

STATUS OF THE JEF AND EFF PROJECTS

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Abstract: Following the positive experience gained with the first version of the JEF (Joint Evaluated File) library, which was distributed to NEA Data Bank member countries in 1985, a significantly improved version of the library, JEF-2.0 (in ENDF-6 format), was distributed for testing at the end of February 1990. It is planned to compile, in the middle of 1991, following intensive benchmark testing, a version of the JEF-2 library for general use.

The EFF (European Fusion File) project and the associated EAF (European Activation File) project are sponsored by the European Community's Fusion Technology Programme. The programme of the EFF-project is in its second phase, after the successful completion of the EFF-1 data file. This phase has been defined from 1989 to 1991 and the emphasis is on the improvement of a shielding data base. The EFF-2 library will be ready at the end of 1991 and contain new evaluations for most of the important fusion reactor materials. A follow-up programme, including benchmark testing has been defined.

The creation of a joint JEF-EFF data file has been agreed. The file will be compiled during 1992.

Background

The Joint Evaluation File (JEF) project was started in October 1981 in order to coordinate the evaluation efforts within the NEA Data Bank member countries (Western Europe and Japan). A first version of the data library was distributed in 1985. The library was extensively benchmark tested [ref. 1], and the results showed very good agreement with experiments for different aspects of reactor physics calculations. Nevertheless, it was felt that significant improvements could be achieved, and it was decided to create an improved version in ENDF-6 format of the JEF-1 library. While starting the re-evaluation work for JEF-2, it was decided to release the JEF-1 data also to users outside the NEA Data Bank community. This decision affects also group cross section libraries derived from JEF-1.

The European Fusion File (EFF) project and the associated European Activation File Project (EAF) are sponsored by the European Community's Fusion Technology Programme. The first programme is directed to the short-term needs of the NET team, which designs the Next European Torus, whereas the second programme is directed to long-term needs in the development of a Fusion Demonstration Reactor, in particular in connection with the study of low activation materials. Various European laboratories participate in these projects.

The programme of the EFF-project is in its second phase, after the successful completion of the EFF-1 data file. The second phase programme has been defined from 1989 to 1991. The emphasis of the first phase was on the improvement of the tritium breeding and neutron

multiplication cross-sections, whereas the second phase emphasizes the improvement of a shielding data base. In practice the EFF-1 and EFF-2 projects aim to supplement the JEF-1 and JEF-2 data files, respectively, with high-energy data relevant for fusion applications. Therefore the two projects are closely related.

Joint Evaluated File (JEF)

Content of the JEF-2 library

General Purpose Files

The JEF-2 general purpose tape contains 312 isotopes. A few of these isotopes have been taken over from the JEF-1 library, but the most important have been either updated or re-evaluated. Special attention has been given to the structural materials, the fission products and the actinide data. The stable isotopes of Cr, Fe and Ni have, for example, all been completely re-evaluated as well as the major actinides: ^{235}U , ^{238}U and ^{239}Pu . The unresolved data for ^{241}Pu and $^{242\text{m}}\text{Am}$ have been revised. Covariance data will be included for the most important isotopes.

The resolved resonance region of a large number of the fission products have been updated with recent information and improvements to the particle production reactions have been included. A few fission product isotopes (^{96}Tc , ^{129}I , ^{135}Cs and ^{107}Pd) have been selected for particular investigation in view of the interest in for example transmutation applications. An examination,

covering both theory and experiments, of the inelastic cross section of the even-even fission products has been performed, but the application of the results to the JEF-2 data will be performed at a later stage.

Thermal Scattering Law Data

The JEF-2 thermal scattering law data ($S(\alpha, \beta)$) tape will contain:

H (H_2O)	8 temperatures from 293.6 to 623.6 K
D (D_2O)	8 temperatures from 293.6 to 673.6 K
Graphite	11 temperatures from 293.6 to 3000. K
Be	8 temperatures from 293.6 to 1200. K
Polyethylene	2 temperatures 293.6 and 350. K

Pointwise data generated with NJOY-89.62+ will also be available for the following cold moderators:

para-Hydrogen	(H in para- H_2) T=20.38 K (liquid)
ortho-Hydrogen	(H in ortho- H_2) T=20.38 K (liquid)
para-Deuterium	(D in para- D_2) T=23.65 K (liquid)
ortho-Deuterium	(D in ortho- D_2) T=23.65 K (liquid)

The corresponding $S(\alpha, \beta)$ data for these cold moderators have 3-digit exponents. As this was not foreseen in the ENDF-6 format and as the processing can only be done on 64 bit computers, the pointwise files should be preferred.

