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by A. G. MCARTHUR*

SUMMARY

The Longford fire commenced on 17th November, 1962, in poor-quality eucalypt forest some 5 miles south-west of the Longford plantation of 9,000 acres of *Pinus radiata* aged 1-12 years and owned by A.P.M. Forests Proprietary Limited. The Longford area is located about 4 miles south-west of Sale in Gippsland, Victoria.

Overnight and during the early morning hours the meteorological conditions were mild. However, by midday strong winds, high temperatures and low humidities resulted in a day of extreme fire danger. The fire moved rapidly through the poor-quality hardwood forest but in a direction away from the plantations.

A sudden wind change at 4.45 p.m. caused the fire to change direction and threaten the plantation areas. The suppression forces fell back on the external boundary of the pines in an attempt to prevent entry of the fast-moving hardwood fire.

Despite the presence of control burnt strips and wide, well maintained firebreaks, the hardwood fire entered the pines at 5.50 p.m. by throwing burning embers across the break. It is probable that these embers were being thrown a distance of between 15 and 20 chains. A high-intensity fire developed in the 9½-year-old pines and spread at an initial rate of 30 chains per hour. An improvement in meteorological conditions coupled with bold suppression action halted the main headfire in the pines around 7.15 p.m. Another fire which entered the pines further to the north was controlled by 8.30 p.m.

Both the hardwood and pine plantation fire provided valuable information on fire behaviour in these fuels. The hardwood fire spread at a very fast rate yet crowned only in isolated patches. The rate of spread almost doubled after the south-westerly change occurred. This may have been due to extreme turbulence associated with such a change. Whatever is the reason, the high-intensity fire behaviour associated with such changes presents a major suppression problem and adds weight to the necessity of bringing the north-eastern flank of a fire under quick control when a south-westerly change is imminent.

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The plantation fire also spread at a fast rate and this was probably due to the fact that the plantations were unpruned and at a stage of development when the fuels are at their most hazardous stage. The vertical distribution of fuel encouraged crown fire development and damage was severe. Spot fires were thrown considerable distances in advance of the headfire until 8 p.m. by which time weather conditions were relatively mild.

A comparison has been made between fire behaviour in pruned and unpruned pine plantations. All other factors being equal, a fire in an unpruned plantation will spread almost three times as fast as one in a pruned plantation. If forward spread is increased by a factor of 3, area spread will increase by a factor of 9. Suppression difficulty and crew safety are also vitally affected by fuel distribution.

Evidence suggests that fire damage can be reduced in pine plantations by the complete pruning of the stand to a height of 8-12 feet. This may not be an economic operation on short rotation crops and the increased risk of fire damage may be balanced against the considerable cost of pruning.

Added protection against fire may be achieved by:—

(*a*) pruning strategic strips along external boundaries and major access roads;

(*b*) area control burning in adjoining hardwood forest; and

(*c*) reducing fuel quantities within the plantations by mechanical or chemical methods or by the prescribed use of fire.

FIRE BEHAVIOUR CHARACTERISTICS OF THE LONGFORD FIRE

1. INTRODUCTION

An analysis of the fire behaviour associated with the Longford plantation fire has been attempted from information derived from reports by Forest Supervisor R. J. McCabe and Foreman Gourlay, meteorological information supplied by the R.A.A.F. Station at Sale and personal field inspections.

In many instances the information available is insufficient to properly interpret the behaviour of the fire and some of the spread data can be accepted with reserve.

2. ORIGIN OF THE FIRE

The fire was first reported at 0915 hours on Saturday, 17th November. This presumably refers to a smoke column seen from a distance and the fire could have been burning for some time prior to this. From a description of the fire perimeter at 1115 hours as seen by McCabe and Gourlay and taking into account prevailing meteorological conditions and topographic features, it would appear fairly certain that the fire commenced on or near Lime Quarry Road sometime during the previous afternoon or evening. Overnight conditions were very mild and the fire would have been dormant. Rekindling may have occurred around 0800 hours but probably not before 0900 hours when the fuel was commencing to dry out.

3. PROGRESS OF THE FIRE

(a) Period 0900—1200 hours

Meteorological records at Sale Aerodrome show that the wind was dead calm until 0950 hours. Thus the rate of spread must have been very slow up to 1000 hours.

By 1100 hours the wind velocity had risen to 8 m.p.h. with the air temperature in the mid-80's and relative humidity around 20 per cent. Wind direction was from the west-north-west and it is reasonably certain that the headfire had just crossed Chessum Road and was moving towards Holey Hill on rising ground.

By 1200 hours the wind velocity had risen to 26 m.p.h. The temperature was 91° F. and the relative humidity had fallen to a low of 14 per cent. These conditions represent a forest fire danger index of 58, an

extreme classification. The headfire wou'd be moving rapidly in a south-south-easterly direction and would be near the main Holey Hill ridge and about one and a half miles west of the hill. The area burnt by 1200 hours would be in the vicinity of 540 acres and the perimeter of the fire around 4.5 miles. The average rate of forward spread between 1100-1200 hours would be around 50 chains per hour.

