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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

PREPARATION OF FUSION BENCHMARKS IN ELECTRONIC FORMAT FOR NUCLEAR DATA VALIDATION STUDIES

Summary Report of the IAEA Consultants' Meeting
organized by the International Atomic Energy Agency
and held at the IAEA Headquarters, Vienna, Austria,
13 to 16 December 1993

Prepared
by

S. Ganesan
IAEA Nuclear Data Section
Vienna, Austria

March 1994

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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Abstract

An IAEA Consultants Meeting on "Preparation of fusion benchmarks in electronic format for nuclear data validation studies" was convened by the International Atomic Energy Agency and held during December 13-16, 1993 at the IAEA Headquarters, Vienna. The main purpose of the meeting was to review the current status of work in the subject of compilation of fusion neutronic benchmarks for the purpose of integral validation of Fusion Evaluated Nuclear Data Libraries (FENDL working libraries). The compiled information in electronic format on fusion benchmarks will be used to integrally validate the working nuclear data libraries in processed form derived within the scope of the FENDL project of the Agency for neutron and photon transport. The detailed agenda, the complete list of participants and the recommendations of the Consultants Meeting are presented in this report.

Reproduced by the IAEA in Austria
March 1994

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Summary of the Meeting

1. Introduction

The IAEA Nuclear Data Section, in co-operation with several national nuclear data centers and research groups, is creating an internationally available Fusion Evaluated Nuclear Data Library (FENDL), which will serve as a comprehensive source of processed and tested nuclear data tailored to the requirements of the Engineering and Development Activities (EDA) of the International Thermonuclear Experimental Reactor (ITER) Project and other fusion-related development projects. The FENDL project of the International Atomic Energy Agency has the task of coordination with the goal of assembling, processing and testing a comprehensive, fusion-relevant Fusion Evaluated Nuclear Data Library with unrestricted international distribution. The IAEA sponsored international comparison of benchmark measurements and calculations in the subject of fusion neutronics is a sub-task of the FENDL activity.

The working nuclear data libraries for neutron and photon transport in processed form for use by the ITER team in the early phase of ITER EDA are being derived by R.E. MacFarlane, Los Alamos National Laboratory, USA by processing the basic data libraries of the first version of FENDL, FENDL-1 using the NJOY code system. The integral validation of FENDL-1 based on analysis of IAEA benchmarks which assumes high priority will be discussed at the planned Advisory Group Meeting in Garching in September 1994. The plans and initiation of selections of basic nuclear data evaluations for FENDL-2 which will be a significant improvement over FENDL-1 will also be performed at the meeting in Garching.

The well tested and validated nuclear data libraries in processed form are expected to be ready by mid 1996 for use by the ITER team in the final phase of ITER EDA, after iterative feedback to the evaluators through extensive benchmarking and integral validation studies of FENDL-2 in 1994-96 period.

An IAEA Consultants Meeting on "Preparation of fusion benchmarks in electronic format for nuclear data validation studies" was held during December 13-16, 1993 at the IAEA Headquarters, Vienna. The main purpose of the present meeting was to review the current status of work in the subject of compilation of fusion neutronic benchmarks for the purpose of integral validation of FENDL working libraries. The compiled information on fusion benchmarks will be used to integrally validate the working nuclear data libraries derived within the scope of the FENDL project of the Agency.

The present Consultants recommend that the international community of benchmark specialists should continue to make progress in the compilation of benchmarks as a sub-task of the FENDL activity of the IAEA, with high priority. The meeting participants recommended that the Agency should ensure a follow-up Consultants' Meeting by the end of 1994.

2. Organization of Consultants' Meeting and Meeting Proceedings

The scope of the present Consultants Meeting was considered at the the previous IAEA Advisory Group Meetings: "FENDL and Associated Benchmark Calculations" organized by the International Atomic Energy Agency and held in Vienna, Austria, 18-22 November 1991, Report INDC(NDS)-260 (March 1992), "Nuclear Data for Neutron Multiplication in Fusion-Reactor First-Wall and Blanket Materials" organized by the International Atomic Energy Agency and hosted by the China Southwest Institute of Nuclear Physics and Chemistry (SWINPC) at Chengdu, China, 19-21 November 1990, Report INDC(NDS)-264 (September 1992), and, of the Advisory Group Meeting on "Review of Uncertainty Files and Improved Multigroup Cross Section Files for FENDL," held by the Agency, in cooperation with the Japan Atomic Energy Research Institute, and organized during 8-12 November 1993 at the Tokai Research Establishment, JAERI, Japan, Report INDC(NDS)-297 (January 1994).

