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ANALYSIS OF THE THORIUM AXIAL BLANKET EXPERIMENTS IN THE PROTEUS REACTOR*

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EXPERIMENTS IN THE PROTEUS REACTOR

An extensive program of reactor physics experiments in GCFR fuel pin lattices[1] has been completed recently at the PROTEUS critical facility located at EIR laboratory in Switzerland. The PROTEUS reactor consists of a central test zone surrounded by a uranium buffer and thermal driver region. The test lattices included a PuO_2/UO_2 fuel region with internal and axial blankets of UO_2, ThO_2, and thorium metal. Detailed analysis of the thorium-bearing lattices has been performed at EIR and at ORNL in order to validate nuclear data and methods used for reactor physics analysis of advanced GCFR designs. Results of the analysis of reaction rate measurements made at the center of the PuO_2/UO_2 core have been presented earlier[2-4]; however, a thorough investigation of reaction rate measurements in the axial blankets has just recently been performed at ORNL, and indicate significantly different conclusions than the core center analysis.

The two primary configurations which have been analyzed by ORNL are: (1) a PuO_2/UO_2 core with a ThO_2 axial blanket (Core 14), and (2) a PuO_2/UO_2 core with a thorium metal axial blanket (Core 16). The core center results for Core 14 (Ref. 2) and similar core center results for Core 16 showed that ENDF/B-IV thorium data underpredicts the ^{232}Th capture and fission rates with calculated-to-measured (C/E) values ranging from 0.93 to 0.96 for the (^{232}Th capture/^{239}Pu fission) ratio (C2/F9), and 0.88 to 0.90 for the (^{232}Th fission/^{239}Pu fission) ratio (F2/F9). Also, the use of ENDF/B-V thorium data yielded a 7 percent lower capture rate and a 5 percent higher fission rate relative to ENDF/B-IV-based data. These results indicate that in the contributing energy range of 100 eV to 1 MeV, the current thorium capture data appears inadequate for GCFR fuel cycle analysis, since a 5 to 15 percent uncertainty in the thorium capture rate is compounded to yield an unacceptably large uncertainty in the calculated breeding ratio and fuel doubling time for a thorium-bearing reactor.

The core center analysis, however, considered thorium only in an infinitely dilute environment, and hence did not include resonance self-shielding effects. To investigate these effects, comparisons were made of reaction rate measurements and calculations in the ThO_2 and Th metal axial blankets of Core 14 and Core 16. The results from the Core 16 analysis are given in Table 1 which gives C/E values for three important reaction rate ratios at the center of the axial blanket. Calculations of the reaction rates were performed using several different cross-section data sets and both diffusion theory and transport theory methods. In general, the calculations and measurements show a much larger disagreement in the blanket than at core center. Also, the cross sections generated at ORNL from ENDF/B-IV and -V data files showed improved agreement relative to the cross section data supplied by EIR. In contrast to the core center results, using ENDF/B-V thorium data improved the C/E values for both the capture and fission rates (relative to ^{239}Pu fission rate).

A careful investigation of the relatively large discrepancies observed in the blanket calculations concluded that modeling and/or methods uncertainties were the dominant factors, and consequently, very little useful information regarding the adequacy of the nuclear data could be obtained from the analysis. In particular, it was felt that the procedure for collapsing fine-group cross sections to the 10 broad groups used in the two-dimensional calculations seemed inadequate. The collapse was performed using flux spectra determined from a 1-D calculation in the axial direction along the reactor centerline. While this procedure gives an adequately representative weighting spectrum at the core center, the spectrum calculated in the axial blanket lacks a significant low-energy component due to the thermal driver region which surrounds the test zone. Figure 1 gives the groupwise contribution of several reaction rates calculated in the axial blanket, and shows that the lower energy groups are significant in the blanket region. This large sensitivity of the reaction rates to the low-energy flux, combined with the inadequate weighting of the low-energy broad-group cross sections amply explain the disagreements between the calculated and measured reaction rates in the axial blanket.

Therefore, unlike the core center analysis which showed the need for improved thorium capture data, the axial blanket analysis has shown the need for a more sophisticated method and improved modeling of the test reactor. It is expected that the C/E values in the axial blanket could be noticeably improved if either a better procedure for cross section collapsing were used such as a fine group 2-D calculation of the weighting spectra, or a finer group structure were used for the broad-group 2-D calculations.

