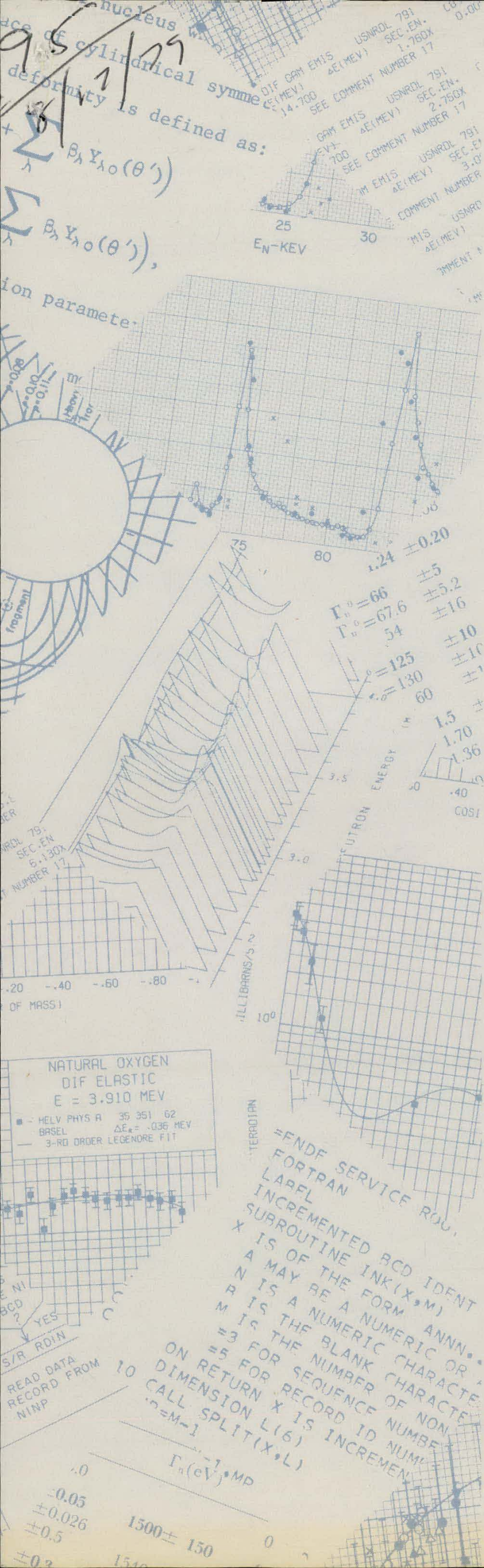

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MINUTES OF THE THIRD ANNUAL MEETING OF THE PANEL ON REFERENCE NUCLEAR DATA

BROOKHAVEN NATIONAL LABORATORY
October 5, 1978

Edited by
T.W. BURROWS, L. STEWART, AND
J.J. COYNE

May 1979

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BROOKHAVEN NATIONAL LABORATORY
October 5, 1978

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*Subject to Panel approval at the Fourth Annual Meeting, Fall 1979.

NATIONAL NUCLEAR DATA CENTER

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Table of Contents

Appendices

Welcome

The attendees and observers to the third annual meeting of the Panel on Reference Nuclear Data were welcomed to Brookhaven National Laboratory by H.J.C. Kouts, Chairman of the Department of Nuclear Energy, Brookhaven National Laboratory.

Organization, Approval of Minutes of the Second Meeting and Approval of Agenda

Prior to approving the minutes, J.E. Cline asked F. Feiner, Knolls Atomic Power Laboratory (KAPL), to discuss the status of the G.E. Chart of the Nuclides effort and the evaluation philosophy employed in producing the Chart. This discussion will be summarized below, under publications. After this discussion, it was moved and approved that the last sentence of 3.1 of the 1977 minutes be amended to read:

> The Panel recommends that a Wall Chart of the Nuclides be regularly updated every two years based on standard reference files as a starting point. The task of the international data networks will be to provide these standard files to the appropriate organizations.

The 1977 Minutes were approved as amended.

The agenda (Appendix A) was approved. J.E. Cline opened the elections by noting the decision of the Panel in 1977 to have the Vice-Chairman serve as Chairman-elect. Therefore, unless there were other nominations, L. Stewart would become chairman. There were no other nominations for Chairman. D.S. Brenner and J.J. Coyne were nominated for Vice-Chairman and J.J. Coyne was elected. There were no objections to T.W. Burrows continuing as secretary. The attendance at the meeting and the Panel membership are enclosed as Appendices B and C, respectively.

Review of Nuclear Data Compilation and Evaluation Efforts

National and International Interest

S. Pearlstein, National Nuclear Data Center (NNDC), began by describing the report "National Needs for Critically Evaluated Physical and Chemical Data" (National Research Council, 1978); portions of this report are enclosed as Appendix D. The report noted that data evaluations have a large impact and that the cost is a fraction of 1% of the cost of obtaining the original data.

The Committee on Data Needs recommends that the present annual support of $7,000,000 be increased over a five year period to $18,000,000, that the Office of Standard Reference Data be responsible for categories of data of a very broad utility and for general coordination, and that each agency place its responsibility for data compilation and evaluation on one key official at a high level.

