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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

REVIEW OF UNCERTAINTY FILES AND IMPROVED MULTIGROUP CROSS SECTION FILES FOR FENDL

Summary Report of the IAEA Advisory Group Meeting
organized by the International Atomic Energy Agency
in cooperation with the Japan Atomic Energy Research Institute
and held at the Tokai Research Establishment, JAERI, Japan,
8 to 12 November 1993

Prepared
by

S. Ganesan
IAEA Nuclear Data Section
Vienna, Austria

March 1994

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Abstract

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 present report contains the summary of the IAEA Advisory Group Meeting on "Review of Uncertainty Files and Improved Multigroup Cross Section Files for FENDL," held during 8-12 November 1993 at the Tokai Research Establishment, JAERI, Japan, organized in cooperation with the Japan Atomic Energy Research Institute. The report presents the current status of the FENDL activity and the future work plans in the form of conclusions and recommendations of the four Working Groups of the Advisory Group Meeting on (1) experimental and calculational benchmarks, (2) preparation processed libraries for FENDL/ITER, (3) specifying procedures for improving FENDL and (4) selection of activation libraries for FENDL.

Reproduced by the IAEA in Austria
March 1994

94-01154

Table of Contents

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.

FENDL library is composed of the several sublibraries describing the transport of both the plasma-source neutrons and secondary gamma rays through fusion reactor components, as well as the resulting radiation effects, such as nuclear heating, tritium breeding activation and material damage. Also included are cross sections for fusion and other important charged-particle nuclear reactions of the plasma constituents, as well as data for fusion-relevant neutron dosimetry. The sublibraries of FENDL are:

1. Coupled neutron-gamma cross section sets (presently in the VITAMIN-J structure) processed with the NJOY system for neutron and gamma-ray transport calculations for 65 elements and isotopes of primary interest.

2. The most important neutron activation cross sections for the estimation of radiation hazards.

3. Charged particle nuclear reaction cross sections of the D-T plasma constituents p, d, T, ^{3}He and ^{4}He.

4. Fusion relevant neutron dosimetry cross sections.

The Agency, in cooperation with the Japan Atomic Energy Research Institute, organized an Advisory Group Meeting on "Review of Uncertainty Files and Improved Multigroup Cross Section Files for FENDL," during 8-12 November 1993 at the Tokai Research Establishment, JAERI, Japan. Forty three nuclear data experts from 11 countries including two participants from the International Thermonuclear Experimental Reactor (ITER) team reviewed the current status of the following and made recommendations: 1.Experimental and calculational benchmarks for fusion neutronics. 2. Preparation of processed nuclear data libraries, consisting of coupled neutron-photon multigroup libraries and point Monte Carlo cross section libraries for FENDL/ITER. 3. Specifying procedures for improving FENDL, and, 4. Selection of activation libraries for FENDL. The report presents the current status of the FENDL activity and the future work plans.

The working nuclear data libraries in processed form for use by the ITER team in the early phase of ITER Engineering Design

Activity (EDA) are being derived by R. E MacFarlane by processing the first version of FENDL/E using the NJOY code system.

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. 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 extensive benchmarking and integral validation studies in the 1994-96 period.

The detailed Agenda, the complete list of participants and the recommendations of these Working Groups are presented in the appendices to this report.

The scope of the present AGM was considered at the two previous AGMs: "FENDL and Associated Benchmark Calculations" organized by the International Atomic Energy Agency and held in Vienna, Austria, 18-22 November 1991, and, "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.

Considering the urgent needs of engineering design activity of the ITER reported at the previous 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 AGM was considered very timely in order to facilitate international cooperation with the purpose to review the current status of production and accelerate integral testing of improved multigroup cross section libraries for ITER applications.

2. Organization of Advisory Group Meeting and Meeting Proceedings

The above Advisory Group Meeting was organized in cooperation with the Japan Atomic Energy Research Institute (JAERI). The local organizers did an excellent job in providing all the necessary arrangements which greatly contributed to the success of the meeting. The excellent cooperation of Dr. Hiroshi MAEKAWA, Head, Fusion Neutronics Laboratory, JAERI and Dr. Yasuyuki Kikuchi, General Manager, Nuclear Data Center, JAERI and their colleagues deserves a special mention in this respect. The participants of the meeting attended,with great enthusiasm, a technical tour on 10th afternoon arranged by the local organizers to the fusion machine, JT-60, and, the Fusion Neutronics Source, FNS, of JAERI. In the inaugural session, after the opening remarks by Dr. Y. KIKUCHI, the local organizer, S. GANESAN, the IAEA Scientific Secretary, delivered an address on behalf of the Director General of the IAEA. The main focus in this Advisory Group Meeting is on

reviewing, in detail: a.The present status of production and integral validation of coupled neutron-photon multigroup cross section of FENDL for use in discrete ordinates - neutronics calculations of fusion machines with emphasis to the urgent needs of engineering design activity phase of ITER. b.To discuss the current status of production and integral validation of point libraries for use in Monte Carlo calculations and C. To recommend procedures for improving the FENDL library.

The Meeting participants performed in-depth discussions mainly on the current status, bottlenecks, problem areas, tasks, goals, time schedule, information and man power sharing, formulation of future strategy in the light of past experience, etc. Oral presentations of papers were made covering the following subject areas, items 1 to 9.

1. Current status of production of coupled neutron-photon multigroup cross section libraries of FENDL for use in fusion neutronics.

2. Checking and validation of FENDL multigroup libraries by analysis of selected fusion benchmarks.

3. Production and use of cross section libraries for use in coupled neutron photon Monte Carlo transport calculations.

4. Checking of consistency, validation, and use of libraries to be adopted for FENDL for Monte Carlo calculations.

5. Submittal and discussion of experimental and calculational benchmarks in electronic format for inclusion in the compilation of IAEA benchmark problems for validation of methods and nuclear data in fusion neutronics. Define an improved benchmarking activity.

6. Final preparation of FENDL and processing of the transport activation and decay data files for ITER applications;

7. Define standards for improved evaluations for FENDL;

8. Define the evaluation selection procedure for an improved FENDL library;

9. Indicate the source of possible improved evaluations for FENDL;

10. Present status of uncertainty files, their processing and sensitivity studies related to FENDL.

The focus of this Meeting was on the first nine items

mentioned above. Item 10 is expected to be covered in detail as part of the agenda in the follow-up FENDL meeting planned at Garching, Germany, in September 1994.

