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RADIATION SHIELDING INFORMATION CENTER DATA ACTIVITIES*
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Activities developed at the Radiation Shielding Information Center (RSIC) play an important role in the utilization of nuclear cross sections in various radiation transport applications and help improve the general utility of the national ENDF/B effort. The activities involving processed and evaluated data libraries on behalf of RSIC's various sponsoring agencies are described.

(Information, cross sections, radiation, shielding, evaluation, processing, analysis)

Introduction

A significant proportion of the activities of the Radiation Shielding Information Center¹ (RSIC) involves data of various kinds but primarily neutron and gamma-ray cross-section data. The reason for this work is that the solution of most shielding (radiation transport) problems requires the use of large computer codes and their corresponding cross section libraries which together adequately treat the physics of neutron and gamma-ray interaction and production. As is discussed later, RSIC is involved in various aspects of this general problem by helping to provide evaluated neutron and gamma-ray cross-section data in standard formats, by packaging and distributing computer codes and associated cross-section libraries, by packaging and distributing specialized libraries of various types, and by assisting in the compilation of benchmark problem data for testing computation methods and cross section data.

The first section which follows outlines the role of RSIC in the cooperative effort to develop evaluated cross section data in the Evaluated Nuclear Data File (ENDF) format.² Here the emphasis is on providing neutron, gamma-ray production and gamma-ray interaction cross sections pertinent to radiation transport problems within various disciplines. All efforts are designed to augment and support the national ENDF/B effort. The next section describes activities associated with the acquisition, generation, and distribution of processed data libraries for direct use in treating various types of radiation transport problems. The final section deals with standards and benchmark data activities.

These activities are sponsored by the Reactor Research and Development (RRD) and the Controlled Thermonuclear Research (CTR) divisions of the Energy Research and Development Administration (ERDA), the Defense Nuclear Agency (DNA), and the Electric Power Research Institute (EPRI). They involve cooperation and collaboration with the National Neutron Cross Section Center (NNCSC) at Brookhaven National Laboratory, the Shielding Subcommittee of the Cross Section Evaluation Working Group (CSEWG), the CTR Subcommittee of the United States Nuclear Data Committee, and the ANS-6 Shielding Standards Committee of the American Nuclear Society.

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Evaluated Cross Section Data Activities at RSIC

Efforts dealing with evaluated cross sections began with various activities to help meet the needs of the shielding community through CSEWG. These were expanded to include a major effort for the Defense Nuclear Agency and have been extended to a similar program for the CTR neutronics community. All these efforts are designed to feed new evaluated data into the ENDF/B system.

Clearinghouse for CSEWG Shielding Evaluations

RSIC has always been concerned with cross sections and the problems associated with the proliferation of data in non-standard formats. Thus, the development of the ENDF program was supported by RSIC from inception. An RSIC staff member participated in the early planning stages, but more significant contributions were possible once the CSEWG Shielding Subcommittee was organized early in 1967. Since then, RSIC participation has been extensive, with emphasis on areas of vital interest to the shielding community.

RSIC continues to collaborate with NNCSC at Brookhaven National Laboratory and the CSEWG Shielding Subcommittee. The Center's role in this activity is to assist in the acquisition, checkout, and review of "shielding" cross sections in ENDF format which may ultimately be placed in the ENDF/B file. In this context, "shielding" cross sections are evaluations performed in the shielding, radiation effects or weapons communities which are likely to have an emphasis on gamma-ray production cross sections, gamma-ray interaction cross sections, and neutron cross sections in the energy range of interest for shielding with detailed energy and angular distribution resolution.

In preparation for the release of ENDF/B-IV, thirty-eight evaluations were received by RSIC and processed through checking codes, modified to conform to the ENDF format as necessary and forwarded to NNCSC, which prepared and distributed a packet for Phase I testing. These are listed in Table 1. Phase I testing discovers and eliminates clerical and format errors and results in a data set which seems reasonable. Phase II testing involves the use of the data to compare radiation transport calculations with integral experiments and results in knowledge about the adequacy of the data.

