5.5.1 Temperature distribution

If the temperature of the coolant reaches the boiling point before the top of the reactor then virtually all the heat generated will go into latent heat to produce vapor and the temperature above that boiling point elevation will remain approximately constant as illustrated in figure 1 (an adaption of the figure in section 5.2). This is because the pressure change is small and so the thermodynamic state of the multiphase fluid remains at approximately the same saturated temperature and pressure while the mass quality of the *steam* flow, $\mathcal{X}$, increases with elevation (the mass quality, $\mathcal{X}$, is defined as the ratio of the mass flux of vapor to the total mass flux, see section 6.2.1). This relative constancy of the pressure and temperature will hold until all the liquid has evaporated. Of course, if the critical heat flux is reached (see sections 6.5.2 to 6.5.4 and 5.6 below) and film boiling (see sections 6.5.5 and 6.5.6) sets in the fuel rod temperature would rise rapidly and the potential for meltdown could exist. This critical accident scenario is discussed in chapter 7.

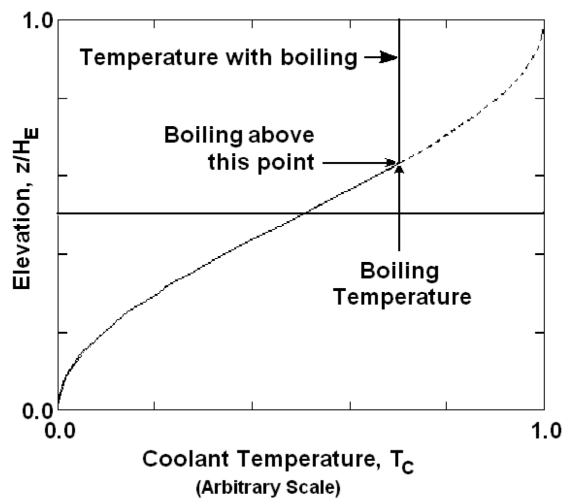

Figure 1: Typical modification of the axial coolant temperature distribution due to boiling where the curve below the boiling point is reproduced from figure **??**.

Above the elevation at which boiling starts and assuming that the critical heat flux is not reached, it is roughly true that all the heat flux from the fuel rods, $\mathcal{Q}$, is converted to latent heat. Therefore, it follows that the rate of increase of the mass quality, $d\mathcal{X}/dz$, in the coolant flow will be given by

$$\frac{d\mathcal{X}}{dz} = \frac{\mathcal{Q}}{\dot{m}\mathcal{L}} \tag{1}$$

where $\dot{m}$ is the mass flow rate per fuel rod (equal to $\rho_L \dot{V}$ below the boiling elevation) and $\mathcal{L}$ is the latent heat of the coolant. Since the temperature and pressure do not change greatly above the boiling point elevation, the latent heat, $\mathcal{L}$, is also relatively constant and therefore equation 1 can be written in the integrated form

$$\mathcal{X} = \frac{1}{\dot{m}\mathcal{L}} \int_{z_B}^{z} \mathcal{Q} dz \tag{2}$$

where z_B is the elevation at which boiling starts and where the mass quality is therefore zero. Note that the rate of increase of the mass quality decreases with the mass flow rate, $\dot{m}$, and increases with the heat flux, $\mathcal{Q}$.

The evaluation of the mass quality (and other multiphase flow properties) is important for a number of reasons, all of which introduce a new level of complexity to the analysis of the core neutronics and thermo-hydraulics. In the next section consideration is given to how the calculations of these quantities might proceed.