Bush-Fire Smoke and Air Quality

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For many thousands of years, fires have burned over much of earths' surface. But, whether the smoke from these fires should be regarded as "pollution," or not, depends to a large degree upon definition: for naturally occurring emissions are hardly to be compared with the noxious gases arising from industrial complexes.

The results of Australian work on this subject have been reported in two previous papers.[2] While much work remains to be done, it already appears that the air-borne smoke from bush-fires is unlikely to be a health hazard; and even large fires will not give rise to dangerous concentrations of gaseous products in the air above them. It is true, of course, that smoke reduces visibility through the atmosphere, and, indeed, the large-scale practice of prescribed burning in Australian forests has sometimes been criticized because of the huge volumes of smoke arising from these operations. However, wildfires also produce smoke, and unless prescribed burning is prac-

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[2] See 1). "On the Nature, Properties and Behaviour of Brush-fire Smoke." Vines, R. G., L. Gibson, A. B. Hatch, N. K. King, D. A. MacArthur, D. R. Packham, and R. J. Taylor. CSIRO. Aust. Div. App. Chem. Tech. Pap. No. 1 (1971) and 2), "Studies on Bushfire Smoke." N. K. King, D. A. MacArthur, D. R. Packham, R. J. Taylor and R. G. Vines. Proceedings of Conference on "Fire in the Environment". Denver, Colorado (1972).

ticed in spring and autumn the incidence of devastating summer wildfires can be very high. In other words, smoke emission is to be expected from either wildfires or prescribed burns— though, with proper planning, the smoke nuisance from the latter can be minimized, and the public inconvenienced as little as possible.[3]

Some of the features of the Australian smoke-work are summarized briefly below:—

EXPERIMENTAL RESULTS

Smoke samples were collected in a small aircraft, which was flown through the smoke columns from a series of large prescribed burns in the forest areas of Western Australia in the spring of 1970. The smoke particles were deposited on air-filters or in an electrostatic precipitator, and both methods of collection gave similar results. Most particles were less than 1 μ m in diameter (the majority being $\sim$ 0.1 μ m), but there were many tarry particles which were larger than this. In thick smoke, the particulate concentration appeared to be between 10^5 and 10^6 per cm^3.

The composition of the smoke varied from fire to fire but was, on average, as follows:—tar $\sim$ 55 percent, soot 25 percent and ash 20 percent. The total weight of solid particulate matter entering the atmosphere, during one of these typical large-scale fires, was between 1 and 2 percent of the mass of fuel on the forest floor. Since very large areas of 20,000 to 30,000 acres are now burned to prescription during a single day as a matter of routine, and since the fuel quantities may sometimes be as much as 10 tons/acre, the total quantities of smoke produced in these operations can be some thousands of tons.

[3] One important difference should be mentioned between uncontrolled wildfires and those Australian prescribed burns designed to reduce fuel quantities in high-quality forests. The large uncontrolled fire usually burns in an unstable atmosphere, so that the smoke produced rises to great heights: and this is in marked contrast to fuel-reduction fires which are carried out in the presence of an atmospheric-inversion, in order to keep convective activity at a low level. The implication is that smoke from these prescribed fires is usually trapped beneath the inversion, and will not be so readily dissipated.

SMOKE DIFFUSION

The smoke columns were blown many miles downwind, and the movement of smoke was followed in the aircraft. A continuously recording nephelometer was used to detect the edges of the column (cf., Fig. 1), so that the spread of the smoke could be traced with considerable accuracy. For all the fires studied in detail, with measured winds between 15 and 30 knots as averaged over the depth of the column, the smoke spread out in a narrow fan of included angle $\sim 12\frac{1}{2}°$— (cf., Fig. 2). A photograph of an extended smoke column, as taken from a Gemini space-craft, shows exactly the same feature: and, in this case, the narrow smoke-trail (from a wildfire near the Queensland coast) extended downwind over a distance of nearly 100 miles.

This interesting result is clearly of importance in the planning of

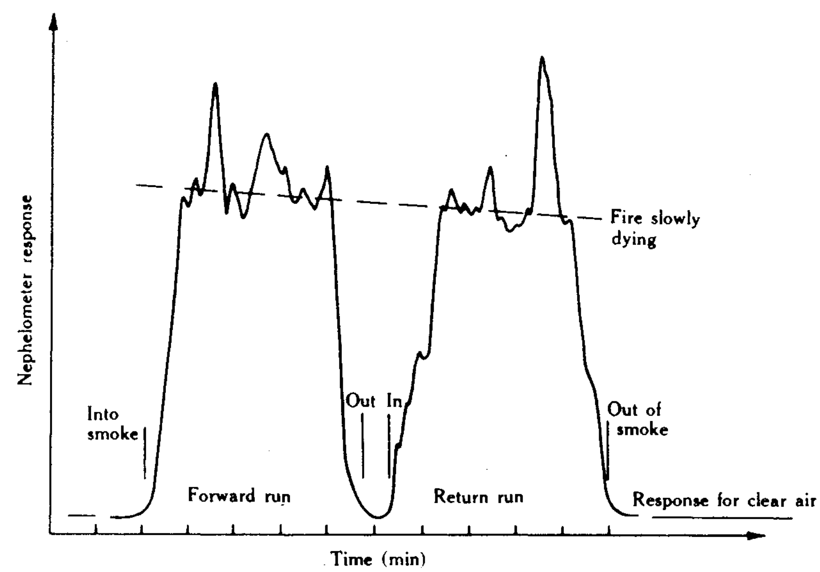

FIG. 1. Typical nephelometer trace obtained during flight through a smoke column: numerous smoke "eddies" are clearly evident, both within the column and at the edges of the smoke.

