2.2 Integral Testing of JENDL-3.2

2.2.1 Benchmark Tests of JENDL-3.2 for Thermal and Fast Reactors

Hideki Takano
Japan Atomic Energy Research Institute
Tokai, Ibaraki, 319-11, Japan
+81-292-82-6151

Benchmark calculations for a variety of thermal and fast reactors have been performed by using the newly evaluated JENDL-3 Version-2 (JENDL-3.2) file. In the thermal reactor calculations for the uranium and plutonium fueled cores of TRX and TCA, the k_{eff} and lattice parameters were well predicted.The fast reactor calculations for ZPPR-9 and FCA assemblies showed that the k_{eff}, reactivity worth of Doppler, sodium void and control rod, and reaction rate distribution were in a very good agreement with the experiments.

I .INTRODUCTION

A great deal of effort have been required for development and validation of various neutronic calculation methods and nuclear data libraries, and various critical experiments for thermal and fast reactors have been performed to verify these methods and data. Especially, the development of new nuclear data library requires accurate verification and validation

JENDL-3.1[1)] was revised on the basis of much feedback information by various benchmark tests[2)], and the revised version (JENDL-3.2) was released in June 1994[3)]. In this paper, the benchmark tests of the newly evaluated JENDL-3.2 file will be described for thermal and fast reactors.

In thermal critical experiments were selected the uranium fuel cores TRX[4)] and TCA-UO_2[5)] with water moderated lattice of slightly enriched uranium metal and oxide rods, respectively, and as plutonium fueled cores TCA-MOX[5)] with 3.0 wt.% Pu rods and the tight lattice Pu cores of PROTEUS experiments[6)]. Furthermore, a lots of critical safety experiments such as ORNL[4)] of U-cores, PNL[4)] of Pu-cores and M&J[7)] of ^{233}U-cores were selected. The benchmark calculations were performed with the continuous energy Monte Carlo code MVP[8)] and integral transport code SRAC-93[9)]. The results calculated will be described here.

Fast reactor benchmark cores consist of various critical assemblies such as MONJU plot type mock-up core (FCA-VI-2), the large LMFBR mock-up core (ZPPR-9), the FCA-IX cores with a wide variety neutron spectrum shapes, very small cores such as GODIVA, JEZEBEL and FLATTOP with hard neutron spectra. The benchmark calculations were performed by using the 70-group cross section library JFS-3-J32 based on JENDL-3.2. The very small cores were calculated with the MVP code. The basic integral data such as effective multiplication factor, central reaction rate ratios, sodium void reactivity, Doppler reactivity and control rod worth are compared between the calculations and experiments.

II. THERMAL REACTOR BENCHMARK

Various cores were analyzed with some different nuclear libraries; JENDL-2, JENDL-3.1, JENDL-3.2P and JENDL-3.2. JENDL-3.2P is the preliminary version for the final version of

JENDL-3.2. The main difference between both libraries are as follows: In JENDL-3.2 the inelastic scattering cross sections of ^{238}U is smaller than those of JENDL-3.2P, and the fission spectrum of ^{233}U is softer than that of JENDL-3.2P.

A. Uranium (^{235}U) Fueled Cores

Figure 1 shows the k_{eff} and lattice parameters in TRX-2 core calculated with the continuous energy Monte Carlo code MVP. The k_{eff} value of JENDL-3.2 is increased by 0.5% as comparing that of JENDL-3.1, because the capture resonance integral of ^{235}U is considerably decreased in JENDL-3.2 as shown in Table 1. The lattice parameters of ρ-28, δ-25 and δ-28 are better predicted with JENDL-3.2. The k_{eff} values calculated for the TCA with UO_2 rods are slightly overestimated as shown in Fig. 2. The k_{eff} calculated with MVP for the critical safety ORNL cores are shown in Fig. 3. The results for JENDL-3.2 improve a tendency of underestimate observed in JENDL-3.1, excepting for the ratio of H/U = 0.

B. Plutonium Fueled Cores

The k_{eff} values of the TCA cores with the MOX rods in the cell pitch from 1.8 to 2.5 cm are compared in Fig. 4. The calculations were conducted with the MVP code. The results of JENDL-3.2 predict very well the experiments. Figure 5 shows the k_{eff} values calculated for the PNL cores, and they overestimate the experiments in lower ratio values than H/Pu = 1000.