To further assist in the Phase I review process, an RSIC representative coordinated the review of structural materials being considered for inclusion in ENDF/B-IV.

In addition to the above activities, RSIC has coordinated the writing of a computer code³ to translate, and subsequently has translated, earlier versions of the UKAEA library to ENDF/B format for NNCSC. A project currently underway involves working with the evaluators⁴ to update the ENDF/B photon interaction cross section library and, for the first time, to provide photon

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scattering form factors in the ENDF format for consideration as the official ENDF/B-IV version.

Through active participation in the activities of CSEWG and through cooperation with NNCSC, RSIC strives continually to improve the adequacy of the ENDF/B system as an evaluated library of general applicability.

TABLE 1. ENDF/B-IV "Shielding" Materials Checked by RSIC for CSEWG and NNCSC

Material Name	ENDF/B-IV MAT	In DNA Library
H-1	1269	X
H-2	1120	X
H-3	1169	X
He-4	1270	X
Li-6	1271	
Li-7	1272	
Be-9	1289	X
B-10	1273	
C-12	1274	X
N-14	1275	X
O-16	1276	X
F	1277	X
Na-23	1156	X
Mg	1280	X
Al-27	1193	X
Si	1194	X
Cl	1149	
K	1150	
Ca	1195	X
Ti	1286	
V	1196	
Cr	1191	
Mn-55	1197	
Fe	1192	X
Co-59	1199	
Ni	1190	
Cu	1295	X
Nb-93	1189	
Mo	1287	
Ta-181	1285	X
W-182	1128	X
W-183	1129	X
W-184	1130	X
W-186	1131	X
Au-197	1283	X
Pb	1288	X
U-235	1261	
U-238	1262	
Np-237	1263	
Pu-239	1264	
Pu-240	1265	
Pu-241	1266	

Defense Nuclear Agency Working Cross Section Library

RSIC maintains and distributes the DNA cross-section library.⁵ This is a working library in ENDF format whose content can be modified and revised as often as the evaluator deems such changes to be necessary. The key to this approach is a selected evaluator, the person responsible for making the original evaluation for a particular element or elements. He is then responsible for authorizing changes in evaluations for those elements. The evaluated data are for those materials of interest to DNA, whose cross-section values are in a state of rapid change, and emphasis is placed on neutron energies up to 20 MeV and on secondary gamma-ray production. Evaluations of interest to DNA which are not in a state of rapid change are found in the ENDF/B library, which is available in the USA from NNCSC at Brookhaven National Laboratory.

The clearinghouse for the DNA program is RSIC. Initial versions of evaluations are received, processed through checking codes to eliminate obvious format errors, and modified as necessary in collaboration with the evaluator. Next, DNA Phase I data testing is performed whereby selected reviewers are provided with listings, output from checking codes, graphics, etc., and are asked to review the data and feed back their comments. These are relayed to the evaluator and, upon his instruction, appropriate changes are made. Changes are initiated only by the evaluator and each change is documented so that users can, at any time, refer to an identifiable data set when reporting results of their calculations.

Because the data are apt to be revised with some frequency, each evaluation is designated by a DNA MAT number and a MOD number. The DN MAT number is a unique identification number for an evaluation and is usually equal to the corresponding NNCSC-assigned ENDF MAT number plus three thousand for those evaluations which are submitted for inclusion in the ENDF/B library. The MOD number designates the number of times the DNA evaluation has been modified since its initial availability through RSIC.

Since the DNA library is in ENDF format and is available for consideration by CSEWG to become part of the ENDF/B library, the DNA program offers a good opportunity for improving the state of shielding cross sections. Materials from the DNA library which become part of ENDF/B-IV are indicated in Table 1.

The data, along with available documentation, are distributed upon request. The users are asked to feed back any comments they have, based on experience in using the data.

