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RESEARCH ARTICLE

A COMPARATIVE STUDY OF INTEGRAL PARAMETERS FOR TRX AND BAPL BENCHMARK LATTICES OF THERMAL REACTORS FOR NEUTRONICS ANALYSIS OF TRIGA MARK-II RESEARCH REACTOR AT CNESTEN USING THE CROSS-SECTION ENDB-VII AND JEFF3.1

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ABSTRACT

The objective of this paper is to present the results of comparative study of integral parameters for TRX and BAPL benchmark lattices of thermal reactors. The nuclear data processing code NJOY'99 was deployed for the generation of the 172-group cross-section library from the basic evaluated nuclear data files ENDFB-VII and JEF-3.1. TRX and BAPL benchmark lattices were modeled with optimized inputs, which were suggested in the final report of the WIMS Library Update Project .The inputs were the results of a detailed parametric study of the WIMS input options and also optimized for accuracy. The integral parameters (such as keff, ρ28, δ25, δ28, C*) of five uranium-fuel thermal assemblies: TRX-1 and TRX-2 and BAPL-1, BAPL-2, and BAPL-3 were calculated with the help of WIMSD-5B code based on the generated 172-group cross section library. The calculated results are compared with those of experiments and it is found that the obtained results between the two libraries are in good agreement with each other, which reflect the validation of the generated 172-group cross-section library and this library thus obtained is necessary to meet up the nuclear data for neutronics calculation of TRIGA Mark-II research reactor at CNESTEN, Rabat, Morroco.

INTRODUCTION

The WIMS package (Askew *et al*., 1966) is widely used for reactor calculations of a wide variety of thermal reactors. It consists of a lattice transport code and the associated library. One of the most commonly uses is to generate a few group cross-section library in problem dependent form to interface with neutronic codes. In this study, the 172-group cross-section libraries were generated for the lattice code WIMS based on basic evaluated data files ENDFB-VII and JEF-3.1 using nuclear data processing code NJOY'99 (MacFarlane and Muir, 1999). These cross-section libraries were used to benchmark the integral parameters of the TRX and BAPL lattices (CSEWG, 1981) calculated by WIMSD-5B (Kulikowska, 1996) reactor lattice code. These integral parameters were compared against the measured values. It has been found that this study shows a good performance of these libraries which are based on ENDFB-VII and JEF-3.1 data files and also the validation of the generated 172-group cross-section library for the lattice transport code WIMS through the analysis of the integral parameters of TRX and BAPL benchmark lattices (CSEWG, 1981).

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WIMS energy group structure

A library should have sufficient groups to make its group cross sections effectively independent of the condensation spectra used when generating them. In Table 1, the 172 group structure of WIMS library is shown. In the fast range, above 9.119 keV, there are 45 groups. In the resonance range, from 9.119 keV to 4 eV, there are 47 groups, and 80 thermal groups from 4 to10^{-5} eV

MATERIALS AND METHODS

Two computer codes, NJOY99 and WIMSD-5B, were used to validate the evaluated data files ENDFB.VII and JEFF-3.1 through benchmarking TRX and BAPL benchmark lattices.

NJOY code system

The version NJOY99.0 of NJOY has the capability to process data in ENDF/B-6 (Rose and Dunford, 1990) format, which is used in ENDF/B-VII (The US Evaluated Nuclear Data Library, 1993), and JEFF-3.1 (Nordborg and Salvatores, 1994). This nuclear data processing code was used to generate 172 group cross-section library based on evaluated data files ENDFB-VII and JEFF-3.1, respectively. The flow chart of nuclear data processing code NJOY99 for generation of WIMS library is shown in Fig. 1.