Pearlstein emphasized the unique role the Panel can play in its recommendations and that there is a wide international interest in the results of the Panel meetings. In the area of reference nuclear data there is substantial coordination, the NNDC coordinates the Cross Section Evaluation Working Group (CSEWG) and the U.S. Nuclear Data Network (NDN), acts as the interface between the NDN and the IAEA-sponsored Nuclear Structure and Decay Data Network, and is a member of the Four-Center and Charged-Particle Data Networks. The international network has achieved some success with the U.K. and German groups already publishing one mass chain evaluation each in the Nuclear Data Sheets. There is also an exchange of experimental nuclear reaction data via the Four-Center and Charged-Particle Data Networks.

Master Data Files

C.L. Dunford reviewed the status of master data files and their contents. The reader is referred to the previous minutes for the type of data contained in each file. New entries to CINDA, the Computer Index of Neutron Data, are at a constant rate. A current review effort is under way to organize all old entries by measurement and to add missing data lines. An archival volume of CINDA will be published in March, 1979, with a December, 1976, cutoff. Additional volumes will be published annually for data received after December, 1976, with semi-annual supplements. The charged-particle nuclear data bibliography has increased by approximately 25% since January 31, 1978, and an updated cumulative edition is scheduled for publication in March, 1979. The NSR (Nuclear Structure References) file is growing at a constant rate and a new tape covering 1960-1978 will be issued by the Nuclear Data Project (NDP) shortly. New additions to this file are published in the Nuclear Data Sheets three times a year with the last edition being cumulative for the year.

EXFOR, the international file of experimental nuclear reaction data, contains approximately 35,000 neutron data sets and 1,100 charged-particle and photonuclear data sets.

The general purpose file of ENDF/B-V, Evaluated Nuclear Data File, Version V, is scheduled for release in January, 1979, with subsequent release of the special purpose actinide, fission product, dosimetry, gas production, and activation files. The ^{235}U(n,f) standard file will be revised before release. The contents of ENSDF, Evaluated Nuclear Structure Data File, are published in the Nuclear Data Sheets and in Nuclear Physics. Currently the file has 6320 data sets, including approximately 1500 on radioactive decay. Excluding those evaluations published in Nuclear Physics, approximately 30 mass chains have been evaluated in the past year.

C.L. Dunford concluded his discussion with a review of serv ices which will be available from the NNDC in the near future. The NNDC plans to have on-line all the master data files and its developing dial-up retrieval capabilities. A new retrieval system is due for the charged-particle bibliography in the spring. Computation formats and improved quantity indexing are being developed for EXFOR. An in-house retrieval system for NSR has been completed and will undergo full-scale testing after the new computer is in. A dialog extraction program for ENSDF should be ready in approximately 6 months.

Publications

F. Feiner, L. Gevantman, M. Martin, W. Morgan, and T.W. Burrows presented summaries of publications produced by their and other organizations. The status of these publications and others mentioned later in the meeting is outlined in Appendix E.

F. Feiner, KAPL, stated that they plan to produce a Chart of the Nuclides every four years and that this schedule, appropriately interleaved with the

Karlsruhe effort, will result in a revised Chart being issued every two years. The effort on the Chart is essentially a complete evaluation every time, with particular attention given to half-lives and cross sections. S. Pearlstein noted that Karlsruhe has a similar philosophy, starting from standard files and that people depend on KAPL both for the re-evaluation and for GE bearing the cost of publication. T.W. Burrows noted that, in addition to these two charts, there are two independent continuing chart efforts in Japan and that charts have been produced in France and Russia, the continuing status of which is not known. D.S. Brenner asked for a clarification on the cost of the Chart free, \$4.00 or \$7.00. F. Feiner will attempt to clarify the situation, (see Appendix E). The Panel congratulated KAPL for their shortening the time schedule for the publication of the twelfth Edition and for providing the Chart and the booklet at such nominal prices.

L. Gevantman noted that the Photonuclear Data Index, 1973-1977 (NBS-SP-380, Supp. 1 (1978)) has been published. He also mentioned a technical note by Gimm and Hubbell on the evaluation of total photon cross sections below 10 MeV and that Hubbell's new publication on photon attenuations and cross sections would be published by the end of the year. In response to questions from the chair and the floor, he stated tha- there are no plans to continue G. Fuller's compilation of spins and moments. The Photonuclear Data Center at the moment is concentrating its efforts on a comprehensive evaluation of the photonuclear reaction data for the p-shell nuclei. It does, however, compile (γ,f), (γ,n) and (γ,2n) data for all parts of the periodic table and on an ad hoc basis makes special purpose evaluations of such data on a time available basis.

M. Martin mentioned that NCRP Report 58, which he worked on, has been sent to the publisher.

W. Morgan brought the publication, Proceedings of the Second ASTM-Euratom Symposium on Reactor Dosimetry, October 3-7, 1977, Palo Alto (NUREG/CP-004), to the Panel's attention and noted that the third meeting will be held in ISPRA next year.

T.W. Burrows summarized publications from the NNDC, the Radiopharmaceutical Research Group, Chemistry Dept., BNL, the University of Pennsylvania, Utrecht, the Nuclear Data Project, and other groups. He also outlined plans for the Nuclear Wallet Cards and the Handbook of Nuclides (Appendix F) proposed by the NDN and plans by the Karlsruhe Charged-Particle Data Group (KACHAPAG) to publish a loose-leaf compilation of angle-integrated charged-particle nuclear data (Appendix G).

