International Atomic Energy Agency

INDC(RUM)-9/GV

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COMPARISON OF SOME MULTIGROUP NUCLEAR DATA SETS ON EXISTING FAST NEUTRON ASSEMBLIES

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January 1979

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

Reproduced by the IAEA in Austria
January 1979
79-00069

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ABSTRACT

In the present paper some multigroup nuclear data sets are analysed in terms of the neutronic parameters of some existing fast assemblies.

I. INTRODUCTION

It is well known the importance of nuclear data in providing design parameters for a nuclear reactor. In the last time some multigroup nuclear data sets for fast reactor studies were published /1, 2, 13/. In this paper an analysis of neutronic parameters of existing fast assemblies is done by using the sets published in /1, 2/, comparatively with the elder set of Abagyan et al. /3/.

The following approximations have been used: homogeneous and heterogeneous fundamental mode and one-dimensional diffusion and transport.

II. THE MULTIGROUP DATA SETS ANALYSED

II.1. ABBN - 1964 set /3/

This set is very known. It was used in many fast reactor calculations and contains the majority of elements entering in fast reactor compositions.

II.2. The Modified ABBN set /1/

The basic data of this set are those from the ABBN-1964 set excepting for U-235, U-238 and Pu-239 isotopes which have

been reevaluated. For U-235 and Pu-239, the cross sections for infinite dilution only have been reevaluated, the selfshielding factors being the same as in ABBN-1964 set.

II.3. The UKNDF set /2/

We call UKNDF set, the microscopic multigroup data set in ABBN scheme obtained by Menapace et al /2/ using the English nuclear data file (UKNDF), version 1970.

The selfshielding factors in the unresolved resonance region were calculated by making use of ENDF/B data library, version 2 (1970). The set contains the majority of fissile elements and structural materials for fast reactors.

III. FAST ASSEMBLIES

In order to draw as complete as possible conclusions, many types of reactors varying as geometry, dimensions, fuel type and enrichment, neutron spectrum and core structure have been analysed.

To meet this end, a selection of twelve plutonium and uranium based fast critical assemblies was made for criticality studies.

The considered assemblies are : JEZEBEL, ZPR-III-48, ZEBRA-6A, ZEBRA-3, ZPR-6-7, GODIVA, SUAK UH 1B, ZPR-III-10, ZPR-III-25, SNEAK-3A1, MINERVE and PROTEUS cells.

A part of these assemblies were selected by the Cross Section Evaluation Working Group /11/ and others were taken from the papers of E.Kiefhaber and J.J.Schmidt /4/, J.Bouchard et al. /7/ and S.Seth et al. /8/.

The selected assemblies cover a wide range of neutron spectra: from very soft to very hard ones. Therefore, they are indicated for testing the group cross-section sets in the keV to MeV energy range. The main characteristics of the assemblies and the references used are presented in the Table I.

IV. THE TYPE OF CALCULATIONS

IV.1. Homogeneous fundamental mode

The homogeneous fundamental mode equation mainly gives the material buckling for a composition, the neutron spectrum and neutron balance. In this paper the material buckling is to be compared for the multigroup data sets under study. It is known that

the material buckling gives information about the critical dimension of the homogeneous composition.

The code EROS /5/ with the macroscopic data prepared with the code PRESEC /6/ have been used in order to calculate the material buckling for the following reactors: SUAK-UH 1B (composition 1), ZPR-III-10 (composition 1), ZPR-III-25 (composition 1), ZPR-III-48 (composition 1), ZEBRA-6A (composition 1), SNEAK-3A1 (composition 4).

