Status of the JEFF project: 2006

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Arjan Koning

NRG
1755 ZG Petten, The Netherlands

General

The objective of the OECD Nuclear Energy Agency (NEA) coordinated Joint Evaluated Fission and Fusion (JEFF) data project 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. The project maintains close links with other similar international efforts and 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). 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 at providing users with a more extensive set of data for a wider range of applications. While existing reactors and fuel cycles remain the essential application areas of the nuclear data library, innovative reactor concepts (Gen-IV systems), transmutation of radioactive waste, fusion, medical applications, and various non-energy related industrial applications are now also envisaged as scientific application areas that will make use of the JEFF data. The European Fusion File (EFF) also contributes to the JEFF project through evaluations and data validation.

Organisation

The JEFF Scientific Coordination Group (SCG), whose members are nominated by the Nuclear Science Committee Executive Group, has responsibility for the overall management of the project. The technical activities are organised in different Working Groups. The current organisation of JEFF is as follows:

- Chair   : Arjan Koning, NRG
- Working Group chairs:
    - Radioactive Decay and Fission Yield data: Olivier Bersillon, CEA/DAM
    - Fusion data (EFF group)   : Robin Forrest, UKAEA
- Secretariat   :Yolanda Rugama, Hans Henriksson,
                                                  NEA Data Bank

JEFF meetings are generally held twice per year. It consists of a general (plenary) session that deals with evaluations, processing and benchmarking. In addition, there are parallel sessions for the Working Groups and a meeting for the SCG.

Recent developments

A. The release of JEFF-3.1

The JEFF-3.1 library was released in May 2005. An important reason for releasing JEFF-3.1 is that the nuclear industry (in particular in France) has expressed the desire to start validating the new JEFF library in the fall of 2005. The JEFF-3.1 release consists of the following libraries:

Neutron general purpose library
Neutron activation library
Thermal scattering library
Decay data library
Fission yield data library
Proton special purpose library

A1. The neutron general purpose file

The general-purpose neutron data file contains data for 381 materials. For the upgrade to JEFF-3.1 the following procedure was followed:

1. New data files for neutrons:
   - Ca-40, 42, 43, 44, 46, 48   (0-200 MeV, NRG)
   - Sc-45   (0-200 MeV, NRG)
   - Ti-46, 47, 48, 49, 50   (0-20 MeV, IRK Vienna)
   - Fe-54, 56, 57, 58   (0-200 MeV, NRG)
   - Ge-70, 72, 73, 74, 76   (0-200 MeV, NRG)
   - Tc-99   (0-200 MeV, CEA/Saclay/Cad, NRG)
   - Rh-103   (0-20 MeV, CEA/Cad)
   - I-127, 129   (0-20 MeV, CEA/Cad)
   - Hf-174,176,177,178,179,180 (0-20 MeV, CEA/Cad)
   - Pb-204, 206, 207, 208   (0-200 MeV, NRG)
   - Bi-209   (0-200 MeV, NRG)
   - U-236, 237   (0-30 MeV, CEA/BRC)
   - U-238   (0-30 MeV, CEA/CAD/BRC)
   - Am-241   (thermal, CEA)

2. Update of source evaluations of JEFF-3.0 (e.g. JENDL-3.2 → JENDL-3.3)
3. Alternative choices for source evaluations from other libraries if there was a clear indication to change them.
4. Decay time constants for all actinides in JEFF-3.1 in an 8-group structure, as recommended by WPEC SG6. The other world libraries have 6 groups for all nuclides. It is considered that the 8-group representation has two advantages - the longest lived, dominant precursors are explicitly represented and there is the calculation convenience of having the same set of time constants for all fissionable isotopes.
5. Various small changes to correct format errors and to ensure proper NJOY-processing.

A quality assurance procedure has been developed at NEA for the assembly, basic testing and loading of the JEFF-3.1 library into a database for distribution.

Various experimental nuclear data activities have taken place during the development of JEFF-3.1. The programme at the N-TOF facility at CERN comprised capture and fission cross-section measurements including isotopes of relevance to the Thorium fuel cycle and several transuranic isotopes. The HINDAS programme covered reactions with neutrons and protons above 20 MeV. The measurement programme at IRMM Geel covered mainly neutron data related to waste transmutation and other innovative concepts, as well as basic nuclear physics and standards data.

In parallel, the nuclear model code TALYS has been under development by NRG and CEA and has been extensively used to produce new evaluations for JEFF-3.1.