(b) Period 1200-1500 hours

The very strong wind persisted during the afternoon and reached a maximum of 30 m.p.h. from the west-north-west at 1500 hours. The fire danger index varied between 55-60 during the period and remained in the extreme classification. The fast-moving headfire burning to the south of Chessum Road reached the top of the main Holey Hill ridge and by 1500 hours was some 50 chains to the E.S.E. of Holey Hill Trig. The rate of spread of the headfire had increased to around 70 chains per hour.

(c) Period 1500-1800 hours

At around 1515 hours a backburn along Kelly's Road spotted over and a rapidly moving head raced away to the east-south-east under a still strong, but decreasing, west to west-north-west wind. The north-eastern side of this breakaway was contained but the head and south-easterly flank were free burning. At the same time the main headfire was still burning along the Holey Hill ridge some 120 chains to the south.

Between 1640-1645 hours a decided wind change occurred, the wind direction moving through 45 degrees from west-north-west to west-south-west (as recorded at Sale aerodrome). The wind velocity had fallen below 20 m.p.h. prior to the change and rose slightly to around 22 m.p.h. by 1700 hours. This wind change had a very significant bearing on subsequent fire behaviour and the eventual entry of the hardwood fire into the 1952 pine plantations lying to the north-east. The wind change took the north-eastern flank away on a broad face at a rapid rate of spread. Several high-intensity fast-running heads developed and were a direct threat to the plantations lying some three miles to the north-east. The most immediate threat was the head running just south of and parallel to Chessum Road. This was the head which had developed from the backburn breakaway at around 1515 hours. Another major head crossed Kelly's Road about one and a half miles north of its junction with Chessum Road. This head also directly threatened plantation areas. The original main headfire along the Holey Hill ridge was slowing down due to down-hill travel and possibly due to the fact it ran into sparse or perhaps greener fuel types. This head eventually passed to the south of Murphy's block and was controlled early the following morning when it eventually approached plantation areas.

The two northern heads were spreading at around 60-70 chains per hour and were undoubtedly spotting heavily. At around 1750 hours the Chessum Road head entered Compartment 45 probably by spotting across the well-maintained break into unburnt windrows.

(d) Period 1800-2100 hours

During this period the main suppression effort concentrated on control of the fire which entered the pines in Compartment 45 at 1750. Although the south-west change had not caused any marked variation in temperature and relative humidity, the wind velocity was falling steadily from the time the fire first entered the pines. At 1800 hours the velocity was 18 m.p.h. at 1900 hours it was 14 m.p.h. and by 2005 hours it had dropped to a dead calm which lasted for one hour. This fact would have materially aided the suppression effort in the pines and enabled the headfires to be knocked down.

Although a systematic attack on the *P. radiata* fire in Compartment 45 was made within ten minutes of commencement, the initial rate of spread was too fast to enable the successful use of water in knocking down the headfire.

An examination of the damage pattern within Compartments 44, 45 and 46 clearly indicates that two major headfires developed in the pines. The northern headfire developed some 20 chains south-east of the fire tower and burnt in a north-easterly direction into Compartment 44. This headfire was stopped on the break between Compartment 44 and 43 at 1915 hours by the use of water tankers and live reels. The headfire proceeded as a crown fire in the unpruned 40-45 ft. high 9½-year-old pines at a rate of 27 chains per hour. The side fire seldom crowned except on isolated upslopes and its spread was naturally much slower.

The second major head must have entered Compartment 45 some 15 chains further south of the first fire and burnt in a north-easterly direction into Compartments 46 and 47. The fairly steep fall into Deep Creek together with the almost complete absence of wind slowed down the headfire and it was contained along the firebreaks and the western side of Deep Creek. Between 1800 and 2000 hours this fire spread at a similar rate to the northern head, i.e., around 25 chains per hour.

The junction zone between these two heads produced severe damage in Compartment 45 but in Compartment 44 unburnt patches of pine were left.

Around 1900 hours the northern headfire in the hardwood area, which had crossed Kelly's Road around 1700 hours, spotted into Compartment 18 about 1 mile west of the fire tower.

By this time the wind had dropped markedly and the fuel-moisture content would have been rising. Control of this pine fire was fairly readily achieved by flank and head attack by 2030 hours. The rate of spread during the period 1900-2030 hours was around 16 chains per hour. By the time this fire was controlled the temperature had fallen to 70° F. and the relative humidity was 30 per cent. The fire danger index had fallen to a value of 11, which is classified as moderate.

By 2100 hours all headfire runs had been halted and the massive task of mopping up the active perimeters, both within and outside the plantation areas, continued. All perimeters within the plantation areas were controlled by midnight. The southern edge of the hardwood fire was controlled during the following day.

