SOME CONTROL PROPERTIES OF REFLECTOR MODERATED REACTORS

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The current trend in the design of research reactors is toward heavily loaded cores in which most of the neutrons are thermalized in the reflector before returning to the core. These reactors often have control properties quite different than the usual thermal reactors. In this paper some of these properties are examined and it is shown that extreme care must be used in the design of such reactors.

The effect of control rod motion may well be quite different from what a casual glance might indicate. This is because an important characteristic of such reactors is that the thermal flux peaks in the reflector and drops as one goes toward the core center; the thermal adjoint, on the other hand, behaves in a normal manner, peaking at the core center and decreasing as a function of radius. Since the reactivity effect of a thermal absorber is proportional to the product of flux and adjoint it can easily happen that an absorber is most effective when placed in the reflector. As an example, we consider a fully enriched, heavy water moderated and reflected reactor having a core D/U ratio of about 180.
In spherical geometry, a system with a core radius of 24 cm and a reflector thickness of about 100 cm has been studied. In this reactor the thermal flux peaks in the reflector, about 10 cm from the core, and drops to about a tenth of the peak value at the core center. We assume that a control rod, whose length is equal to a core diameter, can move along a radius in the core and reflector. Figure 1 is the result of a perturbation theory calculation of the relative effectiveness of such a rod as a function the distance of the tip into the core. One can see that if the rod were to be dropped from half insertion to full insertion, the reactivity of the reactor would increase.

Xenon control characteristics can be badly in error unless proper space dependent calculations are performed. This is because the fission density, which has a contribution due to epithermal neutrons, does not vary as rapidly as does the thermal flux. The fission density does, however, peak at the core reflector interface. For moderate power densities (average about 0.5 kw/cc) the equilibrium xenon
A concentration will be largest at the core center because of a higher burn-out to production ratio near the reflector. However, after a shutdown the xenon distribution shifts so as to follow the fission distribution, and is thus in a position of relatively higher effectiveness. If this is not taken into account, the amount of reactivity needed to override xenon can be underestimated by about 15% or more. One also has the situation that when restarting after a shutdown the xenon is so distributed that burn-up is greater than in the equilibrium distribution and fairly rapid increases in reactivity can occur.

Caption:
Figure 1. Relative effectiveness of a control rod whose length is one core diameter as a function distance inserted into core; the insert shows the geometry considered.
REFLECTOR

CONTROL ROD

CORE

24 cm

Z

-8k

Z

-12 0 12 24 36 48 cm

END