Considering the urgent needs of engineering design activity of ITER reported at the previous IAEA meetings and at the "International Workshop on Nuclear Data for Fusion Reactor Technology", Del Mar, California, U.S.A., 3-6 May 1993, the present Consultants' meeting was considered very timely in order to facilitate international cooperation with the purpose to review the current status of preparation of fusion benchmarks in electronic format for nuclear data validation studies, and, to help accelerate integral testing of working nuclear data libraries for ITER applications.

After formal presentation of papers following the agenda presented in Appendix A, the meeting participants discussed the following:

1. Presentation of fusion benchmarks in electronic format for all the selected benchmark experiments relevant to ITER material selection for blanket and shield. A sample is presented in Appendix C.

2. Inclusion of additional benchmarks useful in fusion neutronics.

3. Future plans for integral validation of fusion evaluated nuclear data files by analyses of benchmarks.

4. Plans to prepare the first comprehensive report on the benchmarks to help scientists performing nuclear data validation studies.

3. Meeting Attendance

The meeting was attended by 11 experts working in the subject area of the meeting from 7 Member States (China, Italy, Germany, Japan, Russia, Switzerland, and the U.S.A) in addition to the Scientific Secretary from the Agency. In all, 5 experts were awarded by the Agency limited financial support in the form of lump sum grant to defray partially the travel and subsistence expenses. The complete list of participants and their affiliations are presented in Appendix D.

4. Results of the Meeting:

The meeting participants took note of the schedule that the integral validation of FENDL-1 based on analysis of IAEA benchmarks will be discussed at the planned Advisory Group Meeting in Garching in September 1994. Therefore the compilation of benchmarks assumes high priority. The well tested and validated nuclear data libraries of FENDL-2 in processed form are expected to be ready by mid 1996 for use by the ITER team in the final phase of ITER EDA after iterative feedback to the evaluators through extensive benchmarking and integral validation studies in 1994-96 period.

The consultants of the present meeting critically examined the status of compilation of fusion benchmarks as presented by the Working Group I of the Advisory Group Meeting on "Review of Uncertainty Files and Improved Multigroup Cross Section Files for FENDL," held by the Agency, in cooperation with the Japan Atomic Energy Research Institute, and organized during 8-12 November 1993 at the Tokai Research Establishment, JAERI, Japan. The summary, conclusions and recommendations are presented in Appendix B. The selected benchmark experiments relevant to ITER material selection for blanket and shield is presented in Table 1 of Appendix B.

Data validation by experimental benchmarks should be a continuous process. The submission of further experimental data to the IAEA-Nuclear Data Section should be taken up as soon as possible by official request of the Nuclear Data Section to the organizations contributing. In the near future (before April 1, 1994) the benchmark items 1 (except Fe, Ni), 2, 3, 5-11, 13, 18 and 19 of the list (Table 1 of Appendix B) are expected to be submitted. Items 3 (partial), 14 and 15 have already been submitted. The feedback of the benchmark calculation results to the experimental groups (as well as feedback to the nuclear data evaluators) should be ensured.

The participants feel that the IAEA-Nuclear Data Section is the suitable body for the coordination and encouragement of FENDL validation by experimental benchmarks in view of the use of FENDL in the ITER project.

The present Consultants recommend that the international community of benchmark specialists should continue to make progress in the compilation of benchmarks as a sub-task of the FENDL activity of the IAEA. The Agency should ensure a follow-up Consultants' Meeting by the end of 1994.

APPENDIX A

International Atomic Energy Agency

IAEA Consultants' Meeting

on

"Preparation of Fusion Benchmarks in Electronic Format
for Nuclear Data Validation Studies"

IAEA Headquarters, Vienna, Austria

13 to 16 December 1993

AGENDA

Monday, 13 December

08:30 - 10:00		Formalities, Registration
10:00		Opening of the Consultants' Meeting C.L. Dunford, Head-Nuclear Data Section, IAEA
		Technical Remarks and Review of Background Information by the Scientific Secretary S. Ganesan, IAEA
		Election of Chairman Adoption of the Agenda
10:30		Coffee Break

Chairman : K. Seidel
Co-Chairman: U. von Moellendorff

Session 1.

