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NEANSC WORKING GROUP ON INTERNATIONAL EVALUATION COOPERATION

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ABSTRACT

In the last three years, several newly evaluated nuclear data libraries have been released. Japan completed JENDL-3 in late 1989, JEF-2/EFF-2 was completed by Europe in 1991, and ENDF/B-VI was completed by the U. S. in 1989. With the support of the NEACRP and the NEANDC, (recently combined into the NEA Nuclear Science Committee NEANSC,) a Working Group was formed in 1989 to promote cooperative activities among the evaluation groups in OECD countries. Technical activities of the Working Group are carried out by subgroups formed to carry out specific investigations. Seven subgroups are currently active, with four more initiated by the Working Group at its meeting in May 1991. Brief descriptions of current subgroup activities are given.

INTRODUCTION

Historically, nuclear data evaluation activities worldwide have been quite independent. In the U.S., most nuclear data evaluation work has been carried out through the Cross Section Evaluation Working Group, CSEWG. Started in 1966, it has been responsible for developing formats and nuclear data libraries through ENDF/B-VI. Because of its comprehensiveness, associated processing programs, and its free availability, in the 1970's ENDF/B was the primary source of evaluated nuclear data in the OECD countries with the exception of Japan. The JENDL evaluation effort was started in Japan in the early 1970's to provide evaluated data for the Japanese reactor programs. Following restrictions on exchange of nuclear data, two European evaluation efforts were initiated. The Joint Evaluated File (JEF), and the European Fusion File (EFF) were began in the early 1980's to meet needs of reactor programs and fusion design needs, respectively. By the end of the 1980's, each evaluation project had completed release of an evaluated library considered adequate by the user communities. In the U.S., ENDF/B-VI was released in 1989, with Mod 1 following in 1991. The Japanese general purpose library JENDL-3 was released in 1989, with revision 1 in 1990. (Several

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special purpose JENDL libraries are in preparation and will be released in the early 1990's). In Europe, the JEF-2 and EFF-2 libraries are undergoing data testing activities and will be completed in early 1992. The new libraries use ENDF-6 formats, with the exception of JENDL-3 which retained the ENDF-5 format.

Following these successes, and with serious funding reductions for nuclear data evaluation work, came the realization that concentrated and specialized efforts would be required to further improve the evaluated libraries. Continuation and improvement of evaluated nuclear data libraries has been a long-standing concern of the NEANDC and the NEACRP. Initial contacts by the Chairman of the NEANDC to the chairmen of the evaluation projects described above ultimately resulted in the formation of the Working Group on International Evaluation Cooperation in 1989. Features of this Working Group include agreements that (1) the evaluated nuclear data files and associated documentation would be freely exchanged between the different projects, (2) the different evaluated nuclear data files would remain separate entities for the foreseeable future, but through increased cooperation, the contents of the different files would tend to merge, (3) cooperative evaluation activities should be promoted in order to prevent unnecessary duplication, (4) personnel exchanges would be encouraged, and (5) exchange of benchmark testing results would be considered.

The Working Group consists of up to four members from each of the evaluation projects and a representative from the parent NEA committee. The NEA serves as secretariat to the Working Group. Technical activities of the Working Group are carried out by subgroups formed to solve specific evaluation tasks. Eleven high priority tasks have been identified for support by the Working Group.

ACTIVE SUBGROUPS

Significant progress has been reported by the seven initial subgroups, and four new ones are in the organizational stages. The remainder of this paper outlines the subgroup tasks and progress made toward solutions to the evaluation problems selected by the Working Group. A member of the Working Group is assigned to monitor the work of each subgroup, and the coordinator is the subgroup chairman.

SUBGROUP 1: INTERCOMPARISON OF EVALUATED FILES FOR ^{52}Cr, ^{56}Fe AND ^{58}Ni, C. Y. Fu, ORNL, Oak Ridge, coordinator, D. C. Larson, ORNL, monitor.

The purpose of this subgroup is to graphically compare selected evaluations for structural materials from the four libraries to identify meaningful differences and determine reasons for the differences. The selected isotopes are important components of stainless steel, and new evaluations for each of the isotopes are available from the libraries.

Several findings have been made by this subgroup. Three of the most interesting result from comparisons of the (n,α) cross sections, energy distributions of outgoing neutrons, and photon production cross sections. The (n,α) cross sections have large spreads among the evaluations, resulting from significantly different shapes as a function of energy. Since the data base is rather sparse, model calculations form the basis of the evaluations. Some of the largest differences (up to a factor of 2) are in the energy region from 8 - 10 MeV, a region of importance to radiation damage. Several ideas have been proposed to explain the differences, including different alpha particle preformation factors, alpha particle optical model parameters, competition of other channels and residual nuclei level densities. The last two ideas help explain much of the ^{58}Ni discrepancy. An

IAEA Coordinated Research Proposal has also been organized to investigate these discrepancies.

