T.O. Penman & Associates, followed by J. A. Hart's critique of it. 11 pages incl. this ID page.
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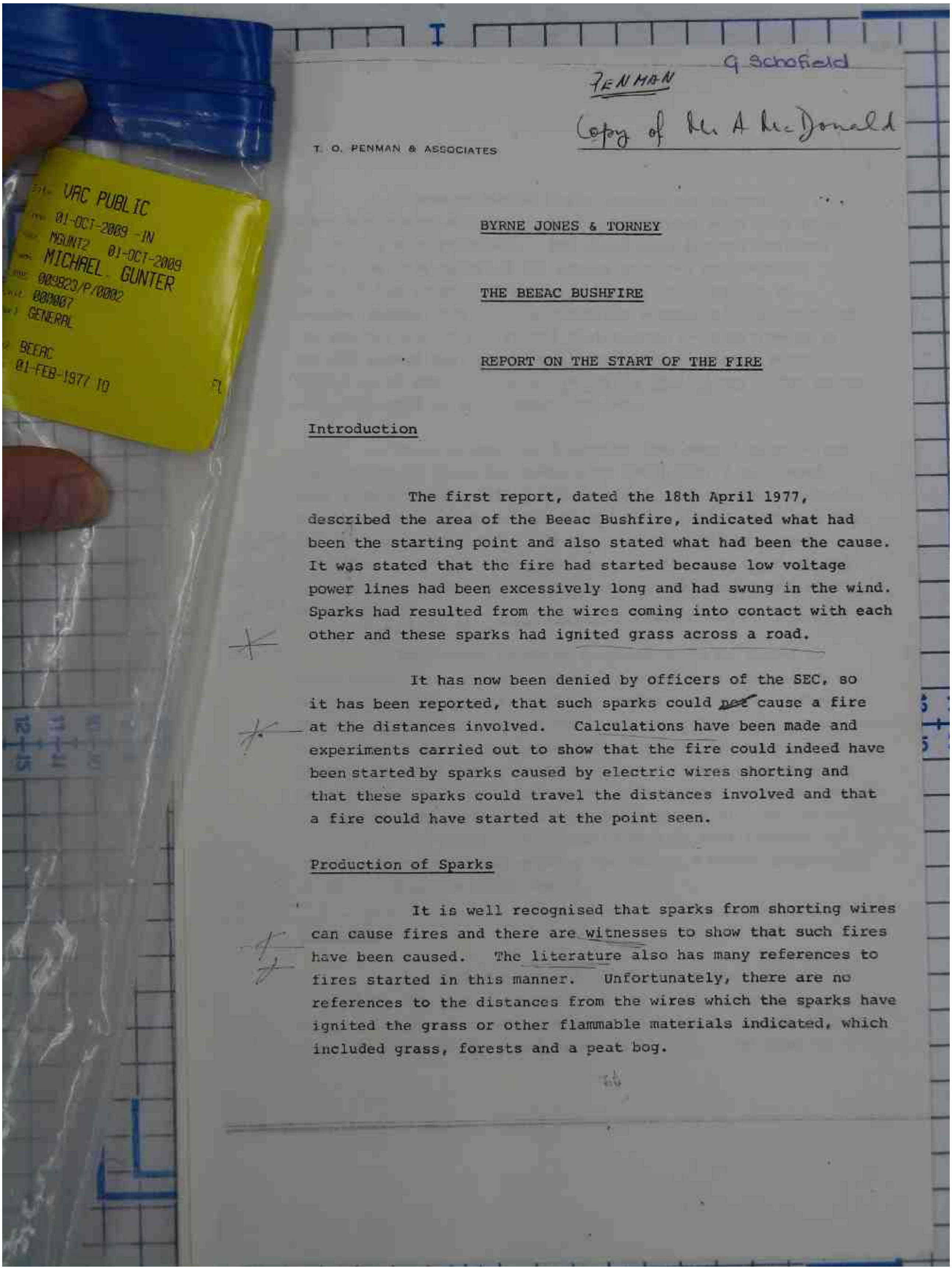

