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Comparison of Reaction Rate Ratio Measurements in ZPPR and in ZEBRA Assembly 12 (MZB)

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1. Introduction

The MZB assembly on ZEBRA was a full-scale mockup of the MONJU prototype reactor. The compositions and dimensions of MZB were similar to those of the U.S. fast reactor benchmark assemblies ZPPR-2 to ZPPR-5. Thus a comparison of the central reaction rate ratios in ZEBRA and ZPPR provides a useful check of experimental techniques in media of similar composition and spectra.

To take into account small differences due to composition and heterogeneity the experimental results are compared via the C/E values obtained using the same nuclear data and calculation method for MZB and ZPPR. The most straightforward comparison is obtained with measurements at the center of ZPPR-2 since this avoide the complication of 'spiked-drawers' and control rods or sodium-filled control rod positions present in the subsequent ZPPR assemblies. In addition, comparisons are made with ZPPR-4 for several positions around the center of the core.

2. Calculations

The MZB and ZPPR-2 assemblies are described in Refs. 1 and 2, and a comparison of core parameters is given in Table I. Since the inner cores of the two assemblies are similar in dimensions and compositions, a fundamental mode calculation alone is sufficient to compare the central reaction rate ratios. This assertion is supported by Table II, which compares ratios for ZPPR-2 obtained from the inner-core cell calculation with those from the full rz reactor model. The ^{238}U capture and ^{235}U fission ratios to ^{239}Pu fission are negligibly different. The ^{238}U fission ratio requires a correction

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of less than 1%. Thus, for MZB, a calculation was made only for the inner core cell (cell C-2 in Ref. 1).

The calculations used the ENDF/B Version III data from a base library in 156 groups prepared for ZPPR analysis. The heterogeneous cell calculations used the SDX code[3]. For MZB, the cell model was set up in as closely as possible the same way as for ZPPR. Some unavoidable differences occur in the model because the ZEBRA plates are of dimension 2 x 2 x 1/4 or 1/8 in., and are positioned transversely in square fuel element tubes, whereas the ZPPR plates, which are normally larger than 2 in., are aligned along the drawers. For calculation of heavy isotope resonance shielding and of flux fine structure, the contents of the ZEBRA plates were calculated for a nominal area of 2 x 2 in. and the complete contributions from isotopes in the steel tubes were put into the diluent regions. Thus the "mid-plate" densities for uranium and plutonium were approximately preserved as in the standard ZPPR cell model. The actual homogeneous atom densities were used in the final fundamental model calculation, again as was done for the ZPPR cells. This calculation gave the cell-average reaction rates for comparison with experiment.

3. Results

The central reaction rate ratios for MZB, ZPPR-2 and ZPPR-4 phase 1 are compared in Table II. For ZPPR-2 the calculated results are taken from the rz calculation. For ZPPR-4[4] an average of a set of results around the core center is given, these calculations were obtained from an xyz diffusion theory model. The variation at different positions for ZPPR-4 is shown in detail in Fig. 1 for the ^{238}U capture ratio.

In MZB the principal reaction rates were measured by two independent techniques, using foils and SSTRs and give cell-average values appropriate for comparison with calculation. The mean experimental values are used from

Table VII, Ref. 1. For ZPPR, cell average values measured with foils are also compared, except for the ^{235}U fission ratio in ZPPR-2. For the ^{240}Pu and ^{241}Pu fission ratios only fission chamber measurements are available. These ratios introduce additional uncertainties when compared with calculation, estimated in Ref. 1 to be ±4% for the case of ^{240}Pu and ±1% for ^{241}Pu.