Large discrepancies are also observed among the energy distributions for outgoing neutrons at incident energies other than 14 MeV, where the data base is generally adequate. A particularly bad case is for ^{58}Ni at 11 MeV, where factors of two differences are observed for outgoing energies below 1.5 MeV. Again, model calculations were used in the absence of experimental data, and level density problems do not appear to be the cause. Work is ongoing in this subgroup to identify the source of the discrepancies.

Discrepancies in photon production cross sections for all three materials may be related to differences (up to a factor of two) in the experimental data base, and this matter will also be investigated.

The nonelastic cross section is very important for the structural materials, and the spread among the evaluations for this cross section is less than 3% for ^{52}Cr and ^{56}Fe, but about 15% for ^{58}Ni. The inelastic scattering cross sections are important for shielding calculations, and are often requested to have uncertainties less than 5% for these materials. However, differences as large as 20% are found between the evaluations in the 2 to 4 MeV energy range. The (n,2n) cross section data bases for ^{52}Cr and ^{58}Ni are adequate, and the evaluated cross sections are in acceptable agreement. However, for ^{56}Fe, a 20% spread in the evaluations around 14 MeV could be important for fusion benchmark testing and is being investigated.

Finally, comparisons of the resonance region showed unacceptably large differences, particularly for ^{52}Cr. This part of the work has spawned Subgroup 11, charged with intercomparing the resonance regions of these materials.

A report from this subgroup is given in Ref. 1.

SUBGROUP 2: GENERATION OF COVARIANCE FILES FOR ^{56}Fe AND ^{nat}Fe, H. Vonach, IRK, Vienna, coordinator, H. Gruppelaar, ECN Petten, monitor.

Covariance data are required to assess uncertainties in design parameters and to refine use of nuclear data, particularly in reactor applications. However, experience in generating evaluated covariance data is not as prevalent as for evaluating cross section data. This subgroup is to review methods for generating covariance files, and recommend methods for uncertainty evaluation.

Several tasks have been completed by this subgroup. Documentation of methods used for covariance evaluation in ENDF/B-VI and EFF-2 has been accomplished. Both methods are empirical, and have been extensively compared at IRK to evaluate the methods used. As part of this comparison, independent evaluations for 14 MeV cross sections for several structural materials were performed at IRK, as a benchmark to check both the quality of the various evaluated data files and their uncertainty estimates. While the empirical methods used for ENDF/B-VI and EFF-2 were often found to be adequate; better, more rigorous methods need to be developed for future uncertainty evaluation work. While empirical methods may be consistent across a material, uncertainties for several materials may not be consistent, especially if done by different evaluators. This leads to difficulties when utilizing uncertainties for stainless steel, for example. Some progress has been made based on Bayesian methods applied to nuclear data evaluation.

This subgroup has also concerned itself with sensitivity studies in an attempt to understand the sensitivity of shielding parameters to secondary neutron energy and

angle distributions. If the secondary distribution uncertainties turn out to be important, formats will have to be developed for File 6 uncertainties.

One of the primary outstanding problems in uncertainty evaluation work is assigning meaningful uncertainties to calculated cross sections. One of the promising approaches is that of Y. Kanda,[2] in which covariance matrices for the parameters used in the nuclear model formulas are used to calculate the cross section uncertainties. Since some parameters are common to both target and residual nuclides, correlations appear between different reactions and can be included in the uncertainty files.

Finally, resonance parameter evaluation work development is being done, initially for the most important resonances in ^{56}Fe.

SUBGROUP 3: ACTINIDE DATA IN THE THERMAL ENERGY RANGE, H. Tellier, CEN, Saclay, coordinator, M. Sowerby, Harwell, monitor.

Thermal nuclear constants for the primary actinides have been extensively studied. The most recent evaluation was performed by E. J. Axton and values based on this work (e.g. ENDF/B-VI standards) are widely used. H. Tellier also evaluated the data, taking into account thermal reactor benchmarks, and significantly different values for some of these constants are obtained, with the data for ^{239}Pu being particularly discrepant. Identification of the origin of these differences is a goal of this subgroup, and reassessment of the evaluations, if required.

The above differences could be associated with the shapes of the cross sections in the thermal energy region for which different values have been adopted in different evaluations. The analysis of lattice temperature coefficient measurements has suggested that η for ^{235}U should be energy dependent below 0.0253 eV to account in part for the discrepancies. One recent measurement at Geel supports this contention, but another measurement at Harwell does not. These measurements are claimed to be accurate (0.5%) but are difficult to perform and analyze as the corrections to the measured data are complex and difficult to evaluate.

