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CONTRIBUTION TO THE BENCHMARK OF JEF2 : RESULTS FOR ESADA LATTICES

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SUMMARY

We study a series of eleven critical experiments[1] with mixed-oxide $PuO_2 - UO_2$ with Apollo2 neutron transport code. We evaluate the effect of PuO_2 grain self-shielding which is more sensitive to water to fuel volume ratio than to Pu240 content. The isotopic composition of Pu240 and the water to fuel volume ratio vary respectively from 8% to 24% and from 1.125 to 8.257. Thus the weight of the thermal spectrum changes considerably. The information on nuclear data we can get from these integral measurements concern mainly Pu239 and Pu240 isotopes. Because of the very high radial buckling for some of these experiments, the results of cell calculations are certainly not enough accurate and even doubtful. Keeping this in mind, the agreement between experiment and calculation is overall satisfactory. Two dimensional transport calculations are planned to remove a part of the uncertainty on neutron leakage. Some part of the Apollo2 calculation will be checked with the Monte Carlo code Tripoli4.

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[1] $PuO_2 - UO_2$ fueled critical experiments WCAP-3726-1(1967)

99 group calculation

All these calculations were done with Wigner-Seitz cell and collision probability method. The transport correction was applied. This is very important for the greatest pitch. The mean effective multiplication factor for 99 group calculation is 1.00240±0.00565. This dispersion is consistent with the uncertainty on buckling.

Experiment	Vm/Vf	bore(ppm)	%at. Pu240	k_{eff}	k_{inf}	$B_r^2(m^{-2})$
1	1.125	0.	8.	0.99457	1.29505	61.00
3	1.557	0.	8.	0.99344	1.35405	81.00
4	3.5	0.	8.	1.00956	1.38186	95.25
6	4.366	0.	8.	1.00987	1.35157	88.90
7	8.257	0.	8.	1.00174	1.16773	40.75
8	1.125	261.	8.	1.00135	1.27186	53.82
9	3.5	261.	8.	1.00149	1.29285	74.19
10	1.125	526.	8.	0.99863	1.24932	49.39
11	3.5	526.	8.	0.99885	1.21530	53.46
12	3.5	0.	24.	1.00902	1.28840	70.00
13	4.366	0.	24.	1.00789	1.25983	63.70

TABLE I 99 group

172 group calculation

The mean k_{eff} for 172 group calculation is 0.99996±0.00553. This mean is approximately 240 pcm less than that for 99 group calculation. The multigroup discretisation is a sensitive parameter.

Experiment	Vm/Vf	bore(ppm)	%at. Pu240	k_{eff}	k_{inf}
1	1.125	0.	8.	0.99213	1.29627
3	1.557	0.	8.	0.99037	1.35491
4	3.5	0.	8.	1.00629	1.38215
6	4.366	0.	8.	1.00681	1.35176
7	8.257	0.	8.	0.99997	1.16768
8	1.125	261.	8.	0.99923	1.27310
9	3.5	261.	8.	0.99890	1.29322
10	1.125	526.	8.	0.99673	1.25059
11	3.5	526.	8.	0.99694	1.21574
12	3.5	0.	24.	1.00657	1.28880
13	4.366	0.	24.	1.00561	1.26010

TABLE II 172 group

172 group calculation with double heterogeneity

The mixed-oxide fuel are composed of PuO_2 and UO_2 particles, the first one having a mean diameter of 25 μm. The double heterogeneity formalism in Apollo2 code was used to take in account this fact. The derivative of k_{eff} over the radius of the grain is accurate only for grain radius less than 30 μm. The mean k_{eff} for 172 group calculation with the double heterogeneity is 0.99867±0.00523. The difference in the mean effective multiplication factor between homogeneous and doubly heterogeneous fuel is 123 pcm with practically no change in dispersion.

Experiment	Vm/Vf	bore(ppm)	slope pcm/μm	k_{eff}	k_{inf}
1	1.125	0.	-3.28	0.99200	1.29592
3	1.557	0.	-6.96	0.98986	1.35408
4	3.5	0.	-18.48	1.00470	1.37998
6	4.366	0.	-21.76	1.00488	1.34923
7	8.257	0.	-31.04	0.99713	1.16441
8	1.125	261.	-4.96	0.99899	1.27263
9	3.5	261.	-22.56	0.99696	1.29071
10	1.125	526.	-6.64	0.99641	1.25003
11	3.5	526.	-26.24	0.99470	1.21300
12	3.5	0.	-13.92	1.00549	1.28745
13	4.366	0.	-17.28	1.00421	1.25839

TABLE III 172 group with double heterogeneity(D.H.)

172 group with double heterogeneity and streaming correction

The cell calculation was made in B1 homogeneous fundamental mode on applying the Benoist streaming correction. The mean k_{eff} for 172 group calculation with streaming correction is 0.99588±0.00466. The dispersion is less than that of the other calculations.

Experiment	Vm/Vf	bore(ppm)	k_{eff}
1	1.125	0.	0.99019
3	1.557	0.	0.98713
4	3.5	0.	1.00050
6	4.366	0.	1.00078
7	8.257	0.	0.99490
8	1.125	261.	0.99735
9	3.5	261.	0.99372
10	1.125	526.	0.99490
11	3.5	526.	0.99230
12	3.5	0.	1.00205
13	4.366	0.	1.00092

TABLE IV 172 group with double heterogeneity and streaming correction

Conclusion

The most accurate calculation namely 172 group with double heterogeneity and streaming correction gives an overall good agreement with experiment. For Pu239 and probably for Pu240, we can conclude that there is no significant errors in JEF2 evaluation at this stage. Two dimensional transport calculation should reduce the dispersion, so it should be possible to precise if a problem exists for nuclear data of Pu239 in thermal range. In any case more benchmark tests are necessary.