milton Keynes, MK17 0QD. Wind sock 4 ft polyurethane.

21. Cloud Nine (Photographic Services) Limited, Unit 9, Old Great North Road, Sutton-on Trent, Newark, Notts, NG23 6QS. Skystalk mast.

22. Hitachi Denshi (UK) Limited, 13-14 Garrick Industrial Centre, Garrick Road, London, NW9 9AP. Colour video camera type C2.

23. Sony (UK) Limited, South Street, Staines, Middlesex. Hi-band 'U'-matic video recorder BVU 950P.

24. Maine Engineering, Howe Park, Kings Langley, Herts. Model SD1200L. This company no longer makes these clocks.

25. Parr Scientific Limited, 594 Kingston Road, Raynes Park, London. Medtherm Heat Flux Transducers types 64-10-20 and 64-1-20.

26. Interdab Limited. The Maltings Industrial Estate, South Minster, Essex CM0 7EQ. Model Jet100M.

27. The time taken for 25% of the area of the foam blanket to be completely eroded by flames to reveal burning fuel below is recorded by observers as the 25% burnback time. Times to 50% and 100% burnback (by area) are also recorded.

Radiometers are also used for recording burnback progress. For these, the time taken for the radiated heat to reach 25% of its preburn level is recorded as the 25% burnback time. Times to 50% and 100% burnback (by radiated heat) are also recorded. In all cases, timing commences from the application of the burnback flame to the foam blanket.

During this trial, the burnback times recorded by observers and obtained from the radiometers were very similar. The radiometer results are generally quoted in this report.

FEU CODE NAME	TRADE NAME	MANUFACTURER	COST PER LITRE[1] (£)
AFFF(1)	Lightwater FC 203	3M Chemicals Division, Manchester	2.54
AFFF(2)	Tridol-S FO305GO	Angus Fire Armour Limited, Thame, Oxfordshire	2.76
AFFF-AR(1)	Lightwater ATC FC 600	3M Chemicals Division, Manchester	2.48
AFFF-AR(2)	Universal	Chubb Fire Engineering, High Wycombe	2.57
FFFP(1)	Petroseal FO801GO	Angus Fire Armour Limited, Thame, Oxfordshire	2.76
FFFP(2)	Centrifoam 903	Croda Kerr Limited, Kirkby, Liverpool	2.68
FFFP-AR(1)	Alcoseal FO704GO	Angus Fire Armour Limited, Thame, Oxfordshire	3.13
FFFP-AR(2)	Centrifoam A936	Croda Kerr Limited, Kirkby, Liverpool	3.07
FP(1)	FP70 FO201GO	Angus Fire Armour Limited, Thame, Oxfordshire	1.05
FP(2)	Plus-F	Chubb Fire Engineering, High Wycombe	0.83
FP(3)	Sabo Fluoroprotein	Sabo, Italy	----[2]
P(1)	Nicerol-HC FO103GO	Angus Fire Armour Limited, Thame, Oxfordshire	0.90
P(2)	Profoam 803	Croda Kerr Limited, Kirkby, Liverpool	0.75
S(1)	Expandol FO401GO	Angus Fire Armour Limited, Thame, Oxfordshire	0.97
S(2)	Hex S	Chubb Fire Engineering, High Wycombe	1.43

NOTES TO TABLE 1 :

1. These costs are per litre of foam concentrate as charged to FEU during February 1992; they do not include VAT or delivery charges.
2. This foam concentrate was supplied to FEU by a Local Authority Fire Brigade free of charge.

TABLE 1 : Details of Foam Concentrates Used

TEST NO.	FOAM TYPE AND NORMAL USE CONC	CONC USED	BRANCH	APP. RATE LPM/M^2	TEMPERATURE °C			EXTINCTION TIMES					BURNBACK TIMES[1]			
					Air	Water Base	Fuel	90%	95%	Virtual Ext.	100%	Foam App. Period	25%	50%	75%	100%[3]
1	AFFF(1) 3%	3%	F225H	4	14.6	–	10	54s	1m 3s	1m 10s	2m 12s	2m 43s	2m 50s	2m 56s	3m 3s	3m 18s
2[3]	AFFF(1) 3%	3%	F225H	4	18.0	–	8	59s	1m 1s	1m 29s	4m 16s	4m 48s	4m 57s	5m 5s	5m 13s	5m 34s
3	AFFF(1) 3%	2%	F225H	4	21.5	–	10	52s	57s	1m 26s	1m 31s	2m 2s	1m 38s	1m 54s	2m 7s	2m 31s
4	AFFF(2) 3%	3%	F225H	4	12.8	18	12	55s	1m 19s	2m 24s	7m 21s	7m 53s	3m 36s	3m 44s	3m 54s	4m 3s
5	AFFF(2) 3%	2%	F225H	4	14.9	20	13	1m 25s	1m 30s	2m 53s	7m 30s	8m	5m 33s[4]	5m 55s[4]	6m 18s[4]	6m 39s[4]
6	AFFF(1) 3%	1.5%	F225H	4	17.8	23	15	1m 24s	1m 29s	2m 29s	4m 2s	4m 33s	2m 26s	3m 9s	3m 27s	3m 27s
7	AFFF(2) 3%	1.5%	F225H	4	18.4	25	17	4m 23s	4m 28s	5m 14s	5m 49s	6m 19s	3m 21s	3m 36s	3m 45s	4m 9s
8[5]	FFFP(1) 3%	3%	F225H	4	17.0	30	17	59s	1m 34s	2m 5s	6m 29s	6m 35s	5m 9s	5m 18s	5m 28s	5m 49s
9	FFFP(1) 3%	2%	F225H	4	17.4	20	17	1m 26s	1m 32s	1m 58s	8m 48s	9m 18s	4m 49s	5m 6s	5m 37s	6m 7s
10	FFFP(2) 3%	3%	F225H	4	20.5	24	17	1m 12s	1m 20s	2m 8s	7m 22s	7m 58s	5m 55s	6m 18s	6m 27s	6m 39s
11	FFFP(2) 3%	2%	F225H	4	22.8	26	16	1m 30s	1m 55s	2m 17s	6m 17s	6m 47s	4m 39s	5m 29s	6m 12s	6m 23s
12	FFFP-AR(1) 3%/6%	3%	F225H	4	14.6	19	12	57s	1m 4s	1m 40s	3m 1s	3m 31s	6m 57s	7m 11s	7m 42s	8m 7s
13	FFFP-AR(1) 3%/6%	2%	F225H	4	16.9	22	16	56s	1m 2s	2m 12s	5m 6s	5m 36s	5m 35s	5m 47s	5m 58s	6m 4s
14	FFFP-AR(2) 3%/6%	3%	F225H	4	19.6	21	19	55s	1m 2s	1m 36s	4m 18s	4m 48s	10m 21s	10m 34s	10m 45s	11m 9s
15	FFFP-AR(2) 3%/6%	2%	F225H	4	21.5	26	19	1m 28s	1m 50s	2m 27s	4m 11s	5m 3s	4m 21s	4m 41s	6m 28s	6m 33s
16	AFFF-AR(1) 3%/6%	3%	F225H	4	14.8	19	16	59s	1m 4s	1m 55s	3m 8s	3m 38s	8m 21s	8m 40s	8m 57s	9m 2s

TABLE 2 : Results of Tests : Extinction and Burnback Times in Chronological Order

TEST NO.	FOAM TYPE AND NORMAL USE CONC	CONC USED	BRANCH	APP. RATE LPM/M²	TEMPERATURE °C			EXTINCTION TIMES					BURNBACK TIMES[5]			
					Air	Water Base	Fuel	90%	95%	Virtual Ext.	100%	Foam App. Period	25%	50%	75%	100%[3]
17	AFFF-AR(1) 3%/6%	2%	F225H	4	18.8	25	18	1m 25s	1m 29s	1m 49s	3m 13s	3m 42s	4m 59s	5m 7s	5m 13s	5m 21s
18	AFFF-AR(2) 3%/6%	3%	F225H	4	17.0	19	10	57s	1m 11s	1m 44s	1m 52s	2m 23s	8m 9s	8m 30s	8m 42s	9m 8s
19	AFFF-AR(2) 3%/6%	2%	F225H	4	18.8	23	13	1m 9s	1m 13s	2m 50s	2m 59s	3m 29s	6m 43s	7m 26s	7m 45s	8m 13s
20	FP(1) 3%	3%	F225H	5	15.2	19	12	1m 38s	1m 57s	3m 48s	4m 15s	4m 45s	11m 58s	12m 21s	12m 54s	13m
21	FP(2) 3%	3%	F225H	5	16.4	24	14	56s	1m 1s	2m 44s	3m 50s	4m 21s	12m 24s	12m 37s	12m 48s	13m 4s
22	FFFP(1) 3%	3%	F225H	4	17.4	22	13	57s	1m 1s	4m 33s	4m 33s	5m 3s	4m 45s	5m 5s	5m 17s	5m 44s
23	FFFP(2) 3%	3%	F225H	4	18.8	21	14	53s	57s	1m 37s	4m 21s	4m 51s	6m 2s	6m 13s	6m 24s	6m 31s
24	P(1) 3%	3%	F450H (8)	6.5	13.8	17	9	2m 44s	4m 16s	6m 4s	6m 47s	7m 17s	14m 56s	15m 6s	15m 23s	15m 33s
25	P(2) 3%	3%	F450H (8)	6.5	15.2	19	12	6m 59s	7m 35s	7m 54s	8m 53s	9m 23s	7m 44s	8m 17s	8m 23s	8m 41s
26[6]	S(1) 3%	3%	F450H (8)	6.5	16.2	24	12	43s	2m 48s	2m 59s	3m 36s	4m 16s	3m 53s	4m 2s	4m 11s	4m 34s
27	S(2) 3%	3%	F450H (8)	6.5	12.4	17	11	1m 5s	2m 3s	5m	5m 6s	6m 9s	5m 29s	5m 46s	6m 1s	6m 11s
28	AFFF-AR(2) 3%/6%	1.5%	F225H	4	13.2	17	11	2m 41s	2m 45s	3m 40s	4m 27s	4m 57s	13m 59s	14m 18s	14m 31s	14m 57s
29	AFFF-AR(1) 3%/6%	1.5%	F225H	4	13.4	17	10	1m 39s	2m 4s	2m 26s	3m 44s	4m 14s	6m 15s	6m 39s	6m 48s	7m 3s
30	FFFP-AR(1) 3%/6%	1.5%	F225H	4	16.0	19	9	1m 29s	1m 53s	2m 22s	3m 13s	3m 43s	5m 55s	6m 7s	6m 22s	6m 33s
31	FFFP-AR(2) 3%/6%	1.5%	F225H	4	16.1	19	11	1m 59s	2m 1s	2m 48s	3m 19s	3m 49s	4m 33s	5m 2s	5m 24s	5m 31s
32	FFFP(1) 3%	1.5%	F225H	4	18.2	23	15	1m 2s	1m 19s	1m 46s	2m 23s	2m 53s	3m 12s	3m 16s	3m 30s	3m 37s

TABLE 2 (Continued): Results of Tests : Extinction and Burnback Times in Chronological Order

TEST NO.	FOAM TYPE AND NORMAL USE CONC	CONC USED	BRANCH	APP. RATE LPM/M^2	TEMPERATURE °C			EXTINCTION TIMES					BURNBACK TIMES[1]			
					Air	Water Base	Fuel	90%	95%	Virtual Ext.	100%	Foam App. Period	25%	50%	75%	100%[2]
33	FFFP(2) 3%	1.5%	F225H	4	19.5	19	16	1m 45s	1m 48s	2m 2s	3m 39s	4m 10s	4m 15s	4m 34s	4m 52s	5m 7s
34[7]	AFFF(1) 3%	3%	F225H	4	18.8	22	15	—	—	—	—	1m	1m 22s	1m 29s	1m 37s	1m 44s
35	FP(1) 3%	3%	F225H	4	15.2	19	15	1m 57s	2m 33s	3m 41s	4m 18s	4m 48s	11m 36s	11m 49s	11m 58s	12m 20s
36	FP(2) 3%	3%	F225H	4	19.2	21	19	1m 12s	1m 38s	2m 37s	2m 49s	3m 19s	5m 12s	5m 33s	6m 34s	6m 42s
37	AFFF(2) 3%	3%	F225H	4	12.2	17	11	46s	49s	1m 36s	2m 52s	3m 22s	4m	4m 6s	4m 14s	4m 36s
38	AFFF(1) 3%	3%	F225H	4	13.2	18	14	45s	49s	1m 29s	3m 55s	4m 25s	6m 15s	6m 25s	6m 51s	7m 4s
39	FP(3) 6%	6%	F225H	5	16.4	19	14	2m 16s	2m 42s	3m 44s	4m 10s	4m 40s	12m 9s	12m 21s	12m 28s	12m 51s
40[7]	FP(1) 3%	3%	F225H	4	17.5	21	12	—	—	—	—	2m	6m 49s	7m 14s	7m 29s	7m 35s
41[7]	AFFF(1) 3%	3%	F225H	4	19.7	20	16	—	—	—	—	2m	3m 11s	3m 18s	3m 24s	3m 34s
42[7]	FFFP(1) 3%	3%	F225H	4	13.8	17	7	—	—	—	—	2m	3m 27s	3m 47s	4m 9s	4m 36s
43[8]	AFFF(1) 3%	3%	F225H	4	16.3	–	10	44s	53s	1m 39s	3m 7s	3m 37s	5m 44s	6m	6m 8s	6m 13s

NOTES FOR TABLE 2:

1. All burnback times ignore any flares that may have occurred. Details of flares are given in Tables 3, 4 and 5.
2. 100% or maximum burnback.
3. 2800 litres of petrol floating on a 1400 litre water base used during this test.
4. Burnback flame not used during Test 5 due to re-ignition of the test fuel 1 minute 30 seconds after extinction.
5. Firefighter experienced problems applying all of the foam stream on to the fire at the beginning of Test 8.
6. Burnback flame not used during Test 26 due to re-ignition of the test fuel 1 minute 43 seconds after extinction.
7. Burnback-only tests.
8. 2800 litres of petrol with no water base used during this test.

TABLE 2 (Continued): Results of Tests : Extinction and Burnback Times in Chronological Order

FOAM TYPE AND NORMAL USE CONC.	CONC. USED	TEST NO.	APP. RATE lpm/m^2	EXTINCTION					25% BURNBACK				
				90%	95%	Virtual Ext.	100%	Foam App. Period	Time of 25% Flare Radiometers	Max Flare and Time Radiometers	Time of 25% Area Flare Observed	Max Flare Area and Time Observed	25% BB (Ignores Flare) Radiometers
AFFF (1) 3%	3%	1	4	54s	1m 3s	1m 10s	2m 12s	2m 43s	—	7% 49s	—	10% 49s	2m 50s
		2[1]	4	59s	1m 1s	1m 29s	4m 16s	4m 48s	—	8% 3m 59s	—	10% 3m 59s	4m 57s
		34[2]	4	—	—	—	—	1m	16s	39% 28s	12s	75% 28s	1m 22s
		38	4	45s	49s	1m 29s	3m 55s	4m 25s	—	6% 4m 4s	4m 4s	25% 4m 4s	6m 15s
		41[2]	4	—	—	—	—	2m	—	12% 1m 53s	1m 49s	35% 1m 53s	3m 11s
		43[3]	4	44s	53s	1m 39s	3m 7s	3m 37s	—	19% 4m 53s	4m 53s	25% 4m 53s	5m 44s
	2%	3	4	52s	57s	1m 26s	1m 31s	2m 2s	—	—	—	3% 30s	1m 38s
	1.5%	6	4	1m 24s	1m 29s	2m 29s	4m 2s	4m 33s	—	2% 1m 38s	—	—	2m 26s
AFFF (2) 3%	3%	4	4	55s	1m 19s	2m 24s	7m 21s	7m 53s	—	—	—	—	3m 36s
		37	4	46s	49s	1m 36s	2m 52s	3m 22s	—	7% 2m 44s	1m 51s	50% 1m 59s	4m
	2%	5[4]	4	1m 25s	1m 30s	2m 53s	7m 30s	8m	—	6% 3m 54s	—	10% 3m 54s	5m 33s
	1.5%	7	4	4m 23s	4m 28s	5m 14s	5m 49s	6m 19s	—	—	—	1% 1m 23s	3m 21s
AFFF-AR (1) 3%/6%	3%	16	4	59s	1m 4s	1m 55s	3m 8s	3m 38s	—	3% 6m 48s	6m 42s	50% 6m 48s	8m 21s
	2%	17	4	1m 25s	1m 29s	1m 49s	3m 13s	3m 42s	—	5% 2m 31s	2m 27s	30% 2m 31s	4m 59s
	1.5%	29	4	1m 39s	2m 4s	2m 26s	3m 44s	4m 14s	—	—	—	10% 1m 39s	6m 15s
AFFF-AR (2) 3%/6%	3%	18	4	57s	1m 11s	1m 44s	1m 52s	2m 23s	—	—	—	—	8m 9s
	2%	19	4	1m 9s	1m 13s	2m 50s	2m 59s	3m 29s	—	16% 2m 42s	2m 41s	30% 2m 42s	6m 43s
	1.5%	28	4	2m 41s	2m 45s	3m 40s	4m 27s	4m 57s	—	9% 28s	—	20% 28s	13m 59s

NOTES TO TABLE 3:

1. 2800 litres of petrol floating on a 1400 litre water base used during this test.
2. Burnback-only tests.
3. 2800 litres of petrol with no water base used during this test.
4. Burnback flame not used during Test 5 due to re-ignition of fuel 1 minute 30 seconds after extinction.

TABLE 3 : Results of Tests : Extinction and 25% Burnback Times (Including Flare Details) for AFFF and AFFF-AR Foam Concentrates

FOAM TYPE AND NORMAL USE CONC.	CONC. USED	TEST NO.	APP. RATE lpm/m^2	EXTINCTION					25% BURNBACK				
				90%	95%	Virtual Ext.	100%	Foam App. Period	Time of 25% Flare Radiometers	Max Flare and Time Radiometers	Time of 25% Area Flare Observed	Max Flare Area and Time Observed	25% BB (Ignores Flare) Radiometers
FFFP (1) 3%	3%	8[1]	4	59s	1m 34s	2m 5s	6m 5s	6m 35s	—	—	—	—	5m 9s
		22	4	57s	1m 1s	1m 25s	4m 33s	5m 3s	—	—	—	10% 2m 27s	4m 45s
		42[2]	4	—	—	—	—	2m	—	16% 1m	1m	25% 1m	3m 27s
	2%	9	4	1m 26s	1m 32s	1m 58s	8m 48s	9m 18s	—	—	—	—	4m 49s
	1.5%	32	4	1m 2s	1m 19s	1m 46s	2m 23s	2m 53s	—	—	—	—	3m 12s
FFFP (2) 3%	3%	10	4	1m 12s	1m 20s	2m 8s	7m 22s	7m 58s	—	—	—	—	5m 55s
		23	4	53s	57s	1m 37s	4m 21s	4m 51s	—	—	—	5% 48s	6m 2s
	2%	11	4	1m 30s	1m 55s	2m 17s	6m 17s	6m 47s	—	6% 3m 6s	—	20% 3m 6s	4m 39s
	1.5%	33	4	1m 45s	1m 48s	2m 2s	3m 39s	4m 10s	—	15% 48s	46s	50% 48s	4m 15s
FFFP-AR (1) 3%/6%	3%	12	4	57s	1m 4s	1m 40s	3m 1s	3m 31s	—	—	—	1% 1m 7s	6m 57s
	2%	13	4	56s	1m 2s	2m 12s	5m 6s	5m 36s	—	—	—	5% 3m 46s	5m 35s
	1.5%	30	4	1m 29s	1m 53s	2m 22s	3m 13s	3m 43s	—	—	—	1% 33s	5m 55s
FFFP-AR (2) 3%/6%	3%	14	4	55s	1m 2s	1m 36s	4m 18s	4m 48s	—	5% 4m 14s	—	10% 7m 57s	10m 21s
	2%	15	4	1m 28s	1m 50s	2m 27s	4m 11s	5m 3s	—	4% 2m 52s	2m 47s	40% 2m 52s	4m 21s
	1.5%	31	4	1m 59s	2m 1s	2m 48s	3m 19s	3m 49s	—	6% 3m 37s	—	10% 2m 13s	4m 33s

NOTES TO TABLE 4:

1. Firefighter experienced problems applying all of the foam stream to the fire during this test.
2. Burnback-only test

TABLE 4 : Results of Tests : Extinction and 25% Burnback Times (Including Flare Details) for FFFP and FFFP-AR Foam Concentrates

FOAM TYPE AND NORMAL USE CONC.	CONC. USED	TEST NO.	APP. RATE lpm/m^2	EXTINCTION					25% BURNBACK				
				90%	95%	Virtual Ext.	100%	Foam App. Period	Time of 25% Flare Radiometers	Max Flare and Time Radiometers	Time of 25% Area Flare Observed	Max Flare Area and Time Observed	25% BB (Ignores Flare) Radiometers
FP (1)	3%	20	5	1m 38s	1m 57s	3m 48s	4m 15s	4m 45s	—	15% 8m	8m	25% 8m	11m 58s
	3%	35	4	1m 57s	2m 33s	3m 41s	4m 18s	4m 48s	—	—	—	5% 4m 57s	11m 36s
		40[1]	4	—	—	—	—	2m	—	9% 17s	14s	30% 17s	6m 49s
FP (2)	3%	21	5	56s	1m 1s	2m 44s	3m 50s	4m 21s	—	12% 7m 9s	7m 7s	40% 7m 9s	12m 24s
	3%	36	4	1m 12s	1m 38s	2m 37s	2m 49s	3m 19s	—	5% 1m 8s	—	10% 1m 14s	5m 12s
FP (3)	6%	39	5	2m 16s	2m 42s	3m 44s	4m 10s	4m 40s	—	—	—	—	12m 9s
P (1)	3%	24	6.5	2m 44s	4m 16s	6m 4s	6m 47s	7m 17s	—	—	—	3% 5m 49s	14m 56s
P (2)	3%	25	6.5	6m 59s	7m 35s	7m 54s	8m 53s	9m 23s	—	—	—	5% 6m 6s	7m 44s
S (1)	3%	26[2]	6.5	43s	2m 48s	2m 59s	3m 36s	4m 16s	—	—	—	15% 3m 31s	3m 53s
S (2)	3%	27	6.5	1m 5s	2m 3s	5m	5m 6s	6m 9s	—	—	—	10% 4m 58s	5m 29s

NOTES TO TABLE 5:

1. Burnback-only test.
2. Burnback flame not used during Test 26 due to re-ignition of fuel 1 minute 43 seconds after extinction.

TABLE 5: Results of Tests : Extinction and 25% Burnback Times (Including Flare Details) for FP, P and S Foam Concentrates

TEST NO.	DATE	TIME OF DAY	TEMPERATURE IN °C				RELATIVE HUMIDITY %	WIND	
			Fuel	Water Base	Foam Solution	Air		Speed in m/s	Direction in degrees
1	13/5/92	10:15	10	–	18.3	15.4	73	4.2	176
2	14/5/92	09:15	8	–	19.8	18.6	67	5.3	164
3	14/5/92	11:15	10	–	20.1	21.7	60	6.3	154
4	15/5/92	09:25	12	18	18.8	13.2	66	2.5	317
5	15/5/92	11:30	13	20	19.0	15.1	55	2.2	313
6	15/5/92	14:15	15	23	20.0	17.9	47	3.0	336
7	19/5/92	10:50	17	25	20.2	19.4	68	2.0	87
8	19/5/92	13:50	17	30	21.0	23.2	59	3.1	127
9	20/5/92	09:20	17	20	20.2	18.1	60	2.0	26
10	20/5/92	11:20	17	24	20.3	20.8	50	2.2	31
11	20/5/92	14:25	16	26	20.5	23.2	46	1.8	109
12	21/5/92	09:40	12	19	19.8	14.9	80	3.5	22
13	21/5/92	11:25	16	22	19.1	17.2	70	2.8	22
14	21/5/92	13:55	19	21	19.7	20.1	55	1.9	315
15	21/5/92	15:25	19	26	19.9	21.6	57	1.6	37
16	22/5/92	09:00	16	19	19.0	15.8	82	1.2	45
17	22/5/92	10:30	18	25	20.1	19.6	69	1.5	101
18	28/5/92	09:00	10	19	21.0	17.1	81	3.5	88
19	28/5/92	10:30	13	23	21.2	19.2	78	3.0	87
20	2/6/92	10:05	12	19	20.2	15.7	69	4.0	230
21	2/6/92	11:40	14	24	20.8	16.6	68	4.0	227
22	2/6/92	14:00	13	22	20.1	17.9	61	2.7	217
23	2/6/92	15:25	14	21	20.4	19.1	56	2.4	185
24	3/6/92	09:20	9	17	17.2	13.9	85	3.6	206
25	3/6/92	11:40	12	19	18.1	15.5	74	4.1	204
26	3/6/92	14:50	12	24	18	16.8	72	3.7	179
27	4/6/92	10:00	11	17	16.4	12.7	84	2.2	7
28	4/6/92	12:05	11	17	17.2	13.5	87	1.8	27
29	4/6/92	14:30	10	17	17.7	13.7	89	3.4	31
30	8/6/92	10:20	9	19	19.4	16.4	80	3.3	191
31	8/6/92	11:45	11	19	19.1	16.3	76	4.0	185

TABLE 6 : Results : Temperatures, Wind Data and Humidity

TEST NO.	DATE	TIME OF DAY	TEMPERATURE IN °C				RELATIVE HUMIDITY %	WIND	
			Fuel	Water Base	Foam Solution	Air		Speed in m/s	Direction in degrees
32	8/6/92	14:05	15	23	19.1	18.5	66	2.9	183
33	8/6/92	15:25	16	19	19.8	19.3	65	3.3	204
34	8/6/92	16:35	15	22	20.1	19.0	65	3.3	212
35	9/6/92	09:45	15	19	18.7	15.8	88	2.2	348
36	9/6/92	15:00	19	21	20.0	20.3	66	1.5	159
37	10/6/92	09:25	11	17	18.6	12.5	98	2.2	332
38	10/6/92	10:40	14	18	18.6	13.6	68	2.1	346
39	10/6/92	12:10	14	19	19.3	17.1	85	2.1	336
40	10/6/92	14:30	12	21	18.8	17.8	84	3.3	340
41	10/6/92	15:45	16	20	19.8	20.2	72	1.5	25
42	11/6/92	09:45	7	17	19.1	14.1	85	4.9	33
43	11/6/92	11:15	10	–	20.0	16.9	78	5.3	350

TABLE 6 (Continued) : Results : Temperatures, Wind Data and Humidity

TEST NO.	FOAM TYPE AND NORMAL USE CONC.	CONC. USED	BRANCH	APP. RATE lpm/ m^2	TEMPERATURES IN °C			EXPANSION RATIO	25% DRAIN TIME
					Foam Solution	Foam	Air		
1	AFFF(1) 3%	3%	F225H	4	18.3	18.5	15.4	15.2	3m 03s
2	AFFF(1) 3%	3%	F225H	4	19.8	NT	18.6	NT	NT
3	AFFF(1) 3%	2%	F225H	4	20.1	24.0	21.7	11.0	<2m 00s
4	AFFF(2) 3%	3%	F225H	4	18.8	16.9	13.2	12.0	2m 00s
5	AFFF(2) 3%	2%	F225H	4	19.0	18.0	15.1	10.5	1m 36s
6	AFFF(1) 3%	1.5%	F225H	4	20.0	20.0	17.9	8.4	<1m 50s
7	AFFF(2) 3%	1.5%	F225H	4	20.2	22.0	19.4	8.2	<1m 30s
8	FFFP(1) 3%	3%	F225H	4	21.0	22.0	23.2	11.7	2m 10s
9	FFFP(1) 3%	2%	F225H	4	20.2	21.0	18.1	9.5	1m 57s
10	FFFP(2) 3%	3%	F225H	4	20.3	21.0	20.8	11.6	1m 58s
11	FFFP(2) 3%	2%	F225H	4	20.5	23.0	23.2	8.2	<2m 00s
12	FFFP-AR(1) 3%/6%	3%	F225H	4	19.8	19.0	14.9	11.5	3m 30s
13	FFFP-AR(1) 3%/6%	2%	F225H	4	19.1	25.0	17.2	8.0	2m 00s
14	FFFP-AR(2) 3%/6%	3%	F225H	4	19.7	22.0	20.1	9.4	5m 10s
15	FFFP-AR(2) 3%/6%	2%	F225H	4	19.9	23.0	21.6	8.0	2m 36s
16	AFFF-AR(1) 3%/6%	3%	F225H	4	19.0	19.0	15.8	14.8	5m 53s
17	AFFF-AR(1) 3%/6%	2%	F225H	4	20.1	NT	19.6	10.0	3m 15s
18	AFFF-AR(2) 3%/6%	3%	F225H	4	21.0	23.0	17.1	11.9	6m 15s
19	AFFF-AR(2) 3%/6%	2%	F225H	4	21.2	23.0	19.2	6.6	2m 40s
20	FP(1) 3%	3%	F225H	5	20.2	20.0	15.7	10.0	5m 00s
21	FP(2) 3%	3%	F225H	5	20.8	19.4	16.6	10.1	5m 15s
22	FFFP(1) 3%	3%	F225H	4	20.1	19.6	17.9	12.5	2m 28s
23	FFFP(2) 3%	3%	F225H	4	20.4	20.3	19.1	12.2	2m 06s
24	P(1) 3%	3%	F450H	6.5	17.2	16.3	13.9	8.6	3m 02s
25	P(2) 3%	3%	F450H	6.5	18.1	17.6	15.5	9.8	3m 00s
26	S(1) 3%	3%	F450H	6.5	18.0	18.8	16.8	14.6	5m 00s
27	S(2) 3%	3%	F450H	6.5	16.4	17.0	12.7	13.6	9m 00s