4. METEOROLOGICAL CONDITIONS

TABLE (1)—AIR TEMPERATURE, DEW POINT AND RELATIVE HUMIDITY RECORDED AT SALE AERODROME

Date	Time	Air Temp.	Dew Point	Relative Humidity
	Hrs.	°F	°F	Per Cent.
17-11-62 ..	0300	49	47	93
	0600	55	53	93
	0900	74	55	51
	1200	91	36	14
	1500	91	39	17
	1800	82	47	30
	2100	69	35	27
18-11-62 ..	0300	62	53	72
	0600	56	46	69
	0900	63	54	72
	1200	64	44	48
	1500	65	40	40
	1800	60	40	49

TABLE (2)—WIND VELOCITY AND DIRECTION RECORDED AT SALE AERODROME ON 17-11-62

Time	Velocity	Direction
Hrs.	m.p.h.	
0300	0	.....
0600	0	.....
0900	0	.....
1000	5	.....
1100	8	.....
1200	26	W.N.W.
1300	25	.....
1400	25	.....
1500	30	W.N.W.
1600	20	.....
1700	22	Change 1640 from W.N.W. to W.S.W.
1800	18	W.S.W.
1900	14	W.S.W.
2000	6	Calm 2005 to 2055 then rising.
2100	8	W.S.W.
2200	14	W.S.W.
2300	18	W.S.W.
2400	14	W.S.W.

Maximum gust from W.N.W. at 1505—48 m.p.h.

TABLE (3)—RAINFALL RECORDED AT SALE AERODROME DURING OCTOBER AND NOVEMBER, 1962

(*a*) October		(*b*) November	
Day	Points	Day	Points
1	3	1	3
2	3	2	1
5	6	3	4
7	5	7	11
8	5	8	1
9	3	11	36
10	7	21	25
13	8	22	8
14	14	24	3
15	12		
20	11	Total	92
21	59		
22	2		
23	3		
24	6		
25	18		
29	112		
30	4		
Total	281		

5. SEASONAL CONDITIONS

From local information it would appear that winter and spring rainfall was slightly below normal. However, reference to the rainfall data shown in Table (3) indicates that rainfall at Sale Aerodrome during October was fairly well distributed and that the last significant rainfall occurred on 29th October, some nineteen days previous to the fire. A fall of 36 points was recorded on 10th November, one week prior to the fire.

The effect of this rainfall would be very largely lost on the fine surface fuel, but would be still very significant on the larger fuel components such as logs and branchwood and on any "duff" layers in the plantations. Surrounding grasslands still showed considerable greenness and were apparently between 55-80 per cent. cured. This would also indicate that the larger fuel components would not be fully dried.

On the forest fire danger meter the drought factor or seasonal severity index is given as 70, against a maximum of 100. Thus the rate of spread, fire intensity and difficulty of control and fire damage would all be lowered to some extent by the fact that not all fuel components were readily available for combustion.

6. FUEL TYPES

Unfortunately, measurements of fuel quantity were not taken in either the hardwood or pine areas.

The natural eucalypt forest largely consisted of a low-quality stand of *E. baxteri, E. radiata, E. consideniana* and *E. eugenioides*. The height growth would seldom exceed 40-50 feet and in places was an almost mallee form 15-25 feet high. Such low height growth would naturally allow strong wind movement close to ground, which would largely account for the rapid fire movement in the hardwood area.

From inspection it would appear that the quantity of leaf and twig material would not exceed 2-3 tons per acre. Heavy bracken 2-3 feet high occurred over most of the area and would probably contribute an additional 2 tons of fuel per acre.

In summary, the hardwood fuel type could be classed as a 5-ton-per-acre fuel with a considerable flash fuel component of bracken and of a height and composition which would allow strong wind movement at ground level. The rate of spread under such conditions would be at least double the spread which would occur under high forest carrying a comparable fuel quantity.

The pine area was a 9½-year-old *P. radiata* plantation planted 7 feet x 7 feet. Height growth would vary between 35-40 feet. The area was unpruned and the green level was at 12-15 feet. Canopy had closed and all bracken had been killed out but was still standing in places and contributing to the available fuel. It is estimated that there was approximately 4-5 tons per acre of needle litter existing at ground level with 1 ton per acre of bracken and grasses and 1-2 tons per acre of dead needles hanging on the standing trees. In summary, the total amount of available fuel would be around 7 tons per acre. The distribution of the fuel was such that flames would readily spread from ground level to the tree tops.

7. FUEL BEHAVIOUR IN RELATION TO FUEL AND METEOROLOGICAL CONDITIONS

(a) The Fire in the Hardwood Area

The main characteristic of this fire was the fact that there were very few areas where the fire had crowned. Generally, it must have been a fast-spreading fire with the flames kept close to the ground by the strong wind. This must have prevented the formation of a strong convection column and long-distance spotting. However, short-distance spotting up to 20 chains could easily occur under these circumstances.

The rate of forward progress prior to the wind change at 1640 hours was around 65 chains per hour at a fire danger index of 40. This is approximately twice the rate of spread normally expected under these meteorological and fuel conditions in a pure eucalypt fuel type. It appears fairly obvious that the very fast rate of progress of the fire has resulted from the presence of a heavy bracken ground fuel. Bracken fires are very intense and normally give a much higher rate of spread than a more normal eucalypt ground fuel with scattered shrubs.

