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A TWO-LUMP FISSION-PRODUCT MODEL FOR FAST-REACTOR ANALYSIS*

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As a part of the Fast-Mixed Spectrum Reactor (FMSR) Project [1,2,3], a study was made on the adequacy of the conventional fission product lump models for the analysis of the different FMSR core concepts.

The need for a more careful study of fission products in the FMSR core concepts arises from the fact that the spectrum in these cores varies from very hard (due to use of metal fuel) to relatively soft (due to existence of moderator in certain regions of the core) and the long fuel exposures which result in a large fission product buildup. A two-lump fission product model consisting of an odd-A fission product lump and an even-A fission product lump with transmutation between the odd- and even-A lumps was developed. This two-lump model is capable of predicting the exact burnup-dependent behavior of the fission products within a few percent over a wide range of spectra and is therefore also applicable to the conventional fast breeder reactor.

The basic motivation for using a two-lump model is due to the fact that the absorption cross section of the odd-A fission products is several times higher than the even-A fission products. As a result, the rate of capture and consequently transfer of an odd-A fission product to an even-A fission

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product is much higher than vice versa. This difference in the rate of transfer results in the buildup of even-A fission products with lower absorption cross sections and depletion of odd-A fission products with higher absorption cross sections as a function of burnup. Thus, the effective fission product absorption cross section drops as a function of burnup. This effect can clearly be seen by looking at Fig. 1 which shows the burnup dependence of the lumped fission product microscopic absorption cross section of the even-A, odd-A and all isotopes due to fission of Pu-239 in the representative soft spectrum. This graph was generated by a detailed study of the burnup behavior of 181 fission product elements in 84 chains using the EPRI-CINDER code [4]. The cross-section data for the fission products were generated from a 154-group fission product library for 181 elements [5] which were collapsed to four groups using the TOAFEW code [5] based on the desired spectrum. In this study two spectra were used to represent the two spectral regions of the reactor. The dashed line in Fig. 1 represents a one-lump microscopic cross section generated at 70,000 MWD/MT. The difference between the dashed line and the microscopic cross section for all isotopes is the error that would be introduced in the microscopic absorption cross section if a one-lump cross section at 70,000 MWD/MT was selected to represent this burnup-dependent behavior.

The burnup-dependent behavior of the microscopic absorption cross section of the two-lump model, a one-lump model generated at 70,000 MWD/MT, and the Garrison-Roos model [6] (which consists of three lumps of saturating, slowly saturating and nonsaturating fission products plus two isotopes of Xe-135 and Sm-149 included in the LIB-IV [7] library) were compared to the detailed 84 chain behavior of fission products [8]. The results showed that the two-lump model can predict the exact behavior in both spectra to within 1% up to 180,000 MWD/MT. The error in the microscopic absorption cross section using a one-lump model ranged from an underprediction of about 4.5% to an overprediction of about 8%. The Garrison-Roos model consistently overpredicted the microscopic absorption cross section by as much as 34%. A 50-group lumped odd- and even-A fission product library compatible with LIB-IV was generated for the fissile and fertile isotopes of interest. Table 1 shows the effect of using the two-lump model on K_{eff} of one particular FMSR core [3] compared to the effect of LIB-IV (Garrison-Roos formulation) fission product cross sections. Also shown is the effect of inclusion of fission product downscattering on K_{eff}. The average burnup in this core is about 8% with a peak burnup of 15%. As can be seen, the overall effect of the two-lump model is quite noticeable.

Based on the results mentioned above, it is concluded that the two-lump model can offer a high degree of accuracy for fission product representation in fast breeder reactors over a large burnup range and a wide spectra.

Table 1. The Effect of Fission Product Models on K_{eff} as a Function of Time

Full Power Days (Years)	K_{eff}		
	LIB-IV Fission Products	Two-Lump Model No Downscattering	Two-Lump Model With Downscattering
0	1.0136	1.0136	1.0136
550 (2)	1.0072	1.0237	1.0218
825 (3)	1.0072	1.0286	1.0258
1375 (5)	1.0073	1.0371	1.0324
1650 (6)	1.0072	1.0408	1.0350
2200 (8)	1.0057	1.0459	1.0382
2750 (10)	1.0027	1.0484	1.0387

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FIGURE CAPTION

Figure 1: Lumped Fission Product Microscopic Absorption Cross Section of Odd-A, Even-A and All Isotopes Due to the Fission of Pu-239 in the Soft Spectrum

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