TABLE 7 : Results : Foam Properties

TEST NO.	FOAM TYPE AND NORMAL USE CONC.	CONC. USED	BRANCH	APP. RATE lpm/m²	TEMPERATURES IN °C			EXPANSION RATIO	25% DRAIN TIME
					Foam Solution	Foam	Air		
28	AFFF-AR(2) 3%/6%	1.5%	F225H	4	17.2	16.0	13.5	4.1	<2m 00s
29	AFFF-AR(1) 3%/6%	1.5%	F225H	4	17.7	16.0	13.7	6.6	2m 00s
30	FFFP-AR(1) 3%/6%	1.5%	F225H	4	19.4	19.0	16.4	5.4	1m 13s
31	FFFP-AR(2) 3%/6%	1.5%	F225H	4	19.1	18.0	16.3	5.9	1m 55s
32	FFFP(1) 3%	1.5%	F225H	4	19.1	19.0	18.5	8.1	<1m 30s
33	FFFP(2) 3%	1.5%	F225H	4	19.8	20.0	19.3	8.1	<1m 30s
34	AFFF(1) 3%	3%	F225H	4	20.1	20.0	19.0	16.2	2m 36s
35	FP(1) 3%	3%	F225H	4	18.7	19.0	15.8	10.8	3m 32s
36	FP(2) 3%	3%	F225H	4	20.0	22.0	20.3	10.6	3m 25s
37	AFFF(2) 3%	3%	F225H	4	18.6	15.7	12.5	16.0	2m 33s
38	AFFF(1) 3%	3%	F225H	4	18.6	17.6	13.6	17.6	2m 50s
39	FP(3) 6%	6%	F225H	5	19.3	20.0	17.1	11.2	5m 03s
40	FP(1) 3%	3%	F225H	4	18.8	20.0	17.8	10.8	3m 30s
41	AFFF(1) 3%	3%	F225H	4	19.8	21.0	20.2	16.0	2m 45s
42	FFFP(1) 3%	3%	F225H	4	19.1	17.0	14.1	12.8	2m 41s
43	AFFF(1) 3%	3%	F225H	4	20.0	24.0	16.9	16.8	2m 20s

NOTE FOR TABLE 7 :

NT = Not Tested

TABLE 7 (Continued) : Results : Foam Properties

FOAM TYPE	APP. RATE lpm/m[2]	CONC USED	KNOCKDOWN GRADE[1]	VIRTUAL EXT. GRADE[2]	25% BURNBACK GRADES[3]		FLARE RESISTANCE GRADE[4]	COST TO VIRTUAL EXT.[5]
					TIME	RATIO		
AFFF(1)	4 4 4	3% 2% 1.5%	□□□□□ □□□□□ □□□□	■■■■■ ■■■■■ ■■■	♦♦ ♦ ♦	◇◇ ◇◇ ◇	OO OOOOO OOOOO	££ £ ££
AFFF(2)	4 4 4	3% 2% 1.5%	□□□□□ □□□□ □	■■■■ ■■■ ■	♦♦ ♦♦ ♦♦	◇◇ ◇ ◇	O OOO OOOOO	£££ £££ ££££
AFFF-AR(1)	4 4 4	3% 2% 1.5%	□□□□□ □□□□ □□□	■■■■ ■■■■ ■■■	♦♦♦ ♦♦ ♦♦♦	◇◇◇◇ ◇◇ ◇◇	O O OOO	£££ ££ ££
AFFF-AR(2)	4 4 4	3% 2% 1.5%	□□□□□ □□□□ □□	■■■■ ■■■ ■■	♦♦♦ ♦♦♦ ♦♦♦♦♦	◇◇◇◇◇ ◇◇◇ ◇◇◇◇◇	OOOOO O OO	£££ £££ £££
FFFP(1)	4 4 4	3% 2% 1.5%	□□□□□ □□□□ □□□□	■■■■■ ■■■■ ■■■■	♦♦ ♦♦ ♦♦	◇◇ ◇ ◇◇	OOO OOOOO OOOOO	££ ££ £
FFFP(2)	4 4 4	3% 2% 1.5%	□□□□□ □□□□ □□□	■■■■ ■■■ ■■■	♦♦ ♦♦ ♦♦	◇◇ ◇ ◇◇	OOOO OO O	£££ ££ £
FFFP-AR(1)	4 4 4	3% 2% 1.5%	□□□□□ □□□□□ □□□□	■■■■ ■■■ ■■■	♦♦♦ ♦♦ ♦♦	◇◇◇ ◇◇ ◇◇◇	OOOO OOOO OOOO	£££ £££ ££
FFFP-AR(2)	4 4 4	3% 2% 1.5%	□□□□□ □□□□ □□□	■■■■ ■■■ ■■■	♦♦♦♦ ♦♦ ♦♦	◇◇◇◇ ◇◇ ◇◇	OOO O OOO	£££ £££ ££
FP(1)	5 4	3% 3%	□□□ □□□	■■ ■■	♦♦♦♦ ♦♦♦♦	◇◇◇◇ ◇◇◇◇	O OOO	£££ ££
FP(2)	5 4	3% 3%	□□□□□ □□□□	■■■ ■■■	♦♦♦♦♦ ♦♦	◇◇◇◇ ◇◇◇	O OOO	£ £
FP(3)	5	6%	□□	■■	♦♦♦♦♦	◇◇◇◇◇	OOOOO	-----[6]
P(1)	6.5	3%	□□	■	♦♦♦♦♦	◇◇◇◇	OOOO	£££££
P(2)	6.5	3%	□	■	♦♦♦	◇◇	OOOO	£££££
S(1)	6.5	3%	□□□□□	■■■	♦♦	◇◇	OOO	£££
S(2)	6.5	3%	□□□□	■	♦♦	◇◇	OOO	£££££

A difference in performance of one grade is not significant due to the tight cut off points between grades and the level of repeatability of the tests. However, where there is a difference in performance of two or more grades, the difference is significant.

TABLE 8 : Performance Gradings for all Foam Concentrates at all Concentrations Tested

NOTES FOR TABLE 8 :

1. Knockdown Grade - The knockdown grades are derived from the 90% extinction times and are as follows:-

Grade	90% Extinction Time
□□□□□	Less than or equal to 1 minute
□□□□	More than 1m but less than or equal to 1m 30s
□□□	More than 1m 30s but less than or equal to 2m
□□	More than 2m but less than or equal to 3m
□	More than 3 minutes

2. Virtual Extinction Grade - These grades are based on virtual extinction times.

Virtual extinction was defined by FEU as the point at which flames, during the extinction phase of the fire test, had been restricted to less than 5% of the tray side. In addition, very small areas of flame on the foam surface were allowed if it was considered that these would have been easily extinguished by a quick change of tactic as occurred during some of the later tests. Complete extinction of these last few flames was shown during this trial to be due to the expertise of the firefighter and his tactics rather than any particular properties of the foams used. Performance grades for virtual extinction are as follows:-

Grade	Virtual Extinction Time
■■■■■	Less than or equal to 1 minute 30 seconds
■■■■	More than 1m 30s but less than or equal to 2m
■■■	More than 2m but less than or equal to 3m
■■	More than 3m but less than or equal to 4m
■	More than 4 minutes

3. Burnback Grade - The burnback resistance of the foam blankets is assessed in two ways. The first assessment is based on the 25% burnback time only and the second is based on what FEU has called the 25% burnback ratio.

The performance grades for the 25% burnback times achieved by each of the foam concentrates used during this trial are as follows (the higher the 25% burnback time the better the performance):-

Grade	25% Burnback Time
◆ ◆ ◆ ◆ ◆	More than or equal to 12 minutes
◆ ◆ ◆ ◆	More than or equal to 9m but less than 12m
◆ ◆ ◆	More than or equal to 6m but less than 9m
◆ ◆	More than or equal to 3m but less than 6m
◆	Less than 3 minutes

The 25% burnback ratio method grades the ratio of the 25% burnback time to the foam application time, ie.

$$25\%\ \textit{burnback ratio} = \frac{25\%\ \textit{burnback time}}{\textit{total foam application time}}$$

The 25% burnback ratio method has been used because of the large variations in the foam application times during this trial, ranging from 2 minutes 2 seconds to 9 minutes 23 seconds. This allowed foam blankets of various depths to be built up.

NOTES FOR TABLE 8 (Continued) :

Performance grades for 25% burnback ratio are as follows (the higher the ratio the better the performance):-

Grade	25% Burnback Ratio
◇ ◇ ◇ ◇ ◇	More than or equal to 2.5
◇ ◇ ◇ ◇	More than or equal to 2 but less than 2.5
◇ ◇ ◇	More than or equal to 1.5 but less than 2
◇ ◇	More than or equal to 0.75 but less than 1.5
◇	Less than 0.75

Flare-ups have not been taken into consideration for any of these burnback results. See below.

4. Flare Resistance Grade - The flare resistance grades are based on the area of the foam blanket involved in a flare-up during the burnback test.

A flare-up involves the foam blanket surface in flames which quickly escalate and then die down leaving the foam blanket intact. Flare-ups are probably due to the ignition of contaminated foam within the foam blankets. Performance grades for flare resistance are as follows (the smaller the area of tray involved in flame the better the performance):-

Grade	Area of Foam Blanket Involved in Large Flare Flames
○○○○○	Less than 1%
○○○○	More than or equal to 1% but less than 5%
○○○	More than or equal to 5% but less than 15%
○○	More than or equal to 15% but less than 25%
○	More than or equal to 25%

5. Cost To Virtual Extinction - This is the total cost for the amount of foam concentrate required to achieve virtual extinction during this trial. These costs are based on the rates charged to FEU, ignoring VAT and delivery, during February 1992.

	Cost of Foam Concentrate Required to Achieve Virtual Extinction
£	Less than or equal to £20
££	More than £20 but less than or equal to £30
£££	More than £30 but less than or equal to £40
££££	More than £40 but less than or equal to £50
£££££	More than £50

The time period from the first application of foam to virtual extinction is used along with the foam concentrate flow rate to calculate the amount of foam concentrate required.

6. This foam concentrate was provided by a UK Fire Brigade, free of charge.

FOAM TYPE AND USAGE CONC.	APP. RATE lpm/m^2	KNOCKDOWN GRADE[1]	VIRTUAL EXT. GRADE[2]	25% BURNBACK GRADES[3]		FLARE RESISTANCE GRADE[4]	COST TO VIRTUAL EXT.[5]
				TIME	RATIO		
AFFF(1) 3%	4	□□□□□	■■■■■	♦♦	◇◇	OO	££
AFFF(2) 3%	4	□□□□□	■■■■	♦♦	◇◇	O	£££
AFFF-AR(1) 3%	4	□□□□□	■■■■	♦♦♦	◇◇◇◇	O	£££
AFFF-AR(2) 3%	4	□□□□□	■■■■	♦♦♦	◇◇◇◇◇	OOOOO	£££
FFFP(1) 3%	4	□□□□□	■■■■■	♦♦	◇◇	OOO	££
FFFP(2) 3%	4	□□□□□	■■■■	♦♦	◇◇	OOOO	£££
FFFP-AR(1) 3%	4	□□□□□	■■■■	♦♦♦	◇◇◇	OOOO	£££
FFFP-AR(2) 3%	4	□□□□□	■■■■	♦♦♦♦	◇◇◇◇	OOO	£££
FP(1) 3%	5	□□□	■■	♦♦♦♦	◇◇◇◇	O	£££
FP(2) 3%	5	□□□□□	■■■	♦♦♦♦♦	◇◇◇◇	O	£
FP(3) 6%	5	□□	■■	♦♦♦♦♦	◇◇◇◇◇	OOOOO	-----[6]
P(1) 3%	6.5	□□	■	♦♦♦♦♦	◇◇◇◇	OOOO	£££££
P(2) 3%	6.5	□	■	♦♦♦	◇◇	OOOO	£££££
S(1) 3%	6.5	□□□□□	■■■	♦♦	◇◇	OOO	£££
S(2) 3%	6.5	□□□□	■	♦♦	◇◇	OOO	£££££

A difference in performance of one grade is not significant due to the tight cut off points between grades and the level of repeatability of the tests. However, where there is a difference in performance of two or more grades, the difference is significant.

TABLE 9 : Performance Gradings for all Foam Concentrates When Used at the Concentrations Recommended by the Manufacturers

NOTES FOR TABLE 9 :

1. Knockdown Grade - The knockdown grades are derived from the 90% extinction times and are as follows:-

Grade	90% Extinction Time
□□□□□	Less than or equal to 1 minute
□□□□	More than 1m but less than or equal to 1m 30s
□□□	More than 1m 30s but less than or equal to 2m
□□	More than 2m but less than or equal to 3m
□	More than 3 minutes

2. Virtual Extinction Grade - These grades are based on virtual extinction times.

Virtual extinction was defined by FEU as the point at which flames, during the extinction phase of the fire test, had been restricted to less than 5% of the tray side. In addition, very small areas of flame on the foam surface were allowed if it was considered that these would have been easily extinguished by a quick change of tactic as occurred during some of the later tests. Complete extinction of these last few flames was shown during this trial to be due to the expertise of the firefighter and his tactics rather than any particular properties of the foams used. Performance grades for virtual extinction are as follows:-

Grade	Virtual Extinction Time
■■■■■	Less than or equal to 1 minute 30 seconds
■■■■	More than 1m 30s but less than or equal to 2m
■■■	More than 2m but less than or equal to 3m
■■	More than 3m but less than or equal to 4m
■	More than 4 minutes

3. Burnback Grade - The burnback resistance of the foam blankets is assessed in two ways. The first assessment is based on the 25% burnback time only and the second is based on what FEU has called the 25% burnback ratio.

The performance grades for the 25% burnback times achieved by each of the foam concentrates used during this trial are as follows (the higher the 25% burnback time the better the performance):-

Grade	25% Burnback Time
◆ ◆ ◆ ◆ ◆	More than or equal to 12 minutes
◆ ◆ ◆ ◆	More than or equal to 9m but less than 12m
◆ ◆ ◆	More than or equal to 6m but less than 9m
◆ ◆	More than or equal to 3m but less than 6m
◆	Less than 3 minutes

The 25% burnback ratio method grades the ratio of the 25% burnback time to the foam application time, ie.

$$25\%\ burnback\ ratio = \frac{25\%\ burnback\ time}{total\ foam\ application\ time}$$

The 25% burnback ratio method has been used because of the large variations in the foam application times during this trial, ranging from 2 minutes 2 seconds to 9 minutes 23 seconds. This allowed foam blankets of various depths to be built up.

NOTES FOR TABLE 9 (Continued) :

Performance grades for 25% burnback ratio are as follows (the higher the ratio the better the performance):-

Grade	25% Burnback Ratio
◇ ◇ ◇ ◇ ◇	More than or equal to 2.5
◇ ◇ ◇ ◇	More than or equal to 2 but less than 2.5
◇ ◇ ◇	More than or equal to 1.5 but less than 2
◇ ◇	More than or equal to 0.75 but less than 1.5
◇	Less than 0.75

Flare-ups have not been taken into consideration for any of these burnback results. See below.

4. Flare Resistance Grade - The flare resistance grades are based on the area of the foam blanket involved in a flare-up during the burnback test.

A flare-up involves the foam blanket surface in flames which quickly escalate and then die down leaving the foam blanket intact. Flare-ups are probably due to the ignition of contaminated foam within the foam blankets. Performance grades for flare resistance are as follows (the smaller the area of tray involved in flame the better the performance):-

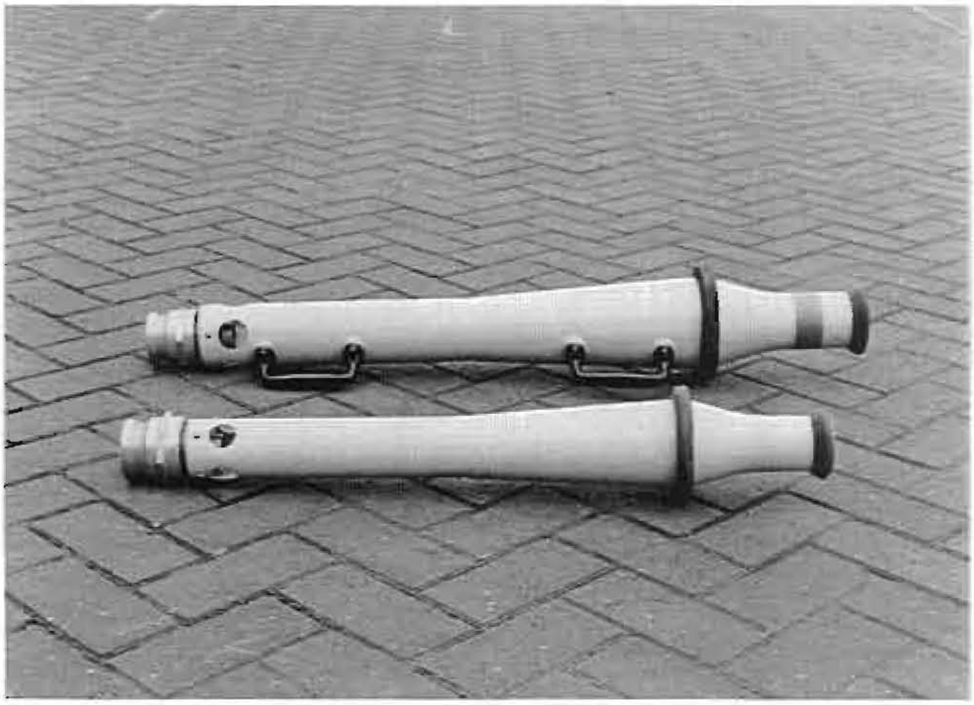
Grade	Area of Foam Blanket Involved in Large Flare Flames
○○○○○	Less than 1%
○○○○	More than or equal to 1% but less than 5%
○○○	More than or equal to 5% but less than 15%
○○	More than or equal to 15% but less than 25%
○	More than or equal to 25%

5. Cost To Virtual Extinction - This is the total cost for the amount of foam concentrate required to achieve virtual extinction during this trial. These costs are based on the rates charged to FEU, ignoring VAT and delivery, during February 1992.

	Cost of Foam Concentrate Required to Achieve Virtual Extinction
£	Less than or equal to £20
££	More than £20 but less than or equal to £30
£££	More than £30 but less than or equal to £40
££££	More than £40 but less than or equal to £50
£££££	More than £50

The time period from the first application of foam to virtual extinction is used along with the foam concentrate flow rate to calculate the amount of foam concentrate required.

6. This foam concentrate was provided by a UK Fire Brigade, free of charge.



B43/93

Figure 1 : Angus F225H and F450H Foam-making Branchpipes

S/273/92

Figure 2 : General View of Test Site

S/226/92

Figure 3 : Portable Dams

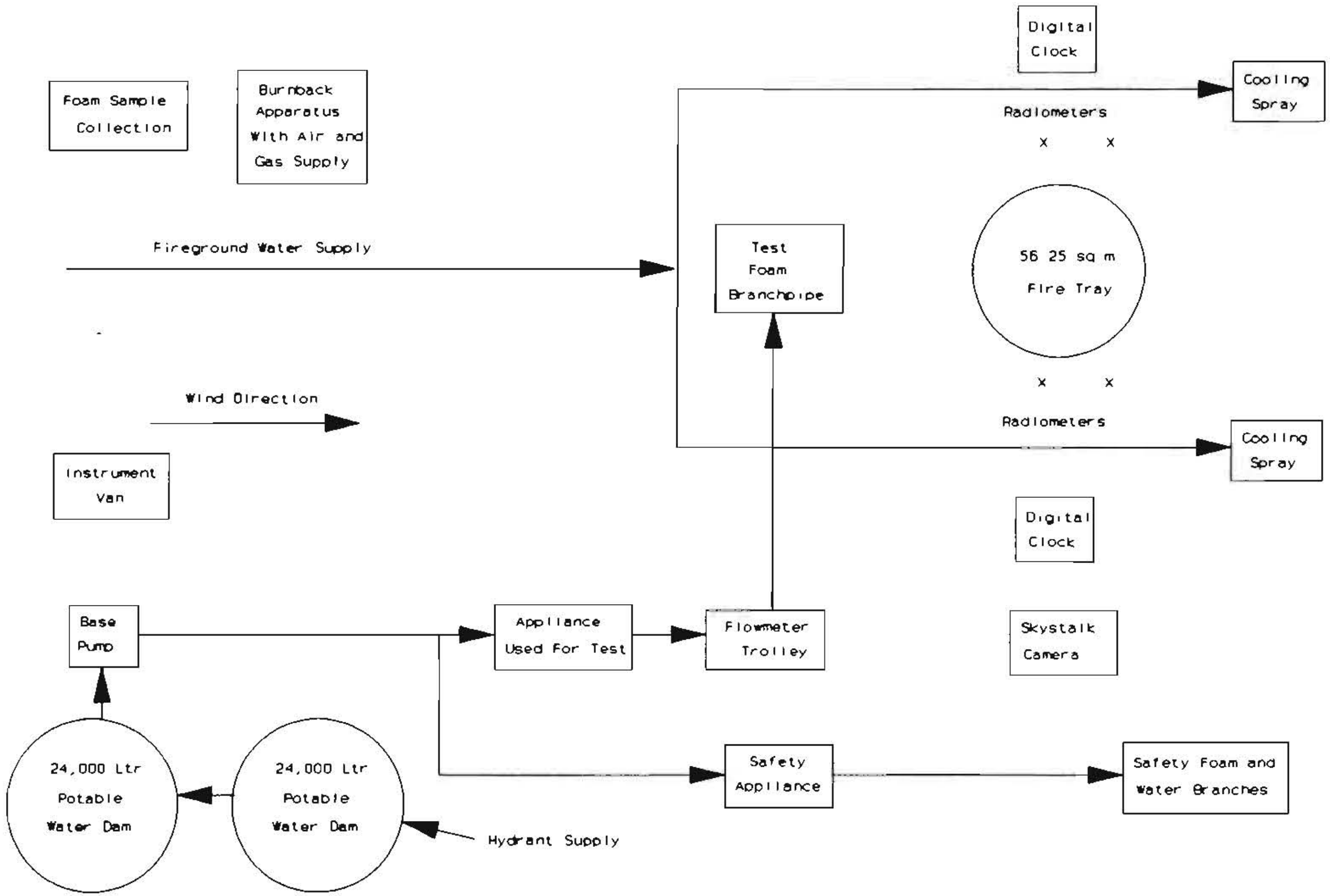


Figure 4 : Typical Layout of Appliances and Equipment

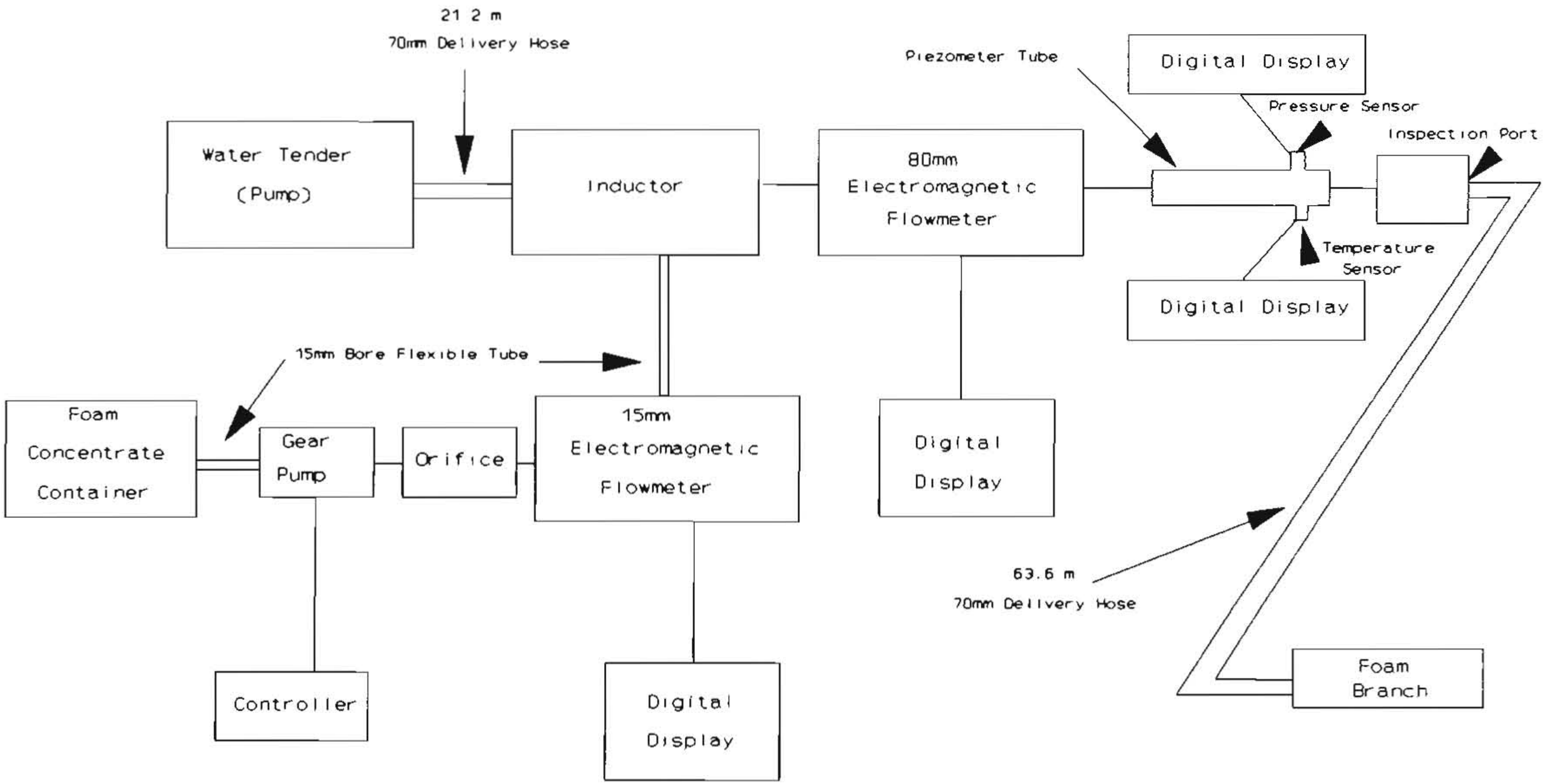
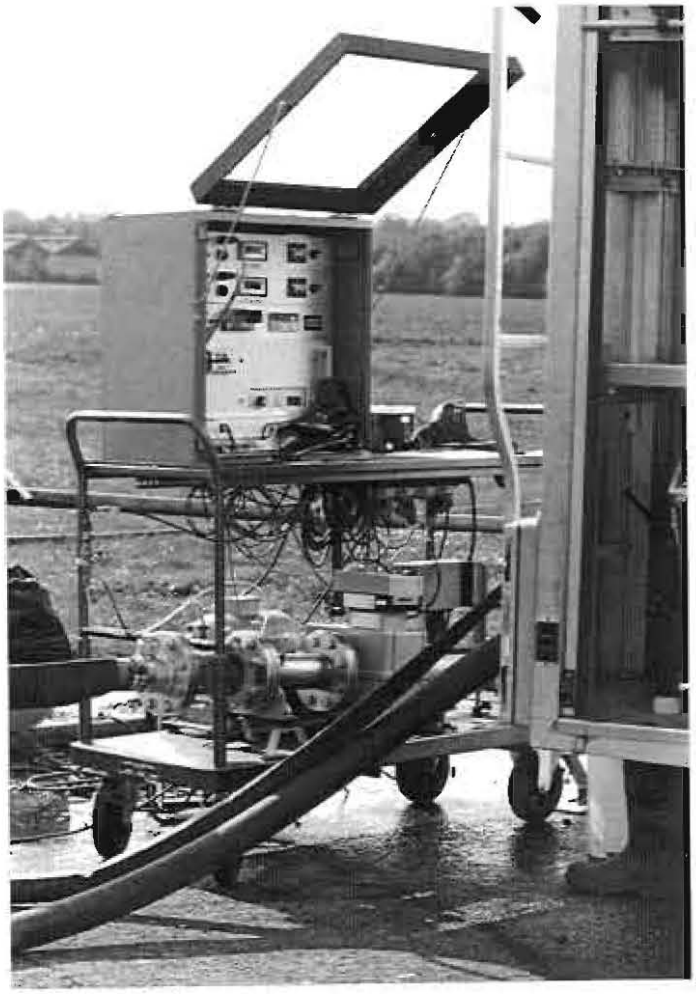


Figure 5 : Hydraulic Arrangement for Fire Tests

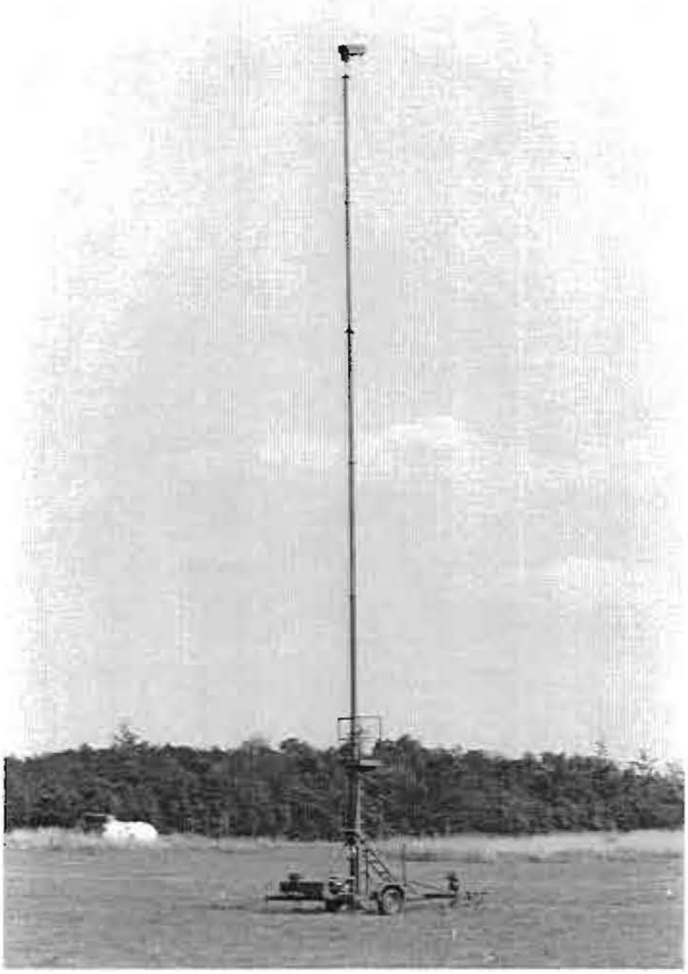


C/426/92

Figure 6 : Flowmeters and Associated Equipment Mounted on a Trolley

C/1473/91

Figure 7 : Instrumentation Van



C/1310/91

Figure 8 : Skystalk Mast With Camera Mounted on Top

C/1486/91

Figure 9 : Two Radiometers Mounted on Masts

C/443/92

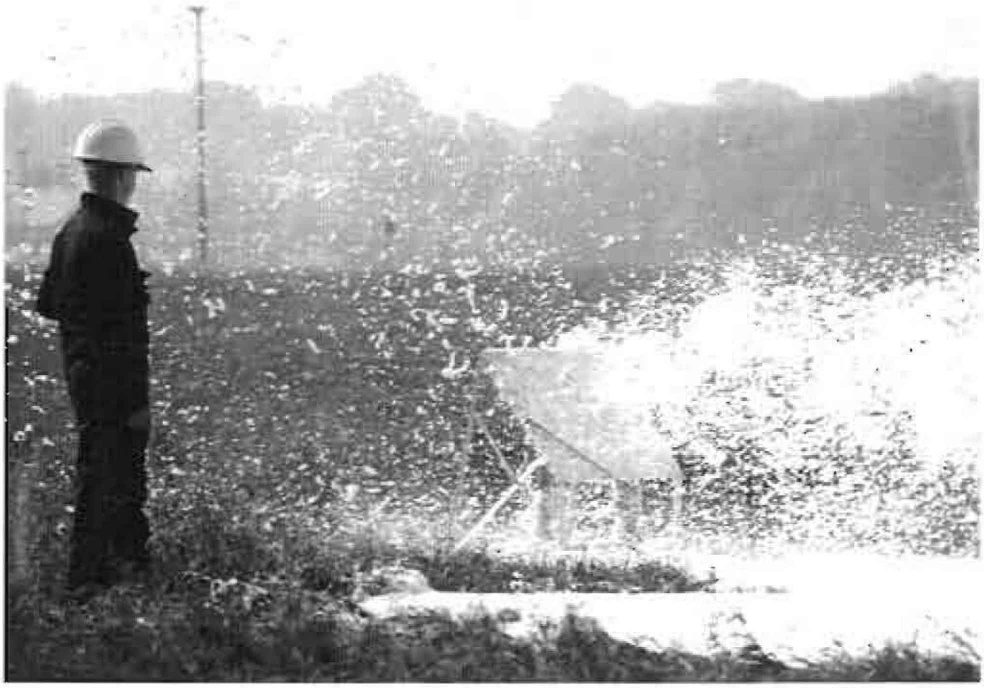
Figure 10 : Petrol Being Transferred to the Fire Tray

S/261/92

Figure 11 : General View of Fire During Preburn

C/434/92

Figure 12 : Foam Stream Being Applied to Fire



S/309/92

Figure 13 : Foam Sample Collection

C/541/92

Figure 14 : Burnback Rig in Position for Burnback Test

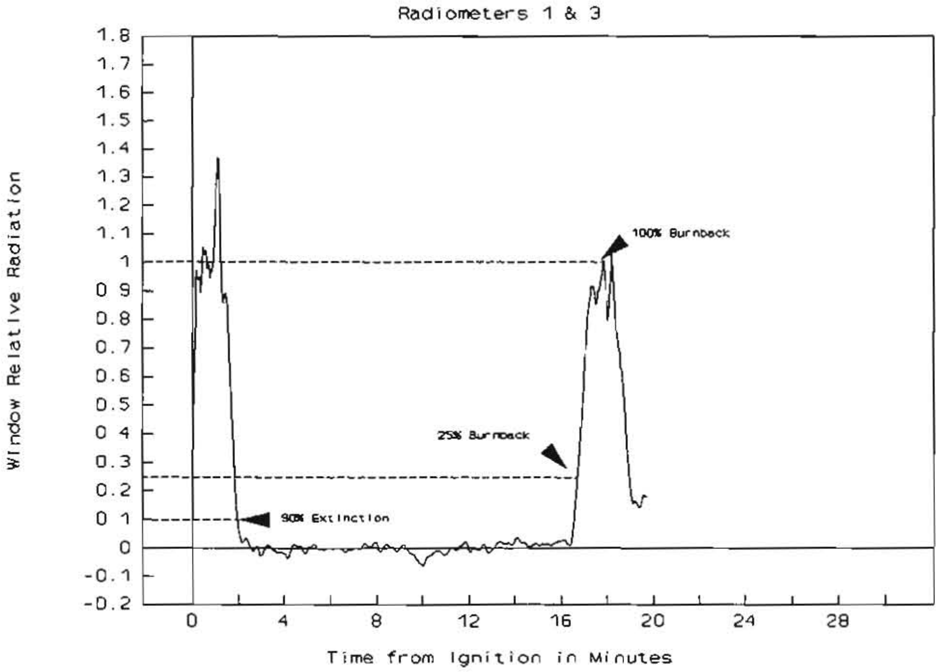


Figure 15 : Example of a Radiometer Record

APPENDIX A - Safety instructions for tray fire tests: May 1992

SAFETY INSTRUCTIONS FOR LARGE PETROL TRAY FIRE TRIALS: May 1992

Introduction

Large petrol fire trials are required to determine the relative performance and extinction rankings of most types of foam concentrate and to compare these with their performance during ISO/CEN medium scale standard fire tests.

