Chapter 15

VALIDATION STUDIES MADE USING JEF-2.2 WITH NEW EVALUATIONS INCLUDED

We consider here studies of the effects of using the new evaluations for ^{235}U, sodium and ^{56}Fe.

The ENDF/B-VI.5 ^{235}U evaluation

This evaluation, produced by Derrien, Larson and Leal at ORNL, is characterised by increased capture in the resolved resonance range. There are also other differences; small changes to the fission cross-section and nubar and revised cross-sections in the thermal energy range. The analyses of the PROFIL sample irradiation measurements have shown a need to increase the capture above the resolved resonance range, but this revision has yet to be made.

Studies for a set of lattices at CEA Cadarache

Alet, *et al*. (JEF/DOC-707 [1]) have made calculations using APOLLO-2 version 3 for a series of LWR lattices, Cristo 1, 2 and 3, Caméléon and UH1.2 measured in the EOLE facility. These are lattices with measured bucklings, which use PWR type UOX fuel pins and have ^{235}U enrichments in the range 3-3.5% and water to UO_2 ratios in the range 0.45-5.5. In addition calculations have been made for the intermediate spectrum system ZPR HiC6 which emphasises the importance of the ^{235}U resonance range.

						(C-E) pcm	(C-E) pcm
	P	R	q	B^2	s.d.	JEF-2.2	Mod. ^{235}U
Cristo 3	0.96	0.45	0.37	1.95	500	1307	531
ZPRHIC6	1.24	0.96	0.51	4.747	400	-87	-603
UH1.2	1.26	1.27	0.51	6.05	300	309	-181
Caméléon	1.26	1.80	0.57	5.085	300	818	434
Cristo 2	1.58	3.56	0.76	3.575	300	-291	-481
Cristo 1	1.86	5.46	0.89	-0.09	300	231	108

P: Denotes the lattice pitch.
R: The water to UO_2 volume ratio.
B^2: The critical buckling ($10^{-3}/cm^2$).
q: The slowing down density.
s.d.: The experimental uncertainty (pcm).
JEF-2.2: The APOLLO-2 version 3 values of (C-E) in pcm.
Mod. ^{235}U: Denotes the results obtained using the ENDF/B-VI.5 (ORNL) ^{235}U evaluation.

One notes the improved agreement, obtained in most cases, using the ^{235}U evaluation incorporated in ENDF/B-VI revision 5.

Studies made at Winfrith relating to the ^{235}U resonance region

C. Dean, D. Hanlon and R. Perry presented a paper at the Reactor Physics Conference [2] studying the effects of the changes incorporated in the ENDF/B-VI revision 5 ^{235}U evaluation. They selected a set of ten benchmarks covering a range of intermediate and thermal spectrum systems. They include two TOPSY reflected uranium hydride systems, UH3Ni and UH3UR, which have hard spectra, the Winfrith Hector intermediate spectrum uranium fuelled system (HISS), two uranium flouride systems (hardest spectrum, UF1 and softest spectrum, UF6), a UO_2 lattice studied at CEA Valduc, DIMPLE SO1, TRX-1 and the hardest and softest spectrum ORNL spheres, ORNL1 and ORNL-10. The calculations were made using the MONK-8 hyperfine Monte Carlo code and the statistical accuracy is typically ±80 pcm.

System	**q**	**MONK-8/JEF-2.2**	**MONK-8 + ^{235}U B-VI, rev. 5**
		(C-E) in pcm	**(C-E) in pcm**
UH3-UR	0.031	1 643	-17
UH3-Ni	0.058	2 577	600
HISS(HUG)	0.141	3 103	1 090
UF1	0.391	700	-127
Valduc UOX lattice	0.488	27	-260
DIMPLE SO1	0.503	-93	-577
TRX-1	0.628	-580	-683
UF6	0.792	20	-23
ORNL-1	0.843	-370	-200
ORNL-10	0.932	-217	-292

One notes the much improved agreement for the four hardest spectrum systems resulting from the use of the ENDF/B-VI revision 5 resonance region data for ^{235}U, with its increased resonance capture. However, the agreement is worsened for DIMPLE SO1, which has a spectrum closer to that of a UOX fuelled PWR.

Studies made for criticality systems by I. Guimier and A. Nouri

In a paper presented to the Criticality Conference [3], I. Guimier and A. Nouri compared calculations made using JEF-2.2 with those using the new ENDF/B-VI.5 evaluation for ^{235}U in place of the JEF-2.2 evaluation. This evaluation is now part of JEFF-3.0. The experiments investigated belong to the six following categories:

1. Low enriched uranium solutions (LEU_SOL_THERM).
2. High enriched uranium solutions (HEU_SOL_THERM).
3. Mixed uranium and plutonium solutions (MIX_SOL_THERM).
4. Uranium dioxide powders of low enrichment, density and moderation (LEU_COMP_INTER).
5. Arrays of low enriched uranium pins (LEU_COMP_THERM).
6. Mixed uranium and plutonium lattices (MIX_COMP_THERM).