3. Meeting Attendance

The Meeting was attended by forty one nuclear data experts from 11 countries (Austria, China, Germany, India, Italy, Japan, The Netherlands, The Russian Federation, Spain, U. K. and the U.S.A.) including two participants from the ITER team. In all, 16 experts were awarded by the Agency limited financial support in the form of lump sum grant to defray partially the travel and subsistence expenses. In addition, two staff members of the IAEA Nuclear Data section attended the Meeting. The complete list of participants is presented in Appendix C.

The meeting was held in conjunction with two other meetings as shown below to enable participation of the experts in more than one meeting where appropriate.

1. November 8-12, 1993,
IAEA Advisory Group Meeting on "Review of Uncertainty Files and Improved Multigroup Cross Section Files for FENDL". IAEA Scientific Secretary, Dr. S. Ganesan, IAEA Nuclear Data Section.

2. November 15-17, 1993,
IAEA Specialists' Meeting on "Comparison of Activation Cross Section Measurements and Experimental Techniques". IAEA Scientific Secretary, Dr. A.B. Pashchenko, IAEA Nuclear Data Section.

3. November 18-19, 1993,
1993 Symposium on Nuclear Data. Organized by JAERI, Local organizer Dr. Y. Kikuchi.

4. Results of the Meeting:

The Meeting was smoothly conducted by the respective chairman of each session as shown in the Agenda presented in Appendix A. After formal presentation of papers, four Working Groups were conducted.

(1) experimental and calculational benchmarks
(2) preparation processed libraries for FENDL/ITER
(3) specifying procedures for improving FENDL
(4) selection of activation libraries for FENDL

The meeting conclusions and recommendations prepared by the chairmen of the Working Groups were discussed at the summary session on the final day and adopted. The conclusions and recommendations are presented in Appendices B.1 to B.4. Some points of interest are mentioned below.

a. INTEGRAL VALIDATION OF NUCLEAR DATA

The working group (1) has indicated the urgent need to validate the FENDL-1 database by performing data testing through available benchmarks. IAEA/NDS has the prime responsibility to compile all the information on the benchmarks sent by providers and distribute them upon request to interested individuals who are validating FENDL data. The documentation and the compilation of these benchmarks at one distribution center (e.g. IAEA/NDS) will provide invaluable information for using these benchmarks in testing other fusion-related databases which may be developed in the future. The working group has selected the benchmarks (shown in Table I of Appendix B.1) that are relevant to ITER material selection for shield/blanket.

b. ITER FENDL Processing:

The final working libraries of FENDL-2 will be ready by mid 1996. MacFarlane described the ITER-funded program to process FENDL-1 for multigroup and Monte-Carlo applications. The multigroup and Monte Carlo libraries of FENDL-1 should be finished by 31 December 1993. The participants recommended that the IAEA Nuclear Data Section should try to continue its verification work to monitor and assure quality in the production of working libraries.

c. DISTRIBUTION OF FENDL:

The files of final working library for use by the design teams are expected to be large, perhaps 100 MB each, or more. It was suggested that many users would want single materials in MATXS format in order to make it easy to use only a subset of the materials. The NDS plans to organize on line access to the FENDL libraries on their VAX, and will provide the data on tapes for those who cannot use on line access (this may be slow).

d. THE ACTIVATION WORKING GROUP:

The Activation Working Group, organized in parallel, by Mr. A.B. Pashchenko, IAEA, considered the changes since the last FENDL meeting (Nov. 1991) caused by the start of the ITER EDA. ITER (represented by Dr. Shatalov) has stated that it wishes the IAEA/NDS to be involved with the production of nuclear data libraries (FENDL) that are required for ITER design.

The FENDL 1.1 activation library is available and will be processed by Dr. Mann for ITER EDA applications. However, this version will require further improvement. More details are given in the Appendix B.4. Regarding the NDS general activities, it was recommended that the IAEA/NDS should act as a repository for the various activation libraries and be prepared to distribute these to interested parties.

IAEA ADVISORY GROUP MEETING ON "REVIEW OF UNCERTAINTY FILES AND IMPROVED MULTIGROUP CROSS SECTION FILES FOR FENDL"

Conference Rooms #6, #7 & #8 in Research Building #1
Tokai Research Establishment, JAERI, Japan
8 - 12 November 1993

Organized in cooperation with the
Japan Atomic Energy Research Institute

GeneralChairman : H. Maekawa

8 November 1993

9:40-10:40 Inaugural session
Opening remarks, Dr. Y. KIKUCHI
Statement by the IAEA Scientific Secretary, S. GANESAN
Discussion on Agenda and adoption
Announcements by local organizers

10:40-12:00 Plenary Session : Requirements for ITER (Meeting Room # 7)
Chairman : E. Cheng
"Codes and FENDL library data for ITER Project,"
by G. CHATALOV (30 minutes)
Discussions

11:30-12:00 Plenary Session : Testing the performance of processed libraries by analyses of benchmarks
Chairman : U. Fischer
"Deriving Design safety factors from experimental and analytical results of engineering oriented integral experiments,"
by M. YOUSSEF (30 minutes)

12:00-13:40 Lunch

13:40-17:30 Plenary Session : Testing the performance of processed libraries by analyses of benchmarks (continued)
"FENDL benchmark analyses at KFK, Karlsruhe,"
by U. FISCHER (15 minutes)
"Bulk Shielding Experiments and Analyses at FNS,"
by Chikara KONNO (15 minutes)

"Benchmark Experiments for Validation of Gamma-Ray Production Cross Section Data," by Fujio MAEKAWA (15 minutes)
"Status of Beryllium Neutron Multiplication Excperiments and Analyses," by E. T. Cheng (15 minutes)

15:50-16:00 Coffee Break

16:00-17:30 Plenary Session :
Experiences in the preparation of processed libraries using the NJOY code system for ITER
Chairman : R. Roussin

