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MOMENTS OF THE FOURIER-TRANSFORMED NEUTRON SLOWING-DOWN KERNEL: THE COMPUTER CODE "MAGGIE"

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ABSTRACT

The computer code MAGGIE and its first results are presented. This code has been elaborated for the calculation of the moments of the Fourier-transformed neutron slowing down kernel. Several conclusions can be drawn on the basis of the first applications of the code concerning epithermal scattering cross sections.

АННОТАЦИЯ

Программа MAGGIE и первые результаты её применения представлены в отчёте. Программа была разработана для расчёта моментов преобразованного по методу Фурье ядра замедления нейтронов. Некоторые выводы получены из надтепловых сечений рассеяния, на основе первых применений программы.

KIVONAT

A MAGGIE számitógépi kód leirását és az első kapott eredményeket tartalmazza a report. A kód a Fourier-transzformált neutron lassulási magfüggvény momentumainak kiszámitására alkalmas. A kóddal nyert első eredmények alapján több következtetést lehet levonni epitermikus szórási hatáskeresztmetszet adatokat illetően.

1. INTRODUCTION

Fermi-age and higher moments of the Fourier transformed slowing-down kernel are characteristic to the slowing-down properties of reactor materials. Series of measurements were performed for water and for mixtures of Al, Zr and Fe and water [3, 4, 5, 6]. Results of these measurements were used for testing the corresponding parts of multigroup constant libraries.

Moments of the Fourier transformed slowing-down kernel are calculated by a computer code named MAGGIE. This code was developed on the basis of the already existing code GRACE [2], which is a B_1 or P_1 neutron spectrum calculating program similar to MUFT [8]. The algorithm of the calculation is described in Chapter 2. A similar technique was used for testing the WIMS library [7].

Two libraries were analyzed as far as slowing-down moments are concerned. The first of them is the traditional GRACE library. The second library was generated by the FEDGROUP program system [9] using generally the KEDAK evaluated nuclear data file [10]. Results of the calculations are presented in Chapter 3. The calculational results are generally in reasonable agreement with the reported experimental WIMS library analysis results.

2. SOLUTION OF THE FUNDAMENTAL EQUATIONS

Moments of the Fourier-transformed slowing-down kernel for a plane source in an infinite homogeneous medium are defined as

$$N_n(E) = \int_{-\infty}^{\infty} \phi(z,E)z^n dz,$$

where $\phi(z,E)$ is the neutron flux at energy E in the point Z. The Fermi-age (τ) corresponds to $N_2/2No$ at a given E, if N_2 and N_o are calculated in the Fermi approximation.

In the program MAGGIE the moments of the Legendre polynomial expansion terms of the neutron flux are calculated. According to [1] they are defined as

$$M_{n\ell}(E) = \frac{1}{n!} \int_{-\infty}^{\infty} Z^n f_{\ell o}(Z,E)dZ,$$

where $f_{\ell o}$ is taken from the expansion

$$\phi(Z, E, \underline{\Omega}) = \sum_{\ell=o}^{\infty} \sum_{m=-\ell}^{\ell} f_{\ell m}(Z,E) P_{\ell m}(\underline{\Omega}).$$

It can be easily seen, that

$$N_n = 4\pi n! \, M_{no}.$$

The equations for the moments $M_{n\ell}$ are derived in [1] /eq. 11.45/. After slight modifications one obtains:

$$\frac{4\pi}{2\ell+1} \int_0^{\infty} S_\ell(E' \to E) \, M_{n\ell}(E') \, dE' + I_n(E) \, \delta_{\ell o} + S(E)\delta_{\ell o}\delta_{no} =$$

$$= - \left[\frac{\ell+1}{2\ell+3} M_{n-1,\ell+1}(E) + \frac{\ell}{2\ell-1} M_{n-1,\ell-1}(E) \right] + \Sigma_T(E) M_{n\ell}(E). \qquad /1/$$

for $\ell = 0, 1, 2, \ldots$
$n = 0, 1, 2, \ldots$.

