



**ACT Rural Fire Service
Bushfire CRC
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ASSESSMENT OF THE APPLICATION OF COMPRESSED AIR FOAM TECHNOLOGY FOR GRASSFIRE FIGHTING

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Executive Summary

This research project was established to determine the most appropriate use of compressed air foam (CAF) for suppressing grassland fires. Experiments compared various applications of CAF, water and aspirated foam to determine their durability, effectiveness as a wet line for stopping fire spread and effectiveness for direct attack. These experiments were conducted in a *Philaris sp.* grassland (6.2 t/ha) in MonashACT, under high fire danger conditions.

The durability of a range of CAF solutions applied in wet lines were investigated by monitoring fuel moisture content and ground level humidity. Elevated fuel moisture content and ground level humidity was found to persist for up to two hours after application, with moisture persisting at the base of the grass longer than in the tops. The dry on wet CAF mix application maintained the highest moisture contents and persisted longer than other applications tested. The dry mix provides some insulation to the wet mix. This application requires more water to generate than others tested, as it requires two passes. Wet CAF solutions were found to persist for longer periods than dry solutions.

The effectiveness of wet lines of different CAF solutions, normal aspirated foam and water were tested against two moderately intense (4000 kW/m) grassfires. All solutions tested were ineffective at stopping a fire lit 45 minutes after application, but were found to stop a fire lit 15 minutes after application. This second wet line was breached by spotting. Wet CAF applications applied 2.5 hours prior to ignition were found to prevent spot ignitions from ember attack, while dry mix applications allowed spot fires to start. This testing occurred under milder conditions than the durability tests and the expected periods effectiveness under extreme fire weather would be significantly less.

The testing of CAFs for direct attack on fires was very limited and subject to complications. While the CAF mix was observed to be more efficient than water, this

test can only be considered a pilot study as due to differences in fire behaviour experienced between runs. Smouldering material underneath dry CAF mixes suspended in thick grass could potentially lead to fire escape.

While these experiments give a good insight to the longevity of CAF lines under high grassland fire danger , more experiments are required to fully understand the usefulness of CAF for direct and indirect grassfire suppression. These would include more replicates of the fire experiments conducted here to investigate the useful lifespan of CAF applications against flaming and ember attack under a range of fuel and weather conditions, and as a direct suppressant.

Acknowledgements

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1 Objective

The primary objective of this research was to determine the most appropriate use of compressed air foam (CAF) for suppressing grassland fires and protecting assets. Experiments were conducted to determine the longevity of increased fuel moisture content from foam barriers laid in grassland and to determine the effectiveness of similar foam barriers as protection against an advancing fire.

2 Project Background

Following the 2003 Bushfires in Canberra, there has been a focus on the capability of the various fire services to control fires in the region. Over the past 12 months, the ACT Fire Brigade (ACTFB) and the ACT Rural Fire Service (ACTRFS) have invested in Compressed Air Foam Fire fighting Systems (CAFS) for urban, urban interface and rural bushfire fighting. This CAFS fire fighting technology is relatively new in Australia and there is only a limited knowledge of its effective use and practical application.

2.1 Compressed Air Foam description

CAF is a regulated mixture of foam concentrate (class A foam), air and water that produces a uniform bubble solution. CAF has a number of qualities that can make it superior to water and aspirated foams for suppressing fires. The foaming agent expands the volume of quantity of water by the formation of bubbles (Gould *et al.* 2000, Goodwin 1939), effectively using less water to cover the same area of fuel. The foam acts as a blanket on the fuel, restricting the amount of oxygen available for the fire. CAF is sticky and persists on the fuel surface for a longer period than water. The foam has a surfactant that helps break the surface tension of water in the fuels, allowing better penetration of the moisture into the fuel.

The new CAF systems that are to be tested during this research are mounted on three ACTRFS 4wd Isuzu trucks (Spel 2005). The trucks have a 2200 litre water tank and been

specifically fitted out with a pump, an exclusive pump engine, and an air compressor. They can produce CAF from three different outlets, two 38mm outlets at the rear of the truck and one rear deck mounted outlet that can accommodate 2 monitors. The three CAF outlets also have the capability to deliver straight water or compressed air. In addition to the CAFS capability, the trucks are equipped with two quick response reels mounted in the rear sides that can produce water or aspirated foams. There is also a water spray boom mounted on the front bullbar. The foam is stored as a concentrate in a 200 L tank and is injected into the water at a valve near the pump. Compressed air is then injected into the water-foam concentrate mixture before entering the hose, allowing the foam to form as the solution is travelling through the hose. The foam can be produced at various concentrations ranging from 0.1 -1 % by selecting the appropriate setting on a dial. Figure 1 shows one of the a fire trucks that were used in experiments.



Figure 1 A fire truck in direct attach experiment

The characteristics and fire suppression ability of the foam is related to the solution concentration, at 0.1 % the foam mix appears wet and sloppy with poorly formed

bubbles, at 1.0% concentration the foam appears considerably drier and is comprised of many larger bubbles. The outlet on the trucks rear crew bay is equipped with a gate valve, which can restrict the water/concentrate flow allowing a greater proportion of air, to produce light dry foam.

Prior to the procurement of the CAFS tankers the ACTRFS used aspirated foam for many fire-fighting operations. Aspirated foam is made up of the same water and concentrate solution but it is not injected with compressed air, an aspirating nozzle at the end of the hose achieves aeration of the solution.

2.2 Preliminary work and familiarisation

The ACTRFS and the ACTFB have conducted training exercises to familiarise fire-fighting personnel with the CAFS equipment and determine some suitable application methods that are appropriate for various fire fighting scenarios. During training it was demonstrated that a CAF solution is not as susceptible to friction loss as water when travelling through the hose, showing that CAF can be pumped through several lengths of hose and up a gradient without considerable loss of pressure. Using 3 lengths of 38mm hose connected to 38mm/25mm gated breach piece with 1 length of 25mm hose on either side, the CAFS was pumped through the hoses to an elevation that was 15 – 20m above the pump. Other training included laying wet line using multiple trucks in formation using a concerted effort to provide a fire protection barrier along a pine plantation edge. Another training session involved laying a line in open grassland comparing water only, a 0.3% CAFS solution, and a 0.3% CAFS solution with reduced water

The equipment has proven to be versatile but somewhat more complicated than standard water tankers. It has been found that competent operators require a high level of training and familiarisation. It is desirable to establish some repeatable standard techniques or standard operating procedures.