"Processing of ENDF/B-VI and FENDL for Multigroup and Monte Carlo Applications," by R.E. MACFARLANE (40 minutes)
"Nuclear Data Processing at ENEA:FENDL validation by integral experiments," by G.C. PANINI (25 minutes)
"IAEA activities on processing, verification and benchmarking for FENDL: Current status and future plans," by S.GANESAN (15 minutes)

9 November 1993

9:40-12:00 Plenary Session :
Experimental benchmarks and analyses
Chairman : R. Santoro

"Benchmark Problems based on Time-of-Flight Experiments and Integral Experiments at FNS," by Yukio OYAMA (25 minutes)
"Outline of Benchmark Experiments under the JAERI/USDOE Collaborative Program on Fusion Blanket Neutronics," by Hiroshi MAEKAWA (20 minutes).
"An experimental benchmark of iron neutron and photon data," by K. SEIDEL (15 minutes)
"Status of beryllium transmission experiment," by U. FISCHER (15 minutes)
"Status of the bulk Shield benchmark experiment for NET/ITER (ENEA/CEA collaboration)," by M. MARTONE (15 minutes)
"Inventory code for activation in Fusion and use of multigroup cross section files for safety and waste management," by J.M. Perlado (15 minutes)
"Experimental Validation on Activation Files," by Yujiro IKEDA (15 minutes)

12:00-13:00 Lunch

13:00-14:45 Plenary Session : Basic evaluations
Chairman : M. Baba

"JENDL Fusion file, JENDL 3.2," by S. Chiba (25 minutes)

"Status of experimental facilities remaining to obtain differential nuclear data required for improving fusion evaluations and Extensions of ENDF/B-VI"
by D.C.LARSON (20 minutes)
"Recent Activities of CSEWG with regard to ENDF/B-VI,"
by R.W. ROUSSIN (20 minutes)
"Status of the ENDF/B-VI Data File: Release 2 and Future Plans,"
by P.G. YOUNG (20 minutes)
"Status of the European Fusion File EFF-2.4,"
by J. Kopecky (15 minutes)

15:00-17:30 Plenary Session :
Additional papers.
"Evaluation of Neutron Induced Data on ^{56}Fe and Their Uncertainties "
by Zhao Zhixiang (15 minutes)
"Current Status of Production of Multigroup Cross Section, and Future Intention in IAPCM and SWINPC" by Liu Cheng-an
"Fusion Blanket Neutronics Activities in B.A.R.C"
by T. K. Basu (10 mitutes)
"EASY2" by R. Forrest (10 minutes)

Organization of working groups
Election of chairman for each Working Group
Chairman : H. Maekawa
(1) experimental and calculational benchmarks
(2) preparation processed libraries for FENDL/ITER
(3) specifying procedures for improving FENDL
(4) selection of activation libraries for FENDL

16:00-17:30 Working Group Meeting
(1) Experimental and calculational benchmarks **(Meeting Room # 8)**
Chairman : U. Fischer

(4) Selection of activation libraries for FENDL **(Meeting Room # 6)**
Chairman : R. Forrest

10 November 1993

9:40-12:00 Working Group Meeting
(1) Experimental and calculational benchmarks **(Meeting Room # 8)**
Chairman : U. Fischer

(4) Election of activation libraries for FENDL **(Meeting Room # 6)**
Chairman : R. Forrest

12:00-13:20 Lunch

13:20-17:20 Technical Tour of JT-60 and FNS (See separate sheet)

18:00-20:00 Reception at "Akogi Club"

11 November 1993

9:40-12:00 Working Group Meeting
(2) Preparation processed libraries for FENDL/ITER **(Meeting Room # 8)**
Chairman : R. MacFarlane
(4) Selection of activation libraries for FENDL **(Meeting Room # 6)**
Chairman : R. Forrest

12:00-13:00 Lunch

13:00-17:30 Working Group Meeting
(3) Specifying procedures for improving FENDL **(Meeting Room # 8)**
Chairman : D. Larson / H. Vonach

Preparation of Working Group Report

12 November 1993

9:40-10:30 Plenary Session (Meeting Room # 7)
Chairman : T. Basu
"Testing of BROND files on the basis of benchmark data,"
"Problem of processing BROND library using the NJOY system,"
"The modifications of BROND file for FENDL, and, the intercomparisons of BROND data with ENDF/B-6 and JENDL-3"
by A. BLOKHIN (30 minutes)

10:30-12:00 Final session: Summary, conclusions and recommendations, adoption of final report of the Advisory Group Meeting. (Meeting Room # 7)
Chairman: S. Ganesan
Working Group Report by each W. G. Chairman

12:00-13:20 Lunch

13:20-17:30 Continued

CONCLUSIONS AND RECOMMENDATIONS:

Working Group I : Experimental Benchmarks for Neutron and Gamma Transport

Members

U. Fischer (Chairman)

M. Baba	T. K. Basu	S. Chiba	S. Ganesan
Y. Kanda	Y. Kikuchi	C. Konno	Liu Cheng-an
R. E. MacFarlane	F. Maekawa	H. Maekawa	M. Martone
Y. Oyama	G. C. Panini	R. W. Roussin	
K. Seidel	A. Takahashi	M. Z. Youssef	(Scientific Secretary)

Summary

The working group has indicated the urgent need to validate the FENDL-1 database by performing data testing through available benchmarks. The task requires an organized effort among interested participants who will be provided with the documented experimental data. The following are the procedures the working group has suggested to acheive this goal.

- Selection of benchmarks that are relevant to the material selection for ITER as the highest priority. However, other benchmarks can be selected in a latter stage for other fusion-related purposes.

- Compilation of the selected benchmarks. The recommended procedures were identified such that the organizations which performed the selected benchmarks will provide IAEA/NDS with the following items:

  - Technical description of the experiments including the details of the geometrical arrangement and material selection/composition.

  - The measured data and the associated experimental uncertainties. This should include a description of the method applied to obtain the experimental data, the corrections made and the associated uncertainties in the final results.

  - Provide a test calculational model the providers have applied in comparing the measured data to the experimental values in addition to the final calculational results. This is needed for comparing the prediction of

the providers to those obtained by others who will perform the data testing for the selected benchmarks.

