5.2 Core temperature distributions

As a representative numerical example of the temperature distribution in a reactor core consider a homogeneous cylindrical reactor without reflectors and without control rod insertion. The neutron flux has the form given by equation 5, section 3.7.1 (coordinates defined in section 3.7.1) and therefore $\mathcal{Q}$ will be given by

$$\mathcal{Q} = \mathcal{Q}_M \cos\left(\frac{\pi z}{H_E}\right) J_0\left(\frac{2.405r}{R_E}\right) \tag{1}$$

where the constant $\mathcal{Q}_M$ is the maximum value at the center of the reactor core. Note for future use that the average heat flux would then be about $0.4\mathcal{Q}_M$. Substituting equation 1 into equation 2, section 5.1.4, and integrating, the temperature of the coolant, T_C, within the reactor core becomes

$$T_C = T_{CI} + \frac{\mathcal{Q}_M H_E}{\pi \rho_L \dot{V} c_p} J_0\left(\frac{2.405r}{R_E}\right)\left[\sin\left(\frac{\pi z}{H_E}\right) + 1\right] \tag{2}$$

where T_{CI} is the coolant inlet temperature. The form of this temperature distribution along the centerline of the reactor core ($r = 0$) is shown labeled $\beta = 0$ in figure 1. Similar integrations can readily be performed for the neutron flux distributions at various control rod insertions (see section 3.7.4) and three such examples are also included in figure 1. Note that the temperature rise in

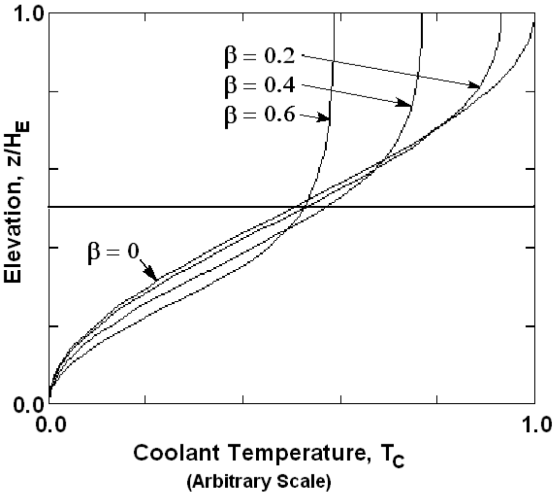

Figure 1: Axial coolant temperature distributions within a cylindrical reactor where the horizontal scale may differ for each line plotted. Solid lines: $\beta = 0$ is a homogeneous reactor and the lines for $\beta = 0.2$, 0.4 and 0.6 are for various control rod insertions corresponding to the neutron fluxes in figure 2 (for the case of $H_E/R_E = 2.0$ and $L_2/R_E = 0.36$).

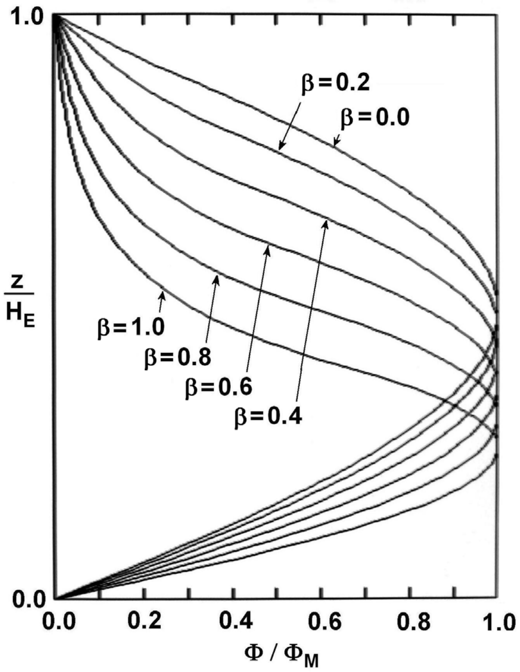

Figure 2: The change in the shape of the axial distribution of the neutron flux, ϕ (normalized by the maximum neutron flux, ϕ_M), with fractional control rod insertion, β, for the case of $H_E/R_E = 2.0$ and $L_2/R_E = 0.36$.

the upper part of the core is reduced due to the decrease in the heat production in that part of the reactor.

It is important to emphasize that, even in the absence of boiling (addressed in section 5.5), these calculations of the axial temperature distribution are only of very limited validity. In practical reactors variations in the fuel and moderator distributions are used to even out the heat distribution. Moreover, thermal and transport properties like the heat transfer coefficient may vary significantly within the reactor core. Nevertheless the above calculations combined with the knowledge of the radial distribution of temperature implicit in equation 2 and coupled with the temperature distribution within each fuel rod as described in section 5.1.3 allow construction of the temperatures throughout the core in a way that is qualitatively correct.