3 Methods

This research is based on three experiments, a durability test and two fire experiments. The durability experiment was designed to determine how long different CAF solutions persist in grass during typical bushfire weather. The first of the fire experiments tested how CAF solutions perform as a fuel break in front of a grass fire. The second fire test was used to assess the effectiveness of CAFs sprayed directly onto grassfire flames. The tests were conducted on days with a high fire danger index (FDI).

3.1 Research site and fuel assessment

The site of the research is an open area of grasslands, approximately 5 ha, on the corner of Clive Steele Avenue and Isabella Drive, Monash, ACT (Figure 2) ($35^{\circ} 25.1' S$, $149^{\circ} 5.6' E$). The Bureau of Meteorology (BOM) Tuggeranong weather station is located adjacent to the site.

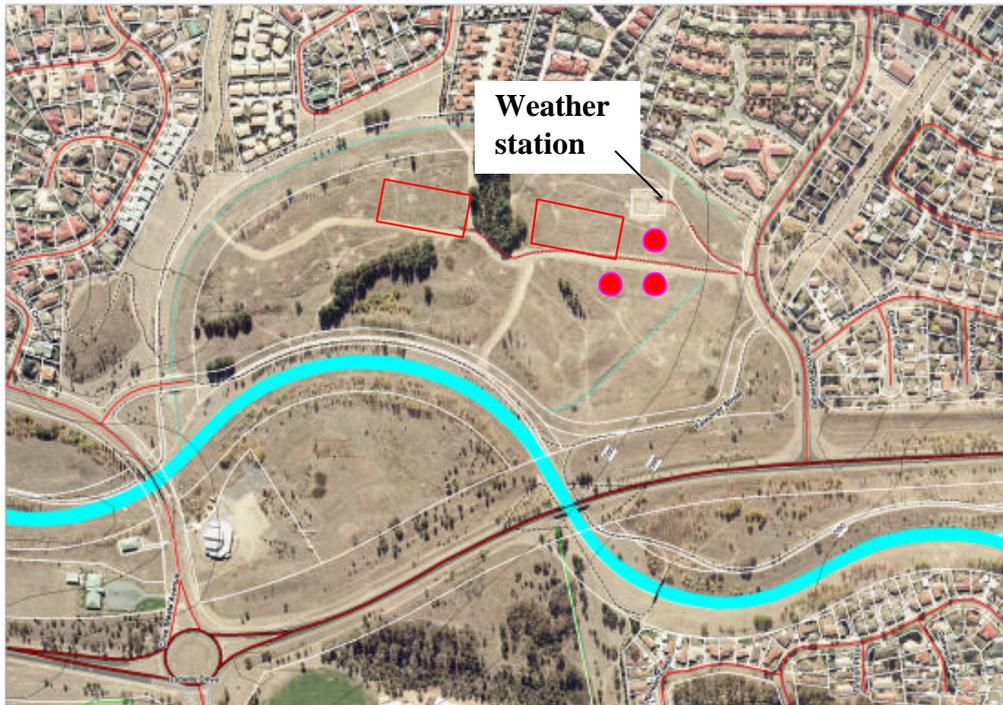


Figure 2 Monash site showing plots locations of plots (red rectangles for indirect attack and red circles for direct attack), the weather station

The site is level although there are a number of drainage lines and some mounded areas. The improved pasture grasses are predominantly a *Phalaris sp.* with some variation in the drainage lines and low areas. The site is a large block of ACT government land that is designated to become a sports playing field, but at times has been used as a dumping ground for builder's rubble. Three areas with relatively uniform fuels and slope characteristics were identified and used for experiments. A portion of the western plot is shown in Figure 3.



Figure 3 the water section of the plot in the western grassland

The fuel assessment was undertaken to determine fuel load and the degree of curing. All of the grass in eight 50cm * 50cm quadrat grids was collected. The samples were cut from predetermined locations between plots to minimise bias. The cured grass was separated from the green grass, both were then weighed and subsequently oven dried at 95 deg C for 24 hours. After being dried, the cured grass was weighed again to estimate

the fuel moisture content (FMC) and the dry fuel volume. The average fuel load is then estimated from the above data.

3.2 Weather

The weather conditions at the site were recorded before and during each test using data from the onsite Tuggeranong weather station. The tests were conducted during the peak fire danger period of the day when, between 1300 and 1700 hours. The relative humidity, temperature, wind speed and grassland fire danger index (GFDI) were recorded over the period of the tests.

3.3 Durability test

The durability test was designed to compare how well different foam concentrations (wet or dry) application types (single layer or dry on wet) and plain water and aspirated foam persist under peak fire weather conditions. Changes were monitored over time.

The blocks for the durability tests were situated close to each other and aligned in an east west direction. The arrangement of the plots is shown in Figure 4. The procedure for applying the wet line involved spraying the various concentrations of foam, water and aspirated foam consecutively along a 50m long by 5m wide wet line.

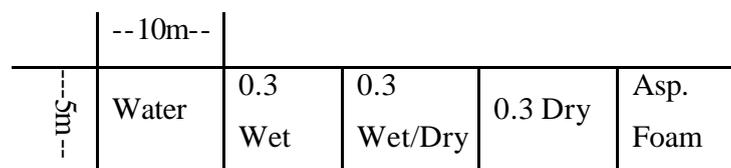


Figure 4: Experimental CAF line

Three people using an Isuzu 2000 litre RFS CAFS tanker laid down the wet lines. The tanker drove in 1st gear low range at idle speed in a westerly direction parallel to the plots and keeping 2 metres away. Water/ CAF foam was sprayed out of the back of the tanker onto the plots using the deck-mounted monitor with a 20mm straight bore nozzle.

Normally aspirated foam was sprayed from the same position using a 38 mm normally aspirating nozzle on a 3m x 38 mm dia hose. The CAF was applied by one person operating the monitor while a second person on the back of the truck operated the pump and air compressor. The CAF concentrations were changed as the truck was in motion along the line. All of the different solutions and water were applied in a similar fashion using a horizontal side-by-side motion, providing as even coverage as possible over the area of the plots. To avoid the area where changeover of solutions occurred all of the measurements were taken at the centre of each plot

3.3.1 Microclimate

The temperature and relative humidity at ground level was measured with an Assman psychrometer across the treated plots and a reference plot. This was done continually until no differences between treated plots and a reference plot could be detected.

3.3.2 Coverage level at ground

The moisture level at ground was estimated by measuring the water and/or foam left in small plastic containers in the plot. Five containers were carefully placed in a line transect through the centre of each plot before the CAF application. The containers were removed from the ground immediately after the foam was applied. The contents of the containers were determined by weighing them on site with a set of laboratory scales. The coverage level for each plot was estimated using the average of the five containers in each plot.

