3.7.2 Effect of a reflector on a spherical reactor

In the examples of the last section it was assumed that all neutrons leaking out were lost. In practice, reactor cores are usually surrounded by a reflector that scatters some of the leaking neutrons back into the core. In this section two examples of diffusion theory solutions with reflectors will be detailed.

Perhaps the simplest example is the spherically symmetric reactor of the preceding section now surrounded by a reflector of inner radius R and outer radius R_R. Since there is no source of neutrons in the reflector the diffusion equation that governs the neutron flux in the reflector (denoted by ϕ_R) is then

$$\nabla^2 \phi_R - \frac{1}{L_R^2}\phi_R = 0 \tag{1}$$

where L_R is the diffusion length in the reflector. The boundary conditions that must be satisfied are as follows. At the interface between the core and the reflector both the neutron flux and the net radial neutron current (see section 3.2) must match so that

$$(\phi)_{r=R} = (\phi_R)_{r=R} \qquad \text{and} \qquad D\left(\frac{\partial \phi}{\partial r}\right)_{r=R} = D_R\left(\frac{\partial \phi_R}{\partial r}\right)_{r=R} \tag{2}$$

where D and D_R are the diffusion coefficients in the core and in the reflector. At the outer boundary of the reflector the vacuum condition requires that $\phi_R = 0$ at $r = R_R + 1/2D_R = R_{RE}$.

As in the preceding section the appropriate solution for the neutron flux in the core is

$$\phi = \frac{C}{r}\sin B_g r \tag{3}$$

where C is an undetermined constant. Moreover, the appropriate solution to equation 1 in the reflector is

$$\phi_R = \frac{C_R}{r}\sinh\left(\frac{r^* - r}{L_R}\right) \tag{4}$$

where C_R and r^* are constants as yet undetermined. Applying the above boundary conditions it follows that

$$r^* = R_{RE} \qquad \text{and} \qquad C\sin B_g R = C_R \sinh\left(\frac{R_{RE} - R}{L_R}\right) \tag{5}$$

and

$$DC\left(\sin B_g R - B_g R\cos B_g R\right) \tag{6}$$
$$= D_R C_R\left(\frac{R}{L_R}\cosh\left(\frac{R_{RE} - R}{L_R}\right) + \sinh\left(\frac{R_{RE} - R}{L_R}\right)\right)$$

Eliminating the ratio C/C_R from the last two relations yields

$$D\left(1 - B_g R\cot B_g R\right) = D_R\left(1 + \frac{R}{L_R}\coth\left(\frac{R_{RE} - R}{L_R}\right)\right) \tag{7}$$

Given all the material constants involved, this relation can be solved numerically to determine the critical size (or critical geometric buckling) of such a spherical reactor.

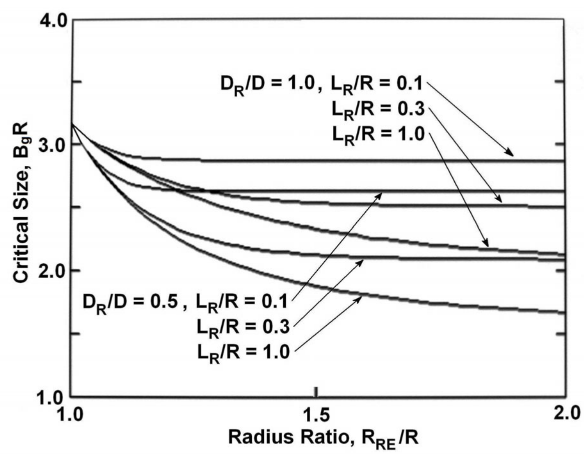

Figure 1: The non-dimensional critical size or geometric buckling, $B_g R$, for a spherical reactor with a reflector as a function of the radius ratio, R_{RE}/R, for various values of L_R/R and D_R/D.

Sample results are shown in figure 1 that presents the non-dimensional critical size or geometric buckling, $B_g R$, as a function of the radius ratio, R_{RE}/R, for various values of L_R/R and D_R/D. The change in the shape of the neutron flux as the size of the reflector is increased is shown in figure 2; note that the uniformity of the neutron flux within the core can be somewhat improved by the presence of the reflector.

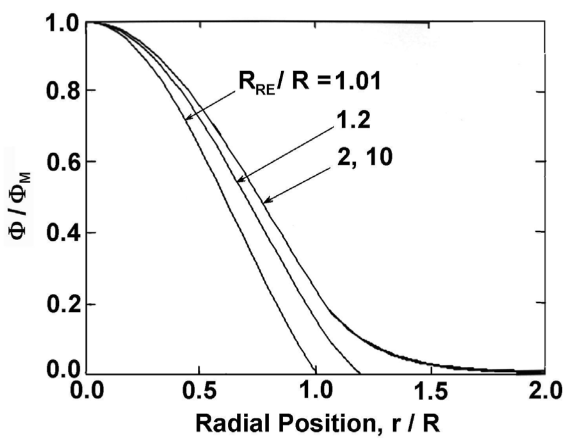

Figure 2: The shape of the neutron flux distribution in a spherical reactor surrounded by a reflector, ϕ (normalized by the maximum neutron flux, ϕ_M), for various radius ratios, R_{RE}/R, as shown and for $D_R/D = 1$.