At the onset of the west-south-westerly change at 1640 hours the rate of spread increased very markedly to around 80 chains per hour, although the fire danger index had fallen.

Although faster spreading, the fire was not crowning and only isolated patches of tree crowns were consumed.

The very fast spread associated with the passage of a cold front where a broad fire front is carried away by the wind change defies any reasonable explanation at the present stage of our fire behaviour knowledge. Generally, the rate of spread is doubled for a given fire danger index, as shown in Figure 3.

The phenomenon of a greatly increased spread when a wind shift occurs has been well authenticated on many occasions. One notable instance which can be mentioned was the Wandilo fire in South Australia, which burnt on April 5th, 1958. In this case the frontal passage occurred at 2045 hours, when conditions had moderated to a temperature of 82° F., a relative humidity of 40 per cent. and a wind velocity of 11 m.p.h.—conditions not very different from the Longford fire. The whole north-eastern flank of the eucalypt fire broke away on a massive spread of 160 chains per hour, which was exactly double the spread in similar eucalypt fuel types during the early afternoon under apparently more severe conditions. The forest type was very similar to the Longford area, with *E. baxteri* as the major species and a ground cover of Ti-tree, bracken and blackboy. The fuel quantity in the case of the Wandilo area would be at least 10 tons per acre, or double the Longford type.

The greatly increased rate of spread which occurs when the normal anti-clockwise wind shift takes place with the passage of a cold front is one of the major suppression problems in fire control. The phenomenon certainly dictates that control of the north-eastern flank is a major necessity on any fire where a frontal wind shift is imminent.

There was no recorded evidence of long-distance spotting resulting from the hardwood fire, either before or after the change. This is consistent with the fact that crown fire formation did not take place over any large area. Undoubtedly, fairly intense short-distance spotting was occurring up to 5-10 chains in front of any major head and it is probable that the fire which entered the plantation area resulted from this short- to moderate-distance spotting.

The effect of control burning on the eucalypt fire is noteworthy. The hardwood area lying to the west of the fire tower and between Chessum Road and Compartment 18 had been fairly heavily control burnt some two years previously. The fuel quantity was insufficient to support a ground fire, although it lay between two major heads and would normally have burnt quite fiercely. On the southern side of Chessum Road, some strip burning had been carried out. Apparently the strip width varied between 3-5 chains. This was insufficient to halt the major running head which entered Compartment 45. The headfire either spotted or burnt directly across the control burnt strip.

These two examples serve to illustrate the fact that control burning must be carried out "in depth" to be effective in stopping a fast-running headfire. There is little doubt that the Longford plantations can be adequately protected from fires originating in the scrublands lying to the west and south by area control burning. An adequate system of tracks already exist as a basis for such work.

(b) The Fire in the Plantation Area

Two features of the fire behaviour in the nine- to ten-year-old *P. radiata plantations are of interest*:—

(i) the rate of spread was very fast for the meterological conditions under which the fire burnt;

(ii) the relatively long-distance spotting which took place as late as 2000 hours under what were then mild meteorological conditions.

The reason for the fast rate of spread and fairly severe spotting is probably due to the fuel distribution in the standing pines. Canopy would have closed in the last year or two and the green level was around 10-15 feet, depending on the site. The fairly large mass of dead and dying needles in the lower canopy level, combined with recently suppressed bracken, provides a fuel distribution ideally suited for high flames to develop, which in turn would ignite the green crown and produce a fairly intense crown fire. This immediately induces a strong convection column formation which would carry up burning embers (probably large clusters of needles held in the angle of the branches and stem) and deposit them some distance in front of the fire. Most spot fires appear to have taken on windrow material left unburnt or partially burnt from the original plantation clearing. Observation and research have shown that logs and stumps are a much more receptive medium for spot fire development than fine fuel lying close to ground level.

The fuel distribution problem was largely due to the fact that the 1952 and 1953 plantations were unpruned. There is little doubt that the creation of a break between the ground and green aerial fuels is highly desirable from a fire control viewpoint. When such a break is created by pruning to 12 feet or more, a crown fire has difficulty in developing. Not only will the intensity of the fire be reduced by lessening the convection processes but rate of spread and difficulty of control will be significantly reduced. A lowering of these three factors will result in a significant reduction of the area burnt.

In the case of the Longford fire it was somewhat difficult to estimate the rate of spread due to the fact that meteorological conditions were constantly improving from the time the fire first entered the pines until the headfires were stopped. Over a period of an hour, the distance travelled was at least 27 chains. During the period between 1700-1800 hours, it is reasonable to assume that the headfire may have travelled at a speed in excess of 40 chains per hour over short distances. The damage pattern indicates that the headfires proceeded as full crown fires and burnt very severely.