Here $S_\ell(E' \to E)$ are the expansion coefficients of the elastic scattering kernel

$$\Sigma_s^{el}(E' \to E, \underline{\Omega}' \to \underline{\Omega}) = \sum_{\ell=o}^{\infty} S_\ell (E' \to E) \, P_\ell (\underline{\Omega}\underline{\Omega}')$$

and $i_\ell(E' \to E)$ are the analogous coefficients for inelastic scattering:

$$\Sigma_s^{inel}(E' \to E, \underline{\Omega}' \to \underline{\Omega}) = \sum_{\ell=o}^{\infty} i_\ell (E' \to E) \, P_\ell (\underline{\Omega}\,\underline{\Omega}').$$

Assuming isotropic inelastic scattering $/i_\ell = 0$ for $\ell > 0/$, the only contribution of inelastic scattering to eq./1/ is

$$I_n(E) = 4\pi \int_0^{\infty} i_o(E' \to E) \, M_{no}(E') \, dE'.$$

Assumption of isotropic angular plane source distribution leads to the term $S(E)\,\delta_{\ell o}\delta_{no}$. $\Sigma_T(E)$ is the total macroscopic cross section of the medium.

In the actual equation for n = O the bracket on the right hand side vanishes. It can be expressed as

$$M_{n\ell} \equiv 0 \quad \text{for } n < 0 .$$

Eq. /1/ can be rewritten in the lethargy variable as

$$\frac{4\pi}{\ell+1} \int_0^\infty S_\ell \,(u' \rightarrow u)\, M_{n\ell}\,(u')\, du' + I_n\,(u)\,\delta_{\ell o} - \Sigma_T\,(u)\, M_{n\ell}\,(u) =$$

$$= -\left[\frac{\ell+1}{2\ell+3} M_{n-1,\ell+1}\,(u) + \frac{\ell}{2\ell-1} M_{n-1,\ell-1}\,(u)\right] - S\,(u)\,\delta_{\ell o}\delta_{no} \; . \qquad /2/$$

For given n and ℓ, the right hand side is considered as a "source" term for the equation. For $n=\ell=0$ only the term S(u) gives the "source", while for other values of n and ℓ only the bracket on the right hand side represents the "source". $M_{o\ell}$ is equal to zero for $\ell>0$, as the "source" is zero. $M_{1\ell}$ is not vanishing only for $\ell=1$, as the right hand side contains a non-zero term $/M_{oo}/$ only in this case. Continuing this argumentation, it can be easily seen that $M_{n\ell} \neq 0$ only for $n \geq \ell$ and $n + \ell$ even.

Solution of the system of equations /2/ is performed step by step. The following assumptions are made /corresponding to the usual structure of our group constant libraries [2]/:

a./ Integrals of the elastic slowing-down kernels S_ℓ are evaluated for light elements in the Greuling-Goertzel, for heavy elements in the Fermi approximation.

b./ P_1 - approximation is used in the expansion of the elastic scattering kernel, i.e. $S_\ell \,(u' \rightarrow u) \equiv 0$ for $\ell > 1$.

The method of the step by step solution of the system of equations /2/ is based on the recognition, that pairs of these equations /for $\ell = 0$ and $\ell = 1$/ can be coupled to equations of the multigroup P_1 /or B_1/ code GRACE [2]. Exceptions are the case /n = O, ℓ = O/, which corresponds to the infinite medium case of GRACE, and the cases $\ell \geq 2$, which give simple algebraic expressions, as $S_\ell \,(u' \rightarrow u) \equiv 0$ for $\ell \geq 2$.

The equation solved in GRACE can be written in the form

$$4\pi \int_0^\infty S_o\,(u' \rightarrow u)\,\psi\,(u')\,du' - BJ(u) + S(u) + I(u) = \Sigma_T(u)\psi(u) \qquad /3a/$$

$$\frac{4\pi}{3}\int_0^\infty S_1\ (u' \to u)\ J\ (u')\ du' + \frac{B}{3}\psi\ (u) = \Sigma_T\ (u)\ J(u)\ , \qquad /3b/$$

where the unknown functions are the flux - $\psi(u)$ and the current - $J(u)$. In our case $M_{no}(u)$ and $M_{n1}(u)$ play the role of these functions. In Eq./3/ B is the buckling, which is taken to be zero in our case. All other quantities are defined in agreement with Eq. /2/.