10:45 - 11:15	(1)	JIANG Wenmian, Chengdu, China: "Systematic error studies in measurement of neutron multiplication."
11:15 - 11:45	(2)	K. Seidel, Pirna, Germany: "Presentation of experimental benchmark data and their uncertainties."

11:45 - 12:00		Discussions
12:00 - 14:00		Lunch Break
		Session 2.
14:00 - 14:30	(3)	U. von Moellendorff, Karlsruhe, Germany: "Measurements of fusion neutron multiplication in spherical beryllium shells."
14:30 - 15:15	(4)	Ms. P. Batistoni, Frascati (Rome), Italy: "The SS bulk shield benchmark experiment at FNG."
15:15 - 15:45	(5)	Y. Oyama, JAERI, Japan: "Integral Experiments at FNS."
15:45 - 16:00		Coffee Break
16:00 - 16:30	(6)	P. Androssenko, Obninsk, Russia: "Calculational analysis of error for various mathematical models of experiment on measuring escape neutron spectra."
		Discussions

Tuesday, 14 December

		Session 3.
09:30 - 10:15	(7)	J.E. White, Oak Ridge Tennessee, U.S.A.: "Benchmark activities in the Radiation Shielding Information Center."
10:15 - 10:45	(8)	S.P. Simakov, Obninsk, Russia: "Review of experiments and specifications on leakage spectra from spherical shells." - "Analysis of influence of experimental factors (energy-angular distributions of source neutrons, measuring technique, shell geometry...) on measured data quality and possibility of comparison with transport calculations."

10:45 - 12:00	(9)	Chihiro ICHIHARA, Katsuhei KOBAYAHI, Shu A. HAYASHI, Itsuro KIMURA, Junji YAMAMOTO, Akito TAKAHASHI, Japan "Numerical Data of Leakage Neutron Spectra from Various Sphere Piles with 14 MeV Neutrons"
		Session 4.
14:00 - 17:30		Working Group: Summary, Conclusions and Recommendations.
		Critical Examination of Available Benchmark Specifications.
12:00 - 14:00		Lunch Break
17:30		WINE and CHEESE PARTY, VIC Restaurant.

Wednesday, 15 December

09:30 - 12:00	Session 4 (continued).
12:00 - 14:00	Lunch Break
14:00 - 17:30	Session 4 (continued).

Thursday, 16 December

09:30 - 12:00	Session 4 (continued).
12:00 - 14:00	Lunch Break
14:00 - 17:30	Conclusion of the Meeting.

APPENDIX B

Conclusions and Recommendations

IAEA Consultants' Meeting on "Preparation of Fusion Benchmarks in Electronic Format for Nuclear Data Validation Studies"
December 13-16, 1993

The participants of the meeting (Appendix D) discussed in connection with prepared presentations (Appendix A) and in working group sessions the possibilities how to follow the recommendations of Working Group 1 (WG I), Experimental Benchmarks for Neutron and Gamma Transport, of the IAEA Advisory Group Meeting on "Review of Uncertainty Files and Improved Multigroup Cross Section Files for FENDL-2", November 8-12, 1993.

1. The benchmarks selected in WG I (Table 1) are felt to be a suitable base for starting the Fusion Evaluated Nuclear Data Library (FENDL) Validation.

2. It was shown in some examples that several experiments on the same material, possibly involving different measured quantities, may be required for reliable validation. Therefore, the redundancy apparent from the list of Selected Benchmark Experiments Relevant to ITER Material Selection for Blanket and Shield (Table 1), for e.g., beryllium and iron is considered to be highly desirable.

3. Calculations using libraries other than FENDL (e.g. ENDF/B-VI, EFF, JENDL, BROND, ...) will be helpful, in particular for tracing back any observed discrepancies.

4. Data validation by experimental benchmarks should be a continuous process. The submission of further experimental data to the IAEA-Nuclear Data Section should be taken up as soon as possible by official request of the Nuclear Data Section to the organizations contributing. In the near future (before April 1, 1994) the benchmark items 1 (except Fe, Ni), 2, 3, 5-11, 13, 18 and 19 of the list (Table 1) are expected to be submitted. Items 3 (partial), 14 and 15 have already been submitted. The feedback of the benchmark calculation results to the experimental groups (as well as feedback to the nuclear data evaluators) should be ensured.