8. THE EFFECT OF PRUNING ON FIRE BEHAVIOUR IN P. RADIATA PLANTATIONS

The only means by which the effect of pruning can be evaluated as a fire control measure is to compare the behaviour of fires burning under similar meteorological conditions in a pruned and unpruned plantation. It is perhaps significant that most plantation fires of any size over the last 10 years have burnt in unpruned plantations. These include the Wandilo and Kongorong fires in South Australia and the Barcoongere plantation fire in northern New South Wales.

One recent example of a well-documented fire in a pruned plantation was the Gnangara fire of 22nd January, 1962, in Western Australia. The behaviour of this fire will be used to illustrate the difference between a fire in pruned and unpruned coniferous plantations. The comparison in Table (4) is conservative in so far as the meteorological conditions were far more severe than those existing during the course of the Longford plantation fire and the fact that the fire burnt during the heat of the day, commencing at 1150 hours and being controlled by 1700 hours.

TABLE (4)—COMPARISON BETWEEN FIRE BEHAVIOUR OF THE GNANGARA AND LONGFORD PLANTATION FIRES DURING THE MAIN BURNING PERIOD

Characteristic	Gnangara	Longford
1. Burning period	1150-1700 hours	1750-2100 hours.
2. Fuel type	30-40 y.o. *P. pinaster*	9½-10½ y.o. *P. radiata.*
3. Treatment	Pruned to 12 ft. Recently thinned	Unpruned. Unthinned.
4. Height of stand	40 ft.—60 ft.	30 ft.—50 ft.
5. Estimated quantity of dead fuel.	8-9 tons/acre	6-8 tons/acre.
6. Air temperature	102° F.	80° F.
7. Relative humidity	13 per cent.	30 per cent.
8. Wind velocity	Increasing 6-15 m.p.h.	Decreasing 18 to 6 m.p.h.
9. Rate of Spread	Varying 6-21 chains/hr.	Average 30 c.p.h.
10. Flame height of headfire	10 ft.-12 ft. with isolated patches of crown fire under heavy logging slash.	30 ft.-50 ft. almost continuous crown-fire.
11. Spotting	Intense spotting up to a distance of 20 chains around 1300 hours decreasing to a distance of 3-5 chains at 1700 hours.	Heavy spotting for a distance of 15 chains at 2000 hrs.
12. Area burnt at time of control.	120 acres	278 acres.
13. Suppression	Direct attack with water at head. Hand tools and D4 plough on flanks.	Direct attack with water at head and flanks.

In terms of rate of forward progress, Table (4) shows that the Longford fire spread at about twice the rate of the Gnangara fire. This is somewhat false due to the fact that the meteorological conditions were much more severe during the Gnangara burning period. If these conditions are converted into terms of fire danger index a direct comparison is possible. This is shown in Figure 4.

This shows that for a given fire danger index, the rate of spread in the unpruned plantation is almost three times that in the pruned plantation. It is of interest that the rate of spread of the Wandilo fire which burnt near Mt. Gambier on 5th April, 1958, is identical to that of the Longford fire between the hours of 1230-1430. This was also an unpruned fuel type. At 1500 hours the Wandilo fire "blew-up" and assumed fire storm characteristics. A group of eight firefighters lost their lives in this fire.

Both the topography and the soil types of the Longford, Gnangara and Wandilo plantations show remarkable similarity. The pines in all cases are growing on coastal sands. The topography is dominated by old sand dune formations which result in short sharp rises of 5 to 10 degrees over perhaps 4-5 chains. Over a sustained run of an hour or more such topography must be assumed as being equivalent to level ground. Both headfires of the Longford fires were aligned along major ridges and can be considered as travelling over level ground.

The Longford fire did not exhibit any erratic behaviour characteristics. This is probably due to the fact that the main burning period was after sunset when vertical air motions tend to be damped down. Had the Longford fire entered the pines early in the afternoon, there is little doubt that the fire would have burnt out of control for six or eight hours, resulting in a greatly increased burnt area.

The spread relationship shown by Figure 4 may not persist over the whole range of fire danger index to a "worst possible" of 100. Logic would suggest that beyond an index of 50, which is the commencement of an extreme or "acute" danger classification, long-distance spotting would result in a greatly increased rate of spread and the spread in pruned plantations may approach the unpruned rates of spread.

Rate of forward spread is by no means the only criterion which can be used when attempting to arrive at a comparison between fire behaviour in pruned and unpruned pine plantations. Other factors which are of significance to the forest owner are:—

(a) Area Spread

If forward spread per hour doubles, area increase per hour will increase fourfold and if forward spread trebles, area spread will increase ninefold. As an example the area burnt by the Gnangara fire after 2 hours was 30 acres. The area burnt by the Longford plantation fire in the same period was around 270 acres, as theoretically expected. The difference in rate of forward progress gives a disastrous increase in the area burnt.

