

BLOWUP FIRES—THE BYRAM WIND PROFILE

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ABSTRACT

A qualitative explanation of the relationship between fire blowup - burning with an intensity that seems far out of proportion to apparent burning conditions - and certain wind profiles is presented.

Byram (1954) defined blowup fires as those that burn with 'an intensity that seems far out of proportion to apparent burning conditions'. He concluded from a study of a number of such fires that in addition to plentiful and dry fuel blowup occurred with some atmospheric instability and the following wind conditions:

- (i) a free air wind of 18 miles per hour (~8 m/s) or more at the elevation of the fire or just above;
- (ii) wind decreasing with height for several thousand feet above the fire with the possible exception of the first few hundred feet.

The profile of wind increasing up to some low level and then decreasing is referred to as a low level jet.

Examples of the profiles he found to be the most hazardous are shown in Fig 1. They will henceforth be referred to as the Byram wind profiles.

It will be noted that his conclusions made no reference to direction changes with height. However, most of his case studies reveal only small wind direction changes; especially in the region of winds decreasing with height or below it.

Byram's conclusions have been quoted frequently in the fire meteorology literature, e.g., Turner, Lillywhite, and Pieslak (1961), Bureau of Meteorology, Australia (1963), and Brown and Davis (1973). Whittingham (1964) and Kiil and Grigel (1969) have studied cases in which fire blowup was associated with a low level jet.

Byram (1959) presented an 'energy criterion' that is supposed to identify circumstances in which fire circulations become three dimensional leading to blowup. Two quantities, $P_f = I/C_p T$ and $P_w = \rho (v-r)^3/2g$, which he described as the rate of conversion of thermal energy to kinetic energy in the convection column and the rate of energy flow in the wind, were compared. In the above definitions I is the fire intensity, C_p the specific heat at constant pressure, T the (absolute) temperature, ρ and v the density and wind speed (both functions

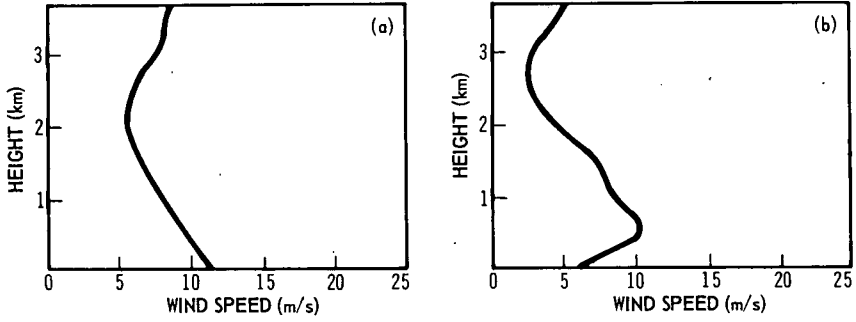


Fig 1 Typical profile of wind with height that Byram found associated with 'blowup' fires—wind decreasing with height (left) and a low level wind maximum (right)

