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BNL-NCS--37084

DE86 001740

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presented at the

Kerntechnische Gesellschaft/European Nuclear Society
International Seminar on
Nuclear Data, Cross Section Libraries and
Their Application in Nuclear Technology

at Bonn, Germany
October 1-2, 1985

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I. Assessment of ENDF/B-V

The Evaluated Nuclear Data File (ENDF/B) system, whose formats[1] are in wide use, places emphasis on assessing the adequacies and deficiencies of each completed version. The primary assessment method is the comparison between calculation and experiment for selected integral benchmarks.[2] The Cross Section Evaluation Working Group (CSEWG), which helps develop ENDF/B, has developed benchmark specifications in several areas; fast reactors, thermal reactors, shielding for fast, thermal, and fusion reactors, fission products and actinides, and dosimetry. Some of the adequacies and deficiencies that have been observed for ENDF/B-V[3] are summarized here.

For fast reactors the criticality for both uranium and plutonium field assemblies is generally within experimental uncertainty and the dispersion in calculated values from independent analyses of the same assembly. There does not appear to be any bias related to spectral hardness. The fission ratios $^{49}f/^{25}f$ and $^{28}f/^{25}f$ are well predicted in large assemblies, but the $^{28}f/^{25}f$ for smaller harder spectrum assemblies is underpredicted in JEZEBEL and overpredicted in GODIVA. The ^{238}U capture rate relative to ^{235}U or ^{239}Pu fission is overpredicted in large assemblies.

For thermal reactors the criticality for light water highly enriched uranium assemblies is calculated quite well. For slightly enriched assemblies criticality is also calculated well, and the long standing discrepancy in calculating ^{238}U resonance capture has been substantially removed. The calculated criticalities for light water plutonium assemblies average high when compared to experiment and the discrepancy cannot be explained on the basis of obvious data deficiencies.

The shielding parameters that receive the most attention are the total neutron cross-section via transmission measurements and secondary spectra of gamma-rays and neutrons from neutron capture, inelastic

scattering and (n,2n) reactions. Integral benchmark experiments to test shielding data have inherently larger uncertainties than criticality and spectrum averaged cross-section ratio measurements. Total cross sections are adequate for shielding materials tested except for C in the 5-8 MeV and Cr and Ni in the 1-3 MeV region. There are adequate thermal neutron gamma-ray production data for the shielding materials tested except for Cl and Cu below 6 and 4.5 MeV respectively. Pulsed sphere studies of neutron spectra from 14 MeV neutron reactions indicate that 15-30% discrepancies exist for Mg, Ca, Ti, V, Cr, Ni, Cu, and Nb.

Of the 196 materials for which fission product and actinide cross-section data are represented in ENDF/B-V, calculated integral reaction cross-sections for 43 have been compared with measurements in reference spectra. The average ratio of calculation to experiment is about 1.1 with a standard deviation of about 0.2. Decay data for 750 unstable nuclides is used to compare calculated gamma and beta-ray decay energies with experiment. In general, for cooling times less than 100 seconds, calculated gamma decay energies are higher than measured for low energy gammas and lower than measured for high energy gammas. In general, for all cooling times, the reverse is true for betas. As a consequence, when summed, the agreement between calculation and experiment for total decay heat is better than for the individual components.

Reaction cross-sections for 26 materials are chosen for dosimetry applications and testing in reference spectra. Most of the calculated reaction rates are consistent with integral measurements, but the reaction rates for $^{10}B(n,total\text{-}alpha)$, $^{47}Ti(n,p)$, $^{58}Fe(n,\gamma)$, and $^{27}I(n,2n)$ differ by 10% or greater.

II. ENDF/B-II Objectives

Drastic reduction in funding for ENDF/B-VI by the United States fast breeder reactor program has led to significant changes in the ENDF/B-VI development plans. The major responsibility now lies with the U.S. Department of Energy, Office of Basic Energy Sciences (BES). Major evaluation improvements will be made for materials of interest to the fusion and fission reactor programs. However, we also expect to include some evaluated data for incident charged particles, namely protons.

At present, data evaluation activity will be carried out at Argonne National Laboratory (ANL), Idaho National Engineering Laboratory (INEL), Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), National Bureau of Standards (NBS) and Oak Ridge National Laboratory (ORNL). In addition, we hope to have some contributions from Hanford Engineering Development Laboratory (HEDL). The National Nuclear Data Center (NNDC) at Brookhaven National Laboratory will continue to provide the coordination of the program and basic support services but will not be significantly involved in neutron data evaluation.