The results of these trials may also be used as a performance basis for a new small scale fire test to replace, or in addition to, the ISO and CEN fire tests.

Trials are to commence on the 12th May 1992 and are likely to continue for up to five weeks after that date.

The trials will be carried out on the fireground of the Fire Service College, in the FEU 56.25 m^2 circular tray using either 1400 or 2800 litres of unleaded petrol as fuel for each test.

Before each test, the tray will be thoroughly cleaned out. All equipment will be operated to check correct functioning.

When preparations are complete, a petrol tanker will be driven to a point on the runway alongside the tray and the fuel transferred to the open tray.

The fuel will be ignited by an electrical detonator, then, after a one minute preburn, the fire will be extinguished with the foam under test. A burnback test will then be carried out.

The proposed test plan is as follows:

> Preliminary tests
>
> Three tests in total. Two tests using 2800 litres of fuel (one test with a water base, one without) and one test using 1400 litres of fuel (with a water base) will be carried out to investigate the effects of depth of fuel and use of a water base on the firefighting performance of foam concentrates. Two further tests may be carried out if necessary.
>
> Main Tests
>
> Either 24 tests at 2800 litres of fuel per test or up to 45 tests at 1400 litres of fuel per test will be carried out. Actual number will be known after the above preliminary tests have been performed.

The following instructions concern the safety aspects of these tests. These instructions must be complied with throughout the test series.

THE "HEALTH AND SAFETY AT WORK POLICY STATEMENT AND SAFETY

INSTRUCTIONS FOR THE FIRE EXPERIMENTAL UNIT" ISSUE 5 SEPTEMBER 1989 MUST BE READ IN CONJUNCTION WITH THESE INSTRUCTIONS.

SAFETY PROCEDURE

1. General

1.1 Personnel Directly Involved in the Fire Tests

The trial will be directed by B P Johnson. The senior FEU Fire Officer, DO Follett, will be responsible for all matters concerned with fire safety, this also includes fire safety matters during the transfer of fuel from the tanker to the fire tray. The senior FEU officer present will be in charge overall.

The following personnel will be involved:-

B Johnson Project Officer, observer
Dr M Thomas Head of FEU, observer
J Foster Observer, handling of detonators
J Price Pump operator and foam concentrate handler
K Bosley Instrumentation van
G Roberts Instrumentation van, foam quality measurements

J Rimen Burnback Rig

DO Follett Senior FEU Fire Officer
STN O Fay FEU Fire Officer

Local Authority Firefighters will provide the safety cover.

Other contract personnel may supplement the FEU team.

Unless a task demands otherwise, personnel should remain upwind of the tray during the tests. Personnel involved in the tests will wear Nomex fire tunics, Nomex leggings and safety fire-boots. Safety helmets or fire helmets will also be worn. All personnel must wear safety goggles or a helmet with a visor. Fire Officers will wear standard fire kit.

1.2 Visitors and Casual Observers.

These are personnel who are not directly involved in the fire tests. These people may or may not be members of the Home Office. In all cases they must remain in the allocated areas during fuel handling and the fire tests.

They will wear safety helmets at all times on the fireground.

1.3. Fuel for the tests

All tests will use unleaded petrol. The Health and Safety Data Sheet for unleaded petrol can be found in the Health and Safety Data Sheet Library in the FEU Information Desk.

1.4. Foam Concentrates

The following types of foam concentrates will be used during the fire tests.

Protein
Fluoroprotein
Film Forming Fluoroprotein (FFFP)
Alcohol Resistant FFFP (FFFP-AR)

Synthetic
Aqueous Film Forming Foam (AFFF)
Alcohol Resistant AFFF (AFFF-AR)

The Health and Safety Data Sheets for these foam concentrates can be found in the Health and Safety Data Sheet Library in the FEU Information Desk. All personnel involved in the trial should carefully read these safety data sheets.

1.5 Safety Fire Appliance.

A fire appliance (Registration No. VLU 208G), equipped with at least a diffuser branch, an in-line inductor, foam branchpipe and a supply of foam concentrate, will be standing-by throughout the tests. The pump will be running and manned at all times during the transfer of fuel to the tray and the fire tests. The foam branches will be tested before any of these operations commence by producing foam.

The appliance will also have two dry powder extinguishers, a leather fire blanket and a first aid kit stowed in a locker.

1.6 Test area

The area of the runway used for the tests will be marked with cones.

Personnel involved in the tests should contact B Johnson before leaving the test area.

1.7 No Smoking

No smoking will be allowed in the vicinity of the test site throughout the trials.

1.8 Emergency Procedures

The Fire Service College nurse and ambulance will be informed that the trials are taking place.

A portable phone will be available to summon assistance if necessary. This phone will be checked immediately before each test.

1.9 Filtered air supply

A filtered air supply unit will be available to the pump operators. This will be used if it is necessary for them to operate the pumps in smoke for a short period.

2. Transfer of fuel to the tray

2.1 The tray will be cleaned out by scrubbing with brooms and potable water. Contaminated water will be drained via the valved outlet. After a final wash with clean water, the surface will be dried as far as possible using squeegees or a wet vacuum cleaner.

2.2 The drain valves will be closed after the tray has been dried.

2.3 Water will be poured into the area between the metal tray rim and the outer concrete bund. If a water base is required, water will also be poured into the fire tray to a height of 25mm.

2.4 When all equipment has been deployed and checked, fuelling will commence. Each test requires either 1400 or 2800 litres of petrol.

2.5 A Fire Officer will take charge of the safety fire appliance and will stand by with appropriate equipment to deal with any incidents during the fuel transfer to the tray and the whole of the fire tests.

2.6 The tanker driver will drive the petrol tanker to a position upwind of the tray on the runway. The runway in front of the tanker must be kept clear at all times.

2.7 Radio's must not be used during fuel handling.

2.8 Personnel not directly involved in this fuel transfer operation should be standing at an appropriate distance upwind of the tray.

2.9 Three or four lengths of 3" petrol hose will be connected from the tanker and into the tray.

2.10 The tanker, petrol hose and metal ring will be earthed to an earthing point to the side of the fire test site. The tanker driver will do this operation with the assistance of a Fire Officer or a member of staff from FEU.

2.11 The valve on the tanker will be opened and petrol transferred by gravity into the tray. If possible, an appropriate flowmeter will be used to measure the fuel volume, otherwise a dip stick in the tanker will be used. The volume of fuel transferred to the tray will be measured by the tanker driver.

2.12 While the fuel is being transferred, the pump operator (manning the appliance to be used for the test) will ensure that foam concentrate is available, the pump is primed and the foam branch is connected to the hose.

2.13 When the required quantity of fuel has been discharged, the valve on the tanker will be closed. The petrol delivery hose will be underrun towards the tray. The end of the hose will be withdrawn from the tray and capped. The hose will be disconnected from the tanker and capped.

2.14 The tanker and hose earth will be removed, and the tanker driven away from the test site by the tanker driver.

2.15 The petrol hose will be removed from the test site to a marked area on the opposite side of the runway. (This is preferred to restowing on the tanker to save time at this critical point in the trials).

2.16 When the tanker is off the site, two electrical detonators will be placed over the tray edge by a person wearing protective clothing including helmet with visor. This person should be in possession of the safety key for the firing box. This person will also measure the temperature of the fuel in the tray with an intrinsically safe thermocouple probe and indicator.

2.17 The earth connection to the tray rim will be removed.

2.18 The firing box will be sited within the Instrumentation Pod, upwind of the tray.

2.19 When the detonators are in place, the trials director will ensure that all personnel are at their designated places before the last connection is made to the firing box using the safety key.

2.20 The large digital clocks will be preset to 99-00. The following sequence will follow:-

Clock Time	Action
	Start Instrumentation
	Solution fed to test foam branch
99-00	Clock started
00-00	Fire ignition
01-00	Foam applied to fire

After 100% extinction foaming will be continued for 30 secs.

On direction of the trials director, the burnback torch will be lit.

The aim is to apply the burnback torch to the foam 5 minutes after 100% extinction has been achieved.

If a water base for the test fuel has not been used then water will be poured into the test tray once the burnback has developed beyond 25%. All of the fuel will be allowed to burn off.

2.21 Before the tray is drained and cleaned, a torch flame will be passed over the surface of the liquid within the tray, the tray bund, the drainage channel and the drainage pit to ensure that all of the fuel has been burnt off.

2.22 The hoses and all other firefighting equipment used during the test will be flushed out with clean water after each test.

2.23 These procedures will be repeated for subsequent tests.

3. Tanker Storage Area

This refers to the area to be used for overnight storage of the tankers and fuel.

3.1 The tanker storage site will be not less than 20ft from any building or boundary.

3.2 The site will be either bunded by a retaining wall or in a depression in the ground.

3.3 The storage site will be not more than 150ft from a source of water, either a hydrant or an EWS.

3.4 Two 9kg dry powder extinguishers will be provided either on each tanker or adjacent to the tanker units at all times.

3.5 Notices 'PETROLEUM SPIRIT - HIGHLY INFLAMMABLE - NO SMOKING' will be displayed.

3.6 A fence not less than 7 ft 6 ins of the non-climbable type will be provided around the tanker site.

APPENDIX B - General trial procedure instructions for tray fire tests: May 1992

GENERAL TRIAL PROCEDURE INSTRUCTIONS FOR LARGE PETROL TRAY FIRE TRIALS: MAY 1992

A. ALLOCATION OF DUTIES

The first of the fire trials is due to take place on Tuesday 12th May 1992.

The following personnel will be involved:-

B Johnson - Project Officer and Observer.
Dr M Thomas - Head of FEU and Observer.
J Foster - Observer and handling of detonators.
J Rimen - Observer and burnback rig.
J Price - Pump Operator and foam concentrate handler.
K Bosley - Instrumentation Operator.
G Roberts - Foam tests and instrumentation.

DO Follett - Senior FEU Fire Officer
SO Fay - FEU Fire Officer

Local Authority firefighters will provide the safety cover.

A video contractor, Viewpoint, will operate the video equipment.

Other contract personnel may supplement the FEU team.

B. WATER SUPPLY

Two flexible water dams will be positioned near to the FEU 40m^2 tray site. The two dams will be connected to each other with a length of 4" suction hose. They will be filled from the potable water hydrant supply connected underground to the FSC treatment plant.

Should the hydrant supply not be adequate then a supply will be run from FEU.

An appliance (ALT 469H) will be connected to one of the dams using 4" suction. This appliance will pump potable water to the FEU 56m^2 fire tray site and the appliance used for fire fighting.

A fireground hydrant supply will be connected from the FSC Oil Tray area to the FEU 56m^2 fire tray site. This will supply cooling water if required.

The potable water pump (ALT 469H) will be connected to the trial appliance (GJD) to ensure that this appliance tank remains full of water throughout each test. The potable water pump will be kept running throughout the test with one delivery used to recirculate water to the dam or the appliance tank to prevent overheating.

C. INSTRUMENTATION

4 radiometers will be deployed around the test site. These will be cooled by pumps mounted in plastic boxes with their own water supply. 1 pump will supply 2 radiometers. A 110 volt supply will be required for the pumps with a spare outlet for checking of the radiometers using an Ianebeam.

The radiometers will be positioned 15 metres from the tray side, at 90° to the wind direction, at a height of 3 metres and with the sensor face angled down at 10 degrees from the vertical. The outputs from the radiometers will be recorded on the Orion data logger and a Chart Recorder.

The wind speed and direction sensors will be mounted on a mast on the pod. The output will be displayed and recorded on a chart recorder and also be recorded on the Orion data logger. Air temperature and humidity will also be recorded.

After the tests, a backup copy of the Orion data disk will be made. The data will then be imported into a Lotus Spreadsheet and processed as per the September 1991 lead-free fire tests. Each file name will begin with the characters BJLP* (ie BJ Large Petrol), where * is the test number.

D. FOAM TESTS

Foam expansion ratio and drainage time will be measured after each extinction.

After 100% extinction foaming will continue for 30 seconds and then the foam stream will be directed onto the foam collection plate. The foam collection plate will be at the same distance from the branch for each test sample. The foam sample will be taken to the Lynton Trailer for the expansion ratio and drainage time to be measured with the procedure used for the ISO/CEN tests. The results will be recorded on the *Foam Quality Results* sheet.

The Lynton Trailer will be sited adjacent to the $40m^2$ test site.

The calibration of the scales used for these measurements must be checked at the beginning of each test day.

E. VIDEO EQUIPMENT

The trials will be recorded using the camera on the Skystalk mast and a camera on the platform on the video/instrumentation pod. The Skystalk camera will be recorded on a Sony BVU950P recorder and a low-band U-matic. The Hitachi C2 camera will be recorded on a Sony BVU950P recorder.

Once the likely test wind conditions have been finalised and the trials equipment has been positioned, the cameras will be set up and checked out by Viewpoint.

A microphone will be positioned near to the fire tray to record the background noise on channel 1 of all the video recorders.

Channel 2 will be connected to the PA system.

Unless otherwise instructed, both cameras will be set to a fixed field of view and locked in position. Consideration must be given to the effects of fire plume on automatic aperture settings, a manual setting should be used. The cameras will be white balanced before each test and the back-focus on the Skystalk camera will be checked. If any doubt, the camera will be lowered and the camera adjusted.

Viewpoint will ensure that an FEU video-8 camera is available and ready for use if necessary.

Viewpoint will do a test recording on each recorder and check the picture quality of the recording. Viewpoint will ensure that new video tapes are used for each test. These should be retensioned (forward wind then rewind) before use.

Viewpoint are responsible for ensuring that all recorders are running, video quality is maintained and that framing is correct throughout each test. The Instrumentation Operator will be responsible for ensuring that stocks of video tape are maintained.

After each test, the recording of the pod video camera will be replayed and recorded onto a tape in the low band u-matic (see NOTE below). Following this, Viewpoint will check the quality of all of the recorded videos and prevent over recording of the test tapes by removing the safety tabs. Viewpoint will label each tape with date and test number.

NOTE: The low band u-matic tapes will each have two tests recorded on them in sequence. One tape will contain two tests from the skystalk camera, the other, two tests from the pod camera.

F. PUMP OPERATOR

The trial appliance (GJD) will be used for supplying foam solution to the firefighter. The appliance water tank will be filled with potable water. The foam induction equipment will be checked before each test. The calibration of the flowmeters will be checked before each test by filling a tank of known volume, or checking with a calibrated nozzle and calibrated pressure gauge. At a suitable break in the trials the flowmeters will be returned to the FEU Heavy Equipment lab for calibration on the platform scales.

Before each test, the Pump Operator will ensure that he knows which foam concentrate is to be used, the branch flowrate required and the inductor flowrate required. The Pump Operator will ensure that he has sufficient quantities of the required foam concentrate readily available.

For each test, the Pump Operator will record the approximate amount of foam concentrate and water used by use of the totaliser. The Pump Operator will also record all of the other information required on the *Pump Operator Results* Sheet. This will include the solution temperature.

G. TIMING

The timing of the trial will be indicated by the use of the three large digital clocks. These will be started from the start box in the Instrument Pod.

Before each test, the clocks will be deployed in a location dependent on the wind direction and checked to ensure that each segment operates correctly. They will be in such a position that the face of one clock will be seen clearly in the field of view of each of the video cameras.

Digital stopwatches will be used by Observers. These will be checked for correct functioning before each test by the Observers.

H. IGNITERS

The igniters will be locked in a metal tool box and placed in an empty locker on the side of the trial appliance (GJD). This box will only be opened when connection of the igniters is due to take place. Only enough igniters for one days trials will be contained in the box at any one time. Two igniters will be used for each test.

Before each test the lead from the Instrumentation Pod DC supply will be connected to the igniter connector block. The lead and the connector block will be checked for damage. The lead will be checked to ensure that it is long enough to easily reach the tray. If in doubt these items will be replaced.

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

I. INSTRUCTIONS FOR INSTRUMENTATION AND VIDEO EQUIPMENT SETUP

Preparations for a test

1. All equipment in the Instrument Pod will be switched on as follows:-

   a. Main circuit breakers for transformers
   b. Circuit breaker for 110V and 240V
   c. Orion data logger
   d. Start/event interface
   e. Communications interface
   f. PA amplifier
   g. Computer
   h. Printer
   i. Video cameras
   j. Video recorders
   j. Chart recorders
   k. Wind display
   l. Humidity/temperature

2. A 110 volt supply will be connected to each clock and the clocks will be switched on in order to charge their batteries. Switch on the digital clocks by use of the rotary switch at the side of each clock. Press the Stop button on the control unit to stop the clocks counting.

3. Connect a 110 volt supply to the flowmeter trolley. Check both flowmeter digital displays, digital temperature indicator and pressure indicator are illuminated.

4. Check that the wind sock is positioned correctly.

5. Ensure that there are ample new video tapes and data disks available. Stocks for at least two days testing will be maintained in the Instrumentation Pod.

6. Update the test number on each of the three clocks.

Video

7. The Skystalk mast will be erected and the control unit positioned in the Instrument Pod. Switch on.

8. Deploy the camera on the pod roof.

9. Put the microphone in place and switch on.

10. Switch on the video recorders.

11. Check the Skystalk camera for correct functioning.

12. Check the pod roof camera for correct functioning.

13. Check the white balance and framing on both cameras.

14. Check the PA system, including the audible tone.

15. Load a new video tape into each recorder. Re-tension tape (forward wind and rewind) and then record and check a short video and audio sequence on each recorder.

16. Ensure a Video-8 camera is available and ready for use if necessary.

Instrumentation

17. Load program into the Orion. The program will include the radiometer calibration factors.

18. Format Orion data disk first on computer (using double sided 1MB disks, format using FORMAT A:/t:80/n:9 command). If no errors are reported, reformat this disk on the Orion and include the program.

19. Check wind speed and direction. Switch to the calibrate position. Check 25m/s and North settings on the Orion monitor channel and that the chart recorder is also functioning correctly. Check that wind direction is correct by observation in conjunction with a compass.

20. Ensure wind instrument is reset to read and **not on CAL**.

21. Check settings on chart recorders are as follows:-

Paper speeds Recorder 1 (wind speed/direction) 6 cm/min.
Recorder 2 (radiometers) 6 cm/min.

NOTE: Recorder 1 to be left running at 6cm/hour between tests

Recorder. Channel Number	Parameter	Sw 1	Sw 2	Sw 3	FSD ie 10cm On chart Paper
1.1	Wind speed	cal	0.1	20	2v
1.2	Wind direction	cal	0.1	50	5v
1.5	Event	cal	0.1	500	50v
1.6	Start	cal	0.1	500	50v
2.1-4	Radiometer 1-4	Cal	Mv	10	10mv
2.5	Event	cal	0.1	500	5v
2.6	Start	cal	0.1	500	5v

22. The digital clocks should be preset to 99-00 using the start/event interface.

23. The Orion should be set to run and the digital clocks started.

24. The Chart recorder for the radiometer should be set to run.

25. Check water flow through radiometers

26. Use Ianebeam to check each radiometer. Set to 6.5 inches on the calibrator scale. Note readings.

27. Check that the start signal and radiometers 1 to 4 are recorded on the chart recorder and the orion.

28. Ensure 35 mm cameras available with film and checked.

Flowmeter Trolley

29. Trials director to ensure that Pump Operator knows flow rates and foam concentrate to be used.

30. Run water through 80mm flowmeter and inductor gear pump. Check functioning of system. CONNECT TEST BRANCH AND RUN UP TO REQUIRED INDUCTION RATE.

31. Check pressure gauge on appliance and digital pressure gauge at trolley.

32. Check PRT.

33. Check flowmeter calibration by volume or weight v time or using calibrated orifice.

34. Reconnect up for test.

35. Ensure foam concentrate available for test.

36. Ensure water tank full and appliance primed.

J. TEST PROCEDURE

37. Ensure that the tanker is on site.

38. Ensure that all of the equipment has been checked as detailed earlier.

39. Check that the Orion is programmed and that a clean formatted disc has been installed.

40. Check that there is sufficient paper in chart recorders and that the pens are down. Pen gap on.

41. Check that the computer is programmed for on-line data.

42. Check that all of the video camera shots are ok.

43. Check that water is being pumped to the radiometers. Check that their sensor covers are not on and that their angles are correct.

44. Preset the clocks to 99:00 and ensure that they are on.

45. Check that there are tapes in all recorders (Type KSP-60 for new recorders).

46. Check that the DC supply for the igniters is on and that the person fitting the igniters has control of the special key.

47. Ensure that the test details and procedures are known to all.

48. Check that the test number is displayed correctly.

49. Pump Operator to switch off and reset total flow indicator.

50. Ensure that the drain valves from the tray are closed.

51. Fill up the outer ring of the fire tray with potable water.

52. All non-essential personnel to be behind barriers.

53. No smoking or naked lights allowed.

<u>Transfer Of Fuel To Tray</u>

54. Petrol Hose line will be connected and earthed.

55. Fire cover will be checked.

56. On direction of trial director the fuel will be dispensed.

57. The amount of fuel delivered will be controlled by the tanker driver.

58. When either 1400 or 2800 litres have been dispensed, the petrol hose will be underrun, disconnected and removed to the $40m^2$ fire test site.

59. The tanker will be driven from the site.

60. Sample cans will be filled with fuel if fuel is to be sampled.

61. Fuel depth will be measured.

62. Fuel temperature will be measured with intrinsically safe digital thermometer.

63. Igniters will be connected and positioned and the shorting link removed.

64. On direction of the trial director, the DC supply will be connected to the igniter control box. The trial director will have the safety key.

65. Start the Squirrel data logger if it is to be used.

66. Start the video recorders. Check their record status. Start Chart recorders and check that they are running. Press Run on the Orion and check that it is running.

67. Check that the lance is available for lighting petrol if all else fails.

68. Trials director will confirm that all equipment is ready.

69. Trials director will then, at his discretion, use the PA to announce test and press start.

70. Foam production will commence at 99:00.

71. Operators will check that clocks have started and that they are indicating the correct test time.

72. At zero test time, as indicated on the clocks, the Trials Director will fire the igniters.

73. If the fire is ignited late, then the Instrumentation Operator will press the event button.

74. Throughout the test, the Operators will check the correct operation of all of the equipment as far as possible. Instrumentation and video Operators will remain in the Instrumentation Pod and be prepared to rectify problems. If the mains power supply fails then the video 8 camera will be used to record the test.

75. Observers will note 25% control, 50% control, 90% control, 99% control and extinction times plus any other comments.

76. After extinction, foam will be applied to the fire tray for a further 30 seconds.

77. The foam stream will then be directed onto the foam collection stand and foam quality measurements will be made.

78. If required, a sample of fuel will be collected with

appropriate fire cover.

79. Drainage time and expansion ratio, air and foam temperatures will be recorded on the *Foam Results* sheet.

80. The pipe for pouring water into the tray will be positioned if required. It will not be connected to the water supply at this stage.

81. On direction of trials director, the burnback torch will be lit. The aim is to apply the burnback torch to the foam 5 minutes after extinction. The Instrumentation Operator will press the event button when the burnback flame first impinges on the foam surface within the tray.

82. Burnback will be allowed to develop and should be allowed to develop until 75% burnback.

83. Potable water (if required) will then be run into the tray via the water pipe. The burnback will be allowed to fully develop until all of the petrol has been burnt off. Water may also be added by hand held equipment.

84. The Observers will note times for 25%, 50% and 100% burnback plus any other comments.

85. A torch will be passed over the surface of the tray, to ensure that all of the fuel has been burnt, before the tray is drained. Special care will be taken to ensure that petrol is cleared from the drain pipe and drainage pit.

86. After the test has finished the Operators will check with the Trials Director before switching off the Orion, the chart recorders and the video recorders.

87. The Orion disk will be labelled and a backup will be made. The chart from the chart recorder will be labelled with test number, date and chart settings.

88. The radiometer cooling water temperatures will be checked and recorded.

89. At the earliest opportunity, and without prejudicing any preparations for the next test, the Orion data will be reformatted to produce the Radiation data.

90. The pod camera video will be recorded onto a low band U-matic tape.

91. The video tapes will be labelled with test number and date.

92. The tray will be thoroughly cleaned and all hoses and foam equipment will be flushed.

93. The metal sides of the tray will be scrubbed.

K. PROCEDURE IN CASE OF BURST LENGTH IN FIRE FIGHTING HOSE

At least one length of checked hose will be available on the trials site during each test. If a burst should occur then the Pump Operator will knock-off and the Observers will change the burst hose length .

As soon as possible after this, the Pump Operator will re-establish the correct flow rates and then signal to the branch men who will then continue to extinguish the fire.

L. PROCEDURE IN THE CASE OF ELECTRICAL FAILURE

The stand-by Honda Generator will be positioned adjacent to the electrical supply point.

In the event of a mains electrical failure, the Trials Director will connect the flowmeter trolley then the Instrumentation Pod to the generator and run up the generator.

The video 8 camera will be used to continue the trials recording.

The Pump Operator will connect the spare pick-up tube directly into the inductor and set the inductor to 3%.

The Instrumentation Operator will prepare the Orion standby program and be ready to use it.