Table 1. 172 Energy group structure

Fast groups		Resonance Groups		Thermal Groups	
Group	Emax(ev)	Group	Emax(ev)	Group	Emax(ev)
1	1.96403E+07	46	9.11882E+03	93	4.00000E+00
2	1.73325E+07	47	7.46586E+03	94	3.38075E+00
3	1.49182E+07	48	5.53085E+03	95	3.30000E+00
4	1.38403E+07	49	5.00450E+03	96	2.76792E+00
5	1.16183E+07	50	3.52662E+03	97	2.72000E+00
6	1.00000E+07	51	3.35463E+03	98	2.60000E+00
7	8.18731E+06	52	2.24867E+03	99	2.55000E+00
8	6.70320E+06	53	2.03468E+03	100	2.36000E+00
9	6.06531E+06	54	1.50733E+03	101	2.13000E+00
10	5.48812E+06	55	1.43382E+03	102	2.10000E+00
11	4.49329E+06	56	1.23410E+03	103	2.02000E+00
12	3.67879E+06	57	1.01039E+03	104	1.93000E+00
13	3.01194E+06	58	9.14242E+02	105	1.84000E+00
14	2.46597E+06	59	7.48518E+02	106	1.75500E+00
15	2.23130E+06	60	6.77287E+02	107	1.67000E+00
16	2.01897E+06	61	4.53999E+02	108	1.59000E+00
17	1.65299E+06	62	3.71703E+02	109	1.50000E+00
18	1.35335E+06	63	3.04325E+02	110	1.47500E+00
19	1.22456E+06	64	2.03995E+02	111	1.44498E+00
20	1.10803E+06	65	1.48625E+02	112	1.37000E+00
21	1.00259E+06	66	1.36742E+02	113	1.33750E+00
22	9.07180E+05	67	9.16609E+01	114	1.30000E+00
23	8.20850E+05	68	7.56736E+01	115	1.23500E+00
24	6.08101E+05	69	6.79040E+01	116	1.17000E+00
25	5.50232E+05	70	5.55951E+01	117	1.15000E+00
26	4.97871E+05	71	5.15780E+01	118	1.12535E+00
27	4.50492E+05	72	4.82516E+01	119	1.11000E+00
28	4.07622E+05	73	4.55174E+01	120	1.09700E+00
29	3.01974E+05	74	4.01690E+01	121	1.07100E+00
30	2.73237E+05	75	3.72665E+01	122	1.04500E+00
31	2.47235E+05	76	3.37201E+01	123	1.03500E+00
32	1.83156E+05	77	3.05113E+01	124	1.02000E+00
33	1.22773E+05	78	2.76077E+01	125	9.96000E-01
34	1.11090E+05	79	2.49805E+01	126	9.86000E-01
35	8.22975E+04	80	2.26033E+01	127	9.72000E-01
36	6.73795E+04	81	1.94548E+01	128	9.50000E-01
37	5.51656E+04	82	1.59283E+01	129	9.30000E-01
38	4.08677E+04	83	1.37096E+01	130	9.10000E-01
39	3.69786E+04	84	1.12245E+01	131	8.60000E-01
40	2.92830E+04	85	9.90555E+00	132	8.50000E-01
41	2.73944E+04	86	9.18981E+00	133	7.90000E-01
42	2.47875E+04	87	8.31529E+00	134	7.80000E-01
43	1.66156E+04	88	7.52398E+00	135	7.05000E-01
44	1.50344E+04	89	6.16012E+00	136	6.25000E-01
45	1.11378E+04	90	5.34643E+00	137	5.40000E-01
		91	5.04348E+00	138	5.00000E-01
		92	4.12925E+00	139	4.85000E-01
				140	4.33000E-01
				141	4.00000E-01
				142	3.91000E-01
				143	3.50000E-01
				144	3.20000E-01
				145	3.14500E-01
				146	3.00000E-01
				147	2.80000E-01
				148	2.48000E-01
				149	2.20000E-01
				150	1.89000E-01
				151	1.80000E-01
				152	1.60000E-01
				153	1.40000E-01
				154	1.34000E-01
				155	1.15000E-01
				156	1.00000E-01
				157	9.50000E-02
				158	8.00000E-02
				159	7.70000E-02
				160	6.70000E-02
				161	5.80000E-02
				162	5.00000E-02
				163	4.20000E-02
				164	3.50000E-02
				165	3.00000E-02
				166	2.50000E-02
				167	2.00000E-02
				168	1.50000E-02
				169	1.00000E-02
				170	6.90000E-03
				171	5.00000E-03
				172	3.00000E-03
					1.00000E-05