For the ratio of primary importance in fast reactor performance, ^{238}U capture to ^{239}Pu fission, the basic experimental data are in surprisingly close agreement. However, the proper comparison between ZPPR and MZB is obtained from the C/E values. These differ at the most by about 2.5%, which is within two standard deviations for the estimated uncertainties. The variation in C/E around the core center for ZPPR-4 shows no obvious correlation with proximity to control rod positions or with 'spiked' drawers so that a useful comparison is obtained for the mean value. The fission ratios yield C/E values for MZB and ZPPR which agree within the estimated uncertainties of 1 to 2% for ^{238}U and ^{235}U and within 3 to 4% for ^{240}Pu and ^{241}Pu. Thus, the comparisons give a useful cross-check of the measurements made in ZEBRA and ZPPR.

References

1. G. Ingram, et al., "Critical Size and Central Reaction Rate Results From the MOZART Programme and Their Predictions", Proc. Tokyo Symposium on Physics of Fast Reactors, Oct. 1973, p. 269.

2. A.L. Hess and R.G. Palmer, "Prescription of a Benchmark Model of ZPPR Assembly 2 for Data Testing of ENDF/B", Applied Physics Division Annual Report 1970 to 1971, ANL-7910, p. 299.

3. W.M. Stacey, Jr., et al., "A New Space-Dependent Fast Neutron Multigroup Cross-Section Preparation Capability", Trans. Am. Nucl. Soc., 15 p. 291, 1973.

4. L.G. LeSage, et al., "The ZPPR-4 Demo Criticals Program," Proc. ANS Conf. on Advanced Reactors; Physics Design and Economics, Georgia, Sept. 1974.

TABLE I. Comparison of MZB and ZPPR-2 Assemblies

	ZPPR-2	MZB
Core height	92 cm	89 cm
Inner core diameter	129 cm	124 cm
Outer core thickness	27 cm	17 cm
Total plutonium loading	1024 kg (11% ^{240}Pu)	960 kg (17% ^{240}Pu)

TABLE II. Comparison of Central Reaction Rate Ratios From SDX Fundamental Mode Calculation and From RZ Full Reactor Calculation for ZPPR-2

	SDX F-M Calculation	RZ Model	Ratio RZ/SDX
C_8/F_9	0.1535	0.1534	0.999
F_5/F_9	1.114	1.113	0.999
F_8/F_9	0.0228	0.0230	1.009

TABLE III. Comparison of Central Reaction Rate Ratios in MZB and ZPPR

		Experiment	Calculation	C/E
C_8/F_9	ZPPR-2	0.1427 ± 1.4%	0.1534	1.075 ± 1.4%
	ZPPR-4/1[a]	0.1428 ± 1.4%	0.1517	1.063 ± 0.3%
	MZB	0.1427 ± 1.2%	0.1498	1.050 ± 1.2%
F_8/F_9	ZPPR-2	0.02424 ± 1.3%	0.02298	0.948 ± 1.3%
	MZB	0.02438 ± 1.7%	0.02297[d]	0.942 ± 1.7%
F_5/F_9	ZPPR-2	1.067 ± 1.5%[b]	1.113	1.043 ± 1.8%
	ZPPR-4/1[c]	1.092 ± 1.5%	1.113	1.020 ± 0.5%
	MZB	1.066 ± 1.2%	1.086	1.019 ± 1.2%
F_0/F_9	ZPPR-2	0.1818 ± 2.1%[b]	0.1991	1.095 ± 4.5%
	MZB	0.2023 ± 1.9%[b]	0.2146	1.061 ± 4.4%
F_1/F_9	ZPPR-4/3	1.38 ± 2.0%[b]	1.35	0.98 ± 2.2%
	MZB	1.352 ± 3.0%[b]	1.360	1.006 ± 3.2%

[a] Average of 20 positions near the core center, error on C/E from the distribution.

[b] Fission chamber measurement.

[c] Average of 9 positions near the core center, error on C/E from the distribution.

[d] Calculation adjusted by rz/F-M ratio from Table II.