For n = O, ℓ = O one obtains from Eq./2/:

$$4\pi\int_0^\infty S_o\ (u' \to u)\ M_{oo}(u')\ du' + I_o(u) + S(u) = \Sigma_T\ M_{oo}(u).$$

This coincides with Eq./3a/, i.e. running GRACE with B = O and the fission source S(u) results in $M_{oo}(u)$.

The equations for M_{2O} and M_{11} are

$$4\pi\int_0^\infty S_o\ (u' \to u)\ M_{2O}(u')\ du' + I_2(u) + \frac{1}{3}M_{11}(u) = \Sigma_T(u)M_{2O}(u)$$

$$/4/$$

$$\frac{4\pi}{3}\int_0^\infty S_1\ (u' \to u)\ M_{11}(u')\ du' + M_{oo}(u) = \Sigma_T(u)M_{11}(u).$$

Here M_{oo} is known form the previous step. Equations /3/ should be only slightly modified. Using the notations of Eq. /43/ in [2], the GRACE equations are written as

$$\left.\begin{aligned} \alpha_{11}^j\ \psi_j + \alpha_{12}^j\ J_j &= \alpha_{13}^j \\ \alpha_{21}^j\ \psi_j + \alpha_{22}^j\ J_j &= \alpha_{23}^j \end{aligned}\right\} \quad /j \text{ is the group index}/$$

Here the terms α_{11}^j, α_{22}^j, α_{13}^j and α_{23}^j are complicated expressions containing slowing-down and absorption terms, and α_{12}^j and α_{21}^j are proportional to the buckling. Comparing eqs. /3/ and /4/, it can be seen that the following changes are necessary in the α coefficients:

- $\alpha_{12}^j = -\frac{1}{3}$;

- $\alpha_{21}^j = 0$;

- from α^j_{13} the S_j fission source term should be excluded;
- the extra term M^j_{oo} should be added to the original α^j_{23}.

A GRACE calculation with this modifications gives M_{oo} and M_{11}.

$M_{22}(u)$ and $M_{33}(u)$ can be directly expressed as

$$M_{22}(u) = \frac{2}{3\Sigma_T(u)} M_{11}(u)$$

and

$$M_{33}(u) = \frac{3}{5\Sigma_T(u)} M_{22}(u) = \frac{2}{5\Sigma_T^2(u)} M_{11}(u).$$

Equations for $M_{40}(u)$ and $M_{31}(u)$ read as

$$4\pi \int_0^\infty S_o (u' \rightarrow u) M_{4o} (u') du' + I_4(u) + \frac{1}{3} M_{31}(u) = \Sigma_T(u) M_{40}(u)$$

$$\frac{4\pi}{3} \int_0^\infty S_1 (u' \rightarrow u) M_{31}(u') du' + \frac{2}{5} M_{22}(u) + M_{20}(u) = \Sigma_T(u) M_{31}(u).$$

The necessary changes in the α coefficients are the same as in the foregoing case, but here instead of M^j_{oo} the extra term $M^j_{20} + \frac{2}{5} M^j_{22}$ should be included in α^j_{23}. From such a GRACE calculation one obtains M_{40} and M_{31}.

