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Status of the JEFF Nuclear Data Library

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Abstract. The status of the Joint Evaluated Fission and Fusion file (JEFF) is described. The next version of the library, JEFF-3.1, comprises a significant update of actinide evaluations, evaluations emerging from European nuclear data projects, the activation library JEFF-3/A, the decay data and fission yield library, and fusion-related data files from the EFF project. The revisions were motivated by the availability of new measurements, modelling capabilities, or trends from integral experiments. Various pre-release validation efforts are underway, mainly for criticality and shielding of thermal and fast systems. This JEFF-3.1 library is expected to provide improved performances with respect to previous releases for a variety of scientific and industrial applications.

INTRODUCTION

The objective of the Joint Evaluated Fission and Fusion (JEFF) file project of the OECD/NEA is to develop and promote the use of high quality evaluated nuclear data sets in standard formats for a wide range of scientific and technical applications. The JEFF project assesses the needs for nuclear data improvements and brings together experts in different areas such as experiments, data evaluations, verification and compilation of the data under strict quality assurance procedures, file processing and benchmarking. JEFF is a collaborative effort between NEA Data Bank member countries, though in practice mainly European countries participate in the project. The project maintains close links with other similar international efforts or projects aimed at producing evaluated nuclear data, for example through active participation in the NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC) [1]. The chart in Fig. 1 shows the organisation of the project. While the objective of the JEF-2.2 library (1992) was to achieve improved performance for existing reactors and fuel cycles, its successor, the JEFF-3 project, aims to provide users with a more extensive set of data for a wider range of applications. Apart from existing reactors and fuel cycles, innovative reactor concepts (GEN-IV), transmutation of radioactive waste, fusion, medical applications, and various non-energy related industrial applications are envisaged as scientific activities that will make use of the JEFF data. The European Fusion File (EFF) and the European Activation File (EAF) projects also contribute to this initiative.

STATUS OF JEFF-3.0

Following the release of the JEFF-3.0 general-purpose file in April 2002, various benchmark tests have confirmed the expected performance improvements over JEF-2.2. However, they have also confirmed that the reactivity of small low-enriched Uranium systems is underestimated by about 500 pcm with JEFF-3.0. Possible reasons for this underestimation have been identified as U-238 inelastic scattering and a slight overestimation of the U-238 capture cross section. A new U-238 evaluation has been constructed (CEA in collaboration with ORNL) that results in a significant improvement of k-eff values, similar to the recent improvement achieved for the ENDF/B library (see Fig. 2). WPEC SG22 [2] has contributed significantly to these improvements. Very extensive automated benchmarking tests have been set up, which probe the current quality of the new data file. These include MCNP (NRG), TRIPOLI (CEA) and APOLLO (CEA) criticality calculations for an unprecedented set of benchmark cases. The current-day computer power enables near-future revisions of JEFF-3 to be quickly tested with this scheme. Additional validation is now possible with a Monte Carlo approach to calculating the ef-

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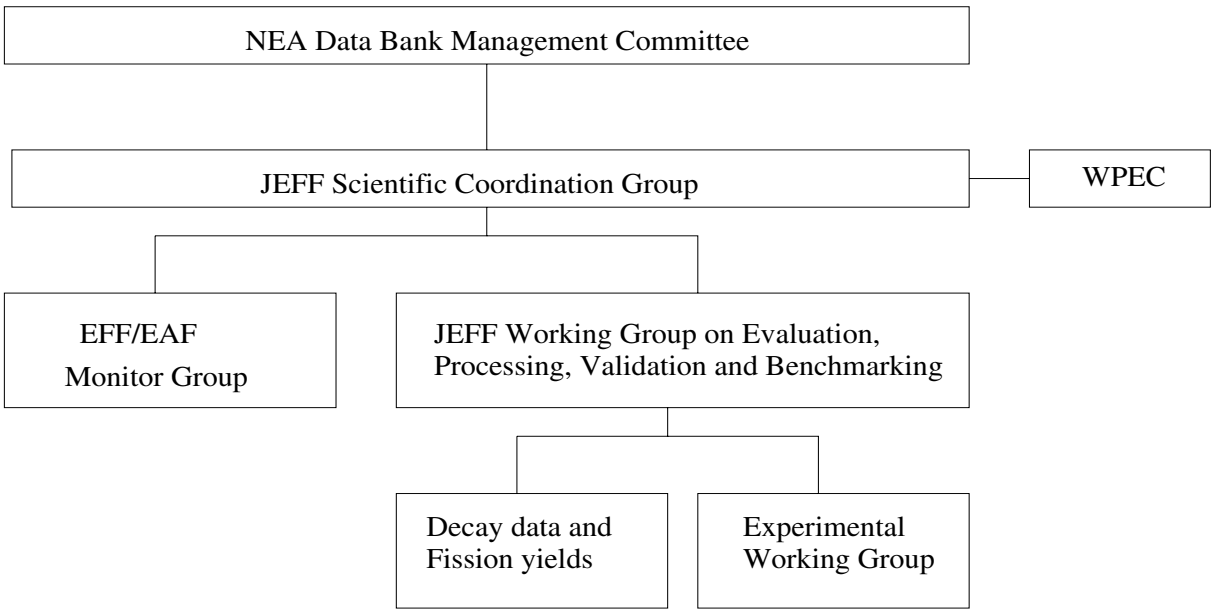