(b) Difficulty of Suppression

This is perhaps the most significant factor. Up to a danger index of 50, fires in pruned pine plantations (and in clean eucalypt forests) can be attacked with a reasonable chance of control. Visibility is good and men and equipment can move fairly rapidly. Flame heights are within reasonable limits and water can be used effectively. In an unpruned pine plantation the reverse is true. Due to loss of mobility working conditions become very hazardous and common sense dictates that crews cannot work in advance of the fire. Even though effective safe work can be achieved by flank attack, mobility is still lost and the work output per man or machine hour is low. Difficulty of suppression leads to longer control time and greatly increased areas burnt.

(c) Crew Safety

There is little doubt that erratic or unexpected fire behaviour is associated with heavy fuel concentrations. Crown fire development is almost inevitable when there is a continuous combustible fuel layer existing from ground to tree top level.

Such development produces a high-intensity fire which in turn is liable to throw spot fires for long distances in advance of the actual flame front. It is this factor which makes suppression operations extremely hazardous in such a fuel type.

Most experienced firefighters recognise the danger and naturally exhibit a marked reluctance to move in on a head attack in such fuels. Even flank attacks present a certain element of danger and it is essential to work systematically from the rear, making sure that the crews can move back on to a well-controlled edge if a sudden wind change occurs.

9. CONCLUSION

The main differences between fire behaviour in pruned and unpruned pine plantations have been outlined. From a purely fire control viewpoint there are strong reasons for pruning pine plantations at an early age. Evidence from many plantation fires have shown that complete pruning of the stand is highly desirable to provide a break between ground and aerial fuels. If even a small percentage of trees are left unpruned, these are generally sufficient to carry fire up into the crowns and produce an area of crownfire development and a possible source of spot fires which may endanger the whole suppression effort.

On the other hand, there may be very good economic reasons for the forest owner avoiding the cost of pruning, especially on short rotation crops.

If unpruned plantations are accepted as management policy, then the cost of pruning must be weighed against the increased area which will be burnt if a fire starts in or enters the plantation area. The increased loss may be adequately covered by fire insurance.

The danger of heavy fire losses may be reduced by the complete pruning of a strip several chains wide around the external boundary and along major access roads. Certainly the clearing of heavy debris from along access roads would materially reduce the hazards of firefighting and give the firefighters a greater sense of security.

There is every possibility that control burning can be practised in *P. radiata* stands older than 10 years and this would provide an even better fire barrier than a pruned strip.

Control burning on an area basis in hardwood areas adjoining pine plantations should provide adequate protection against wildfires entering the pines on a broad face as in the case of the Longford fire. Fuel accumulations in these hardwood areas should not be allowed to build up to more than 2 tons per acre and this would necessitate burning at least every three years. In heavy bracken areas burning should be possible every two years.

The occurrence of severe fire weather during spring months is fairly common in south-eastern Australia, especially along the coastal areas of New South Wales. The extension of this weather into Gippsland is probably fairly rare but should occur at least twice every 10 years. Although a fire may occur out of season, it can assume major proportions providing the meteorological and fuel conditions are conducive to extreme fire behaviour. Early fire seasons generally create organizational difficulties especially in respect of training of fire crews and of bringing equipment up to a state of readiness.

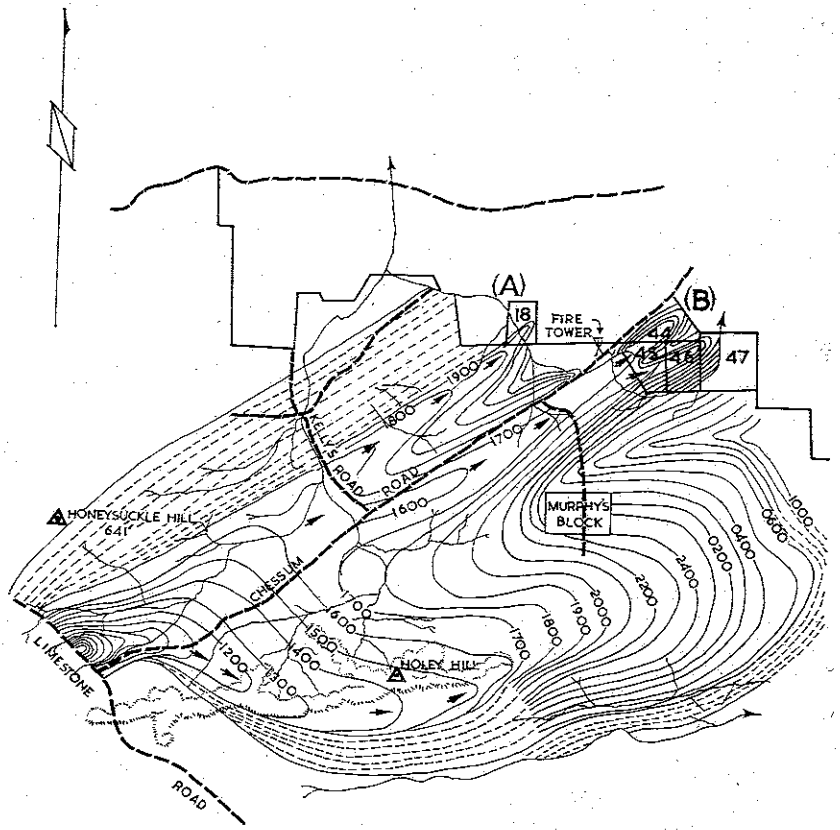

FIGURE 1.—Progress of the Longford fire during 17th-18th November, 1962, at indicated time intervals. The two heads which entered the *P. radiata* plantations at (A) and (B) are shown in greater detail in Figure 2.

