MULTIPLE IGNITION PILOT STUDY

(W.P. NO. 28/78) TONE BLOCK

BY
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SUMMARY

A pilot study to examine the behaviour of coalescing fires was severly hampered by an inability to observe fire behaviour. From observations made on edge fires, it was evident that multiple ignition fires under dry summer conditions behaved more erratically than the prediction made for single ignition, steady state fires

1. INTRODUCTION

The purpose of this study was to set up two experimental burn plots of about 120 ha each, to monitor hot-fire behaviour and test monitoring techniques in a large scale, coalescing multiple ignition fire situation. The experiment also provided a base for assessing 70mm aerial photography as a fire behaviour monitoring technique. Examination of all information collated could help explain rates of spread (R.O.S.). From this, comparisons and contrasts could be made between each burn and behaviour predicted by the Forest Fire Behaviour Tables (Sneeuwjagt & Peet, 1976).

The area selected for study was a jarrah stand with 6 year old fuels. It was centrally located in a protected aerial burn (M 65) and situated more than 3 km from the nearest private property.

2. METHOD

2.1 Pre-Burn Assessment

Using chain and compass, five sample lines (Van Wagner) were set up approximately 200 m apart, running east-west in each plot. Samples were taken to determine available fuel (Appendix 1), related to the Fire Behaviour Tables and expressed in tonnes per hectare. Method is described below;

2.1.1 Every 10 metres:-

a) Litter depth recorded with a depth gauge (Appendix 2).

b) Trash height visually assessed and recorded (to nearest 0.1 m) (Appendix 3).

c) Dominant scrub species recorded (Levy and Madden 1933, Sneeuwjagt 1971). Assessments classed into density profiles.

d) Logs assessed using the Van Wagner line intersect method and grouped into diameter classes (Appendix 1).

2.1.1 Every 100 metres:-

Litter collected from an area of exactly 30 cm square. It was oven-dried and weighed.

Biomass samples cut from a quadrat of exactly one square metre, species recorded, cut in to 40 cm height classes, then oven-dried and weighed.

2.1.3

Canopy cover was assessed at 10 metre intervals, and expressed as a percentage over each 100 metres. Crown recovery assessments will be made at a later date.

2.1.4 Tree Tagging

Approximately 100 healthy, undamaged trees in each plot were selected with 5 metres of the sample lines. This facilitated quick reference for later surveys. Assessments will be made to determine damage and recovery.

2.2 Post-Burn Assessment

The sample lines were re-assessed to determine the weight of unburnt fuel remaining and calculate fuel consumed at each point. Techniques 1a - d and 2 in the pre-burn assessment were the subject of this assessment. In addition, scorch height and defoliation height (Appendix 4) were visually assessed and recorded at 20 metre intervals (B1) and 50 metre intervals (B2). The purpose of these recordings was to gather further information on fire behaviour throughout the plots which could support information from aerial photography. Freeze direction bearings (Appendix 5) were taken at 20 metre intervals (B1) and 50 metre intervals (B2). Freeze direction bearings are taken as an indication of the passage of fire travel. Freeze direction can be identified where severe scorch occurs on scrub and trees as the fire passes. This causes the leaves, twigs and branches to bend over and "freeze" with the direction of travel of the headfire. Charring of the leeward side, caused by chimney effect of the fire wind on trees and shrubs, can also provide a freeze direction indication.

2.3 Fire Data

2.3.1 Weather

A fire weather station was set up approximately 1 km N.N.W. of the burn areas. One mechanical Casella anemometer was set up at a height of 2 metres, and an electrical Casella anemometer set at 10 metres, to record tower wind speeds. Wind speed readings were taken at 5 minute intervals. A Casella aspirated Hygrometer was also set up to record temperature and relative humidity and readings taken every half hour.