Following the release of JEFF-3.0 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. For JEFF-3.1, a new U-238 evaluation has been constructed (CEA) which results in a significant improvement of k-eff values. Very extensive automated benchmarking tests have been set up, which probes 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 improvements have been presented at e.g. the GEN-IV workshop adjacent to the WPEC meeting of last year and at the last JEFF meeting. WPEC SG22 ("ueval") has contributed significantly to these improvements.
More validation of the JEFF-3.1 library, with different codes, is expected at the next JEFF meeting.

A2. Activation library , JEFF-3.1/A

The Activation Data Library in ENDF-6 format, JEFF-3.1/A, is based on the European Activation File (EAF-2003). The JEFF-3.1/A library contains 12 617 excitation functions involving 774 different targets from ^{1}H to ^{257}Fm, atomic numbers Z=1 to Z=100, in the energy range 10^{-5} eV to 20 MeV. Uniquely, an uncertainty file is also provided that quantifies the degree of confidence placed in the data for each reaction channel.
The EAF nuclear data library has been developed as part of the EFDA (European Fusion Development Agreement) Fusion Technology Programme. A series of measurements on fusion relevant materials in several complementary neutron fields have been carried out over the last few years. In addition, analyses of measurements, carried out outside Europe and outside the fusion programme, have been undertaken.
Cross section validation exercises, against both experimental data and systematics, enable a comprehensive assessment of the data. The SAFEPAQ-II software is used to apply a series of modifications to the original source data. A very important set of modifications concerns renormalization and branching using experimental or systematic data. A total of 3,225 reactions (26% of all the reactions) have thus been changed. This is a challenging task as the source contains non-threshold reactions with an energy dependent branching ratio.
Validation using integral data has been performed by means of direct comparison with measurements of sample materials under fusion-relevant neutron spectra. Irradiations have been carried out at ENEA FNG, FZK Isochron-cyclotron, Sergiev Posad SNEG-13 and JAERI FNS and integral C/E comparisons made (C/E is the ratio of the library value to the experimental

value). The results of these benchmark exercises, in concurrence with differential data, have indicated where modifications to the data should be applied.

A3. Thermal scattering data library

The thermal scattering law library contains the following 9 evaluations: hydrogen bound in water, zirconium, polyethylene (CH_2) and CaH_2, deuterium bound on D_2O, ^{9}Be, Graphite, ^{24}Mg and finally calcium bound in CaH_2. All files are new evaluations, except ^{9}Be and hydrogen in polyethylene, which are from the JEFF-3.0 library. Many of the evaluations are the result of an IAEA coordinated project on thermal neutron scattering, in which Univ. Stuurgart played an important role. Calculations for a variety of temperatures were made with the LEAPR module of NJOY to obtain thermal scattering data that are accurate over a wider range of energy and momentum transfer. To validate these files on a microscopic level, detailed comparisons with a significant number of measurements of differential and integral neutron cross sections and other relevant data have been performed. The current models used for these files are able to describe the experimental data reasonably well. The generating and processing chain for the thermal neutron scattering files with NJOY was carefully investigated.

A4. Radioactive decay data library, JEFF-3.1/RDD

Radioactive decay data forms an integral part of the nuclear data requirements for nuclear applications. The JEFF-3.1 decay data library contains 3 852 nuclides from the neutron to ^{272}Rg.
The basis for the selection of isotopes was taken from the NUBASE-2003 file. Three evaluated libraries, from within Europe, were used to replace individual NUBASE files, for almost 600 nuclei in all. Two libraries originated from the UK (UKPADD-6.4 and UKHEDD-2.4) and the third from the Decay Data Evaluation Project (DDEP) conducted by the Laboratoire National Henri Becquerel (LNHB) at Saclay, France.
Files were also selected from the ENSDF library - these files contain decay data derived from basic nuclear structure data. Approximately 900 nuclei, containing sufficient data to allow calculation of their energy balance to a consistency of better than 1%, were selected from ENSDF.
The JEFF-3.1 library stores all data in the internationally accepted ENDF-6 format. Recent enhancements, allowing the storage of basic nuclear properties for stable nuclei (i.e. spin and parity), have been adopted in this library. The isotopic abundances for all appropriate nuclei (taken from NUBASE-2003) have been added as the last line in the comments section (MF=1, MT=451) whilst an un-used field in the format is investigated.
Throughout the compilation process the library has followed the NEA QA procedures and been checked with the standard ENDF Utility Codes STANEF, CHECKR and FIZCON. Significant enhancements to the FIZCON code have been added for the verification of decay data and also minor corrections to the latest versions (7.00/7.01) have been implemented following problems noted in checking this JEFF library, most notably the checking of the symbol field for meta-stable states and the inclusion of stable nuclei. Users should be warned that earlier versions of the checking codes, e.g. version 6.11, should not be used in testing this library.