- The above information has to be submitted in electronic format to the IAEA/NDS. The recommended format is that submitted previously to the IAEA/NDS by Dr. H. Maekawa for FNS beryllium, iron and lead slabs and by Prof. Seidel for TUD leadsphere benchmark experiments.

- The working group also recommends the submission of the same benchmark data to RSIC by the IAEA/NDS for inclusion in their already existing archival information on other shielding benchmarks (e.g. SINBAD library). RSIC has agreed to follow up this task.

- IAEA/NDS has the prime responsibility to compile all the information on the benchmarks sent by providers and distribute them upon request to interested individuals who are validating FENDL data. In the case limited man-power is forseen by some benchmark providers in preparing these benchmarks in the required electronic format, IAEA/NDS has agreed to explore the possibility of obtaining assistance in undertaking this task by IAEA fellows who visit IAEA on short term basis.

- In the process of FENDL validation through analyzing the identified benchmarks, the Monte Carlo MCNP code should be used for that purpose along with the processed FENDL pontwise data (FENDL/MC-1.0) as well as multigroup data (FEND/MG-1.0) with discrete ordinates and Monte Carlo codes. However, the application of other databases (e. g. processed libraries derived from the JENDL-FF, BROND-2, EFF-2 files etc.) and transport codes is highly recommended for comparison purposes and cross-checking.

- Upon finding discrepancies between measured and calculated responses, the WG further recommends performing sensitivity/uncertainty analysis to identify the sources of discrepancies and provide these information to evaluators through IAEA/NDS for further improvement in the FENDL file.

- The documentation and the compilation of these benchmarks at one distribution center (e.g. IAEA/NDS) will provide invaluable information for using these benchmarks in testing other fusion-related databases which may be developed in the future.

- The working group has selected the benchmarks shown in Table I that are relevant to ITER material selection for shield/blanket. The selected benchmarks are grouped in the following categories:

  - Benchmarks for shielding materials testing

  - Benchmarks for breeding/multiplication materials

  - Benchmarks for testing other materials of potential importance for fusion design application.

- The benchmarks selected are those characterized by having simple geometry and material composition for the prime purpose of FENDL cross section data testing. However, the Working Group recognizes that analysing other integral experiments that are design-oriented are very useful in quantifying the design margins needed to cover all possible discrepancies between measured and calculated responses.

- The selected benchmarks to be sent to IAEA/NDS described above are those agreed upon by the working group participants. Where needed, IAEA/NDS will officially request the benchmark data for such a submittal. It is recognized, however, that the selection can be further enriched by adding other existing benchmark experiments conducted by other researchers who did not attend the present FENDL meeting (e.g. Obninsk, LLNL). The selection shown in Table I will be further refined and more benchmarks added as will be discussed during the upcoming FENDL benchmarks meeting scheduled in December 13-16, 1993 to be held in Vienna.

  The processed libraries are expected to be ready by December 31, 1993 as pointed out in the report of the WG II. To start the benchmark analyses without delay the description of the experiments should be submitted to NDS as soon as possible. First results of the benchmarking are expected to be reported at the IAEA-AGM scheduled for September 1994 at Garching.

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 B.2

Report of Working Group 2 on
Preparation of Processed Libraries for FENDL/ITER
R. E. MacFarlane, Chairman
List of Attendees attached

1. ITER FENDL Processing

MacFarlane described the ITER-funded program to process FENDL-1 for multigroup and Monte-Carlo applications. The work will be completed as soon as the last few missing materials are received. Multigroup processing will use the VITAMIN-J group structures and weight function. Monte-Carlo processing will be delayed until the multigroup work is complete. Both libraries should be finished by 31 December 1993.

2. Alternate FENDL Processing

It was reported that Roger White of LLNL offered to process and validate a FENDL library using Livermore methods. Roussin announced that ORNL will convert the LANL FENDL results to AMPX format within 1 month of the completion of the LANL task.

3. Non-FENDL Data Processing

Work under NEA/NSC Standing Subgroup B is expected to make JEF and EFF libraries available through RSIC and NEA-DB. LANL will make a 175-group ENDF/B-VI library available. JAERI will have several libraries available, including FSXLIB-J3 for MCNP, and JSSTDL, a 295x104 multigroup library. Some data in DDX format may also be made available, although libraries based on JENDL3.2 won't be ready until March 1994.

4. Quality Control and Benchmarking

Roussin recommended the "Standard Blanket" problem, which has been used for previous 175-group libraries. His action is to provide it to MacFarlane. Ganesan recommended providing complete NJOY input decks for all the library runs to make it easy for others to check, repeat, or extend the work. The version numbers of the codes used to run the library production jobs should also be given. Ganesan also stated that the IAEA Nuclear Data Section will try to continue its verification work using students and fellows. Roussin said that ORNL plans to run the AMPX checking code RADE as a part of converting the LANL GENDF files to AMPX format. A new calculational benchmark based on some protype ITER arrangement was suggested. An action was put on Santoro to provide the specifications for this problem together with ANISN and ONEDANT input decks.

5. Distribution

The files are expected to be large, perhaps 100 MB each, or more. It was suggested that many users would want single materials in MATXS format in order to make it easy to use only a subset of the materials. Ganesan stated that the NDS would do no production processing runs, but they would continue some QA work, and they would take care of distribution and maintenance of the libraries. They hope to have online access to the FENDL

libraries on their VAX, and they will provide the data on tapes for those who cannot use online access (this may be slow). The NDS cannot commit itself to produce graphs of the data at this time. It was asked, "How do we define what the library is at any one time?" Each new version should be flagged with a version number, e.g., FENDL/MG-1.2. Users should be notified when new versions become available. MacFarlane described a "mail robot" program that could help to automate this notification through E-mail. Blokhin asked what is the standard contents of the FENDL processed library. It was explained that the processing will preserve the contents of the original evaluated files, therefore this would depend on the contents of the FENDL/E evaluated data library.

6. Library Specifications

The specifications for the multigroup library were reviewed. Some users would like more thermal groups, with upscatter, to be provided. Maekawa suggested that, based on his analysis of benchmarks, more groups are needed above 10 MeV. These two changes will be discussed later for use with FENDL-2. Proposals will be welcomed at the Garching meeting in September of 1994. Panini stated that the VITAMIN-J weighting option with T-dependent Maxwellian should be used. It was noted that the libraries would have to include dosimetry cross sections. An action was put on Vonach to provide IRDF 90.2 to MacFarlane in ENDF format. He will add them as special materials, for example, AL27D, for both multigroup and Monte-Carlo libraries.