BURN I 25/2/82

TIME	(AMBIENT TEMP.) DRY BULB	WET BULB	RELATIVE HUMIDITY %
1315	31.5°	19°	28%
1530	29.5°	17.5°	27%
AVERAGE	30.5°	18.25°	27.5%

WIND SPEED		
HEIGHT	SPEED KM/HR	DIRECTION
1.5m	5.2	SW ¼
10.0m	7.8	SW ¼
900.0m	17.5	ENE

BURN II 3/3/81

TIME	(AMBIENT TEMP.) DRY BULB	WET BULB	RELATIVE HUMIDITY %
1350	30.5°	16.5°	22%
1452	32.0°	17.0°	18%
1552	29.0°	16.0°	20%
AVERAGE	30.5°	16.5°	21%

WIND SPEED		
HEIGHT	SPEED KM/HR	DIRECTION
1.5m	2.5	E ¼
10.0m	6.5	E ¼
900.0m	17.5	NE

2.3.2

Litter moisture content was recorded immediately before light-up at each fire.

B I

$\bar{x}$ = 5.03% (

B II

$\bar{x}$ = 5.0% (SD · ·8)

2.3.3 Soil Dryness Index

BURN 1	25/2/81	1455
BURN 2	3/3/81	1515

2.4 Lighting Technique

Aerial lighting was utilised in each burn. Incendaries were dropped out at approximately 50 metre spacing in lines about 100 metres apart in Burn 1 and 50 metre spacing in lines about 150 metres apart in Burn 2. The lighting of each burn spanned about 10 minutes.

Burn 1 was lit with 8 north to south flight lines commencing from the east. This direction was favoured due to prevailing winds from the south. Burn 1 was lit at 1412 hours on 25/2/81.

Burn 2 was lit with 9 east to west flight lines commencing from the south. This direction was favoured to assist aerial photography. (Note: - lines numerical order on maps is the reverse to that flown by plane). Burn 2 was lit at 1412 hours on 3/3/81.

2.5 Fire Behaviour Surveillance

2.5.1 Aerial Monitoring - 70mm Photography (see report elsewhere)

Fire mapping and outside air temperature readings taken every 1,000 feet to 12,000 feet.

TABLE 1

ADIABATIC TABLE

<table>
<tr><th>ALTITUDE A.G.L. x 1,000 FEET</th><th>BURN 1</th><th>BURN 2</th></tr>
<tr><td>12</td><td rowspan="4">STABLE</td><td rowspan="3">STABLE</td></tr>
<tr><td>11</td></tr>
<tr><td>10</td></tr>
<tr><td>9</td><td>INVERSION</td></tr>
<tr><td>8</td><td>INVERSION</td><td rowspan="3">STABLE</td></tr>
<tr><td>7</td><td>NEUTRAL</td></tr>
<tr><td>6</td><td rowspan="3">STABLE</td></tr>
<tr><td>5</td><td rowspan="5">UNSTABLE</td></tr>
<tr><td>4</td></tr>
<tr><td>3</td><td rowspan="3">NEUTRAL</td></tr>
<tr><td>2</td></tr>
<tr><td>1</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

2.5.2 Ground Observations - R.O.S.

Eight observers were utilised in Burn 1 and ten in Burn 2. These personnel were distributed at points at each end of the fire lines to observe fire behaviour from incendiaries. Safety precautions dictated that observers could not move in further than the first fire on the fire. This necessity limited observations to edge affected fires only. Observers were despatched to observe spot fire behaviour from ignition time until the fires linked. Headfire, flank fire and backfire behaviour (rates of spread, headfire flame height and length) and estimates recorded at five minute intervals (Appendix 6, 6a, b, c, d, e, f).

2.5.3 Thermocoupling Trial

A 30 probe Leeds and Northrup unit was installed west of the creek and north of line one in Burn 2. Six fire probe lines were laid out in a grid 75 metres by 100 metres. This was electrically ignited at eight points at the completion of the aerial ignition of line one at 1417 hours. Machine failure occurred at 1420 hours, and during the elapsed time, only three probe points had registered a change in temperature. Failure was diagnosed as overheating of connecting wire which caused excessive resistance.