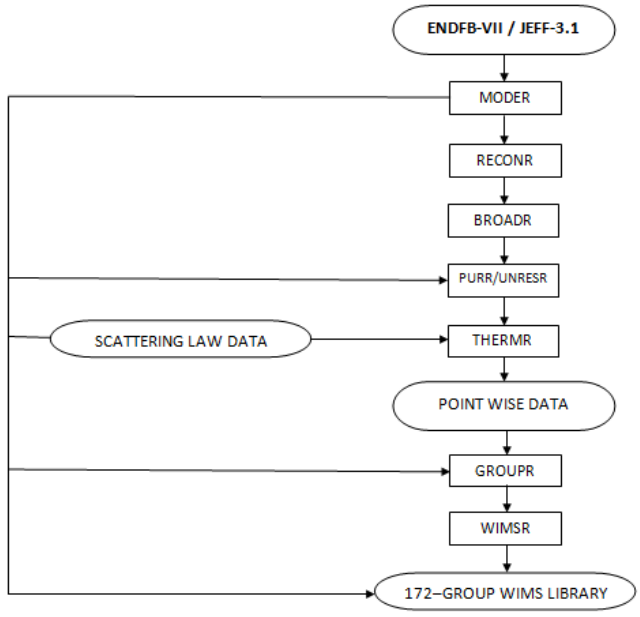

Fig 1. Flow chart of nuclear data processing code NJOY99.0 for generation of WIMS library

WIMSD-5B code

The Winfrith Improved Multigroup Scheme, WIMS package (Askew *et al*., 1996) was widely used for reactor calculations of a wide variety of thermal reactors. It consisted of a lattice transport code and the associated library. In particular, the code accepts rod or plate fuel geometries in either regular arrays or in clusters and the energy group structure has been chosen primarily for thermal calculations. The library has been compiled with 45 fast groups, 47 resonance groups and 80 thermal groups, but the user is offered the choice of accurate solutions in many groups or rapid calculations in few groups. Temperature dependent thermal scattering matrices for a variety of scattering laws are included in the library for the principal moderators which include hydrogen, deuterium, graphite, beryllium and oxygen. WIMSD-5B is a successor version of WIMS-D4. The treatment of resonances is based on the use of equivalence theorems with a library of accurately evaluated resonance integrals for equivalent homogeneous systems at a variety of temperatures. The collision theory procedure gives accurate spectrum computations in the 172 groups of the library for the principal regions of the lattice using a simplified geometric representation of complicated lattice cells. The computed spectra are then used for the condensation of cross sections to the number of groups selected for solution of the transport equation in detailed geometry. Solution of the transport equation is provided either by use of the Carlson DSN method or by collision probability methods. Leakage calculations including an allowance for streaming asymmetries may be made using either diffusion theory or the more elaborate B1-method. The output of the code provides eigenvalues for the cases where a simple buckling mode is applicable or cell-averaged parameters for use in overall reactor calculations. Various reaction rate edits are provided for direct comparison with experimental measurements. One of the most commonly uses was to generate a few group cross-section library in problem dependent form to interface with neutronics codes. In this study the reactions of uranium

isotopes U-235 and U-238 have been taken to calculate the integral parameters of TRX and BAPL benchmark lattices using the lattice cell code WIMSD-5B. The cross section data sets (group constants) in thermal region have been processed using the WIMS library utility code WILLIE for the isotopes U-235 and U-238 and were compared

Selected Benchmarks

For this analysis, two types of benchmark lattices were used:

- H2O moderated uranium metal(UME) lattices: TRX-1 and TRX-2 (Hardy *et al*., 1970)
- H2O moderated uranium oxide (UO2) critical lattices: BAPL-UO2-1, BAPL-UO2-2 and BAPL-UO2-3 (Hellens and Price, 1964).

The specifications of the TRX and BAPL benchmarks are shown in Tables 2 and 3 respectively. The input file of wimsd-5b of the TRX and BAPL benchmarks are shown in Appendix A and Appendix B. respectively

Table 2. TRX benchmarks specifications

Pitch (cm)	Trx_um1: 1.8060
	Trx_um2: 2.1740
Lattice geometry	hexagonal
Water/fuel volume ratio	Trx_um1 : 2.35
	Trx_um2 : 4.02
Moderator	H2O
Fuel material	
Fuel isotopic concentration (1024 atomes/cm^3)	U-235 : 0.0006253
	U-238 : 0.047205
Radius of fuel rods (cm)	0.4915
Clad material	Al
Clad isotopic concentration (1024 atomes/cm^3)	Al : 0.06025
Outer radius of clad (cm)	0.5753
Thickness of clad (cm)	0.0711
Temperature (all components) (k)	293
Experimental buckling B2 (cm^{-2})	Trx_um1 : 0.00517 ± 0.0005
	Trx_um2 : 0.004943 ± 0.000526

Calculation of benchmark parameters

Calculation of benchmark parameters are as follows:

keff – effective multiplication factor,
ρ28 – the ratio of epithermal to thermal capture reaction rates in ^{238}U,
δ25 – the ratio of epithermal to thermal fission reaction rates in ^{235}U,
δ28 – the ratio of total fission reaction rates in ^{238}U and ^{235}U,
C* – the ratio of capture reaction rates in ^{238}U to fission reaction rates in ^{235}U.