The names between brackets correspond to the ICSBEP classification, the majority of the experiments being taken from this source. The last part of the name is an indication of the spectrum in the system, thermal, intermediate or fast.

The average discrepancies between calculations and experiments for JEF-2.2 and JEFF-3.0 for the different classes of media are given in the following table:

Class	Average (C-E) for JEF-2.2	Average (C-E) for JEFF-3.0
LEU_SOL_THERM	126	-18
MIX_SOL_THERM	247	281
HEU_SOL_THERM	702	52
LEU_COMP_INTER	452	-258
LEU_COMP_THERM	177	-107
MIX_COMP_THERM	-162	-207

From this table, we can see that JEFF-3.0 improves the overall average prediction and reduces the calculation-experiments discrepancies for systems having a significant component of the spectrum at intermediate energies (wet powder media, tight lattices and highly enriched solutions with high concentrations). The systematic over-predictions observed in the past for high concentrated highly enriched solutions and for wet uranium powders are removed.

Effect of using the new evaluation for sodium

A large number of sodium voiding measurements have been made in the MASURCA critical facility. In JEF/DOC-725, G. Rimpault, *et al*. describe analyses of sodium voiding measurements made in MASURCA as part of the CIRANO programme [4]. In addition to the analysis made using the JEF-2.2 library the adjusted library, ERALIB1 was used, and also ERALIB1 together with a new evaluation for sodium based on recent measurements of total and inelastic scattering cross-sections made at ORNL and IRMM Geel.

Measurements are made for different zones of the reactor thus having different contributions from the leakage and non-leakage terms to the total sodium voiding reactivity effect. It is usual to interpret the results in terms of factors to be applied to the non-leakage and the axial and radial leakage terms. However, the factor to be applied to the non-leakage term can be strongly dependent on the accuracy of the adjoint flux calculation and can vary with the core composition. Results for two different cores, ZONA2A and ZONA1/R1 (8% ^{240}Pu), shown in Tables 15.1 and 15.2, illustrate the effects. The factors are those that give a best fit to the E/C values measured for the different voided zones of a particular core, a measure of the goodness of fit being the chi-squared value.

One sees that the E/C values are closer to unity and that the chi-squared values indicate a much better consistency in the fit. Using ERALIB1 without the new sodium evaluation does not show a marked improvement relative to JEF-2.2 for sodium voiding effects.

Table 15.1. E/C values for the non-leakage and axial and radial leakage terms, and the corresponding values of chi-squared – JEF-2.2 results

	Non-leakage	Axial leakage	Radial leakage	Chi-squared
ZONA2A	0.966	1.058	1.007	4.60
ZONA1/R1	0.911	1.061	1.002	4.30

Table 15.2. E/C results for ERALIB1 plus the new evaluation for sodium

	Non-leakage	Axial leakage	Radial leakage	Chi-squared
ZONA2A	1.025	1.017	0.994	0.68
ZONA1/R1	0.959	1.018	0.986	1.14

The new evaluation for ^{56}Fe

Calculations have been made for the iron benchmark described in Chapter 8, using the new evaluation for ^{56}Fe based on recent high resolution transmission and inelastic scattering measurements made at IRMM Geel (JEF/DOC-790) [5]. The sulphur, indium and rhodium reaction rates have been recalculated using MCBEND. For sulphur the results are similar to those obtained using JEF-2.2, increasing from 0.83 to 1.11. The indium results are much improved, being approximately constant through the shield at an average value of 0.96. For rhodium the C/E values increase from 0.96 to 1.11 through the shield, in contrast to the decrease from 0.94 to 0.87 obtained when using JEF-2.2. Overall there is an improvement in the agreement, although some differences remain.

An intercomparison of files for ^{240}Pu in fast reactor calculations

In JEF/DOC-724 P. Smith, G. Rimpault and O. Bouland compare calculations made using JEF-2.2, the adjusted library ERALIB1 and JEF-2.2 with a partial new evaluation for ^{240}Pu included [6]. This new resolved resonance region evaluation, by O. Bouland, H. Derrien, N. Larson and L. Leal, is based on measurements made at ORNL, Hanford and IRMM Geel and extends to 5.7 keV [7]. The new evaluation is similar to the ^{240}Pu data in the adjusted library, ERALIB1. A comparison of critical mass calculations for three cores having different plutonium isotopic vectors shows no marked differences between the results obtained using the different data sets. However, for sodium voiding reactivity effects the calculated effects are significantly different. The authors conclude that the new evaluation should be extended.

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