Summary of 1977 Panel Meeting

J.E. Cline referred the Panel to the minutes for details. For the benefit of the new members, he briefly outlined the history, purposes, and the results of the Panel.

Definition of Reference Nuclear Data

After a brief introduction by L. Stewart in which she noted that the definition should be in terms of this Panel, a wide-ranging discussion began covering this topic and many of the other topics at the meeting. Among the many definitions were the following two:

> A reference data set describes an unique set of numbers evaluated at the state of the art by scientists who are expert in the field. From this set one may derive other sets of numbers varying in use from very applied to very basic.
>
> Reference nuclear data are critically evaluated data which are well-documented and widely available.

Associated with the definition, many other points were raised. Publications derived from these reference data sets should be simple and concise, although the data sets may be very complex. However, publications are generally, by definition, out of date by the time they are published.

M. Martin pointed out that, as an evaluator, there are more aspects to reference data than can be resolved in any simple definition. These include the following questions.

1) Are the appropriate types of data being evaluated?

2) Are those quantities being evaluated precise enough or do they exist in certain cases?

3) Assuming everything is well-known, what are the sources of information?

C. Weisbin felt that a reference data set should be one data set. L. Stewart pointed out the difference between a standard data set and a reference data set. Later, she continued by noting that a referencc data set is not frozen, but should be documented and referenceable. J.J. Coyne noted the importance of referring to the appropriate reference set and justifying any changes applied and the importance of having reference sources which are traceable and well-documented.

J. McDonald suggested that the Panel should recommend specific reference data sources at this time. From the ensuing discussion, it appears that the Panel feels that it should not recommend sources, but should publicize the existence of various sources to the memberships of their appropriate societies. Along the same line of thought, W. Morgan had suggested earlier that a series of publications should be established which would be appropriate as reference sources.

M. Martin suggested that another line of approach would be liason with the funding agencies on measurement needs. C. Dunford pointed out that this is done in the neutron area, but feels that, in reality, there is little impact. M. Martin pointed out that an evaluator, if there are missing data, will contact people to see if there are measurements. He would like to know if there is some method of communicating these needs to a wider audience.

Discussion of Specific Data Needs and Possible Data Center Contributions

Reactor Physics

D. Harris began the discussion by presenting the survey results of the Reactor Physics Division of the ANS (Appendix H). There are approximately 1500 people in the division so the response amounts to 5%. He fears that the sample is not representative and, therefore, there is probably a bias in the response. L. Stewart noted that there was probably a bias in their survey also. D. Harris also noted that many of the members are associated with groups which have or use proprietory data sets and that these sets may have no connection with current reference data sets. L. Stewart noted that the utilities are only now asking questions about data bases and D. Harris pointed out that although the utilities have established the Electric Power Research Institute (EPRI) as an organ to satisfy these questions, the vendors have no such organ. Table 1 summarizes the nuclear data needs for applied physics as extracted from the present survey and the surveys presented at the first two meetings of the Panel.

Medicine and Biology

F. Castranovo presented a letter he sent to J.E. Cline as representative of the needs of the Radiopharmaceutical Science Council of the Society of Nuclear Medicine (Appendix I). He noted that several of these needs were not related to nuclear data but to radiopharmaceutical science. It was noted that perhaps some day nuclear reference data would include this area. He will poll the members of the Radiopharmaceutical Science Council to better understand their needs and forward this information to the chairman. (Note Added in Proof: The poll is in progress).

R. Rohrer continued by pointing out that the Panel should home in on nuclear data needs and that the needs of the Society of Nuclear Medicine differ from those of the Health Physics Society and of the American Association of Physics in Medicine. The Society's primary needs are two:

1) Very good spectroscopic data from radioactive atoms, including
   a) Half-lives for specific nuclei
   b) External bremstrahlung for imaging
   c) Internal doses
   d) Calibration energies and intensities
2) Charged-particle nuclear data for radioisotope production.

He also suggested that since it is the policy of KAPL to present the strongest transitions rather than the strongest radiations, this sometimes misleads the users of the Chart in the case of highly converted gamma transitions. F. Feiner (KAPL) said that there is no reason why the Chart couldn't include spectral information instead of transitional information. The Panel after some discussion decided that this change would lead to further confusion. The Panel would recommend instead that a Chart of Medical Radionuclides be produced, following a suggestion of F. Castronovo. As noted by F. Feiner, there is a precedence of special purpose charts (e.g. the Hanford Chart). R. Rohrer suggested the possibility of approaching various pharmaceutical companies to fund such an effort.

J. McDonald stated that the AAPM is primarily interested in external radiation and presented a summary of the more exotic uses of such radiation (Appendix J). There are more problems to be solved with neutron sources. In particular, with the definite program of establishing three to four more intense neutron facilities in large, easily accessable hospitals, there will be problems with the intense radiation produced by cyclotrons. M. Bhat noted that LASL has developed a data base for high-energy neutrons and that these problems were also discussed at the Brookhaven High-Energy Neutron Symposium. L. Stewart noted that experiments to measure neutron cross sections at these energies are very difficult, but there is a substantial effort to calculate the data. Other programs mentioned in the neutron area were at the University of California, Davis (experimental), Lawrence Livermore Laboratory (calculational), NASA (experimental and calculational; no longer funded), Texas A and M (some experimental and calculational work performed for a thesis project at LASL).

