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Abstract

With reference to the WIMS-D/4 lattice code, the effects of the P_1 scattering matrices in integral parameters were investigated. Since the P_1 matrices are given only for the principal moderators, there exists an ambiguity in defining the number densities for the P_1 scatterers in important materials such as UO_2, where the P_1 matrices for uranium isotopes are not available. The analysis reveals the importance of internal data consistency and tends to support the recommendation, that non-zero number densities should be specified only when all principal constituents of a material have P_1 scattering matrices available. The work was performed within the WIMS Library Update Project under research contract No. 6291/RB with the International Atomic Energy.

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1 Introduction

Transport calculations in the **WIMS-D/4** lattice are performed in the P_0 approximation, where the P_1 correction is included in the self-scattering term. On the other hand, P_1 scattering can be accounted for explicitly in the B_1 leakage-edit option of **WIMS-D/4**, at least for the principal moderators.

The WIMS-D library allows the P_1 scattering matrices to be specified only for four principal moderators, without allowance for any temperature dependence. In practice this causes some ambiguity in defining the input for **WIMS-D/4** when the **BEEONE** option is applied: for example, should one specify non-zero number densities for oxygen in the case of uranium oxide fuel or not. This question was raised by Dr.F.Leszczynsky [1], a participant on the WIMS-D Library Update Project (WLUP) from Argentina, arguing that better results were obtained for some benchmarks if the oxygen P_1 scattering matrix in the fuel was considered explicitly.

2 Scope of the analysis

From the benchmark test cases which were analyzed in detail in WLUP [2], the BAPL-2 test case was arbitrarily taken as an example. Reference results were obtained using standardized **WIMS-D/4** inputs, resulting from Stage-1 of WLUP.

First the original WIMS-D library was considered. Starting from the original cross section data of oxygen (**MAT=16**), a correction to the self-scattering term was made and the new data were added to the library under **MAT=9016**. Secondly, cross sections for all the materials were generated from the ENDF/B-IV evaluated nuclear data library. This also allowed a data set **MAT=9238.4** to be defined, representing the uranium-238 data with the P_1 scattering matrix and no self-scattering term correction. In this case the deuterium P_1 scattering matrix was overwritten, since it was not needed in the test calculations. The list of relevant **MAT** numbers is evident from Table 1. A number of calculations was made to see the effects of different input assumptions on the multiplication factor and the spectral indices, defined in Table 2.

Table 1: WIMS **MAT** numbers for some materials of interest

MAT	Description
16	Oxygen data with P_1 scattering matrix.
9016	Oxygen data without P_1 scattering matrix.
2238.4	Uranium-238 data without P_1 scattering matrix.
9238.4	Uranium-238 data with P_1 scattering matrix.

3 Results

The results using the data from the original WIMS-D library are presented in Table 3. Run A is the reference, corresponding to the recommended input resulting from WLUP, using the **BEEONE** input option for the B_1 leakage edit and non-zero

Table 2: Definitions of some of the parameters

k_∞	infinite medium multiplication factor,
k_{eff}	finite medium effective multiplication factor,
ρ^{28}	ratio of epithermal to thermal ^{238}U capture reaction rate,
δ^{25}	ratio of epithermal to thermal ^{235}U fission reaction rate,
δ^{28}	ratio of ^{238}U fission to ^{235}U fission reaction rate,
C^*	ratio of ^{238}U capture to ^{235}U fission reaction rate.

Table 3: Sensitivity of the B_1 Leakage Edit in WIMS-D/4 on the P_1 Scattering Matrix in the original WIMS-D library.

Run	Fuel				Moder.		BEEONE	k_{eff}	ρ^{28}	δ^{25}	δ^{28}	C^*
	U	DNB	O	DNB								
A	2238	0	16	0	16	n	1	1.00292	1.358	.08404	.07548	.8002
B	2238	-	16	-	16	-	0	1.00486	1.356	.08394	.07462	.7997
C	2238	-	9016	-	9016	-	0	1.00486	1.356	.08394	.07462	.7997
D	2238	-	9016	-	16	n	1	0.99969	1.358	.08405	.07538	.8002
E	2238	0	9016	-	16	n	1	1.00292	1.358	.08404	.07548	.8002
F	2238	0	16	n	16	n	1	1.00103	1.360	.08418	.07618	.8009

number densities on the **DNB** input card for the moderator only. Runs B and C represent the results with the B_0 leakage edit. Obviously, the differences in the group self-scattering terms of oxygen do not influence the B_0 results, which are on the other hand significantly different compared to the B_1 results. Runs D to F represent different combinations of material selection and **DNB** input option specifications. From run D it can be seen that omitting a DNB option card is not equivalent to setting the number densities to zero. This observation may be machine-dependent since Leszczynsky [1] does not report this problem. Comparing Runs A and E it is seen that the self scattering term correction in the oxygen data in the fuel does not influence the results when the oxygen number density is zero on the **DNB** card for the fuel. On the other hand, defining a non-zero number density for oxygen in the fuel seems to produce better agreement with the measured data for the benchmark in question, as seen from Run F. Unfortunately the analysis with the original WIMS-D data is incomplete, because the P_1 scattering data for uranium-238 are not available.