Radioactive Decay and Fission Yield Data

The JEF-2 Radioactive Decay Data File will contain all necessary decay information, such as half-life, average decay energies, spectra etc., for about 2340 unstable isotopes. This is almost double as many isotopes as was present in JEF-1. The JEF-2 library has been updated and complemented with new information, mainly from the Evaluated Nuclear Structure Data File (ENSDF) compiled at the National Nuclear Data Center at Brookhaven, USA. This information has also been supplemented by recent experimental information, especially from G. Rudstam et al., Studsvik, Sweden.

The Fission Yield Library for JEF-2 is completely new and is based on a recent evaluation by M. James et al. [ref. 2]. It contains data for 39 different fissioning systems, and both independent and cumulative yields are given.

Photon Interaction Data

No special effort was devoted, within the JEF project, to the photon interaction data. The most recent data from D.E. Cullen et al. [ref. 3] was adopted for the JEF-2 library. The tape contains evaluations of cross sections (MF=23) and form factors (MF=27) for 100 elements.

Status of the JEF-2 library

A preliminary version, called JEF-2.0, of the general purpose files was sent out at the end of February 1990 to laboratories involved in the benchmark testing of the library. Revised data for ^{55}Mn , ^{235}U , ^{239}Pu and the major structural materials were issued in October 1990. This library was named JEF-2.1. Following the initial processing of the data for benchmark testing, a few minor problems, mainly format problems, have been identified.

The Radioactive Decay Data and the Fission Yield Data were distributed for testing in the middle of June 1990. A final version of the Fission Yield library was issued in January 1991. The Radioactive Decay Data library would be ready in the early autumn of 1991, following the testing of an intermediate version of the library to be issued at the end of May 1991.

The work on the Thermal Scattering Law data ($S(\alpha, \beta)$ data) for the above mentioned moderators was terminated in the beginning of April 1991. Pointwise data have been processed using the computer code NJOY-89.62 with additional updates from IKE Stuttgart.

It is planned to have a version of the complete library, called JEF-2.2, available for general use in the Data Bank member countries in the autumn of 1991.

First results from the benchmark testing of JEF-2

The benchmark testing of the first version of the JEF-2 library has been started at several laboratories directly involved in the JEF project and the first preliminary results have already been discussed at a recent meeting of the JEF group.

Thermal reactor data

The integral validation for thermal neutron reactors of the JEF-2 major actinides (^{235}U , ^{238}U and ^{239}Pu) has been performed at Saclay, France, by H. Tellier et al. [ref. 4]. The tendency research method was used and the comparison with calculations was performed for 66 different clean integral experiments.

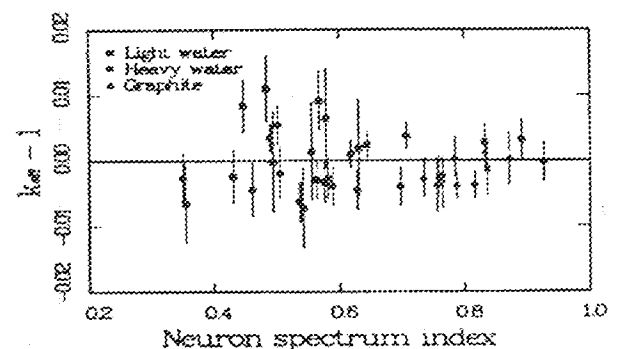


Figure 1 Residual deviations after tendency research for multiplying media which only contain uranium [ref. 4].