For the tight lattice PROTEUS cores, the k_{eff} values and central reaction rate ratios were calculated with the SRAC-93 code and the results are compared in Tables 2 and 3. JENDL-3.2 predicts very well the k_{eff} for the coolant unvoid and voided cores. The C/E values of the ratio of ^{238}U capture to ^{239}Pu fission reaction rate (C8/F9) depends on the coolant voided fractions.

C. ^{233}U Fueled Cores

Figure 6 shows the k_{eff} values calculated with MVP for ^{233}U cores. It is observed that they are predicted very well in the values of H/^{233}U from 400 to 2000, but they are overestimated in the small values of H/^{233}U.

Ⅲ. FAST REACTOR BENCHMARK

A. GODIVA, JEZEBEL and FLATTOP

Very small cores with hard neutron spectrum were selected as plutonium fueled JEZEBEL,JEZEBEL-Pu,FLATTOP-Pu and THOR, enriched ^{235}U fueled GODIVA,FLATTOP-25 and BIGTEN, and enriched ^{233}U fueled JEZEBEL-23 and FLATTOP-23. These cores were analyzed by using the MVP code, and the results are shown in Fig. 7. The k_{eff} values for Pu cores are slightly underestimated excepting for that of THOR with thorium reflector. The results for ^{235}U cores are in good agreement with the experiments, and those of ^{233}U cores are improved but overestimated still.

B. ZPPR-9 and FCA-VI-2

The k_{eff} values are well predicted with JENDL-3.2 as shown in Table 4. In Table 5, the C/E values for Doppler reactivities of natural UO_2 sample are increased by JENDL-3.2 and become closer to the experimental values. Because the unresolved resonance region of ^{238}U is expanded up to 150 keV.

The C/E values of central reaction rate ratios for ZPPR-9 are shown in Fig. 8. The fission rate ratios of ^{238}U to ^{235}U and ^{239}Pu are underestimated by about 6 % due to softer fission spectrum of JENDL-3.2 than Madland-Nix one of JENDL-3.1. The ratio of ^{238}U capture to ^{239}Pu fission rate is overestimated by 5 %.

Figure 9 shows the C/E values of the sodium void reactivities with the increase of void regions, and they are satisfactory both of JENDL-3.1 and 3.2.The C/E values of control rod worth are well predicted with JENDL-3.2 as shown in Fig. 10.

Figure 11 shows the C/E values of ^{239}Pu fission rate radial distribution, and JENDL-3.2 overestimates slightly the experiments in the outer core region.

C. FCA-IX

The FCA-IX-1, 2 and 3 are uranium fueled cores with soft spectrum well moderated by graphite. As shown in Fig. 12, the k_{eff} values underestimated by JENDL-3.1 are well predicted with JENDL-3.2. This is due to decreasing the capture resonance integral of ^{235}U in JENDL-3.2 as described at the thermal reactor benchmark.

Ⅳ. CONCLUSION

The k_{eff} values of ^{235}U fueled thermal and fast reactor cores were well predicted with JENDL-3.2 as improving the underestimate by JENDL-3.1.

In Pu fueled cores, JENDL-3.2 predicted very well the k_{eff} values for various thermal MOX cores from tight to loose lattice assemblies. And in the fast reactor benchmark, the values calculated with JENDL-3.2 for k_{eff}, Doppler effect, sodium void reactivity, control rod worth and power distribution were in good agreement with the experimental results. But, the reaction rate ratio of ^{238}U capture to ^{239}Pu fission and the threshold fission rate ratio of ^{238}U to ^{235}U was underestimated by 4 and 6 % in ZPPR-9, respectively.

References

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Table 1 Comparison of resonance integrals and thermal cross sections in JENDL-3 nuclear data library (barn)

		2200m/s		R.I.	
		fission	capture	fission	capture
U-235	JENDL-3.1	584.0	96.0	275	152
	JENDL-3.2	584.4	98.81	279	134
U-238	JENDL-3.1	0.110E-6	2.681	2.02	279
	JENDL-3.2	11.8E-6	2.717	1.72	277
Pu-239	JENDL-3.1	746	270	299	185
	JENDL-3.2	747.4	270.3	302.6	181.6
Pu-241	JENDL-3.1	1015	363.0	590	187
	JENDL-3.2	1012.0	361.53	572.6	179.9

Table 2 The C/E values of k-inf calculated with SRAC for PROTEUS 1,2 and 3

Core	Exp.	JENDL-2	JENDL-3.1	JENDL-3.2P	JENDL-3.2
1	1.045±1.1%	1.000	1.003	1.003	1.004
2	0.991±1.5%	0.996	1.000	0.999	1.000
3	0.905±1.1%	0.992	1.011	0.995	1.000

Void fraction: core-1; 0.0 %, core-2; 100 %, core-3; 42.5 %.