3.3.3 Fuel moisture content of the grass profile

The fuel moisture content (FMC) at different heights through the grass profile was measured by taking samples from the 0-10cm, and 10-20cm heights of the grass sward in each plot. One hand full of grass at each height was collected in each plot at approximately 10 minute intervals. Additional grass samples were regularly collected from a similar area outside the plot as a reference. The grass samples were weighed in the field, and then oven dried at 95 deg C for 24 hours, and weighed again to determine

the percentage of moisture in each sample. The fuel moisture sampling continued until the relative humidity of the plots was measured to be the same as the relative humidity at the reference site.

3.4 Indirect fire test: Block layout and procedure

The indirect fire test was designed to test the effectiveness of CAFS applied as a barrier to grass fire spread. The procedure for laying the CAF line for the indirect fire test was the same as for the durability tests although there were three additional plots and applications of foam. Posts marked with flagging tape were placed at 10 metre intervals across burn area of the block so that a rate of spread could be determined. The block layout design and applications for the indirect fire test is shown in

Figure 5. The indirect fire tests were videoed by 2 cameras (one on each side of the plot) and a stills camera. These were used to record events and assist in the calculation of spread rates and flame dimensions.

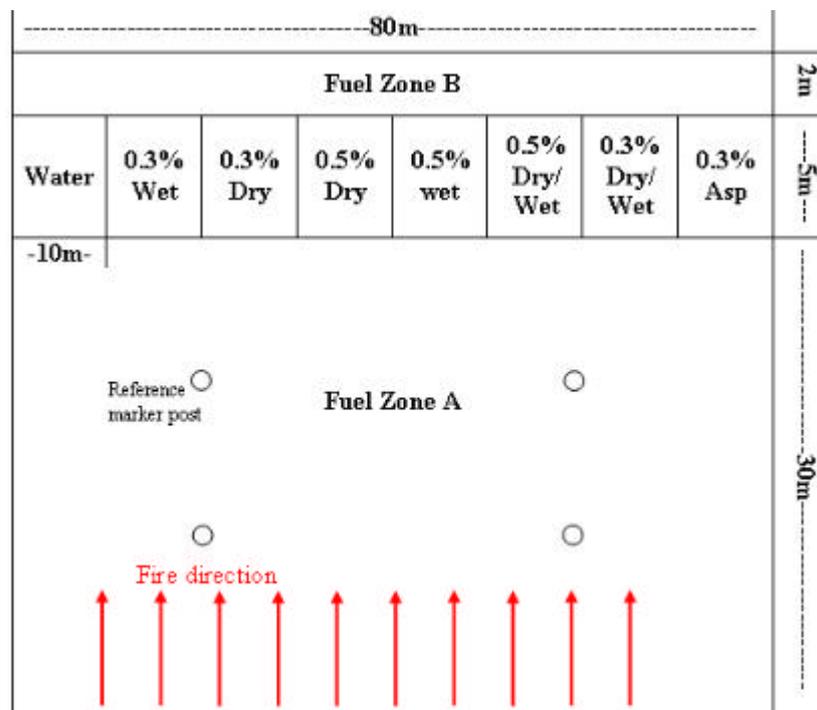


Figure 5. Design of Block Layout (not to scale)

3.4.1 Western plot

The West plot wet line was laid down at 13:45, and the fire line was lit 45 minutes after the wet line application at 14:30. An 80 metre drip torch line was ignited by two people from a central point along the northern edge of the fuel zone. The fire proceeded to burn toward the wet-line driven by a light northerly wind.

There were two complications during the spraying of the western line. The first was that the monitor was inverted and unable to spray below the horizontal in this position. This meant that the water/foam was not driven in to the litter layer, but was laid on top. The second problem was that the foam solution was not switched on immediately for the normally aspirated plot, meaning that this plot received mostly water. To compensate for this, normally aspirated foam was continued approximately 10 m beyond the marked out plot area.

3.4.2 Eastern CAF line

The first CAF line in the eastern plot was laid down at 14:04. A brief assessment of the results of the western fire indicated that the CAF line and all the variables had failed to arrest the fire in the prevailing weather conditions. As the time lapse between laying and ignition for this test was approaching the previous failed test, it was decided to lay a new CAF line to the northern side of the original eastern line and ignite a fire 10 minutes after application. A second line was laid down adjacent to the first line at 14:26. This line consisted of the same variables as the first line. However the tanker was driven through the middle of this plot, compressing the fuel along the tyre tracks. The fire in this plot was ignited 16 minutes after the application of the CAFS line (14:42) in the same manner and under similar conditions to that in the first plot.

3.5 *Direct attack fires Block layout and procedure*

The direct attack fire tests were carried out to examine the effectiveness of the different applications in extinguishing a running grass fire. Three blocks were laid out in 1.3m

phalaris grassland (Figure 2), with fires lit and attacked using plain water, 0.3% dry CAF, and 0.3% wet CAF. The direct attack experiments conducted in quick succession so that weather conditions were kept as consistent as possible. A 15m long ignition was ignited using two drip torches from a central point along the northern edge of each block. This was allowed to run for around 10 m when the CAFS tanker crew were instructed to commence attack. The front spray bar was in operation throughout the all of the direct attack tests.

4 Results

4.1 Fuel assessment

The volume of grass fuel at the site was assessed to be 6.2 t/ha. The average height of the grass was 1.3m and the curing at the site was 95%.

4.2 Weather

Two durability tests of CAF were conducted in high fire danger weather conditions on Monday 30th January and Wednesday 1st of February respectively. CAFS lines were laid at 13:30 on both of these days. The weather during these two tests was stable and similar, as shown in Figure 6 and Figure 7. The drought factor was 8 on these days.

