Opening session

Chair: Robert Jacqmin

Overview of nuclear data activities
at the OECD Nuclear Energy Agency

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Abstract

The Nuclear Energy Agency (NEA) is a specialised agency within the Organisation for Economic Co-operation and Development (OECD). The mission of the NEA is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally friendly and economical use of nuclear energy for peaceful purposes. All activities relevant to nuclear data measurements, evaluations and applications are managed by the NEA Nuclear Science Committee through the Nuclear Science section and the Data Bank, which work closely together. This paper gives an overview of current and planned nuclear data activities at the Nuclear Energy Agency through the program of work of the Data Bank in general and of the NEA Working Party on international nuclear data Evaluation Co-operation (WPEC) in particular.

Introduction

The objectives of the NEA Nuclear Science Committee (NSC) program are to help member countries develop, preserve, and disseminate basic scientific and technical knowledge required to enhance the performance and safety of current nuclear systems as well as to allow, through this expertise, the development of next-generation nuclear technologies. Nuclear data evaluation is at the core of this knowledge. The NEA ensures co-operation between the major nuclear data evaluation projects to improve the quality and completeness of evaluated nuclear data libraries through the Working Party on international nuclear data Evaluation Co-operation which promotes the exchange of information on evaluations, measurements, model calculations and validations. The WPEC assesses common needs for nuclear data improvements and addresses them by initiating joint evaluation efforts [1]. Working closely with the NSC, the NEA Data Bank, a member of the international network of Nuclear Reaction Data Centres (NRDC), is a centre of reference with respect to basic tools, such as computer codes and data, for use in different nuclear energy applications [2].

The NEA Data Bank

Knowledge preservation and knowledge transfer are at the core of the Data Bank's services to the scientific community. The Data Bank's primary role is to provide nuclear scientists in member countries with reliable nuclear data and computer programs. The Data Bank ensures, through its Computer Program Services, the distribution of documented codes and data sets to more than 900 nominated establishments around the world. The Data Bank also contributes to the correct use of these programs by organizing and hosting, throughout the year, various training seminars and workshops on many of the codes it distributes (visit *www.oecd-nea.org/dbprog/* for more information).

Nuclear Data

The Data Bank compiles and maintains large databases of experimental, evaluated and bibliographic nuclear data. Experimental data compilation has grown from historical fission-related measurements to encompass nowadays all types of nuclear reaction data, including charged-particle induced reactions and photonuclear data necessary to other nuclear applications, such as accelerator driven systems, fusion reactors, nuclear medicine, materials analysis, environmental monitoring, or fundamental research. The following databases are made available to users via its website or via advanced graphic-user-interfaces which the Data Bank develops (*i.e.* the JANIS display software):

- EXFOR: Experimental nuclear data for neutron and charged-particle induced reactions, as well as for photonuclear data.

- CINDA: Bibliographic information on experimental, theoretical and evaluated nuclear data.

- EVA: Evaluated nuclear data libraries (latest releases of the JEFF, ENDF/B, JENDL and many more libraries, including special purpose files) in ENDF format describing reaction data, decay data, fission yields, etc.

The EXFOR database, of which the NEA Data Bank is one of the four NRDC co-ordinating centres, was created in 1969 with the merge of several experimental reaction databases into the standardised EXFOR format. In addition to comprehensively storing experimental data points and their bibliographic references, other information such as source of uncertainties are also compiled. EXFOR contains all published neutron reaction data, and is intended to cover also photo-fission and photo-neutron data, as well as all charged-particle data up to ^{12}C with incident energies up to 1 GeV. Other reaction data are included on a voluntary basis. EXFOR contains at present about 18 000 experiments divided in 134 000 different data sets [3]

The bibliographic database CINDA is closely linked to EXFOR, and contains an almost complete bibliography of all neutron data published until ~2003, as well as an index to the corresponding EXFOR entries and evaluated data. Besides neutron data, CINDA also covers charged-particle data, photo-neutron, photo-fission, and spontaneous fission data. CINDA is available on web retrieval, through the JANIS program, and as an archive book [4].

In addition, the Data Bank collects and makes available upon request integral benchmark experiments for data and code validation in areas such as criticality safety (ICSBEP, see [5]), reactor physics (IRPhE, see [6]), fuel performance (IFPE, see [7]), and radiation shielding (SINBAD, see[8]). More information can be found at *www.oecd-nea.org/dbdata*

JANIS

To help the use and visualization of data, the Data Bank develops a java-based computer program, JANIS, to display, compare, and manipulate nuclear data. Various navigation and search tools are available to explore the main nuclear databases containing experimental, evaluated, and bibliographic data. JANIS is designed to allow the user to access numerical and graphical representations without prior knowledge of the data format. A variety of output formats exist in JANIS. The latest JANIS 3.2 version [9] allows the user to access the most recent evaluated data libraries and implements new features to display covariance data (Figure 1), photon-production data, radioactive Beta-decay spectra, isotopic fission yields, and thermal-neutron scattering cross-sections.

