7. Flame dimensions and temperatures

Flames are complex and random pulsating transient phenomena that are constantly changing (Chandler *et al.* 1983, Johnson 1982). It is difficult enough to measure such phenomena in the laboratory, but the difficulty is magnified during bushfires that are emitting large quantities of heat, are partly obscured by smoke and vegetation, and are potentially dangerous to the observer (Gill and Knight 1991). However, flames are the most striking characteristic of a bushfire and the aspect that people most readily relate to. Flame size and shape are useful for describing the character of the fire, and in predicting or describing fire behaviour and effects (Pyne *et al.* 1996). Flame height is related to rate of heat output or intensity (Byram 1959), and therefore can be further related to the likelihood of scorching, crowning and resistance to control. Lofting of firebrands is dependent on flame height, along with convection currents and velocity (Ellis 2000). The amount of radiant and convective heat transferred from the flame to its surroundings depends on the size, shape and temperature of the flames.

There are many examples in the literature of thermocouples being used to measure 'temperature' of fire in grass and forest (Walker and Stocks 1966, Packham 1970, Packham and Pompe 1971, Gill and Knight 1991, Moore *et al.* 1995, Gould *et al.* 1997, Mangan 1997). However the temperatures measured from these flames are not measurements of a single substance but are representative of a mixture of gases, liquids and solids, each with its own emissivity and temperatures. Therefore, the extrapolation of radiant heat involving flame temperature is not straightforward. Flame temperatures vary over a considerable range, and fluctuate rapidly. Since the radiation depends on the fourth power of the temperature (Packham and Pompe 1971, Vines 1981), any errors in flame temperature measurements result in large errors in calculated radiation output (Chandler *et al.* 1983).

Research staff from the Canadian Forest Service collaborated in the Project Vesta experiments over two seasons. During the 1998 experiments, vertical flame temperature profiles were measured in selected fire plots in 8 and 19 year-old fuel with sparse understorey shrubs at the Dee Vee site. In the 1999 experiments temperature profiles were measured at both the McCorkhill and Dee Vee sites to investigate the contribution of the understorey shrub layer to flame dimensions. Also, during these experiments up to 28 thermocouples attached to data loggers (thermologgers) were used to measure flame arrival time and temperature at ground level in a predetermined grid pattern throughout the 200 x 200 m fire plot. These data were used to determine head fire width, rates of spread, flame residence time and flame depth (see Chapter 6).

Since flames directly affect the amount of radiant and convected heat from bushfires, it is necessary to gain an improved understanding of the temperature structure within and above the flaming zone. Laboratory experimentation has shown that flames ranging from 0.5 to 2 m show a strong vertical variation in flame temperature, with maximum temperatures occurring at the base of the flame (Wotton and Martin 1998), and temperature decreased with increasing height to a minimum of approximately 200°C at the flame tip. However, these experiments were based on laboratory work