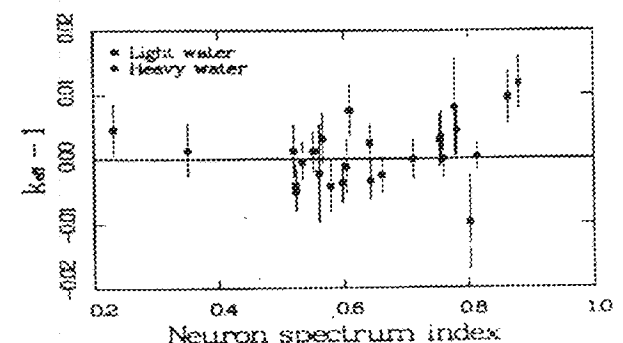


Figure 2 Residual deviations after tendency research for multiplying media which contain plutonium or an uranium and plutonium mixture [ref. 4].

The results could be summarised as follows:

- The moderators would need a small decrease of the light water migration area of about 1%. This modification affects only the leakage of small critical assemblies and will be of no importance for large size power reactors.
- No modifications are at present proposed for the fissile nuclei, ^{235}U and ^{239}Pu . The thermal data for these isotopes agree very well with the recommendations by Divadeenam [ref. 5] and Axton [ref. 6].
- The effective capture integral of ^{238}U may need to be decreased by about 0.25 barn. For a typical light water reactor this represents about 1.3 per-cent.

The above mentioned results has been fed back to the responsible evaluators for their consideration, and will be further checked on integral experiments.

Fast reactor data

Two independent set of results for the calculation of some fast critical assemblies were presented at the last meeting of the JEF working group in December 1990. E. Fort, CEN Cadarache, France and M. Caro, PSI, Switzerland, had calculated, using the preliminary JEF-2.1 data, the JEZEBEL, GODIVA, FLATTOP and BIG TEN cores and the results agreed well with each other and with the experimental results. The calculations recently performed at PSI will be presented at this conference [ref. 7].

Only limited new work has been devoted to the higher actinides of JEF-2. Most of the isotopes have been taken over from the JEF-1 library, as these isotopes, such as ^{237}Np , ^{241}Am and ^{243}Am , have shown excellent performance in both thermal and fast energy spectrum systems. Table 2 below shows the results of calculations using the ^{237}Np capture and (n,2n) data in the analysis of ^{237}Np sample irradiation in PHENIX [ref. 8].

Reaction	C/E
Capture	0.90 ± 0.05
(n,2n)	1.19 ± 0.15

Table 1 C/E values with JEF-2 data on ^{237}Np reaction rates, obtained from a ^{237}Np sample analysis after irradiation in the PHENIX core.

Fission products

The JEF-1 fission product data were thoroughly tested by H.J. Janssen et.al. [ref. 9]. This effort will not be repeated for the JEF-2 data, as most of the isotopes were taken over from the JEF-1 file with additional updates of the resonance region. A document containing a comparison between JEF-2 and other recent evaluated libraries for some simple integral data, such as thermal values, resonance integrals etc., will be issued.

A paper, presented at this conference, gives indications on the integral test of the fission product data in the thermal range [ref. 10].

Fission Yields and Decay Data

A provisional version of the JEF-2 Decay Data File was issued in June 1990 for testing purposes. A. Tobias, Nuclear Electric, UK and G. Rudstam, Studsvik, Sweden performed decay heat calculations using these data and concluded that the new data yielded improved agreement, relative to JEF-1, with measured results at most cooling times. The gamma heat part was particularly improved. A few isotopes in need of re-evaluation was identified. The delayed neutron yields have been examined by J. Blachot et.al. It is expected that the latest revisions to the JEF-2 Decay Data File will further improve the calculated results.

European Fusion File (EFF)

A break-down of the 1989-1991 EFF-2 programme, which also contains some benchmarking and test calculations to facilitate its use by the designers of NET, is as follows:

1. Completion of the working libraries derived from EFF-1, in particular with respect to problems with kerma, DDX, gas-production, MCNP library and benchmarking (Pb, ^7Li , Be).
2. Evaluate Fe, Cr, Ni cross-sections with emphasis on DDX, photon production and covariance data.
3. Create an EFF-2.0 starter file as an extension to EFF-1, with new evaluations for ^7Li , Be, Al, Fe, Cr, Ni, and Pb, process these data into the VITAMIN-J structure and perform benchmark calculations.
4. Create the EFF-2.1 data file with new or updated cross-sections for Si, Ti, V, Mn, Co, Cu, Zr, Nb, Mo, Ba, Ta, In and other materials.
5. Create the EFF-2.2 data file with cross sections for C, N, O, Mg, S, P, Ca, Sn, Re, and W.
6. Perform shielding and sensitivity calculations and estimate the effect of uncertainties in DDX calculations.
7. Perform benchmark and test calculations related to shielding, including the development of tools.

