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ENDF/B THERMAL DATA TESTING

The thermal data testing group is concerned with establishing the merit of ENDF/B cross sections for the analysis of thermal systems. The integral experiments used in the testing are designed to analyze each of the phenomena identified in the familiar four-factor formula, $k = \eta f p \epsilon$. The experiments are simple, clean and well-documented to minimize the complexity of the analysis and provide the clearest test of the cross sections. Personnel from six organizations participated in Version III thermal data testing, thus blending a diversity of calculational methods: Floyd Wheeler (ANC); Jud Hardy (BAPL); D. S. Craig and M. Hughes (CRNL); Don Mathews (GGA); Lester Petrie (ORNL); and R. L. Reed and F. J. McCrosson (SRL).

For brevity, only the testing of the cross sections in uranium systems is described below. The results for plutonium systems are summarized in reference 1.

Uranyl Nitrate Spheres

CSEWG benchmark experiments ORNL-1, 2, 3, 4, and 10 in Table 1 refer to experiments by R. Gwin and D. W. Magnuson[2,3] in which critical compositions were determined for aqueous solutions of ^{235}U in spherical geometry. These experiments are useful for testing H_2O fast scattering data, the ^{235}U fission spectrum, thermal capture and fission of ^{235}U, and thermal absorption of hydrogen.

There is no ready explanation why the GGA results in Table 1 are 0.2 to 0.3% higher than the BAPL and SRL results. The GGA and SRL calculations used S_n methods, whereas the BAPL calculations were P_3 epithermally and double P_1 thermally with Marshak boundary conditions. Taken collectively, the BAPL, GGA, and SRL results indicate ENDF/B-III underpredicts k_{eff} by about 0.4%. This underprediction has been attributed in part to an underestimation of $\nu\sigma_f$ for ^{235}U at thermal energies. Also shown in Table 1 are ENDF/B-IV data testing results obtained at SRL. These results indicate there is a small improvement in the prediction of criticality for the ORNL spheres in going from Version III to Version IV. The observed increase in k_{eff} is primarily the result of a 0.7% increase in the ENDF/B-IV ^{235}U thermal values for $\nu\sigma_f$. Fast leakage is increased somewhat using ENDF/B-IV because the effective nuclear temperature for the ^{235}U fission spectrum is 1.30 MeV in Version III and 1.323 MeV in Version IV.

Uranium Lattices

Benchmark experiments TRX-1 and 2 in Table 1 correspond to lattice measurements by J. Hardy, Jr., D. Klein and J. J. Volpe.[4] These lattices contain slightly enriched (1.3%) uranium rods with diameters of 0.4915 cm. Benchmarks MIT-1, 2, and 3 correspond to D_2O-moderated lattices of natural uranium rods with diameters of 2.565 cm.[5] In addition to material bucklings, the TRX and MIT series of experiments determined several important activation parameters:

ρ^{28} = The ratio of epithermal-to-thermal ^{238}U captures

δ^{25} = The ratio of epithermal-to-thermal ^{235}U fissions

δ^{28} = The ratio of ^{238}U fissions to ^{235}U fissions

These benchmark experiments directly test the thermal and epithermal cross sections for ^{238}U capture and ^{235}U fissions and the ^{238}U fast fission cross section. They are sensitive to ^{238}U inelastic scattering, the ^{235}U fission spectrum, and the moderator cross sections.

The calculated values of k_{eff} reported by the laboratories for the lattices differ by as much as 3%. Part of this large variation may be attributed to the multiplicity of calculational methods used. Some laboratories used Monte Carlo, others the S_n approximation, and others integral transport theory. All the laboratories used detailed resonance treatments to account for resonance self-shielding, but again, there were variations in the methods and approximations. Differences can arise in the initial step of processing the ENDF/B point-wise data to multigroup form, but some of the laboratories were able to compare multigroup edits to eliminate this possibility.

The SRL results in Table 1 indicate that ENDF/B-IV yields a 1.0% increase in k_{eff} for the TRX lattices and a 1.4% increase for the MIT lattices. These increases significantly improve the prediction of k_{eff}, particularly when they are applied to the ~~[illegible]~~ average ENDF/B-III k_{eff} as determined by all the participating laboratories.

The calculated values of ρ^{28} in Table 2 correspond to a thermal cutoff energy 0.625 eV. The ENDF/B-III values are about 10% higher than experiment. This suggests epithermal ^{238}U neutron capture is being overpredicted by about 10%. This overprediction of epithermal ^{238}U capture largely accounts for the 1.5 to 2.0% underprediction of k_{eff} for the benchmark lattices. The ENDF/B-IV results for ρ^{28} are about 3% lower than the ENDF/B-III results obtained at SRL.

In concluding this section on thermal data testing, it will only be noted that the results for δ^{25} and δ^{28} for the lattices did not reveal any deficiencies in the ENDF/B-III or ENDF/B-IV data. The first of these parameters tests the epithermal ^{235}U fission cross section, while the second tests not only the ^{238}U fast fission cross section, but also the ^{238}U inelastic cross section and the ^{235}U and ^{238}U fission neutron spectra.

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TABLE 1

Criticality

CHMARK	DESCRIPTION	k_{eff} (ENDF/B-III) ANC	BAPL	CRNL	GGA	ORNL	SRL	k_{eff} (ENDF/B-IV) SRL
NL	Unref. spheres of uranyl nitrate sol.							
-1	H/U-235=1378; R=34.595 cm		0.9965		0.9999		0.9973	
-2	H/U-235=1177; R=34.595 cm		0.9963		0.9995			
-3	H/U-235=1033; R=34.595 cm		0.9933		0.9963			
-4	H/U-235= 971; R=34.595 cm		0.9947		0.9980		0.9958	
-10	H/U-235=1835; R=61.011 cm		0.9931		0.9956		0.9935	
X	H_2O moderated U lattices							
-1	Mod/Fuel = 2.35	0.9741	0.9872	0.9808	0.9791	0.995	0.9766	0.9875
-2	Mod-Fuel = 4.02	0.9823	0.9913	0.9876	0.9924	0.998	0.9859	0.9941
T	D_2O moderated U lattices							
-1	Mod/Fuel = 20.74			0.9801	0.9888	0.984	0.9735	0.9883
[illegible]	Mod/Fuel = 25.88			0.9804	0.9925	0.974	0.97[illegible]	0.9888
[illegible]	Mod/Fuel = 34.59			0.9826	0.9996	0.975	0.97[illegible]	0.9911

TABLE 2

Ratio of Epithermal-to-Thermal ^{238}U Captures*

BENCH-MARK	EXP	ρ^{28} (ENDF/B-III) ANC	BAPL	CRNL	GGA	ORNL	SRL	ρ^{28} (ENDF/B-IV) SRL
TRX-1	1.311 ±0.020	1.438	1.422	1.419	1.416	1.44	1.454	1.417
TRX-2	0.830 ±0.015	0.906	0.899	0.874	0.877	0.91	0.890	0.868
MIT-1	0.498 ±0.008			0.5319	0.534	.535	0.5683	0.5464
MIT-2	0.394 ±0.002			0.4365	0.435	.430	0.4659	0.4483
MIT-3	0.305 ±0.004			0.3400	0.334	.346	0.3624	0.3490

* Thermal cutoff energy = 0.625 eV