3. ANALYSIS

3.1 R.O.S. Analysis - Burn 1

Significant differences occurred in recorded R.O.S. between the north side (points 8, 5 & 4) and the south side (points 8, 6 & 4) of the Burn. The Logarithmic Linear Regression graphs (Appendix 7 & 8) illustrate that no comparison can be drawn between fire behaviour witnessed on the south side of the burn with that on the north. Pre-burn sampling from lines 1 and 5 could not be considered as representative for either north or south observation points as the lines were between 150 and 250 metres from them. The north edge of the burn consisted of low, open forest, with ti tree thickets (including a considerable amount of dead vegetation), and a sparse litter component. The south edge featured heavy litter and tall, closed forest. There was no significant variation in slope factors north and south. It became apparent that fuel and tree density alone could not explain the vast difference in fire behaviour.

From information drawn from aerial photographs R.O.S. recorded data (Appendix 6a - f) and post-burn freeze direction (Appendix 5), some conclusions may be put forward concerning the likely fire behaviour pattern, and perhaps an explanation of factors affecting the different fire behaviour recorded north to south.

Aerial photographs suggest that plume development was centred in the north-east sector of the burn. Ambient wind direction (from the south-west quarter) may have influenced this position as its interaction with spot fire convections could tend towards convection coalescence with a north easterly bias. This phenomenon is evidence in aerial photographs. Lighting pattern (east west) may have assisted its easterly location.

Freeze direction bearings (Appendix 5) taken on lines 1 and 2, point to the possibility of a strong convection draw into the north east sector of the burn. Developing convection influence of this strength could affect ambient wind by blocking its normal path and drawing it upwards on the windward side of the convection column. Creation of Leeward and side effects drawing air through recirculation of the convection column and/or from areas within its vicinity, could result in a greatly increased R.O.S. Interruption of ambient wind condition and the substituting of a convection caused condition might then result in fire behaviour controlled locally by convection influence. The development of fire winds (travelling in to the convection base in the opposite direction to the ambient wind - Appendix 5) would have been necessary to create the R.O.S. recordings and directions evidenced on the north side of the burn. It is suggested that the low pressure created by tremendous heat generated rapidly in and around the base of the convection column, was responsible for the development of rapidly accelerating fire winds drawn towards its base.

Due to the restrictions (safety and limited number) of ground personnel monitoring fire behaviour, no observation data could be gathered to assist analysis of fire behaviour on the flanks and behind the convection centre.

It could be assumed that fire wind behaviour was somewhat similar around the convection centre. It could also be assumed that the bending over of the convection column on the leeward side might cause a much more severe in-draught from the leeward side and that recirculatory pre-heating and turbulence resulted in the swift and erratic increases in R.O.S. In both instances there is insufficient data available to confirm or refute this summation.

A further phenomenon presenting a possible explanation for the north edge R.O.S. is that of a stronger leeward convectional draw caused by the chimneying effect of a relatively strong ambient wind drawing the convection column up, increasing drag and reducing the pressure of the leeward side.

3.2 R.O.S. Analysis - Burn 2

Burn 2 featured basically similar summer weather conditions to Burn 1. Temperatures were comparable, ground winds were light, wind speeds at 900 m were identical, adiabatic conditions somewhat similar, and total fuel loading almost identical (B1 - 11.74 t/ha, B2 - 11.69 T/ha). The fundamental difference was that the ignition points in Burn 2 were wider spaced at 50 metres, with lines 150 metres apart, as opposed to Burn 1 spacings of 50 metres and 100 metres (i.e. 1.3:2). However, lighter, more variable winds, and slightly unstable adiabatic conditions (to 6,000 feet), together with an average R.H. of 29.0% compared to 27.5%, also appeared as possible factors contributing to a considerable difference in fire behaviour from that experienced in Burn 1.

Burn 2 developed more uniformly as spot fires developed and individually developing smoke columns joined just north west of the centre of the plot to form a heavy, almost vertical, slow-rising convection column, much weaker in draw than that of Burn 1. The R.O.S. (Appendix 6a - f) recorded on both east and west sides of the burn progressed in a much more predictable manner with little (by comparison with Burn 1) difference. This, perhaps was indicative of a steady, central, convectional draw. Low R.O.S. recorded at eastern lines 6 and 7 can be attributed to low fuel component and poor burning conditions. High R.O.S. recorded in the 15 - 30 minute period could have been caused by the action of coalescing fires and a strong, developing central convection column draw. A similar interruption (as in Burn 1) to ambient winds was created.