J. McDonald asked if there was a high probability of producing new data. M. Bhat mentioned that the NNDC is planning to evaluate various positron-producing reactions of use in Bragg therapy. In response to a question of R. Rohrer, J. McDonald thought that the data for shielding of linac was in fairly good shape. However, the lack of data for photoneutron reactions in the body may be a problem. The bulk of the present therapy uses 1 - to 40-MeV gammas and electrons from a few MeV to 40 MeV.

R. Lambrecht stated that the Panel recognizes the deficiences in the data needed and should collate information and needs. L. Gevantman pointed out two publications being prepared by the Medical Physics Data Group of the AAPM and by the OSRD, a pocket book of data which addresses some of these problems and a depth dose evaluation for gammas and electrons up to 4 MeV (included in Appendix E).

An action item was placed on the NNDC to survey the data available related to the needs presented by McDonald. C.R. Weisbin noted that a multigroup library prepared by Alsmiller (ORNL) for $E_n \leqslant 50$ MeV is available from RSIC. J. McDonald thought that the Coyne and Caswell calculations of kerma should be extended to higher energies, but would need appropriate input. L. Stewart felt that LASL could generate the appropriate input up to 20 MeV. J.J. Coyne pointed out that collimation and shielding are quite different for medical physics compared to reactor physics due to the extensive use of low-Z materials in the former case.

Table 2 attempts to summarize the biomedical needs based on the problems discussed at this meeting and the prior two meetings and the clarifications brought out below.

Controlled Thermonuclear Reactors and Astrophysics

H. Makowitz began by distributing portions of a 1975 workshop sponsored by the Division of Magnetic Fusion Energy (Appendix K). He noted that little has changed since the workshop. The data needed for CTR reactor blankets are mostly neutronic except for advanced fuels. Problems with which he is acquainted are presented below along with associated comments.

1) Constant maintenance of codes is required due to changes in ENDF formats. He felt there should be a conservative policy to changes.
2) There are no data in ENDF on the transmutation of isotopes to specific isomeric states. It was noted that ENDF/B-V will contain some of these data. An action was placed on the NNDC to provide a list of data required.
3) It is difficult to find the final gamma rays and their fractions.

4) He has found it very difficult to find data on fissile materials (as a blanket in the breeder option), including prompt γ-ray data. L. Stewart noted that for the principle isotopes with the exception of ^{232}Th and ^{233}U these data are available from NNDC and that ^{232}Th and ^{233}U are being prepared. H. Makowitz said that they have not been included in the CTR data sets he has received from RSIC.

5) He has also had problems with NJOY in calculating the neutronics of a vessel with a small pellet design for the gaseous fuel.

In the area of astrophysics and CTR, H. Makowitz noted that in the case of p + ^{11}B there is a violent disagreement between experiments and either an evaluation or more experiments are needed. L. Stewart and D. Harris cited the extensive work done at LASL. W. Fowler of the California Institute of Technology has been funded for many years to study exotic fuels. There appears to be a need for better experiment and evaluations in this area. However, the mechanism of doing these is not clear. Although there is money and well laid-out plans for CTR, there will be little diversion of funds for nuclear data evaluation until the plasma physics problems are better understood. Table 3 attempts a summary of astrophysics and CTR needs based on the results of this discussion and those from prior meetings and the clarifications brought forth below.

Establishment of Current Interest and Future Direction of the Panel

Prior to beginning this discussion, some time was spent on discussing publications. In response to a question on the distribution of the Source List by J.E. Cline and T.W. Burrows' statement that a large number of the first editions were uncirculated, the Panel undertook to provide a better distribution list and to publicize the Source List more. The question of a Panel newsletter was raised and it was decided that no obvious need for a specific newsletter exists at this time. The NNDC undertook to provide the Panel with a generic form to use for announcement of the meetings, availability of the minutes, and of the Source List. The NNDC also undertook to provide the Panel with a basic list of quantities in the present master data files so that the Panel and the respective societies could more easily compare the present efforts with their needs.

In a general discussion of the Handbook of Nuclides, J. Tuli (NNDC) outlined the differences between the Handbook and the Table of Isotopes. In response to a question of page length, he estimated approximately 500 pages for the Handbook compared to 1600 pages for the seventh edition of the Table. L. Stewart asked the members to communicate any strong feelings on the proposed Handbook to the NDN quickly and to communicate with their respective societies on the Handbook. M. Martin questioned the need for drawings; for applied users, perhaps only a table of spectral data is needed. The NDN should prepare for the next meeting of the Panel a comparison between the proposed Handbook and the new edition of the Table of Isotopes. This would consist of a comparison of the pages in the Handbook vs the pages in the Table of Isotope for a typical nuclide.

In regard to the Table of Isotopes, L. Gevantman pointed out that V. Hampel has placed the Table of Isotopes file in his data base at Lawrence Livermore Laboratory and retrievals may be available from this file. J. Tuli noted that the Nuclear Data Sheets are better evaluated than the Table and that for reaction data, ENSDF is more complete. However, as pointed out by M. Martin, the Table of Isotopes file is more current for some nuclei.