IV.2. Heterogeneous fundamental mode

Neutronic parameters given by the heterogeneous fundamental mode equation and used in the present analysis are the followings:

- infinite medium neutron multiplication coefficient, $K_\infty(B_m^2=0)$,
- the neutron multiplication coefficient for the infinite medium with leakage, K^* $(B_m^2 \neq 0)$,
- cell material buckling, B_m^2,
- the neutron multiplication coefficient for the infinite medium with leakage, taking into account the (n,2n) reactions, $K_{n,2n}$,
- the migration area, M^2,
- the one group diffusion coefficient, D,
- the total balance for the cell normalized for a neutron production equals 1,
- reaction rates in the fuel for the main fissile isotopes.

The above parametes have been calculated for two cells with uranium and two with plutonium, studied in the coupled fast-thermal experience ERMINE /7/.

Besides, a cell with uranium and plutonium, studied in the coupled fast-thermal reactor PROTEUS /8/, has been investigated.

By their compositions the five cells cover a wide range of neutron spectra specific to the fast reactors. A simple cylindrical geometry allowing a two regions cell calculation (fuel and diluent) is the main advantage of these cells.

The spectrum of a sodium cooled power fast reactor is simulated by ERMINE cells and of a gas cooled fast reactor by PROTEUS cell.

ERMINE lattice is consisting of uranium fuel rods with 30 % enrichment and U-Pu-Fe alloy introduced in a graphite matrix with different pitches. PROTEUS lattice is a hexagonal one with the pitch of 1 cm.

Calculations were performed by means of the code TRIZON /9/ with the macroscopic cross sections prepared with the code PRESEC.

IV.3. One dimensional diffusion calculations

One dimensional multigroup diffusion equation has been used for calculating the neutron effective multiplication factor, k_{eff}.

The following assemblies with different neutron spectra have been studied: SUAK UH 1B, ZPR-III-10, ZPR-III-25, ZPR-III-48, ZPR-6 6A, ZEBRA-6A, SNEAK-3A1, ZPR-6-7, ZEBRA-3.

Geometry data, transversal bucklings, boundary conditions, number of zones, zone dimensions and number of mesh intervals have been taken from the mentioned references.

The k_{eff} - values have been obtained using the code CAIN /10/ with macroscopic data calculated with the code PRESEC.

IV.4. One dimensional transport calculations

Using one dimensional transport equation, k_{eff} and central spectral indices have been computed for ten assemblies (except for MINERVE and PROTEUS cells) in spherical geometry.

Reactor composition, geometrical dimensions and boundary conditions were taken from the respective references.

In the present calculations the code ANISN /12/ was used with the options recommended in the references for the studied assemblies.

V. THE METHOD OF ANALYSIS

In order to analyse the results obtained the procedures presented bellow have been used:

- comparison of the values calculated using the multigroup sets with the experimental results;
- if there are no experimental values, the results obtained using the multigroup cross section sets have been analysed by comparison with the results obtained by means of other multigroup sets considered as standard ones or which have been tested on experimental measurements.

One has to point out two limitations of these procedures:

- the experimental data for ERMINE and PROTEUS cells which are to be compared with those obtained in heterogeneous fundamental mode approximation should be corrected with factors calculated by using multigroup cross section sets available in the respective center,
- the computing codes used in the present work are different from that used in the papers we are comparing with.

VI. RESULTS OBTAINED

VI.1. Homogeneous fundamental mode

The values for the material buckling are given in the Table II. In the last column the values for SNEAK cross section sets are presented. One can see from the Table II a systematic agreement between the results obtained with ABBN-70 and UKNDF sets.

The difference between ABBN-70 and ABBN-64 results are greater (up to 19 %) than those between UKNDF and ABBN-70 (about 15 %). One can observe that the greatest deviations are for ZPR-III-48 and ZEBRA-6A. This is normal because the two assemblies have plutonium fuel and as was noticed above the plutonium cross sections were reevaluated. The results obtained with ABBN-70 and ABBN-64 sets for the hard spectrum reactors (SUAK-UH 1B) are close, due to the fact that the reevaluation has been done especially in the intermediate range of the spectrum.