The EAF-programme was started in 1989, after an informal collaboration between Petten, Ispra and Harwell, resulting in UK and ECN data files with essentially the same contents. Early this year the first version of the European Activation File (EAF-2) has been released. This file is recommended for fusion reactor activation and transmutation calculations. The file contains all stable and unstable targets with half-lives longer than 0.5 day. Cross-sections leading to isomeric states are treated separately and further those isomeric states living longer

than 0.5 day are included as targets. This version contains now about 11000 reactions on 667 target nuclides and is described in a paper at this conference [ref. 11].

Status of the EFF-2 project

Derived files from EFF-1, processing problems

Some errors were detected in the GEF-1 multi-group library based upon EFF-1 in the VITAMIN-J structure (only in the photon production data). However, meanwhile there is a more extended library based upon JEF-1/EFF-1, which is PSI's MATXS library, in the same VITAMIN-J structure. Since this library was produced with an older version of NJOY, the Pb cross-sections were treated after a transformation of MF6 into MF4 and MF5, loosing the energy-angle coupling. Apart from this the library is very well applicable to calculate transport in fusion reactors blankets. A revision of the Pb cross-sections by calculations with the newest version of NJOY-89 is planned for this year. It is noted that the DDX calculations in GEF-1 for lead were performed with the Penen GROUPXS code. Meanwhile an option to treat MF6 has been included in NJOY-89 as well. This option was tested for Pb of EFF-1 and ^{58}Ni of EFF-2 with very good results, reported at the NJOY workshop at the NEA Data Bank, 1989.

With respect to kerma calculations it was found that negative kerma values resulted from the expressions in NJOY, due to energy balance problems in some evaluations. A further problem was that users previously were adopting kerma values from MACKLIB-IV, which includes kermas due to radioactive decay as well, in contrast to the NJOY results. In fact the MACKLIB values overestimate the heating if one is interested in very short time intervals. This was pointed out both at PSI and at Bologna. In Bologna an EFF-1 based kerma library was made with the help of the MACK code with and without the inclusion of radioactive decay (up to 3 hours). This kerma library is recommended for NET calculations. The library of Bologna also contains other response functions such as gas-production data and DPA data (calculated with NJOY).

For EFF-2 evaluations the files contain revised photon production data and in many cases distributions of all emitted particles, including the recoil nuclei. In that case NJOY calculates the kerma very accurately, but still contributions from short-lived decay products should be added. Otherwise, the user needs to perform an additional calculation with a radioactive inventory code, such as FISPACT, recently developed at Harwell.

Monte Carlo libraries based upon EFF-1 have been produced at PSI and at ENEA-Frascati. Some problems were encountered for Be and Pb, due to format problems. For Be the problems were easily solved: here the LANL evaluation was adopted in EFF-1; for this evaluation the scattering matrices need to be multiplied by a factor of 2. For Pb the current version of NJOY cannot treat the MF6 format. It is understood that NJOY-89.62 has an option in the ACER module to convert the MF6 data into the format in which the Kalbach-Mann systematics is adopted. With this method it is possible to create MCNP libraries that include energy-angle coupling for continuum reactions.

Updates for Pb are forthcoming.

^7Li and ^9Be

The re-evaluation of ^7Li and ^9Be cross-sections is restricted to the energy-angle distributions of emitted neutrons. For the energy-angle integrated cross-sections almost exclusively the existing ENDF/B-VI evaluations are used. In fact there is an agreement with LANL to supply EFF-2 as an update for ENDF/B-VI.

