Compared Performances of ENDF/B-VI and JEF-2.2 for MOX Core Physics

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The US is currently evaluating the use of MOX fuel in commercial LWR's for reducing weapons grade Pu stockpiles. The design and licensing processes will require that the validity of the nuclear data libraries and codes used in the effort be demonstrated. Unfortunately, there are only a very limited number of relatively old and non representative integral experiments' freely available to the US programs.

This lack of adequate experimental data can be partially remediated by comparing the results of well validated European codes with the results of candidate US codes. The demonstration can actually be divided in two components:

- a code to code (Monte Carlo) comparison can easily demonstrate the validity and limits of the proposed algorithms.
- the performances of nuclear data libraries should be compared, major trends should be observed, and their origins should be explained in terms of differences in evaluated nuclear data.

In this paper, we have compared the performances of the JEF-2.2 and ENDF/B-VI.4 libraries for a series of benchmarks for k_{eff}, void worth, and pin power distributions. Note that JEF-2.2 has been extensively validated for MOX applications[1].

DISCLAIMER

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In order to obtain systematic comparisons between JEF-2.2 and ENDF/B-VI results, the two libraries were implemented with the same processing code options in two independent code systems:

- VIM[2], a continuous energy Monte Carlo code developed at ANL, with its own processing codes independent of NJOY
- DRAGON[3], a 2D lattice code developed at Ecole Polytechnique de Montreal. A standard 172 energy group structure was used in the NJOY processing code.

The computational schemes used with DRAGON were extensively benchmarked[4] with respect to VIM, and the same differences between JEF-2.2 and ENDF/B-VI were observed for both code systems.

DRAGON is also linked to a simple perturbation code, which can be used to analyze the origin of observed discrepancies.

A first series of benchmarks consisted of the pin cell model utilized for code validation within the JEF Project, with three types of MOX fuel: weapons grade MOX, first recycle MOX, and third recycle MOX. Calculations were run without buckling (to measure the effects of the principal cross-sections) and with the ENDF/B-VI critical buckling (to measure the effects of the transport cross-sections). Calculations were also run with a voided moderator region, and no buckling.

The second benchmark was similar to the OECD MOX Pin Power benchmark. It consists of a MOX subassembly with 3 MOX enrichment zones, surrounded by a 5 pin layer of UO_2 pins and water holes. The OECD benchmark is representative of an experimental configuration from the EPICURE program for which an excellent agreement between calculated and measured pin powers has been demonstrated for JEF-2 based libraries[5].

RESULTS AND ANALYSIS

Table 1 provides all pin cell results. For all non voided cases, the agreement between ENDF/B-VI and JEF2 results is very good (to within 0.3%) For the non-voided, non leakage cases, the major contribution to the differences is due to the Pu-239 evaluations, (+275 to +444 pcm). Perturbation calculations indicate that the difference is essentially due to the slightly higher ENDF fission cross section in the resonance range. For the case with leakage, the difference is still small (-126 to -294 pcm), but with opposite sign: this is due to the large change in the U238 contribution (from +100 to -100 pcm), due to the higher JEF2 U-238 high energy (>100 Kev) elastic and total cross sections, leading to lower leakage.

For the voided case, the differences are substantial: up to 1.5%. It should be noted that these differences are coherent with the behavior observed in fast reactors. Perturbation analyses demonstrate that this large difference is due to the U238 elastic cross section at high energy, which is higher for JEF-2.2 (note that above , 1Mev, neutron importance has a positive slope with increasing energy: additional scattering reduces total importance).

Furthermore, there is a huge difference in void worths (thus in moderator density coefficient) between the military and civilian MOX cases. This difference is due essentially to the lower Pu enrichment in the military cases: this leads to a slightly lower k in the moderated case (compensated by the reduction in Pu 240 content) and a significantly lower k in the voided case. The differences in pin power for the UO_2 - MOX benchmark are systematically lower than .4% with the ENDF results slightly peaked in the MOX region.

CONCLUSIONS

These results indicate that ENDF/B-VI and JEF2 evaluations give similar results for criticality and power distributions for MOX fuel. Nevertheless important differences arise for voided cases due to differences in the U238 elastic cross section evaluations.

ACKNOWLEDGMENTS

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Table 1: Benchmark Results for MOX Pin Cells

	WEAPONS GRADE MOX			FIRST RECYCLE MOX			THIRD RECYCLE MOX		
	$B^2 \equiv 0$	Critical B-VI B^2	$B^2 \equiv 0$ VOIDED	$B^2 \equiv 0$	Critical B^2	$B^2 \equiv 0$ VOIDED	$B^2 \equiv 0$	Critical B^2	$B^2 \equiv 0$ VOIDED
k_{eff}:									
B-VI	1.32050	1.00000	.76603	1.26064	1.00000	1.18570	1.21548	1.00000	1.15571
JEF-2.2	1.31915	1.00294	.75828	1.25802	1.00126	1.17214	1.21479	1.00229	1.14054
Difference (pcm)	+135	-294	+775	+262	-126	+1356	+69	-229	+1517
Major Contributions (pcm)									
Pu-239	+275	+204	-226	+359	+288	-280	+444	+339	-362
Pu-240	-113	-83	+15	-147	-124	+347	-175	-138	+255
Pu-241	-10	-7	-5	-166	-139	+45	-23	-19	+8
Pu-242				-72	-57	+29	-61	-47	+34
U-238	+76	-222	+1710	+124	-87	+1581	+125	-122	+1515
Zr	-60	-159	-118	-41	-117	-219	-44	-133	-232

a) Critical buckling for B-VI data