Controlled Thermonuclear Research Evaluated Cross Section Library

An evaluated library for the CTR neutronics community was recommended by the USNDC-CTR Subcommittee, and RSIC was chosen as the center for its establishment and distribution. The library is to be patterned after the DNA Working Cross Section Library so that new measurements can be incorporated, as they become available, into evaluated data files. The emphasis will be in the high energy region (8-15 MeV). As with the DNA project, the CTR library will be in ENDF format and will be available for inclusion into the official ENDF/B library.

Processed Cross Section Data Activities at RSIC

The RSIC Data Library Collection

Since inception, RSIC has been deeply involved with the acquisition, checkout, packaging, and distribution of a computer code library. Subsequently, a data library collection has been developed which includes not only cross-section libraries, but other nuclear data and also radiation transport results. The data sets are packaged in a manner analogous to the RSIC Computer Code Collection (CCC). Each data set, packaged as a unit, carries a Data Library Collection (DLC) number. As with the code packages, a particular data package does not remain static but is subject to revision, updating, and expansion as required. Such changes are announced in the RSIC Newsletter.

Data libraries were first announced as available from RSIC near the end of 1968. At that time it became evident that a collection of data libraries would be an extremely helpful companion to the RSIC Computer Code Collection.⁶ The main objective is the interchange of

technology among installations engaged in radiation transport research, development, and application. A partial listing of the current contents of the Data Library Collection is given in Table 2.

The philosophy behind the packaging and distributing of these data libraries is to preserve and make available in a computer-readable form, data which may be useful to those utilizing or performing radiation transport calculations. Since this usually involves the use of large computer programs, several of these libraries are multigroup cross sections in the format utilized by many such programs.

Documentation is very important. The abstract format used for the DLC⁷ sets is similar to that used to describe the code packages. Care was taken to make the format include all of the information necessary for adequately describing the contents and purpose of each data library. The main purpose of the abstracts is to give to a potential data library user several criteria for deciding whether or not he wishes to obtain the data.

Present activities with sponsors (on behalf of their contractors) has involved RSIC in projects where processed cross section libraries are generated directly for a particular user community. These activities on behalf of the DNA and CTR communities are summarized below.

TABLE 2. Partial Contents of RSIC Data Library Collection

Name	Comments (Contributor)*
DLC-2/ 100G	100 group, P _g , neutron cross sections by SUPERTOG from ENDF/B-III (ORNL).
DLC-3/ MEP	Analyzed cascade calculation results for n, p, \bar{n} on several materials (ORNL).
DLC-7/ HPICE	Photon Interaction Library in ENDF format (LLL, NBS).
DLC-8/ BP	Input data for benchmark problems in ORNL-RSIC-25 (ORNL).
DLC-12/ POPLIB	Photon production library for POPOP4 (ORNL).
DLC-15/ STORM- ISRAEL	Storm-Israel photon interaction library- ENDF format (LASL).
DLC-16/ COBB	123 group neutron cross sections from ENDF/B-II for XSDRN (ORNL).
DLC-18/ NAB	100 group neutron cross sections used in analysis of ORNL-LMFBR sodium experiment (ORNL).
DLC-23/ CASK	22-18 group coupled cross sections for shipping cask analysis (ORNL).
DLC-24/ SINEX	100 group neutron reaction cross sections for ENDF/B-III library (ORNL).
DLC-27/ AMPX01	104-22 coupled cross sections by AMPX for concrete elements (ORNL).
DLC-28/ CTR	52-21 coupled cross sections used in ORNL CTR neutronics (ORNL).
DLC-29/ PACLIB	100 group neutron kerma factors by MACK from ENDF/B-III (U. Wisc.)

TABLE 2 (continued)

Name	Comments (Contributor)*
DLC-30/ DECAYREM	Radioactive decay data, EXREM III format, many materials (ORNL).
DLC-31/ DPL	Defense Nuclear Agency processed cross section library - multigroup data ANISN format - point data SAM-CE format (ORNL, MAGI).
DLC-33/ MONTAGE	100 group neutron activation cross sections for CTR studies (LASL).