Table 3 The C/E values central reaction rate ratios calculated with SRAC for PROTEUS-1, 2 and 3

Reaction	Core	Error(%)	J-2	J-3.1	J-3.2P	J-3.2
C8/F9	1	2.2	0.972	0.976	0.972	0.971
	3	2.0	0.993	0.999	0.994	0.993
	2	1.5	1.036	1.025	1.033	1.029

Table 4 The Comparison of the C/E values of k_{eff} in ZPPR-9 and FCA-VI-2

Core	JENDL-2	JENDL-3.1	JENDL-3.2
ZPPR-9	0.9991	1.0063	0.9967
FCA-VI-2	1.0066	1.0014	0.9992

Table 5 The C/E values of the natural UO_2 Doppler reactivity

Core	Temp.(℃)	JENDL-2	JENDL-3.1	JENDL-3.2
ZPPR-9	300-487	0.91	0.94	0.96
	300-644	0.92	0.95	0.97
	300-794	0.89	0.92	0.94
	300-935	0.93	0.96	0.98
	300-1087	0.92	0.95	0.97
FCA-VI-2	300-823	0.93	0.91	0.95
	300-1073	0.93	0.91	0.95

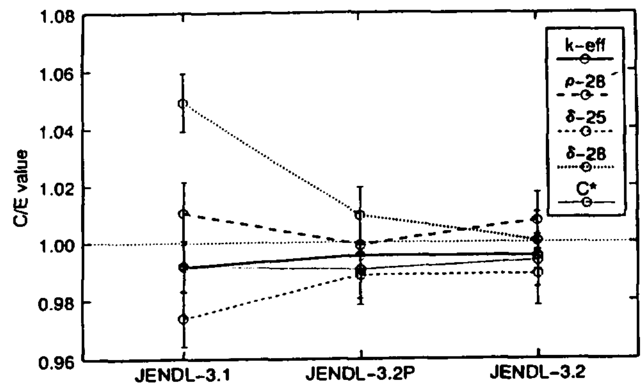

Fig.1 The C/E values of k_{eff} and lattice parameters calculated by the MVP code for TRX-2 core