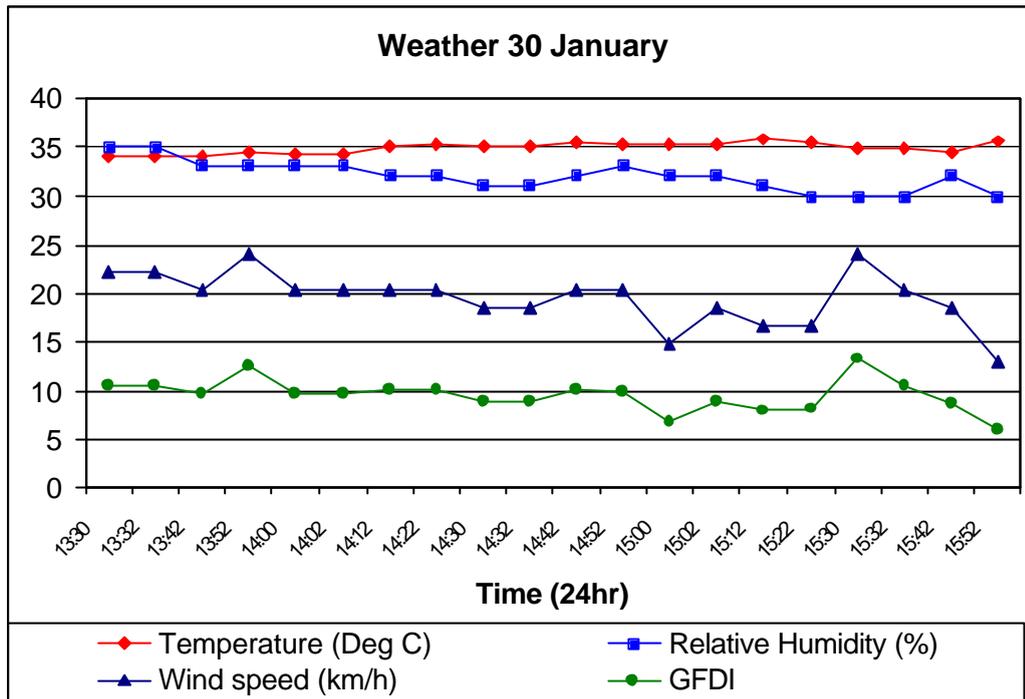


Figure 6 Tuggeranong weather Monday 30th January

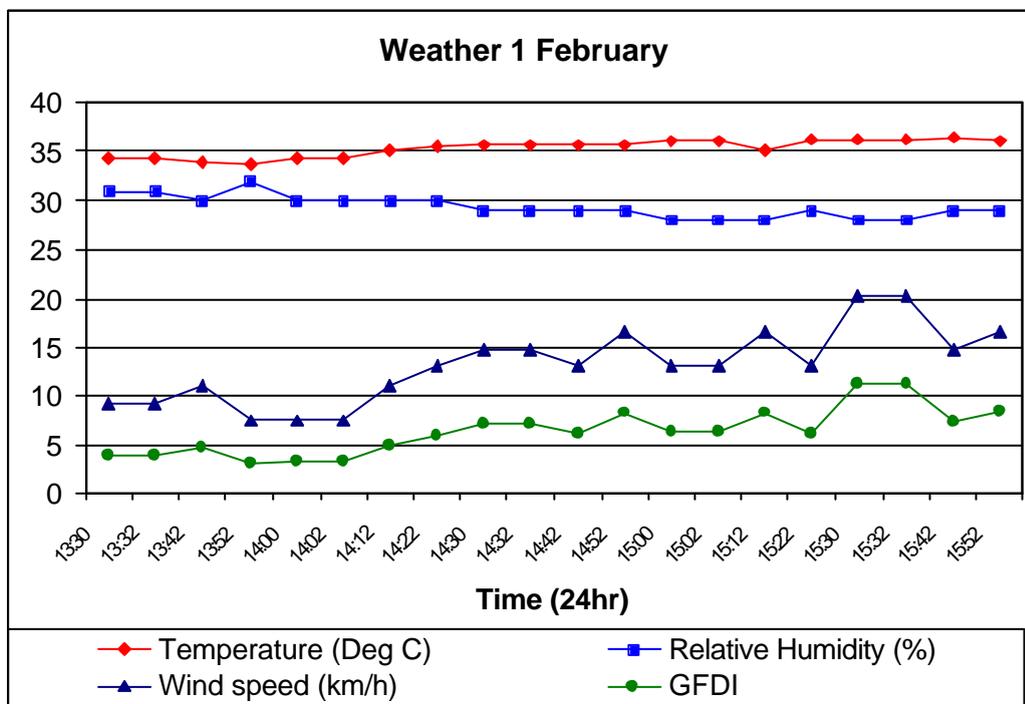


Figure 7 Tuggeranong weather Wednesday 1st February

The fire tests were conducted on Wednesday 8th February when the weather conditions were milder than the two days that the durability tests were performed (Figure 8). The wind direction for the duration of the fire tests was northerly.

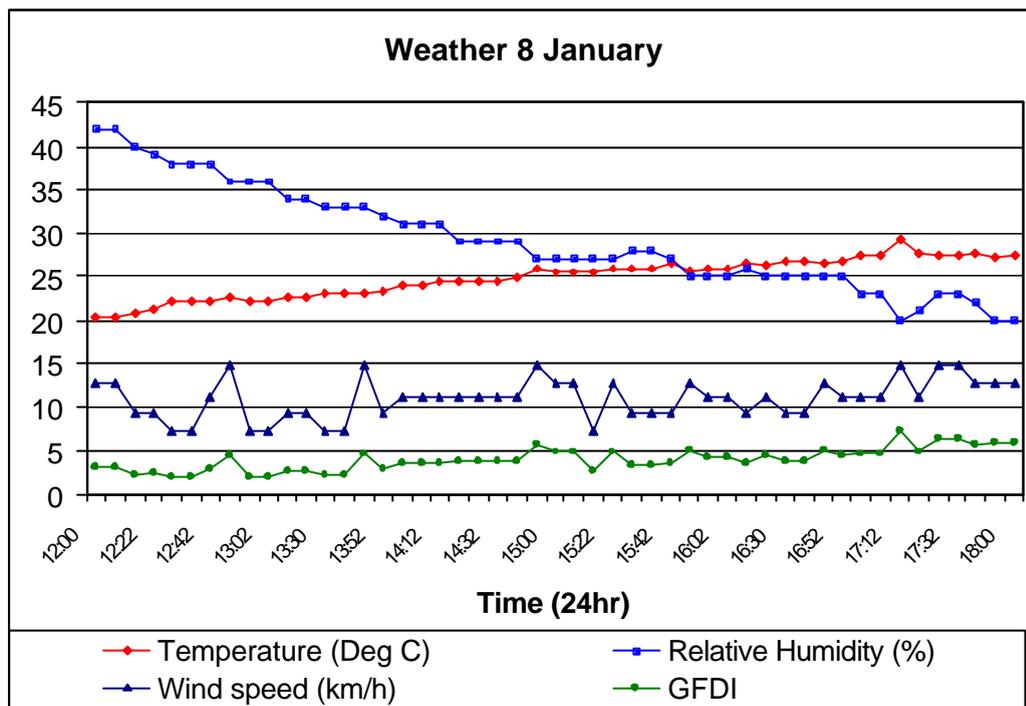


Figure 8 Tuggeranong weather Wednesday 8th February

4.3 Durability test

4.3.1 Microclimate

The ground level relative humidity in all plots fell quickly at first and then slower as time progressed as shown in Figures 9 and 10. Here the relative humidity measured ground level is shown by data points and an exponential fit for each data set. On each of these days it took around 2 hours for the ground level relative humidity in the dry (0.3%) and normal aspirated mixes to return to a level similar to that of the control plots. On both days the wet (0.3%) mix and dry wet mix sustained elevated humidity for the longest

periods. The ground humidity of the plot treated with water remained higher than that of the dry (0.3%) and normal aspirated mixes.