A5. Fission yield libraries, JEFF-3.1/NFY & SFY

The fission product yield libraries include independent and cumulative yields for the neutron-induced fission of ^{232}Th, ^{233,234,235,236,238}U, ^{237,238}Np, ^{238,239,240,241,242}Pu, ^{241,242m,243}Am, ^{243,244,245}Cm and the spontaneous fission of ^{242,244}Cm and ^{252}Cf. The data represent a development of the UKFY3 file, which in itself was developed from earlier UK evaluations. The principle changes from earlier libraries includes; an extended experimental database, calculation of the cumulative

yields using the JEFF-3.1 decay data, improved calculation of uncertainties in the yields, improved adjustment to the physical constraints and the inclusion of new ternary yield data for ^{3}H and ^{4}He from Serot, Wagemans et al.

A6. Proton Special Purpose Library

The proton special purpose library consists of 26 evaluated isotopes. The data are based primarily on a theoretical analysis with the nuclear model code TALYS. The nuclear model parameters of TALYS have been adjusted to reproduce the existing experimental data. For several materials that are of key importance to transmutation programs (ADS), valuable experimental data was provided by the EU FP5 HINDAS project. Together, this results in data files that provide a complete representation of nuclear data needed for transport, damage, heating, radioactivity, and shielding applications over the incident proton energy range from 1 to 200 MeV. These isotopic evaluations are created by running TALYS with input parameters that do not, or only slightly, deviate from the default values.

These isotopic evaluations are thus of comparable quality. The same set of nuclear models is used and, equally important, the same ENDF-6 formatting procedures for each isotope. These data files are complete in their description of reaction channels, and use a compact method to store the data. All transport data for particles, photons and residual nuclides are filed using a combination of MF=1, MF=3 and MF=6. This includes cross sections, angular distributions, double-differential spectra, photon production cross sections, and residual production (activation) cross sections. These evaluations can thus be used as both transport and activation libraries.

The files have been checked by the BNL checking codes CHECKR, FIZCON and PSYCHE and have been successfully processed into an MCNP library by the processing code NJOY.

B Highlights from the JEFF meetings

The JEFF meetings of May 2-4 and November 28-30, 2005 took place at the NEA Headquarters in Issy-les-Moulineaux, each with about 45 participants. A central issue at these JEFF meetings was the release of the JEFF-3.1 library in May 2005 and its subsequent validation. Some highlights of the meeting are given below.

B1. Evaluations

- Around the time of the release of JEFF-3.1, new CEA evaluations for U235,238 were presented. The fast neutron part of these evaluations is model based (Bruyeres-le-Chatel) while further fine-tuning to the U-238 RRR was applied (Cadarache).
- A new n+d evaluation is under construction at CEA.
- New photonuclear activation data are being developed by CEA Saclay using GNASH. In the near future, TALYS will be used as well. Probably a photonuclear sub-library of JEFF will be produced.
- Methods to generate covariance data for nuclear models are under construction.
- There is a persistent problem with the consistency of the Be-9 evaluation.

B2. Validation and benchmarking

- A large collection of testing results has been presented:: CEA, NRG, SERCO and VTT performed extensive benchmarks.

- In general, criticality benchmarks reveal that JEFF-3.1 is comparable in quality to pre-ENDF/B-VII.
- For the validation of the future U235,238 evaluations of CEA, the experiments of the fast neutron core MASURCA are essential.
- Problems to predict criticality values for MOX fuel point to a needed revision of the Pu-isotopes.

B3. Activation data and codes

EAF-2005.1 has been released. In this library, the upper energy limit is extended to 60 MeV. Use has been made of the TALYS code to generate the data above 20 MeV and, for various reactions, data below 20 MeV as well. The new SAFEPAQ-II code (EASY + FISPACT) is able to use these new data. A new activation validation study was performed.

B4. Experiments

Ongoing, partially finished and future experimental activities (as reported by Peter Rullhusen, IRMM) are:

- inelastic scattering on Pb isotopes and Bi-209 with the (n,n'g) technique (Geel)
- Capture and transmission: Pb-206, Bi-209, Rh-103, Th-232, U-236, U-238, Pu-240, Pu,242 (Geel)
- Reactions on stable fission products
- Bi-209 capture branching ratio
- B-10(n,alpha) angular distributions
- Pa-231(n,f).

The new high-resolution (n,n') measurements for all Pb isotopes are recommended to be included as "pure" experimental data in the data files for JEFF-3.2.
In addition, JRC has launched the NUDAME project, in which experimentalists can apply for beam time at the Geel facilities.