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MICHAEL GUNTER
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GENERAL
BEEAC
01-FEB-1977 TO

G Schofield

PENMAN

Copy of Mr A McDonald

T. O. PENMAN & ASSOCIATES

BYRNE JONES & TORNEY

THE BEEAC BUSHFIRE

REPORT ON THE START OF THE FIRE

Introduction

The first report, dated the 18th April 1977, described the area of the Beeac Bushfire, indicated what had been the starting point and also stated what had been the cause. It was stated that the fire had started because low voltage power lines had been excessively long and had swung in the wind. Sparks had resulted from the wires coming into contact with each other and these sparks had ignited grass across a road.

It has now been denied by officers of the SEC, so it has been reported, that such sparks could ~~not~~ cause a fire at the distances involved. Calculations have been made and experiments carried out to show that the fire could indeed have been started by sparks caused by electric wires shorting and that these sparks could travel the distances involved and that a fire could have started at the point seen.

Production of Sparks

It is well recognised that sparks from shorting wires can cause fires and there are witnesses to show that such fires have been caused. The literature also has many references to fires started in this manner. Unfortunately, there are no references to the distances from the wires which the sparks have ignited the grass or other flammable materials indicated, which included grass, forests and a peat bog.

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I have witnessed tests carried out by the SEC where wires were allowed to come into contact with each other and sparks were produced. The wires made several contacts before the fuse operated and arcing occurred over several parts of the lengths of wires. It was not possible to recover sparks from these experiments because of the nature of the ground, but it was stated that controlled experiments by the SEC showed that sparks collected from aluminium wires ranged up to 2mm in diameter averaging about 1 mm. The sparks were collected as solid round droplets.

by 0(2%)
1mm

In an attempt to determine the 'spark' size before the results of these SEC tests were available, I witnessed some aluminium arc welding and obtained weld spatter produced. Particles obtained from this ranged up to 1/8" (3.1mm) but the average was about 0.11" (2.79 mm), taking only the larger particles collected. Many smaller droplets were obtained but they were too small for the purposes of the experiments which were required.

distribution
[illegible]
of sample
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— what shape were these particles & were they oxidized? (rough)

The manner in which droplets would be formed by wires coming into contact and arcing would be identical to the manner in which droplets would be formed during arc welding. The only difference is that the droplets produced during arc welding are produced at the beginning and end of the run when a heavier current is being deliberately produced. There appears to be no reason to differentiate between molten metal produced because of a short-term current and that deliberately started for welding. The only factor which might be different is that because of the higher current with the welding operation, a higher proportion of larger droplets would result.

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Geography

The distance between the fences either side of the road where the fire was first seen was 65 ft. The line of the power poles was 4 ft inside the northern fence, so the distance from the wires to the south fence is 61 ft. The road is 16 ft wide and the edges are 22' and 38' from the line of the wires. There is a grass verge 23' wide between the road and the south fence.

The fire was reported to have been first seen when it was 2 to 5 yards to the south of the south fence and was about 10 ft across. Assuming that the fire was about 10 ft inside the fence, the width would indicate that it had started some distance to the north of this, which is to the windward. Most of the fires that day had an angle of spread of 30°, and this strongly suggests that the fire started at a point 18½' from the place where it was seen. This puts the start at 8½' to the north of the south fence, but clearly there is a margin either side of this depending on the actual distance from the fence that the witness first saw it and the exact nature of the grass and other combustible materials which were burning.

As a first indication, it would appear that the experiments should show if sparks could cause a fire 8½' to the north of the south fence which is about 53 ft from the power lines.