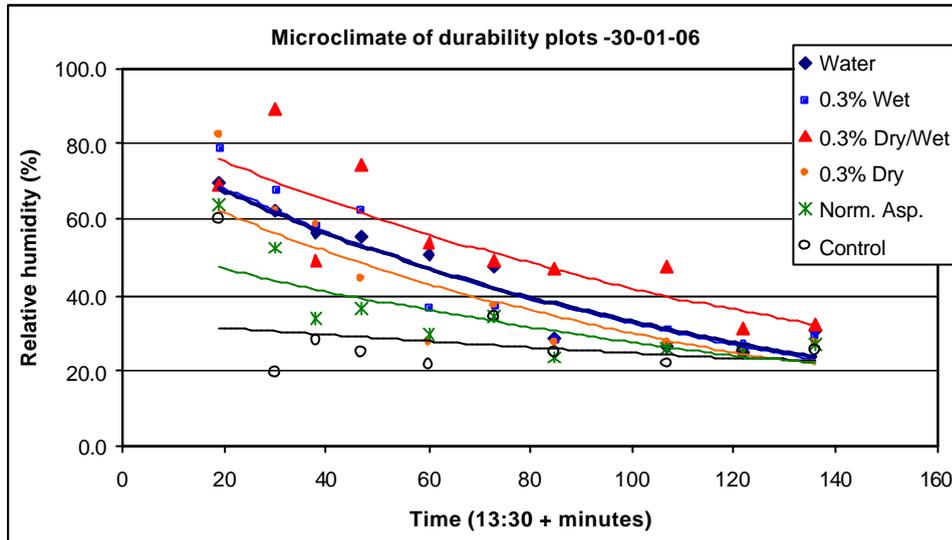


Figure 9 Durability test#1 microclimate of plots

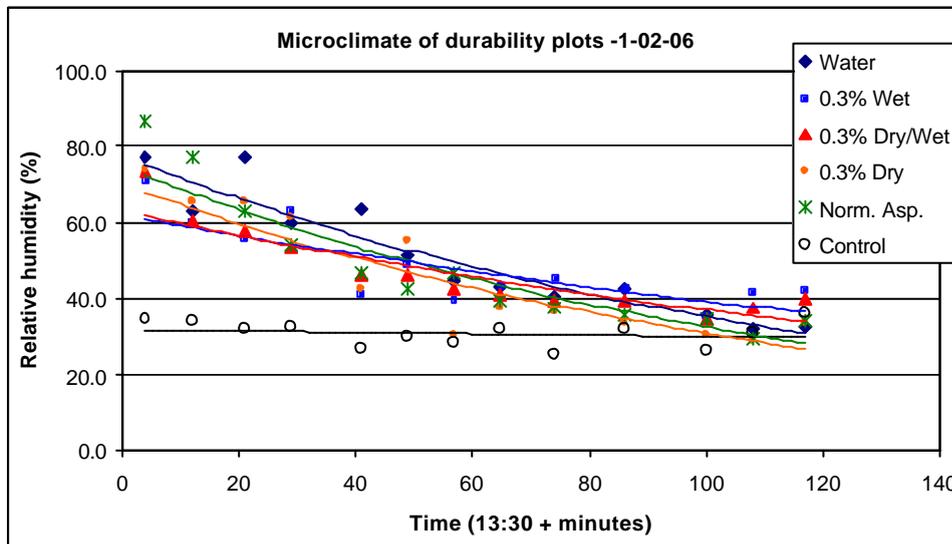


Figure 10 Durability test#1 microclimate of plots

4.3.2 Coverage levels

The coverage levels measured in containers on the ground in each of the plots are shown in Figure 11. These are likely to have varied across the plots due to the application method and interception from grass. The dry (0.3%) and normal aspirated mix plots received less liquid coverage than the other plots.

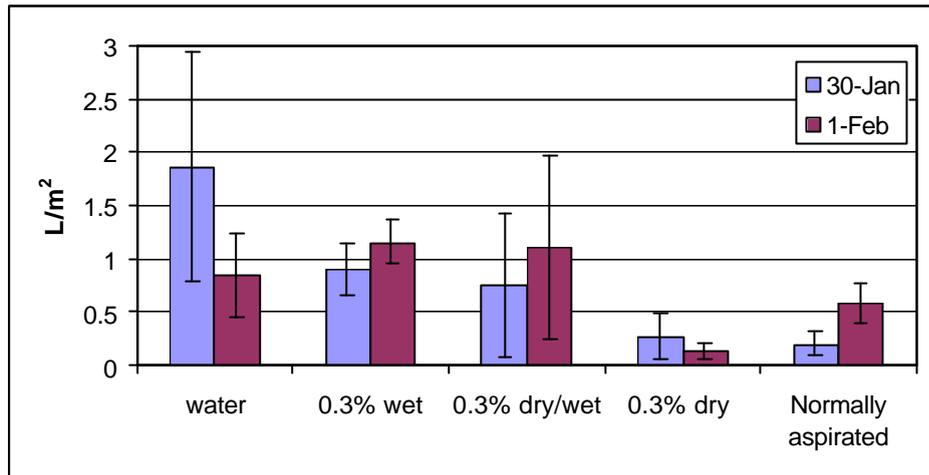


Figure 11 Ground coverage levels (with standard deviations)

4.3.3 Fuel moisture content

The FMC drying curves for the durability tests are given in Figures 12- 15. In all plots the FMC fell quickly at first and then more slowly as the time progressed. The plots that had a double layer of dry foam over wet foam had the highest FMC for the duration of the test in all cases. This was followed by the 0.3% wet solution. These appear to persist for longer than two hours. The normal aspirated foam mix had the lowest FMCs in these trials and would appear not to be effective for 2 hours.

The FMC in the 20-10cm levels dried out more quickly than the 0- 10cm level on both days. Some of the FMCs measured in the reference plot are higher than would be expected and suggest that there may have been some over spray in the reference plot or some of the reference samples were contaminated by live vegetation.