The remainder of the afternoon was spent in a clarification of item 3.3 of last years' minutes. The first item was expanded upon along with an action of the NNDC to survey the literature for available information. Item 2, concerning decay data for specific spallation products, could not be clarified since the originator was not present; however, the NNDC will undertake to survey the literature as in item 1. The need for tritium and prompt gamma-ray production cross sections appears to be satisfied by ENDF/B-V. Item 4, on differential data for particle production is included in Table 2 and again NNDC will survey the literature. After a discussion of the stopping power needs in item 5, it was decided that this data was outside the purview of this Panel. During the discussion, however, it was noted that the Ziegler effort should satisfy the needs except for pions, muons, and electrons, that the ICRU does have programs for evaluation of electron and muon stopping powers, and that no one, to the knowledge of the Panel, is evaluating stopping powers of pions. H. Makowitz also mentioned a need for stopping powers of heavy ions in plasmas. L. Stewart feels that item 6, accurate $^{1}H(n,n)^{1}H$ is satisfied up to 30 MeV by the Hopkins and Breit work and she has their code which would allow generation of data above 30 MeV. However, for the data above 30 MeV, the accuracy is not 1%.

L. Stewart mentioned an additional need in CTR for the data of transmutation of stable nuclides to stable nuclides and noted that the general purpose ENDF/B file is usually not evaluated isotope by isotope. H. Makowitz thought that more exotic materials should be included (e.g. Aluminum compounds).

Although the direction of the Panel was not specifically discussed during this period, it appears from the discussion that the Panel's primary direction should be

1) Monitor the needs of the users for reference nuclear data,
2) Note where and how these needs have been satisfied, and
3) Recommend to the data centers and appropriate funding agencies,
   a) Programs and priorities to satisfy the needs and
   b) Publications and processed computer files of use to the community.

Adjournment

The Panel was adjourned until the next meeting which will be in early October, 1979, and the length of the next meeting will be between one and one and one-half days.

Recommendations

The Panel recommends that the possibility of producing a Wall Chart of Medical Radionuclides be investigated.

Action Items

NNDC To scan the literature for data available on

1) The biomedical data needs expressed in Table 2
2) Decay data of specific spallation products
3) Transmutation of nuclides to specific isomers

H. Makowitz	To provide the NNDC a list of transmutations needed for CTR work.
NNDC	To provide the Panel with a generic form of an announcement of the meetings, the minutes and the Source List.
NNDC	To extract a basic list of the quantities contained in the present data files.
NDN	To provide the Panel with a comparison of the Handbook of Nuclides and the new Table of Isotopes by the next meeting.
L. Gevantman	To keep the Panel informed of the status of the two AAPM/OSRD publications.

Table 1

Summary of Nuclear Data Needs in Applied Physics

TYPE OF DATA NEEDED	IEEE[a] NSPS	ASTM[b] E-10	ANS[c] IRD[d]	ANS[c] RPD[e]	ANS[c] RPSD[f]
Neutron Capture Cross Sections		X	X	X	X
Neutron Fission Cross Sections		X	X	X	NA
Fission Neutron Yields and Distributions		NA	NA	X	NA
Half-lives of Radioactive Nuclei	X		X	X	X
Fission Product Yields and Distributions		NA	NA	X	NA
Neutron Scattering Cross Sections		X		X	NA
Isotopic Abundances	X	X	X	X	X
Gamma Yields and Spectra for Radioactive Nuclei	X	X	X	X	X
Nuclear Decay Modes and genetic relationships	X		X	NA	X
Means of Producing Radioisotopes			X	NA	NA
X-Ray Energies and Intensities	X		X		
Alpha Energies and Intensities			X		
Beta Particle Energies and Intensities			X		
FORMS OF DATA					
Chart of the Nuclides	X			X	X
Table of Isotopes	X		NA	X	X
ENDF/B, ENDL, or other Basic Data Set	NA		NA	X	NA
Uncertainties in Recommended Data	NA		NA	X	NA
Recommended Data	X	X	X	X	X

X = High positive response in survey

NA= Question not asked in survey

a) Institute of Electrical and Electronic Engineers, Nuclear Science and Plasma Society. 19 surveys returned. First Panel Meeting.

b) American Society for the Testing of Materials, E-10 Committee. 11 responses out of 17 subcommittee chairmen. Second Panel Meeting.

c) American Nuclear Society

d) Isotopes and Radiation Division, ANS. 123 responses. Second Panel Meeting.

e) Reactor Physics Division, ANS. 64 responses out of a membership of 1500. Third Panel Meeting.

f) Radiation Protection and Shielding Division, ANS. 120 replies out of 890 questionaires mailed. First Panel Meeting.

Table 2

Nuclear Data Needs in Medicine and Biology[a)]