Freeze direction bearings (Appendix 5) taken at 50 metre intervals on the fire sample lines, are less conclusive than those taken in Burn 1 at 20 metre intervals. Although some pattern emerged, indicating strong convectional pull towards a slightly north west of central location bearings are not as consistent. This could indicate that stronger convectional influence came from the wider spread, developing fires and their coalescing action, in contrast to the rapid conjunctioning experienced in Burn 1. Once again, constraints placed on the positioning of ground observation personnel, and other constraints on aerial observations/photography (i.e. convectional pull on the aircraft and smoke obscuring vision etc.), severely limited data collection.

One, or several factors must have contributed to the different fire behaviour between Burns 1 and 2. The much wider spacing of ignition points was obviously one such factor. This technique could have resulted in stronger individual fire development initially, thus limiting the single, strong central convectional pull as experienced in Burn 1.

Slightly unstable atmospheric conditions (to 6,000 feet) possibly assisted individual convection column developments initially.

Lighter wind conditions may have been instrumental in allowing individual column development initially, and consequently restricted initial R.O.S. and convectional draw accordingly. Conversely, lower R.H. should have contributed to drier litter condition, although in practice the differences in fuel moisture content between Burns 1 and 2 were negligible.

3.3 R.O.S. Analysis - Forest Fire Behaviour Tables

R.O.S. was calculated from the tables as follows:-

BURN 1

Wind = 5.2. km/hr (1:1)

S.M.C. = 5%

R.O.S. = 104

Fuel quantity correction:-

Available fuel = 5.6 T/ha (litter)

Correction faction = 0.7

Adjusted R.O.S. = 104 x 0.7 = 73 m/hr

Slope correction factor:-

slope = 3^{o}

Correction factor = 1.2

Adjusted R.O.S. = 73 x 1.2 = 87 m/hr

Estimated R.O.S. = 87 metres per hour.

BURN 2

Wind = 2.5 km/hr (1:1)

S.M.C. = 5%

R.O.S. = 74 m/hr

Fuel quantity correction:-

Available fuel = 8.5 T/ha (litter)

