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ON RECENT PRESS REPORTS OF HEAT-RELEASE RATES DURING BUSH FIRES IN THE AUSTRALIAN CONTINENT

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1. INTRODUCTION

Bush fires have accounted for the loss of many lives and the destruction of many homes and other properties during the 215 years of European occupancy of Australia. Precise information from further back than that is unavailable though unquestionably what we now call bush fires were known to the pre-1788 inhabitants. Inevitably, and indeed appropriately, the press keep the public informed of bush fires which have occurred and of the periods during which the hazards are high so that vigilance and caution on the part of members of the community are required. This note has to do with a recent statement in the Australian press which attempts to impart quantitative information on bush fire hazards which might be accepted by readers not having a grasp of basic thermal sciences but which is clearly incorrect.

2. DETAILED CALCULATIONS

A statement is made that in recent bush fires in the Australian State of New South Wales heat-release rates have been in the neighbourhood of 100,000 kWm^{-2} ($\equiv 10^8$ Wm^{-2}). There are several ways of examining this figure all of which would show that it cannot be correct. The simplest is to treat the burning forest material as a black body and use the Stefan-Boltzmann (S-B) Law. This is in effect application of the 'solid flame model' widely used, for example, in risk assessment at hydrocarbon plants. Using the figure of 10^8 Wm^{-2} and imagining that the fire is radiating to surroundings at 300 K:

$$10^8 \text{ Wm}^{-2} = \sigma (T^4 - 300^4)$$

where σ is the S-B constant (5.7×10^{-8} $Wm^{-2}K^{-4}$) and T the combustion temperature. This gives:

$$T = 6472 \text{ K}$$

which colossally exceeds even the <u>adiabatic</u> flame temperature, which is of the order of 2000 K.

In the above calculation the implicit assumption has been made that the figure of 10^8 is the radiative flux whereas there might also of course be significant contributions to the heat balance from convection and loss of sensible heat in the product gases. Examination of this point is not difficult. For a gaseous flame, e.g. a propane fireball, the proportion of heat transferred by radiation is about 25% [1]. For a solid fuel the proportion of heat transferred by radiation is much higher so if we apply a figure of 25% to the bush fire this can be seen as a lower bound on the radiative flux. The above calculation then becomes:

$$0.25 \times 10^8 \text{ Wm}^{-2} = \sigma (T^4 - 300^4)$$

$$\Downarrow$$

$$T = 4576 \text{ K}$$

which, though certain to be an underestimate, is still impossibly high. Sufficient has been said to prove that the claimed 10^8 Wm^{-2} for the heat release by a bush fire cannot possibly be correct.

In fact, the propagating front in a bush fire is usually at red heat, and this provides a basis for estimating the true radiative flux. Red heat represents emission of radiation of just under 1 μm wavelength at an intensity such that the eye can detect it. Plots of the amount of energy at a particular wavelength for blackbodies at various temperatures are available in many heat transfer texts (e.g., ref. [2]). A black body at 300 K will emit negligibly in the wavelength range of visible light, whereas one the temperature of the surface of the sun will have its maximum emission at such a wavelength. If one examines a diagram such as that referred to and given in [2] it is clear that temperatures of about 1000 K are the lowest at which there is significant encompassment of the visible range, with red emissions exceeding violet by orders of magnitude. Such a body would look red. This suggests that a temperature of this order applies to the propagating front and happily this can be corroborated by direct experimental evidence. In oven heating tests [3] on forest litter at natural packing densities peak temperatures are about 500°C (773 K) during the propagation which follows ignition. In a bush fire there is convection due to air currents as there is in the oven heating tests, which always used a fan-assisted oven, so convective losses will be comparable for the two.

It therefore appears that if we use the range 773 to 1000 K for the temperature of the propagating front a reliable range for the heat flux can be obtained.

For a propagating temperature of 1000 K:

$$\text{Flux} = 5.7 \times 10^{-8} (1000^4 - 300^4) = 57 \text{ kWm}^{-2}$$

For a propagating temperature of 773 K:

$$\text{Flux} = 5.7 \times 10^{-8} (773^4 - 300^4) = 20 \text{ kWm}^{-2}$$

It can therefore be stated with reasonable confidence that heat flux from a propagating bush fire is in the approximate range 20 to 60 kWm^{-2} and most certainly not 100,000 kWm^{-2} as recently asserted. The comments made previously about the dominance of radiation in solid combustion also of course apply here.

3. FURTHER COMMENTS AND CONCLUSIONS

The basis of the impossibly high heat-release rate quoted in the press is the equation:

Fire intensity = Hwr

where w is the amount of forest litter in tonnes per hectare, r the rate of spread (units metre $minute^{-1}$) and H is the energy content in kJ kg^{-1}. In fact, if this equation is written correctly in consistent SI units the right hand side has to be divided by 600. The claimed figure of 100,000 kWm^{-2} then recalculates to 167 kWm^{-1}, a much more reasonable figure though the two are not of course strictly comparable as the respective quantities must have different meanings; the units are not the same. A reference to Byram, 1959 [4] is given in [5] as the source for this equation. The present authors have not been able to ascertain whether Byram actually introduced the equation or whether he was himself citing it from another source. In any case, that it has given a wildly erroneous result in the hands of whoever applied it to obtain the figures quoted in the Australian press and reproduced herein is certain.

The view of the authors is that a peer-reviewed note such as this one is useful in that it can be cited when heat-release rates for forest and bush fires in the popular media are questioned. This eliminates the need to enter into detailed discussion or repeat the analysis.

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