Experiments

When particles are carried by the wind, as these would be, the particle is initially at rest. The wind produces an acceleration which is proportional to the square of the velocity of the wind relative to the particle. The acceleration would not be the same for all particles as there is a drag coefficient which depends on densities, dimensions and shapes. Generally, the drag coefficient is well known but it must be realised that at the same time as the particle is being accelerat by the wind in a horizontal direction, it is falling and being accelerated by the force of gravity.

incorrect

When a particle falls, it is initially at rest with respect to the velocity of the air around it. The drag coeffici

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must again be taken into account as this increases in magnitude as the particle accelerates. In the extreme, the forces exerted by the resistance of the air equal the force of gravity and the particle reaches a terminal velocity. As the same drag coefficient would apply to the particle falling as to a particle being blown horizontally, it would appear straightforward to calculate the effect of the drag coefficient.

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this uniquely determines the drag coeff at any given point in time

Unfortunately, the effect of the two relative velocities is not unrelated, and the nature of the inter-relation is not known. Hence experiments were necessary to determine the drag coefficient for these particles. It should be noted that once the drag coefficient is found, then it would apply to a large range of sized particles of a wide range of densities falling in gravity and being affected by winds of varying magnitudes.

Use was made of the wind tunnel at Monash University. This had a major advantage as being the wind tunnel available with the largest velocity produced in Victoria. The limitation of size for testing was of no significance as the drop area was large enough to allow a fall of 8' 9", and the length where horizontal travel would take place was about 14 ft.

2.8 mm

Particles of about 0,11" diameter were used and three wind velocities were selected, 25.6 ft/sec, 32.8 ft/sec and 42.6 ft/sec. This is equivalent to 17.5 mph, 22.4 mph and 29.1 mph or 28.1 km/hr, 36.0 km/hr and 46.8 km/hr. The particles were dropped from the roof and the point of impact of at least three was noted for each of the three wind velocities. The points of impact were surprisingly close, and only 6" separated all those dropped in the fastest wind and which fell about 96" away.

y should
be
prising

It was also of interest to note that a trap was placed at the end of the test section about 14 ft from the dropping point. This was a section of gauze and wood about 6" high so that particles could be collected. Not one particle was collected by this trap during the experiments. The particles a bounce is perfectly for woods.. – [illegible] [illegible] beams ns elation is earth both grass cover.

all bounced too high for any observer to note where they finally finished and were clearly still being accelerated by the wind after they made the initial impact on the floor.

From the data collected from these three trials, an exact calculation was made of the combined drag coefficient. This enabled exact calculations to be made of the distance which the particles would travel to the point of first bounce.

In exp the coeff have vari cont with of rel

relevant

Other tests were carried out to establish to what height the particles would bounce after hitting the ground. As the particles were not exactly round, these results varied widely, but a significant number regained half the height of drop or more to enable a conservative figure for 50% to be used in calculations of bounce.

Calculations

In figure was 6m (20ft)

At the point opposite the starting area of the fire and where the arcing marks were seen on the wires, the wires were 23 ft above the ground. The time that a spark of 2 mm diameter would take to fall would be about 1.4 seconds. During this time it would travel a distance horizontally which would depend on the velocity of the wind.

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don figure 1.4

The wind velocity has been variously reported. Observations made at various places around the Western Districts as indicated by the Bureau of Meteorolgy stated that winds of 60 km/hr with higher gusts were noted. However, it has also been stated that at about 1.30 pm on the day of the fire, the wind was 45 km/hr with possible variations of ±10 km/hr. Wind gusts of up to 40 knots (74 km/hr) may have occurred possibly later in the afternoon.

For the purposes of calculation a wind of 45 km/hr has been assumed. At this velocity, the particle would hit the road at a distance of 24 ft from the power lines. It would then bounce and travel another 51 ft assuming that the wind had no further affect on the particle velocity after it

This is totally unrealistic

hit the ground. This would place the particle at the end of its second bounce at a distance of 75 ft from the power lines which is 14 ft to the south of the south fence.