Spectroscopic Data from Radioactive Atoms	SNM[b)], RC[c)], AAPM[d)], ACS[e)]
Half-lives for Specific Nuclei	SNM, RC, ACS
External Bremstrahlung	SNM, RC
Calibration Energies and Intensities	SNM, RC, ACS
Means of Radioisotope Production	SNM, RC, ACS
1. Evaluation of charged particle excitation functions leading to the production of the most important cyclotron-produced medical radionuclides which include ^{111}In, ^{67}Ga, ^{201}Pb-$^{201}T\ell$, $^{201}T\ell$, ^{28}Mg, ^{18}F, ^{11}C, ^{15}O, ^{13}N, ^{38}K, ^{81}Rb-^{81m}Kr, ^{68}Ge-^{68}Ga, ^{123}I, ^{125}I, ^{73}Se, and ^{77}Br.	
2. Production yields of Medical radionuclides	
3. Thin and thick target yields	
4. Isotopic impurities present in the production of medical radionuclides.	
5. The optimum conditions for production.	
Pion-, Proton-, and Heavy-Ion-Induced Charged-Particle Data ($E_{inc} \leqslant 100$ MeV/amu except $E_{\pi} \leqslant 50$ MeV) for tissue materials and copper, iron, and lead to an accuracy of 5% or better for differential and 10% for total.	AAPM
Neutron Cross Section Data to 100 MeV on tissue material and Na, Ca, P, S, Cl, K, I, and Ar to an accuracy of 10%.	AAPM
Cross sections for processes producing gammas and long-lived isotopes	AAPM
Cross section and thick target yields for Neutron Source Reaction s ($E_{inc} \leqslant 67$ MeV)	AAPM
Particle Production from π^--capture. An accuracy of 5% is desirable although data of any reasonable accuracy would be useful at this time.	AAPM

Table 2 (cont'd)

Forms of Data Used	
Chart of the Nuclides	
Table of Isotopes	RC, AAPM, ACS
MIRD Pamphlets	RC, AAPM, ACS
Nuclear Data Sheets	RC, AAPM, ACS
BNL-325	RC, AAPM, ACS
Landholt-Bornstein, Vol. 5	ACS

a) With the exception of the American Association of Physics in Medicine, no surveys were conducted by those societies whose primary interests were biomedical applications of nuclear data. Therefore, this table has been assembled from the discussions at meetings, various handouts, and correspondence received by the Panel Secretary.

b) Society of Nuclear Medicine

c) Radiopharmaceutical Council, Society of Nuclear Medicine

d) American Association of Physics in Medicine. 19 replies out of membership of 1000. Second meeting. Also includes data needs expressed in Working Paper - Committee B, AAPM, INDC/P(78)-36.

e) Nuclear Chemistry and Technology Division, American Chemical Society.

Table 3

Nuclear Data Needs for Controlled Thermonuclear Reactors and Astrophysics[a]

14-MeV Neutron Cross Sections

Prompt Gamma-Ray Production Cross-Sections

Decay Parameters and Radiation Data

Neutron Cross Sections to 40 MeV

Transmutation cross section data

<u>Forms of Data</u>

- Chart of the Nuclides
- Table of Isotopes
- BNL-325
- Evaluated Data Sets
- Processed data sets
- Error files

a) This table is based primarily on the report of T. England (Controlled Nuclear Fusion Division, ANS) presented at the Second Meeting and on the ensuing discussions and clarifications at the second and present meeting. Since the Panel has received relatively little input on astrophysical or advanced fuels data needs, no attempt has been made to summarize these.

APPENDIX A

PANEL ON REFERENCE NUCLEAR DATA

October 5, 1978

Building 197
Brookhaven National Laboratory
Upton, New York

AGENDA

I.	WELCOME	H.J.C. Kouts	8:45 a.m.
II.	ORGANIZATION AND APPROVAL OF 1977 MINUTES	J.E. Cline, L. Stewart, T.W. Burrows	9:00 a.m.
	A. Approval of Minutes		
	B. Approval of Agenda		
	C. Election of Officers		
III.	REVIEW OF NUCLEAR DATA COMPILATION AND EVALUATION EFFORTS		
	A. National and International Interest	S. Pearlstein	9:15 a.m.
	B. Master Data Files	C.L. Dunford	9:30 a.m.
	C. Publications	T.W. Burrows, Others	9:40 a.m.
COFFEE BREAK			10:10 a.m.
IV.	SUMMARY OF 1977 PANEL MEETING	J.E. Cline	10:25 a.m.
V.	DEFINITION OF "REFERENCE NUCLEAR DATA"	All	10:40 a.m.
VI.	DISCUSSION OF III-V	All	11:00 a.m.
LUNCH			12:00 Noon
VII.	DISCUSSION OF SPECIFIC DATA NEEDS AND POSSIBLE DATA CENTER CONTRIBUTIONS	All	1:00 p.m.
	A. Reactor Physics		
	B. Medicine and Biology		
	C. Astrophysics and CTR		
	D. Other		
COFFEE BREAK			3:00 p.m.

PANEL ON REFERENCE NUCLEAR DATA

AGENDA

(continued)

VIII.	ESTABLISHMENT OF CURRENT INTEREST AND FUTURE DIRECTION OF THE PANEL	L. Stewart	3:15 p.m.
IX.	RECOMMENDATIONS FOR NUCLEAR DATA COMPILATION AND EVALUATION EFFORT	All	3:45 p.m.
X.	ADJOURNMENT	L. Stewart	4:30 p.m.