VI.2. Heterogeneous fundamental mode

In the Tables III - VI are presented the results for ERMINE (U1, U2, P1, P2) cells and for PROTEUS cell in the Table VII.

Concerning the capture contribution to the total balance, the discrepancies were less than 5 % for uranium containing ERMINE cells, but become large for plutonium ERMINE cells, in the order of more than 15.6% for ABBN-64 and ABBN-70.

However an agreement of ∿ 2.5 % between ABBN-70 and UKNDF sets can be observed.

For the PROTEUS cell a discrepancy of 11.5 % between ABBN-64 and ABBN-70 appears, especially due to the Pu-239 capture cross sections because for the uranium cells the discrepancies were smaller.

The results for K_∞, K* and B_m^2, from the Tables III - VII, show a satisfactory agreement between ABBN-70 and UKNDF for all the analyzed cells. The discrepancies between ABBN-64 and ABBN-70 are in order of 6 % for K_∞ and K* and 19% for B_m^2 for the plutonium cells.

Discrepancies can be observed for the cpture reaction rates in U-235, U-238, Pu-239 and mainly in Pu-240.

The greatest discrepancies can be seen for the high isotopes of Pu, thus the cross sections for these elements have to be reevaluated.

A comparison of our results and the theoretical and experimental results from the literature /7,8/ is presented in Tables VIII, IX and X.

The principal quantities to be compared are:

- The neutron multiplication coefficient, K*,

This parameter is presented only for the ERMINE cells.

A good agreement between our results and the results published at Fontenay-aux-Roses (F.A.R.) was found; the differencies are in the range of 3 % for uranium cells, and for the plutonium cells in the range of 6.7 % for ABBN-64 sets.

A general remark for the sets used in this paper is their over reactive character by comparison with F.A.R. results, especially for the plutonium cells.

The parameter K for PROTEUS cell is presented in the literature /8/ without the specification as being an infinite medium value ($B_m^2 = 0$) or an infinite medium with leakage.

K_∞ and K* are close to the values for K for other cross section sets and a greater value is obtained with ABBN-64 set, according to the known over reactive character of this set.

- The material buckling, B_m^2,

The results obtained with the ABBN-70 and UKNDF sets are in good agreement with those published by

F.A.R. (3 %) excepting the U1 cell having a deviation of 10 % for the UKNDF set.

A great dispersion is found for the PROTEUS cell, the maximum deviation is of the order of 30 %; but the values obtained with the ABBN-70 cross sections set are yet in the range of 7 % by comparison with the other sets.

- The spectral index $(28_f/25_f)$ in fuel and diluent

It is an important quantity, mainly for U1 and U2 cells, the uranium being the only contributor to the production and the principal contributor to the absorption (60 %). Differences up to 14 % are found for the ABBN-64 set, comparing with the F.A.R. results, for the cells U1 and U2.

It is interesting to observe the better agreement, for some cases, between ABBN-70 and UKNDF sets and the experimental values, comparing with the F.A.R. results. It was observed, sistematically, greater discrepancies between our results and F.A.R. ones for the diluent values than for the fuel. This could be mainly due to a poor knowledge of the spectrum in the diluent than a difference in cross sections.

- The spectral index $(28_c/25_f)$

Significant differences are to be observed, for the cross section sets under study and between calculated and experimental results. This is consistent with the different values for U-238 capture cross section for various sets and suggest both the necessity of reevaluation of U-238 and the improvement of the treatment for the resonance self-shielding.

- The spectral index $(49_f/25_f)$

An analysis of the calculated results points out the relative good agreement between ABBN-70 and UKNDF sets.

VI.3. One dimensional calculations

The neutron multiplication factors calculated in the diffusion and transport approximations are presented in the Tables XI and XII respectively.

As far as plutonium based assemblies are concerned the maximum deviation between ABBN-64 and ABBN-70 results is of the order of 6.6 % whereas between ABBN-70 and UKNDF is 2.9 % only.