List of Attendees

R. MacFarlane
R. Roussin
G. Panini
K. Seidel
Liu Cheng-an
S. Ganesan
C. Konno
A. Takahashi
Y. Oyama
A. Blokhin
Y. Kikuchi
H. Maekawa
U. Fischer
M. Martoni
T. Basu
F. Maekawa
Y. Kando
R. Santoro
M. Youssef
D. Larson
S. Chiba

WORKING GROUP 3 - SPECIFYING PROCEDURES FOR IMPROVING FENDL

The Working Group participants were as follows:

D. Larson	ORNL Chairman
H. Vonach	IRK Co-Chairman
P. Young	LANL Scientific Secretary
R. MacFarlane	LANL
R. Roussin	ORNL
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Y. Kikuchi	JAERI
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Y. Nakajima	JAERI
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TASK SUMMARY

The Working Group assessed the status of the FENDL/E-1.0 evaluated data library and identified guidelines and procedures to be followed in developing the next version of the library, FENDL/E-2.0. While FENDL/E-1.0 was the best library which could be assembled with evaluations available at the time, since then many new evaluations have become available with significantly improved physics and content. While waiting for results from data testing, work will be initiated on selecting and incorporating evaluations to replace the weakest parts of FENDL/E-1.0.

The group acknowledged the helpful role played by the IAEA/NDS

in developing the FENDL library thus far and urged its active participation in coordinating work on FENDL-2.

RECOMMENDATIONS

Specific recommendations from the Working Group are:

1. The IAEA NDS should assume a central role in coordinating technical information on nuclear data for the ITER JCT. The NDS should utilize the technical expertise of the present Working Group in nuclear data matters and should proactively interact with the ITER neutronics group at the Garching co-center, the ITER safety group at the San Diego co-center, and the various ITER Home Teams.

2. The Working Group adopted the following nomenclature for naming the various FENDL nuclear data libraries, and recommends adoption of this nomenclature in order to avoid confusion and allow precise reference to the various libraries:

FENDL/E-1.0	General Purpose Evaluation Library
FENDL/A-1.0	Activation Library
FENDL/DS-1.0	Dosimetry Library
FENDL/D-1.0	Decay Data Library
FENDL/C-1.0	Incident Charged-Particle Library
FENDL/MC-1.0	Processed Monte Carlo Library
FENDL/MG-1.0	Processed Multigroup Library
FENDL/U-1.0	Processed Uncertainty Library

3. The Working Group Advises the IAEA/NDS to assemble a physical tape or diskette containing the FENDL/E-1.0 materials library as defined in Appendix 1 of this Working Group Summary, and make it available for distribution to interested parties.

4. The processing of FENDL/E-1.0 must be completed by the end of December, 1993. A. Blokhin agreed to provide updated FENDL/E-1.0 evaluations for Zr isotopes and 93-Nb to G. Panini and E. Menapace during their visit to Russia. These data will be electronically transmitted to the IAEA/NDS and to R. MacFarlane for processing by the end of November. In the event the updated evaluations for Zr and Nb are unavailable on that time scale, the existing versions of these evaluations will be processed.

5. The requirements and procedures for the FENDL/E-2.0 evaluations are as follows:

The following information is required for all candidate files:

Gamma-ray production

Neutron and charged-particle emission in File 6 format

File 1 descriptive information

Recoil distributions in File 6 format for major structural materials

Energy balance must be better than 2% at all energies

The following additional recommendations are made:

Simplified File 6 recoil distributions are recommended for other materials.

Inclusion of uncertainty information is strongly encouraged.

Use of Standard Reference Data such as IRDF 90.2 dosimetry cross sections in candidate files is highly recommended.

It is recommended that single isotopic evaluations within a given material be replaced only if the combination is shown to be consistent with the natural element experimental data for the material.

6. Comparison plots of candidate materials compared with FENDL-1 and other candidates, as well as experimental data, are essential for selecting the best candidate. They should include:

File 3: Cross section data, including pointwise reconstruction of resonance region

File 4: 1st 3 Legendre Coefficients a1, a2, a3. If significant differences occur between evaluations, then comparisons should be made between evaluated angular distributions and experimental data.

File 5: Not allowed for new candidates, but some new File 6 data may have to be compared with existing File 5 data in FENDL/E-1.0.

File 6: Methods for comparison of double-differential evaluated data will be determined by a Task Force consisting of R. MacFarlane, H. Vonach, C. Y. Fu, G. Panini and S. Chiba.

Compare energy distributions for neutrons, charged particles, and recoils at 8.0, 11.0 and 14.1 MeV.

For neutron spectra, compare with Vonach evaluation where possible, angle-integrated data of Takahashi for others. Vonach has files of (n,xn) data, which he will provide on floppy disk to evaluators who request it.

For charged-particle spectra, compare with Grimes and Haight data at 14.1 MeV

Generate spectral gamma ray production cross sections at incident neutron energies of 8.0, 11.0 and 14.1 MeV.

Generate integrated gamma ray production cross sections as a function of neutron energy.

Gamma ray production; compare spectral shapes normalized to unity with those of Dickens (or other relevant data) at incident neutron energies of 8.0, 11.0 and 14.1 MeV.

Compare capture gamma ray spectra at thermal neutron energy as a minimum.

If uncertainty files are present, compare the variances as a function of neutron energy for MF=33.

7. The FENDL/E-1.0 library will automatically become the starting point for the FENDL/E-2.0 library, and replacement evaluations will only be included according the procedure worked out in this Working Group and described here. Only new evaluations will be considered for FENDL/E-2.0, that is, no evaluations that were passed over in the FENDL/E-1.0 selection process will be considered for FENDL/E-2.0. The following procedure is recommended for implementing improvements that will lead to the FENDL/E-2.0 library:

A. Beginning immediately, candidate replacement evaluations for the list of FENDL general purpose materials should be sent to R. MacFarlane at LANL for initial processing with NJOY. These evaluations must be cleared through the standard checking codes (available from the NDS) prior to being transmitted to MacFarlane.

