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A SIMPLE PROCEDURE FOR DETERMINING IMPLICATIONS OF DESIGN CHANGES ON FAST REACTOR FUEL CYCLE COST AND BREEDING PERFORMANCE*

by

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DISCLAIMER

Recently, analytical sensitivity methods have been applied[1] to obtain fuel cycle cost implications of data uncertainties. To perform exposure dependent sensitivity analysis without repeating expensive spectrum calculations, simple correlations of the spectrum averaged cross sections (SAXS) were constructed. The correlation coefficients were obtained by fitting the SAXS calculated by direct methods over a wide range of LMFBR core designs. In this paper the procedure has been extended to study sensitivity of fuel cycle cost and breeding ratio to design variation. Briefly, the method involves using the correlations to construct both the SAXS and the sensitivity coefficients. Composition dependent correlations have been found to be accurate for the core while both composition and position have to be included in analysing the blanket.

A postulated design constraint to date has been to maintain the end of cycle(EOC) multiplication constant. In an equilibrium cycle with one-third core refueling this is

$$\bar{K}_{EOC} = p_1 K^1_{EOC} + p_2 K^2_{EOC} + p_3 K^3_{EOC} \qquad (1)$$

where p_1, p_2, p_3 are the power fractions and K^1_{EOC}, K^2_{EOC}, K^3_{EOC} are the EOC multiplication constants of once, twice and thrice burnt fuels respectively.

We considered a number of design options some of which are indicated in Table 1. In each case prediction of $\bar{K}_{EOC}$ by the correlations have been verified by direct spectrum calculation. The correlations have proved sufficiently general to include variation of the coolant fraction provided other volume fractions are self-consistent. The initial enrichment in each case was chosen to maintain the same $\bar{K}_{EOC}$.

Fuel cycle costs and credits were calculated with fissile plutonium, fabrication and reprocessing prices of \$36/gm, \$500/kg-HM and \$200/kg-HM respectively with fabrication and reprocessing penalties of 1%. Proper lead and lag times were assumed. Table 2 shows fuel cycle cost implications of the design variation and the excellent prediction the correlations provide of these sensitivities. It is noted that use of LWR recycle plutonium instead of FFTF grade Pu in CRIC[2] (base case) involves a lower fuel cycle cost mainly because of the lower initial fissile loading. Reduction of coolant volume fraction also involves a lower fuel cycle cost than the base case because of the reduction in enrichment (U/U+Pu) due to the higher reactivity. The GE design[3] which starts as a net breeder, has a lower fuel cycle cost.

The corresponding breeding ratio implications are also shown in Table 2. Use of LWR Pu in CRIC gives a higher breeding ratio because there is larger amounts of U-238 initially resulting in greater Pu-239 production. Similarly, reducing coolant volume fraction increases the breeding ratio.

We have also investigated the sensitivity of the cost and BR to data uncertainties in the various designs with the same design objective of maintaining $\bar{K}_{EOC}$. It has been observed that cost sensitivities to data variations are nearly the same whether FFTF Pu or LWR Pu is used in the CRIC composition. However, sensitivities were greater for the GE core. For some cross sections the sensitivities were small due to cancellation of effects. A positive change in σ_c^{28} led to a large negative change in cost for GE design while the effect was smaller in CRIC case. Variation of σ_c^{49} had a large effect on the breeding ratio in all cases.

Simple analytical sensitivity methods have been extended to study fuel cycle cost and breeding implications in FBR core design variation. These methods have been found to be accurate, and inexpensive (computer time saving of a factor of ten) reducing the need for repeating detailed calculations. It has been found that simple correlations characterize both data changes and design changes. Current effort at RPI involves extending the procedure to

LMFBR blankets where either position or exposure can be of greater significance depending on whether one is considering the homogeneous[4] or heterogeneous[5] design.

References

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Table 1. Fast Reactor Compositions Studies

	Case 1[a]	Case 2[b]	Case 3[c]	Case 4[d]
Initial Enrichment (% Pu/U+Pu)	18.700	20.003	18.170	15.010
Pu Grade:				
N_{49}/N_{Pu}	0.8646	0.6830	0.8646	0.5889
N_{40}/N_{Pu}	0.1169	0.1920	0.1169	0.2572
N_{41}/N_{Pu}	0.0167	0.1010	0.0167	0.1219
N_{42}/N_{Pu}	0.0018	0.0240	0.0018	0.0320
Fuel Volume Fraction	0.3797	0.3797	0.4062	0.4674
Coolant Vol/Structure Vol.	1.9583	1.9583	1.6478	2.3600

[a] Clinch River Inner Core (CRIC) Composition with FFTF Pu

[b] CRIC with LWR Pu

[c] CRIC with FFTF Pu with Coolant Volume Fraction Reduced by 10%

[d] General Electric Advanced Design

Table 2. Fuel Cycle and Breeding Ratio Variation with Design

	FUEL CYCLE COST mills/kwhr(e)		CYCLE AVG. CORE BR†	
	Direct Method	Correlation Method	Direct Method	Correlation Method
Case 1	3.77	3.80	.731	.733
Case 2	3.59	3.58	.750	.755
Case 3	3.69	3.70	.746	.750
Case 4	2.30	2.27	1.005	1.014

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† Standard definition of breeding ratio

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