Figure 1: JANIS display of the self-correlation matrix around the ^{239}Pu resonance at 0.3 eV (JENDL-3.3 data)
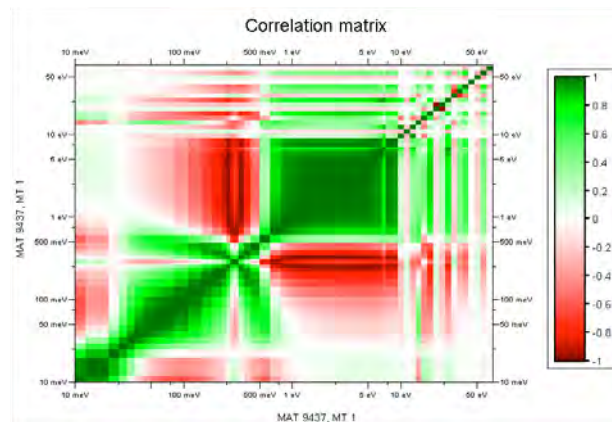
The JEFF Project

The Data Bank is in charge of the compilation, verification, and distribution of the Joint Evaluated Fission and Fusion (JEFF) library. The JEFF project is an international collaboration between NEA Data Bank member countries. The JEFF library comprises sets of evaluated nuclear data, mainly for fission and fusion applications; it contains a number of different data types, including neutron and proton interaction data, radioactive decay data, fission yield data and thermal scattering law data [10].

The JEFF project works in close collaboration with the European Fusion File (EFF) and European Activation File (EAF) projects, holding common meetings with the other JEFF working groups. Joint sessions are organised bi-annually to discuss matters of common interest for the joint evaluated files of the JEFF library.

JEFF-3.1 and JEFF-3.1.1

The latest major release of the JEFF files is the JEFF-3.1 Nuclear Data Library, a complete suite of evaluated data released in May 2005. It contains evaluated files collected and checked at the Data Bank in cooperation with several member country laboratories. The JEFF-3.1 neutron data library covers 381 isotopes or elements. There are 26 isotopes in the proton data library, and 9 materials are covered in the thermal scattering law file. The special purpose library on activation data is based on EAF-2003 and contains 774 target nuclei with over 12 600 neutron induced reactions. Other

special purpose files include radioactive decay data with 3 852 isotopes, as well as spontaneous and neutron-induced fission yield data for 3 and 19 fissioning systems, respectively.

The initial decay heat benchmarking of JEFF-3.1 showed reasonable agreement for the total decay heat, as shown in Figure 2 for [235]U.

Figure 2: Total decay heat from fission products following a [235]U fission pulse [12]
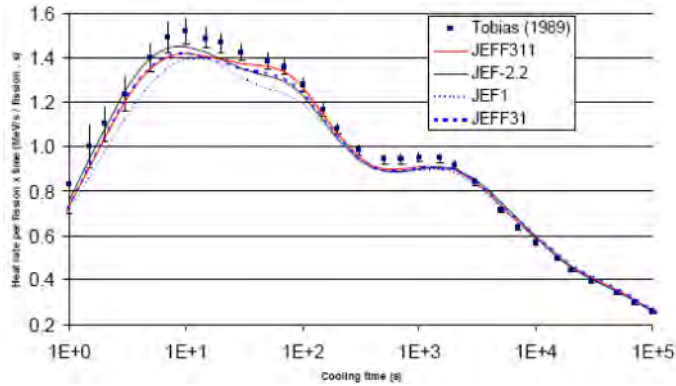
However, discrepancies remained in the individual gamma and beta decay heat components. It was suggested that experimental energy values (from Total Absorption Gamma-ray Spectroscopy measurements) could be used to disentangle between these two contributions and improve the overall consistency with measured data [11]. Therefore, 29 nuclei had their average energies updated in a revised version, named JEFF-3.1.1, released in November 2007 [12]. New decay heat calculations show the expected improvement, especially for the prediction of gamma-ray decay heat, as illustrated in Figure 3 for [235]U.