APPENDIX C - Detailed notes of fire tests

Test Number: 1 **Foam:** AFFF(1)

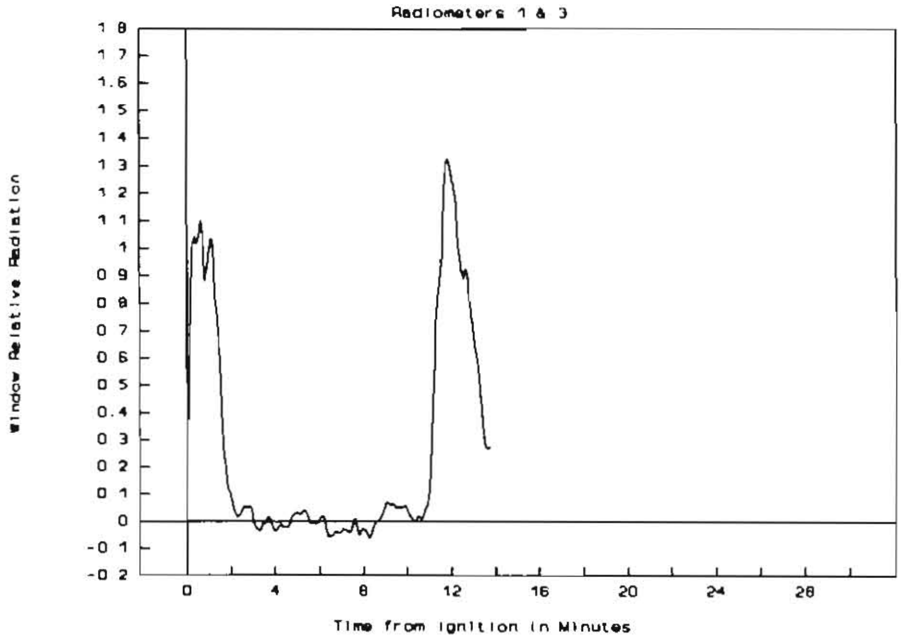
Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny periods

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:03	0:00	Foam applied to rear of the centre of the tray, double foam swirl set up, left side of tray anti-clockwise, right side, clockwise
1:57	0:54	**90% extinction**
2:06	1:03	**95% extinction**, foam falling short of the centre of the tray and falling directly onto the remaining flames at tray edge nearest to branch
2:09	1:06	**99% extinction**
2:13	1:10	**Virtual extinction**
2:19	1:16	Foam being feathered onto remaining flames
3:15	2:12	**100% extinction**
3:46	2:43	Foam off tray
	Time From Start of Burnback	
8:16	0:00	Burnback flame applied to foam
8:39	0:23	Small flames around 25% of the tray edge
8:45	0:29	Build up of flames on foam surface nearest to burnback flame
9:05	0:49	**7% burnback (peak flare radiation)** **10% of the foam surface involved in large flames**
9:27	1:11	Large flames around 25% of the tray edge
9:30	1:14	Burnback flame removed
10:24	2:08	Nearly all flames burnt out, burnback flame re-applied to foam surface
10:35	2:19	2 small holes open up in the foam surface away from the burnback flame
10:42	2:26	Holes total 15% of tray surface
10:52	2:36	Holes total 25% of tray surface, burnback flame removed, 1m^2 of large flames remain
10:57	2:41	Holes ignite
11:06	2:50	**25% burnback**
11:12	2:56	**50% burnback**

11:19	3:03	**75% burnback**
11:34	3:18	**100% burnback**

TEST 1



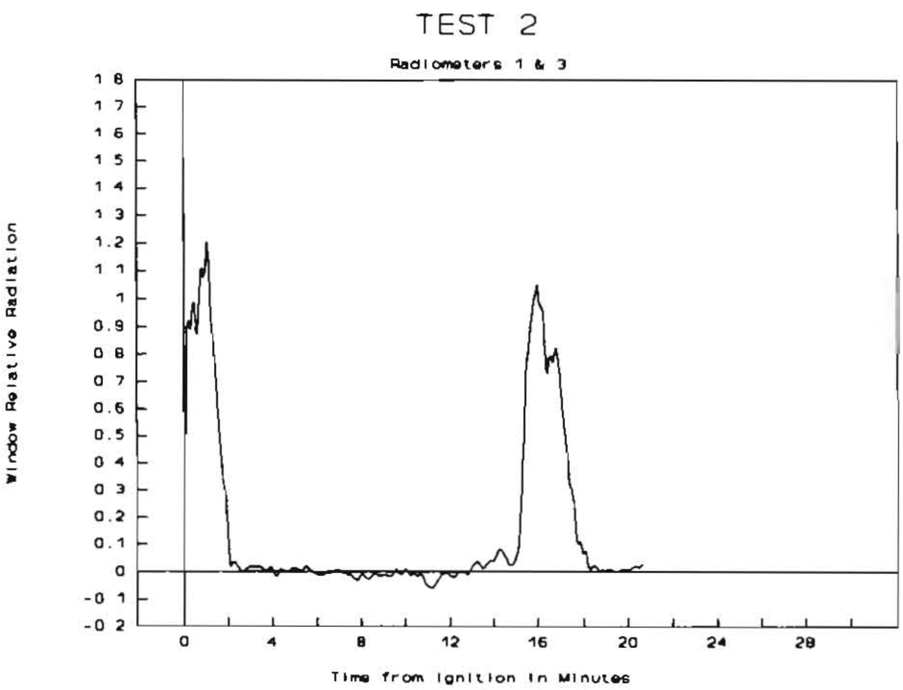
Test Number: 2 **Foam:** AFFF(1)

Application Rate: 4lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:02	0:00	Foam applied to the rear of the centre of the tray, double foam swirl set up, left side of tray anti-clockwise, right side, clockwise
1:55	0:53	Foam falling short of the centre of the tray and falling directly onto the remaining flames at the tray edge nearest to the branch
2:01	0:59	**90% extinction**, foam re-applied to the centre of the tray
2:03	1:01	**95% extinction**
2:14	1:12	Foam application disturbed existing foam blanket causing fire to come back to 96% extinction
2:27	1:25	**99% extinction**
2:31	1:29	**Virtual extinction**
2:41	1:39	Small flames only around 5% of the tray edge nearest to the branch
3:32	2:30	Anti-clockwise foam swirl begins, foam applied to the rear of the right hand side of the fire tray
4:21	3:19	Foam feathering commenced over the front edge of the tray in the vicinity of the remaining flames
5:18	4:16	**100% extinction**, foaming switched to the centre of the tray
5:50	4:48	Foam off tray
	Time From Start of Burnback	
10:18	0:00	Burnback flame applied to foam
12:16	1:58	Small flames begin to spread around the tray edge
12:29	2:11	Small flames around 50% of the tray edge
12:39	2:21	Small flames around 100% of the tray edge
13:58	3:40	Large flames around 50% of the tray edge, some flames spreading across the top surface of the foam layer

14:17	3:59	**8% burnback (peak flare radiation)** **10% of the foam surface area involved in large flames,** smaller flames ghosting across the remainder, flames begin to die down
15:04	4:46	Burnback flame removed, small flames over 5% of the foam surface, $1m^2$ of large flames in open area at burnback point
15:07	4:49	A small hole in the foam blanket appears away from main burnback area
15:14	4:56	Hole reaches 10% of foam blanket area
15:15	4:57	**25% burnback**
15:23	5:05	**50% burnback**
15:26	5:08	Hole ignites
15:31	5:13	**75% burnback**
15:52	5:34	**100% burnback**



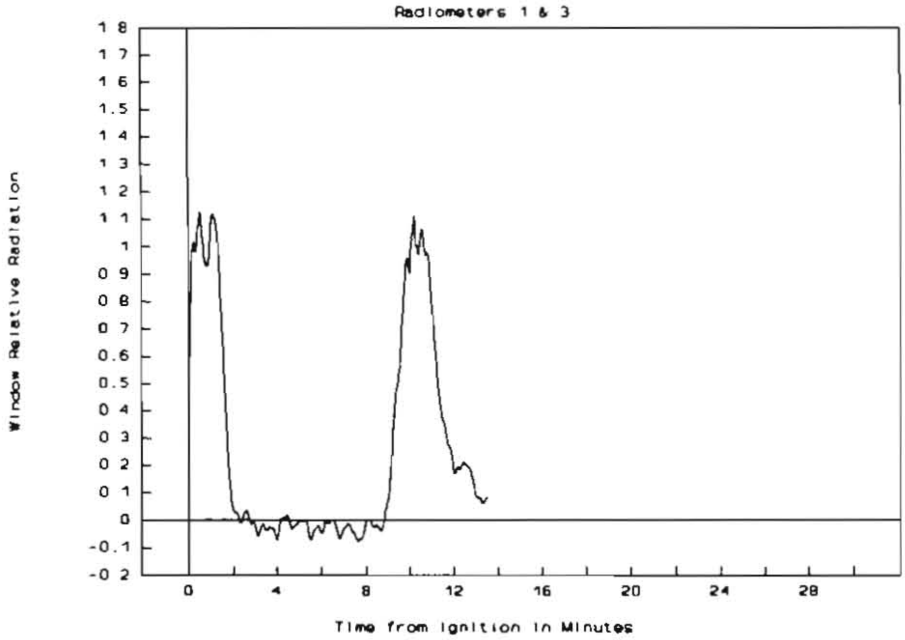
Test Number: 3 **Foam:** AFFF(1)

Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, double foam swirl set up
1:53	0:52	**90% extinction**
1:58	0:57	**95% extinction**, all flames in area and around tray edge nearest to firefighter
2:22	1:21	**99% extinction**
2:27	1:26	**Virtual extinction**, foam feathering commenced over the front edge of the tray in the vicinity of the remaining flames
2:32	1:31	**100% extinction**, foam reapplied to the centre of the tray
3:03	2:02	Foam off tray
	Time From Start of Burnback	
7:33	0:00	Burnback flame applied to foam blanket
7:45	0:12	Flames travelling around tray edge and ghosting over the surface of the foam blanket with larger flames around the contaminated foam swirl patterns
8:03	0:30	Small flames around 50% of the tray edge, **3% of the foam surface area involved in large flames**
8:21	0:48	Nearly all flames burnt out
8:44	1:11	A small hole, 5% in area, opens up in the foam blanket
8:49	1:16	Burnback flame removed
9:01	1:28	Hole ignites
9:11	1:38	**25% burnback**
9:27	1:54	**50% burnback**
9:40	2:07	**75% burnback**
10:04	2:31	**100% burnback**

TEST 3



Radiometers 1 & 3
Window Relative Radiation
Time from Ignition in Minutes

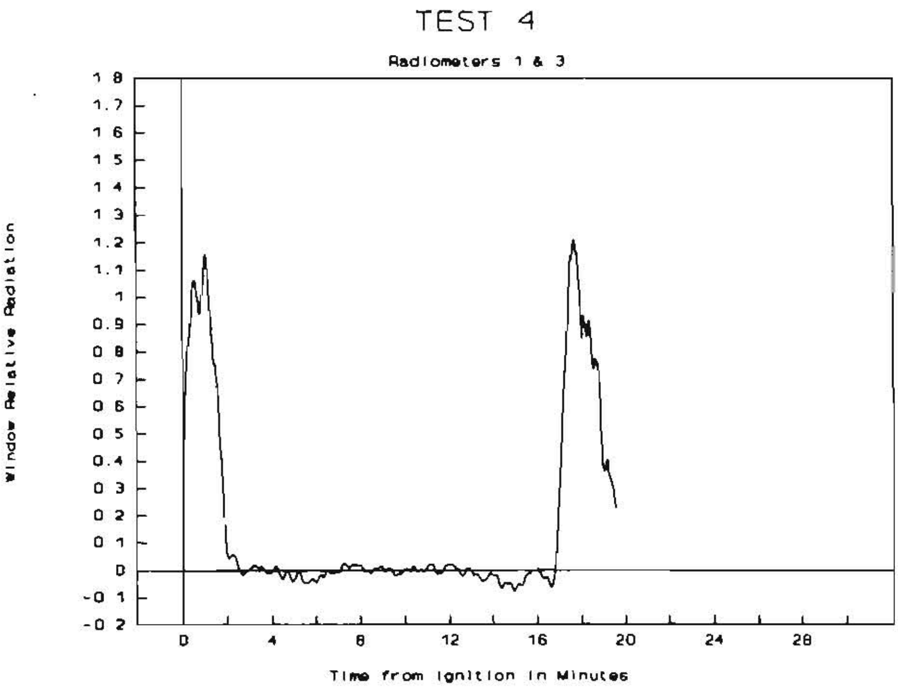
Test Number: 4 **Foam:** AFFF(2)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear left hand side of the tray, double foam swirl set up, clockwise swirl dominant
1:56	0:55	**90% extinction**
2:20	1:19	**95% extinction, remaining flames along the tray edge, and in a small area, nearest to the firefighter**
2:31	1:30	**99% extinction,**
3:25	2:24	Small flames around 5% of tray edge only
5:33	4:32	Foam feathering commenced over the front edge of the tray in the vicinity of the few remaining flames
5:43	4:42	Firefighter walks 15° clockwise around tray, continuing to feather the foam as he moves
5:50	4:49	Firefighter stops walking, tactics vary between feathering and direct jet application onto the remaining flames, small flames visible in several places around the tray edge
7:54	6:53	Firefighter moves a further 15° clockwise
8:08	7:07	Firefighter stops walking
8:22	7:21	**100% extinction**
8:53	7:53	Foam off tray
	Time From Start of Burnback	
813:22	0:00	Burnback flame applied to foam blanket
13:28	0:06	Small flames begin to spread across and through an upper layer of foam, destroying this layer as they proceed
13:46	0:24	50% of the surface area of the upper foam blanket destroyed
14:14	0:52	100% of the surface area of the upper foam blanket destroyed, small flames around 30% of the tray edge
14:20	0:58	Small flames around 50% of the tray edge
15:46	2:24	Larger flames spread to a 3% area of the foam blanket

16:02	2:40	A small hole, 5% in area, opens up in the foam blanket away from the burnback flame
16:17	2:55	Hole grows to an area of 10%
16:42	3:20	Burnback flame removed
16:58	3:36	**25% burnback, hole ignites**
17:06	3:44	**50% burnback**
17:16	3:54	**75% burnback**
17:25	4:03	**100% burnback**



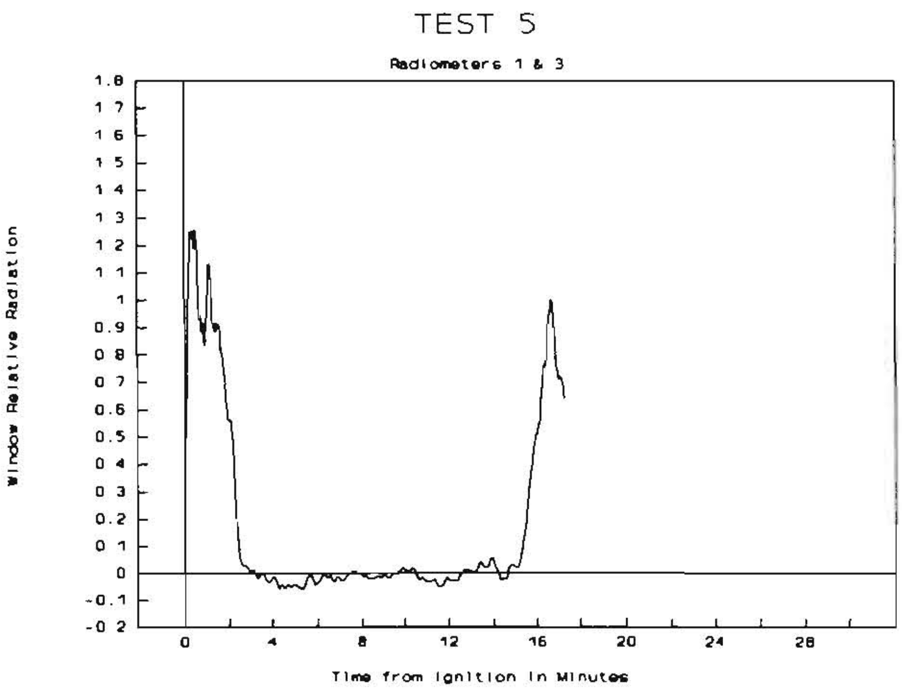
Test Number: 5 **Foam:** AFFF(2)

Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the centre of the left hand side of the tray, a mainly clockwise foam swirl set up
2:25	1:25	**90% extinction**
2:30	1:30	**95% extinction**
2:46	1:46	99% extinction, flames along the tray edge nearest to the firefighter and in a very small area contaminated (black) foam in the centre of the tray
3:05	2:05	Flames in the centre of the tray increase in intensity, 97% extinction
3:16	2:16	Flames in the centre of the tray quickly decreasing, flames at the tray edge increasing
3:35	2:35	Foam jet slowly swept across tray to extinguish tray centre flames
3:43	2:43	Flames in the centre of the tray extinguished, foam being feathered directly onto remaining flames at the edge of the tray
3:49	2:49	**99% extinction**
3:53	2:53	**Virtual extinction**
4:04	3:04	Very small flames only remaining at the tray edge nearest to the firefighter
5:05	4:05	Firefighter walks 20° anticlockwise around the tray, continuing to feather the foam onto the remaining tray edge flames as he moves
5:18	4:18	Firefighter stops walking
5:39	4:39	Firefighter walks a further 20° anticlockwise around the tray
5:48	4:48	Firefighter stops walking
6:24	5:24	Foam application moved to a burning tray edge area opposite current firefighter position. Direct foam application here and around tray edge to previous tray edge flame position
8:30	7:30	**100% extinction**
9:00	8:00	Foam off tray

	Time From Start of Burnback	
10:00	0:00	**BURNBACK FLAME NOT USED**, very small flames observed along a small part of the tray edge
11:30	2:30	Flames around 30% of the tray edge increasing in intensity, two separate flame areas
13:29	3:29	5% of tray area involved in large flames
13:54	3:54	**6% burnback (peak flare radiation) 10% of tray area involved in large flames**
14:07	4:07	Flames decrease, tray edge flames remaining only
14:20	4:20	A small hole, 5% in area, opens up in the foam blanket away from the tray edge flames
14:30	4:30	Hole grows to an area of 10%
14:55	4:55	Hole grows to an area of 20%, 30% of the tray edge involved in large flames
15:09	5:09	Hole ignites
15:33	5:33	**25% burnback**
15:55	5:55	**50% burnback**
16:18	6:18	**75% burnback**
16:39	6:39	**100% burnback**



Test Number: 6 **Foam:** AFFF(1)

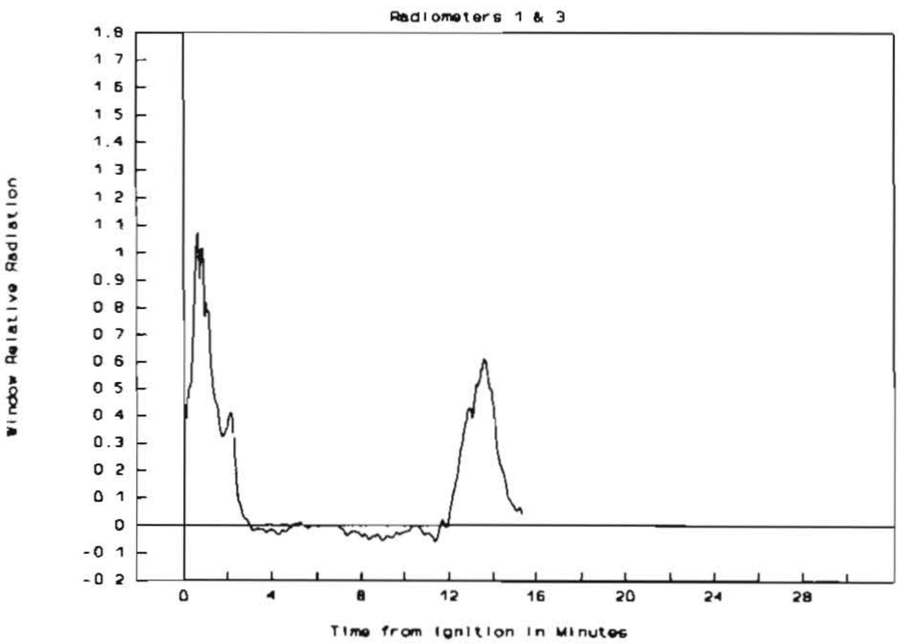
Application Rate: 4 lpm/sqm **Concentration:** 1.5%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the centre of the tray, double foam swirl set up
2:25	1:24	**90% extinction**, all remaining flames around the tray edge nearest to the firefighter
2:30	1:29	**95% extinction**
2:44	1:43	Foam application moved to the rear of the right hand side of the tray, mainly anticlockwise foam swirl set up
3:19	2:19	Foam application moved to the rear of the centre of the tray
3:25	2:24	**99% extinction**
3:30	2:29	**Virtual extinction**
3:31	2:30	Foam applied directly to the remaining flames at the tray edge
3:34	2:33	Very small flames only remain at the tray edge nearest to the firefighter
5:03	4:02	**100% extinction**
5:34	4:33	Foam off tray
	Time From Start of Burnback	
10:04	0:00	Burnback flame applied to foam
10:24	0:20	Small fire starts along the edge of the tray near to the burnback flame
10:28	0:24	Small flames around 25% of the tray edge, ghosting has burnt away a 20% area of the top foam layer
10:33	0:29	Small flames around 50% of the tray edge
10:57	0:53	Small flames around 100% of the tray edge, ghosting has burnt away a 70% area of the top foam layer
11:12	1:08	A small hole, 5% in area, opens up in the foam blanket and ignites
11:26	1:22	Hole increases to 20% in area although less than half of it is involved in flames
11:30	1:26	Burnback flame removed
11:42	1:38	**2% burnback (peak flare radiation)**

12:30	2:26	25% burnback
13:13	3:09	50% burnback
13:31	3:27	75% burnback (maximum peak radiation)

TEST 6



Test Number: 7

Foam: AFFF(2)

Application Rate: 4 lpm/sqm

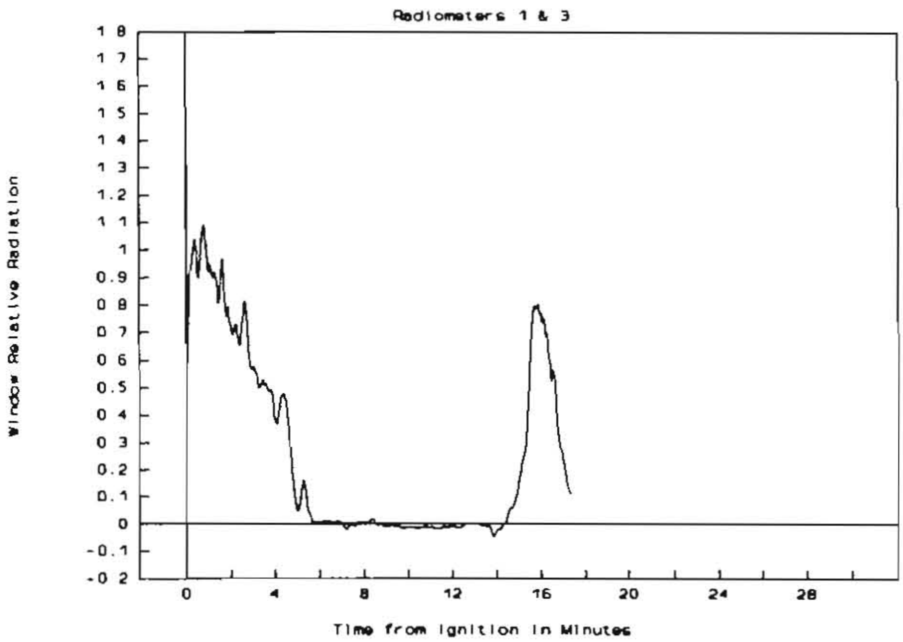
Concentration: 1.5%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the centre of the front of the tray. Some foam (25%-50%) falling short of the tray
1:11	0:10	Foam branch brought in towards the fire, now less than 10% of the foam falling short
2:34	1:33	Foam application point changed to the centre of the left hand side of the tray
5:00	3:59	Foam application point changed to the rear of the left hand side of the tray, a clockwise foam swirl set up
5:24	4:23	**90% extinction**
5:29	4:28	**95% extinction**, the majority of the remaining flames are in the vicinity of the tray edge nearest to the firefighter
5:52	4:51	Some flames remain in a very small area of contaminated (black) foam in the centre of the tray and at various points around the tray edge
6:02	5:01	**99% extinction**
6:15	5:14	**Virtual extinction**
6:34	5:33	Foam stream slowly swept across tray to extinguish tray centre flames
6:39	5:38	Flames in the centre of the tray extinguished
6:47	5:46	Foam stream directed at remaining small flames at tray edge nearest to the firefighter
6:50	5:49	**100% extinction**
7:20	6:19	Foam off tray
	Time From Start of Burnback	
11:52	0:00	Burnback flame applied to foam
12:02	0:10	Small flames begin to ghost over the foam surface and around the tray edge
12:18	0:26	Small flames around 50% of the tray edge

12:33	0:41	Small flames around 100% of the tray edge, small flames have ghosted over the whole of the top surface of the foam and destroyed this upper layer
13:15	1:23	Small flames remain around 20% of the tray edge only, 1% area of flames in contaminated (black) foam in the centre of the tray
14:16	2:24	Burnback flame removed
15:13	3:21	25% burnback
15:28	3:36	50% burnback
15:37	3:45	75% burnback
16:00	4:09	100% burnback (observed)

TEST 7



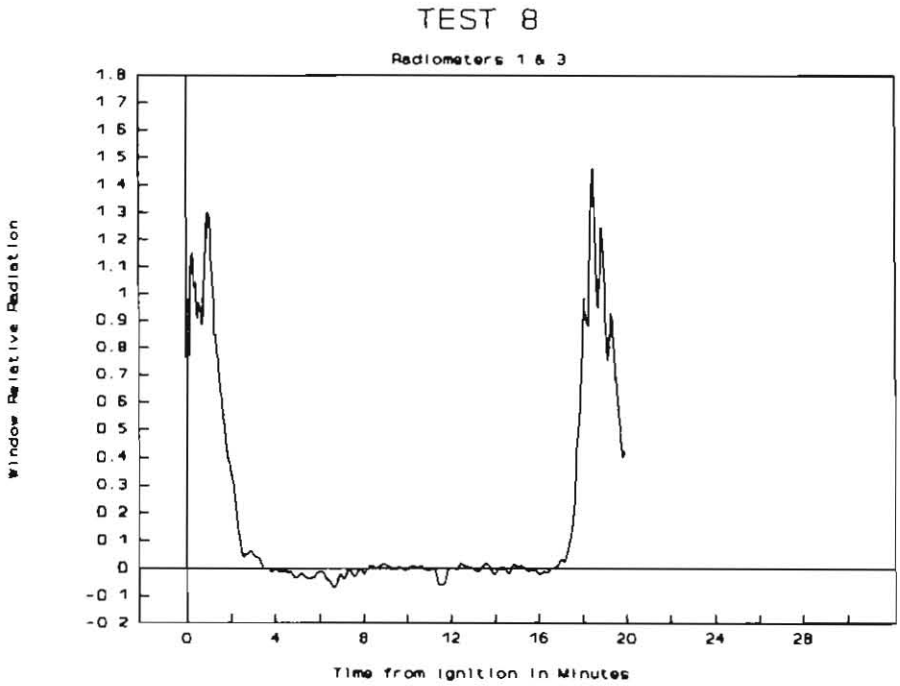
Test Number: 8 **Foam:** FFFP(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the centre of the front of the tray, at least 75% of the foam falling short of the tray
1:25	0:24	Foam branch brought in towards the fire, foam application point changed to the centre of the tray, no significant amount of foam falling short of the tray
2:14	1:13	Foam application point changed to the rear of the left hand side of the tray
2:24	1:23	**90% extinction**
2:33	1:32	Clockwise swirl beginning to move in tray, small flames being pushed around from far tray edge to near tray edge
2:59	1:58	**95% extinction**
3:13	2:12	**99% extinction**, the majority of the remaining flames are along the tray edge nearest to the firefighter
3:30	2:29	**Virtual extinction**
3:53	2:52	Foam stream directed at the few remaining small flames at the near tray edge
7:22	6:21	Foam pushed over the front tray edge
7:30	6:29	**100% extinction**, foam application switched to the centre of the tray
8:00	6:59	Foam off tray
	Time From Start of Burnback	
12:30	0:00	Burnback flame applied to foam, small flames immediately begin to burn at the near tray edge and to ghost across the top surface of the foam
12:45	0:15	Small flames around 50% of the tray edge, 50% area of the top foam surface has been destroyed by ghosting flames
12:53	0:23	Small flames around 100% of the tray edge, 100% area of the top foam surface has been destroyed by ghosting flames
14:55	2:25	Small flames only remain around 20% of the tray edge

16:05	3:35	Wind appears to open up a hole, 5% in area, in the foam blanket away from the burnback flame
16:12	3:42	Hole ignites but only 20% of it burns
16:25	3:55	Several small holes appear in other areas of the foam blanket
17:02	4:32	Burnback flame removed, burnback develops from two separate areas, initial hole now burning fully
17:39	5:09	**25% burnback**
17:48	5:18	**50% burnback**
17:58	5:28	**75% burnback**
18:19	5:49	**100% burnback**



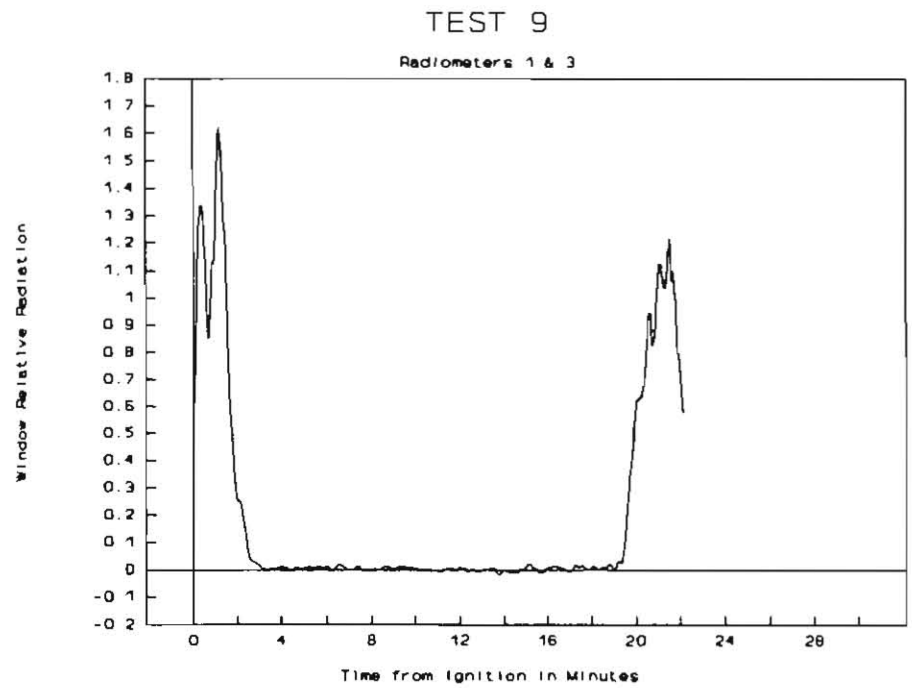
Test Number: 9 **Foam:** FFFP(1)

Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Sunny, still

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a mainly clockwise foam swirl set up
2:26	1:26	**90% extinction**, the majority of the remaining flames along the tray edge to the left hand side of the firefighter
2:32	1:32	**95% extinction**
2:35	1:35	**99% extinction**, small flames remain ghosting over the foam blanket and around the tray edge to the left of the firefighter
2:58	1:58	**Virtual extinction**
3:03	2:03	Very few small flames only remain around the tray edge, some black crusting of the foam at the tray edge preventing complete extinction
4:25	3:25	Feathering and direct application of the foam commenced onto the few remaining flames
6:29	5:29	Branch moved in towards the tray
8:58	7:58	Firefighter moves 35° clockwise, direct foam application continuing
9:48	8:48	**100% extinction**
10:18	9:18	Foam off tray
	Time From Start of Burnback	
14:49	0:00	Burnback flame applied to foam, small flames immediately begin to burn at the near tray edge and to ghost across the top surface of the foam
15:00	0:11	Small flames around 25% of the tray edge
15:04	0:15	Small flames around 50% of the tray edge
15:07	0:18	Small flames around 75% of the tray edge
15:13	0:24	Small flames around 100% of the tray edge, 100% area of the top of the foam surface has been destroyed by ghosting flames
17:13	2:24	Larger flames travelling across the top surface of the foam

19:05	4:16	Burnback flame removed, burnback developed progressively from this area
19:38	4:49	**25% burnback**
19:55	5:06	**50% burnback**
20:26	5:37	**75% burnback**
20:56	6:07	**100% burnback**