Plans for JEFF-3.2

Although no target date has yet been set for the release of JEFF-3.2 (2008-2009 can be indicated as a tentative period), the following programme of work is planned:

- Revision and validation of the evaluations for U-235 and U-238 and probably also U-236 and U-237
- New evaluation for Pu-239
- Inclusion of more covariance data in the evaluations
- Revision of a few selected fission product evaluations and testing of FP library
- More emphasis on minor actinide data
- Update the most recent version of the decay data file
- Update the most recent version of the European Activation file
- Photonuclear data
- New evaluations for the W, Hf and Ta isotopes
- New evaluations using the Geel measurements: Pb, Bi, Am
- New evaluation for Th-232 using n-TOF measurements

The EU FP6 programmes NUDATRA, EFNUDAT and CANDIDE can provide input to JEFF.

THE JEFF TEAM

The following scientists and institutes have contributed to the successful release of the JEFF-3.1 nuclear data libraries.

Chairs:
O. Bersillon (Decay data), R.A. Forrest (EFF) and A.J. Koning (JEFF)
Evaluation:
O. Bouland (CEA), A. Courcelle (CEA), M.C. Duijvestijn (NRG),
E. Dupont (CEA), J. Kopecky (JUKO), D. Leichtle (FZK), F. Marie (CEA),
M. Mattes (Stutt), E. Menapace (ENEA), B. Morillon (CEA),
C. Mounier (CEA), G. Noguerre (CEA), P. Pereslavtsev (FZK),
P. Romain (CEA), O. Serot (CEA), S. Simakov (FZK),
S. Tagesen (IIK), H. Vonach (IIK)
Experimental nuclear data:
P. Batistoni (ENEA), P. Bem (Rez), F. Gunsing (CEA),
M. Pillon (ENEA), A. Plompen (IRMM), P. Rullhusen (IRMM), K. Seidel (TUD)
Nuclear modelling and theory:
M. Avrigeanu (NIP), V, Avrigeanu (NIP), E. Bauge (CEA), H. Leeb (TUW),
M.J. Lopez Jimenez (CEA)
Processing, benchmarking and validation:
D. Bernard (CEA), A. Bidaud (CEN), R. Dagan (FZK), C. Dean (Serco), P. Dos-Santos-Uzarralde (CEA), U. Fischer (FZK), A. Hogenbirk (NRG), R. Jacqmin (CEA), C. Jouanne (CEA), I. Kodeli (IAEA), J. Leppanen (VTT), S.C. van der Marck (NRG),
R. Perel (RIP), R. Perry (Serco), M. Pescarini (ENEA), A. Santamarina (CEA), J.C. Sublet (CEA), A. Trkov (IAEA)
Decay data and fission yields:
M.M. Be (CEA),T.D. Huynh (CEA), M.A. Kellett (IAEA), R. Mills (Nexia), A. Nichols (IAEA)
NEA Data Bank:
H. Henriksson, C. Nordborg, A. Nouri, Y. Rugama, E. Sartori
Participating institutions:
Technische Universitaet Wien (TUW), Vienna, Austria
Institut fuer Isotopenforschung und Kernphysik (IIK), Vienna, Austria
Nuclear Physics Institute Rez (Rez), Czech Republic
VTT Processes (VTT), Finland
Commisariat a l'Energie Atomique (CEA) Bruyeres-le-Chatel, France
Commisariat a l'Energie Atomique (CEA) Cadarache, France
Commisariat a l'Energie Atomique (CEA) Saclay, France
CEN de Bordeaux (CEN), France
Forschungszentrum Karlsruhe (FZK), Germany
Stuttgart University (Stutt), Germany
Technische Universitaet Dresden (TUD), Germany
Racah Institute of Physics (RIP), Jerusalem, Israel
National Agency for New Technology, Energy and the Environment (ENEA), Italy
Nuclear Research and Consultancy Group (NRG), Petten, the Netherlands
JUKO Research (JUKO), Alkmaar, the Netherlands
National Institute of Physics and Nuclear Engineering (NIP), Bucharest, Romania
UK Atomic Energy Authority Fusion (UKAEA), Abingdon, United Kingdom
Nexia Solutions Ltd., Seascale (Nexia), United Kingdom
Serco Assurance (Serco), Winfrith, United Kingdom

International organizations:
Institute for Reference Materials and Measurements (JRC/IRMM)
International Atomic Energy Agency (IAEA)
Nuclear Energy Agency (OECD/NEA) Data Bank