A. Formats

Most of the format revisions for ENDF-6 have been adopted. Some minor revisions will occur as a result of testing of the new formats. The significant changes adopted are:

1. Sublibraries - in order to include charged particle data in ENDF/B-IV, the concept of separate sublibraries for different data types has been introduced. An evaluation will be identified by the target material (MAT) and the sublibrary (NSUB). So far sublibraries have been identified for neutron reaction data, neutron fission yields, thermal neutron data, decay data, atomic interaction data and proton reaction data.

2. Resonance representation - an R-matrix representation for non-fissile, non-fertile materials has been approved for ENDF/B-VI. Energy dependent potential scattering is now permitted and a revised format for a Reich-Moore parameterization has been adopted. The Reich-Moore format has been adopted but will not be permitted in the ENDF/B-VI library although discussions are now underway concerning the removal of this restriction.

3. Outgoing particle distributions - a new format for file 6 permitting the represention of correlated energy-angle distribution of products of a nuclear reaction has been adopted. With this charge the ENDF-6 format will be useful to

higher incident particle energies and for non-neutron incident particles.

4. Thermal scattering law - changes in the file 7 format were made to permit inclusion of some nuclear data now built into processing codes.

5. Covariance files - data covariance files for angular distributions (file 34) and energy distributions (file 35) have been adopted. However, no format for correlated outgoing particle distributions (file 36) has been proposed. Format for covariances of isomer production cross sections (files 39 and 40) were also approved.

B. Processing codes

Work has begun on the improvement of processing codes to handle the new ENDF-6 formats. The utility codes maintained by the NNDC have been upgraded to handle all formats approved except for the covariance file revisions. The codes have been released in version 6.0. Changes to the NJOY maintained by Los Alamos are currently in progress and upgrades to MC^2 at Argonne and MINX-SPHINX at Oak Ridge are planned. The resonance region processing codes are presently being revised by D. Cullen at the IAEA.

C. Data

To date, priority has been given to the evaluation of the "standards" data. This is characterized by a simultaneous evaluation of the traditional standard cross sections for $^{6}Li(n,t)$, $^{10}B(n,\alpha)$, $^{197}Au(n,\gamma)$ and $^{235}U(n,f)$. However, due to the experimental data linkages, evaluations of $^{238}U(n,f)$, $^{238}U(n,\gamma)$ $^{239}Pu(n,f)$ and others have been obtained. Presently, this evaluation is in its final stage where the Hale (LLNL) R-matrix evaluation of ^{6}Li and ^{10}B will be combined with the Poenitz (ANL) evaluation by R. Peelle (ORNL). Evaluation for data not closely linked to the standards is also underway. Evaluations for ^{93}Nb (ANL) and the copper isotopes (ORNL) have been completed. The

Cu evaluations use the new file 6 format for outgoing particle energy-angle distributions.

III. Development of ENDF/B-VI

A. Organization

The National Nuclear Data Center at Brookhaven National Laboratory has responsibility for the organization and development of the ENDF/B system. The NNDC accomplishes its objectives through CSEWG, a group of working level representatives from national laboratories, industrial organizations, and academic institutions. Since its inception, CSEWG has provided a forum where data problems can be discussed, and evaluations performed. The objectives of CSEWG are:

1. to formulate the scope and contents of the reference library (ENDF/B) and establish formats and procedures for its use,

2. to develop the necessary evaluations and perform differential and integral testing of data as part of a continual review directed toward the upgrading of evaluations, and

3. to provide recommendations for new evaluations, experiments, and computer codes needed to improve the accuracy of analyses using nuclear data. These objectives are directed toward the widespread availability of nuclear data reviewed and revised on a regular basis.

The NNDC administers the activities of CSEWG, acting as secretariat and providing meeting facilities, personnel, preparation and distribution of material, as well as other required services. The present CSEWG structure consists of an Evaluation Committee, a Data Testing Committee and a Methods and Formats Committee, reporting to CSEWG and the Executive Committee. The Executive Committee provides

overall guidance to the CSEWG activities and includes representative of funding agents and CSEWG Committee chairmen. CSEWG meetings are held once a year at Krookhaven National Laboratory. In addition to general CSEWG meetings, there are subcommittee meetings organized by subcommittee chairmen which are held when CSEWG meets, and at other times during the year. In addition to the administration of CSEWG, NNDC supplies bibliographic and experimental data retrieval services to the CSEWG evaluators. The NNDC has the responsibility of maintaining and upgrading, when necessary, utility processing codes for the ENDF system. The NNDC also is responsible for processing and correcting incoming data evaluations including preparation of review lists for each material. The NNDC assembles and distributes complete versions of the ENDF/B library.