Correction factor = 1.0

Adjusted R.O.S. = 74 x 1.0 = 74 m/hr

Slope correction factor:-

slope = 2^{o}

Correction factor = 1.2

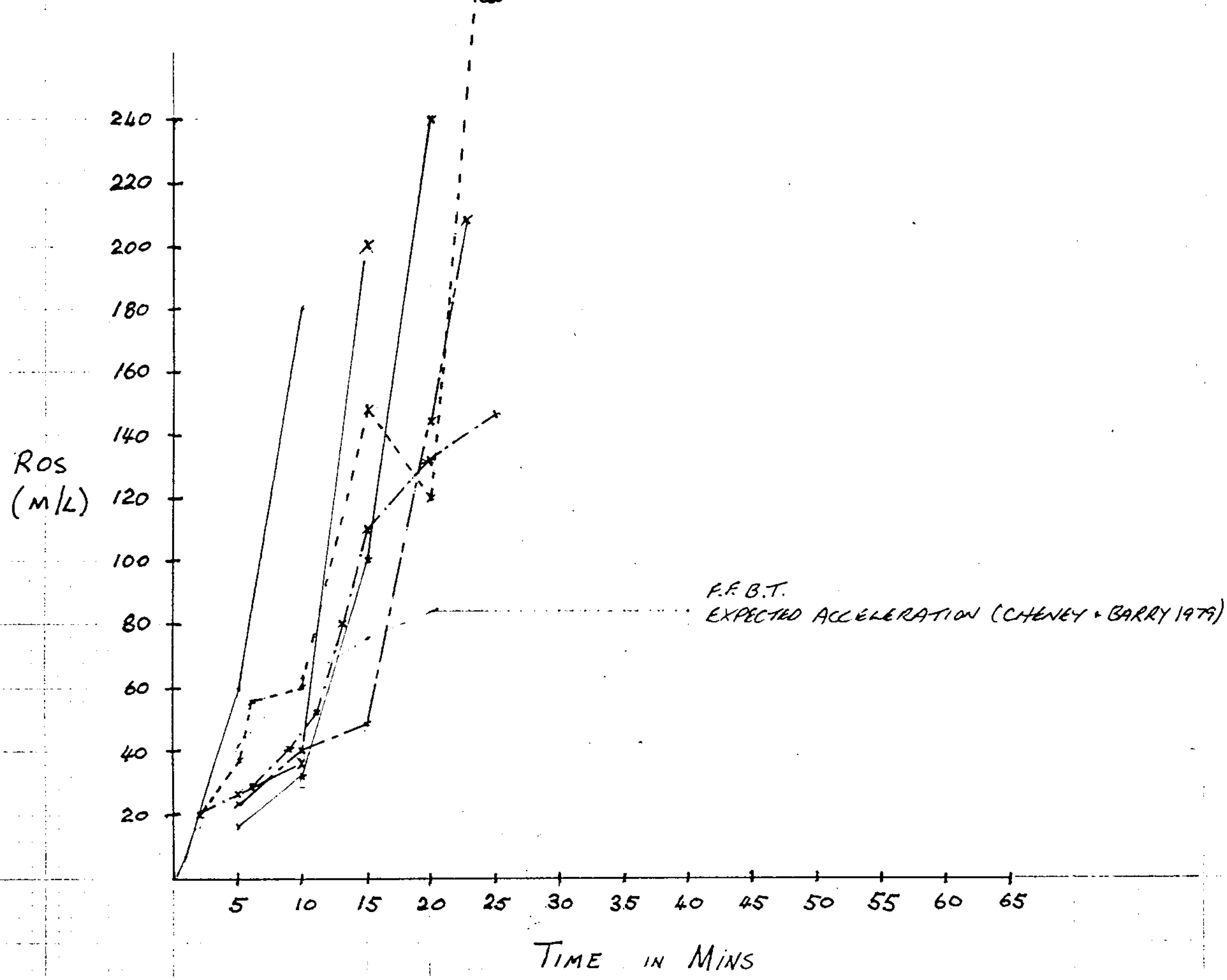
Adjusted R.O.S. = 74 x 1.1 = 81 m/hr

Estimated R.O.S. = 81 metres per hour.