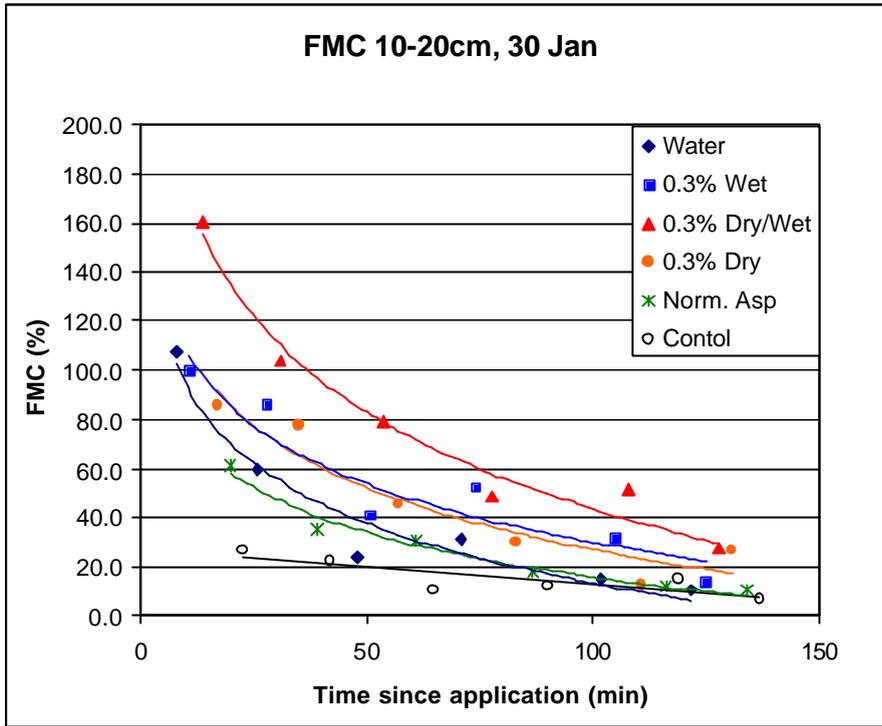


Figure 12 CAF durability test #1 (30 Jan), 10-20cm

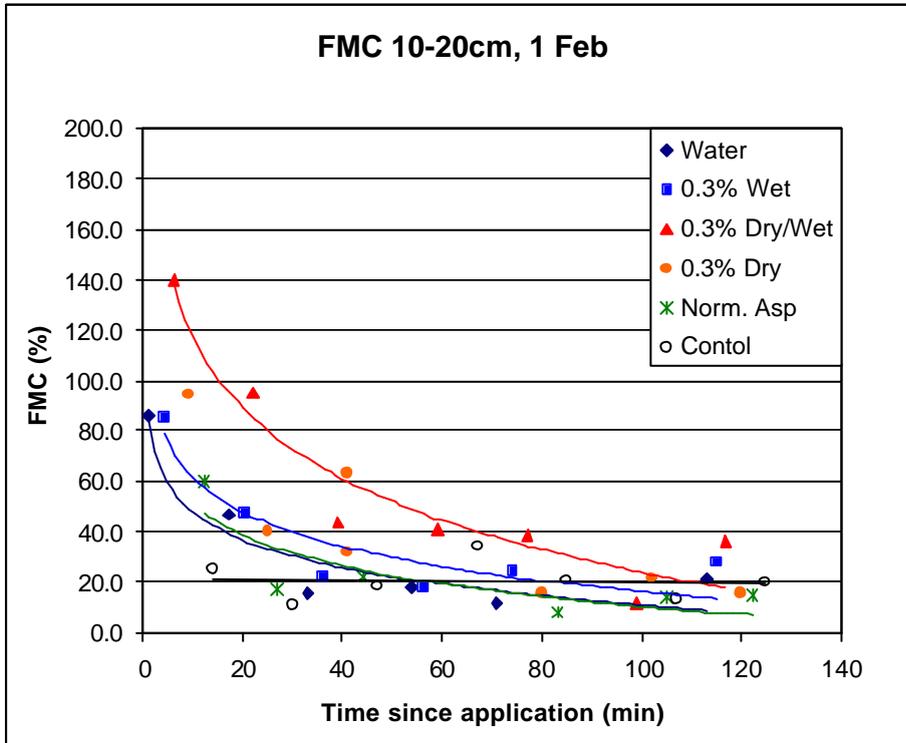


Figure 13 CAF durability test #2 (1 Feb), 10-20cm

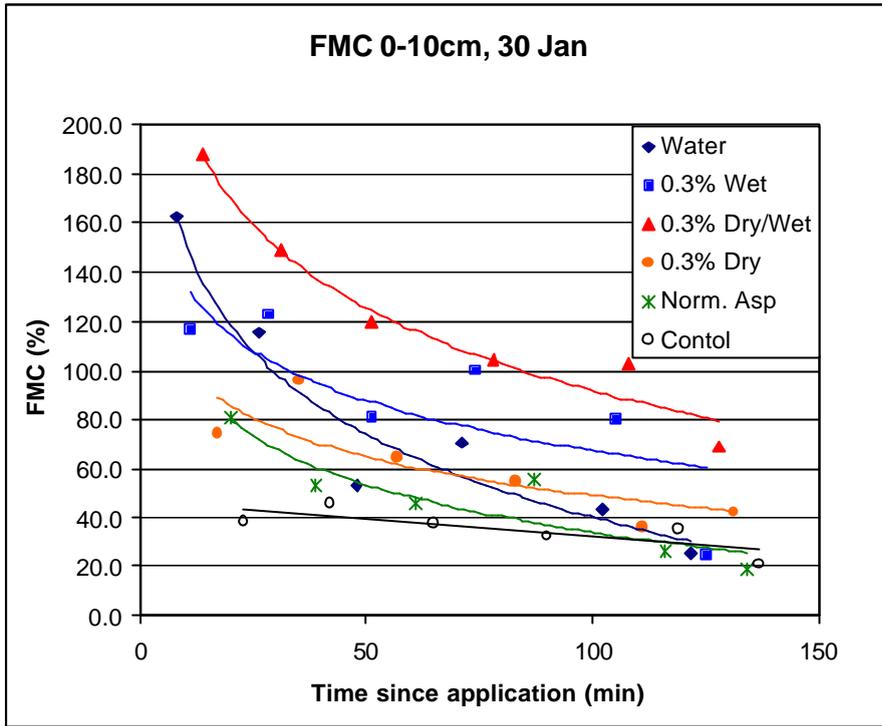


Figure 14 CAF durability test# 1 (30 Jan), 0-10cm

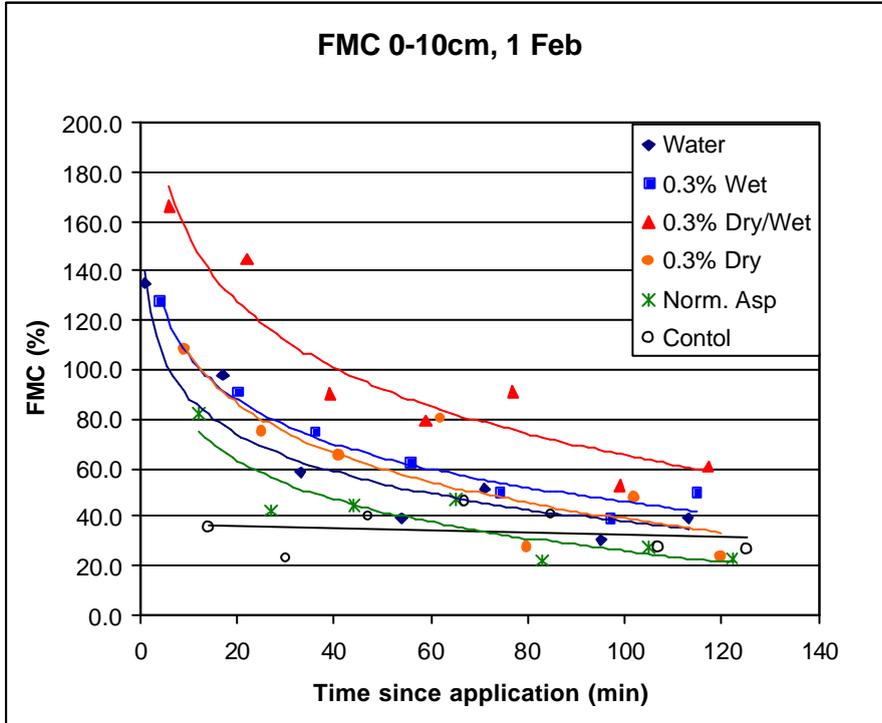


Figure 15 CAF durability test# 2 (1 Feb), 0-10cm

4.4 Indirect Fire Test

The fire rates of spread and intensities for both of the indirect test fires are shown in Table 1. Fire intensity was calculated using Byram's (1959) equation, assuming a heat of combustion of 18 000 kJ/kg (Cheney and Sullivan 1997). The spread rate and subsequent intensity determined for the Western plot is a very low estimate of those that affected the CAFS line, as there was a stall in wind speed after ignition and the fire spread slowly through the first marker post and then picked up in speed before passing the second post and entering the treatment area. The likely characteristics for this fire are likely to be similar to that in the Eastern plot as the video footage shows them to be comparable in flame structures, with flames reaching between 3 and 4 metres height.

Table 1 Fire intensity and rates of spread of the indirect fires

Plot	Time of application	Ignition time	Rate of spread (km/hr)	Intensity (kW/m)
Western CAF	13:45	14:30	0.54	1664
Eastern CAF	16:26	16:42	1.35	4207

4.4.1 Western indirect fire test

The wet-line on the eastern plot was laid at 13:45 and the fire was ignited 45 minutes later at 14:30. The wet-line in the western plot was almost completely burnt through with only both of the dry/wet plots providing any resistance to burning as shown in

Table 2 Fuel condition and barrier potential of the plots ten minutes after the fire

Application	Fuel consumed	Barrier potential
Water	100%	No barrier
0.3% Wet	100%	No barrier
0.3% Dry	100%	No barrier
0.5% Dry	100%	No barrier
0.5% Wet	100%	No barrier
0.5% Dry/Wet	80%	No barrier
0.3% Dry/Wet	80%	No barrier
Normally aspirated	100%	No barrier

. The 10-20cm fuel layer of both the 0.5 dry/wet and 0.3 dry/wet plots was consumed by the fire but the 0-10cm layer remained smouldering and scorched, with some foam still evident at the very base of the tussocks. The area on the southern side of the wet-line was completely burnt out.

Table 2 Fuel condition and barrier potential of the plots ten minutes after the fire

Application	Fuel consumed	Barrier potential
Water	100%	No barrier
0.3% Wet	100%	No barrier