For hard spectrum assemblies the deviations are smaller what seems to indicate the plutonium nuclear data in the high energy range are consistent in the nuclear data libraries underlying the analized sets.

The main differences seem to arise in the intermediate energy range.

For uranium based assemblies the same tendency has been observed: the discrepancies between ABBN 64 and ABBN-70 are greater than those for ABBN-70 and UKNDF.

Generally, the values of the deviations are smaller than those for plutonium based assemblies. Spectral indices calculated with the analized sets are given in Table XIII.

VII. CONCLUSIONS

It should be point out the agreement of the results obtained with ABBN-70 and UKNDF sets for the main part of calculation types. One can see the well known over-reactive character of ABBN-64 set.

Also, the calculations show the over-reactive character of the ABBN-64, ABBN-70 and UKNDF sets in comparison with F.A.R. set.

Discrepancies among the data sets and between calculation and experiments can be observed for capture reaction rates and spectral indices, especially for U-238.

It seems the capture cross section for U-238 to be underestimated. Thus, a new evaluation for U-238 appears to be necessary. A similar conclusion was revealed in /13/.

There are great deviations among the capture and fission reaction rates for Pu-240, Pu-241, Pu-242. It is known that in different works it was recommended the reevaluation of nuclear data for the high isotopes of plutonium /14/.

The present work indicates the necessity of this reevaluation.

For hard spectrum assemblies ABBN-64 and ABBN-70 give comparable results because the reevaluated data in ABBN-70 are mainly in the intermediate energy range.

The ABBN-70 set seems to be appropriate for calculating neutronic parameters of power fast reactors.

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TABLE I: CHARACTERISTICS OF THE ANALYZED ASSEMBLIES

Assembly	Characteristics	Reference
1	2	3
JEZEBEL	A bare core assembly of plutonium metal with a very hard neutron spectrum	/11/
ZPR-3-48	A plutonium fueled small fast critical assembly with a soft spectrum and other characteristics reprezentative of current LMFBR designs	/4/
ZEBRA-6A	A small plutonium assembly with a fuel enrichment of about 24%; Na and C added to influence the neutron spectrum in the desired manner	/4 /
VERA-11A	A cylindrically shaped critical assembly fueled with plutonium and diluted with graphite	/11/
ZPR-6-7	A large plutonium oxide fueled fast critical assembly with a soft spectrum and other characteristics reprezentative of current LMFBR designs	
GODIVA	A bare sphere of enriched uranium metal	/11/
SUAK UH1B	A metal uranium fueled assembly containing a relative large amount of hydrogen in foils of polyethylene	/4/
ZPR-3-10	A metal uranium fueled assembly with a rather small core surrounded by a relatively large reflector of depleted uranium	/4/
ZPR-3-25	A large core with uranium metal fuel	/4/
SNEAK-3A1	It was built to simulate the core of a fast steam cooled power reactor	/4/

TABLE I: CHARACTERISTICS OF THE ANALYZED ASSEMBLIES
(Continuation)

1	2	3
ZPR-6-6A	A uranium oxide fueled fast critical assembly with a soft spectrum	/4/
ZEBRA-3	A9:1 uranium/plutonium metal assembly with hard spectrum	/4/
ERMINE U1, U2 P1, P2	Two of the four cells studied in the ERMINE-II assembly, U2 and P2, are similar with these used for the reactor MASURCA and U1 and P1 are uranium-graphite and plutonium - graphite cells	/7/
PROTEUS	Fast reactor cell with uranium and plutonium, studied in the coupled fast-thermal reactor PROTEUS	/8/