The parameters correspond to a thermal cutoff energy of 0.625 eV.

Table 3. BAPL benchmarks specifications

Pitch (cm)	Bapl_1 : 1.5578
	Bapl_2 : 1.6523
	Bapl_3 : 1.8057
Lattice geometry	hexagonal
Water/fuel volume ratio	Bapl_1 : 1.43
	Bapl_2 : 1.78
	Bapl_3 : 2.40
Moderator	H2O
Fuel material	UO2(1.311 wt% enrichment)
Fuel isotopic concentration (1024 atomes/cm^3)	O : 0.046946
	U-235 : 0.0003112
	U-238 : 0.023127
Radius of fuel rods (cm)	0.48664
Clad material	Al
Clad isotopic concentration (1024 atomes/cm^3)	Al : 0.06025
Outer radius of clad (cm)	0.5753
Thickness of clad (cm)	0.0711
Temperature (all components) (k)	293
Experimental buckling B^2 (cm^{-2})	Bapl_1 : 0.002734 ± 0.000525
	Bapl_2 : 0.003018 ± 0.000529
	Bapl_3 : 0.002892 ± 0.000530

RESULTS AND DISCUSSIONS

The calculated results of integral parameters for TRX and BAPL benchmark lattices of thermal reactors with experiment are summarized in Tables 4.

For each of the benchmark lattices the measured as well as calculated values of integral parameters and the associated % uncertainty are given. In comparison to the experimental results it is found that the calculated values of keff for TRX and BAPL lattices using the said data libraries were generally well agreement with each other. for trx1 and trx2 uncertainty in keff was higher deviation from the experimental. In case of BAPL-1and BAPL-2 and BAPL-3 the values of uncertainty in keff are somewhat over predicted in comparison to the experiment. The discrepancies of the other parameters namely ρ28, δ25, δ28 and C* are:

Tables 4. Comparison of calculated integral parameters for BAPL and TRX lattices

Laticces	library	K-eff	ρ28	δ25	δ28	C*
trx_um1	experiment	1.00000(~.30)	1.320(~1.6)	0.0987(~1.0)	0.0946(~4.3)	0.797(~1.0)
	jeff3.1	0.99508(-.50)	1.364(3.34)	0.0967(-2.0)	0.0958(1.27)	0.796(-.13)
	endfb7	0.99477(-.53)	1.366(3.47)	0.0968(-1.9)	0.0981(3.73)	0.795(-.21)
trx_um2	experiment	1.00000(~.10)	0.837(~1.9)	0.0614(~1.3)	0.0693(~5.1)	0.647(~.93)
	jeff3.1	0.99494(-.51)	0.859(2.69)	0.0595(-3.2)	0.0690(-.45)	0.643(-.66)
	endfb7	0.99464(-.54)	0.860(2.78)	0.0595(-3.1)	0.0703(1.52)	0.642(-.76)
bapl1	experiment	1.00000(~.10)	1.390(~.72)	0.0840(~2.4)	0.0780(~5.1)	----------
	jeff3.1	1.00000	1.423(2.37)	0.0818(-2.6)	0.0748(-4.1)	0.809
	endfb7	0.99992(-.01)	1.426(2.55)	0.0819(-2.5)	0.0763(-2.2)	0.809
bapl2	experiment	1.00000(~.10)	1.120(~.89)	0.0680(~1.5)	0.0700(~5.7)	----------
	jeff3.1	0.99940(-.06)	1.186(5.90)	0.0667(-1.9)	0.0646(-7.6)	0.737
	endfb7	0.99915(-.09)	1.188(6.09)	0.0668(-1.8)	0.0659(-5.9)	0.737
bapl3	experiment	1.00000(~.10)	0.906(~1.1)	0.0520(~1.9)	0.0570(~5.3)	----------
	jeff3.1	0.99924(-.08)	0.934(3.10)	0.0513(-1.4)	0.0533(-6.4)	0.659
	endfb7	0.99904(-.10)	0.936(3.28)	0.0513(-1.3)	0.0543(-4.8)	0.659

For TRX1: 3.34%, -2%, 1.27%, and -0.13% from wims run based on jeff3.1 and 3.47% , -1.9% , 3.73% and -0.21% based on endfb-VII, respectively. The similar tendency is observed in case of trx2 as well. Hence, it can be mentioned that the calculated results are in good agreement with experimental values.