*Library contributors: ORNL, Oak Ridge National Laboratory, Oak Ridge, Tenn.; LLL, Lawrence Livermore Laboratory, Livermore, Ca.; NBS, National Bureau of Standards, Washington, D.C.; LASL, Los Alamos Scientific Laboratory, Los Alamos, N.M.; U. Wisc., Nuclear Engineering Department, U. Wisconsin, Madison, Wis.; MAGI, Mathematical Applications Group, Inc., Elmsford, N.Y.

Special DNA Processed Cross Section Libraries

A new class of data libraries was developed in cooperation with the DNA Radiation Transport Program. They are identified as Data Library Collection 31 (DLC-31) and include both multigroup and point cross section data. A coupled 37-neutron, 21-gamma-ray-g group library in ANISN format was generated at ORNL from recent ENDF/B and DNA evaluations for many materials using the AMPX⁹ cross section processor. Documentation includes results of calculations of neutron sources in air and concrete. Other sets of data suitable for use in the SAM-CE¹⁰ Monte Carlo code were generated at MAGI. They can be used to perform neutron, secondary gamma-ray, and primary gamma-ray transport calculations.

Special CTR Processed Cross Section Library

Using specifications developed through conversations and correspondence with various members of the CTR neutronics community, RSIC will direct the generation of a coupled 156-neutron and 23-gamma-ray multigroup cross section set as the beginning of a CTR Processed Data Library. Most of the materials were taken from the ENDF/B-IV and DNA evaluated libraries. Allowance is made for self-shielding and temperature dependence using the Bondarenko¹¹ scheme. The smooth weighting function used has Maxwellian weighting for the thermal group, a 1/E slowing down spectrum tied to a fission spectrum and joined at high energies to a D-T broadened 14 MeV spectrum. The library will be generated using a combination of the MINX¹² neutron processor and various modules of the AMPX code system with output in the AMPX interface format. In the generation process, a new module for the AMPX system will be programmed to perform the interpolation and iteration required to determine appropriate self-shielded and temperature-broadened cross-section values for a given problem. Special cross section handling codes will be packaged with the data to permit the user to allow for composition and temperature dependence for a specific problem and/or to collapse the data to reduce the group structure down to a number considered reasonable for a specific calculation. It is anticipated that the library will also be available in CCCC format¹³.

Standards Activities in RSIC

A continuing project, in cooperation with the American Nuclear Society, is to collect, edit, and publish reference data in the form of "benchmark

problems." The objective is to compile in convenient form a limited number of well-documented problems in radiation transport which will be useful in testing computational methods used in shielding analysis. The problem solutions, having been determined by several methods, should be representative of the state of the art. The problem descriptions are published⁴ in looseleaf form so that revisions and additions can be easily made. Contributions to the benchmark collection are sought by the ANS Benchmark Problem Group. In conjunction with the benchmark work, data sets are packaged which allow the recalculation, with a particular calculational method, of already published results. An example is the data in DLC-8 which allows the calculation of ANS Shielding Benchmark Problem Number 3. This kind of calculation is useful for testing a new computer code or theoretical treatment.

Conclusions

It has always been RSIC policy to discuss with users their needs and recommend codes and data libraries. Insofar as possible, we assist those who are implementing codes and data at their installations. In cases where we lack experience to advise in particular problem areas, we call upon other experienced personnel locally and elsewhere to help them. This takes the form of offering advice on solving particular problems, as well as helping to diagnose problems in implementing calculational procedures.

As always, RSIC relies on members of the radiation transport and shielding community to share their ideas, codes, and data so that technology as a whole may be advanced.

In summary, RSIC strives to enhance the process of utilizing nuclear cross sections in various radiation transport applications and to improve the general utility of the national ENDF/B effort.

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