5. Any benchmark submission should consist of the description of the experiment, the measured results and their uncertainties.

5.1 The description comprises the geometry, the material composition, the neutron source and the detectors.

- The geometry should be described by one or several dimensioned drawings, e.g., a survey drawing and additional detailed drawings of the neutron source, the detector, the collimator, etc., as well as additional information in the form of tables, mathematical relations, etc., as suitable.

- The material composition should be specified by atomic or mass densities. Any small gaps within the assembly should either be described in the geometry part or taken into account in the densities. Elemental compositions and, if other than natural, isotopic compositions should be given.

The neutron source spectrum should be specified, taking into account any source anisotropy. If in the experiment a spectrum is measured, the source spectrum should be given in the same representation (energy spectrum, time spectrum, ...) and using the same bin structure as the experimental results.

- All details of the detector or detectors that are relevant to the response, including resolutions, should be specified. If time-of-arrival spectra are given, the energy dependent efficiency is required.

5.2 For the experimental results, the physical quantity and its unit should be explained clearly, e.g., leakage neutrons per source neutron and per MeV. Bin mid-point energies, bin average energies, etc., should be clearly distinguished. The method of normalization, e.g., to one T(d,n) source neutron or to one neutron emitted from the accelerator target assembly, should be specified. It should be explained which components of detector background were considered (room-return neutrons, natural radioactivity, ...) and how they were taken into account.

5.3 Experimental uncertainties given should be total uncertainties including all possible contributions. The different contributions such as statistical error, normalization uncertainty and systematic uncertainties should be separable. The origin of systematic uncertainties should be specified to allow for future correction or re-estimation.

6. The complete description of an experiment requires a 3-dimensional approach. However, contributors are encouraged to submit, in addition to the file as described under 5., another file on the same experiment in which a suitable 1- or 2-dimensional model for calculations replaces the detailed 3-dimensional description. This would allow for faster and easier testing of, e.g., library modifications, even if precise reproduction of the experimental results cannot be expected.

7. The format of the files should, as a first step, be the same (IBM/PC, MS-DOS file) as the files already submitted by JAERI and TUD but supplemented by hard copy material including drawings. Improvements should be discussed after the group has feedback information from the users of the files in about 1 year's time.

8. If calculational results are included in the submission as desired by WG I, the model (geometry and materials), the data library and possibly detector response functions (e.g., a reference to the standard cross section library used) are required. Input decks used in the calculations (e.g. MCNP, ANISN, TWODANT, ...)

will also be a helpful supplement to the geometry and material description.

9. The participants feel that the IAEA-Nuclear Data Section is the suitable body for the coordination and encouragement of FENDL validation by experimental benchmarks in view of the use of FENDL in the ITER project. The participants endorse the recommendation made in WG I that the IAEA benchmark data be transmitted to RSIC for inclusion in their already existing archived information on shielding benchmarks. The present Consultants recommend that the international community of benchmark specialists should continue to make progress in the compilation of benchmarks as a sub-task of the FENDL activity of the IAEA. The Agency should ensure a follow-up Consultants' Meeting by the end of 1994.

Table I: Selected Benchmark Experiments Relevant to ITER Material Selection for Blanket and Shield

NO.	Category	Material	Geometry	Facility/ Oranization	Measured Quantity
1.	Bulk shield	Cr, Mn, Fe, Ni, Mo, W	Sphere	OKTAVIAN	neutron and gamma leakage spectra
2.	Bulk Shield	Fe	Sphere	IPPE	Neutron leakage spectra
3.	Bulk Shield	Fe, C, O	Slab	FNS	n-spectra > 50 keV
4.	Bulk Shield	Fe, W, SS316L, SS316*	Slab	FNS	n-spectra >1 MeV, Gamma spectum, R.R., Gamma heating
5.	Bulk/Streaming Shield	Fe	Slab	TUD	neutron and gamma leakage spectra
6.	Bulk Shield	SS316*	Slab	FNG/ ENEA-CEA	In-system Reaction Rates Gamma dose
7.	Bulk/Streaming Shield	Fe, SS304, W, Borated	Slab	ORNL	neutron and gamma leakage spectra
8.	Breeding/ Multiplication	Li, Be, Pb	Sphere	OKTAVIAN	TPR
9.	Breeding/ Multiplication	Be, Be-Li Pb, Li, LiF Pb, LiF	Sphere	OKTAVIAN	Neutron leakage spectra Gamma leakage spectra