For Bapl-1 : 2.37% , -2.6% , and -1.4% from wims run based on jeff3.1 and 2.55% , -2.5% , and -2.2% based on endfb-VII, respectively. Experimental value of C* is not available of comparison. The similar tendency is observed in case of Bapl-2 and Bapl-3 as well. Hence, it can be concluded that the calculated results are in good agreement with the experimental value.

Conclusion

The results from the calculations shows a good consistency on the integral parameters calculated between the generated libraries based on the evaluated data files ENDFB-VII and JEFF3.1 using the WIMSD-5B code. Considering the overall observations it can be concluded that this analysis may put a noteworthy sign of the validation of evaluated nuclear data files ENDFB-VII and JEFF3.1 through benchmarking the integral parameters of TRX and BAPL lattices and can play a significant role to accomplish further neutronic analysis of TRIGA MARK-II research reactor at CNESTEN, RABAT, Morroco.

REFERENCES

Akbari M., A. Minuchehr, A. Zolfaghari, F. Khoshahval, 2012 : An investigation for an optimized neutron energy-group structure in thermal lattices using Particle Swarm Optimization.

Askew, J.R., Fayers, F.J., Kemshell, P.B., 1996. A general description of the lattice code WIMS. Journal of the British Nuclear Energy Society (October), 564.

Fayers, F.J., Davison, W., George, C.H., Halsall, M.J., 1972. LWR-WIMS, A Modular Computer Code for the Evaluation of Light Water Reactor Lattices – Part I: Description of Methods. UKAEA Report AEEW-R 785. Winfrith, England.

Kulikowska, T., 1996. WIMSD-5B: A Neutronic Code for Standard Lattice Physics Analysis, Distributed by NEA Data Bank. Saclay, France.

Lemmel, H.D., Schwerer, O. (Eds.), October 1993. JEF-2.2: the Evaluated Nuclear Data Library of the NEA Data Bank IAEA-NDS-120, Rev. 2.

MacFarlane, R.E., Muir, D.W., 1998. The NJOY Nuclear Data Processing System, NJOY97.0 Code System for Producing Pointwise and Multigroup Neutron and Photon Cross Sections from ENDF/B Data, RSICC Code Package PSR-368.

Nakagawa, T., Shibata, K., Chiba, S., 1995. Japanese evaluated nuclear data library: JENDL-3.2. Journal of Nuclear Science and Technology 32, 1259–1271.

Stamm'ler, R.J.J., Abbate, M.J., 1983. Methods of Steady-State Reactor Physics in Nuclear Design. Academic Press.

Uddin, M.N. *et al*., 2009. Validation of CENDL and JEFF evaluated nuclear data files for TRIGA calculations through the analysis of integral parameters of TRX and BAPL benchmark lattices of thermal reactors. Ann. Nucl. Energy 36 (2009), 1521–1526.

WLUP, 2007. WIMS-D Library Update: Final Report of a Coordinated Research Project. International Atomic Energy Agency, Vienna.