A review of the thermal and epithermal data shows that the situation has improved during recent years. Results from calculations and evaluations using differential data are now in good agreement with values deduced from integral experiments. However, a few problem areas remain. The ^{235}U η measurements remain discrepant, and discussion among the experimentalists involved is promoted. There is a discrepancy between measurements at BNL and ORNL for the parameters of the 1 eV resonance in ^{240}Pu which needs to be resolved. New experiments are needed for ^{239}Pu η, and the ^{238}U Debye temperature problem.

This subgroup has resolved the majority of tasks initially assigned. The primary outstanding discrepancy is the η value of ^{235}U, and the subgroup is now focussing on resolving the shape problem with η in ^{235}U (and ^{239}Pu).

Reference 3 gives a summary of some activities of this subgroup.

SUBGROUP 4: ^{238}U CAPTURE AND INELASTIC SCATTERING CROSS SECTIONS, Y. Kanda, Kyushu University, Fukuoka, coordinator, Y. Kikuchi, JAERI, monitor.

The capture and inelastic scattering cross sections of ^{238}U are of primary importance for fast reactors. Recent evaluations of the capture cross section give lower values than earlier ones between 50 and 300 keV, and the values are lower than the

mean values of several existing experimental data sets. The choices for the low evaluated data may be influenced by results from integral tests. One of the tasks of this subgroup is to review whether these low values are justified, or are, in fact, compensating for deficiencies in other nuclear data, such as ^{238}U inelastic scattering.

Recent evaluations of the inelastic scattering are based on model calculations, as the experimental data base is sparse, and are discrepant. Another goal of this subgroup is to understand these discrepancies, and agree on a common evaluated cross section set.

Regarding the first task, a shape analysis in the resolved resonance region showed that some of the measured capture data needed to be renormalized. Following the proposed renormalization, the measured data are lowered, in agreement with the recent evaluated data in ENDF/B-VI, JENDL-3 and JEF-2. The lower values were also found to be consistent with an unresolved resonance region analysis. Multiple scattering effects are suspected as the reason for the larger measured values. The lower values for capture also improve agreement with integral parameters from fast reactor analysis. The subgroup thus concluded that the lower ^{238}U capture parameters used in the latest evaluations are reasonable and should be retained. Reference 4 provides a summary of this work.

Work on the second problem, ^{238}U inelastic scattering, is underway. Some significant differences in scattering to levels is observed between the evaluations, as well as the total inelastic scattering cross section. New preliminary angular distribution data has been received from ANL and will be used to improve the files. As the work is underway, no conclusions are yet available.

SUBGROUP 5: ^{239}Pu 1 - 100 keV FISSION CROSS SECTION, E. Fort, CEN, Cadarache, coordinator, M. Salvatores, CEN, Cadarache, monitor.

The evaluation of the ^{239}Pu fission cross section is of particular importance for fast reactor design. The simultaneous evaluation of this cross section done for the ENDF/B-VI standards file is 5% higher than average values obtained from a recent resolved resonance parameter evaluation by H. Derrien. The goal of this subgroup is to resolve this difference.

Work of this subgroup is continuing, so no final results are available. The fission cross section measurement of Weston and Todd used in the Derrien analysis is being reviewed in detail. Several checks were performed as part of the measurement, including measuring the ^{235}U fission cross section, and no problems are apparent. However, Weston and Todd have nearly completed a new measurement designed to verify the normalization of their earlier work. Measurements are also planned at Geel to study this problem. Two test evaluations have been prepared, one based on ENDF/B-VI data, and one based on the Weston-Todd data. These evaluations will be tested against clean integral benchmarks to provide additional information on this important cross section. When the work of the subgroup is completed, evaluations of this cross section are expected to be modified to agree with their findings.

A status report from this subgroup summarizing the current findings is given in Ref. 5.

SUBGROUP 6: DELAYED NEUTRON DATA BENCHMARKING, A. Philip, CEN Cadarache, and G. Rudstam, Studsvik Energiteknik, coordinators, R. McKnight, ANL, monitor.

Current C/E discrepancies (up to 10%) on integral measurements of β_{eff} result in undesirable conservatism in design and

operation of reactor control systems. Delayed neutron data uncertainties, which are significant in β_{eff} calculations, are large. For example, absolute yield uncertainties are ± 4-5%, group parameter uncertainties are ± 3-15%, and delayed spectra uncertainties range from ± 10-20%. One purpose of this subgroup is to investigate both experimental and theoretical ways to improve the data, thereby reducing the uncertainties. Tests of the improved results can be tied in with new benchmark integral measurements at the MASURCA reactor on delayed neutron data, which should provide high quality experimental information for ^{239}Pu, ^{235}U and ^{238}U.

The work of the subgroup has been divided into two parts. G. Rudstam is leading the differential data effort, while A. Philip is coordinating the integral data effort. A review of the present status of delayed neutron data[6] identifies the main discrepancies and suggests actions to be taken. The report focuses on the fissile nuclides ^{235}U, ^{239}Pu and ^{238}U, with the major problem being in the area of delayed neutron yields. The β_{eff} benchmark measurements planned at Cadarache are in preparation. There is also a theoretical effort underway for extracting delayed neutron values from the β_{eff} experiment.