The moment M_{42} can be expressed now as

$$M_{42}(u) = \frac{3}{7\Sigma_T(u)} M_{33}(u) + \frac{2}{3\Sigma_T(u)} M_{31}(u) .$$

Finally, for $M_{60}(u)$ and $M_{51}(u)$ one obtains

$$4\pi \int_0^\infty S_o (u' \rightarrow u) M_{60} (u') du' + I_6 (u) + \frac{1}{3} M_{51}(u) = \Sigma_T(u) M_{60}(u)$$

$$\frac{4\pi}{3} \int_0^\infty S_1 (u' \rightarrow u) M_{51} (u') du' + \frac{2}{5} M_{42} (u) + M_{40}(u) = \Sigma_T(u) M_{51}(u) .$$

Now, besides modifying α^j_{12}, α^j_{21} and α^j_{13}, the original α^j_{23} term should be increased by $M^j_{40} + \frac{2}{5} M^j_{42}$.

Such a way solving the GRACE equations four times, the experimentally determined moments can be also calculated:

$$\frac{N_2}{2 N_o} = \frac{M_{20}}{M_{oo}} \quad / = \tau / \qquad \text{Fermi-age}$$

$$\frac{N_4}{N_o} = \frac{4!\, M_{40}}{M_{oo}}$$ Fourth moment

$$\frac{N_6}{N_o} = \frac{6!\, M_{60}}{M_{oo}}$$ Sixth moment

The program MAGGIE, which was developed by modifying GRACE gives these moments. Computing time of the program MAGGE is very short (cca 1 min on the ICL-1905)

As in all the measurements, the 1.46 eV indium resonance was used as indicator, all the moments were evaluated in the 36th GRACE group /energy boundaries 1.84 eV - 1.4 eV/. Small distortions due to the nonexact energy value in the calculations are negligible.

The advantages of such a calculational scheme for the moments of the Fourier-transformed slowing-down kernel can be summarized as follows.

a./ The epithermal library data can be systematically analyzed for some materials. The same library data are used in reactor calculations, so the conclusions of the present analyses can help in the analysis of reactor calculation results, because the applied slowing-down model is strictly identical.

b./ Effect of possible uncertainties in the inelastic scattering data can be studied.

c./ It is possible to calculate the moments in periodic lattices due to the homogenization procedures built in GRACE. In this context it is remarkable, that the non-leakage probability can be expressed as

$$P_{NL} = 1 - \frac{B^2}{2!}\left(\frac{N_2}{N_o}\right) + \frac{B^4}{4!}\left(\frac{N_4}{N_o}\right) - \frac{B^6}{6!}\left(\frac{N_6}{N_o}\right) \pm \dots \qquad /4/$$

Deviations of the calculated and experimental moments can be used for analyzing leakage calculations.

3. Results of calculations

Using the method described in the previous chapter, series of calculations were performed. In the calculations both the traditional GRACE library [2] and the FEDGROUP generated library [9] were used. The calculational results were compared with experimental results [3,4,5,6] and with results of calculations given in the same papers and in [7].

The quantities of greatest interest are the moments in water. They are given in Table 1. It can be seen, that the traditional library results are somewhat lower than the experimental ones. They are very similar to the MOMENTOS results using cross-sections based on an undermoderated spectrum. The agreement between the calculated and measured sixth moments is remarkably good. On the basic of this result it can be assumed, that calculational results for undermoderated lattices will be in better agreement with experiments, than for optimal or overmoderated lattices. It has to be mentioned, that in the FEDGROUP generated library the multigroup constants were obtained by applying the fission spectrum + 1/E weighting spectrum. Further study and refinement of the weighting spectra seem to be reasonable. Results with the FEDGROUP generated library overestimate the moments. The effect of deviations of the calculated moments from the measured ones on the non-leakage probability can be estimated by the formula /4/. For two values of B^2 /100 m^{-2} and 50 m^{-2}/ one obtains the following P_{NL} values:

Method	$B^2 = 100\ m^{-2}$	$B^2 = 50\ m^{-2}$
MAGGIE-trad.l.	0,78784	0,88559
MAGGIE-new l.	0,77394	0,87884
Exp. [4]	0,78511±0,003	0,88323±0,001
Calc. [4]	0,78425	0,88478
[7] pure water	0,78384	0,88447
[7] undermod.	0,78737	0,88642

This comparison shows that the use of the water data in the FEDGROUP generated library leads to a significant error in reactor calculations.