TABLE II: RESULTS CALCULATED IN FUNDAMENTAL MODE APPROXIMATION

SET REACTOR	ABBN-64	ABBN-70	UKNDF	KFK /4/
SUAK UH1B	0.1753E-01	0.1740E-01	0.1873E-01	0.2053E-01
ZPR-III-10	0.8307E-02	0.7710E-02	0.7743E-02	0.8137E-02
ZPR-III-25	0.3017E-02	0.2725E-02	0.2315E-02	0.3172E-02
ZPR-III-48	0.2811E-02	0.2362E-02	0.2289E-02	0.2701E-02
ZEBRA-6A	0.3514E-02	0.3028E-02	0.3028E-02	0.3459E-02
SNEAK 3A1	0.2301E-02	0.2111E-02	0.2191E-02	0.2201E-02

TABLE III: CALCULATED NEUTRONIC PARAMETERS OF THE CELL U1

	ABBN-64	ABBN-70	UKNDF	CALC. F.A.R.
k_∞	1.5462	1.5537	1.5852	
Bm^2	0.00378	0.00368	0.00399	0.00361
K^*	1.5935	1.5965	1.6240	1.5743
K(n,2n)	1.59708	1.60021	1.62760	
$\overline{D}$	1.36512	1.35277	1.31687	
M^2	158	163	157	
C	0.2267	0.2251	0.2156	
F	0.4008	0.4012	0.4002	
A	0.6275	0.6263	0.6158	
L	0.3738	0.3750	0.3856	
$\phi\sigma f5$	164.06	164.76	164.65	
$\phi\sigma c5$	54.927	50.590	46.722	
$\phi\nu\sigma f5$	404.73	406.24	407.72	
$\phi\sigma f8$	6.3572	6.1274	5.9765	
$\phi\sigma c8$	18.877	20.387	19.827	
$\phi\nu\sigma f8$	17.842	17.185	16.543	

C, F, A and L stand for capture, fission, absorbtion and leakage contributions to the total balance.

TABLE IV: CALCULATED NEUTRONIC PARAMETERS OF THE CELL U2

	ABBN-64	ABBN-70	UKNDF	CALC. F.A.R.
K_∞	1.5617	1.5663	1.5966	
Bm^2	0.00426	0.00411	0.00445	0.00406
K^*	1.6115	1.6122	1.6387	1.5966
K(n,2n)	1.61546	1.61617	1.64193	
$\overline{D}$	1.3476	1.33452	1.29757	
M^2	144	149	144	
C	0.2203	0.2197	0.2109	
F	0.4001	0.4005	0.3996	
A	0.6205	0.6202	0.6105	
L	0.3809	0.3812	0.3909	
$\emptyset\ \sigma f5$	144.92	145.54	145.53	
$\emptyset\ \sigma c5$	46.713	43.361	40.171	
$\emptyset\ \nu\sigma f5$	357.92	359.28	360.75	
$\emptyset\ \sigma f8$	5.9661	5.7609	5.6053	
$\emptyset\ \sigma c8$	16.861	18.152	17.733	
$\emptyset\ \nu\sigma f8$	16.749	16.161	15.521	

TABLE V: CALCULATED NEUTRONIC PARAMETERS OF THE CELL P1

	ABBN-64	ABBN-70	UKNDF	CALC. F.A.R.
K_∞	1.5993	1.5106	1.5323	
Bm^2	0.00362	0.00309	0.00332	0.00319
K^*	1.6935	1.5950	1.6083	1.5707
K(n,2n)	1.69651	1.59776	1.61153	
$\overline{D}$	1.32395	1.31241	1.27509	
M^2	192	193	184	
C	0.2481	0.2856	0.2791	
F	0.3423	0.3414	0.3425	
A	0.5905	0.6269	0.6217	
L	0.4107	0.3743	0.3797	
$\emptyset\ \sigma f5$	87.48	296.46	296.16	
$\emptyset\ \sigma c5$	29.29	114.99	109.25	
$\emptyset\ \nu\sigma f5$	704.01	725.74	728.73	
$\emptyset\ \sigma f8$	6.8514	6.7355	6.5498	
$\emptyset\ \sigma c8$	26.395	29.685	28.552	
$\emptyset\ \nu\sigma f8$	19.260	18.919	18.157	
$\emptyset\ \sigma f9$	208.07	207.22	208.84	
$\emptyset\ \sigma c9$	68.219	82.173	86.276	
$\emptyset\ \nu\sigma f9$	610.54	610.11	613.27	