Table I: Selected Benchmark Experiments Relevant to ITER Material Selection for Blanket and Shield (Continued)

No.	Category	Material	Geometry	Facility/ Orangaization	Measured Quantity
10.	Multiplication	Be	Sphere	KfK	n leakage spectra, Total n leakage
11.	Breeding/ Multiplication	Be, Pb, Pb-LI	Sphere	IPPE	n leakage spectra
12.	Multiplication	Be	Sphere	INEL	Total neutron leakage
13.	Multiplication	Be, Pb	Sphere	SWINPC	Total neutron leakage
14.	Multiplication	Be, Pb	Slab	FNS	Angular neutron Spectra
15.	Multiplication	Pb	Sphere	TUD	n-leakage spectra, R.R.
16.	Multiplication	Be, BeO, Pb	Rectangular	BARC	Total n leakage
17.	Breeding	Li-6, Li-7	Sphere	LLNL	n-leakage
18.	Breeding	Li2O	Slab	FNS	Angular neutron spectra
19.	Breeding/ Multiplication	Li2O, Be	Slab	FNS	n-spectum> a few keV, gamma spectra, R.R. , gamma heating

Additional Benchmarks for other Materials conducted at FNS and/or OKTAVIAN : N, Al, Si, Ti, Cu, Zr, Nb
*The benchmark data needed are to be requested officially.

APPENDIX C: A SAMPLE OF BENCHMARK DATA IN ELECTRONIC FORMAT
(Only the README.DOC file is reproduced in this appendix)

Nov. 20, 1992

IAEA Benchmark Problem Based on the Time-of-Flight Experiment on Iron Slabs at FNS/JAERI

Yukio OYAMA and Hiroshi MAEKAWA

Fusion Reactor Physics Laboratory
Department of Reactor Engineering
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken, 319-11 Japan

(Phone) 81-292-82-6075 (for Y.O.) or -6015 (for H.M.)
(Telefax) 81-292-82-5709
(BITNET) J3240@JPNJAERI (for Y.O.) or J2773@JPNJAERI (for H.M.)

1. Numerical Data and Their Format

a) Type of format : IBM-PC, MS-DOS file in (5", 1.2MB) or (3.5", 720kB)

b) There are the following four files except this "**README.DOC**" text:

FETG.DAT ------	Source neutron spectrum
FE05.DAT ------	50 mm-thick angular neutron flux
FE20.DAT ------	200 mm-thick angular neutron flux
FE40.DAT ------	400 mm-thick angular neutron flux
FE60.DAT ------	600 mm-thick angular neutron flux
ENERGY.DAT ----	Boundary energy

c) Units of the data

Source spectrum	[n/sr/lethargy/source]
Angular flux	[n/sr/cm2/lethargy/source]

d) Data format for experimental data

Comment	1 line	20A4
Energy (mid-point) [MeV]	I = 1, 150	6E12.4
Angular flux [See above]	I = 1, 150	6E12.4
Error (fraction) [%]	I = 1, 150	6E12.4

e) Number of data set

FETG.DAT	1	0 degree
FE05.DAT	4	0, 24.9, 42.8, 66.8 degrees
FE20.DAT	5	0, 12.2, 24.9, 42.8, 66.8 degrees
FE40.DAT	5	0, 12.2, 24.9, 42.8, 66.8 degrees
FE60.DAT	5	0, 12.2, 24.9, 42.8, 66.8 degrees

*In the case of 50 mm-thick and 12.2-degree, it was revealed that the measured flux was contaminated by some of direct neutrons from the target and too difficult to analysis. Therefore the data of 50 mm-thick and 12.2 degree is not included in the file.

f) Data format for boundary energy (ENERGY.DAT)

Comment	1 line	20A4
Boundary energy [MeV]	I = 1, 151	8F9.5

2. Flight Path and Effective Measured Area

The flight path and effective measured area are summarized as follows. The meaning of them is described in the references. These data are useful for Monte Carlo calculations.