After these basic calculations the moments of cladding material plates in water were calculated. The cladding materials were iron, zirconium and aluminium.

As zirconium data are missing in the KEDAK file, UKNDL data [11] were processed by FEDGROUP.

Results of calculations x/ and the corresponding experimental values [4, 5, 6] are given in Tables 2 to 4. It can be seen from these tables, that

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x/ = As iron data are not present in the traditional library, only the FEDGROUP generated library was for mixtures containing iron.

- iron scattering cross sections are probably too high in the FEDGROUP generated library, as the experimental moments are underestimated by the calculated ones, in spite of the opposite tendencies for pure water;

- zirconium scattering cross sections are slightly too large in the FEDGROUP generated library, as in the case of high zirconium content the experimental moments are underestimated. /cf. the opposite tendency in water/

- in the traditional library Zircalloy-2 data are stored. Replacing zirconium cladding by Zircalloy-2 leads to a significant error in the moments also in the case of small amount of zirconium;

- aluminium scattering cross sections seem to be too high in both libraries, but for small amount of aluminium this error is not significant.

It might be assumed that the representation of the experimental circumstances by a homogeneous medium may also lead to some discrepancies, but the results of other similar calculations do not support such an assumption.

Finally some calculations were performed for a mixture of UO_2 and H_2O corresponding to 1:1 volume ratio in a regular lattice, similarly to [7]. Here the effects of inelastic and P_1 terms in U^{238} scattering could be investigated. The high sensitivity of the results to the variation of U^{238} inelastic scattering cross sections makes the program especially applicable for such investigations. The calculational results together with MOMENTOS results [7] are given in Table 5. Here the following conclusions can be drawn:

- taking into account both the P_1 and inelastic terms for U^{238}, the deviations of the results with the traditional and the FEDGROUP generated library form the MOMENTOS results are similar to the case of pure water;

- the inclusion of P_1 and exclusion of inelastic terms for U^{238} leads to a significant deviation in the sixth moment and in the case of the FEDGROUP generated library the contribution of the inelastic term to the moments is too high compared to the WIMS library;

- the inclusion of inelastic and exclusion of P_1 terms for U^{238} shows that this terms has a too small contribution to the moments in the case of the traditional library /compared to the WIMS library/.

A further systematic investigation of U^{238} cross sections seems to be desirable.

4. Conclusions

The presented results show the applicability of the MAGGIE code for the evaluation of the moments of the Fourier-transformed slowing-down kernel. The direct application of the multigroup libraries and the slowing-down model used in reactor calculations provides the user with a sensitive tool of library analysis.

On the basis of the first calculational results the following main conclusions can be drawn:

- Water data in the traditional library may lead to water-to-uranium ratio dependent lattice parameter discrepancies between calculated and experimental results, but they cannot be responsible for discrepancies in undermoderated lattices.

- A further study and refinement of weighting spectrum used in multigroup constant generation by FEDGROUP is desireable. Application of the water data in the present FEDGROUP generated library may lead to doubtful results.

- The influence of U^{238} inelastic scattering data on calculational results is surprisingly large. A detailed study of these data seems to be necessary.

- Leakage effects due to different cladding materials can be studied in details by MAGGIE. Such studies can help in the analysis of calculational results for lattices containing different cladding materials.

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List of references

[1] A.M. Weinberg, E.P. Wigner: The Physical Theory of Neutron Chain Reactors Chicago Press, 1958.

[2] Z. Szatmáry, J. Valkó: GRACE - A Multigroup Fast Neutron Spectrum Code, Report KFKI-70-14, 1970.

[3] R.K. Paschall: The Age of Fission Neutrons to Indium-Resonance energy in Water. Nucl. Sci. Eng. 20, 436-444, 1964.

[4] R.K. Paschall: The Age of Fission Neutrons to Indium-Resonance Energy in Zirconium-Water Mixtures. Nucl. Sci. Eng. 23, 3, 256-263, 1965.