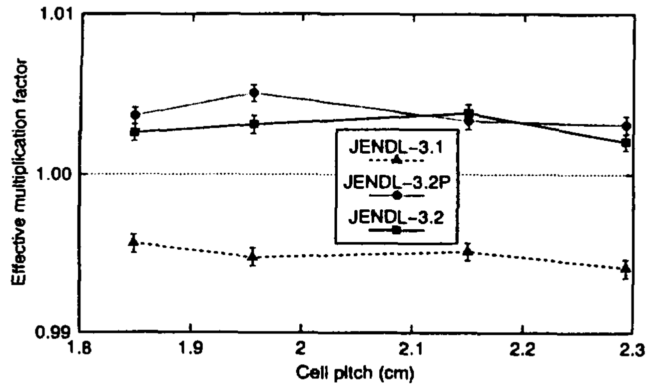

Fig.2 The k_{eff} values calculated by the MVP code for TCA-UO_2 cores

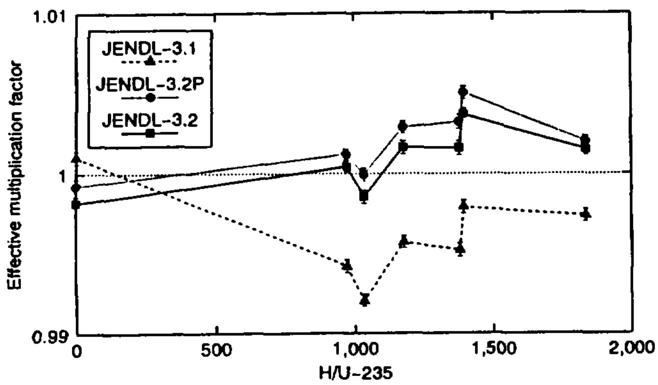

Fig.3 The k_{eff} values calculated with the MVP code for ORNL cores

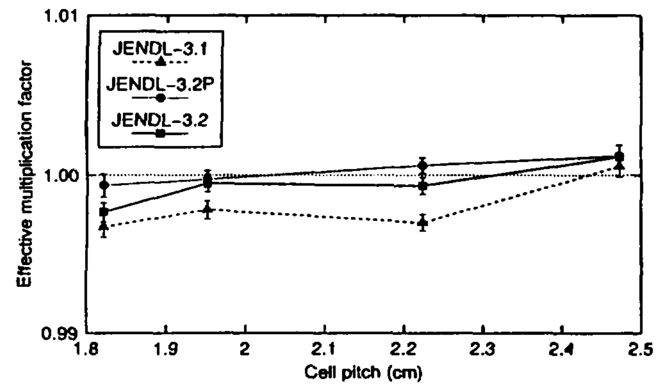

Fig.4 The k_{eff} values calculated with the MVP code for TCA-MOX cores

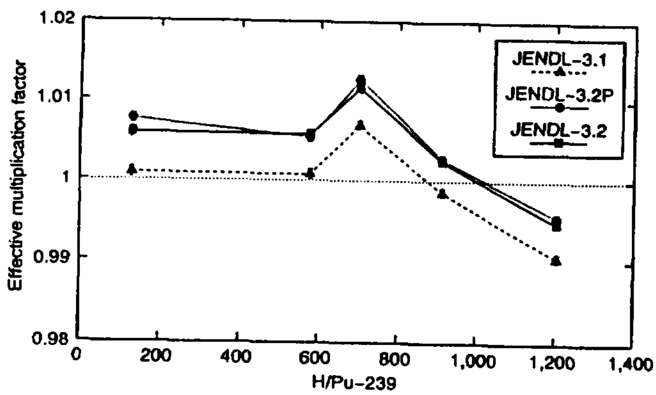

Fig.5 The k_{eff} values calculated with the MVP code for PNL cores.

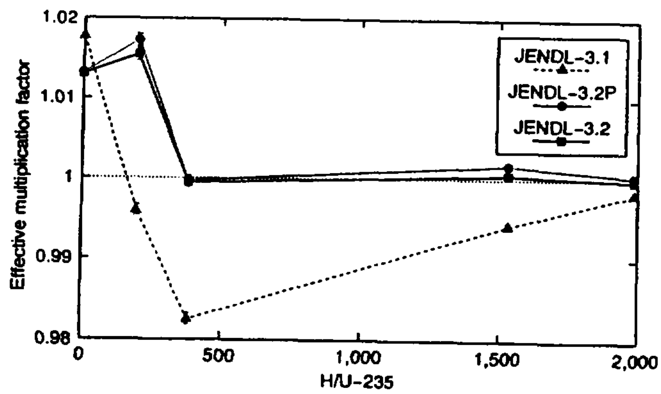

Fig.6 The k_{eff} values calculated with the MVP code for M&J cores.

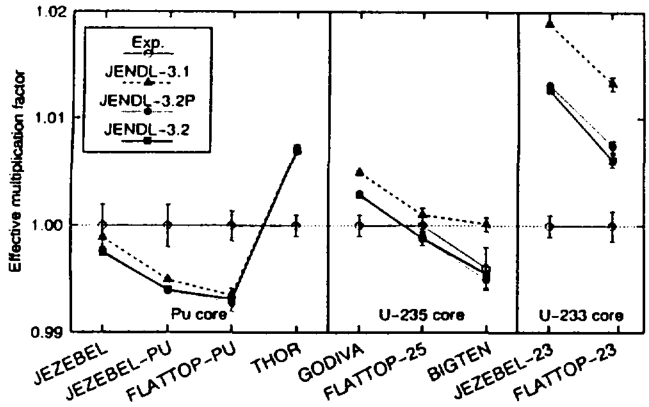

Fig.7 The k_{eff} values calculated with the MVP code for hard neutron spectrum cores