TABLE V: CALCULATED NEUTRONIC PARAMETERS OF THE CELL P1

(Continuation)

	ABBN-64	ABBN-70	UKNDF	CALC. F.A.R.
$\phi \sigma f0$	41.727	43.210	46.453	
$\phi \sigma c0$	115.07	126.50	47.676	
$\phi \nu\sigma f0$	126.61	131.05	143.17	
$\phi \sigma f1$	430.09	467.46	415.80	
$\phi \sigma c1$	87.225	94.865	69.590	
$\phi \nu\sigma f1$	1283.7	1394.7	1189.6	
$\phi \sigma f2$	31.536	32.625	30.151	
$\phi \sigma c2$	161.39	175.49	167.47	
$\phi \nu\sigma f2$	97.727	101.07	93.541	

TABLE VI: CALCULATED NEUTRONIC PARAMETERS OF THE CELL P2

	ABBN-64	ABBN-70	UKNDF	CALC. F.A.R.
1	2	3	4	5
K_∞	1.6417	1.5497	1.5657	
Bm^2	0.00434	0.00373	0.00394	0.00380
K^*	1.74792	1.6483	1.65491	1.6368
K(n,2n)	1.75182	1.65190	1.65901	
$\overline{D}$	1.31987	1.30817	1.26917	
M^2	173	175	167	
C	0.2304	0.2659	0.2623	
F	0.3417	0.3407	0.3419	
A	0.5721	0.6069	0.6043	
L	0.4292	0.3947	0.3973	
$\emptyset\,\sigma f5$	226.52	232.94	235.78	
$\emptyset\,\sigma c5$	95.688	85.298	82.286	
$\emptyset\,\nu\sigma f5$	555.76	571.34	581.05	
$\emptyset\,\sigma f8$	6.2976	6.2036	6.0140	
$\emptyset\,\sigma c8$	21.7009	24.429	23.836	
$\emptyset\,\nu\sigma f8$	17.713	17.435	16.684	
$\emptyset\,\sigma f9$	172.707	172.00	173.38	
$\emptyset\,\sigma c9$	51.805	62.893	66.173	
$\emptyset\,\nu\sigma f9$	507.92	507.60	510.35	

TABLE VI: CALCULATED NEUTRONIC PARAMETERS OF THE CELL P2

(Continuation)

1	2	3	4	5
$\emptyset\ \sigma f0$	38.083	39.520	42.207	
$\emptyset\ \sigma c0$	84.435	92.405	38.102	
$\emptyset\ \nu\sigma f0$	115.61	119.92	130.18	
$\emptyset\ \sigma f1$	329.73	357.45	322.96	
$\emptyset\ \sigma c1$	63.739	68.969	50.824	
$\emptyset\ \nu\sigma f1$	985.75	1068.2	918.30	
$\emptyset\ \sigma f2$	28.787	29.845	27.564	
$\emptyset\ \sigma c2$	105.332	111.09	110.21	
$\emptyset\ \nu\sigma f2$	89.254	92.499	85.556	