Table Flight path and measured area

50 mm-thick Assembly

Angle	Flight Path [cm]	Measured Area [cm**2]
0.0	738	85.88
24.9	740	86.34
41.8	744	87.26
66.8	753	89.33

200 mm-thick Assembly

Angle	Flight Path [cm]	Measured Area [cm**2]
0.0	723	82.42
12.2	724	82.65
24.9	726	83.11
41.8	732	84.49
66.8	746	87.72

400 mm-thick Assembly

Angle	Flight Path [cm]	Measured Area [cm**2]
0.0	703	77.81
12.2	704	78.04
24.9	708	78.96
41.8	716	80.81
66.8	736	85.41

600 mm-thick Assembly

Angle	Flight Path [cm]	Measured Area [cm**2]
0.0	683	73.20
12.2	684	73.43
24.9	689	75.59
41.8	700	77.12
66.8	725	82.88

3. Calculational Model

The calculational model is of course depend on the code used. Basic data are as follows:

Radius of assembly : 50 cm
Thickness of assembly : 5, 20, 40 and 60 cm
Distance between target and assembly : 20 cm
Atom density [10**22 atoms/cm**3] :

Fe : 8.3699
Mn : 0.071857
C : 0.072906
Si : 0.0028132
Cr : 0.0017024
Al : 0.0027944
Ni : 0.0011200

Area of detector : (pai)x2.54**2 [cm**2]

4. How to Calculate the Angular Flux

(1) Neutron source

You can use the data of "PBTG.DAT" as the source. Before you start the calculation you should interpolate the spectrum to adjust it to the group structure used. It is notable that the integrated source spectrum multiplied by 4x(pai) is not unity (1.0) but about 1.12. The source neutrons are generated isotopically at the target position.

(2) Two-dimensional discrete ordinate code such as DOT3.5

You can easily understand from the reference 4) how to do. It is important to average over the measured area when the calculated angular flux is compared with the measured one.

(3) Monte Carlo calculation

You can see a sample of method in the reference 1).

5. Comparison

Two types of comparison will be done for this benchmark problem.

(1) To compare the measured and calculated angular fluxes directly in graph.

(2) To compare the integrated flux over following four energy regions in C/E values (Ratio of calculated to experimental values);

Table Integrated Angular Flux
50 mm-thick Assembly

Energy* [MeV} Angle	10.183 (14)	4.8102 (29)	1.9557 (47)	0.5070 (74)	0.0974 (107)	Total (>0.0974)
0.0	4.628-4# (0.076)	0.058-4 (12.16)	0.119-4 (5.97)	0.208-4 (3.45)	0.050-4 (1.44)	5.064-4 0.072)
24.9	0.9174-5 (0.46)	0.1096-5 (8.02)	0.449-5 (2.18)	0.790-5 (1.43)	0.183-5 (7.25)	2.449-5 (0.030)
41.8	0.5176-5 (0.70)	0.1015-5 (7.68)	0.4639-5 (1.98)	0.877-5 (1.30)	0.191-5 (7.70)	2.151-5 (0.39)
66.8	0.2197-5 (1.11)	0.0923-5 (6.03)	0.4837-5 (1.47)	1.0153-5 (0.90)	0.212-5 (5.43)	2.023-5 (0.32)

200 mm-thick Assembly

Energy* [MeV] Angle	10.183 (14)	4.8102 (29)	1.9557 (47)	0.5070 (74)	0.0974 (107)	Total (>0.0974)
0.0	5.054-5#	0.097-5	0.337-5	1.176-5	0.404-5	7.068-5
	(0.24)	(2.33)	(7.47)	(2.22)	(6.73)	(0.20)
12.2	1.245-5	0.061-5	0.298-5	1.025-5	0.373-5	3.002-5
	(0.46)	(19.25)	(4.16)	(1.35)	(4.24)	(0.28)
24.9	0.2942-5	0.0491-5	0.283-5	1.0057-5	0.356-5	1.988-5
	(0.84)	(10.63)	(2.17)	(0.80)	(2.98)	(0.30)
41.8	0.1280-5	0.038-5	0.2484-5	0.9406-5	0.345-5	1.700-5
	(1.21)	(9.18)	(1.80)	(0.68)	(2.64)	(0.31)
66.8	0.0348-5	0.0213-5	0.1600-5	0.6634-5	0.2484-5	1.128-5
	(4.55)	(17.52)	(2.99)	(0.95)	(3.45)	(0.44)