Appendix A : The input file of wimsd-5b of the TRX

```
**************************************************
*******
* WIMSD5B
* TRX-1   SEQUENCE 1   S12   REGULAR 1 6
* 7.11.91            STAND. INPUT   NMATERIAL 3
**************************************************
*******
CELL     6
SEQUENCE  1
NGROUP  172  2
NMESH    14
NREGION   4  0  4
NMATERIAL 3
NREACT    2
PREOUT
INITIATE
ANNULUS   1 0.4915    1
ANNULUS   2 0.5042    0
ANNULUS   3 0.5753    2
ANNULUS   4 0.94822   3
FEWGROUP
1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,
25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,4
5,46,47,48,
49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,6
9,70,71,72,
73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,9
3,94,95,96,
97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,1
12,113,114,115
,116,117,118,119,120,121,122,123,124,125,126,127,128,129,1
30,131,132,133
,134,135,136,137,138,139,140,141,142,143,144,145,146,147,1
48,149,150,
151,152,153,154,155,156,157,158,159,160,161,162,163,164,16
5,166,167,168
,169,170,171,172
MESH     4  1  1  8
MATERIAL  1 -1  293.0 1 2235 .0006253 8238 .047205
MATERIAL  2 -1  293.0 2   27 .06025
MATERIAL  3 -1  293.0 3 3001 .06676   6016 .03338
REGULAR   1  6
S       12
BEGINC
THERMAL 37
BEEONE    1
DNB       1 0.      0. 0.      0.
DNB       2 0.      0. 0.      0.
DNB       3 0.06676 0. 0.03338 0.
BUCKLINGS 0.005174  0.000526
DIFFUSION 1  3  1
LEAKAGE   5
REACTION  2235,293.0   8238,293.0
PARTITION 135 172
BEGINC
```

```
**********************************************
**
* WIMSD5
* TRX-2  SEQUENCE 1  S 12   REGULAR 1 6
* 17.5.91          STAND. INPUT   NMATERIAL 3
**********************************************
**
ANNULUS   4  1.1414   3
BEGINC
THERMAL  37
BEEONE    1
DNB       1 0.      0.   0.      0.
DNB       2 0.      0.   0.      0.
DNB       3 0.06676 0.   0.03338 0.
BUCKLING  0.004943  0.000526
DIFFUSION 1  3  1
LEAKAGE   5
REACTION  2235,293.0  8238,293.0
PARTITION 135 172
BEGINC
*END
```

Appendix B : The input file of wimsd-5b of the BAPL

```
**************************************************
*******
* WIMSD5
* BAPL-UO2-1   SEQUENCE 1   S12   REGULAR 1 6
* 7.5.91               STAND. INPUT   NMATERIAL 3
**************************************************
*******
CELL     6
SEQUENCE  1
NGROUP  172 2
NMESH    10
NREGION   4 0 4
NMATERIAL 3
NREACT    2
PREOUT
INITIATE
ANNULUS 1 0.4864   1
ANNULUS 2 0.5042   0
ANNULUS 3 0.5753   2
ANNULUS 4 0.8179   3
FEWGROUP
1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,
25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,4
5,46,47,48,
49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,6
9,70,71,72,
73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,9
3,94,95,96,
97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,1
12,113,114,115
,116,117,118,119,120,121,122,123,124,125,126,127,128,129,1
30,131,132,133
,134,135,136,137,138,139,140,141,142,143,144,145,146,147,1
48,149,150,
151,152,153,154,155,156,157,158,159,160,161,162,163,164,16
5,166,167,168
,169,170,171,172
MESH     4  1  1  4
MATERIAL  1 -1 293.0 1  2235 .0003112 8238 .023127 6016
.046946
MATERIAL  2 -1 293.0 2    27 .06025
MATERIAL  3 -1 293.0 3  3001 .06676   6016 .03338
REGULAR   1  6
S        12
BEGINC
THERMAL  37
BEEONE    1
DNB       1 0.   0.   0.    0.
DNB       2 0.   0.   0.    0.
DNB       3 0.06676   0.    0.03338 0.
BUCKLING  0.002734    0.000525
DIFFUSION 1 3 1
LEAKAGE   5
REACTION  2235,293.0  8238,293.0
PARTITION 135 172
BEGINC
**************************************************
******
* WIMSD5
* BAPL-UO2-2   SEQUENCE 1   S 12   REGULAR 1 6
* 17.5.91               STAND. INPUT   NMATERIAL 3
**************************************************
******
ANNULUS   4 0.86752  3
BEGINC
THERMAL  37
BEEONE    1
DNB       1 0.     0.   0.     0.
DNB       2 0.     0.   0.     0.
DNB       3 0.06676 0.   0.03338 0.
BUCKLING  0.003018  0.000529
DIFFUSION 1  3  1
LEAKAGE   5
REACTION  2235,293.0 8238,293.0
PARTITION 135 172
BEGINC
*END
**************************************************
******
* WIMSD5
* BAPL-UO2-3   SEQUENCE 1   S 12   REGULAR 1 6
* 17.5.91               STAND. INPUT   NMATERIAL 3
**************************************************
******
ANNULUS   4  0.94806  3
BEGINC
THERMAL  37
BEEONE    1
DNB       1 0.     0.   0.     0.
DNB       2 0.     0.   0.     0.
DNB       3 0.06676 0.   0.03338 0.
BUCKLING  0.002892  0.000530
DIFFUSION 1  3  1
LEAKAGE   5
REACTION  2235,293.0 8238,293.0
PARTITION 135 172
BEGINC
*END
```

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