Figure 3: Gamma-ray decay heat from fission products following a [235]U fission pulse [12]
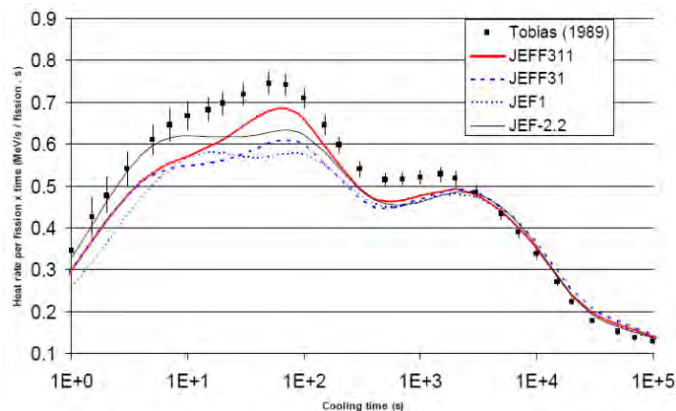
The initial benchmarking of JEFF-3.1 neutron general purpose library showed significant improvements over the JEFF-3.0 library. However, a few deficiencies remained and were confirmed after further validation of the data against light-water-reactor (LWR) mock-up experiments, reactivity loss with fuel burn-up, spent nuclear fuel (SNF) chemical assays, and SNF oscillations. In order to meet LWR target accuracy, a few key isotopes have been identified and improved to be consistent with both differential and integral measurements. Hence, evaluated data for ^{16}O, [91,96]Zr, [237]Np, [239]Pu, and seven fission products ([93]Zr, ^{99}Tc, [103]Ru, [135]Cs, [147]Pm, [148]Pm, [154]Eu) have been revised in a February 2009 update of the JEFF-3.1.1 neutron files [13]. The Data Bank is currently starting the

testing phase of next major release of the JEFF library, the JEFF-3.2 version expected in 2013 and which will incorporate close to 100 new general purpose evaluations. For more information, visit *www.oecd-nea.org/dbdata/jeff*.

Nuclear Data and the Working Party on international nuclear data Evaluation Co-operation

The Working Party on international nuclear data Evaluation Cooperation was created in 1989 to provide a forum for a co-operation between the major nuclear data evaluation projects. The collaboration originally included the US ENDF, the Western European JEFF and the Japanese JENDL projects and was subsequently extended to include the Russian BROND and the Chinese CENDL projects through the support of the International Atomic Energy Agency (IAEA).

During its annual meeting, the WPEC reviews the status of the major nuclear data evaluation libraries, as well as the associated nuclear data measurement efforts. The WPEC indentifies nuclear data improvement needs and establishes subgroups to address them. Thirty-six subgroups have been created since the start of the WPEC. Twenty-four have so far been completed and published their reports, covering many different issues (see *www.oecd-nea.org/science/wpec*). The following is a brief review of the recently concluded or ongoing activities by WPEC subgroups.

Subgroup C: Priority request list

Subgroup C is a long-term subgroup of the WPEC and is responsible for maintaining a priority request list for nuclear data measurements. The purpose of this list is to provide a guide for those planning measurements, nuclear theory and evaluation programmes and to promote discussion on data needs among end-users, experimenters and evaluators. In order to be given high priority status, eligible requests must be based on thoroughly documented sensitivity analyses and reviewed by the group. A request obtaining the status of high priority by NEA WPEC is thus officially recognized as an important need by the international scientific community, and is a valuable supporting argument for new measurement campaigns. Currently, there are 35 documented requests, 25 of which are high-priority. Figure 4 shows an image capture of the current high priority request list for nuclear data webpage.

Figure 4: A view of the web-based high priority request list which can be consulted at *www.oecd-nea.org/dbdata/hprl*

Req.ID	View	Target	Reaction	Quantity	Energy range	Sec.E/Angle	Accuracy	Cov	Field
H 2		8-O-16	(n,a),(n,abs)	SIG	2 MeV-20 MeV		See details	Y	Fission
H 3		94-PU-239	(n,f)	Prompt g-prod	Thermal-Fast	Eg=0-10MeV	7.5	Y	Fission
H 4		92-U-235	(n,f)	prompt g-prod	Thermal-Fast	Eg=0-10MeV	7.5	Y	Fission
H 5		72-HF-0	(n,g)	SIG	0.5-5.0 keV		4	Y	Fission
H 8		1-H-2	(n,ela)	dA/dE	0.1 MeV-1 MeV	0-180 Deg	5	Y	Fission
H 12		92-U-235	(n,g)	SIG, RP	100 eV-1 MeV		3	Y	Fission
H 15		95-AM-241	(n,g), (n,tot)	SIG	Thermal		See details		Fission
H 18		92-U-238	(n,inl)	SIG	65 keV-20 MeV	Emis spec.	See details	Y	Fission
H 19		94-PU-238	(n,f)	SIG	9 keV-6 MeV		See details	Y	Fission
H 21		95-AM-241	(n,f)	SIG	180 keV-20 MeV		See details	Y	Fission