400 mm-thick Assembly

Energy* [MeV] Angle	10.183 (14)	4.8102 (29)	1.9557 (47)	0.5070 (74)	0.0974 (107)	Total (>0.0974)
0.0	2.494-6	0.113-6	0.576-6	3.872-6	2.368-6	9.422-6
	(1.01)	(46.06)	(9.789	(1.74)	(3.60)	(0.51)
12.2	0.8704-6	0.0707-6	0.4939-6	3.539-6	2.236-6	7.210-6
	(1.57)	(41.84)	(6.99)	(1.31)	(2.97)	(0.54)
24.9	0.3089-6	0.0699-6	0.4514-6	3.4728-6	2.399-6	6.702-6
	(3.27)	(3.38)	(6.73)	(1.36)	(3.23)	(0.72)
41.8	0.1123-6	0.0427-6	0.3844-6	2.8036-6	1.988-6	5.285-6
	(7.05)	(45.55)	(7.68)	(1.41)	(3.23)	(0.75)
(66.8	0.1178-6	0.1165-6	0.2218-6	1.7589-6	1.103-6	3.318-6)$
	(11.22)	(26.43)	(16.88)	(2.64)	(5.74)	(1.13)

*Lower energy boundary for each region in MeV and the group number of lower boundary from the higher energy group.
#Read as 5.054x10**(-5), (error in %).

Table Integrated Angular Flux (Continued)
600 mm-thick Assembly

Energy* [MeV] Angle	10.183 (14)	4.8102 (29)	1.9557 (47)	0.5070 (74)	0.0974 (107)	Total (>0.0974)
0.0	2.494-6	0.113-6	0.576-6	3.872-6	2.368-6	9.422-6
	(1.01)	(46.06)	(9.789	(1.74)	(3.60)	(0.51)
12.2	0.8704-6	0.0707-6	0.4939-6	3.539-6	2.236-6	7.210-6
	(1.57)	(41.84)	(6.99)	(1.31)	(2.97)	(0.54)
24.9	0.3089-6	0.0699-6	0.4514-6	3.4728-6	2.399-6	6.702-6
	(3.27)	(3.38)	(6.73)	(1.36)	(3.23)	(0.72)
41.8	0.1123-6	0.0427-6	0.3844-6	2.8036-6	1.988-6	5.285-6
	(7.05)	(45.55)	(7.68)	(1.41)	(3.23)	(0.75)
(66.8	0.1178-6	0.1165-6	0.2218-6	1.7589-6	1.103-6	3.318-6)$
	(11.22)	(26.43)	(16.88)	(2.64)	(5.74)	(1.13)

*Lower energy boundary for each region in MeV and the group number of lower boundary from the higher energy group.
#Read as 5.054x10**(-5), (error in %).

6. References

When you publish the results using this numerical data, you should refer at least following references 1) and 2).

1) Oyama Y., Maekawa H.: "Measurement and Analysis of an Angular Neutron Flux on a Beryllium Slab Irradiated with Deuteron-Tritium Neutrons," Nucl. Sci. Eng., 97, 220-234 (1987).

2) Oyama Y., Yamaguchi S., Maekawa H.: "Experimental Results of Angular Neutron Flux Spectra Leaking from Slabs of Fusion Reactor Candidate Materials (I)," JAERI-M 90-092 (1990).

3) Oyama Y., Maekawa H.: "Measurements of Angle-Dependent Neutron Spectra from Lithium-Oxide Slab Assemblies by Time-of-Flight Method," JAERI-M 83-195 (Nov. 1983).

4) Oyama Y., Yamaguchi S., Maekawa H.: "Analysis of Time-of-Flight Experiment on Lithium-Oxide Assemblies by a Two-Dimensional Transport Code DOT3.5," JAERI-M 85-031 (March 1985).

5) Oyama Y., Maekawa H.: "Spectral Measurement of Angular Neutron Flux on the Restricted Surface of Slab Assemblies by the Time-of-Flight Method," Nucl. Instr. Methods, A245 173-181 (1986).

6) Oyama Y., Yamaguchi S., Maekawa H.: "Measurements and Analyses of Angular Neutron Flux Spectra on Graphite and Lithium-Oxide Slabs Irradiated with 14.8 MeV Neutrons," J. Nucl. Sci. Technol., 25, 419-428 (1988).

7) Oyama Y., Kosako K., Maekawa H.: "Measurements and Analyses of Angular Neutron Flux Spectra on Liquid Nitrogen, Liquid Oxygen and Iron Slabs," Proc. Int'l Conf. on Nuclear Data for Science and Technology, 13-17 May, Juelich (1991).