FIGURE 1. Organisation of the JEFF project.

fective delayed neutron fractions (NRG), and improved thermal scattering data (UT Stuttgart). Apart from reactivity prediction in UO2 fueled systems (CEA), JEFF-3.0 improves the isotopic inventory predictions as inferred from Post Irradiation Experiments.

SPECIAL-PURPOSE LIBRARIES AND WORKING GROUPS

The European Fusion File (EFF)

The European Fusion File has been produced as part of the European Fusion Development Agreement (EFDA) programme. The previous version, EFF-2.4, was a complete library for neutronics calculations of fusion devices. Rather than a stand alone library, EFF-3 is a series of new evaluations that contribute to JEFF. Some of the ongoing evaluations for EFF are described in Table 2. In addition to producing evaluated files, the EFF project carries out integral experiments and develops calculational methods. A more detailed review of the EFF work and results is available in [3]. Test Blanket Modules (TBMs) are required as part of ITER and their design is needed in the near term. A major objective of the TBM tests is to demonstrate the tritium breeding performance of the breeder blanket concepts and to check and validate the capability of the neutronics codes and data to predict the nuclear responses in the TBM with sufficiently high accuracy. To aid this, an experiment is being built at ENEA to model the Helium Cooled Pebble Bed concept. During 2005 measurements of the tritium production rate and nuclear heating (ENEA and TUD) will be analysed with new and existing tools (FZK and JSI) to check the adequacy of the nuclear data. These studies extend the previous measurements on large samples such as tungsten [4]. Other experiments involve irradiation of fusion relevant material, these provide data which can be used to validate the activation library (EAF) described in the next section. New methodologies for measuring the beta and gamma heating (ENEA) have provided a large amount of data [5]. Measurements with neutron spectra containing a significant number of neutrons with energies > 20 MeV are being carried out (NPI). A series of shielding-type benchmark analyses has been carried out by FZK on new EFF files such as Cr-52 and W isotopes, either validating the data or suggesting ways to improve them [6]. An example of development of software tools concerns sensitivity analysis within neutronics codes (FZK). Algorithms dealing with changes in response due to changes in secondary angular distributions and Monte-Carlo track length estimators have been produced and implemented. These tools have then been used in the benchmark analyses. Future work includes investigation of the calculations of covariances, evaluations at a range of energies and activation measurements of further materials (Mo, Ta).