[5] R.K. Paschall: The Age of Fission Neutrons to Indium-Resonance Energy in Iron-Water Mixtures. J. Nucl.Energy. /Part A/B/, 20/1/, 25-35, 1966.

[6] R.K. Paschall:The Age of Fission Neutrons to Indium-Resonance Energy in Aluminium-Water Mixtures. Nucl.Sci.Eng. 26, 73-79, 1966.

[7] F.J. Fayers, P.B. Kemshell, M.J. Terry: An Evaluation of Some Uncertainties in the Comparison Between Theory and Experiment for Regular Light Water Lattices. The Journal of the British Nuclear Energy Society, Volume 6, Number 2, 1967.

[8] H. Bohl Jr., E.M. Gelberd, G.M. Ryan: MKFT-4 Fast Neutron Spectrum Code for the IBM-704. WAPC-TM-72 report, 1957.

[9] P. Vértes: FEDGROUP - A Program System for Producing Group Constants from Evaluated Nuclear Data of Files Disseminated by IAEA, INDC/HUN/-13/ L+Sp., IAEA 1976.

[10] B. Hinkelmann et al.: Status of the Karlsruhe Evaluated Nuclear Data File KEDAK at June 1970, KFK 1340 report, 1970.

[11] A.L. Pope: The Current Edition of the Main Tape NDL-I of the U.K. Nuclear Data Library, AEEW-M 1208 report, 1973.

Table 1.

Moments for water

Method	Age $/cm^2/$	$\frac{N_4}{N_o}$ $/10^4 cm^4/$	$\frac{N_6}{N_o}$ $/10^7 cm^6/$
MAGGIE-trad. lib.	25,91	1,78	1,96
MAGGIE-FEDGROUP library	27,62	2,05	2,54
Exp. [5]	26,6 ± 0,3	1,89 ± 0,1	1,99 ± 0,29
Calculation [5]	26,2 ± 0,2	1,92 ± 0,04	2,43 ± 0,14
Momentos-pure water spectrum	26,23	1,891	2,351
Momentos- undermoderated spectrum	25,73	1,821	2,247

Table 2.

Moments for zirconium-water mixtures

M/W Volume ratio	Method	Age /cm^2/	$\frac{N_4}{N_o}$ /$10^4 cm^4$/	$\frac{N_6}{N_o}$ /$10^7 cm^6$/
0,348	MAGGIE-trad.lib.	30,50	2,13	2,20
	MAGGIE-FEDGROUP library	34,10	2,72	2,23
	Exp. [4]	33,5 ± 0,6	2,60 ± 0,06	2,94 ± 0,15
	Calcutation [4]	33,4 ± 0,2	2,68 ± 0,04	3,29 ± 0,14
0,565	MAGGIE-trad.lib	33,56	2,40	2,45
	MAGGIE-FEDGROUP library	38,27	3,23	3,88
	Exp. [4]	37,2 ± 0,5	3,23 ± 0,05	4,05 ± 0,15
	Calculation [4]	37,9 ± 0,2	3,20 ± 0,06	4,00 ± 0,14
1,20	MAGGIE-trad.lib.	42,85	3,43	3,55
	MAGGIE-FEDGROUP library	50,21	5,00	6,51
	Exp. [4]	49,7 ± 0,9	5,41 ± 0,14	7,99 ± 0,51
	Calculation [4]	50,4 ± 0,3	4,98 ± 0,06	6,57 ± 0,29
2,0	MAGGIE-trad.lib.	50,48	5,12	5,68
	MAGGIE-FEDGROUP library	65,08	7,83	11,61
	Calculation [4]	66,4 ± 0,3	7,84 ± 0,1	11,14 ± 0,29

Table 3.