A. Approximate Date of Next Meeting

B. Length of Next Meeting

APPENDIX B

PANEL ON REFERENCE NUCLEAR DATA MEETING

List of Attendees

NAME	REPRESENTING
BAUER, Thomas J. University of Florida	Health Physics Society
BRENNER, Daeg S. Clark University	American Chemical Society/Division of Nuclear Chemistry & Technology
BURROWS, Thomas W. Brookhaven National Laboratory	Secretary, Panel on Reference Nuclear Data
CASTRONOVO, Frank P. Massachusetts General Hospital	The Radiopharmaceutical Science Council/Society of Nuclear Medicine
CLINE, James E. Science Applications, Inc.	Institute of Electrical and Electronic Engineers/Nuclear Science & Plasma Society
COYNE, Joseph National Bureau of Standards	Radiation Research Society
HARRIS, Donald R. Rensselaer Polytechnic Institute	American Nuclear Society/Division of Reactor Physics
KAMYKOWSKI, Edward (Representing Dr. Michael D. D'Agostino) Grumman Aerospace Corporation	American Nuclear Society/Division of Isotopes and Radiation
LAMBRECHT, Richard Brookhaven National Laboratory	American Chemical Society/Division of Nuclear Chemistry & Technology
MAKOWITZ, Henry (Representing Dr. Donald Dudziak) Brookhaven National Laboratory	American Nuclear Society/Division of Controlled Nuclear Fusion
McDONALD, Joseph C. Memorial Sloan-Kettering Cancer Center	American Association of Physics in Medicine
MORGAN, William Battelle Northwest Laboratories	American Society for Testing Materials
ROHRER, Robert H. Emory University	Society of Nuclear Medicine
STEWART, Leona Los Alamos Scientific Laboratory	American Nuclear Society/Division of Radiation Protection & Shielding
WEISBIN, Charles R. Oak Ridge National Laboratory	American Nuclear Society/Division of Radiation Protection & Shielding

PANEL ON REFERENCE NUCLEAR DATA MEETING

List of Observers

NAME	REPRESENTING
BHAT, Mulki	Brookhaven National Laboratory
DUNFORD, Charles	Brookhaven National Laboratory
FEINER, Frank	General Electric - Knolls Atomic Power Laboratory
GEVANTMAN, L.H.	National Bureau of Standards
GOODMAN, Leon J.	Brookhaven National Laboratory
HOLDEN, Norman	Brookhaven National Laboratory
MARTIN, Murray J.	Oak Ridge National Laboratory
PEARLSTEIN, Sol	Brookhaven National Laboratory
TULI, Jagdish	Brookhaven National Laboratory

APPENDIX C

PANEL ON REFERENCE NUCLEAR DATA

Membership 12/8/78

American Chemical Society:

Division of Nuclear Chemistry and Technology

Dr. Daeg S. Brenner
Chemistry Department
Clark University
Worchester, Massachusetts 01610

Dr. Richard Lambrecht
Chemistry Department, 55A
Brookhaven National Laboratory
Upton, New York 11973

Radiation Research Society:

Dr. Joseph Coyne
Center for Radiation Research
National Bureau of Standards
Washington, D.C. 20234

American Nuclear Society:

Division of Isotopes and Radiation

Dr. Michael D. D'Agostino (ex officio)
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Bethpage, New York 11714

Dr. E. Kamykowski
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Research Department, Plant 26
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Dr. Jack Trombka
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Laboratory for Theoretical Studies
Greenbelt, Maryland 20910

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Division of Controlled Nuclear Fusion

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Los Alamos Scientific Laboratory
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Los Alamos, New Mexico 87545

PANEL ON REFERENCE NUCLEAR DATA

Membership (continued) 12/8/78

American Nuclear Society

Division of Controlled Nuclear Fusion

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Los Alamos Scientific Laboratory
Post Office Box 1663
Los Alamos, New Mexico 87545

Division of Reactor Physics

Professor Donald R. Harris
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

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Oak Ridge National Laboratory
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Society of Nuclear Medicine:

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PANEL ON REFERENCE NUCLEAR DATA

Membership
(continued)

12/8/78

American Association of Physics in Medicine:

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Memorial Sloan-Kettering Cancer Center
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ASTM, E-10 Committee

Dr. William Morgan
Battelle Northwest Laboratories
Post Office Box 999
Richland, Washington 99352

Dr. W.N. Bishop
Babcock and Wilcox Company
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Lynchburg, Virginia 24505

IEEE/Nuclear Science and Plasma Society

Dr. James E. Cline
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Dr. George H. Miley
University of Illinois
214 Nuclear Engineering Laboratory
Urbana, Illinois 61801

The Radiopharmaceutical Science Council Society of Nuclear Medicine:

Dr. Frank P. Castronovo
The Massachusetts General Hospital
Radiology Department
Boston, Massachusetts 02114

National Needs for Critically Evaluated Physical and Chemical Data

NATIONAL ACADEMY OF ENGINEERING · NATIONAL ACADEMY OF SCIENCES · INSTITUTE OF MEDICINE · The National Research Council

Committee on Data Needs

Numerical Data Advisory Board

Assembly of Mathematical and Physical Sciences

Committee on Data Needs

Walter H. Stockmayer, *Chairman*
Dartmouth College

Edward P. Bartkus
E.I. du Pont de Nemours & Company

Carlos M. Bowman
The Dow Chemical Company

Leo Brewer
University of California, Berkeley

Joseph J. Katz
Argonne National Laboratory

John L. Margrave
Rice University

John W. Murdock
Informatics, Inc.

Richard F. Taschek
Los Alamos Scientific Laboratory

Kurt L. Wray
Physical Sciences, Inc.