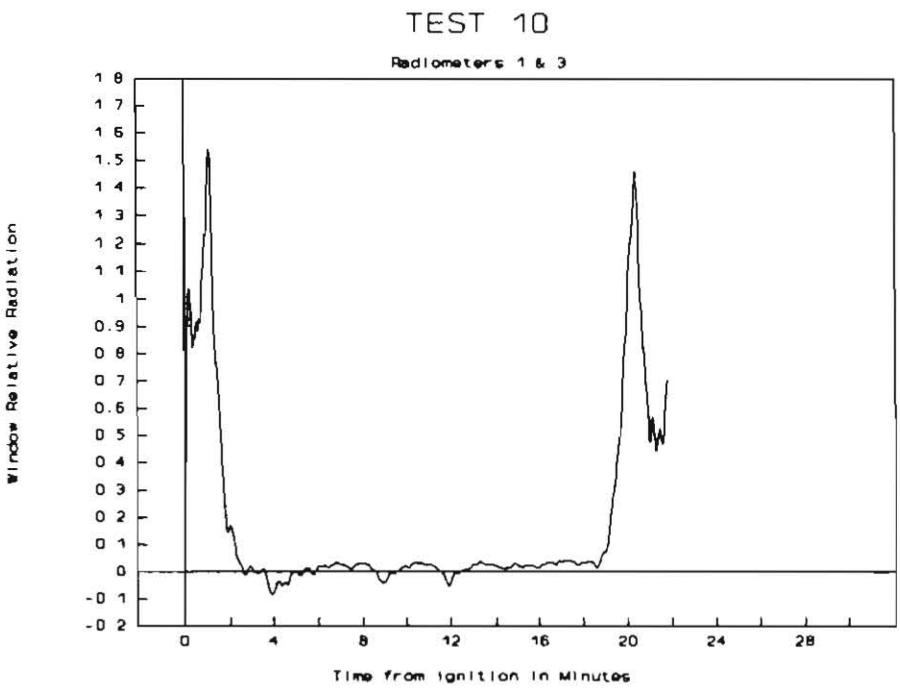
Test Number: 10 **Foam:** FFFP(2)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the centre of the tray, a mainly clockwise foam swirl set up
2:12	1:12	**90% extinction**
2:20	1:20	**95% extinction**, the majority of the remaining flames are in the vicinity of the near tray edge, also, some flaming occurring at the foam application point
2:36	1:36	Flames extinguished at the foam application point
2:59	1:59	**99% extinction**
3:08	2:08	**Virtual extinction**
3:15	2:15	Very small flames only remaining along the tray edge
4:45	3:45	Foam jet slowly swept across tray
4:56	3:56	Foam application point now to the rear of the right hand side of the tray
6:13	5:13	Foam jet applied directly to the remaining flames at the tray edge
6:27	5:27	Foam feathered over the front edge of the tray
7:58	6:58	Firefighter walks 45° clockwise around the tray continuing to feather foam
8:22	7:22	**100% extinction**, firefighter stops walking, foam application changes to the centre of the tray
8:58	7:58	Foam off tray
	Time From Start of Burnback	
13:23	0:00	Burnback flame applied to foam, small flames immediately begin to burn at the near tray edge
13:43	0:20	Small flames around 25% of the tray edge
13:48	0:25	Small flames around 50% of the tray edge
13:54	0:31	Small flames around 100% of the tray edge, some ghosting across foam surface, mainly around contaminated foam swirl patterns

15:00	1:37	90% area of top foam surface has been destroyed by ghosting flames
16:40	3:17	Small flames across 40% of the foam blanket, 75% of the tray edge alight
17:45	4:22	A hole, 5% in area, opens up near to the burnback flame
18:07	4:44	A second 5% area hole opens up
18:17	4:54	First hole closes up
18:19	4:56	Second hole drifts into burnback flame and ignites
18:38	5:15	Another 5% area hole opens up away from the burnback flame
18:44	5:21	Tray edge fire burnt out
18:48	5:25	Burnback flame removed, burnback develops progressively from this area, open area closes up
19:18	5:55	**25% extinction**
19:41	6:18	**50% extinction**
19:50	6:27	**75% extinction**
20:02	6:39	**100% extinction**



Test Number: 11 **Foam:** FFFP(2)

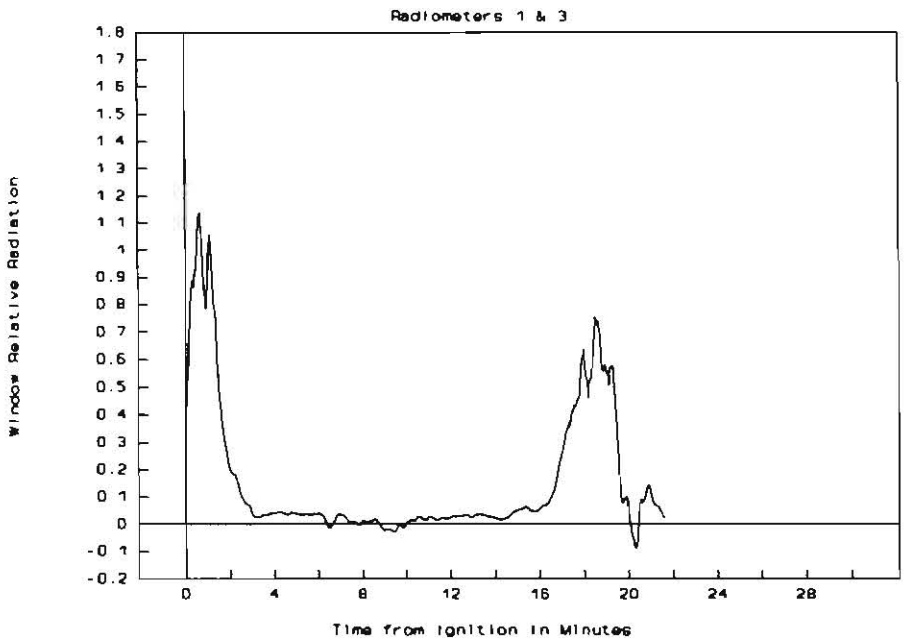
Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the fire tray, a clockwise foam swirl set up in the tray
2:31	1:30	**90% extinction**
2:56	1:55	**95% extinction**, the majority of the remaining flames are in the vicinity of the tray edge to the left hand side of the firefighter
3:01	2:00	99% extinction, flaring at foam application point extinguished
3:18	2:17	**Virtual extinction**, a few small flames remaining at the tray edge, some small flames in a contaminated (black) area of foam in the centre of the tray
3:53	2:52	Flames in the centre of the tray now burning more fiercely
5:00	3:59	**99% extinction**, centre flames swirled around to foam application area and extinguished
6:30	5:29	Firefighter walks 45° clockwise directing foam at few remaining tray edge flames
6:41	5:40	Firefighter stops walking
6:48	5:47	Firefighter walks 90° anticlockwise
7:17	6:16	Firefighter stops walking
7:18	6:17	**100% extinction**, foam application switched to the centre of the tray
7:48	6:47	Foam off tray
	Time From Start of Burnback	
12:18	0:00	Burnback flame applied to foam
12:23	0:05	Small flames begin to burn at near tray edge
12:31	0:13	Small flames around 25% of the tray edge
12:38	0:20	Small flames around 50% of the tray edge
12:47	0:29	Small flames around 100% of the tray edge

14:37	2:19	Small flames flashing over 30% of the foam blanket surface, large flames over 10% of the surface, upper layer of foam collapsing
15:01	2:43	Large flames over 15% of the foam surface
15:24	3:06	**6% burnback (peak flare radiation)** **Large flames over 20% of the foam surface**
15:58	3:40	Burnback flame removed, burnback developed progressively from this area, majority of the centre flames burnt out
16:57	4:39	**25% burnback**
17:47	5:29	**50% burnback**
18:30	6:12	**75% burnback**
18:41	6:23	**100% burnback (observed)**

TEST 11



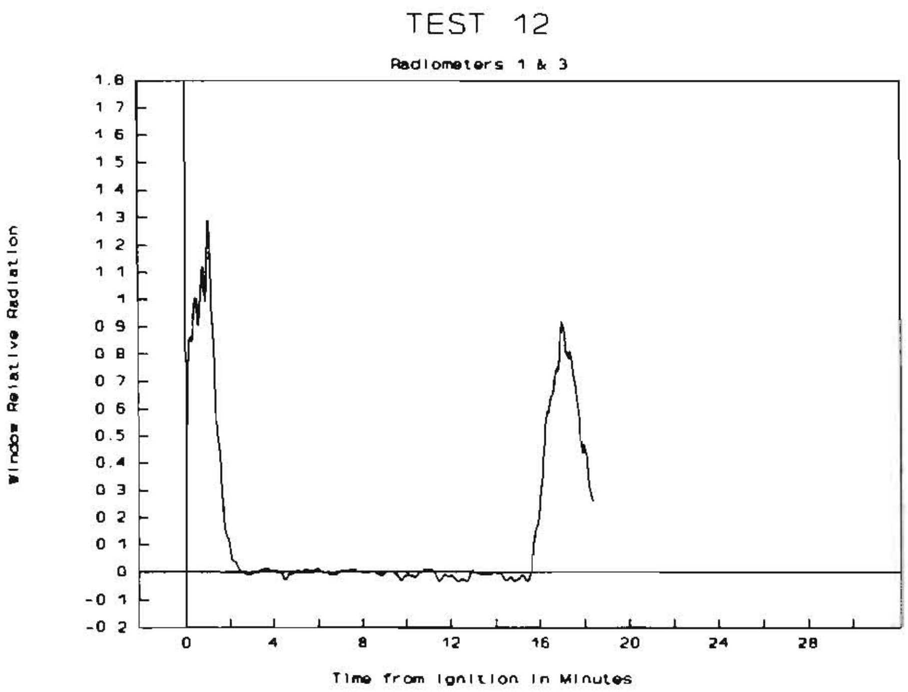
Test Number: 12 **Foam:** FFFP-AR(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:58	0:57	**90% extinction**, the majority of the flames area in the vicinity of the tray edge to the left hand side of the firefighter
2:05	1:04	**95% extinction**
2:23	1:22	**99% extinction**, remaining flames along the tray edge to the left of the firefighter
2:41	1:40	**Virtual extinction**, a few very small flames remaining along the tray edge
3:41	2:40	Foam applied directly to the remaining tray edge fires
3:59	2:58	Firefighter walks 2 metres forward
4:01	3:00	Firefighter stops walking
4:02	3:01	**100% extinction**, foam application returned to the rear of the left hand side of the tray
4:32	3:31	Foam off tray
	Time From Start of Burnback	
9:03	0:00	Burnback flame applied to foam
9:28	0:25	Small flames around 25% of the tray edge, small flames ghosting across the top surface of the foam following the swirl patterns and destroying this foam layer
9:46	0:43	Small flames around 100% of the tray edge
10:10	1:07	**1% area of large flames** burning in contaminated (black) foam in the centre of the tray
11:10	2:07	Small flames around 50% of the tray edge
12:10	3:07	Small flames around 10% of the tray edge
13:40	4:37	Tray edge flames burnt out, only a few very small flames remain burning on the foam surface
14:31	5:28	Hole begins to open up in the foam blanket close to the burnback flame

15:08	6:05	Hole increases to 5% of tray area
15:17	6:14	Hole ignites
15:23	6:20	Burnback flame removed
16:00	6:57	**25% burnback**
16:14	7:11	**50% burnback**
16:45	7:42	**75% burnback**
17:10	8:07	**100% burnback (observed)**



Test Number: 13 **Foam:** FFFP-AR(1)

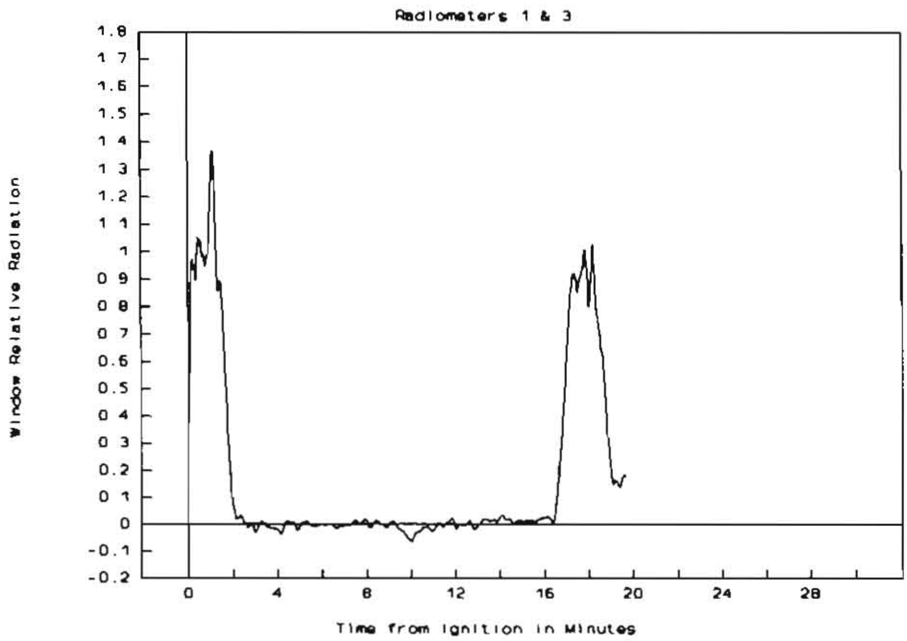
Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:57	0:56	**90% extinction**
2:03	1:02	**95% extinction**
2:15	1:14	Remaining flames along the tray edge to the left of the firefighter, small flames ghosting across the top surface of the foam, flaring at foam application
2:31	1:30	99% extinction
2:38	1:37	Flaring at application point extinguished, small flames along tray edge and in a contaminated (black) area of foam in the centre of the tray
2:47	1:46	Flaring restarts at the foam application point
2:59	1:58	**99% extinction**, flaring at the foam application point extinguished
3:13	2:12	**Virtual extinction**, flames in the centre of the tray burnt out, some very small flames remain along the tray edge
4:12	3:11	Contaminated area reignited - small flames burning in the centre of the tray
4:40	3:39	Foam jet swept across to extinguish flames in the centre of the tray, firefighter moves 15° clockwise around the tray
4:45	3:44	Centre tray flames extinguished, foam directed onto remaining flames at the edge of the tray
4:48	3:47	Firefighter stops walking
4:55	3:54	Firefighter walks 10° clockwise around the tray
5:01	4:00	Firefighter stops walking
5:06	4:05	Firefighter walks 45° clockwise around the tray
5:23	4:22	Firefighter stops walking
5:39	4:38	Firefighter walks 135° anticlockwise around the tray
5:59	4:58	Firefighter stops walking

6:07	5:06	**100% extinction**, foam application returns to the rear of the left hand side of the tray
6:37	5:36	Foam off tray
	Time From Start of Burnback	
11:08	0:00	Burnback flame applied to foam
11:17	0:09	Small flames around 25% of the tray edge, small flames spreading over the top surface of the foam and around the swirl pattern
11:20	0:12	Small flames around 50% of the tray edge
11:24	0:16	Small flames around 100% of the tray edge
12:44	1:36	Large flames moving across 50% of the foam blanket
13:52	2:44	Large flames continuing to move across, and destroy, the upper layer of foam
14:54	3:46	**5% of the foam blanket, in the centre, involved in large flames**
16:10	5:02	Burnback flame removed, centre flames nearly burnt out, burnback proceeds from burnback flame area
16:43	5:35	**25% burnback**
16:55	5:47	**50% burnback**
17:06	5:58	**75% burnback**
17:12	6:04	**100% burnback (observed)**

TEST 13



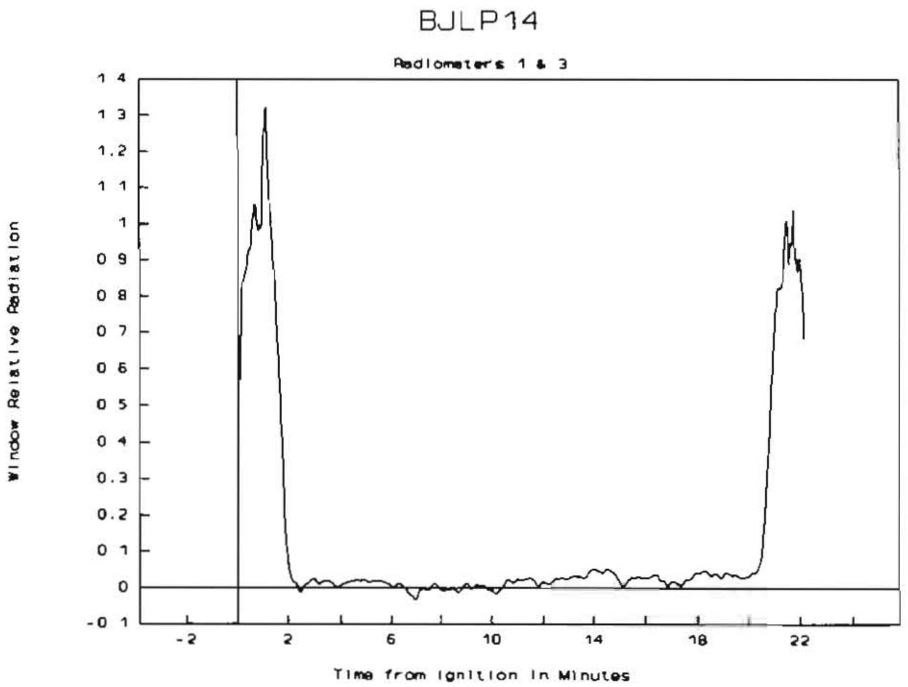
Test Number: 14 **Foam:** FFFP-AR(2)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:56	0:55	**90% extinction**
2:03	1:02	**95% extinction**, flaring at foam application point
2:16	1:15	**99% extinction**,
2:37	1:36	**Virtual extinction**, flaring at application point extinguished, remaining flames are around the tray edge and in a small area of contaminated (black) foam in the centre of the tray
3:10	2:09	Flames in the centre of the tray extinguished, a few very small flames remain around the tray edge
4:10	3:09	Firefighter walks 90° clockwise around the tray, foam applied to the flames around the tray edge
4:26	3:25	Firefighter stops walking
4:45	3:44	Firefighter walks 135° anticlockwise around the tray
5:04	4:03	Firefighter stops walking
5:19	4:18	**100% extinction**, foam application changed to the rear of the left hand side of the tray
5:49	4:48	Foam off tray
	Time From Start of Burnback	
10:19		Burnback flame applied to foam
10:26	0:07	Small flames around 25% of the tray edge
10:30	0:11	Small flames around 50% of the tray edge
10:38	0:19	Small flames around 75% of the tray edge
10:41	0:22	Small flames around 100% of the tray edge, small flames ghosting over the surface of the foam blanket and destroying the upper layer
14:33	4:14	**5% burnback (peak flare radiation)**

15:20	5:01	Small flames over 10% of the foam blanket burning around the contaminated (black) foam swirl pattern, upper layer being destroyed
17:00	6:41	Large flames continuing to burn over small areas of the foam blanket and around parts of the tray edge
18:16	7:57	**Large flames burning over 10% of the foam blanket**
19:37	9:18	Nearly all of the foam blanket flames burnt out
19:41	9:22	Burnback flame removed, burnback proceeds from the burnback flame area
20:40	10:21	**25% burnback**
20:53	10:34	**50% burnback**
21:04	10:45	**75% burnback**
21:28	11:09	**100% burnback**



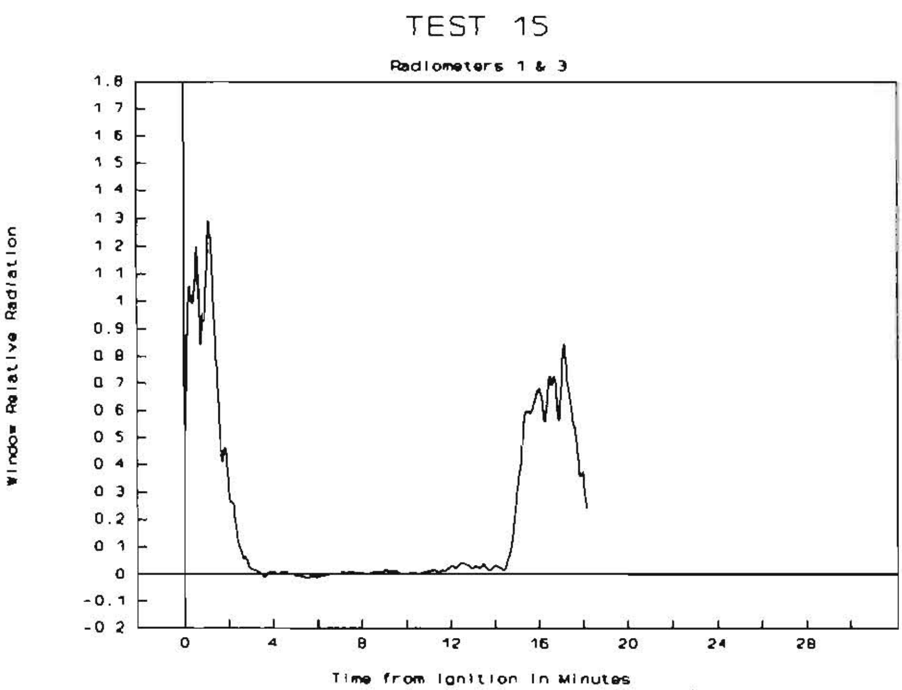
Test Number: 15 **Foam:** FFFP-AR(2)

Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
2:29	1:28	**90% extinction**, flaring at foam application point
2:51	1:50	**95% extinction**, ghosting of small flames across the whole surface of the foam blanket
3:16	2:15	Two main areas of flame; in the contaminated (black) foam in the centre of the tray and at the application point
3:22	2:21	**99% extinction**, flames at the application point extinguished
3:28	2:27	**Virtual extinction**, the main burning area remains in the centre of the tray
3:47	2:46	One small flame in the centre of the tray and a few flames around the tray edge only
4:08	3:07	Flames in the centre of the tray burnt out, a few small flames remain around the edge of the tray
4:52	3:51	Firefighter walks 20° clockwise around the tray, foam applied to the flames around the tray edge
4:57	3:56	Firefighter stops walking
5:04	4:03	Firefighter moves 70° clockwise
5:12	4:11	**100% extinction**, firefighter stops walking
5:17	4:16	**FUEL REIGNITED** by burning detonator case
5:34	4:33	**100% extinction**, foam application changed to the centre of the tray
6:04	5:03	Foam off tray
	Time From Start of Burnback	
10:35	0:00	Burnback flame applied to foam, flames immediately travel around the tray edge and ghost across the foam surface

10:57	0:22	Small flames around 100% of the tray edge, flames have swept over the upper surface of the foam and destroyed 75mm of the depth of the foam blanket
11:37	1:02	Large flames around 50% of the tray edge
11:44	1:09	Large sparse flames over 10%, and small sparse flames over 40%, of the foam surface
12:19	1:44	Large sparse flames over 20% of the foam surface
12:52	2:17	Large sparse flames over 35% of the foam surface
13:27	2:52	**4% burnback (peak flare radiation) Large sparse flames over 40% of the foam surface,** flames continuing to travel around the foam surface
14:26	3:51	The majority of the foam surface flames burnt out, 10% of the tray edge, away from the burnback flame, burning fiercely
14:40	4:05	Burnback flame removed
14:45	4:10	Burnback flame area and tray edge flame area join, burnback proceeds from here
14:56	4:21	**25% burnback**
15:16	4:41	**50% burnback**
17:03	6:28	**75% burnback**
17:08	6:33	**100% burnback (observed)**



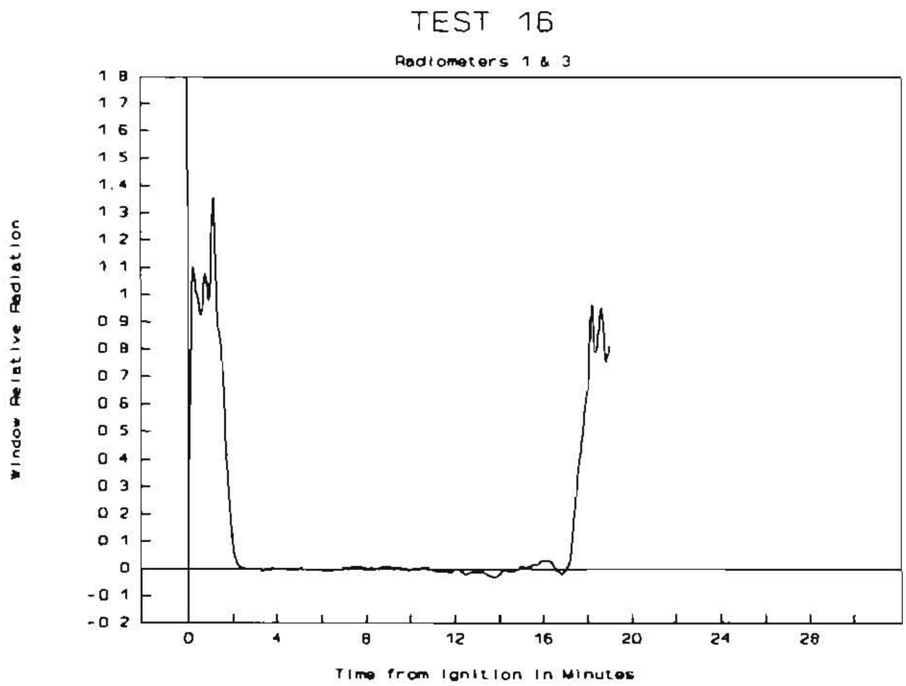
Test Number: 16 **Foam:** AFFF-AR(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
1:59	0:59	**90% extinction**
2:04	1:04	**95% extinction**, flaring at the foam application point
2:28	1:28	**99% extinction**
2:31	1:31	Flames at the foam application point extinguished
2:55	1:55	**Virtual extinction**, a few small flames remaining around the tray edge only
3:55	2:55	Firefighter moves in and sweeps the foam jet across to flames along the right hand side of the tray
4:01	3:01	Firefighter walks 30° anticlockwise directing the foam jet at flames along the left hand side tray edge
4:06	3:06	Firefighter stops walking
4:08	3:08	**100% extinction**, foam application changed to the rear of the left hand side of the tray
4:38	3:38	Foam off tray
	Time From Start of Burnback	
9:08	0:00	Burnback flame applied to foam
9:11	0:03	The tray edge nearest to the burnback flame ignites, a small wall of flame begins to ghost over the upper surface of the foam
9:35	0:27	Small flames around 100% of the tray edge, the whole of the upper surface of the foam blanket has been damaged by the wall of flame
11:20	2:12	Small flames around 20% of the tray edge
11:52	2:44	Small flames begin to burn more fiercely in the centre of the tray
14:31	5:23	5% of the foam surface involved in sparse large flames

15:08	6:00	10% of the foam surface involved in sparse large flames
15:56	6:48	**3% burnback (peak flare radiation)** **50% of the foam surface involved in sparse large flames**
16:43	7:35	Nearly all flames on the foam surface extinguished
17:03	7:55	10% of the tray edge near to the burnback flame burning fiercely
17:11	8:03	Burnback flame removed, tray edge burning area joins with burnback flame area
17:29	8:21	**25% burnback**
17:48	8:40	**50% burnback**
18:05	8:57	**75% burnback**
18:10	9:02	**100% burnback**



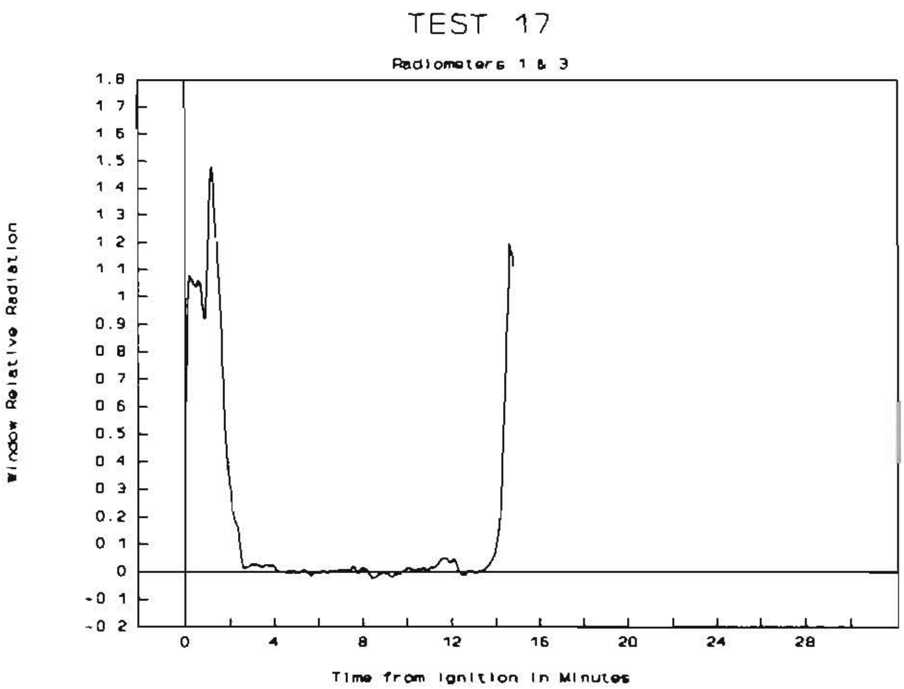
Test Number: 17 **Foam:** AFFF-AR(1)

Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
2:26	1:25	**90% extinction**
2:30	1:29	**95% extinction**, flaring at the foam application point
2:33	1:32	**99% extinction**, flames at the foam application point extinguished
2:35	1:34	Small flames ghosting over the middle of the foam blanket
2:50	1:49	**Virtual extinction**, a few small flames remain around the tray edge and in the centre of the foam blanket
2:56	1:55	Flames in the centre of the foam blanket burnt out
3:50	2:49	Firefighter moves 45° clockwise, foam applied to remaining tray edge flames
3:58	2:57	Firefighter stops moving
4:10	3:09	Firsfighter walks forward
4:14	3:13	**100% extinction**, foam application point changed to the rear of the left hand side of the tray
4:43	3:42	Foam off tray
	Time From Start of Burnback	
9:14	0:00	Burnback flame applied to foam, flames immediately travel around the tray edge and ghost across the foam surface
9:35	0:21	Small flames around 100% of the tray edge, flames have ghosted over the complete surface of the foam blanket
9:45	0:31	The centre, contaminated (black) area of the foam blanket, becoming involved in large flames
10:21	1:07	10% of the foam blanket involved in sparse large flames
11:01	1:47	20% of the foam blanket involved in sparse large flames

11:45	2:31	**5% burnback (peak flare radiation) 30% of the foam blanket involved in sparse large flames**
12:34	3:20	Flames around the tray edge and in the foam blanket almost completely burnt out
13:49	4:35	Burnback flame removed. A 5% area of the foam blanket, opposite to the burnback flame, involved in large flames
14:13	4:59	**25% burnback**
14:21	5:07	**50% burnback**
14:27	5:13	**75% burnback**
14:35	5:21	**100% burnback**