TABLE VII: CALCULATED NEUTRONIC PARAMETERS OF THE CELL PROTEUS

	ABBN-64	ABBN-70	UKNDF
K_∞	1.4362	1.3611	1.3571
Bm^2	0.00144	0.00119	0.00109
K^*	1.5403	1.4644	1.4416
K(n 2n)	1.5454	1.4692	1.4467
$\bar{D}$	2.0929	2.0660	2.1695
M^2	378	395	408
C	0.3063	0.3408	0.3498
F	0.3428	0.3419	0.3438
A	0.6492	0.6828	0.6936
L	0.3529	0.3193	0.3088
$\phi\,\sigma f5$	227.79	235.33	245.89
$\phi\,\sigma c5$	65.357	64.557	65.327
$\phi\,\nu\sigma f5$	562.23	580.56	608.28
$\phi\,\sigma f8$	7.4931	7.3853	7.3093
$\phi\,\sigma c8$	28.340	31.399	32.821
$\phi\,\nu\sigma f8$	21.114	20.792	20.318
$\phi\,\sigma f9$	224.15	221.79	223.53
$\phi\,\sigma c9$	43.100	48.645	54.065
$\phi\,\nu\sigma f9$	660.11	655.55	658.98

TABLE VII: CALCULATED NEUTRONIC PARAMETERS OF THE CELL PROTEUS

(Continuation)

	ABBN-64	ABBN-70	UKNDF
$\phi \sigma_{f0}$	52.236	54.373	58.755
$\phi \sigma_{c0}$	67.199	77.949	39.882
$\phi \nu\sigma_{f0}$	157.55	163.89	180.26
$\phi \sigma_{f1}$	298.37	343.01	320.82
$\phi \sigma_{c1}$	41.960	49.245	42.217
$\phi \nu\sigma_{f1}$	896.86	1029.6	907.14

TABLE VIII: EXPERIMENTAL - CALCULATION COMPARISON FOR SPECTRAL INDICES OF THE CELLS U1, U2, P1, P2

U1	ABBN-64	ABBN-70	UKNDF	CALC. F.A.R.	EXP. F.A.R.
$(^{28}f/^{25}f)^F$	0.0387	0.0372	0.0363	0.0338	0.0363 ± 0.001
$(^{28}f/^{25}f)^D$	0.0308	0.0297	0.0288	0.0280	0.0296 ± 0.0006
U2					
$(^{28}f/^{25}f)^F$	0.0412	0.0396	0.0385	0.0360	0.0357 ± 0.0007
$(^{28}c/^{25}f)^F$	0.1163	0.1247	0.1220	0.124	0.138 ± 0.004
$(^{28}f/^{25}f)^D$	0.0339	0.0324	0.0311	0.0306	0.0322 ± 0.0005
P1					
$(^{28}f/^{25}f)^F$	0.0238	0.0227	0.0221	0.0243	—
$(^{28}c/^{25}f)^F$	0.0918	0.1001	0.0998	0.1201	—
$(^{49}f/^{25}f)^F$	0.723	0.699	0.705	0.863	0.95 ± 0.001
$(^{28}c/^{25}f)^D$	0.0190	0.0182	0.0179	0.0206	0.0213 ± 0.0004
$(^{49}f/^{25}f)^D$	0.929	0.928	0.944	0.966	—
P2					
$(^{28}f/^{25}f)^F$	0.0278	0.0266	0.0251	0.0281	0.0297 ± 0.0007
$(^{28}c/^{25}f)^F$	0.0958	0.1049	0.1011	0.1195	0.130 ± 0.004
$(^{49}f/^{25}f)^F$	0.7525	0.7384	0.7353	0.880	—
$(^{28}f/^{25}f)^D$	0.0226	0.0221	0.0212	0.0240	0.0248 ± 0.0005
$(^{49}f/^{25}f)^D$	0.925	0.912	0.924	0.959	0.95 ± 0.01

F stands for fuel and D for diluent

TABLE IX: COMPARISON OF CALCULATED NEUTRONIC PARAMETERS FOR PROTEUS CELL /15/

	ENDFB/3		ASEA	KFK	FGL	CAD	ABBN	ABBN	UKNDF
	GGC5	SPENG	ATOM	INR	4	III	64	70	
K_∞	1.436	1.437	1.490	1.486	1.501	1.519	1.436	1.361	1.357
Bm^2		12.87	12.98	13.17	13.65	13.01	14.46	11.87	10.94
K^*							1.540	1.464	1.441
K(n,2n)							1.545	1.469	1.446
$\bar{D}$							2.093	2.066	2.170
M^2		340	378	369	367	397	378	394	408