0.3% Dry	100%	No barrier
0.5% Dry	100%	No barrier
0.5% Wet	100%	No barrier
0.5% Dry/Wet	80%	No barrier
0.3% Dry/Wet	80%	No barrier
Normally aspirated	100%	No barrier

4.4.2 Eastern indirect fire test

The original CAFs line for the eastern plot was laid at 14:04, the second line, which was parallel and closer to the ignition line was laid at 16:26, with the fire being ignited 16 minutes later at 16:42. The second wet-line in the eastern plot was laid in a different fashion than all previous lines as the foam was laid down behind the truck as it drove through the plots, on top of the tyre tracks. This was done by accident.

All of the treatment plots in the 16:26 wet line, had provided some barrier to the advancing fire. They were all burnt into to some degree from the side adjacent the fire and had some fuel remaining on the leeward side Table 3. In both of the dry/wet plots the fire halted at the wheel tracks in the grass.

Table 3 Fuel condition and barrier potential of eastern wet line 5 minutes after the fire- eastern plot

Application	Fuel consumed	Barrier potential
Water	50 %, 2m into plot	Effective barrier
0.3% Wet	60%, 2m into plot	Effective barrier
0.3% Dry	60%, 2m into plot	Effective barrier
0.5% Dry	60%, 2m into plot	Effective barrier
0.5% Wet	60%, 2m into plot	Effective barrier
0.5% Dry/Wet	50 %, 1m into plot	Effective barrier
0.3% Dry/Wet	50 %, 1m into plot	Effective barrier
Norm aspirated	50 %, 2m into plot	Effective barrier

The original wet line that was laid down at 14:04 for the test was subject to pressure to burn from spotting across the firebreak. The effects of spotting on the original wet-line for the eastern plot are shown in Table 4. The two dry mix plots burned slowly in this line, indicating that there was still some effect from elevated fuel moisture content.

Table 4 The results of spotting on the original wet line

Application	Fuel consumed
Water	Nil
0.3% Wet	Nil
0.3% Dry	100%
0.5% Dry	100%
0.5% Wet	Nil
0.5% Dry/Wet	Nil
0.3% Dry/Wet	Nil
Norm aspirated	Nil

4.5 Direct attack fire test

The three direct attack fire tests were conducted in quick succession starting at 15:25 hours. The weather conditions were similar for the first two direct attack fires, but unfortunately the wind dropped when the third fire was lit, and it did not achieve the same intensity as the preceding fires. A front spray bar that only sprays plain water was used in all of the direct attack tests. The results of the direct attack fire tests are shown in Table 5.