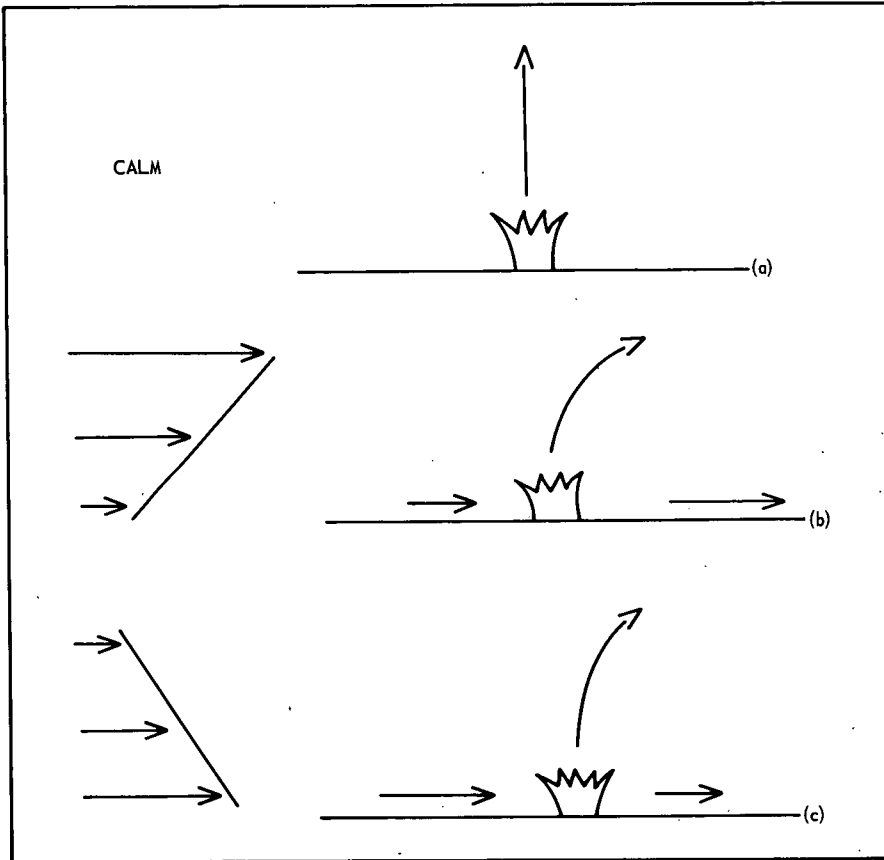


Fig 2 The effect of various patterns of wind flow on fire development

of height), r is the propagation speed of the fire, and g the acceleration due to gravity.* For blowup fires Byram asserts that P_f is greater than P_w in a deep layer. He does not present a derivation of the 'energy criterion'. No relationship between the criterion and other work on shear flows is apparent.

An alternative theory to at least qualitatively explain Byram's empirical results is presented below.

Consider first of all a fire in a still environment. The convective column rises vertically (Fig 2(a)). The convective circulation brings more air into the region of the fire, which expands outward.

If instead the ambient wind increases with height (with the direction nearly constant) the convective column is tilted downwind (Fig 2(b)). As a result of the convection there is enhanced mixing of air from various levels on the downwind side of the fire. Momentum exchanges due to the mixing will lead to stronger low level winds occurring on the downwind side of the fire than on the upwind side. There is thus a tendency to get horizontal divergence at the surface near the fire. This divergence counteracts the convergence created by the fire column. Thus there will be less intake of air into the fire region and hence less intense fire development.

If the ambient wind decreases with height the convective column is again tilted downwind (Fig 2(c)). The effect of the momentum exchange due to the fire is to cause lighter surface winds downwind from the fire than those upwind. The convergence in the vicinity of the fire is thus augmented and the fire can become more intense than in the case of a still environment.

The reason why profiles such as Fig 1(b) - the low level jet - are associated with blowup fires must still be explained. In this case the convective column is again tilted downwind so that momentum exchange due to the fire occupies a deeper layer downwind than upwind. If on the upwind side mixing takes place mainly of air from levels below the jet while downstream mixing extends to levels well above the jet the situation will be similar to that for ambient profiles of wind decreasing with height at all levels (Fig 2(c)). Hence, as discussed above, increased convergence will lead to blowup.

The low level jet may create an additional hazard. It is likely to spread embers downwind ahead of the main fire front - thus causing 'spotting' - the start of new fires ahead of the main fire front.

Can the Byram profile effect the formation of fire whirlwinds? For the formation of a fire whirlwind ambient low level vorticity and atmospheric instability are required. The instability leads to a constriction and stretching of the vortex tubes (Morton 1970). Presumably, in the presence of instability and ambient vorticity, a whirlwind can occur irrespective of the profile of wind with height. The Byram wind profile is not then a necessary condition for whirlwind formation. Indeed Graham (1955) found that such a profile was not usually present at the time of formation of whirlwinds in the Pacific northwest of the United States.

However, if a Byram wind profile is present then it is possible that the locally enhanced convergence due to the vertical exchange of momentum may assist in the vortical stretching process. Thus the onset of fire blowup may be associated with whirlwind formation in those regions where because of the topography or for other reasons there is sufficient ambient vorticity present in the low level flow. In the cases of the blowup fires discussed by Whittingham (1964) and Kiil and Grigel (1969) violent whirlwinds accompanied the blowup.

* In the presentation of this work in the *Manual of Meteorology: Fire Weather Supplement 2* (height) is inserted in the numerator of the equation for P_w .

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