This work is performed at Birmingham University by G.M. Field and D. Beynon, with experimental support from CBNM and formatting support from ECN-Petten. A new feature of this evaluation is the use of sophisticated kinematics with cm angular distributions fitted to experimental data where available. The neutron emission data are stored in MF6 of ENDF/B-VI, with an interesting application of the LIP parameter to distinguish between various physical processes.

The work for ^7Li and ^9Be has been completed and the files have been checked at ECN-Petten and have been combined with the energy-angle integrated ENDF/B-VI evaluated data. The comparison with experimental data is excellent. A problem is that there are no distributions of other particles than neutrons and that covariance data for the MF6 data are not given.

A review of the work for ^7Li and ^9Be was presented at Chengdu [ref. 12]. A paper on recent developments on ^9Be is given at this conference [ref. 13].

Fe, Cr, Ni

The work for these materials is supplementary to the JEF-2 evaluations for the stable isotopes of Fe, Cr, Ni. In fact, in the EFF-2 project the high-energy regions (above 1 MeV) of the JEF-2 evaluations for ^{56}Fe , ^{52}Cr , ^{58}Ni and ^{60}Ni are replaced by recent evaluations of Uhl et al. [ref. 14]. These evaluations contain the lumped quantity MT10 describing all continuous particle and recoil emission. The EFF-2 evaluations also contain the individual reaction cross-sections, though without secondary distributions, as these are given in the lumped quantity MT10. This approach makes it very easy to create a group constant library for transport calculations. With respect to kerma all ingredients are on the file to perform these calculations. The present status is that all major structural isotopes (^{52}Cr , ^{56}Fe , ^{58}Ni and ^{60}Ni) are ready, including photon-production data. The other isotopes are taken from the JEF-2 data file.

Covariance data have been evaluated recently. The work was performed mainly at Vienna (see paper by Tagesen and Vonach [ref. 15]), but also at KfK and Petten. An international cooperation has been set up on the covariance problem for Fe and the results of this cooperation will be used to improve the quality of the covariance data gradually. The first priority was to evaluate uncertainties in the high-energy range, where the needs for these data are the highest. This has been performed initially by inspecting the dispersion of cross-sections in three new evaluations: ENDF/B-VI, JENDL-3 and EFF-2 [ref. 15] and by evaluating uncertainties for the strongest resonances

(KfK). The 14 MeV experimental data have also been re-evaluated [ref. 16], because these data are quite important in relatively thin coil shielding. Further methods, to determine uncertainties in secondary energy and angle distributions will match the capabilities of presently available user-oriented codes like SENSIT or SUSL.

Sensitivity and uncertainty calculations

At Petten, sensitivity calculations have been performed [ref. 17] to study the nuclear data sensitivity to shielding of super-conducting coils. Using the current NET design for the inboard shielding, mainly consisting of stainless steel and (borated) water, 1D neutron and photon transport calculations were performed using the EFF-1 data from the MATXS library. This library was connected to the SENSIT code to study the sensitivities to nuclear data. The nuclear heating in the super-conducting coils was taken as a representative quantity for the heat production.

It appeared that the sensitivity contributions of elastic and inelastic scattering cross-sections to the heating are about equal. The contribution from the 14 MeV peak is significant and there is very little contribution below a few hundred keV. This and other information was very useful to set the priorities in the calculation of covariance information. It appeared that due to the fact that the loss and gain terms of both elastic and inelastic scattering largely cancel, the sensitivities are rather small. With the available covariance information for EFF-1 the uncertainty in the heating was estimated. The uncertainty of the contribution of Fe was in the order of 10%. Similar calculations, recently performed at CEA-Cadarache [ref. 18] yield larger uncertainties. Further work will be necessary to solve this discrepancy. However, these numbers do not take into account uncertainties in the energy and angular distributions, nor the correlations between elastic and inelastic cross-sections.

A first estimate of the effect of angular distribution uncertainties was made using the uncertainties in the Legendre coefficients of elastic scattering, evaluated by Tagesen and Vonach [ref. 15]. The results indicate a contribution of 5 % due to elastic scattering above 0.8 MeV, which might increase if the uncertainties at low energies are added. The effect of inelastic scattering angular distributions can also be significant, more than that of secondary energy distributions [ref. 19].