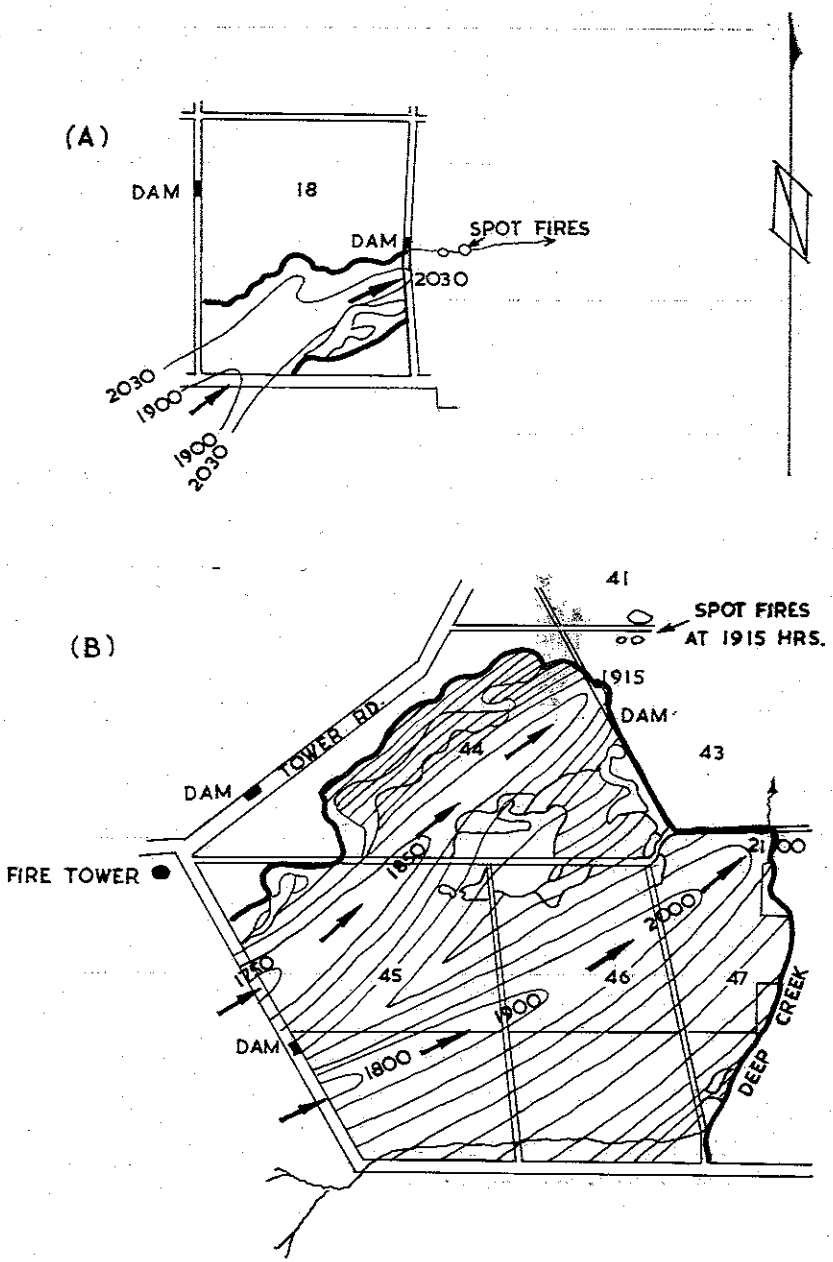

FIGURE 2.—Progress of the fire heads which entered the plantation area on the evening of 17th November, 1962, at indicated time intervals.