TABLE X: COMPARISON OF EXPERIMENTAL AND CALCULATED (C/E) VALUE OF THE SPECTRAL INDICES FOR PROTEUS CELL /8/

	ENDFB/3		ASEA	KFK	FGL	CAD	ABBN	ABBN	UKNDF	EXP
	GGC5	SPENG	ATOM	INR	4	III	64	70		/8/
$^{28}c/^{49}f$	1.057	1.082	1.042	1.030	0.980	0.975	0.942	1.0557	1.095	0.1341
$^{28}c/^{49}f$	0.955	0.969	0.981	1.005	0.963	1.023	1.072	1.068	1.049	0.0312
$^{25}f/^{49}f$	1.018	1.030	0.993	1.009	1.019	1.004	1.003	1.046	1.085	1.0137

TABLE XI: ONE DIMENSIONAL DIFFUSION CALCULATIONS FOR k_{eff}
(spherical model)

Reactor \ Set	ABBN-64	ABBN-70	UKNDF	KFK/4/
SUAK UH1B	0.93234	0.92732	0.94990	0.8808
ZPR-III-10	0.99758	0.97568	0.97044	0.9752
ZPR-III-25	0.99285	0.97800	0.95455	0.9700
SNEAK-3A1	1.01659	0.99237	1.00295	0.9911
ZPR-6-6A	1.02614	1.00090	0.99952	–
ZPR-III-48	1.01882	0.95942	0.94441	–
ZEBRA-6A	1.01831	0.95714	0.95289	0.9630
ZPR-6-7	1.03562	0.97112	0.95012	–
ZEBRA-3	0.98580	0.95685	0.92914	–

TABLE XII: ONE DIMENSIONAL TRANSPORT CALCULATIONS FOR k_{eff}

Reactor \ Set	ABBN-64	ABBN-70	UKNDF
GODIVA	1.03508	1.0133	1.01587
ZPR-III-10	1.008168	0.98615	0.980478
ZPR-III-25	0.99572	0.98088	0.95703
SNEAK-3A1	1.02000	0.99582	1.01047
ZPR-6-6A	1.02701	1.00026	1.00050
ZPR-III-48	1.02642	0.96663	0.95159
ZEBRA-6A	1.02345	0.97254	0.96330
ZPR-6-7	1.03794	0.97326	0.95254
ZEBRA-3	0.99436	0.96530	0.93683
JEZEBEL	1.01749	0.99518	0.99185

TABLE XIII: SPECTRAL INDICES CALCULATED WITH ANISN

SPECTRAL INDEX	JEZEBEL ABBN-64	JEZEBEL ABBN-70	JEZEBEL UKNDF	JEZEBEL EXP	ZPR-3-48 ABBN-64	ZPR-3-48 ABBN-70	ZPR-3-48 UKNDF	ZPR-3-48 EXP
$^{28}f/^{25}f$	.1924	.1889	.1892	.205 ± .008	.0332	.0333	.0316	.0321 ± .0076
$^{28}c/^{25}f$	.0765	.0773	.0821	—	.1284	.1380	.1381	.131 ± .007
$^{49}f/^{25}f$	1.3860	1.3769	1.3713	1.49 ± 0.03	.9660	.9368	.9064	—
	GODIVA				ZEBRA-3			
$^{28}f/^{25}f$	.0846	.1478	.1566	.156 ± .005	.0440	.0434	.0398	.0461 ± .0008
$^{28}c/^{25}f$	.1050	.0861	.0885	—	.1141	.1137	.1206	—
$^{49}f/^{25}f$	1.1857	1.3349	1.3479	1.42 ± 0.02	1.1777	1.1525	1.1182	1.190 ± 0.014