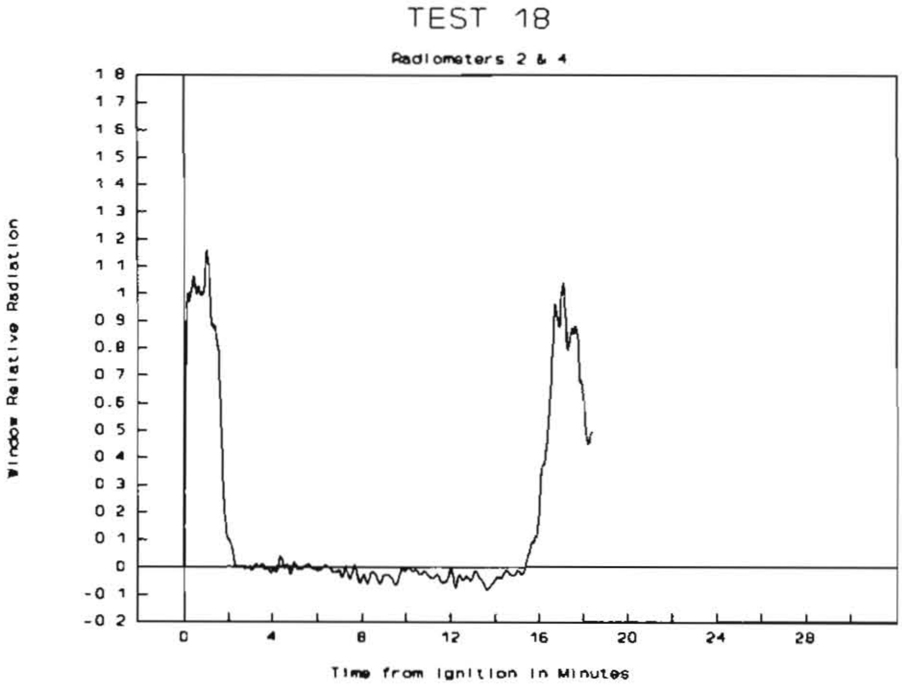
Test Number: 18 **Foam:** AFFF-AR(2)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:58	0:57	**90% extinction**, all remaining flames are in the vicinity of the tray edge nearest to the firefighter, flaring at application point
2:12	1:11	**95% extinction**
2:14	1:13	Flames at the foam application point extinguished
2:27	1:25	**99% extinction**, variations in the wind velocity causing the foam application point to vary between the rear and the front of the left hand side of the tray, when at the front, wind causing foam to feather onto remaining flames
2:45	1:44	**Virtual extinction**, a few very small flames only remain along the tray edge nearest to the firefighter
2:53	1:52	**100% extinction**
3:24	2:23	Foam off tray
	Time From Start of Burnback	
7:53	0:00	Burnback flame applied to foam
7:55	0:02	Flame begins to travel around the tray edge from near to the burnback flame
8:03	0:10	Small flames around 50% of the tray edge
8:09	0:16	Small flames around 75% of the tray edge
8:15	0:22	Small flames around 100% of the tray edge
8:50	0:57	Small flames around 30% of the tray edge
13:05	5:12	Small flames around 5% of the tray edge
13:35	5:42	A hole begins to open up in the foam blanket just in front of the burnback flame
13:52	5:59	Hole closes up
14:50	6:57	Large flames around 15% of the tray edge
15:09	7:16	Almost all tray edge flames burnt out
15:18	7:25	Burnback flame removed

16:02	8:09	**25% burnback**
16:23	8:30	**50% burnback**
16:35	8:42	**75% burnback**
17:01	9:08	**100% burnback**



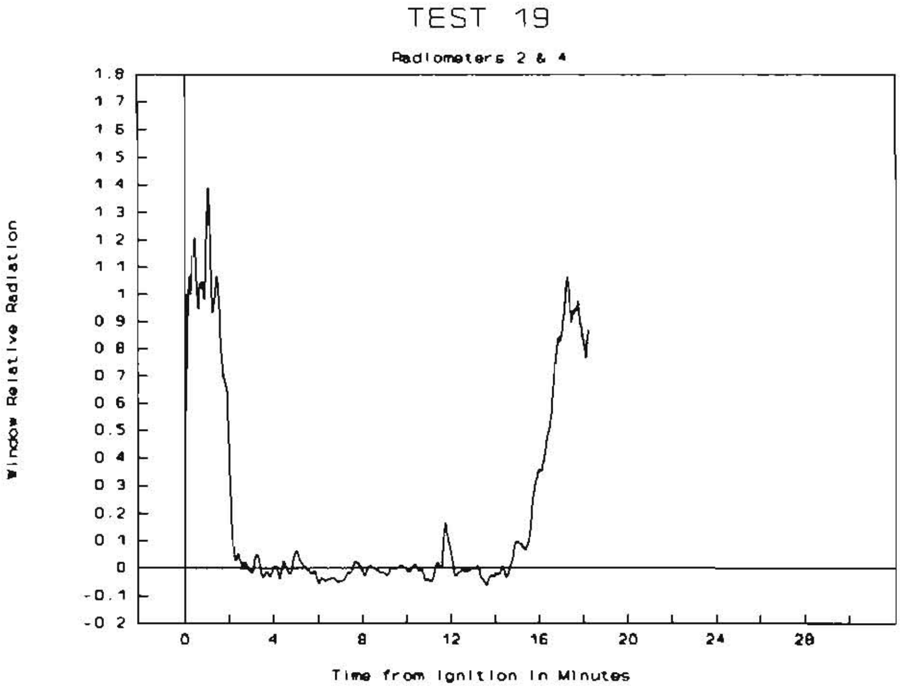
Test Number: 19 **Foam:** AFFF-AR(2)

Application Rate: 4 lpm/sqm **Concentration:** 2%

Weather: Overcast

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
2:09	1:09	**90% extinction**
2:13	1:13	**95% extinction**, flaring at the foam application point
2:45	1:45	Flames at the foam application point extinguished, contaminated (black) area of foam in the centre of the tray burning strongly, a few small flames also remain at the tray edge
3:23	2:23	**99% extinction**, central area almost extinguished
3:50	2:50	**Virtual extinction**, firefighter sweeps the foam jet across the tray, centre flames extinguished
3:53	2:53	Foam applied to the remaining small flames at the far tray edge
3:59	2:59	**100% extinction**
4:29	3:29	Foam off tray
	Time From Start of Burnback	
9:00	0:00	Burnback flame applied to foam, flames immediately travel around the tray edge and ghost across the foam surface
9:10	0:10	Very small flames around 100% of the tray edge
11:30	2:30	A 10% area of the foam surface involved in large flames
11:42	2:42	**16% burnback (peak flare radiation)** **30% area of the foam surface involved in large flames**
12:18	3:18	All foam surface flames burnt out
13:00	4:00	All tray edge flames burnt out
15:13	6:13	Burnback flame removed
15:43	6:43	**25% burnback**
16:26	7:26	**50% burnback**
16:45	7:45	**75% burnback**

17:13	8:13	**100% burnback**



Test Number: 20

Foam: FP(1)

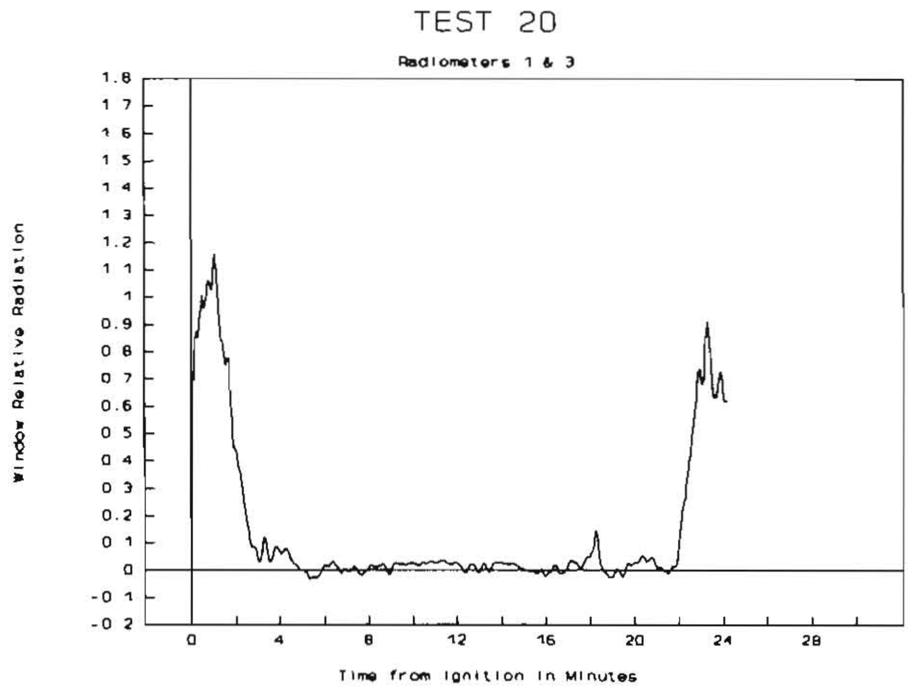
Application Rate: 5 lpm/sqm

Concentration: 3%

Weather: Sunny

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
2:38	1:38	**90% extinction**, flaring at the foam application point
2:57	1:57	**95% extinction**, the majority of the remaining flame is in the vicinity of the right hand side tray edge
4:42	3:42	**99% extinction**, flames at the foam application point and along the right hand side tray edge extinguished, very small flames remain along the tray edge nearest to the firefighter
4:48	3:48	**Virtual extinction**
5:15	4:15	**100% extinction**
5:45	4:45	Foam off tray
	Time From Start of Burnback	
10:16	0:00	Burnback flame applied to foam
15:22	5:06	Contaminated (black) area of the foam blanket, near to the burnback flame, ignited
16:41	6:25	The tray edge nearest to the burnback flame ignites
17:37	7:21	Small flames around 25% of the tray edge, a 5% area of small flames in the centre of the foam blanket
17:55	7:39	Flames around the tray edge and on the surface of the foam blanket begin to increase in intensity
18:16	8:00	**15% burnback (peak flare radiation)** **A 25% area of the foam surface involved in large flames**
18:51	8:35	All tray edge and foam surface flames burnt out
19:46	9:30	A small hole opens up in the foam blanket away from the burnback flame
20:07	9:51	Hole reaches an area of 2%
21:19	11:03	Hole completely closes up

21:48	11:32	Burnback flame removed
22:14	11:58	**25% burnback**
22:37	12:21	**50% burnback**
23:10	12:54	**75% burnback**
23:16	13:00	**100% burnback**



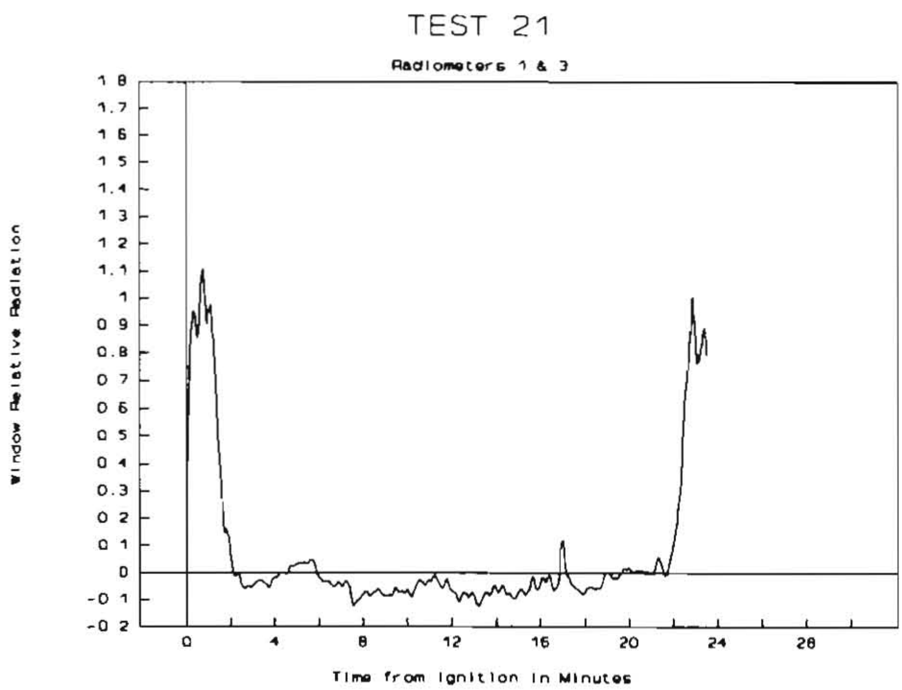
Test Number: 21 **Foam:** FP(2)

Application Rate: 5 lpm/sqm **Concentration:** 3%

Weather: Sunny Periods

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:56	0:56	**90% extinction**, flaring at the foam application point
2:01	1:01	**95% extinction**
2:39	1:39	**99% extinction**
2:40	1:40	Flames at the foam application point extinguished, small flames around the tray edge and in a 2% area in the centre of the foam blanket
2:48	1:48	Flames remain around the tray edge only
2:56	1:56	Small flames spread from the right hand side tray edge over 5% of the foam blanket
3:04	2:04	Blanket flames burnt out
3:18	2:18	Further small flame spread from the right hand side tray edge
3:44	2:44	**Virtual extinction**, blanket flames burnt out
4:44	3:44	Foam jet feathered and directed at remaining tray edge flames
4:50	3:50	**100% extinction**, foam application returned to the rear of the left hand side of the tray
5:21	4:21	Foam off tray
	Time From Start of Burnback	
9:50	0:00	Burnback flame applied to foam
11:23	1:33	Wall of very small flames ghosts over the surface of the foam blanket from the burnback flame
11:49	1:59	Very small flames around 50% of the tray edge
11:52	2:02	The whole of the foam blanket has been affected by the flame wall
13:13	3:23	Very small flames around 100% of the tray edge

13:29	3:39	The flames at the tray edge beginning to increase in size, large flames spreading from the burnback flame and across the foam surface
15:38	5:48	40% of the foam surface involved in large sparse flames, followed by flames subsiding
16:59	7:09	**12% burnback (peak flare radiation)** **40% of the foam surface involved in large flames**
17:18	7:28	All foam surface flames extinguished
21:34	11:44	Burnback flame removed
22:14	12:24	**25% burnback**
22:27	12:37	**50% burnback**
22:38	12:48	**75% burnback**
22:54	13:04	**100% burnback**



Test Number: 22 **Foam:** FFFP(1)

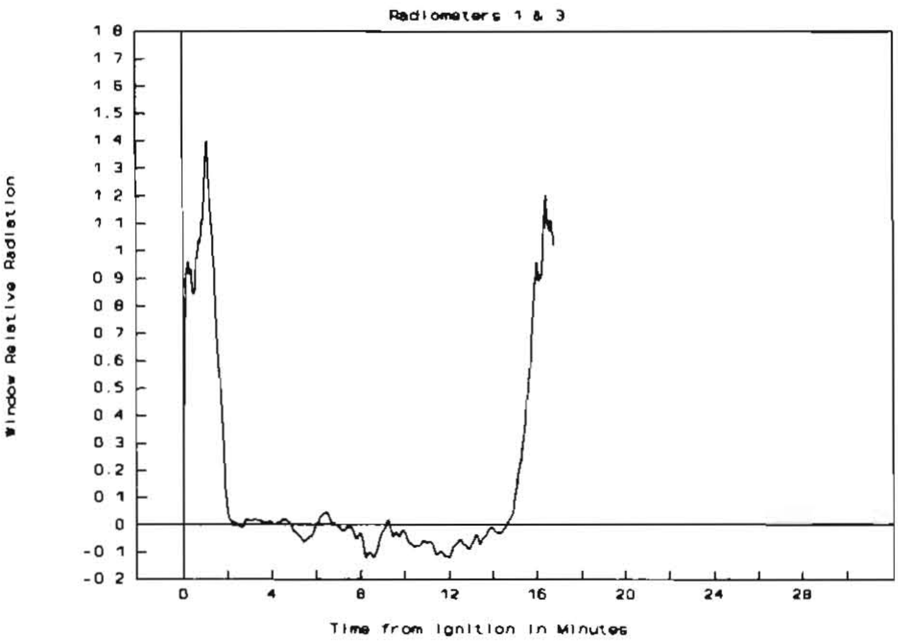
Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny Periods

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:57	0:57	**90% extinction**
2:01	1:01	**95% extinction**
2:21	1:21	99% extinction, a small area of flame remains on the foam surface in the centre of the tray, a few small flames around the tray edge
2:25	1:25	**Virtual extinction**
2:56	1:56	Flames in the centre of the tray burn back to 97% extinction
3:11	2:11	Small flames on the foam surface in the centre of the tray and around tray edge
4:10	3:10	**99% extinction**
4:11	3:11	Firefighter walks 30° clockwise, foam jet applied directly to the flames in the centre of the tray
4:22	3:22	Firefighter stops walking
4:28	3:28	Flames in the centre of the tray extinguished, foam applied directly to the flames at the tray edge
4:40	3:40	Firefighter walks 90° anticlockwise
5:02	4:02	Firefighter stops walking
5:33	4:33	**100% extinction**, foam application changed to the rear of the left hand side of the tray
6:03	5:03	Foam off tray
	Time From Start of Burnback	
10:33	0:00	Burnback flame applied to foam
10:37	0:04	Tray edge nearest to burnback flame ignites and flames begin to ghost over the surface of the foam blanket
10:50	0:17	75% of the tray edge involved in small flames, 75% of the surface of the foam blanket has been affected by the small ghosting surface flames

10:55	0:22	100% of the tray edge involved in small flames, ghosting flames have ewept over 100% of the surface of the foam blanket. Areas of flame on the foam blanket continue to increase and decrease in size and intensity
12:48	2:15	A 5% area of the foam blanket involved in large flames
12:52	2:19	5% area burnt out
13:00	2:27	**A 10% area of the foam blanket involved in sparse large flames**
13:10	2:37	10% area burnt out
13:34	3:01	A 5% area of the foam blanket involved in large flames, a small hole opens up in the foam blanket away from the burnback flame
13:39	3:06	5% area burnt out
14:43	4:10	Burnback flame removed
15:18	4:45	**25% burnback**
15:38	5:05	**50% burnback**
15:50	5:17	**75% burnback**
16:17	5:44	**100% burnback**

TEST 22



Test Number: 23

Foam: FFFP(2)

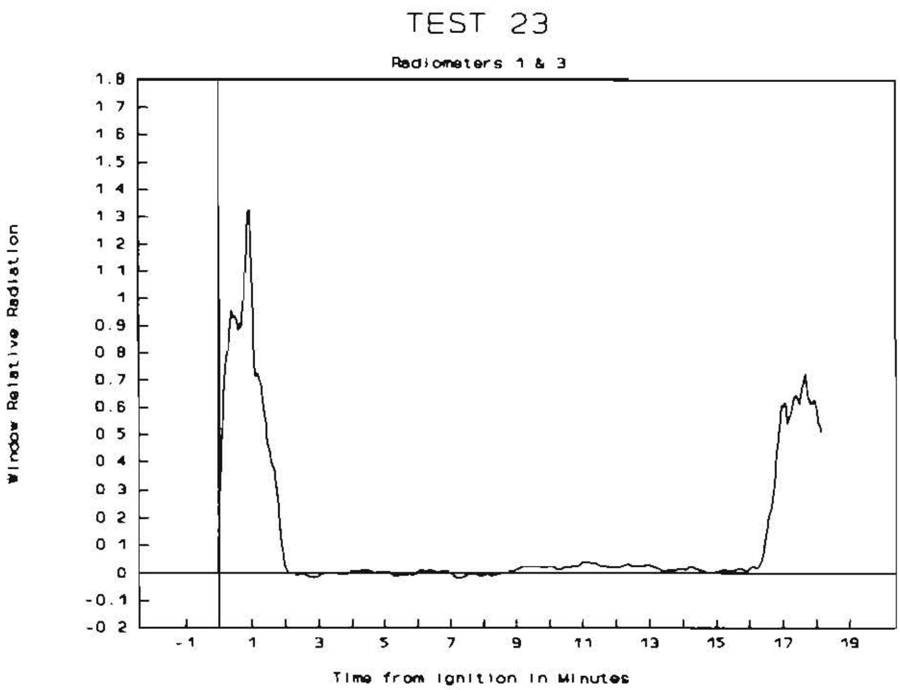
Application Rate: 4 lpm/sqm

Concentration: 3%

Weather: Overcast

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:54	0:53	90% extinction, flaring at foam application point
1:58	0:57	95% extinction
2:17	1:16	Flames at the foam application point extinguished
2:20	1:19	99% extinction
2:38	1:37	Virtual extinction, small flames remain around 3% of the tray edge and in a contaminated (black) area of foam in the centre of the tray
3:38	2:37	Firefighters walk 45° anticlockwise, foam jet swept across tray, flames in the centre of the tray increase in intensity
3:46	2:45	Flames in the centre of the tray extinguished
3:53	2:52	Firefighters stop walking, foam applied directly to the remaining flames at the tray edge
4:12	3:11	Firefighters walk 30° anticlockwise
4:19	3:18	Firefighters stop walking
5:22	4:21	100% extinction, foam application changed to the rear of the left hand side of the tray
5:52	4:51	Foam off tray
	Time From Start of Burnback	
10:22	0:00	Burnback flame applied to foam, small flames immediately ghost across the top surface of the foam blanket and around the tray edges
10:37	0:15	Small flames around 50% of the tray edge
10:44	0:22	Small flames around 75% of the tray edge
10:50	0:28	Small flames around 100% of the tray edge, the whole of the upper surface of the foam blanket has been damaged by the small ghosting flames

11:10	0:48	**5% of the top surface of the foam blanket involved in large flames**
14:10	3:48	5% of the top surface of the foam blanket continues to involved in large flames
15:21	4:59	Almost all of the tray edge and surface flames burnt out, small holes open up in the foam blanket away from the burnback flame
16:07	5:45	Burnback flame removed, small holes total 5% in area
16:24	6:02	**25% burnback (observed)**
16:35	6:13	**50% burnback (observed)**
16:46	6:24	**75% burnback (observed)**
16:53	6:31	**100% burnback (observed)**



Test Number: 24 **Foam:** P(1)

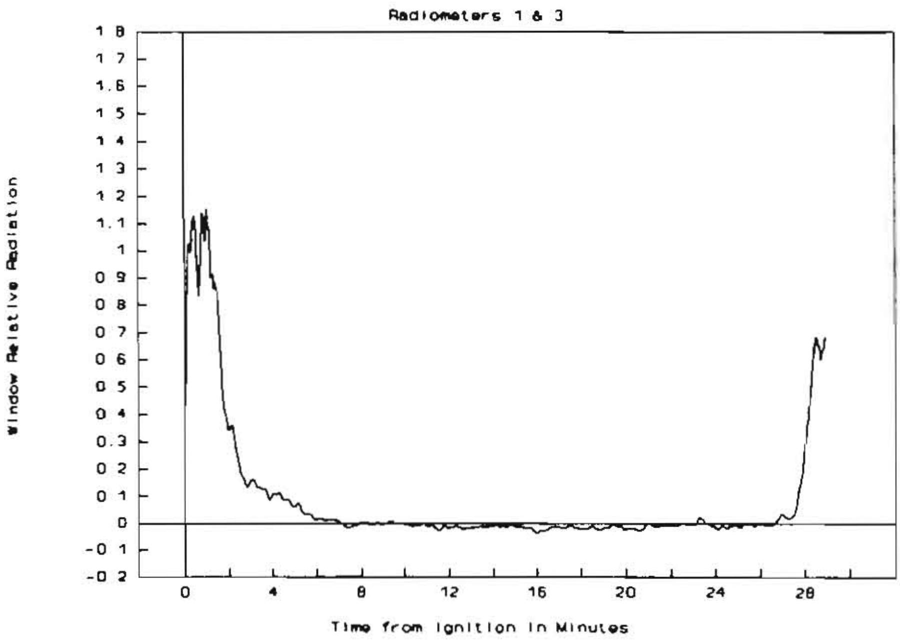
Application Rate: 6.5 lpm/sqm **Concentration:** 3%

Weather: Overcast

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
3:10	2:09	50% extinction
3:45	2:44	**90% extinction**, flaring along complete foam application foot print
5:00	3:59	Small flames over most of the foam blanket, large flames around the tray edge
5:17	4:16	**95% extinction**
6:25	5:24	Flames along foam foot print extinguished, flames mainly restricted to tray edge
6:31	5:30	Foam jet swept across the foam surface, flaring occurred in the centre of the foam blanket where the foam jet hit a contaminated (black) area of foam
6:49	5:48	**99% extinction**, remaining flames around 50% of the tray edge to the left of the firefighter
7:05	6:04	**Virtual extinction**
7:09	6:08	Only a few small flames remain around the tray edge, foam applied directly to these remaining flames
7:42	6:41	Firefighter walks 60° anticlockwise
7:48	6:47	**100% extinction**
7:49	6:48	Firefighter stops walking, foam applied to the rear of the left hand side of the tray
8:18	7:17	Foam off tray
	Time From Start of Burnback	
12:49	0:00	Burnback flame applied to foam
15:42	2:53	Small flames begin to burn around the tray edge nearest to the burnback flame
16:00	3:11	Very small area of flame burning on foam surface near to the burnback flame

16:48	3:59	1% of the foam blanket area involved in flames, 25% of the tray edge involved in small flames
17:49	5:00	50% of the tray edge involved in small flames
18:38	5:49	**3% of the foam blanket involved in flames**
21:04	8:15	25% of the tray edge involved in large flames
21:23	8:34	75% of the tray edge involved in flames
22:20	9:31	100% of the tray edge involved in flames, foam blanket surface flames burnt out
24:30	11:41	Tray edge flames burnt out
25:04	12:15	Foam surface near to the burnback flame ignites, flame travels across the foam surface towards the left side of the tray
25:20	12:31	25% of the tray edge, on the left hand side, involved in flame
26:21	13:32	Further flames travel across the foam surface
26:56	14:07	Burnback flame removed
27:45	14:56	**25% burnback (observed)**
27:55	15:06	**50% burnback (observed)**
28:12	15:23	**75% burnback (observed)**
28:22	15:33	**100% burnback (observed)**

TEST 24



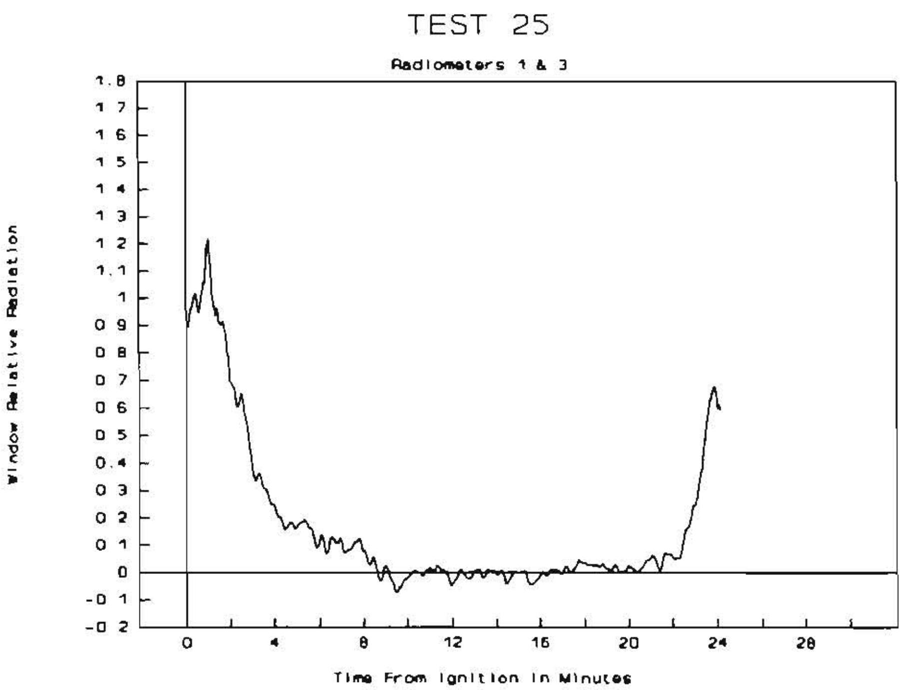
Test Number: 25 **Foam:** P(2)

Application Rate: 6.5 lpm/sqm **Concentration:** 3%

Weather: Sunny periods

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
2:48	1:48	Flame intensity reduced, the foam blanket is visible but flames burning over the whole tray surface
5:25	4:25	A coherent foam blanket (ie no flames burning on its surface) over 50% of the tray. Flaring along complete foam application foot print
6:47	5:47	90% extinction
7:00	6:00	Foam jet feathered over complete tray surface causing further flaring
7:08	6:08	95% extinction
7:38	6:38	Large flames along and adjacent to the tray edge nearest to the firefighter
7:50	6:50	Foam applied directly to the flames at the tray edges causing further flaring, back to 85% extinction
7:59	6:59	90% extinction
8:35	7:35	95% extinction
8:48	7:48	99% extinction
8:54	7:54	Virtual extinction, flaring extinguished, very small flames along the tray edges only
9:53	8:53	100% extinction, foam applied to the centre of the tray
10:23	9:23	Foam off tray
	Time From Start of Burnback	
14:53	0:00	Burnback flame applied to foam, the foam surface near to the burnback flame immediately begins to burn
15:10	0:17	Flames spread to the tray edge
15:22	0:29	25% of the tray edge involved in small flames, 25% of the area of the foam blanket affected by surface flame damage
15:50	0:57	Flames at the tray edge burnt out

16:09	1:16	Flames on the foam blanket burnt out, 35% of the top of the foam blanket damaged
20:50	5:57	Further flame spread across the surface of the foam blanket from the burnback flame
20:59	6:06	**5% of the foam blanket surface involved in large flames**
21:27	6:34	Surface flames spread across previously damaged foam surface and burn out
22:03	7:10	Burnback flame removed
22:37	7:44	**25% burnback (observed)**
23:10	8:17	**50% burnback (observed)**
23:16	8:23	**75% burnback (observed)**
23:34	8:41	**100% burnback (observed)**



Test Number: 26

Foam: S(1)

