An Interpolational Scheme for Monitoring the Refueling
Operations in an LMFBR

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It is desirable to have precise knowledge of the reactivity status of an LMFBR during the refueling operations. Since many of the control mechanisms may be inoperable during this period owing to maintenance demands, the consequences of misloadings are unacceptable from safety and economics considerations. We have developed an interpolational scheme for monitoring the refueling operations in a LMFBR which relates available information from the low-level flux monitoring system to the reactive state of the system through the modified source multiplication (MSM) method¹ and inexpensive computations.

The problems associated with monitoring the state of a system during refueling are numerous. First, as in any monitoring situation, we are attempting to obtain global information about the system from a point measurement outside the system. The complexity includes space-energy effects in a far shutdown system. Second, the nuclear character of the system is continually being perturbed by fuel and control element movements. In monitoring the refueling process then it is necessary to account for the effects of such perturbations on the monitoring process itself.

To monitor the shutdown status, the following quantities in the modified source multiplication scheme must be continually updated:

$$S_0(r, E), \quad \int_{\text{DET VOLUME}} \int_E \sum_f^{\text{DET}} (r, E) \phi(r, E) dr dE,$$

and

$$\int_{\text{CORE VOLUME}} \int_E v \sum_f (r, E) \phi(r, E) dr dE,$$

S_0 is the inherent source and the integrals represent the total neutrons detected and the total neutron production in the core. In principle, the variation in these quantities can be obtained from transport solutions for each configuration. In practice, the number and variety of possible configurations make this method impractical.

The general problem of estimating the effect on the integral quantities of any material change anywhere in the system can be treated using a special application of perturbation theory. The flux distribution for the initial unaltered system is found from an inhomogeneous transport calculation using the inherent source as the driving function. The adjoint function is found in a similar calculation using the appropriate fission cross section as the response function. Using formulations analogous to material reactivity worth equations, the effect on detector response of any material change anywhere in the system can be readily computed.

A simple example of this interpolational scheme is shown in Fig. 1. The effect on the response of the indicated detector of substituting zone 2 fuel assemblies for control assemblies, or vice versa using the interpolating scheme, is compared with "exact" calculations. We have made similar computations for zone 1 and zone 2 fuel substitutions, zone 1 fuel and control material substitutions, and new fuel for old substitutions. Data such as these are used to adjust count rate data for the MSM measurements by making changes in the parameter consistent with each loading change that is made.

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Reference

1. R. C. Kryter, N. J. Ackermann, Jr., and A. R. Buhl, "Subcriticality Measurements in the FTR-3: The Homogeneous Mockup of the Fast Test Reactor," ORNL-TM-3715, Oak Ridge National Laboratory (1972).

FIGURE CAPTION

Fig. 1. The Effect of Adding or Removing Fuel or Control Material During Refueling.

PERCENT CHANGE IN DETECTOR RESPONSE PER 3 ASSEMBLY SUBSTITUTION