Subgroup 21: Evaluated Data Library for the Bulk of Fission Products

WPEC Subgroup 21 was formed to assess and make recommendations for fission product neutron cross-sections by reviewing all available evaluations, as well as experimental and theoretical information. Subgroup 23 was formed and mandated to produce a fission product cross-section library as recommended by Subgroup 21 and to perform an initial validation of this library. The final version of this library was assembled in the fall of 2006. The library, which contains evaluation for 219 fission products, has been adopted in full by ENDF/B-VII.0. Validation of the library was performed by the Cross-Section Evaluation Working Group (CSEWG) and the Oak Ridge national Laboratory (ORNL) in the United States, as well as by Serco Assurance in the UK. A detailed description of the compilation and validation is given in the WPEC subgroup report [14].

Subgroup 25: Assessment of Fission Product Decay Data for Decay Heat Calculations

In order to generate correct estimations of radioactive decay heat, decay data libraries usually resort to theoretical data. Although these models have sound bases for their adoption, calculations based on mean decay data derived from total absorption gamma-ray spectroscopy (TAGS) measurements are able to better describe total decay heat, although beta and gamma contributions may differ significantly when compared with measured data and decay heat standards. Subgroup 25 has reviewed availability of TAGS data [15]. It has produced recommendations for fission product radionuclides TAGS measurements in order to improve decay heat calculations. An example of such an improvement is given in Figure 5.

Figure 5: Gamma components of ^{238}U and ^{239}Pu fission product decay heat showing the effect of introducing preliminary TAGS results for ^{104,105}Tc compared to experimental data from Yayoi [11]
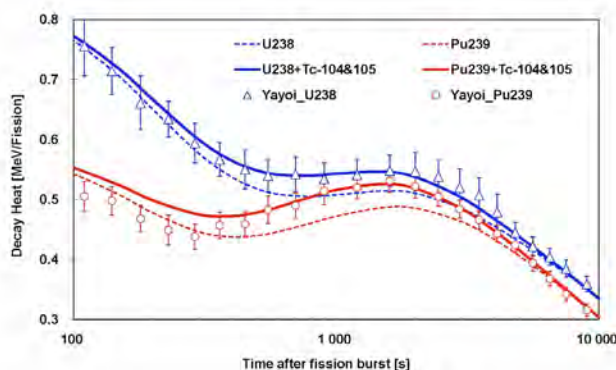
Subgroup 26: Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations

The design requirements of new reactor systems will require improvements to existing nuclear data as well as new nuclear data needs. In order to estimate the target accuracy which will be needed, WPEC Subgroup 26 was established with the goal to develop a systematic study of the sensitivity to neutron cross-sections uncertainties of the most important integral parameters of a wide range of innovative systems. These sensitivity/uncertainty analyses used a specifically developed library of covariance matrices to calculate integral parameter uncertainties. This study has demonstrated the strong impact that correlation data has on the uncertainty assessment, indicating that any credible uncertainty analysis should include the best available covariance data, accounting for energy correlations, possibly cross-correlations among reactions, and even cross correlation among isotopes. A significant result of this work has been the compilation of "design target accuracies", along with a quantitative evaluation of nuclear data improvement needs by isotope, nuclear reaction and energy range, which are required to meet these design target accuracies [16]. This has provided a number of new high priority requests in Subgroup C.

Subgroups 24, 28, 32: covariance data

Generation of covariance data through different methodologies as well as the handling of such data by processing codes have been addressed by different subgroups of the WPEC.

Subgroup 24 was established to develop a methodology for generating covariance data in the fast neutron region, and to implement covariance capabilities in the major nuclear reaction codes (*e.g.* TALYS, EMPIRE). Deterministic, stochastic and "hybrid" methods for covariance data generation have been compared and advantages and disadvantages of the different methods have been evaluated [17]

Processing codes implementing Sensitivity/Uncertainty analyses tools are able to use covariance data in evaluated nuclear data files. WPEC identified the need to carry out an assessment of the consistency of the results these tools produce and to verify that they correctly propagate cross-section uncertainty data to calculated quantities of interest. Subgroup 28 was set up to produce resonance cross-section evaluations with covariance data for important nuclides, such as ^{235}U, ^{238}U, and ^{239}Pu, and to implement methods to process and test covariance data. The work carried out by this subgroup has shown that the investigated S/U analysis tools correctly propagate the uncertainty information in the calculations, but has found that discrepancies exist in the results obtained by the processing codes NJOY and PUFF which need to be further investigated.