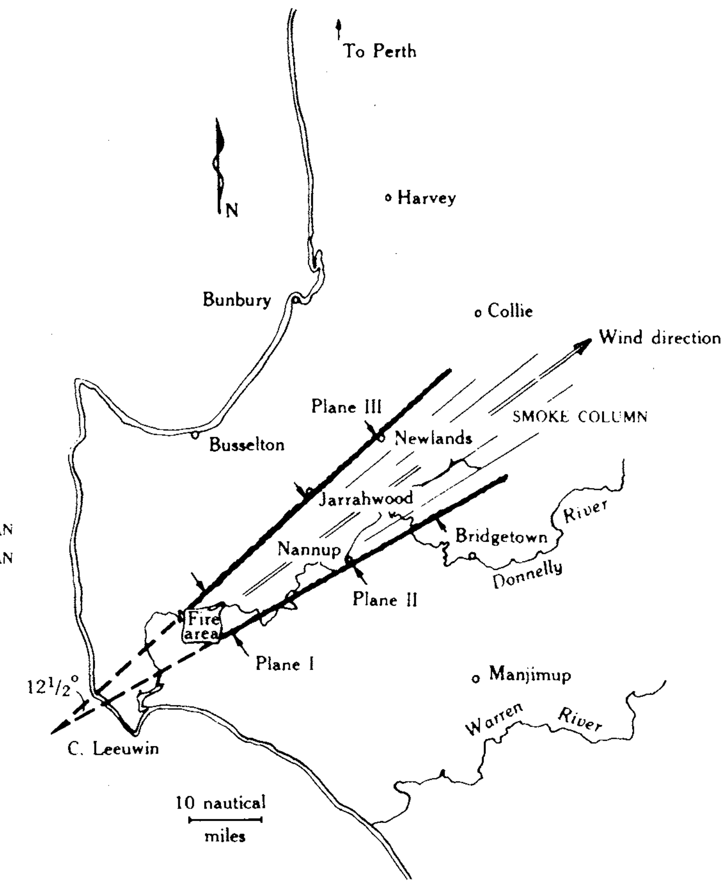

FIG. 2. Spread of smoke from a large prescribed fire in Southwestern Australia. The lateral extension of the column was determined by aircraft traverses through the smoke at Planes I, II, and III as shown: the corresponding angle of spread, as measured in this way, was $\sim 12\frac{1}{2}°$.

burning-operations: for, if accurate meteorological forecasts are available, smoke can be kept away from populated areas. Additionally, pilots of light aircraft can be warned of the likely locations of hazardous smoke-concentrations, which could make visual navigation difficult.

Visibility in the smoke was such that the "visual-range", as determined from the nephelometer records, varied from about 200 yards in the thickest smoke, to 5 miles, or more, in diffuse haze. These values may be compared with that for clear air, in which the normal visual-range is approx. 100 miles.

GASEOUS COMBUSTION-PRODUCTS

Dräger tubes were used to measure gas concentrations in the smoke, and typical values for various components were:—CO, 0.5–2 ppm; CO_2, about 150 ppm above clean-air level; O_3, 0.02–0.03 ppm (identical with the value for clean air); NH_3, not detected; SO_2, not detected; oxides of nitrogen, < 0.5 ppm. Dangerous concentrations of these gaseous pollutants were never recorded: and since the ozone concentration was always identical with that for clean air,[4] it appears unlikely that large-scale burning in forest areas will ever lead to the production of photochemical smog.

It seems, therefore, that reduced visibility, resulting from smoke build-up, is the most undesirable feature of a large fire. When an extensive column has been established, a thick haze can be distributed over wide areas; but, under normal weather conditions, smoke does not persist for long, as it is spread and diluted by the wind. Since the particles are much to small to settle, it is probable that rain is the main agent for removing smoke from the atmosphere.

Postscript

I should like to conclude with a piece of speculation. We all like the smell of bushfire smoke—and the human race is, we are told, roughly a million years old. If smoke were harmful, it is conceivable that man,—from the evolutionary point of view,—would have developed some antipathy towards smoke. Surely the fact that we find smoke pleasant may mean that "fire" is not necessarily detrimental to man? It is equally conceivable, as Dr. Komarek has already pointed out, that the highly adsorptive carbonaceous components of smoke may serve to keep the earth's atmosphere relatively free of undesirable compounds.

[4] cf., however, "Ozone Measurements in smoke from Forest Fires" by L. F. Evans, N. K. King, D. R. Packham and E. T. Stephens. Envir. Sci. and Tech *8*, 75 (1974).