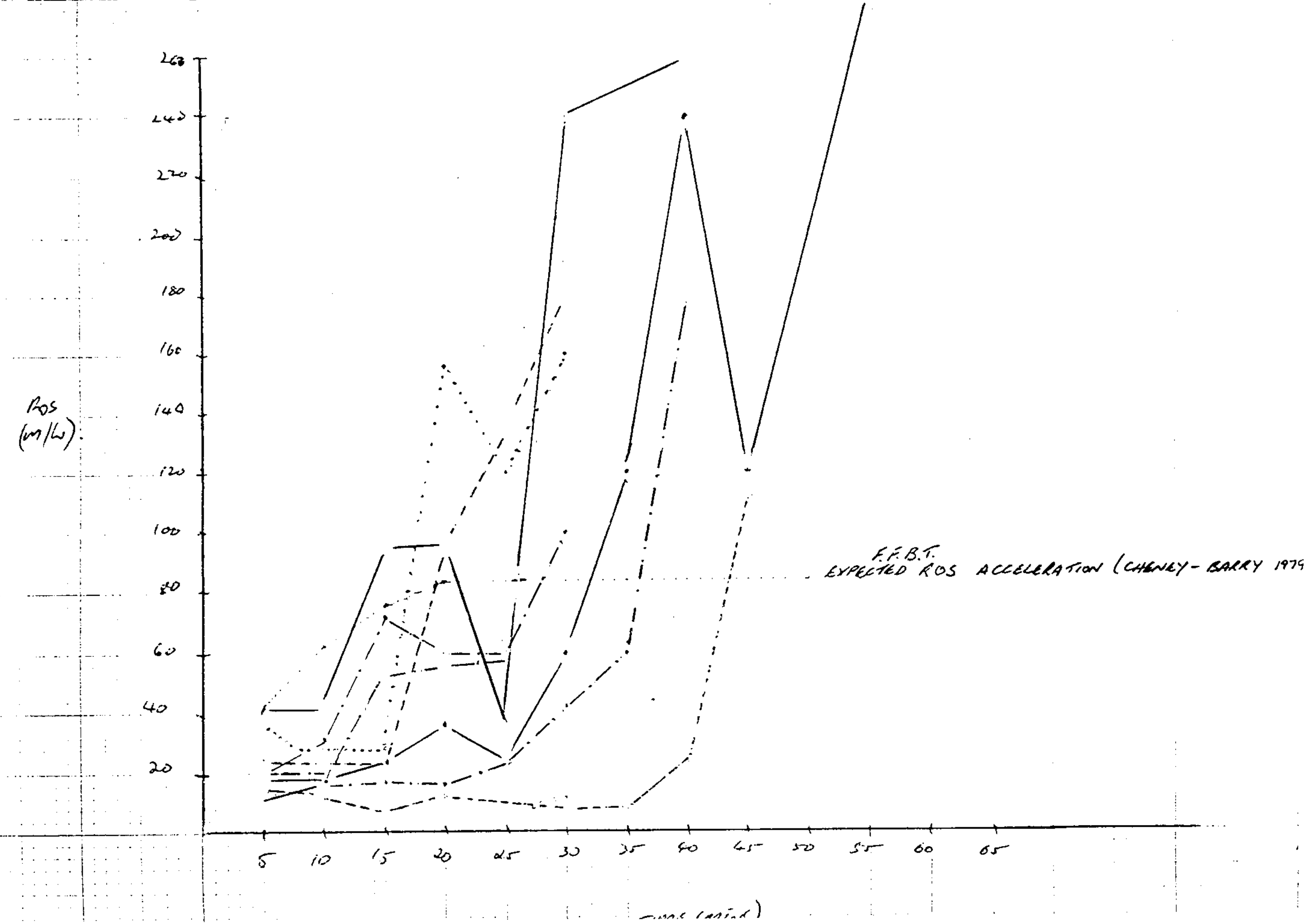
With similar fuel and weather conditions, predicted R.O.S. from the Forest Fire Behaviour Tables for Burns 1 and 2 were similar. However, observation data illustrates tremendous differences between those R.O.S. predicted and actual rates observed. Significant differences between Burns 1 and 2 were also experienced. Using a formula devised by Cheney & Barry (1979),

TONE BURN 1 R.O.S. WITH TIME

FIG. 1



TONE BURN 2 R.O.S. WITH TIME Ground observation records FIG 2.



to plot an acceleration curve for summer fire predictions from the Forest Fire Behaviour Tables, the graphs (figs. 1 & 2) have been drawn to illustrate those differences in Burns 1 and 2 and relationship with predicted R.O.S.