The time that the particle would take to reach this distance is just under 3 seconds. A particle of this size cools from just below the melting point of aluminium (1220°F) at a rate which leaves it still hot enough to ignite paper after 6 seconds. This was a figure which was derived by observation of a heated particle. This figure is comparable with the calculated value of a particle which cools from 1200 to 600°F in still air in 8 seconds and which would cool to 600°F while moving through the air in 4 seconds. Hence it is clear that the time which is available for the particle to remain in motion and yet still ignite paper is in excess of the calculated time for the particle to reach the point where the fire started. It should be pointed out that the theoretical temperature at which paper ignites is 451°F and it is indicated that grass and other vegetable matter of a similar nature would ignite at similar temperatures.

under what conditions?

What is dim

whose calculation?

flash point of paper?

totally unjustified analogy.

This temperature if correct is for uniform heat — but not for 'point' heat source such as metal partic

Hence the calculations show that not only can a particle be blown by the wind to the area of the fence but the time that is taken by the wind to take it to this area is short enough for the heat energy still remaining in the particle to be high enough for the particle to ignite vegetable matter there. Thus it has been clearly demonstrated that the sparks created by the wires touching can be blown to the fence and start a fire there. Thus the start of the fire can be easily caused by sparks and the fire starting where it was seen was most probably caused by the sparks from the wires.

It can be easily seen that particles which are lighter than this can be blown further by the wind, and also that if the wind is of a higher velocity than that used in the above calculations, the particles would also be blown further. It has not been thought necessary to show the effect of these other factors as the ease by which the particles selected for calculations can reach the starting point of the fire has been shown.

Conclusions

Sparks formed by wires arcing produce sparks.

The metal droplets from these sparks can be about 1 to 2 mm diameter. – but only 2.8mm were further examined

These droplets can travel distance of 75 ft or more with only one bounce on the ground. – bounce depends on striking groun similar to wooden tunnel floo

The fire started at a distance of about 53 ft from the power lines.

The fire was first seen at a distance of about 71 ft from the power lines.

Sparks can carry this distance in about 3 seconds.

Sparks of 2 mm diameter are still hot enough to burn paper after 6 seconds. — what temperature is this?

It is probable that the fire started as a result of the sparks formed when the wires arced which were blown across the road.

Penman

T. O. Penman & Associates
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12th May 1977

481-10

JAH:VJ
Ext 471
17 May 1979

STATE ELECTRICITY COMMISSION OF VICTORIA

COPY for MR K H MARKS, QC

BS

NOTE FOR COUNSEL

REPORT BY DR T O PENMAN ON THE START OF THE BEEAC BUSHFIRE

Copy to: Mr K H Marks, QC
Mr A McDonald
Mr R J Weatherhead

SUMMARY

Although Dr Penman's conclusion, if moderately stated as, eg, "hot metal particles ejected from clashing aluminium conductors cannot be ruled out as the source of the Beeac bushfire", is not inconsistent with the SEC findings, the premises on which it is based are radically different. In three important respects his assumptions are unfavourable, and in my opinion unfairly so, to the SEC; they are:

a **that the particle temperature which can initiate ignition is as low as 600°F (315°C);**

b **that the particles can bounce large distances; and**

c **that arc welding typically produces particles comparable, especially in size, with those produced by conductor clashes.**

Detailed comment on each is given below. I also believe that the report shows clearly that Dr Penman does not have a thorough grasp of the mechanics governing the motion analysed and I have selected four specific examples of incorrect statements on which his credibility could be challenged. It is more difficult to challenge his temperature history calculation because so little information is given, but I strongly suspect that it is grossly over-simplified.