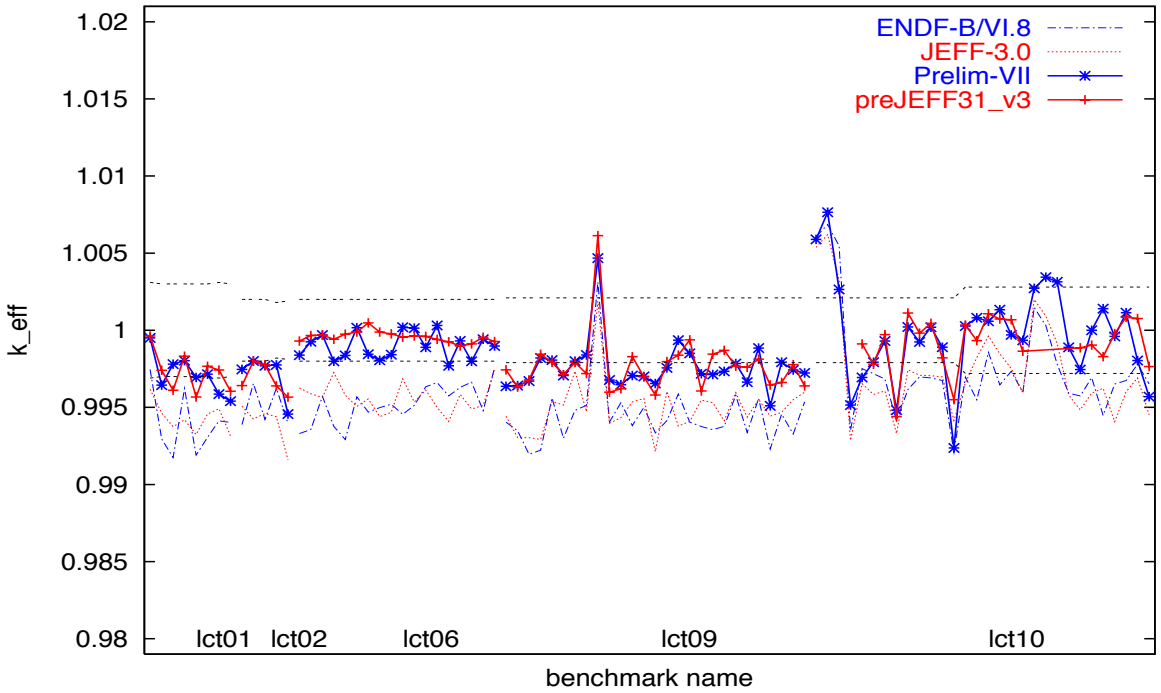

FIGURE 2. Performance of pre-JEFF3.1 library (including a new U-238 evaluation) for a few criticality benchmarks.

Activation Data

The European work on activation data centres on the EAF library. The evaluation, measurement and validation efforts result in new libraries typically every two years. The current library, EAF-2003 [7], contains activation data for 774 target nuclei in the energy range below 20 MeV. A total of 12,617 excitation functions are included. The library can be used as input to the FISPACT inventory code for activation calculations. To make this special purpose data more accessible to other codes, it has been translated into the ENDF-6 format to form the JEFF-3.0/A library [8]. The ENDF utility codes were used to check the library, which was also processed using NJOY-99.65+. The data are stored in MF3,8,9,10. Current work (UKAEA) is extending the EAF library to higher energies (60 MeV) to enable calculations on IFMIF to be performed [9]. This involves extending the current library by adding new reactions (about 50,000) typically with thresholds $>$ 20 MeV and adding calculated data $>$ 20 MeV to the existing reactions. Most of the calculated data are taken from TALYS results [10]. A summary of the integral data and its use in validation of EAF-2003 has been produced [11]. A complementary effort, for the EFF project, concerns the Intermediate Energy Activation File IEAF-2001 [12] (FZK), which contains interaction data for incident neutron energies up to 150 MeV and nuclei up to Z=84. This was then processed into a format that could be used with a modified version of FISPACT.

Decay Data and Fission Yields

Work on the decay data and fission yields files for JEFF-3.1 is nearing completion. The CEA has devoted special effort to decay data, in order to deliver a complete and well-validated file for JEFF-3.1 in the spring of 2005 and is working actively with BNFL on the fission yields file.

The current decay data file contains data for 3625 radioactive nuclides and 226 stable nuclides and so should cover all major current needs, e.g., reactor analysis, fusion devices, accelerator driven systems, etc.. The file is based on data in NUBASE-2003 along with data from:

- two libraries partly updated recently in the UK (Winfrith) containing about 600 isotopes (fission products and activation products),
- the new comprehensively evaluated library for 162 isotopes produced at LNHB (CEA Saclay),
- an ENSDF based file for 1300 radionuclides selected for the good quality of their decay description.