SUBGROUP 7: MULTIGROUP CROSS SECTION PROCESSING, R. Roussin, ORNL, Oak Ridge, coordinator, E. Menapace, ENEA, Bologna, monitor.

The goal of this subgroup is to produce processed multigroup libraries based on the four major evaluated cross section libraries. A common set of specifications for processed data will be used, so that differences in preparation of the libraries can be minimized. The initial project will focus on producing a library based on the "VITAMIN" concept that has been used for previous libraries. It involves generation of a fine-group pseudo-problem-independent cross section library using the shielding-factor method to account for resonance self-shielding and temperature effects. The 175 group VITAMIN-J energy structure will be used. The weighting spectrum for neutron groups is Maxwellian in the thermal region, and includes a fission spectrum and a fusion peak. 1/E slowing-down regions are used in other energy ranges. A constant weighting spectrum is used for photon groups. The expansion order for neutron and photon scattering is P5 or higher. Output formats will primarily be MATXS and AMPX. The NJOY91 processing system will be used for generating cross sections from ENDF/B-VI and JEF-2/EFF-2, and the PROF-GR system for JENDL-3.

Processing has begun on evaluations from the four libraries. For JENDL-3, more than 60 elements and isotopes have been processed. Over 38 materials have been processed from the JEF/EFF libraries, using NJOY89.62 from Los Alamos, THEMIS from Saclay, and MILER from ENEA, Bologna. Output formats include GENDF, MATXS, AMPX and ANISN. For ENDF/B-VI, about forty data sets have been processed at ORNL using NJOY into the VITAMIN-J group structure and weighting functions. Upon completion of the processed libraries, results will be shared and used for benchmark testing of the evaluated data. The resulting data libraries will be distributed in standard formats via the NEA Data Bank, Issy-les-Moulineaux, France, and the Radiation Shielding Information Center (RSIC), Oak Ridge.

Further information on this subgroup is given in Ref. 7.

NEWLY FORMED SUBGROUPS

Four new Subgroups have been approved, and are in the organizational stages. They are:

- Subgroup 8: Minor Actinide Data, M. Sowerby, Harwell, UK, monitor.

This group will initially review evaluations for ^{237}Np and ^{241}Am, and look for appropriate benchmark tests.

- Subgroup 9: High Priority Request List for Data Needs in Future/Advanced Reactors, M. Salvatores, CEN, Cadarache, coordinator

  This subgroup will select topics of concern to reactor development efforts where physics play an important role, use sensitivity analysis to determine high priority data needs, and thus establish a priority list for new measurements and evaluation work.

- Subgroup 10: Fission Product Inelastic Scattering, H. Gruppelaar, ECN, Petten, monitor.

  Inelastic scattering in fission products needs to be refined in fission product evaluations, and this subgroup will study available techniques and provide a recommended solution.

- Subgroup 11: Intercomparison of the Resonance Region of ^{52}Cr, ^{56}Fe and ^{58}Ni, D. C. Larson, ORNL, Oak Ridge, monitor.

  This subgroup is a follow up to Subgroup 1, and will focus its efforts on resonance region evaluation comparisons for the four libraries.

RESULTS OF THE INTERNATIONAL COOPERATION

Any reports, conclusions and evaluated data resulting from the cooperation will be available without restriction. For specific information, interested parties should contact the secretariat at the Nuclear Energy Agency Data Bank, Issy-les-Moulineaux, France. The evaluated data files ENDF/B-VI, JENDL-3 and JEF-1 are released for world-wide distribution. It is expected that JEF -2 will be similarly released following completion of integral benchmark testing. For information from the evaluated files, contact the National Nuclear Data Center at Brookhaven National Laboratory, Upton, New York.

At present, this cooperative effort involves only evaluation activities of OECD countries. However, experts from non-OECD countries can work with the subgroups as needed. Extension of this cooperative effort to projects outside of the OECD is being investigated.

SUMMARY

Evaluation cooperation in nuclear data among the OECD countries is presented, and activities of the seven active subgroups are outlined and progress is summarized. Activities of four new subgroups are outlined. While existing data files are expected to continue as separate entities for the foreseeable future, contents of the files will converge with time as subgroup results are incorporated. The work of the subgroups will tend to resolve differences in approach and conflicts in conclusions of the different evaluators by involving them together in the search for a solution to common problems. Revised evaluated data resulting from these joint studies will be reflected in future releases of the individual libraries. The end result will be improved libraries of nuclear data for applied purposes. Research managed by the Office of Energy Research, Division of Nuclear Physics, U. S. Department of Energy, under contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

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