The objectives of WPEC Subgroup 32 were to review existing unresolved resonance parameter formalisms, generate unresolved resonance parameters for ^{235}U and ^{238}U, and compare the results when calculating cross-sections with the resolved and unresolved formalisms and to make recommendations for a more rigorous treatment of the unresolved resonance region within the ENDF format.

Subgroup 30: Improvement of the Accessibility and the Quality of the EXFOR Database

Nuclear data evaluators need to have easy and reliable access to experimental nuclear data into a standardised format. The internationally maintained EXFOR database is the principal source of such data. WPEC Subgroup 30 was set up to investigate whether the data were correctly compiled into the database and if and how it could be rendered more easily accessible. The Subgroup mainly focused on two activities; the translation of the entire EXFOR database into computational format, and the identification and correction of the most obvious errors, using checking codes, plotting packages and comparisons with model codes. Figure 6 illustrates a case of a data set with wrongly assigned nuclear reaction type or isotope identifier. Subgroup 30 has identified several paths to follow for the integral verification of the database, a challenging task which will require automated checks. These could include data sampling through statistical methods for automatically identifying outliers and signalling them as potential errors to be corrected or discarded.

**Figure 6: Graphical comparison of evaluated data with experimental
data from EXFOR for the total neutron cross-section of ^{27}Al**

Subgroup 31: Meeting Nuclear Data Needs for Advanced Reactor Systems

In 2010 the WPEC launched subgroup 31 with the goal to review the scope of the nuclear data needs identified by subgroup 26 on "Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations", and consider the practicality of meeting those data needs. In addition, Subgroup 31 will evaluate existing experimental data accuracies versus requirements for new measurements, identify gaps in existing worldwide capabilities to meet these needs and recommend collaborative ways forward.

Subgroup 33: Methods and issues for the combined use of integral experiments and covariance data

Following the work of WPEC Subgroup 26, it was noted that many of the target accuracies, which have been defined to satisfy reactor design requirements for many integral neutronic parameters, are very tight and are not likely to be achieved with current experimental measurement techniques. It was therefore decided to start subgroup 33 to investigate whether the combined use of integral experiments and differential information (*e.g.* experimental and uncertainty data) would make it possible to provide designers with improved nuclear data that would meet design target accuracies for a wide range of innovative reactor and fuel cycle systems. The activities of this subgroup are still ongoing.

Newly established WPEC subgroups

The ENDF and JEFF projects have adopted the same evaluation for the ^{239}Pu resonance region, largely based on work from ORNL, USA, and the CEA, France. A general over-prediction of about 0.5 % for thermal Pu solution assemblies has been noted when using these evaluated data. In recent years, the JEFF community has developed an updated ^{239}Pu file for JEFF-3.1.1 with modifications at thermal energies, which has improved some of the above mentioned discrepancies. A new set of resonance parameters for ^{239}Pu has also been developed at ORNL. This evaluation is more consistent with the cross-section resonance data and believed by the evaluators to be the best representation of these data to date. Nonetheless, this new evaluation does not improve the poor integral performance of the ENDF/B-VII.0 file, and in fact most of the discrepancies have slightly increased.

Subgroup 34 was established in 2010 with the purpose of investigating the development of a new ^{239}Pu evaluation, one that incorporates the most accurate fundamental cross-section data with nuclear theory constraints, and would also better model the relevant integral criticality data.

Two other subgroups; subgroup 35 on "Scattering Angular Distribution in the Fast Energy Range" and subgroup 36 on "Evaluation of experimental data in the resolved resonance region were established by the WPEC in June 2010.

Summary

The OECD NEA, as an international forum for scientific and technical co-operation, pools the expertise of its member countries working in close collaboration with other main national and international organisations. The NEA Nuclear Science Committee, through the Working Party on international data Evaluation Co-operation identifies nuclear data needs and establishes international expert groups to address them. The NEA Data Bank provides its member countries with reference materials in the field of nuclear energy applications. These services include the compilation, verification, and distribution of nuclear data, chemical thermodynamic data, integral benchmark experiments, as well as computer programs and associated application libraries, among others.

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