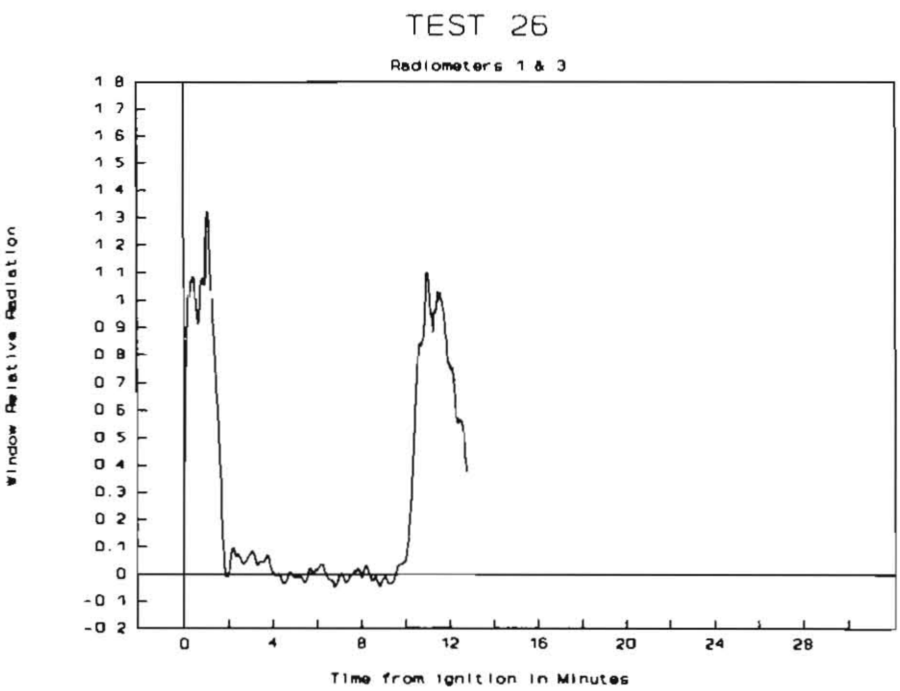
Application Rate: 6.5 lpm/sqm

Concentration: 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up in the tray
1:44	0:43	**90% extinction**, flaring at the foam application point
1:46	0:45	95% extinction
2:23	1:22	99% extinction
2:49	1:48	Flames at application point extinguished
3:30	2:29	Foam jet swept across foam blanket to extinguish flames in the centre of the tray but causing further flaring
3:45	2:44	Foam applied directly to the remaining flames at the tray edge
3:49	2:48	**95% extinction**
3:52	2:51	**99% extinction**
4:00	2:59	**Virtual extinction**
4:37	3:36	**100% extinction**, foam applied to the rear of the left hand side of the tray, some flames remaining along the outside channel of the tray due to fuel pushed out of the fire tray by the foam jet
5:17	4:16	Foam off tray
	Time From Start of Burnback	
6:20	0:00	Flames begin to burn around the rear tray edge, ignition source from flames outside of the tray **BURNBACK FLAME NOT USED**
6:35	0:15	Small flames around 100% of the tray edge, some flames ghosting around the foam blanket destroying the upper layer of foam
8:53	2:33	5% of the foam blanket surface involved in small flames
9:18	2:58	10% of the foam blanket surface involved in sparse flames
9:51	3:31	**15% of the foam blanket surface involved in sparse flames**
10:13	3:53	**25% burnback**

10:22	4:02	**50% burnback**
10:31	4:11	**75% burnback**
10:54	4:34	**100% burnback**



Test Number: 27

Foam: S(2)

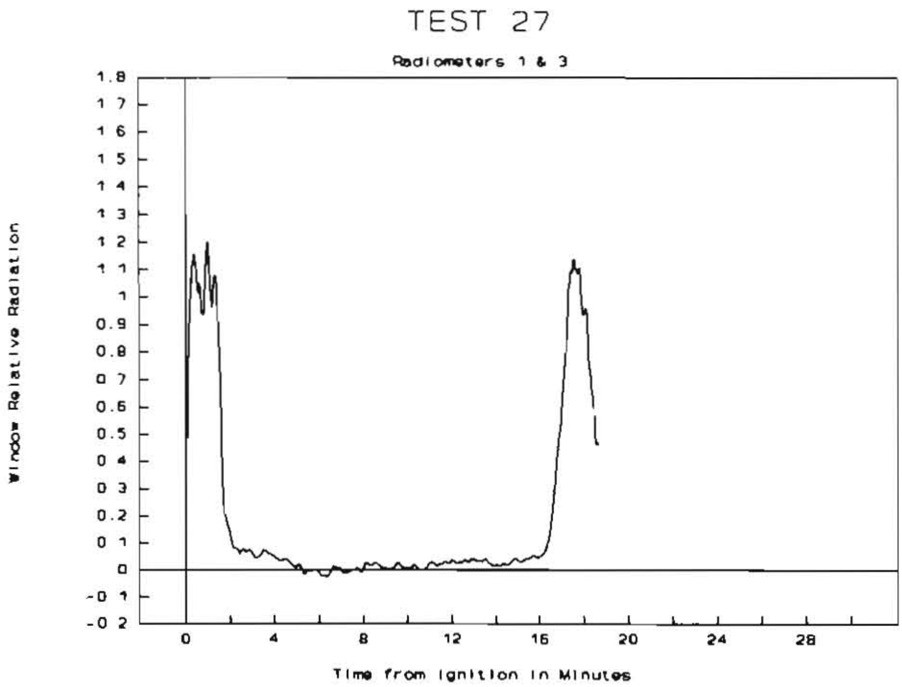
Application Rate: 6.5 lpm/sqm

Concentration: 3%

Weather: Overcast

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
2:05	1:05	90% extinction, flaring at foam application point, although intensity reduced by 90%, almost all of the foam blanket is still involved in sparse flames
3:04	2:03	95% extinction, 20% of blanket involved in sparse flames
4:00	2:59	Foam jet oscillated to feather foam over whole tray area
4:57	3:56	Majority of the remaining flames are around or in the vicinity of the tray edge
5:04	4:03	99% extinction
6:01	5:00	Virtual extinction
6:07	5:06	100% extinction, immediately reignited rear edge of tray due to flames outside of the tray. Foam application continued in this area, foam extinguished flames inside and outside the tray
7:10	6:09	Foam off tray
	Time From Start of Burnback	
11:08	0:00	Burnback flame applied to foam, tray edge nearest to the burnback flame immediately ignited
11:37	0:29	Small flames around 50% of the tray edge
11:50	0:42	Small flames around 75% of the tray edge
13:26	2:18	Small flames around 100% of the tray edge, some damage to the upper layer of 25% of the foam blanket
15:35	4:27	Large flames around 25% of the tray edge, 5% of the foam blanket involved in large flames
16:06	4:58	Large flames around 50% of the tray edge, 10% of the foam blanket involved in large flames

16:14	5:06	Burnback flame removed, burnback developed from various areas of the tray edge and not from the burnback flame location
16:37	5:29	**25% burnback**
16:54	5:46	**50% burnback**
17:09	6:01	**75% burnback**
17:19	6:11	**100% burnback**



Test Number: 28 **Foam:** AFFF-AR(2)

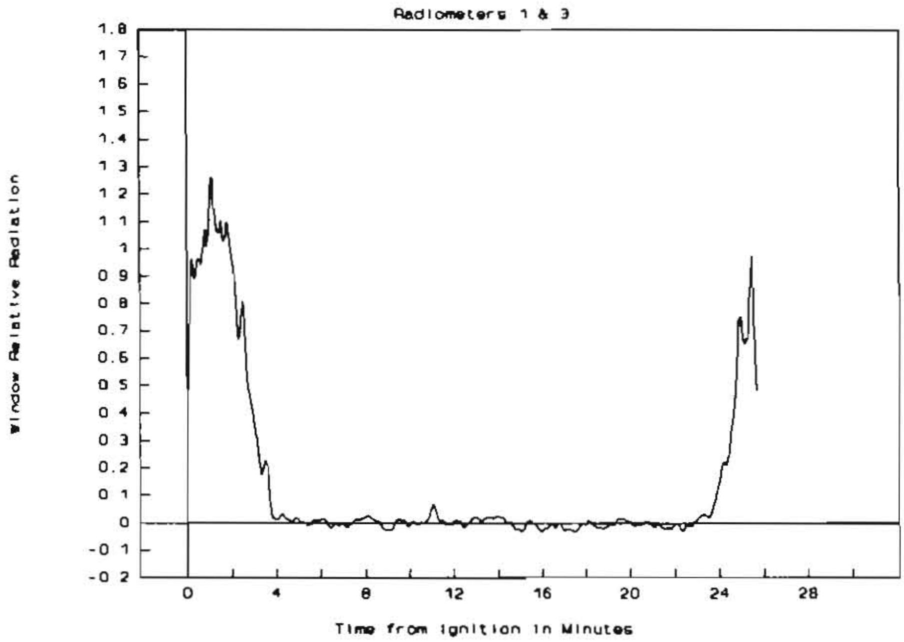
Application Rate: 4 lpm/sqm **Concentration:** 1.5%

Weather: Overcast

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
3:35	2:35	Flaring at the foam application point, foam blanket around 85% of the tray edge, large 25% burning area at the centre rear of the tray, branch application point changed to this area
3:41	2:41	**90% extinction**
3:45	2:45	**95% extinction**
3:50	2:50	99% extinction
3:57	2:57	Flames in the centre of the tray and application point flames extinguished, remaining flames along the tray edge only, foam application returned to the rear of the left hand side of the tray
4:09	3:09	Small flames at the tray edge reignite the foam application point
4:29	3:29	Flames at the foam application point extinguished
4:33	3:33	**99% extinction**, small flames remain around the tray edge
4:40	3:40	**Virtual extinction**
5:20	4:20	Foam jet feathered and applied directly to the burning tray edges
5:27	4:27	**100% extinction**, foam application changed back to the rear of the left hand side of the tray
5:57	4:57	Foam off tray
	Time From Start of Burnback	
10:28	0:00	Burnback flame applied to the foam blanket, small flames immediately begin to ghost over the foam surface and around the tray edge
10:40	0:12	Small flames around 100% of the tray edge
10:49	0:21	Small flames in the centre of the foam blanket begin to increase in size and intensity

10:56	0:28	**9% burnback (peak flare radiation) 20% of the foam blanket, at the rear of the centre of the tray, involved in large flames**
11:40	1:12	Foam blanket flames burnt out
11:53	1:25	Only remaining flames around 10% of the tray edge
15:27	4:59	5% of the foam blanket, to the left of the burnback flame, involved in large flames
16:13	5:33	All surface and tray edge flames burnt out
22:03	11:23	Burnback flame removed, burnback develops from this area
24:27	13:59	**25% burnback**
24:46	14:18	**50% burnback**
24:59	14:31	**75% burnback**
25:25	14:57	**100% burnback**

TEST 28



Test Number: 29

Foam: AFFF-AR(1)

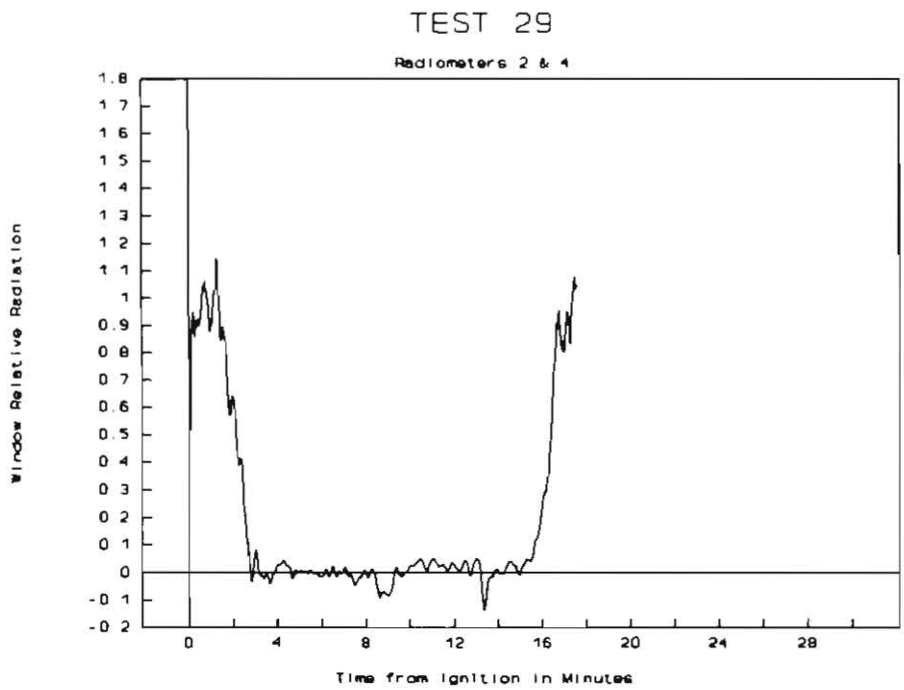
Application Rate: 4 lpm/sqm

Concentration: 1.5%

Weather: Overcast, slight drizzle

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the fire tray, a clockwise foam swirl set-up in the tray
2:39	1:39	90% extinction, flaring at the foam application point
2:56	1:56	Majority of remaining flames in centre of the tray
3:04	2:04	95% extinction
3:08	2:08	Foam jet slowly swept across tray to extinguish tray centre flames
3:12	2:12	99% extinction
3:20	2:20	Foam jet returned to original application point
3:26	2:26	Virtual extinction, A few small flames remaining, mainly around tray edge
4:15	3:15	Firefighters move anticlockwise
4:20	3:20	Foam feathered over remaining tray edge flames
4:44	3:44	100% extinction
5:14	4:14	Foam off tray
	Time From Start of Burnback	
9:45	0:00	Burnback flame applied to foam
10:20	0:35	Small flames around 25% of tray edge
10:23	0:38	Small flames around 50% of tray edge
10:41	0:56	Small flames around 100% of tray edge, some small flames in centre of tray, all flames increasing in intensity and burning on top layer of foam
11:13	1:28	Large flames in centre of tray
11:24	1:39	10% of the foam surface involved in large flames
12:46	3:01	All tray flames burnt out
13:27	3:42	Burnback flame removed, burnback developed progressively from this area
16:00	6:15	25% burnback

16:24	6:39	**50% burnback**
16:33	6:48	**75% burnback**
16:48	7:03	**100% burnback**



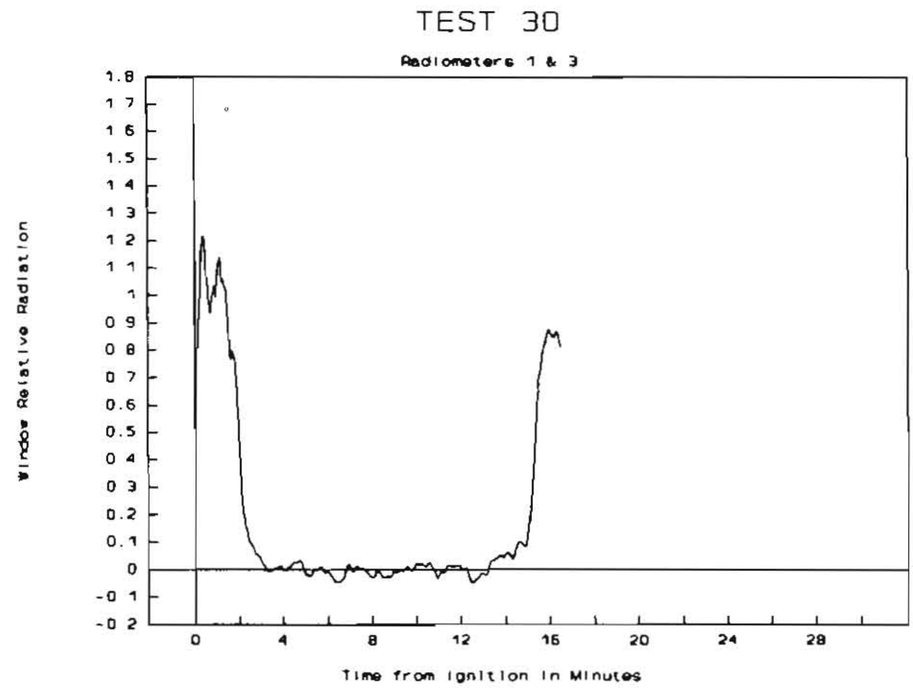
Test Number: 30 **Foam:** FFFP-AR(1)

Application Rate: 4 lpm/sqm **Concentration:** 1.5%

Weather: Hazy sunshine

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
2:19	1:18	A coherent foam blanket with no burning areas visible over 60% of the tray surface, flaring along the foam application foot print
2:30	1:29	**90% extinction**
2:52	1:51	Foam application point extinguished, an area of flame remains in the centre of the tray
2:53	1:53	**95% extinction**
2:56	1:55	Foam jet slowly traversed across the tray from left to right
3:13	2:12	**99% extinction**, foam jet reached the right hand side of the tray
3:23	2:22	**Virtual extinction**, all flames in the centre of the tray extinguished, only small flames remaining around the tray edge
3:37	2:36	Anticlockwise foam swirl set up in the tray, only a small area of flame remains along the left hand edge of the tray
4:14	3:13	**100% extinction**, foam application continued to the rear of the right hand side of the tray
4:44	3:43	Foam off tray
	Time From Start of Burnback	
9:14	0:00	Burnback flame applied to the foam blanket, small flames immediately begin to ghost over the foam surface and around the tray edge.
9:39	0:25	Small flames around 75% of the tray edge
9:47	0:33	Small flames around 100% of the tray edge, **1% of the foam area involved in flames in the centre of the tray.** The whole of the top layer of the foam blanket has been damaged
10:25	1:11	Tray edge fires burnt out

12:05	2:51	Flames in the centre of the tray burnt out
12:39	3:25	A small hole begins to open up in the foam blanket near to the burnback flame
13:20	4:06	Hole increases to 1% of the foam blanket area
14:02	4:48	Hole increases to 2% of the foam blanket area
14:03	4:49	Hole ignites
14:28	5:14	Burnback flame removed, burnback develops from this area
15:09	5:55	**25% burnback**
15:21	6:07	**50% burnback**
15:36	6:22	**75% burnback**
15:47	6:33	**100% burnback (observed)**



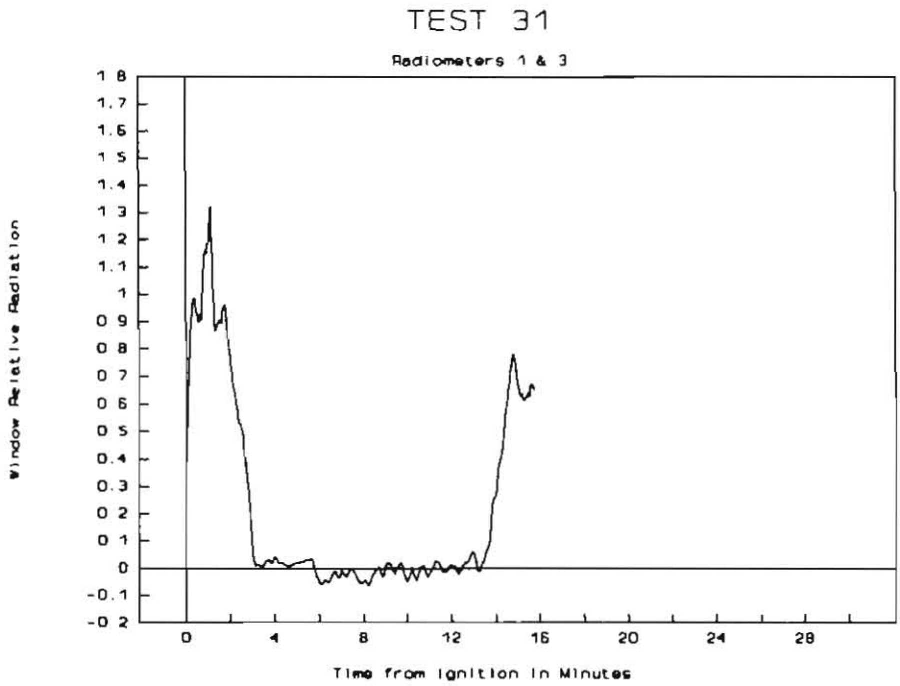
Test Number: 31 **Foam:** FFFP-AR(2)

Application Rate: 4 lpm/sqm **Concentration:** 1.5%

Weather: Hazy sunshine

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
2:50	1:49	A coherent foam blanket with no burning areas visible over 70% of the tray surface, large area of flame in the centre of the tray
2:56	1:55	Foam jet slowly traversed across the tray from left to right
3:00	1:59	**90% extinction**
3:02	2:01	**95% extinction**
3:06	2:05	**99% extinction**, flames in the centre of the tray extinguished, flames restricted to along the tray edge, foam jet reached the right hand side of the tray
3:11	2:10	Anticlockwise foam swirl set up in the tray
3:27	2:26	Only remaining burning area along the left hand tray edge
3:39	2:38	Remaining flames pushed along to the tray edge nearest to the firefighter
3:49	2:48	**Virtual extinction**
4:05	3:04	Firefighter walks 90° anticlockwise, foam applied directly to the remaining flames
4:20	3:19	**100% extinction**, foam application changed to the rear of the left hand side of the tray
4:50	3:49	Foam off tray
	Time From Start of Burnback	
9:20	0:00	Burnback flame applied to the foam blanket, small flames immediately begin to ghost over the foam surface and around the tray edge
9:42	0:22	Small flames around 100% of the tray edge, the whole of the top layer of the foam blanket has been damaged
10:06	0:46	1% of the foam blanket area, near to the burnback flame, involved in flames

11:00	1:40	Tray edge flames burnt out, a small area of foam burning in the centre of the tray
11:33	2:13	**A 10% area of the foam blanket, in the centre of the tray, involved in sparse large flames** along the contaminated (black) foam swirl pattern, flames continue to travel around these swirl patterns
12:57	3:37	**6% burnback (peak flare radiation)**
13:27	4:07	Burnback flame removed, burnback develops from this area
13:53	4:33	**25% burnback**
14:22	5:02	**50% burnback**
14:44	5:24	**75% burnback**
14:51	5:31	**100% burnback (observed)**



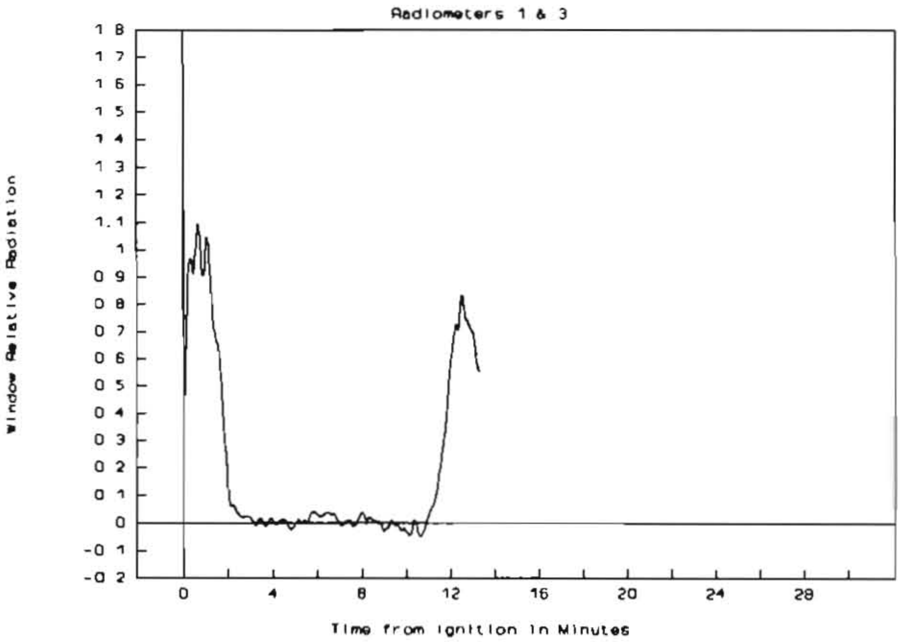
Test Number: 32 **Foam:** FFFP(1)

Application Rate: 4 lpm/sqm **Concentration:** 1.5%

Weather: Hazy sunshine

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
2:02	1:02	**90% extinction**, flaring along the foam application foot print
2:19	1:19	**95% extinction**
2:29	1:29	**99% extinction**
2:41	1:41	All flames at the application point extinguished, remaining flames along the tray edge to the left of the firefighter
2:46	1:46	**Virtual extinction**
3:23	2:23	**100% extinction**
3:53	2:53	Foam off tray
	Time From Start of Burnback	
8:24	0:00	Burnback flame applied to the foam blanket, small flames immediately begin to ghost over the top layer of the foam blanket and around the tray edge
8:34	0:10	Small flames around 50% of the tray edge
8:41	0:17	Small flames around 75% of the tray edge
8:46	0:22	Small flames around 100% of the tray edge, the whole of the top layer of the foam blanket has been damaged
9:53	1:29	Almost all of the flames on the foam blanket and around the tray edge burnt out
11:00	2:36	Burnback flame removed
11:36	3:12	**25% burnback**
11:40	3:16	**50% burnback (observed)**
11:54	3:30	**75% burnback (observed)**
12:01	3:37	**100% burnback (observed)**

TEST 32



Radiometers 1 & 3
Window Relative Radiation
1 8
1 7
1 6
1 5
1 4
1 3
1 2
1.1
1
0 9
0 8
0 7
0 6
0 5
0 4
0 3
0 2
0 1
0
-0 1
-0 2
0
4
8
12
16
20
24
28
Time from ignition in Minutes

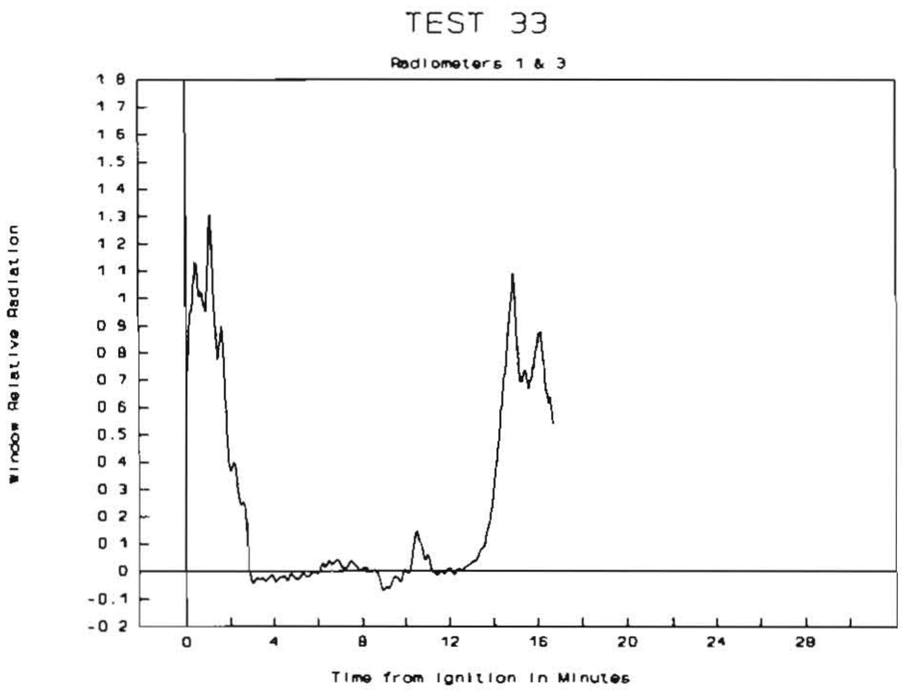
Test Number: 33 **Foam:** FFFP(2)

Application Rate: 4 lpm/sqm **Concentration:** 1.5%

Weather: Hazy sunshine

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
2:18	1:17	A coherent foam blanket with no areas visible over 60% of the tray surface, large area of flames in the centre of the tray
2:40	1:39	A 20% area of large flames in the centre of the tray, foam jet slowly traversed across the tray from left to right
2:46	1:45	**90% extinction**
2:49	1:48	**95% extinction**
2:58	1:57	**99% extinction**
3:03	2:02	**Virtual extinction**, flames in the centre of the tray extinguished, flames restricted to the left hand side tray edge, foam jet reached the right hand side of the tray
3:11	2:10	Anticlockwise foam swirl set up
3:41	2:40	Remaining flames along the tray edge nearest to the firefighter
4:00	2:59	Firefighter walks 45° anticlockwise, foam applied directly to the remaining flames
4:10	3:09	Firefighter stops walking
4:40	3:39	**100% extinction**, foam applied to the rear of the left hand side of the tray
5:11	4:10	Foam off tray
	Time From Start of Burnback	
9:41	0:00	Burnback flame applied to the foam blanket, small flames immediately begin to ghost over the top layer of the foam blanket and around the tray edge
10:03	0:22	Small flames around 100% of the tray edge, the whole of the top layer of the foam blanket has been damaged
10:29	0:48	**15% burnback (peak flare radiation)** Large sparse flames over 50% of the foam surface

11:32	1:51	All tray edge and foam surface flames burnt out
13:34	2:53	Burnback flame removed
13:56	4:15	**25% burnback**
14:15	4:34	**50% burnback**
14:33	4:52	**75% burnback**
14:48	5:07	**100% burnback**



BURNBACK TEST ONLY

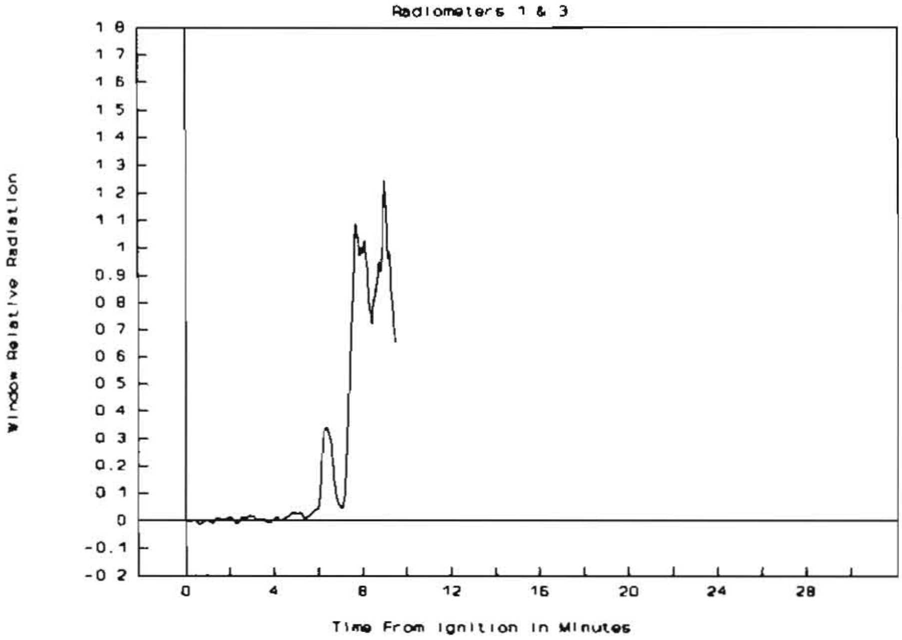
Test Number: 34 **Foam:** AFFF(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Hazy sunshine