B. The files will be processed by MacFarlane upon receipt.

C. Any diagnostic information or errors will be communicated back to the evaluator (with a copy to the NDS) for consideration and updating/improving the candidate evaluation.

D. After any needed corrections are made and the evaluation is successfully processed, MacFarlane will check with U. Fischer to ascertain whether clean fusion benchmark data is available for testing. If so the NDS, in coordination with Fischer and others, will organize the needed calculations, and convey results and recommendations back to MacFarlane and the evaluator.

E. It is recommended that the IAEA convene an Advisory Group Meeting in September or October, 1995 to perform selection of evaluations which will comprise the preliminary FENDL/E-2.0 library. Prior to this meeting, detailed review kits containing comparison plots, as described below, must be provided. Analysis of the kits, together with both FENDL 1.0 benchmark testing results and results from the simple benchmarks described above, will guide the selection process. The final FENDL/E-2.0 Library will be released after data testing in July 1996, after which it will be provided to the ITER/EDA activity as well as to other fusion projects by the IAEA/NDS.

8. The status and progress of the procedure for obtaining FENDL/E-2.0 will be reviewed at the September, 1994 Advisory Group Meeting in Garching.

9. A preliminary list of candidate replacement evaluations for FENDL/E-2.0 was compiled. These new candidates are in addition to those listed in Table 1 of the summary from the 18-22 November 1991 FENDL meeting:

27-Al	ENDF/B-VI.3
28-Si	JENDL-FF
Isotopes Ti	JENDL-FF
50,52-54-Cr	JENDL-FF
63,65-Cu	JENDL-FF
Isotopes Zr	ENDF/B-VI.3
	JENDL-FF
	BROND-2
93-Nb	BROND-2
Isotopes Mo	EFF-2
	JENDL-FF
Isotopes Sn	JENDL-FF
208-Pb	JENDL-FF
	ENDF/B-VI.3

A list of candidate replacement evaluations (the above list, combined with portions of Table 1 of the Summary Report from the November 1991 meeting) is given in Appendix 2. Additional candidates are still possible and encouraged.

10. It is recommended that the review kits and comparison plots that are essential for the comparison process at the 1995 Advisory Group Meeting be prepared at LANL in conjunction with the data processing activity outlined in Item 5. Additional review and testing at other facilities will be encouraged and coordinated with MacFarlane. The IAEA/NDS is requested to stress the importance of, and recommend support for, this activity to the ITER JCT and US Home Team.

APPENDIX 1

List of FENDL/E-1.0 Evaluations

MATERIAL	LIBRARY
H-1	ENDF/B-VI.1
H-2	BROND-2
H-3	ENDF/B-VI.0
Li-6	ENDF/B-VI.1
Li-7	ENDF/B-VI.0
Be-9	ENDF/B-VI.0
B-10	ENDF/B-VI.1
B-11	ENDF/B-VI.0
C-Nat	ENDF/B-VI.1
N-14	BROND-2
N-15	BROND-2
O-16	ENDF/B-VI.0
F-19	ENDF/B-VI.0
Na-23	JENDL-3.1
Mg-Nat	JENDL-3.1
Al-27	JENDL-3.1
Si-Nat	BROND-2
P-31	ENDF/B-VI.0
S-Nat	ENDF/B-VI.0
Cl-Nat	ENDF/B-VI.0
K-Nat	ENDF/B-VI.0
Ca-Nat	JENDL-3.1
Ti-Nat	JENDL-3.1
V-Nat	ENDF/B-VI.0
Cr-50	ENDF/B-VI.1
Cr-52	ENDF/B-VI.1
Cr-53	ENDF/B-VI.1
Cr-54	ENDF/B-VI.1
Mn-55	ENDF/B-VI.0 (JENDL-3.1)
Fe-54	ENDF/B-VI.1
Fe-56	ENDF/B-VI.1
Fe-57	ENDF/B-VI.1
Fe-58	ENDF/B-VI.1
Co-59	ENDF/B-VI.2
Ni-58	ENDF/B-VI.1
Ni-60	ENDF/B-VI.1
Ni-61	ENDF/B-VI.0
Ni-62	ENDF/B-VI.1
Ni-64	ENDF/B-VI.1
Cu-63	ENDF/B-VI.2
Cu-65	ENDF/B-VI.2

MATERIAL	LIBRARY
Zr-90	BROND-2
Zr-91	BROND-2
Zr-92	BROND-2
Zr-94	BROND-2
Zr-96	BROND-2
Nb-93	BROND-2
Mo-Nat	JENDL-3.1
Sn-Nat	BROND-2
Ba-134	ENDF/B-VI.0
Ba-135	ENDF/B-VI.0
Ba-136	ENDF/B-VI.0
Ba-137	ENDF/B-VI.0
Ba-138	ENDF/B-VI.0
Ta-181	JENDL-3.1
W-182	ENDF/B-VI.0
W-183	ENDF/B-VI.0
W-184	ENDF/B-VI.0
W-186	ENDF/B-VI.0
Pb-206	ENDF/B-VI.0
Pb-207	ENDF/B-VI.1
Pb-208	ENDF/B-VI.0
Bi-209	JENDL-3.1

APPENDIX 2

COMPLETE LIST OF CANDIDATE REPLACEMENT EVALUATIONS FOR FENDL/E-2.0

1-H	CENDL-2
2-H	CENDL-2
3-He	CENDL-2
4-He	ENDF/B-VI
6-Li	JENDL-FF
7-Li	JENDL-FF
	EFF-2
9-Be	EFF-2
	JENDL-FF
14-N	ENDF/B-VI.2
	JENDL-FF
15-N	ENDF/B-VI
27-Al	ENDF/B-VI.3
	EFF-2
	JENDL-FF
28-Si	JENDL-FF
	EFF-2
	ENDF/B-VI.3
29-Si	ENDF/B-VI.3
30-Si	ENDF/B-V
Isotopes Ti	JENDL-FF
50,52-54-Cr	JENDL-FF
52-Cr	EFF-2
56-Fe	EFF-2
	CENDL-2
	JENDL-FF
59-Co	JENDL-FF
58-Ni	EFF-2
	JENDL-FF
60-Ni	EFF-2
63,65-Cu	JENDL-FF
Isotopes Zr	ENDF/B-VI.3
	JENDL-FF
	BROND-2
93-Nb	BROND-2
	JENDL-FF
Isotopes Mo	EFF-2
	JENDL-FF
Isotopes Sn	JENDL-FF
208-Pb	JENDL-FF
	ENDF/B-VI.3
209Bi	JENDL-FF