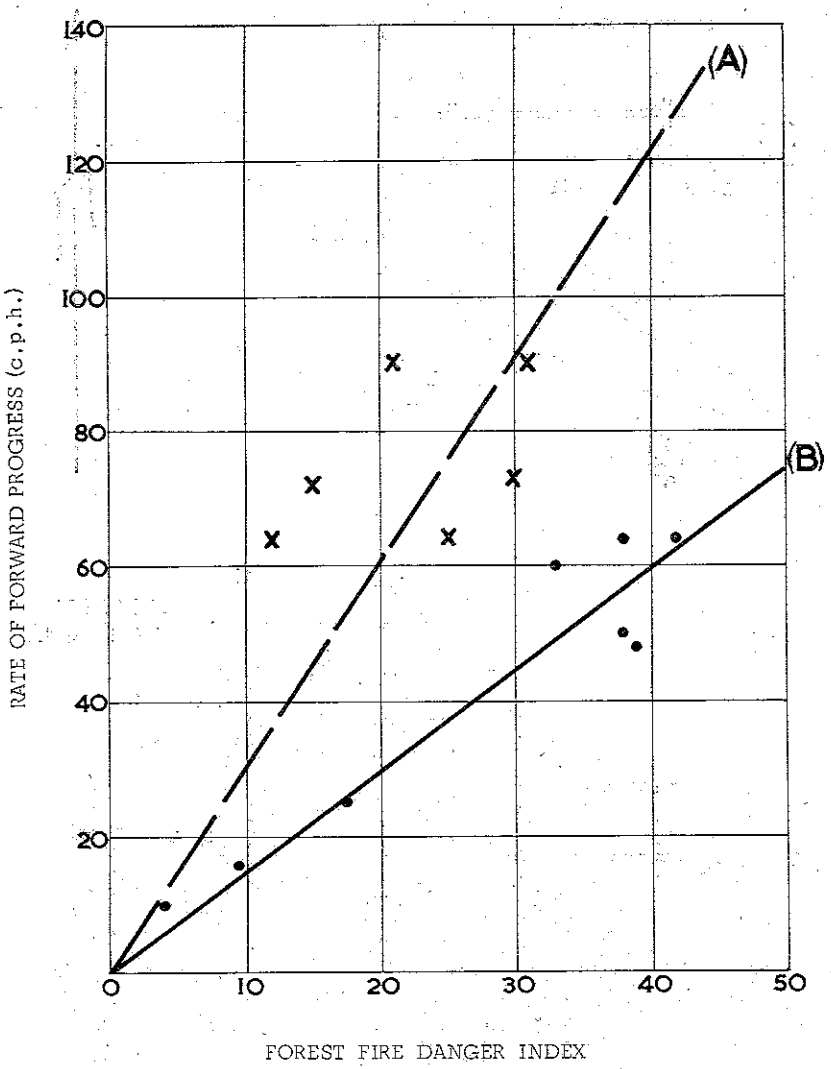

FIGURE 3.—Rate of spread in the hardwood area related to the forest fire index—

(A) following the cold front passage at 1640 hours, and

(B) prior to the frontal passage.

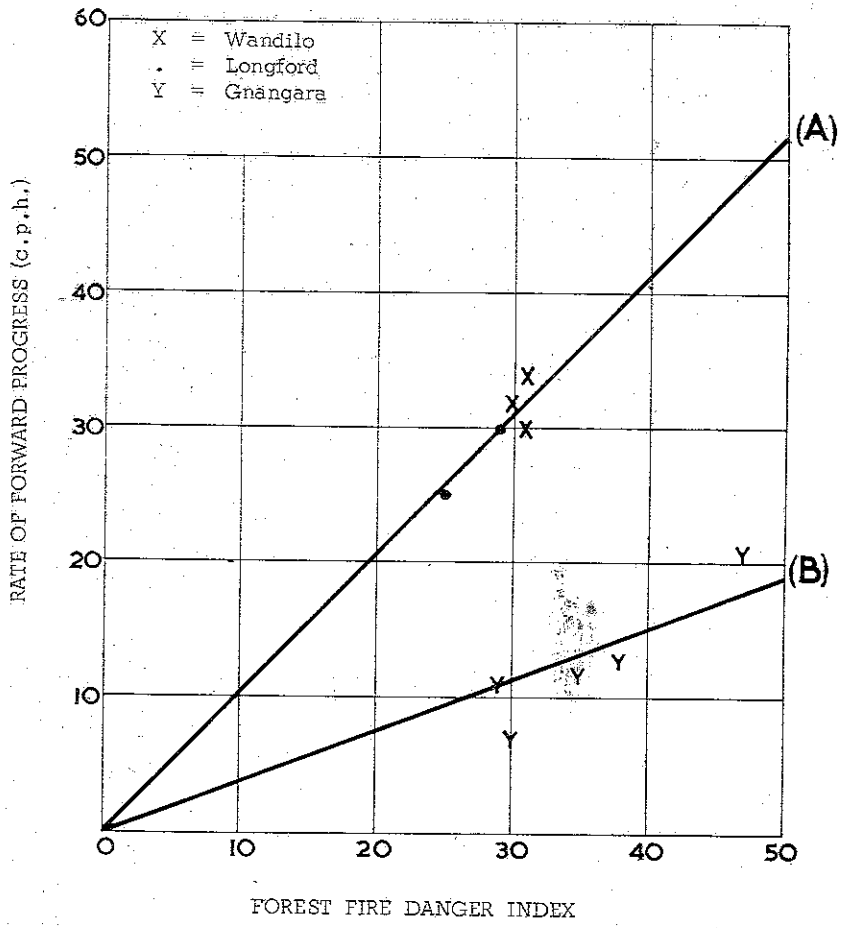

FIGURE 4.—Rate of spread in exotic pine plantations related to the forest fire danger index—

(A) in unpruned *P. radiata* plantations at Longford and Wandilo, S.A.,

(B) in pruned *P. pinaster* plantations at Gnangara, W.A.