References

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Table 1. Comparison of Calculated Reaction Rate Ratios at the Center of the Axial Blanket of Core 16

Reaction Rate Ratio	Measured Value	Calculated-to-Measured Value (C/E)			
		EIR* Data	ENDF/B-IV Data		ENDF/B-V Thorium Data
			Transport	Diffusion	
C2/F9	0.1066	1.34	1.20	1.22	1.13
C8/F9	0.3969	0.56	0.89	0.85	0.75
F2/F9	1.28×10^{-3}	1.34	1.17	1.19	1.13

*EIR data were derived from British FGL5 data library except for ^{232}Th and ^{233}U data which were derived from ENDF/B-IV.

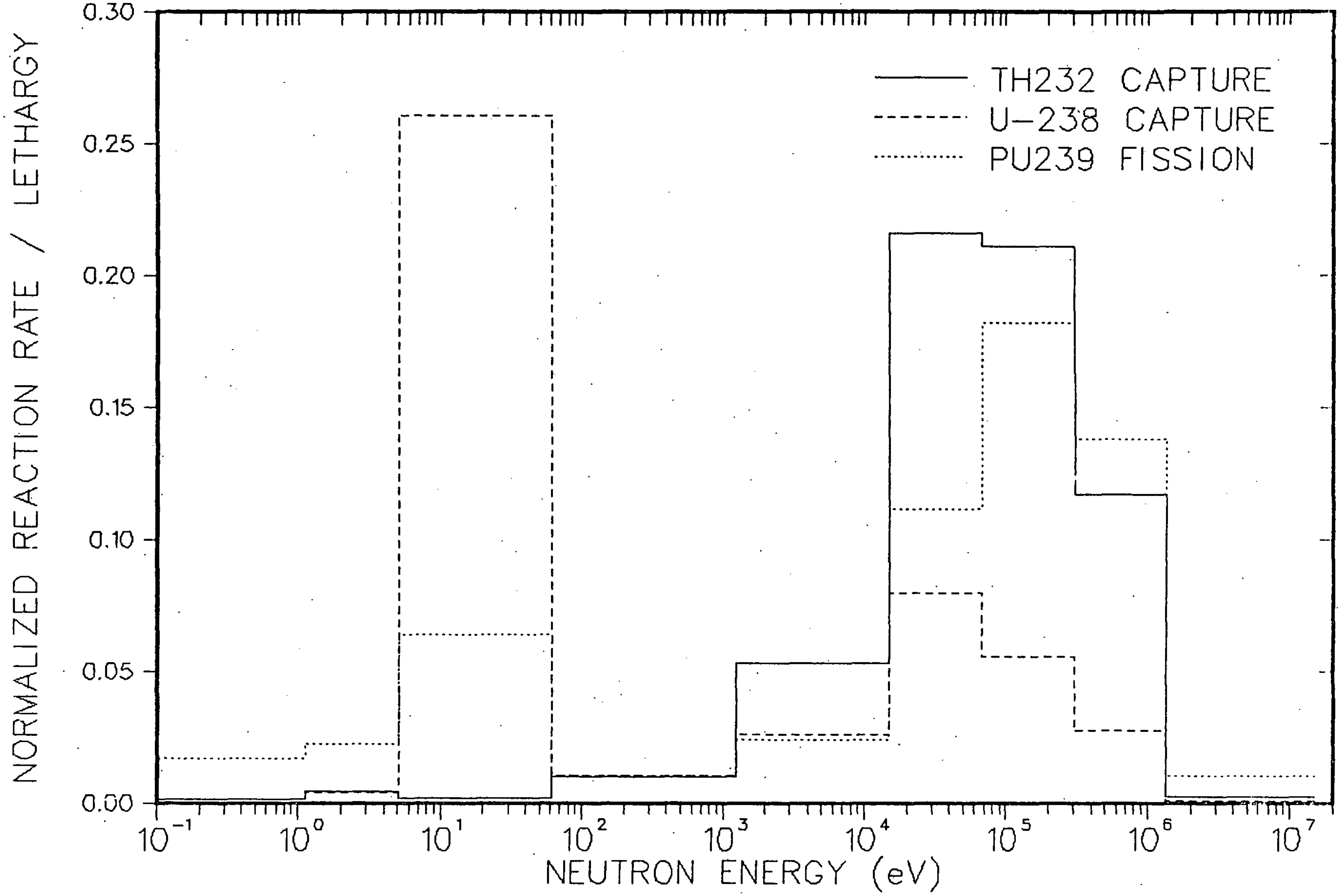

Fig. 1. Groupwise reaction rates at the center of the thorium metal axial blanket.