APPENDIX B.4

Working Group 4 - Selection of Activation Libraries for FENDL

The meetings of the Activation Working Group were attended by the following:

R. A. Forrest	AEA Fusion, Culham (Chairman)
F. Mann	WHC (Scientific Secretary)
E. Cheng	TSI
S. Chiba	JAERI
Y. Ikeda	JAERI
Y. Kikuchi	JAERI
J. Kopecky	ECN Petten
D. Larson	ORNL
E. Menapace	ENEA-INN.SVIL
Y. Nakajima	AERI
A. Pashchenko	IAEA/NDS
J. M. Perlado	Institute Nuclear Fusion, Madrid
G. Shatalov	ITER/Garching
Y. Uno	JAERI
H. Vonach	IRK
P. Young	LANL
Z Zhoa	IAE/China

The Activation Working Group considered the changes since the last FENDL meeting (Nov. 1991) caused by the start of the ITER EDA. ITER (represented by Dr. Shatalov) has stated that it wishes the IAEA/NDS to be involved with the production of nuclear data libraries (FENDL) that are required for ITER design.

The FENDL 1.1 activation library is available and will be processed by Dr. Mann for ITER EDA applications. However, this version will require further improvement. The following organisations were identified as likely to produce evaluations useful for activation library production (the organisations in parenthisis will likely produce individual evaluations for relatively few reactions):

ECN	
JAERI	
IPPE+IATE	
CIAE	
WHC	(LANL, ORNL)
	(IRK, ENEA)

The work of IAEA/NDS in the production of the FENDL activation library and in encouraging library development are gratefully acknowledged by the members of the Activation Working Group.

The following recommendations were made by the Activation Working Group.

IAEA/NDS Coordination Role

1. IAEA/NDS should proactively act as a coordinating body for technical advice on

nuclear data for the ITER JCT, using the expertise of the present Working Groups. In particular, the IAEA/NDS should interact with the ITER neutronics group at the Garching co-centre, the ITER safety group at the San Diego co-centre as well as the various ITER Home Teams.

2. The Activation Working Group endorses the recommendations of the Del Mar Workshop to the IAEA (Appendix B.4.1 which is enclosed) with the following addition.

Development of a standard interface (neutron flux to activation code to photon flux) with standard neutronics transport codes as those codes become identified by ITER.

3. The IAEA/NDS should actively communicate (preferably via e-mail) with members of the Activation Working Group between meetings whenever the advice of the Group is needed by the IAEA/NDS in its ITER coordination role. Members of the Group should keep the IAEA/NDS informed of information that may need to be distributed to members of the Group.

4. A periodic (probably bi-annual) news-sheet giving details of new evaluations, updated libraries, activation calculation results and benchmark data should be distributed to members of the Activation Working Group by the IAEA/NDS to improve communication. The news-sheet should also include activities of the IAEA/NDS and other IAEA groups of interest to the Activation Working Group.

5. The IAEA/NDS should encourage the ITER JCT to support relevant calculations using the various libraries and codes and the comparisons of the results.

6. The work supported by ITER through the Home Teams should be available to IAEA/NDS for further distribution to interested parties.

7. At future FENDL meetings the IAEA/NDS should report on the mechanisms set up for fulfilling its coordinating role and the issues that have arisen.

8. The IAEA/NDS should attempt to have ITER representation at future FENDL meetings. The ITER representative should give details of the various tasks (relevant to activation) that have been placed and present the future work programme.

Validation of Existing Libraries

9. The data generated by the JAERI/USDOE collaboration for the experimental benchmark is recognised as an extremely valuable tool to improve activation libraries. Consequently IAEA/NDS should ensure that the data are made available and distributed to library developers. By 1 January 1994 Dr. Ikeda will supply the data on electronic media to the IAEA/NDS for distribution.

Before the 1994 FENDL meeting any comparisons should be sent to the IAEA/NDS and should be collected for presentation at the meeting. The FENDL/A-1.1 activation library should also be compared in this fashion.

As a part of the validation process for libraries developers should calculate the JAERI/USDOE benchmark and report the results to IAEA/NDS.

10. The IAEA/NDS should aid in the validation of decay data libraries by requesting that each decay data library be presented in a summary form, e.g. half-life, decay mode, average α, β and γ decay energies and in a format to be decided by Drs. Mann and Forrest (by 1 January 1994) so that a computer comparison between libraries can be made. Obvious mistakes such as miss-assignment of isomeric states and double counting can then be corrected.

11. The IAEA/NDS should encourage the ITER JCT to support new benchmark experiments at higher fluence and with a wider range of materials to aid in the validation of activation libraries.

12. The IAEA/NDS should encourage library developers to plot data for any of the important reactions that they study. Such plots should be sent to the IAEA/NDS where they can be stored. These plots should be made available at future FENDL meetings. In addition, the IAEA/NDS should seek volunteers to plot all relevant data and evaluations for the important reactions.

New Libraries

13. As an aid to revising and extending the activation library the list of important reactions constructed for FENDL/A-1 should be reviewed and extended. Potential candidates for the list of important reactions shall be sent to the IAEA/NDS by 1 April 1994. By 1 June 1994 the IAEA/NDS shall send the merged list of all potential reactions to all who contributed candidates. A new list will be approved at the 1994 FENDL meeting.

14. The Del Mar recommendations recognise that the current FENDL/A-1.1 activation library is not adequate for most calculations required for the ITER design. The most efficient means of generating the FENDL/A-2 activation library would be for the IAEA/NDS to recommend to the ITER JCT that work on library development be supported by the ITER Home Teams. The strengths of the various new libraries can be judged by the results of benchmark comparisons and a composite library then constructed without detailed inter-comparisons of individual reactions (this work having been done by the library developers).