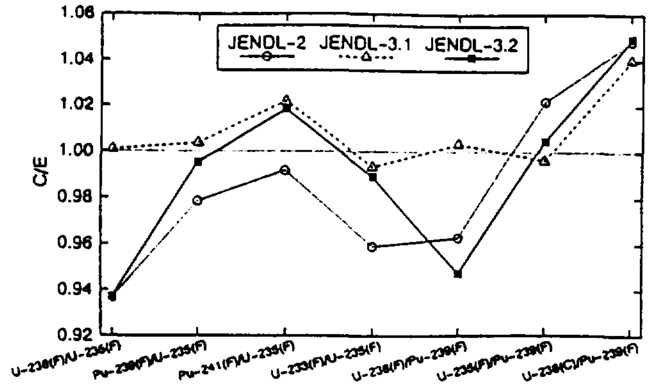

Fig.8 The C/E values of central reaction rate ratios in ZPPR-9

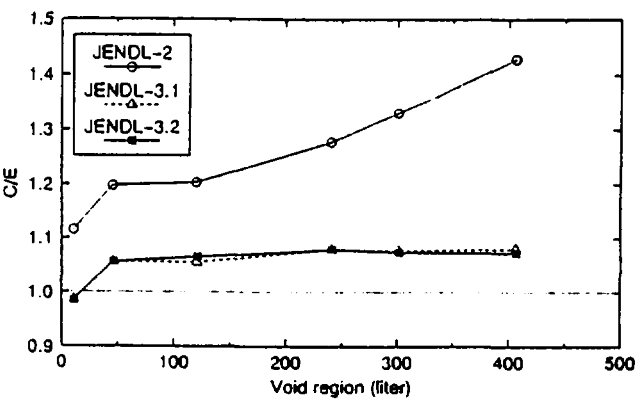

Fig.9 The C/E values of Na-void reactivity in ZPPR-9

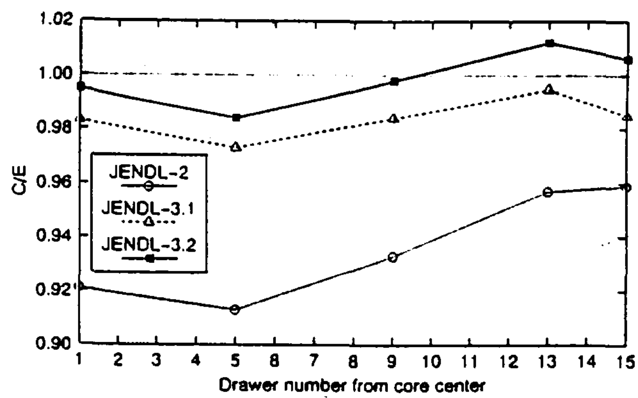

Fig.10 The C/E values of control rod worth in ZPPR-9

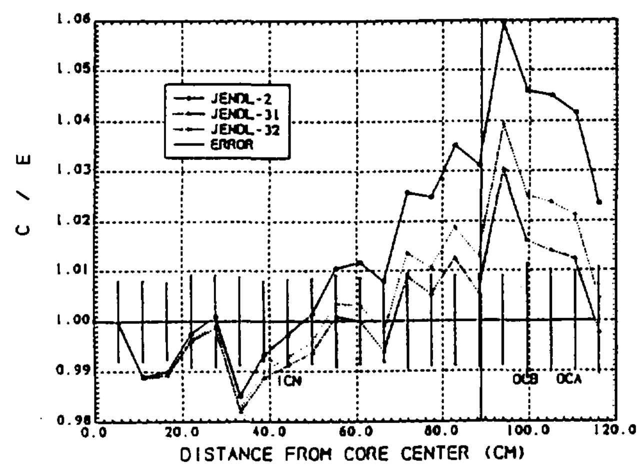

Fig.11 The C/E values of ^{239}Pu fission rate distribution in ZPPR-9

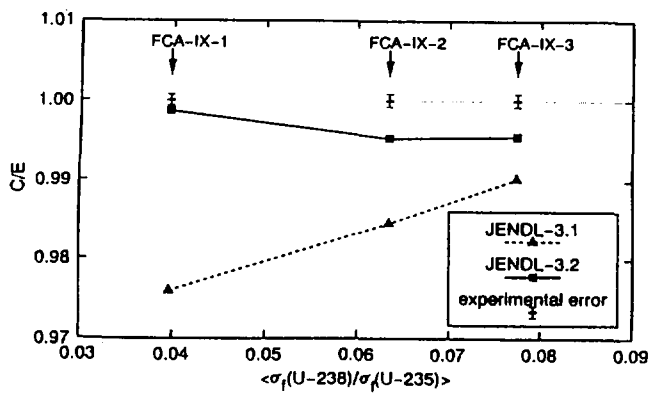

Fig.12 The C/E values of k_{eff} in FCA-IX -1,2 and 3