1 IGNITION THRESHOLD TEMPERATURE (p6)

Dr Penman's treatment of this is cavalier in the extreme. He does not quote the temperature of the 2 mm particle when it was observed to be still hot enough to ignite paper after six seconds, and one suspects that he did not know what that temperature was, although the information is clearly necessary if one is to judge whether particles cooled at some other rate remain hot enough to do the same. In any event the ignition threshold temperature of particles would have to be considerably hotter than the quoted theoretical temperature of 451°F (233°C) because resistance to transfer of heat from particle to paper would require a substantial temperature difference between the two to exist, and because the heat loss from the particle to paper during the finite time taken to heat the paper and initiate self-sustaining combustion would cause its temperature to fall.

The SEC experiments show that the ignition threshold temperature of a 2 mm particle in extremely dry grass is at least 1200°C, strongly suggesting that Dr Penman has no basis for assuming similarity between his paper and any grass. A CSIRO expert, Dr R Vines, advised the SEC on these tests and has stated that he can see no significant dichotomy between his findings (on the ignition of cotton wool by carbon particles from tractor exhausts) and ours.

2 PARTICLE BOUNCE (p5)

The extent to which a dropped particle rebounds after hitting the ground depends importantly on the nature of the ground, and would in any case only be substantial from surfaces more elastic than macadamised road or natural earth. Also, the subsequent trajectory depends on the angle of impact, some of the horizontal component of motion also being dissipated, but to a different extent than that of the vertical component of motion to which it must be presumed Dr Penman's 'other tests' apply. We view Dr Penman's assertion that a 2 mm particle would travel 51 ft between a first and second bounce as totally unrealistic, especially as he has ignored the effect of wind during this period, despite his wind tunnel observations (the bouncing behaviour off the wooden tunnel floor is in other respects quite misleading in the field context).

3 PARTICLE SIZE (p2) Re SEC Bld me

Dr Penman incorrectly states that the average diameter of particles collected from the clashing of aluminium conductors was 1 mm, and that they were solid, round, droplets. In fact 50% were less than 0.3 mm diameter and less than 5% were greater than 1 mm; there were virtually no particles as large as the 2.8 mm particles collected by Dr Penman from arc welding. More than 10 000 particles were measured in the SEC samples.

4 PARTICLE FLIGHT CALCULATION

Several statements made by Dr Penman indicate poor understanding of the mechanics involved:

a "drag coefficient ... depends on (particle) densities" (p3) - it is in fact independent of particle density;

b "drag coefficient (of a falling particle initially at rest with respect to the velocity of air around it) ... increases in magnitude as the particle accelerates" (p3/4) - in fact it decreases as the particle acquires an increasing speed relative to the air;

c "the effect of the two relative velocities is not unrelated, and the nature of the interrelation is not known" (p4) - actually there is only ever one velocity of relative motion at a particular point in a particle flight and it uniquely determines the prevailing drag coefficient in an entirely predictable way from standard information;

d "an exact calculation was made of the combined drag coefficient" (p5) - the motion of the test particles relative to the tunnel air stream would certainly have been such that the drag coefficient

> varied from point to point as the relative velocity varied so the calculation could have been in no sense exact, and any calculated single value would be at best an average.

Dr Penman appears not to have taken account of the direct effect of particle temperature on its motion (because the surrounding fluid is heated), nor of its indirect effect through oxidation changing the size, shape, density and surface roughness, but our experience is that overall these effects are small and our calculation corresponding to his time of about 1.4 s for the free fall of a 2 mm particle from rest 23 ft above ground is 1.45 s.

5 RATE OF COOLING CALCULATION

Nowhere near enough information is given to appraise the adequacy of Dr Penman's temperature history calculation but it appears likely to have been grossly over-simplified. The main deficiency is undoubtedly the neglect of particle oxidation, but this is of course 'conservative' in the sense of underestimating the resulting particle temperature because heat is released during oxidation. However, we would need to know that radiative heat transfer, which Dr Penman does not mention, had been correctly taken into account, using an emissivity appropriate to the particular particles, before we could be sure that the neglect of heat generation was not offset by neglect of an important heat loss.

J A Hart
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