15. The format of future FENDL activation libraries should be the same as agreed for FENDL/A-1 (namely the EAF format). However, the IAEA/NDS should produce additional formats as needed.

16. At the next FENDL meeting code developers should present details of the dose conversion factors and range of nuclides covered for the following:

a) gamma flux to tissue dose conversion
b) waste disposal criteria
c) activity to ingestion dose
d) activity to inhalation dose

17. Although not of high priority, further research is encouraged on γ-induced reactions. The importance of sequential charged particle reactions needs to be

established before large-scale library development within FENDL occurs.

IAEA/NDS General Activities

18. The IAEA/NDS should act as a repository for the various activation libraries and be prepared to distribute these to interested parties.

19. The Activation Working Group acknowledges the start of the CRP on the establishment of a reference data library of nuclear cross sections and encourages the CRP to have an active role and to report progress to the Working Group.

20. The IAEA/NDS is recommended to publish the report on the Second International Activation Calculational Benchmark Comparison Study, the final draft of which was available at this meeting. This study is an item (II C) in the validation procedure outlined in the Del Mar recommendations.

21. The IAEA/NDS is urged to continue to sponsor Activation Working Group Meetings to enable collaboration and comparison of libraries and results. The IAEA/NDS should seek representatives from other groups in the IAEA with useful information for the Activation Working Group to attend future FENDL meetings.

The Activation Working Group appreciates the hospitality of the staff of the Japanese Nuclear Data Centre and the Fusion Neutron Source (FNS) Group in hosting this meeting.

APPENDIX B.4.1

ACTIVATION*

Discussion Leaders: R. A. Forrest, J. Kopecky

Following the presentations the discussions focused on three areas:

I. Criteria for Activation Files
II. Criteria for Inventory Codes
III. Validation of Data and Codes

I. CRITERIA FOR ACTIVATION FILES

There are three crucial criteria that must be satisfied by activation files for fusion applications:

A. Completeness
B. Validation, and
C. Inclusion of Uncertainties

A. Completeness

1. Reaction data should cover the energy range 0-20 MeV and include all energetically possible reactions.
2. The file should include as targets all nuclides with a half-life > 5 days. The importance of shorter half-life targets is not proven, but inclusion of these data can be viewed as a bonus.
3. Data for actinide targets are essential. Preliminary studies with EAF-3 indicate that U and Th impurities in the range 1 ppb - 1 ppm could be significant. Feedback on typical U and Th impurity levels in materials should be obtained from the materials community.
4. Data for nuclides with half-lives > 1 second should be included in the decay library. Such data are vital for afterheat calculations following shutdown.

B. Validation

This subject is treated in Section III.

C. Inclusion of Uncertainties

Activation files should contain for each reaction typical uncertainty values. They are essential to enable designers to make sensible decisions. It is satisfactory that each reaction should contain 1-3 group values of uncertainty, as in the current EAF libraries. Lack of experimental data means that systematic estimates or guesses have to be used at this time.

In addition to these three major points the following recommendations were also agreed:

D. Consistency between the general purpose file and activation file should be a long term goal. It is recognized that at the present time many activation files contain reaction data that are not consistent with the general purpose file. In many cases the activation data selected from another evaluation is of higher accuracy than the general purpose file and these reactions should be flagged so that special care can be taken in subsequent evaluations.

E. The importance of sequential charged particle reactions will be studied within the long-lived radioactive nuclides for fusion CRP [Coordinated Research Project] of the IAEA. The results from this CRP should be studied to determine in which ways the data libraries should be extended.

II. CRITERIA FOR INVENTORY CODES

Results from the Second International Activation Calculation Benchmark Study (organized under the FENDL activity) were summarized. A conclusion of this study is that some activation codes are not able to model accurately multistep reaction pathways.

The main recommendation of the discussion was that an inventory code should be accompanied by the following:

A. Code specifications
B. User manual
C. Verification results

A. Code specifications

The various criteria that an inventory code should satisfy were divided into three levels of importance. The highest level of importance contains the following three criteria:

1. accurate treatment of multistep reactions;
2. correct treatment of isomeric states, both as targets and as daughters; and
3. the ability to input uncertainty data files to perform uncertainty and sensitivity calculations.

The second level of criteria are:

4. the ability to input standard data libraries in the format recommended for FENDL;
5. the ability to calculate gas production (H and He isotopes); and
6. the ability to use additional data libraries, e.g., for potential biological hazards.

The following criteria were identified, but with limited importance:

7. calculations for an arbitrary irradiation history (pulsed irradiation);

8. treatment of sequential charged particle reactions; and
9. the ability to calculate inventories in many regions and present the output as a sum of data for these various regions.

B. A comprehensive user manual should be available for the code.

C. Proof of the adequacy of the code to satisfy the above specification should be presented. As a minimum the results of running the two irradiations in the Code Comparison Study (irradiation of natural iron and 50Cr) must be presented.

In addition it is recognized that other uncertainties apart from those in the cross section can contribute to the uncertainty in the radiological response functions. It would be of interest to incorporate uncertainties in the neutron spectrum as these become available from neutronic calculations.

III. VALIDATION OF DATA AND CODES

It is recognized that activation files contain many data for nuclides where no experimental measurements are available. It is therefore essential to validate these libraries against experimental irradiations to test the adequacy of the theoretical predictions used.

A. It is recognized that the JAERI/UCLA collaboration on experimental benchmarks is an extremely valuable first step on this validation program. The relatively low fluences compared with those anticipated in fusion reactors means that multistep reactions cannot be tested. However, many valuable tests of both the cross section and decay libraries are possible.

B. It is recommended that the input data for this benchmark be supplied to the IAEA NDS for subsequent distribution to interested parties.

C. It is recommended that code developers and compilers of activation libraries use these input files to compare the results of calculations with their system to the experimental results.

A secondary recommendation is additionally made that the new CRP on activation libraries should consider the possibility of computational benchmarks - comparing calculations of various irradiations using different activation libraries. Such studies could provide a cost effective method of identifying deficiencies in the participating libraries.

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*This Appendix is an extract from the Summary of "International Workshop on Nuclear Data for Fusion Reactor Technology, May 3-6, 1993, Del Mar, California, U.S.A."

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