Moments for aluminium-water mixtures

M/W Volume ratio	Method	Age /cm^2/	$\frac{N_4}{N_o}$ /$10^4 cm^4$/	$\frac{N_6}{N_o}$ /$10^7 cm^6$/
0,25	MAGGIE-trad. library	32,35	2,50	2,92
	MAGGIE-FEDGROUP library	34,36	2,85	3,68
	Exp. [6]	33,9 ± 0,6	2,90 ± 0,05	3,83 ± 0,06
	Calculation [6]	33,8 ± 0,2	2,88 ± 0,06	3,97 ± 0,16
0,50	MAGGIE-trad. library	38,80	3,33	4,10
	MAGGIE-FEDGROUP library	41,12	3,75	5,03
	Exp. [6]	43,2 ± 0,8	4,32 ± 0,14	6,28 ± 0,43
	Calculation [6]	41,3 ± 0,3	3,96 ± 0,08	5,81 ± 0,26
1,00	MAGGIE-trad. library	52,15	5,37	7,35
	MAGGIE-FEDGROUP library	55,13	5,99	8,71
	Exp. [6]	59,6 ± 0,9	7,42 ± 0,13	12,62 ± 0,33
	Calculation [6]	57,2 ± 0,3	6,68 ± 0,10	10,89 ± 0,39

Table 4.

Moments for iron-water mixtures

M/W Volume ratio	Method	Age /cm^2/	$\frac{N_4}{N_o}$ /$10^4 cm^4$/	$\frac{N_6}{N_o}$ /$10^7 cm^6$/
0,465	MAGGIE-FEDGROUP library	30,44	1,96	1,70
	MOMENTOS	31,11	2,12	2,04
	Exp. [5]	30,3 ± 0,5	2,04 ± 0,05	1,88 ± 0,09
	Calculation [5]	30,5 ± 0,2	2,05 ± 0,03	1,91 ± 0,07
0,908	MAGGIE-FEDGROUP library	35,36	2,43	2,07
	MOMENTOS	36,62	2,67	2,49
	Exp. [5]	37,4 ± 0,5	2,81 ± 0,04	2,68 ± 0,06
	Calculation [5]	36,3 ± 0,2	2,60 ± 0,03	2,34 ± 0,06
1,737	MAGGIE-FEDGROUP library	45,77	3,82	3,70
	MOMENTOS	46,9	4,02	4,03
	Exp. [5]	46,4 ± 0,5	4,00 ± 0,06	4,14 ± 0,12
	Calculation [5]	47,3 ± 0,2	4,04 ± 0,04	3,99 ± 0,99

Table 5.

Moments for UO_2 - H_2O mixture characteristic of a 1:1 lattice

With P_1 and inelastic terms for U^{238} included.

Method	Age /cm^2/	$\frac{N_4}{N_0}$ /$10^4 cm^4$/	$\frac{N_6}{N_0}$ /$10^7 cm^6$/
MAGGIE-trad. library	32,34	1,98	1,61
MAGGIE-FEDGROUP library	35,93	2,54	2,33
Calculation [7]	33,48	2,36	2,32

With inelastic terms for U^{238} excluded.

Method	Age /cm^2/	$\frac{N_4}{N_0}$ /$10^4 cm^4$/	$\frac{N_6}{N_0}$ /$10^7 cm^6$/
MAGGIE-trad. library	45,75	4,65	6,61
MAGGIE-FEDGROUP library	47,37	5,17	7,90
Calculation [7]	48,84	6,18	14,45

With inelastic terms for U^{238} reduced by 10%.

Method	Age /cm^2/	$\frac{N_4}{N_0}$ /$10^4 cm^4$/	$\frac{N_6}{N_0}$ /$10^7 cm^6$/
MAGGIE-trad. library	33,15	2,12	1,80
MAGGIE-FEDGROUP library	36,68	2,69	2,57
Calculation [7]	34,34	2,53	2,64

With P_1 terms for U^{238} excluded.

Method	Age /cm^2/	$\frac{N_4}{N_0}$ /$10^4 cm^4$/	$\frac{N_6}{N_0}$ /$10^7 cm^6$/
MAGGIE-trad. library	30,21	1,64	1,13
MAGGIE-FEDGROUP library	33,05	2,05	1,58
Calculation [7]	30,32	1,80	1,39

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