B. Distribution Policy

The ENDF/B system was developed for direct use in nuclear applications. Because the developers of ENDF/B included thermal, fast, and fusion reactor and shielding physicists there was much interest in related benchmark testing but not in adjusted data that would be application dependent. At first mixed success was obtained for the agreement between calculations and experiments, e.g. the agreement for fast reactor benchmarks was better than for thermal reactor benchmarks. The continued use of feedback from the calculation of benchmark experiments spurred selected measurements of differential data and revised evaluations for successive versions of ENDF/B. With ENDF/B-V, issued in 1979, the results in most applications were comparable with those using adjusted data. Special purpose ENDF/B-V files were released, but a limited distribution policy similar to that followed by some countries for adjusted group sets was applied to the general purpose ENDF/B-V data. With the comparitively recent growth in team efforts to evaluate data for a wide range of applications, there are increased opportunities for collaboration and reciprocity. No limitation on the release of ENDF/B-VI data is planned.

C. International Cooperation

Current requirements for evaluated nuclear data files are very ambitious; extended energy range and reaction types, non-neutron libraries, double differential data, covariances, etc. The extensive resources necessary to accomplish these objectives are not available in today's budgets. It is clear that the reduction in available evaluation manpower will require a stretch out in the schedule for release of ENDF/B-VI and reduce the number of materials which can be reevaluated. In order to alleviate these problems, CSEWG is enlisting support from others. Specifically, 1) U.S. evaluators are encouraged to cooperate with non-U.S. evaluators in reevaluating materials for which they are responsible; 2) freely available non-U.S. evaluations will be reviewed for inclusion in ENDF/B-VI; 3) foreign experts will be asked to review evaluations proposed for ENDF/B-VI and 4) ENDF/B-VI will be available for release without restrictions. Some initiatives in international collaboration between U.S. and non-U.S. evaluators have taken place as a result of a meeting at the May 1985 International Conference on Nuclear Data for Science and Technology held in Santa Fe, New Mexico.

IV.

D. ENDF/B-VI Schedule

The projected schedule for ENDF/B-VI is currently:

1.	Completion of format revisions	June 85
2.	Standards evaluation completion	February 86
3.	Begin processing and review of evaluations	September 86
4.	Begin release of materials not requiring data testing	June 87
5.	Last evaluation completed	June 88
6.	Phase I reviews complete	January 89
7.	Phase II testing complete	June 89
8.	ENDF/B-VI release complete	October 89
9.	Summary documentation	March 90

A list of specific evaluations that are completed, in progress or planned is the following:

Material	Evaluator	Target Date	Material	Evaluator	Target Date
1-H	Dodder/LANL +Standards	done	55-Mn	Muir/LANL, Shibata/ORNL	FY86
6-Li	Standards/LANL	4/86	Fe	Fu/ORNL	FY88
7-Li	P. Young/LANL	FY88	59-Co		
9-Be	S. T. Perkins/LLNL	done	Ni	Hetrick/ORNL	FY86
10-B	Standards/LANL	4/86	63,65-Cu	Hetrick,Fu, Larson/ORNL	done
11-B	P. Young/LANL	6/86	Nb	Smith/ANL	done
16-O	NNDC find one		Au	Standards/LANL	FY86
19-F	NNDC find one		Pb	Fu/ORNL	FY87
27-Al	NNDC find one		235-U	Standards/ANL	FY88
Si	Hetrick,Larson/ORNL	FY87	238-U	ANL	FY88
Ti	Smith/ANL	FY86	239-Pu	Arthur/LANL	FY88
V	Smith/ANL	FY87	240-Pu	Weston/ORNL	FY86
Cr	Hetrick,Fu, Larson/ORNL	FY87			

IV. Summary

A new edition, ENDF/B-VI, is planned that contains several extensions to existing data and formats as well as some changes in procedures. The plans include opportunities for increased international cooperation and reciprocity in the exchange of data.

References

1. Kinsey, R. Editor. Data Formats and Procedures for the Evaluated Nuclear Data File, BNL-NCS-50496 (ENDF-102), 2nd Edition (ENDF/B-V), Revised October 1979, Revised November 1983.

2. Kinsey, R., compiled by ENDF/B Summary Documentation BNL-NCS-17541 (ENDF-201), 3rd Edition (ENDF/B-V) July 1979. See also 3rd Edition (ENDF/B-V) Supplement I, January 1985.

3. Weisbin, C. R., et. al., Editors. Benchmark Data Testing of ENDF/B-V BNL-NCS-31531 (ENDF-311), August 1982, Informal Report.