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**Post-Initiating Phase Neutronics Analysis
of an Unprotected LOF Event in CRBRP**

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The reactor system is expected to achieve permanent subcriticality in a loss-of-flow (LOF) event by virtue of fuel removal from the core even under the hypothetical assumption that both shutdown systems fail to function. Based on the analysis performed by S. K. Rhow, et al.,¹ adequate fuel removal would occur in the CRBRP heterogeneous core during a meltout period after the initiating phase of the unprotected LOF event. This paper discusses reactivity levels relative to fuel removal in the accident progression beyond the initiating phase for the CRBRP core at the beginning of cycle 1 (BOC-1).

The primary objective throughout this neutronics analysis has been to retain as much rigor in the computational modeling as possible while retaining efficient computations. For significantly disrupted core configurations, as are encountered in the post-initiating phase analysis, the presence of large internal voids makes the use of diffusion theory suspect. In order to adequately handle the complex streaming associated with large internal voids S-4 transport theory with isotropic scattering was selected as the computational mode. The use of S-4 transport theory and its associated high cost precluded the use of a detailed 3D model. The accurate modeling of the voids in RZ geometry is deemed more important than the impact of isolated control rods and blankets in a 3D model,

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i.e., the RZ model will adequately handle the isolated blanket islands and control rods while giving the benefit of a rigorous treatment of the internal voids.

The basic cross section data used for the neutronics analysis were generated from the ENDF/B-IV data files. The MC²-SDX code package^{2,3} was used to process these data. A base library of 171-groups ($\Delta u = 0.1$) was generated using a weighting spectrum from a 2040-group slowing down calculation for an appropriate Pu/U fueled LMFBR core composition.⁴ Resonance self-shielding effects were accounted for in voided and nonvoided driver, internal blanket, and radial blanket assemblies. An eight group and a twenty group library were obtained for operating conditions (1500°K) and for an elevated temperature (3000°K). The reference core design and core mass inventory at BOC-1 were taken from the CRBRP PSAR.

At termination of the initiating phase, many fuel assemblies would have experienced fuel melting/disruption, followed by melt-through of the hexcan walls. Subsequently molten fuel from the assemblies would flow out of the core region through the interassembly gaps.¹ Design information based on the PSAR has shown that the interassembly gaps outside the core region have potential for accommodating more than the total fuel inventory. In other words, fuel could be removed from the core through the gaps as fast as melting occurs. It is noted that there are other fuel removal paths such as control assemblies and axial blanket flow paths.

Although potential exists to remove essentially all the fuel from the core, other factors such as plugging, availability of molten fuel and the timing of fuel removal relative to energetics potential may limit fuel removal in the neutronics analysis. In the present analysis four disrupted core configurations were analyzed with limited fuel removal, and the results are presented in Table I. Case 1 represents core conditions after approximately 43% of the total fuel inventory is removed from the outer annular region of the core. The remaining fuel in the core annular regions is homogenized and fully compacted, while the internal blanket and control assemblies remain intact. The system is subcritical for this configuration. Case 2 is identical to Case 1 except that the fuel removal is reduced to 33% of the total inventory. The system is substantially above critical for this configuration. This means that the fuel-steel mixture in the core region will be boiled up in the process of fuel compaction. The result for Case 3 indicates that the system will be deeply subcritical with a fully boiled-up configuration. More fuel removal is expected during this boilup period, which would lead to permanent subcriticality. In Case 4, about 41% of the total fuel inventory is again removed from the core. The remaining fuel, internal blanket and control assemblies (without B_4C) are assumed to be homogenized and fully compacted. This homogeneous pool configuration is substantially subcritical. In all cases, one-third of the cladding and wire wrap in all fuel assemblies is assumed to relocate into the upper axial blanket region, and another one-third relocates into the lower axial blanket region. The remaining residual steel including the hexcan walls is assumed to be homogenized with the molten fuel.

From the above neutronics results, it can be concluded that the system will achieve permanent subcriticality as long as about 40% of the total fuel inventory is removed from the core.

References

1. S. K. Rhow, et al., "An Assessment of HCDA Energetics in the CRBRP Heterogeneous Reactor Core," CRBRP-GEFR-00523, December 1981.
2. H. Henryson II, et al., "MC²-2: A Code to Calculate Fast Neutron Spectra and Multigroup Cross Sections," Argonne National Laboratory, ANL-8144, June 1976.
3. B. J. Toppel, et al., "ETOE-2/MC²-2/SDX Multigroup Cross Sections," March 14-16, 1978, Radiation Shielding Information Center, Oak Ridge, Tennessee.
4. C. E. Till, et al., "Fast Breeder Reactor Studies," Argonne National Laboratory, ANL-80-40, July 1980.

Table 1**Reactivity Levels for Various Disrupted
Core Configurations at BOC-1**

Case	Description of Core Configuration	Reactivity (ρ)
1	43% of total fuel inventory removed from the core. The remaining fuel in the annular regions is homogenized in the core and fully compacted with IB and CR assemblies intact.	-1.4
2	Same as Case 1 except that only 33% of total fuel inventory is removed.	+10.2
3	Same as Case 2 except that fuel/steel is boiled up with uniform void fraction.	-36.7
4	41% of total inventory removed from core. The remaining fuel, the IB and CR (except B₄C) assemblies are homogenized and fully compact.	-10.5

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