8) Oyama Y., Kosako K., Maekawa H.: "Measurement and Calculations of Angular Neutron Flux Spectra Leaking from Slabs Bombarded with 14.8 MeV Neutrons," To be published in Nucl. Sci. Eng.

9) Oyama Y., Maekawa H.: "Experimental Results of Angular Neutron Flux Spectra Leaking from Slabs of Fusion Reactor Candidate Materials (II)," To be published in JAERI-M Report.

APPENDIX D

IAEA Consultants' Meeting on
"Preparation of Fusion Benchmarks in Electronic Format
for Nuclear Data Validation Studies"

IAEA Headquarters in Vienna, Austria

13 to 16 December 1993

List of Participants

Prof. Dr. JIANG Wenmian
Southwest Institute of Nuclear Physics and Chemistry (SWINPC)
P.O. Box 525
Chengdu 610003
CHINA
FAX: +86-816-25851

Prof. Dr. Klaus Seidel
Institut fuer Kern- und Teilchenphysik
Fakultaet fuer Naturwissenschaften und Mathematik
Technische Universitaet Dresden
Aussenstelle Pirna-Copitz
Pratzschwitzer Strasse 15
D-01796 Pirna
GERMANY
FAX: +49-3501-527544
TEL.: +49-3501-527544
E-MAIL: seidel%copitz.uucp@ruucp.urz.tu-dresden.de

Dr. Ulrich von Moellendorff
Kernforschungszentrum Karlsruhe GmbH
Institut fuer Neutronenphysik und Reaktortechnik
Postfach 3640
D-76021 Karlsruhe
GERMANY
FAX: +49-7247-82-4874
TEL.: +49-7247-82-2739 or -4977
E-MAIL: inr282@dkakfk3.bitnet

Dr. (Ms.) Paola Batistoni
ENEA
Centro Ricerche Energia Frascati
Dipartimento Fusione
Divisione Neutronica
Via E. Fermi, 27
I-00044 Frascati (Roma)
ITALY
FAX: +39-6-94005314
TEL.: +39-6-94005739
E-MAIL: $FBAST1@IRMENEA

Dr. Chihiro Ichihara
Research Associate
Institute of Research Reactor
Kyoto University
Noda, Kumatori-cho, Sen-nan-gun
Osaka 590-04
JAPAN
FAX: +81-724-53-0360
TEL.: +81-724-52-0901
E-MAIL: A50457@jpnkudpc.bitnet

Dr. Yukio Oyama
Fusion Neutronics Laboratory
Department of Reactor Engineering
Japan Atomic Energy Research Institute (JAERI)
Tokai-mura, Naka-gun
Ibaraki-ken 319-11
JAPAN
FAX: +81-292-82-5709
TEL.: +81-292-82-6075
E-MAIL: oyama@fnshp.tokai.jaeri.go.jp

Dr. Petr A. Androssenko
Head of Laboratory
Institute of Physics and Power Engineering
(Fiziko-Energeticheskij Institut)
Bondarenko Sq. 1
249020 Obninsk, Kaluga Region
THE RUSSIAN FEDERATION
FAX: 095-2302326
TEL.: 084-3998850
E-MAIL: AAA@BRAND.OBNINSK.SU

Dr. Stanislav P. Simakov
Institute of Physics and Power Engineering
(Fiziko-Energeticheskij Institut)
Bondarenko Sq. 1
249020 Obninsk, Kaluga Region
THE RUSSIAN FEDERATION
FAX: 095-2302326
E-MAIL: POA@CJD.FEI.OBNINSK.SU

Dr. Sandro Pelloni
Head Group Advanced Systems
Department of Reactor Systems and System Engineering
Paul Scherrer Institute
CH-5232 Villigen/PSI
SWITZERLAND
FAX: 056/982327 PSI CH
TEL.: 056/992075
E-MAIL: PELLONI@CAGEIR5A.BITNET

Dr. John E. White
Radiation Shielding Information Center
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, Tennessee 37831-6362
U.S.A.
FAX: +1-615-574-6182
TEL.: +1-615-574-6176
E-MAIL: jew@ORNL.GOV

IAEA Staff Member:

Dr. Srinivasan Ganesan (Scientific Secretary of the Meeting)
RIPC-Nuclear Data Section