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

P.J. Finck, K. Laurin-Kovitz, A. Mohammed, G. Palmiotti, C. Stenberg
Reactor Analysis Division - Argonne National Laboratory

Summary of a Paper to be Submitted to:
1998 ANS Winter Meeting and The Meeting Of The Americas
November 15-19, 1998, Washington, DC

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 applications¹.
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
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**, a continuous energy Monte Carlo code developed at ANL, with its own processing codes independent of NJOY
- **DRAGON**, 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 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 \( \text{UO}_2 \) 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.
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)
esthetic 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 UO2 - 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


REFERENCES


4. P. Finck et al., "Validation of DRAGON for LWR MOX Applications", this meeting

5. J. P. Chauvin et al., "EPICURE: Synthesis of an Experimental Program Devoted to the Validation of a Calculation Scheme for PWR's Recycling MOX," Procs. PHYSOR 96, Mito, Japan (9/96)
Table 1: Benchmark Results for MOX Pin Cells

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

a) Critical buckling for B-VI data