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00	0:00	Foam applied to the rear of the left hand side of the tray
0:04	0:04	Foam commenced a clockwise swirl
0:10	0:10	50% of fuel area covered with foam
0:33	0:33	100% of fuel area covered with foam
1:00	1:00	Foam off tray
	Time From Start of Burnback	
6:00	0:00	Burnback flame applied to foam
6:01	0:01	Immediate flaring around burnback flame
6:05	0:05	Flame ghosting over surface of foam towards centre of the tray
6:11	0:11	Large flames in centre of tray burning away top layer of foam
6:12	0:12	25% of the foam surface involved in large flames
6:16	0:16	25% burnback (radiation) 50% of the foam surface involved in large flames
6:28	0:28	**39% burnback (peak flare radiation)** **75% of the foam surface involved in large flames**
6:36	0:36	Burnback flame removed
6:44	0:44	Flames dying down, 50% of the foam surface involved in flame
6:46	0:46	25% of the foam surface involved in flame
6:56	0:56	Burnback flame re-applied to foam, burnback now develops progressively from this area
7:22	1:22	**25% burnback**
7:23	1:23	Burnback flame removed
7:29	1:29	**50% burnback**
7:37	1:37	**75% burnback**
7:44	1:44	**100% burnback**

TEST 34



Radiometers 1 & 3
Window Relative Radiation
Time From Ignition in Minutes

Test Number: 35

Foam: FP(1)

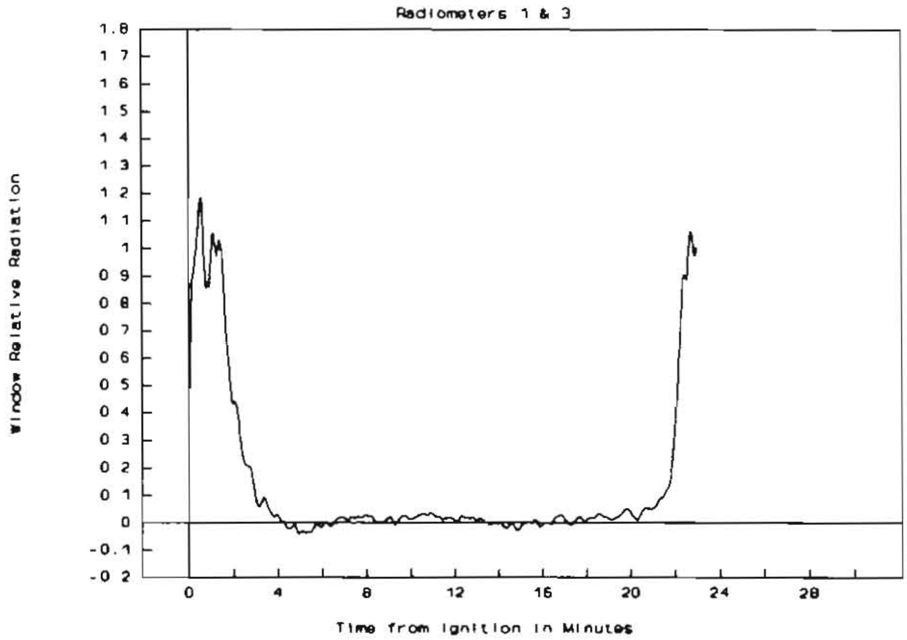
Application Rate: 4 lpm/sqm

Concentration: 3%

Weather: Overcast

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:00		Ignition
1:00	0:00	Foam applied to rear of left hand side of tray, a clockwise foam swirl set up
2:57	1:57	90% extinction, flaring along the foam application footprint
3:13	2:13	Small sparse flames over 80% of the foam surface, 20% of the tray involved in large flames
3:33	2:33	95% extinction
4:36	3:36	99% extinction, foam application point flames extinguished
4:41	3:41	Virtual extinction, only small flames remain around the tray edge
5:18	4:18	100% extinction
5:48	4:48	Foam off tray
	Time From Start of Burnback	
10:18	0:00	Burnback flame applied to foam blanket
11:38	1:20	Small flames around 5% of the tray edge near to the burnback flame
13:25	3:07	Small flames around 25% of the tray edge, large flames around 5% of the tray edge, small flames have swept over and damaged 50% of the top surface of the foam
13:50	3:32	Large flames around 10% of the tray edge
14:43	4:25	A contaminated (black) area of foam in the centre of the tray ignites
15:03	4:45	Large tray edge flames almost burnt out
15:15	4:57	5% of the foam blanket area, centre of the tray, involved in large flames
16:39	6:21	Almost all foam surface and tray edge flames burnt out
20:48	10:30	Burnback flame removed
21:54	11:36	25% burnback
22:07	11:49	50% burnback
22:16	11:58	75% burnback
22:38	12:20	100% burnback

TEST 35



Radiometers 1 & 3
1.8
1 7
1 6
1 5
1 4
1 3
1 2
1 1
1
0 9
0 8
0 7
0 6
0 5
0 4
0 3
0 2
0 1
0
-0.1
-0 2
Window Relative Radiation
0
4
8
12
16
20
24
28
Time from Ignition in Minutes

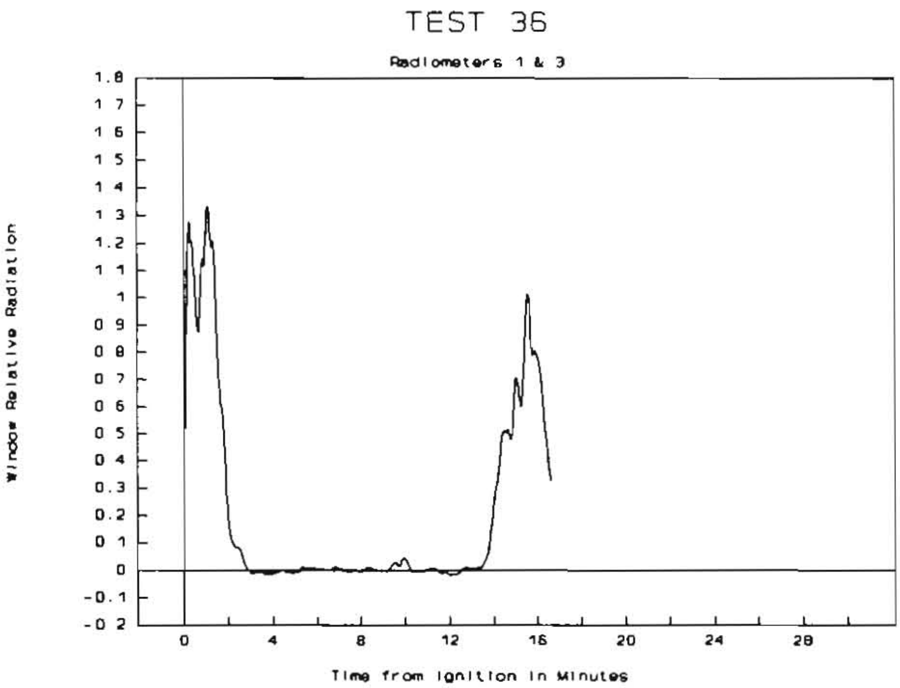
Test Number: 36 **Foam:** FP(2)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray
2:09	1:09	Small sparse flames over 80% of the foam blanket area, large flames over the remainder of the tray, flaring along the foam application foot print
2:12	1:12	**90% extinction**
2:38	1:38	**95% extinction**
2:51	1:51	**99% extinction, small flames remaining around the tray edge, in the centre of the tray and at the foam application point**
3:37	2:37	**Virtual extinction,** flames in the centre of the tray and at the foam application point extinguished
3:49	2:49	**100% extinction**
4:19	3:19	Foam off tray
	Time From Start of Burnback	
8:49	0:00	Burnback flame applied to the foam blanket
9:15	0:26	Flame spreads from the burnback flame, across the foam blanket and around the tray edge
9:34	0:45	Large flames around 25% of the tray edge, small flames around a further 25% of the tray edge, 50% of the foam surface damaged by surface flames
9:57	1:08	**5% burnback (peak flare radiation)**
10:03	1:14	**Large flames over 10% of the foam blanket area.** Large flames around 25% of the tray edge (different tray area) and small flames around the remainder of the tray edge, 100% of the foam surface damaged by flame
10:43	1:54	Small flames around 100% of the tray edge
12:14	3:25	Large flames around 5% of the tray edge
13:25	4:36	Burnback flame removed
14:01	5:12	**25% burnback**

14:22	5:33	**50% burnback**
15:23	6:34	**75% burnback**
15:31	6:42	**100% burnback**



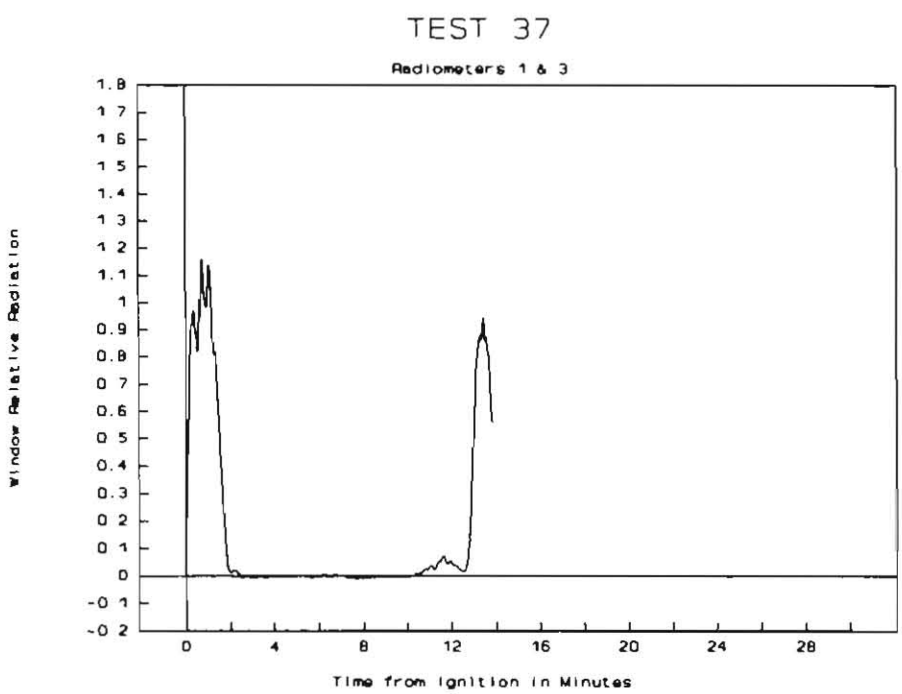
Test Number: 37 **Foam:** AFFF(2)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Misty

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
1:47	0:46	**90% extinction**
1:50	0:49	**95% extinction**, some ghosting of small flames over the foam blanket surface
2:08	1:07	3% area of flame in the centre of the foam blanket
2:18	1:17	Foam jet slowly traversed across the tray from left to right
2:26	1:15	Tray centre flames extinguished, jet across to the right hand side of the tray, jet slowly traversed across the tray from right to left
2:30	1:29	**99% extinction**
2:33	1:32	Jet back to rear left of the tray
2:37	1:36	**Virtual extinction**
3:33	2:32	Only remaining flames along the tray edge nearest to the firefighter, firefighter walks 90° anticlockwise, foam applied directly to the remaining flames
3:50	2:49	Firefighter stops walking
3:53	2:52	**100% extinction**, foam application returned to the rear of the left hand side of the tray
4:23	3:22	Foam off tray
	Time From Start of Burnback	
8:53	0:00	Burnback flame applied to the foam blanket, small flames immediately begin to ghost over the foam surface and around the tray edge
9:08	0:13	Small flames around 50% of the tray edge, 50% of the foam surface damaged
9:19	0:26	Small flames around 100% of the tray edge, 100% of the foam surface damaged, small flames continuing to ghost over the foam surface

10:52	1:59	**Large sparse flames over 50% of the foam surface,** small sparse flames over the remainder
11:37	2:44	**7% burnback (peak flare radiation)** Further flare up as above
11:54	3:01	Further flare up as above
12:44	3:51	Burnback flame removed
12:53	4:00	**25% burnback**
12:59	4:06	**50% burnback**
13:07	4:14	**75% burnback**
13:29	4:36	**100% burnback**



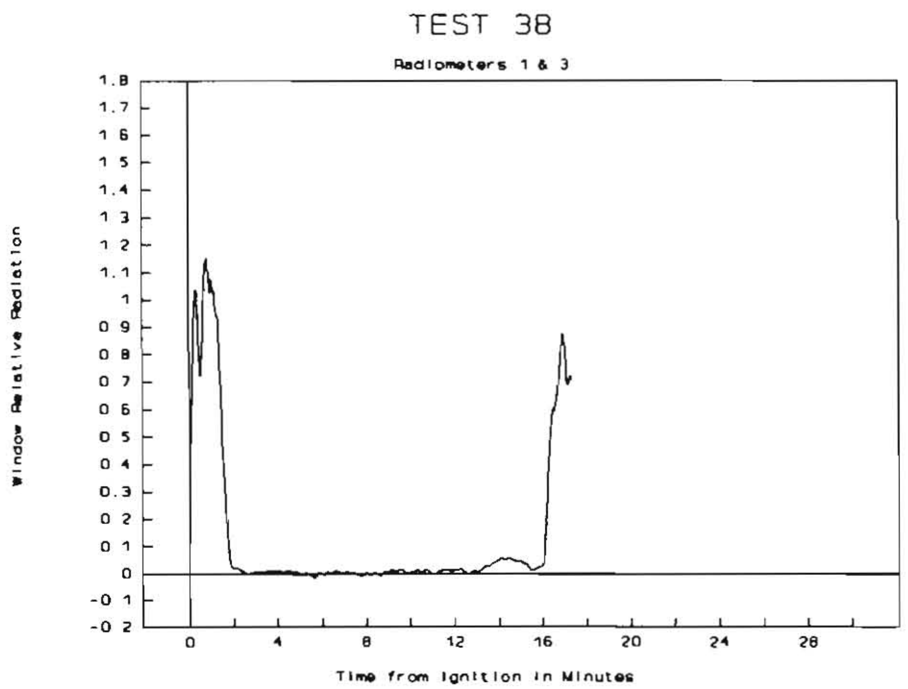
Test Number: 38 **Foam:** AFFF(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Overcast

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:01	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
1:46	0:45	**90% extinction**, flaring at the foam application point
1:50	0:49	**95% extinction**
2:07	1:06	**99% extinction**, application point flames extinguished, flames mainly restricted to the tray edge, some very small flames on the foam surface in the centre of the tray
2:22	1:21	Foam jet slowly traversed across the tray from left to right
2:28	1:27	The flames in the centre of the tray extinguished, jet across to the right hand side of the tray, jet slowly traversed across the tray from right to left
2:30	1:29	**Virtual extinction**
2:34	1:33	Jet back to rear left of the tray
3:28	2:27	Firefighter walks 45° anticlockwise, foam feathered directly onto burning tray edges
3:38	2:37	Firefighter stops walking
3:47	2:46	Firefighter walks a further 45° anticlockwise
3:52	2:51	Firefighter stops walking
4:26	3:25	Firefighter walks a further 45° anticlockwise
4:33	3:32	Firefighter stops walking
4:38	3:37	Firefighter walks a 135° clockwise
4:56	3:55	**100% extinction**, firefighter stops walking, foam application returned to the rear of the left hand side of the tray
5:26	4:25	Foam off tray
	Time From Start of Burnback	

9:56	0:00	Burnback flame applied to the foam blanket, small flamee immediately spread to the tray edge
10:15	0:19	Small flames around 50% of the tray edge
10:36	0:40	Small flames around 100% of the tray edge
11:25	1:29	20% of the foam surface involved in small flames
14:00	4:04	6% burnback (peak flare radiation) 25% of the foam surface involved in large flames
14:57	5:01	50% of the foam surface damaged by surface flames
15:55	5:59	A hole, 5% of the foam blanket, opens up away from the burnback flame
15:59	6:03	Hole ignites
16:01	6:05	Burnback flame removed
16:11	6:15	25% burnback
16:21	6:25	50% burnback
16:47	6:51	75% burnback
17:00	7:04	100% burnback



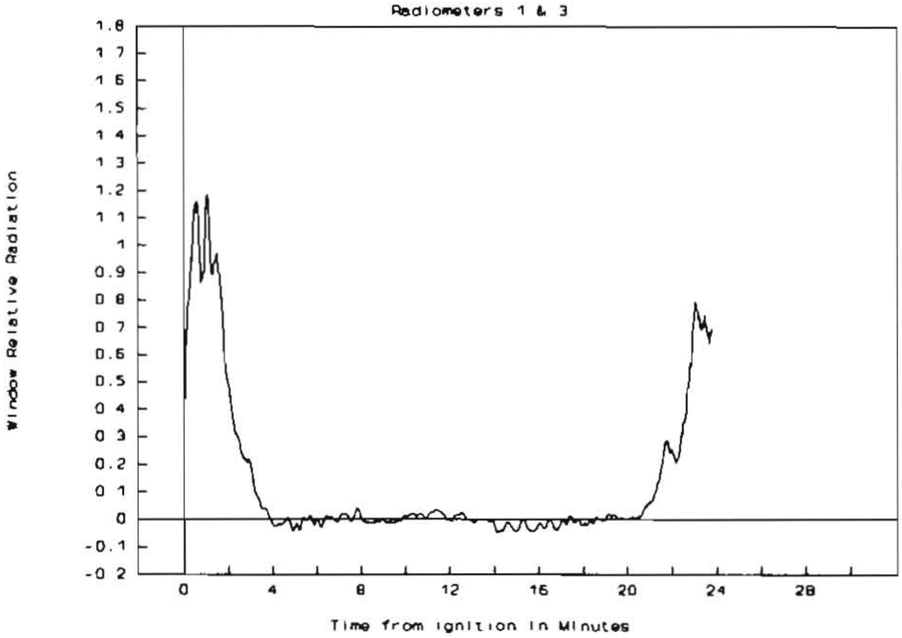
Test Number: 39 **Foam:** FP(3)

Application Rate: 5 lpm/sqm **Concentration:** 6%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray
2:50	1:50	Flaring along the foam application foot print
3:11	2:11	Large sparse flames over 50% of the foam blanket, small sparse flames over the remainder
3:16	2:16	**90% extinction**
3:42	2:42	**95% extinction**
4:10	3:10	**99% extinction**
4:44	3:44	**Virtual extinction**, application point flames extinguished, small flames around the tray edge only
5:04	4:04	Foam feathered directly onto the remaining flames at the rear tray edge
5:10	4:10	**100% extinction**, foam application returned to the rear of the left hand side of the tray
5:40	4:40	Foam off tray
	Time From Start of Burnback	
10:10	0:00	Burnback flame applied to the foam blanket
11:20	1:10	Some small flames ghosting over 10% of the foam surface, gradually spreading
17:40	7:30	Small flames ghosted across to the rear of the tray and ignited the tray edge, 100% of the top of the foam blanket damaged
19:38	9:28	Burnback flame removed
22:19	12:09	**25% burnback (observed)**
22:31	12:21	**50% burnback (observed)**
22:38	12:28	**75% burnback (observed)**
23:01	12:51	**100% burnback (observed)**

TEST 39



Radiometers 1 & 3
Window Relative Radiation
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0
4
8
12
16
20
24
28
Time from ignition in Minutes

BURNBACK TEST ONLY

Test Number: 40

Foam: FP(1)

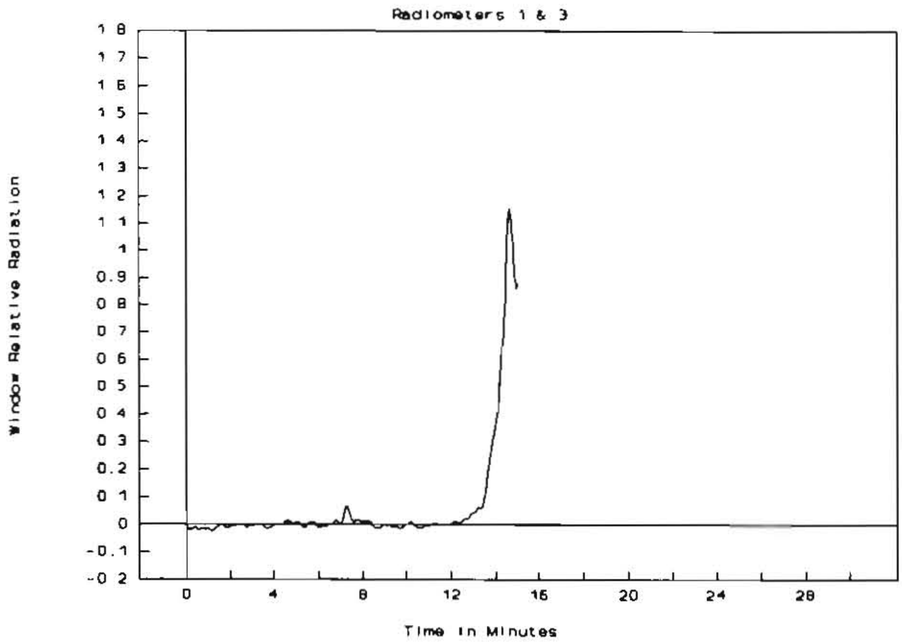
Application Rate: 4 lpm/sqm

Concentration: 3%

Weather: Overcast

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:01	0:00	Foam applied to the rear of the left hand side of the tray
0:04	0:03	Foam commenced a clockwise swirl
0:19	0:18	50% of fuel area covered with foam
0:55	0:54	100% of fuel area covered with foam
2:01	2:00	Foam off tray
	Time From Start of Burnback	
7:01	0:00	Burnback flame applied to foam
7:08	0:07	Small flames spread across top surface of foam to the centre of the tray
7:15	0:14	25% of the foam surface involved in sparse large flames
7:17	0:16	Flames reach the far edge of the tray
7:18	0:17	**9% burnback (peak flare radiation) 30% of the foam surface involved in sparse large flames**
7:25	0:24	100% of the tray edge alight
7:38	0:37	Flames burnt out in the centre of the tray, only very small flames remain at the tray edge
9:00	1:59	All surface and edge flames burnt out
12:43	5:42	Burnback flame removed
13:50	6:49	**25% burnback**
14:15	7:14	**50% burnback**
14:30	7:29	**75% burnback**
14:36	7:35	**100% burnback**

TEST 40



BURNBACK TEST ONLY

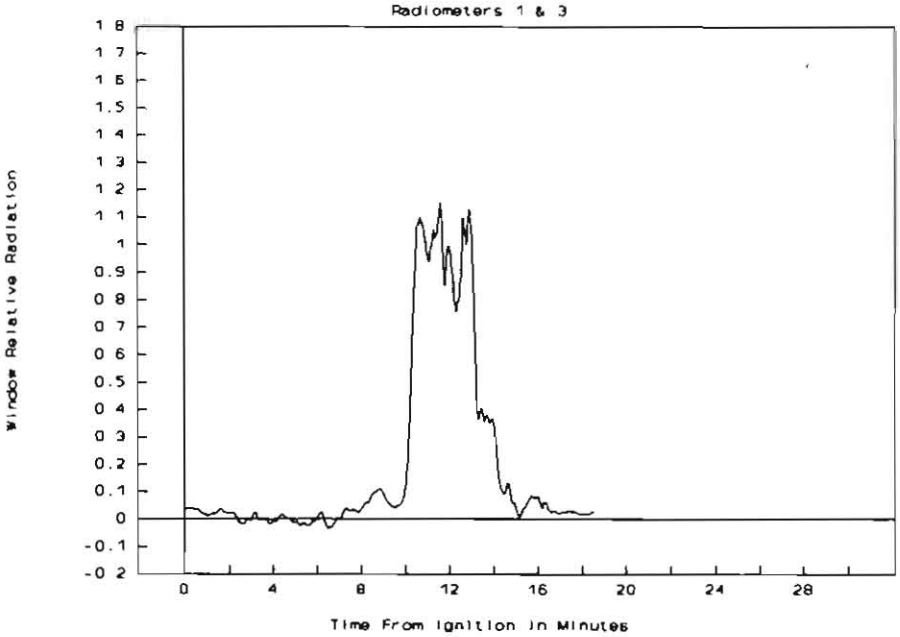
Test Number: 41 **Foam:** AFFF(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny, still

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:01	0:00	Foam applied to the rear of the left hand side of the tray
0:06	0:05	Foam commenced a clockwise swirl
0:10	0:09	50% of fuel area covered with foam
0:37	0:36	100% of fuel area covered with foam
2:01	2:00	Foam off tray
	Time From Start of Burnback	
7:01	0:00	Burnback flame applied to foam
7:10	0:09	Small flames around 50% of tray edge, small flames ghosting across top layer of foam blanket
7:20	0:19	Small flames around 100% of tray edge
7:35	0:34	15% of tray area involved in large flames
7:50	0:49	Larger flames present along 50% of tray edge
8:50	1:49	25% of the foam surface involved in large flames
8:54	1:53	**12% burnback (peak flare radiation) 35% of the foam surface involved in large flames**
9:35	2:34	All surface flames burnt out, small flames remain around 50% of the tray edge
9:50	2:49	A 5% hole opens up in the foam blanket away from burnback flame
10:00	2:59	Burnback flame removed
10:02	3:01	Hole ignites, burnback proceeds from 2 separate areas
10:12	3:11	**25% burnback**
10:19	3:18	**50% burnback**
10:25	3:24	**75% burnback**
10:35	3:34	**100% burnback**

TEST 41



Radiometers 1 & 3
Window Relative Radiation
Time From Ignition in Minutes

BURNBACK TEST ONLY

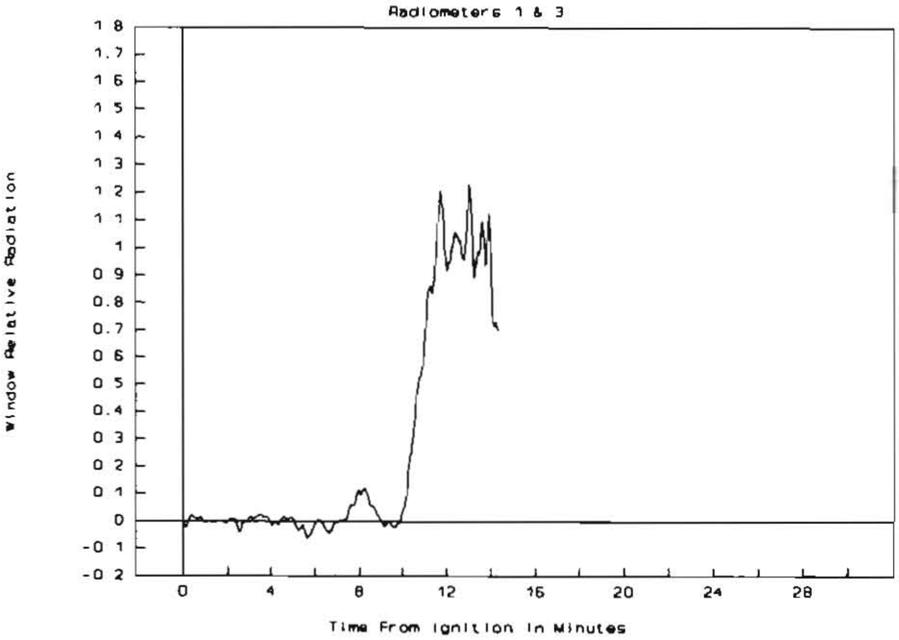
Test Number: 42 **Foam:** FFFP(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Overcast

Clock Time min:sec	Time From Application of Foam min:sec	Observations
0:01	0:00	Foam applied to the rear of the left hand side of the tray
0:05	0:04	Foam commenced a clockwise swirl
0:13	0:12	50% of fuel area covered with foam
0:41	0:40	100% of fuel area covered with foam
2:00	1:59	Foam off tray
	Time From Start of Burnback	
7:01	0:00	Burnback flame applied to foam, immediate spread of small flames over the foam surface and around the tray edge
7:14	0:13	Small flames around 100% of the tray edge
7:25	0:24	Large flames around 50% of the tray edge
8:01	1:00	**16% burnback (peak flare radiation)** **25% of tray area involved in large flames**
9:30	2:29	Nearly all flames burnt out
9:40	2:39	A small hole opens up in the foam blanket away from the burnback flame.
9:59	2:58	Hole increases to 10% of foam blanket area
10:00	2:59	Hole ignites
10:13	3:12	Burnback flame removed, burnback proceeds from 2 separate areas
10:28	3:27	**25% burnback**
10:48	3:47	**50% burnback**
11:10	4:09	**75% burnback**
11:37	4:36	**100% burnback**

TEST 42


Radiometers 1 & 3
Window Relative Radiation
1 8
1.7
1 6
1 5
1 4
1 3
1 2
1 1
1
0 9
0.8
0.7
0 6
0 5
0.4
0 3
0 2
0 1
0
-0 1
-0 2
0
4
8
12
16
20
24
28
Time From Ignition In Minutes

Test Number: 43 **Foam:** AFFF(1)

Application Rate: 4 lpm/sqm **Concentration:** 3%

Weather: Sunny

Clock Time min:sec	**Time From Application of Foam** min:sec	**Observations**
0:00		Ignition
1:00	0:00	Foam applied to the rear of the left hand side of the tray, a clockwise foam swirl set up
1:44	0:44	**90% extinction**
1:53	0:53	**95% extinction**
2:08	1:08	**99% extinction**, small area of flames on the foam surface in the centre of the tray, small flames around the tray edges mostly along the tray edge nearest to the firefighter
2:39	1:39	**Virtual extinction**
2:46	1:46	Foam jet traversed across the tray from left to right
2:49	1:49	Flames in the centre of the tray extinguished, jet across to the right hand side of the tray, jet traversed across the tray from right to left
2:52	1:52	Foam application returned to the rear of the left hand side of the tray, main area of flaming now along the tray edge to the left of the firefighter
3:25	2:25	Firefighter walks 60° anticlockwise, foam applied directly to the remaining flames at the tray edge
3:38	2:38	Firefighter stops walking
4:00	3:00	Firefighter walks a further 30° anticlockwise
4:06	3:06	Firefighter stops walking
4:07	3:07	**100% extinction**, foam application returned to the rear of the left hand side of the tray
4:37	3:37	Foam off tray
	Time From Start of Burnback	
9:07	0:00	Burnback flame applied to the foam blanket
9:30	0:23	Small flames around 50% of the tray edge
9:37	0:30	Small flames around 75% of the tray edge
9:54	0:47	Small flames around 100% of the tray edge

11:12	2:05	10% of the top of the foam blanket damaged by small flames
11:48	2:41	10% of the foam blanket involved in sparse large flames
12:48	3:41	15% of the foam blanket involved in large sparse flames, 50% of the tray edge involved in large flames
14:05	4:53	**19% burnback (peak flare radiation) 25% of the foam blanket involved in large sparse flames, 50% of the tray edge involved in large flames,** flames die down slightly
14:51	5:44	**25% burnback**
14:53	5:46	Burnback flame removed, 10% hole in the foam blanket opened up away from the burnback flame, burnback developing along the right hand side of the tray
15:00	5:53	Hole ignites
15:07	6:00	**50% burnback**
15:15	6:08	**75% burnback**
15:20	6:13	**100% burnback (observed)**