To overcome the drawback of not having the P_1 scattering matrix for uranium-238, the analysis was repeated with a test library, which was generated entirely from the ENDF/B-IV evaluated nuclear data. The results are presented in Table 4. The purpose of the exercise was to investigate the relative differences in the results due to the use of different data and WIMS input options, so the use of the rather old basic data base was not a disadvantage. Additional runs were performed to cover all combinations of input options and available data. The most important is Run H in which all materials had a P_1 scattering matrix and non-zero number densities specified on the **DNB** card, including uranium-238. Unfortunately the **BEEONE** option effects were much smaller when a consistent library based on ENDF/B-IV data was used. Nevertheless the results indicate that the term "principal moderator" in the

Table 4: Sensitivity of the B_1 Leakage Edit in WIMS-D/4 on the P_1 Scattering Matrix in the library based on ENDF/B-IV data.

Run	Fuel				Moder.		BEEONE	k_{eff}	ρ^{28}	δ^{25}	δ^{28}	C^*
	U	DNB	O	DNB								
A	2238	0	16	0	16	n	1	0.99320	1.429	.08433	.07172	.8146
B	2238	-	16	-	16	-	0	0.99690	1.427	.08419	.07129	.8139
C	2238	-	9016	-	9016	-	0	0.99690	1.427	.08419	.07129	.8139
D	2238	-	9016	-	16	n	1	0.99085	1.430	.08433	.07160	.8146
E	2238	0	9016	0	16	n	1	0.99320	1.429	.08433	.07172	.8146
F	2238	0	16	n	16	n	1	0.99338	1.429	.08433	.07172	.8146
G	9238	0	16	n	16	n	1	1.00237	1.429	.08433	.07197	.8146
H	9238	n	16	n	16	n	1	0.99318	1.429	.08432	.07169	.8146
I	9238	-	16	-	16	-	1	0.99690	1.427	.08419	.07129	.8139
K	2238	-	16	-	16	n	1	0.99085	1.430	.08433	.07160	.8146
L	9238	0	9016	0	16	n	1	0.99320	1.429	.08433	.07172	.8146
M	9238	n	9016	0	16	n	1	0.99298	1.429	.08433	.07171	.8146
N	9238	0	16	0	16	n	1	0.99320	1.429	.08433	.07172	.8146
O	9238	n	16	0	16	n	1	0.99534	-	-	-	-

WIMS manual should be interpreted considering the moderating properties of a material. In this respect, using the original WIMS-D library, the number density of oxygen in the fuel should be set to zero on the **DNB** card, because the uranium nuclei provide a non-negligible contribution to the neutron slowing down process while no P_1 scattering data are available for uranium-238.

Considering the results using the two libraries it is rather curious, that various combinations of the input options in the tests have a much stronger influence on the results when the original WIMS-D library is used. The effect of the **BEEONE** option in **WIMS-D/4** is to force the program to use the total cross section rather than the transport cross section [3]. The total cross section is calculated by summing the elements of the scattering matrix and the absorption cross section. According to a recommendation on the WIMS-D library, the total and the transport cross section should be the same for materials without explicitly given P_1 scattering matrices. This recommendation is followed in the library derived from the ENDF/B-IV data, but a consistency check on the original library shows a discrepancy. The differences in these two cross sections are responsible for the high sensitivity of the results on the specified number densities when the **BEEONE** option of **WIMS-D/4** is used with the original WIMS-D library.

4 Conclusions

Taking Run A as reference, the following conclusions can be drawn:

- Applying the B_0 leakage edit causes a change of $+195\,pcm$ in k_{eff} with the original library and $+371$ *pcm* with an ENDF/B-IV based library.

- The self-scattering term does not affect the results in the B_0 leakage edit option.

- The adopted conventions on the self-scattering term correction in the WIMS library are correctly interpreted in the **WIMS-D/4** code and do not influence the results when consistent input data are used. Namely, if the number density is set to zero on the **DNB** card for a material without a self-scattering term correction and the B_1 leakage edit is requested, the self-scattering term does not affect the results.

- In the B_1 leakage edit option, setting the number densities to zero is in general *not* equivalent to omitting the corresponding **DNB** card.

- The number densities on the **DNB** card must be set to zero unless all components in a material, which contribute to neutron slowing down, have a P_1 scattering matrix available. Failure to observe this recommendation may lead to errors.

- Although the non-zero number density of oxygen on the **DNB** card for the fuel improves the agreement between the calculation and measurements when the original WIMS data are used, the results with the ENDF/B-IV data suggest that this may be a coincidence due to some cancellation of errors and can not be accepted as a general recommendation.

- Internal consistency of the WIMS-D library requires that the sum of the group scattering matrix elements and the absorption cross section should be consistent with the transport cross section. This is not followed in the original WIMS-D library and is probably the main cause for the high sensitivity of the results on the specified number densities for the P_1 scattering matrices when the original WIMS-D library is used.

References

[1] F.Leszczynsky: *WIMS Library Update Project Stage-1 Report*, Centro Atòmico Bariloche, Comisiòn Nacional de Energia Atòmica, 8400 S.C.de Bariloche RN, Argentina, Sep.1992.

[2] S.Ganesan(Ed.), *Update of the WIMS-D/4 Nuclear Data Library*, Status report of the IAEA WIMS Library Update Project, International Atomic Energy Agency, INDC(NDS)-290, Dec.1993.

[3] M.Halsall, (private communication), AEA Technology - Reactor Services, Winfrith Technology Centre, Dorchester, England, Sep. 9^{th} 1994.