Key: C / E / C/E

Mean of 20 positions: C = 0.1517 ± 0.0003
E = 0.1428 ± 0.0005
C/E = 1.063 ± 0.003

S = Spiked drawer

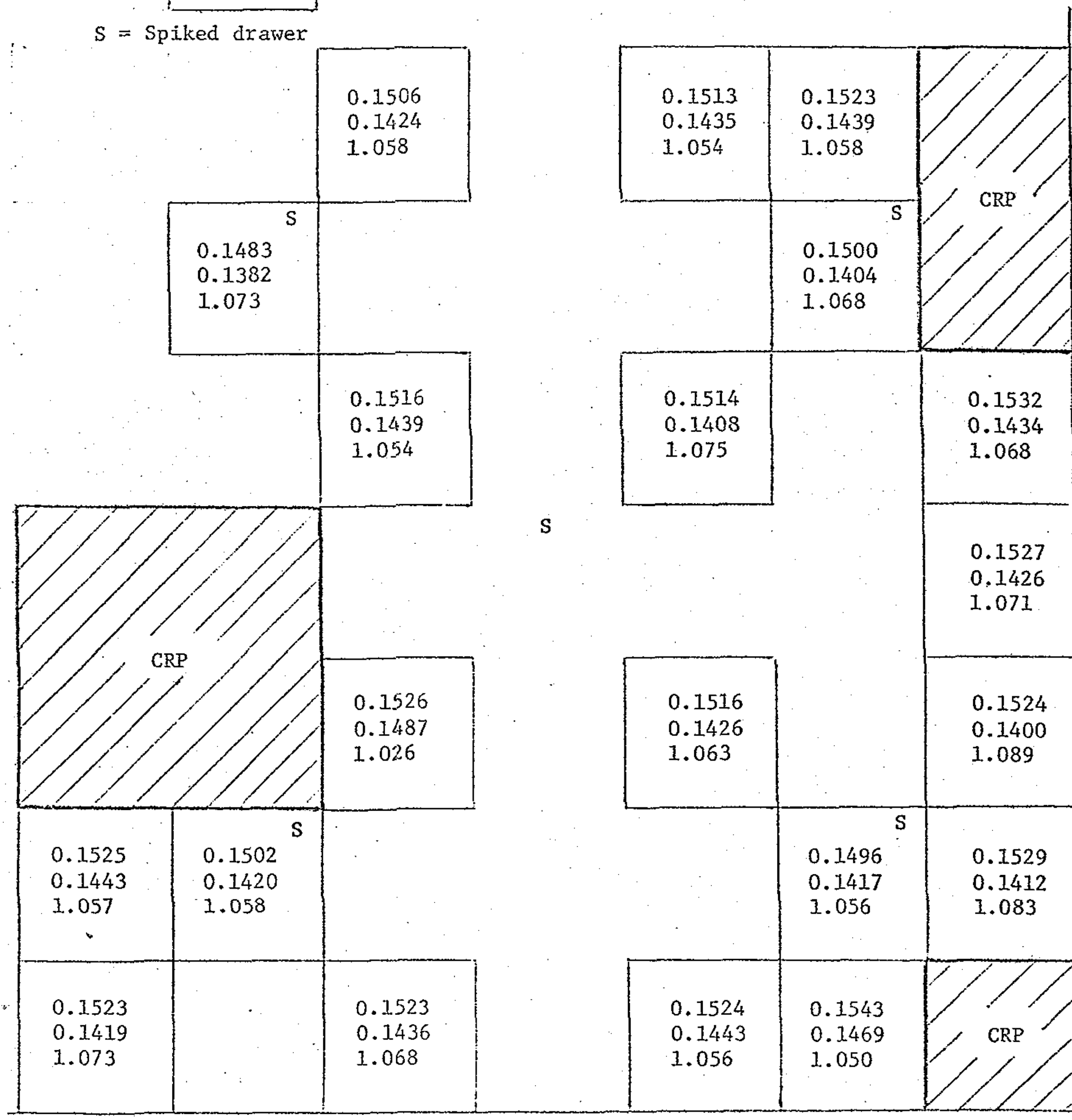

Fig. 1 Variation of C_8/F_9 Near the Center of ZPPR-4/1