Further work is performed to study uncertainties due to the neutronics modelling. At KfK rigorous 1D- and 2D-methods for studying the effect of large an-isotropic cross-sections has been developed. These methods will be used to study model errors from neutronics calculations. There is special emphasis on the study of the effect of coupled energy-angle calculations.

Furthermore, some realistic Fe shielding benchmarks are calculated to investigate possible other sources of uncertainties, e.g. due to the treatment of self shielding. Both KfK and CEA-Cadarache are involved in this activity.

Evaluations for other materials

New evaluations for Al and Si have been completed at ENEA-Bologna. An important step to store the data on a file in ENDF-6 format is the development of a code that reformats the output of the Bologna code system. This code has been used for Al and will also be applied for Si.

With respect to Pb some minor modifications are made by adding (n,p) and (n, α) reactions and by re-evaluating the (n, γ) cross-section. This work has been completed recently. The additions still have to be made in the file. Some small modifications in the (n,2n) cross-sections have already been applied.

A large part of the requirements for other materials is fulfilled by adopting evaluations from elsewhere, if the JEF-2 data were insufficient at high energy.

Benchmark and test calculations

Benchmark calculations for Pb and Be have been performed at KfK [ref. 20]. For Pb the newest measurements from Dresden, Osaka and Kurchatov have been analysed. The results are in agreement with the EFF-1 evaluations, if the (n,2n) cross-section is increased to about 2.2 barn at 14.5 MeV. This value is in agreement with a recent high precision evaluation of Vonach, based upon differential data. The EFF-2 evaluation for lead has been adjusted to this value.

Also for Be several integral experiments were used to check the EFF-1 evaluation. The Be evaluation in EFF-1 (obtained from LANL) gave a very good performance for the total multiplication and satisfactory results for the leakage spectra from these experiments. More work is scheduled at KfK, after the analysis of their KANT experiment. The forthcoming EFF-2 evaluation will be included.

In view of the emphasis of the NET project on shielding it has been decided to analyse some shielding benchmarks at KfK and CEA-Cadarache. At KfK the KANT facility will be used to study Fe as well. Finally, a new 14-MeV facility will be used at ENEA-Frascati for benchmark testing of the NET shielding.

Concluding remarks

The EFF-2 project is in good shape. The evaluations for ^7Li , ^9Be , Al, Si, Fe, Cr, Ni, and Pb have been completed, although some minor corrections may still be necessary. A detailed scheme for the completion of the EFF-2 project has been established and it is expected that the project will meet the dead line of December 31, 1991. By that time the EFF-2 data file will consist of new evaluations for the most important fusion reactor materials, partly from EFF evaluators and partly from elsewhere (selected from JEF-2 or other recent evaluations). Covariance data will be available for the most important materials only.

The close cooperation between users and evaluators in the framework of the NET project is quite important for both parties. Therefore a nuclear data activity, integrated in

the neutronics programme of NET/TER, is important also in the years after 1991. Currently a follow-up programme is defined. There are still many problems to be solved. First of all the EFF-2 file needs to be benchmark tested and the feedback of integral data experiments should be used to improve the data file. It is expected that still quite some work is needed to obtain reliable photon production data that are consistent with the neutron data. Also some work is needed to include distributions of all emitted particles and recoil nuclei on the files in order to enable accurate kerma assessments. A major activity will be the systematic update of covariance information, not only for smooth cross-sections, but also for resonance parameters and for energy-angle distributions of neutrons and photons. A covariance calculational benchmark will be defined to gain experience in the use of covariance data in shielding problems. Finally, there is a very large task to update the activation and transmutation library EAF with uncertainties. It should be stressed that the amount of work is quite large and therefore active involvement of users is required to set priorities.

Cooperation between the JEF and EFF projects

The present cooperation between the JEF and EFF projects has been discussed and it was decided to create a common library to be used both for fission and fusion purposes. A starter file of this common library, for which the acronym J/EFF is proposed, will be prepared during 1992, from an agreed choice of isotopes from both libraries. The two projects would still keep their identities and work in parallel and close cooperation on the improvement of the data. It has for example been decided that future releases of EFF-2 will only contain materials that are different from JEF-2 and that the meetings of the projects will be combined in the future.

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