TABLE 1. High-priority requests from the JEFF experimental working group.

Reaction	Energy	Comments
Hf-177,178,179(n,γ)	1-100 eV	2% accuracy, naval reactors
U-235 fission spectrum	thermal	too many discrepancies in existing data
Pu-239(n,γ)(n,f)	0.01-0.5 eV	2% accuracy
Am-241,242m(n,γ)	resonance range	Am-242m and Cm buildup in PWR
Gd-155,157(n,γ)	thermal	2% accuracy
U-238(n,γ)	0-120 eV	
O-16(n,α)	2-7 MeV	

Consistency checks on decay energy balance showed very good agreement. Extensions to the ENDF-6 format and enhancements of the physics checking codes were necessary (in agreement with CSEWG) for the assembly of this comprehensive library. One major planned upgrade concerns the completion of the spectral data. Many of these data have now been extracted from ENSDF for inclusion in the decay data file. The current version of the decay data file is undergoing basic validation and decay heat benchmarks are being undertaken at BNFL, CEA/Cadarache and elsewhere [13]. A special website and mailing list for the decay data library have been set up at the NEA Data Bank for all involved in the construction/testing of the library.

The current fission yields file (UKFY-3.5) has been created using an updated version of the UKFY3 file, which is based on a large experimental database containing 14710 measurements. It contains data for three spontaneous fissioning systems and 19 neutron induced fissioning systems, with data given for thermal, fast and high neutron energies as appropriate. A further update is expected before the end of 2004 for inclusion in JEFF-3.1. Particularly close attention is being given to the ternary fission yields and tritium production. A major review of the Pu-241 yields is also underway. The fission yields file is being compiled in close collaboration with the decay data file and hence all cumulative yields are calculated using the current decay data file for maximum consistency. A number of enhancements have already been included in both files during 2004 based on user feedback.

Experimental Working Group

The objective of the Working Group on Experimental Activities (WGEA) is to provide a forum for discussion between users, evaluators and experimentalists, on requests for new or improved experimental data for the improvement of the JEFF evaluated nuclear data file. The WGEA assesses the feasibility of requests for new measurements from the JEFF and EFF/EAF communities for inclusion in the WPEC high-priority request list (HPRL). The WGEA supports the WPEC subgroup in charge of the HPRL in maintaining this list. After each JEFF meeting the participants agree on a short list of high-priority requests for nuclear data. The current status of this list is shown in Table 1.

FROM JEFF-3.0 TO JEFF-3.1

The next release of the library, JEFF-3.1, is foreseen for May 2005. The three main reasons for this release are:

- A significant number of isotopes have undergone a major revision in the last few years. This holds for both the general purpose and the special purpose libraries.
- A particular need for a revised U-238 file to improve the aforementioned criticality predictions.
- There is a desire from the (French) nuclear industry to start validating the new JEFF library in the fall of 2005.

Table 2 shows that presently various evaluated data files are under construction. The evaluation methods fall roughly into three categories:

- A (primarily) experimental evaluation approach with full covariance information. This is mainly coordinated by IRK Vienna and collaborators, and concerns basically fusion-relevant materials.
- A (primarily) theoretical approach using the TALYS code, mainly coordinated by NRG Petten, to provide complete data files beyond the resonance region.
- A combined resonance region + high energy approach, mainly followed by CEA Cadarache and Bruyeres-le-Chatel.

Revised thermal scattering data have been produced for all-important moderator and structural materials (UT Stuttgart) and will be included in JEFF-3.1. Also, it was decided to adopt an 8-time-group representation for delayed neutron data, as suggested by WPEC/SG6. It is considered that this representation has two advantages - the longest lived, dominant precursors are explicitly represented and there is the calculational convenience of

TABLE 2. Recent (1998-) and upcoming isotopic data evaluations for JEFF.