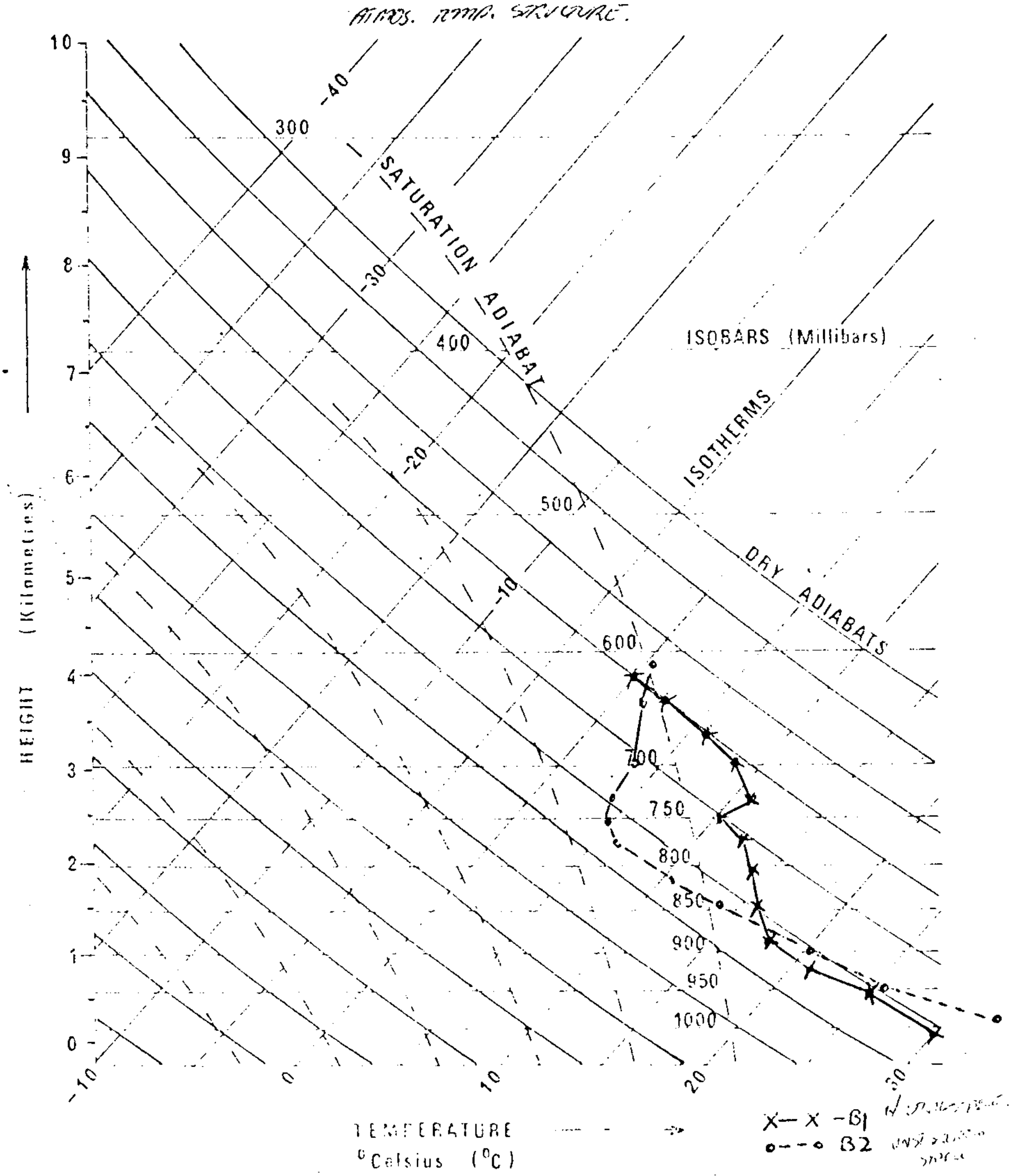
The expected R.O.S. acceleration plotted against actual acceleration indicates that most fires observed in Burn 1 had shown initial acceleration in the first 5 - 10 minutes, but thereafter actual acceleration, peaking at up to 350 m/hr, was rapid and bore no relationship to that predicted. In Burn 2, with fires of longer duration, actual fire R.O.S. fluctuated below predicted R.O.S., peaking at up to 260 m/hr after it passed predicted R.O.S. at 20 - 25 minutes. However, in both Burns, as the R.O.S. graphs (figs. 1 & 2) clearly illustrate, no quasi steady state (85 m/hr) is reached, as the Forest Fire Behaviour Tables and Cheney and Barry (1979) suggest. Conversely, in fact, R.O.S. continued to increase rapidly.

The only R.O.S. observations successfully expedited were ground observations necessarily taken from the edge of the Burns. Although all observations failed to furnish any reasonable information from inside the Burns, it is most probable that R.O.S. were considerably higher there.

4. CONCLUSIONS

1. It is clearly evident that there is insufficient information available to allow any reliable predictions to be made for multiple ignition fires in summer conditions.

2. Monitoring techniques at present utilised are incapable of providing any one fire which might facilitate a better understanding of fire behaviour. This particularly applies to internal fire weather, interaction of coalescing fires, R.O.S. and convection development.


ATMOS. TEMP. STRUCTURE.
SATURATION ADIABAT
ISOBARS (Millibars)
ISOTHERMS
DRY ADIABATS
300
400
500
600
700
750
800
850
900
950
1000
-40
-30
-20
-10
HEIGHT (Kilometres)
0
1
2
3
4
5
6
7
8
9
10
-10
0
10
20
30
TEMPERATURE
°Celsius (°C)
X—X -B1
o- - -o B2