Table 5 Measurements during and after the direct attack fire tests

Application	Perimeter (m)	Area (m2)	Rate of spread (Km/hr)	Intensity (kw/m)
Water	164	1171	0.65	2032
Dry mix 0.3	121	854	1.20	3726
Wet mix 0.3	60	200	0.45	1397

4.5.1 Water only

The first direct attack test was with plain water. The fire developed quickly after ignition, with flames approximately 3m high. The truck drove in behind the fire as it passed the 10 m marker. Using the monitor on the back of the truck, the crew applied water to the right flank of the fire moving around to the front and then the left flank. The first pass knocked down the flames and the intensity of the fire and the second mopped up the residual burning areas. It took approximately two minutes to extinguish the fire. The truck used a full tank of water (2200 L) in this plot. The crew had difficulty knocking down the flames on the right flank and head fire, having to repeatedly douse them before moving onto the less intense left flank. The truck did two full circles before the fire appeared to be extinguished. The decision was made to start the following attacks at an earlier point in the fire's development so they would not reach reduced fuels. The crew had difficulty manoeuvring the monitor to get a direct hit on the flames and suggested that a free hose would have been more efficient. This problem with the monitor also affected the other direct tests.

4.5.2 0.3% dry

The second fire attack was undertaken in a similar way to the first but using 0.3% dry CAF. The fire again developed quickly and had similar characteristics i.e. 3m flame heights and 15 degree flame angle. Approximately 500 litres of water was used to extinguish the fire. It took just over 2 minutes to extinguish the flames, although the monitor was turned off for a short period as the truck reversed for a better angle of attack. The ease of suppression seemed to be increased, as less dousing was required to knock down the flanks and head fires. An examination of the site ten minutes after the experiment showed that there was still some grass smouldering underneath areas that had been covered in foam. The smouldering sections eventually self extinguished due to the large amounts of CAF surrounding them.



Figure 16 Commencing the 0.3 foam direct attack

4.5.3 0.3% wet

The third direct attack test was completed when there was a lull in the wind and as such fire did not develop as much as in the previous fires. This fire was more easily suppressed. The fire was extinguished in less than two minutes using approximately 500 litres of water in a 0.3% wet CAF solution.

5 Discussion

Durability tests

The durability tests showed that elevated levels of moisture from the different CAFS applications lasted up to 2 hours. This was evident from the measurements of FMC and ground level humidity. This period would be reduced on extreme fire danger days. The effectiveness of the applications would gradually decrease with time as the moisture evaporated.

In both duration tests the dry/wet application consistently exhibited the highest FMC for the longest time. This was to be expected, as CAF has a number of advantages over the other applications that can aid it in wetting down fuels. The surfactants in a CAF solution can help to increase the FMC to higher percent than water would. The adhesive properties of the CAF and its lightweight relative to aspirated foam can cause it to stick to the fuels better and persist higher in the fuels longer than aspirated foam. Finally, dry foam laid over the top of wet foam can insulate the wet foam from the weather and allow it to persist and have a longer period to penetrate the fuels.

Although the trends in FMC are the same in both layers, the 0- 10cm layer consistently had a higher FMC than the 10-20cm layer. This is due to both a higher exposure to evaporative forces as well as gravity causing the foam mix applied to upper parts of the grass fuels to migrate towards the ground.

The microclimate measurements in each the durability plots follow a similar trend to the FMC in the corresponding plots over time. The increased FMC levels resulting from the various CAF applications will not persist for more than two hours under typical summer conditions in grassland fuels.

The results from the duration testing are limited to the conditions used for the experiments and methods used for applying the CAF. The application methods used were designed to be repeatable, while representing current methods used by ACTRFS fire fighters. While every effort was made to keep the coverage levels consistent across the plots there are likely to have been some inconsistencies. This would have localised effects on FMC and may explain some of the variation on the FMC plots.

Indirect attack test

The first indirect wet line tested in the western plot failed to halt the fire that was ignited 45 minutes after application. The fire completely consumed all but two of the plots in the wet-line, the two plots with applications of dry mix on wet mix had been burnt over the top with some unburnt fuel remaining in the lower layers (Table 2). Even though these

two plots were not completely consumed, they did not stop the fire spread. There was no indication that the fuel consumption decreased across the 5 metre width of the plot.

The second indirect wet line tested in the eastern plot did not burn completely when challenged by a fire ignited 16 minutes after application. The fire halted at the line, with unburnt fuel remaining in all of the plots. The fire did burn on the other side of the wet line, and spread by flying embers. If the wet line was wider than the throw distance of the embers it would have effectively stopped the fire from spreading. This experiment showed that a period of 15 minutes rather than 45 minutes between the laying of a wet line and a fire encroaching will be a lot more successful in halting a fire's advance.

The original wet line laid down in the eastern plot 2.5 hours before being challenged by the fire had mixed results, with the dry foam sections being burnt. This line was exposed to only ember attack and showed that the wet applications of CAF could continue to be effective against ember attack after it has become ineffective against direct flame attack. This longevity of effectiveness against ember attack could be used operationally to widen an existing break such as a road, by application on the far side. It must be noted that the weather on the burning day (8 February) was milder than that on the durability test days when elevated fuel moisture was able to be detected for two hours (see section 4.2).

The differences in application procedures in the two plots affected the comparison. This was mainly due to the truck driving through the eastern plot and the spray being aimed directly off the back rather than at an angle from the side. This caused some of the fuels to be compacted in this plot. In some cases the fire in the eastern plot burnt up to 1m into the wet line and halted near the tyre tracks from the truck.

Direct attack test

The direct attack tests can only be treated as a pilot study due to the differences in wind speed experienced between tests. A comprehensive study of direct attack effectiveness would require many more replicate tests and measurements of the volume of water and foam used. The direct attack test here showed that using CAF can decrease the volume of

water used on a fire, but the extent of this cannot be determined. The limited manoeuvrability of monitor used to aim the CAF from the truck limited the efficiency. This could be improved by using a flexible hose for delivery. There is a potential for smouldering combustion to persist under dry CAF mixes suspended in thick grass fuels. These sections of fire line would need to be extinguished by mop up crews following the CAF truck.

Conclusions

The experiments described here showed that the most effective CAF solution in terms of durability and effectiveness against ember attack was the dry on wet foam solution. This application uses more water and CAF than other solutions. The effects of this solution could be detected for up to 2 hours on a high fire danger day, though its effectiveness as a wet line against a 4000kW/m grass head fire will only last somewhere between 15 and 45 minutes. CAFS solutions would be effective against ember attack for longer periods than they are for flame attack.

These results presented here are limited to the conditions in which they were tested. CAF was also shown to be effective for direct attack of fire, but should be investigated further to determine the extent of this effectiveness and increased efficiency in conserving water.

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