Isotope	Version	Lab	Energy Range	Comments
Be-9	JEFF-3.0	IRK Vienna+IPPE Obn	0-20 MeV	EFF
Na-23	JEFF-3.0	CEA Cadarache	thermal range	
Ca-40, 42, 43, 44, 46, 48	JEFF-3.1	NRG Petten	0-200 MeV	+ proton files
Sc-45	JEFF-3.1	NRG Petten	0-200 MeV	+ proton files
Ti-46, 47, 48, 49, 50	JEFF-3.1	IRK Vienna	0-20 MeV	+ covariance data, EFF
Cr-52	JEFF-3.0	IRK Vienna+CEA Cad	0-20 MeV	+ covariance data, EFF
Fe-54, 56, 57, 58	JEFF-3.1	NRG Petten	0-200 MeV	+ proton files, Fe-56 from JEFF-3.0
Ni-58,60	JEFF-3.0	IRK Vienna+IJS Lubl	0-20 MeV	+ covariance data, EFF
Ge-70, 72, 73, 74, 76	JEFF-3.1	NRG Petten	0-200 MeV	+ proton files
Rh-103	JEFF-3.1	CEA Cadarache	0-20 MeV	
W-182, 183, 184, 186	JEFF-3.1(2)	IRK Vienna, FZK	0-150 MeV	end of 2005, EFF
Pb-204, 206, 207, 208	JEFF-3.1	NRG Petten	0-200 MeV	+ proton files, HINDAS project
Bi-209	JEFF-3.1	NRG Petten	0-200 MeV	+ proton files, HINDAS project
U-238	JEFF-3.1	CEA Cadarache+BRC	0-30 MeV	
Pu-239,240	JEFF-3.0	CEA Cadarache+BRC	0-30 MeV	
Am-241	JEFF-3.1	CEA Cadarache	thermal range	
Many nuclides	JEFF-3.1(2)	N-TOF	E < 1 MeV	((n,gamma) and (n,f)

having the same set of time constants for all fissioning isotopes.

The selection, compilation, and validation of the isotopes for the JEFF-3.1 data file is now underway. A quality assurance procedure has been developed for the assembly and loading of the database. Verifications performed at the loading stage include format checks (CHECKR), physics checks (FIZCON and PSYCHE), processing using different versions of NJOY, and graphical comparisons with other data libraries. Specific tools were developed in this framework (e.g., JANIS and the EVA database loading programs) and existing programs (e.g., FIZCON, INTER) were extended to enable more stringent consistency checks.

OUTLOOK

Future development of the JEFF-project will mainly depend on the input of users and on the available financial support. A detailed time path for future releases of JEFF is not yet fixed. Possible user needs may arise in the coming years from GEN-IV reactors, a serious handling of the radioactive waste problem (transmutation), lifetime extension of power plants, and the ITER fusion design. If safety and economical aspects are considered crucial for these technological developments, then so is the parallel development of a high-quality nuclear data library. Anticipating such scenarios, we can list various challenges for JEFF for the coming decade:

- A global update of isotopic evaluations for the general purpose file. In particular, many fission product evaluations, which date back to JEF-2.2, are in need of revision. Two helpful ingredients for this will be at our disposal: powerful nuclear modelling and a new large scale resonance analysis by Mughaghab.
- Complete covariance information for each evaluation, from (preferentially) measurement or theory.
- A systematically extended energy range up to 200 MeV to cover even more applications.
- New high-precision measurements, which implies that neutron facilities, such as IRMM Geel, Uppsala, and N-TOF remain operational.
- A more complete and automated integral validation suite, in particular for criticality and shielding, exploiting the expected increase in computer power.

CONCLUSIONS

The JEFF Project brings together all available expertise in Europe relating to the nuclear data requirements of existing and future nuclear systems. To date the Project has produced an internationally recognised nuclear data library for applications, JEFF-3.0, and is participating significantly in the successful development of the future JEFF-3.1 library.

The Project continues to improve the quality of nuclear data and, in particular, strives to reduce the uncertainties involved in the calculation of various parameters relevant to the successful running of existing power reactors and the future construction of innovative systems. Specifically these include data required for particle transport modelling within the system, criticality, activation, burn-up, and decay heat.

All the nuclear data libraries mentioned in this paper are available free of charge from the OECD NEA Databank's website "http://www.nea.fr/html/dbdata." All documents presented within the JEFF Project meetings

(cited as JEFF/DOC-xxx) are held at the NEA and are available to Project members. Individual requests from non-members are treated on a case-by-case basis, but in general most documents can be supplied upon written request to the Databank or via email to db@nea.fr.

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