NUMERICAL DATA ADVISORY BOARD

CONTENTS

SUMMARY AND MAJOR RECOMMENDATIONS

1. SUMMARY

Reliable values of numerical data that express in quantitative terms the properties and behavior of materials are essential in all branches of science and technology and are needed to arrive at valid decisions whenever a governmental or industrial decision involves elements of science and technology. The scientific literature contains many valuable data covering a wide range of diverse fields. Unfortunately, it also contains many erroneous values. A substantial intellectual effort is required to select reliable values from the large and growing total of those reported (see Section 3.1).

The selection of the best available values for data in a given field requires the background of a specialist in that field. Most users are not specialists in all the fields in which they require data. Furthermore it is inefficient for many individuals who need the same data for different purposes to each go through this selection process.

For this reason, a number of specialized data centers have been established to compile and evaluate data in a systematic fashion. Typically, such a center gathers all the data applicable to its limited area, assesses the validity of the measurements on which these data are based, selects recommended or best values, and attempts to estimate how far the "true" values are from those recommended. These results are then published and made available to all who need them (see Chapter 4).

The cost of this evaluation in established data centers is a fraction of 1 percent of the cost of obtaining the original data (see Chapter 5). The benefits to the nation of having compilations of reliable data readily available are substantial. Such compilations save time for engineers and scientists in research and development. If the reliability of a needed set of data is known, designs can be made more precise, tolerances reduced, and R&D options narrowed. The resulting savings can amount each year to from one to several thousand times the cost of evaluation (see Chapter 6).

The present level of data evaluation activities is about one third to one half that needed to carry out activities planned for the next five years by federal agencies with major mission responsibilities that require the use of reliable scientific data (see Chapter 7). These same data will be used by industry also, but the benefits of evaluated data are spread among so many users that the major responsibility for financing their acquisition must rest with the federal government (see Chapter 8).

1.2 MAJOR RECOMMENDATIONS

Our three major recommendations follow:

1. The present annual support for organized data evaluation activities of slightly under $7 million should be increased over a period of five years to $18 million. For reasons outlined in Chapter 8 this support will have to come primarily from the federal government.
2. When a particular mission relies heavily on results from a field of research, responsibility for data compilation and evaluation in that field should be accepted by the agency responsible for the mission. The Office of Standard Reference Data of the National Bureau of Standards should be responsible for categories of data of very broad utility and for general coordination of the overall system.
3. Each agency should be required to place its responsibility for data compilation and evaluation on one key official at a level high enough to ensure that the agency's responsibilities in this area will be fulfilled.

Additional recommendations appear in Chapter 8.

Appendix A of Appendix D

TABLE A.1 Data Analysis Centers in the United States

Center	Sponsor	Funding, FY 1977
A. Energy and Environmental Data		
1. Atomic Energy Levels Data Center	OSRD	$ 72,000
	ERDA[a]	50,000
2. Atomic Line Shapes and Shifts	OSRD	16,000
	ERDA	40,000
3. Atomic Collision Cross Section	OSRD	145,000
	NSF	55,000
4. Ion Energetics Data Center (formerly Atomic and Molecular Ionization Processes)	OSRD	65,000
	NIH	60,000
5. Chemical Kinetics Information Center	OSRD	100,000
	DOT and NASA	72,000
	ERDA	100,000
6. Controlled Fusion Atomic Data Center	ERDA	85,000
7. Radiation Chemistry Data Center	OSRD	51,000
	ERDA	51,000
8. Molten Salts Data Center	OSRD	37,000
	NSF	30,000
9. X-Ray and Ionization Radiation Data Center	OSRD	54,000
10. Photo Nuclear Data Center	OSRD	61,000
11. Table of Isotopes Project	ERDA	200,000
12. Physical Data Group	ERDA	350,000
	NSF	35,000

TABLE A.1 (cont.)

Center	Sponsor	Funding, FY 1977
13. Nuclear Data Project	ERDA	$ 700,000
14. National Nuclear Data Center	ERDA	1,200,000
	Electric Power Research Institute	100,000
15. Gamma Ray Spectrum Catalogue	ERDA	25,000
16. Atomic Transition Probabilities Center	OSRD	45,000
	ERDA	40,000
B. Industrial Process Data		
1. Phase Diagrams for Ceramics	American Ceramic Society	3,000
2. Chemical Thermodynamics Data Center	OSRD	370,000
3. Electrolyte Data Center	OSRD	79,000
4. Texas A&M Thermodynamics Research Center	OSRD	105,000
	API	25,000
	Sale of data	160,000
	Texas A&M U.	157,000
5. Cryogenic Data Center	OSRD	105,000
	NASA	70,000
	American Gas Assoc.	32,000
6. Thermophysical Properties Research Center	OSRD	114,000
	DOD	250,000
	ERDA	100,000
	DOT	50,000
	NSF	52,000
	Payment for service	75,000
	Purdue University	70,000
7. High Pressure Data Center	OSRD	35,000
	Sale of Data	10,000
8. Alloy Data Center	OSRD	62,000
9. JANAF Thermochemical Tables	AFOSR	100,000
	ERDA	80,000
10. Data on Theoretical Metallurgy	BuMines	40,000
11. Thermochemistry for Steelmaking	Int. Copper Research Assoc.	20,000

TABLE A.1 (cont.)

Center	Sponsor	Funding, FY 1977
12. Thermodynamic Research Laboratory Data Center	OSRD	$ 90,000
13. Thermodynamic Properties of Ethylene	OSRD	70,000
14. National Center for Thermodynamic Data of Minerals	USGS	90,000
15. Electronic Properties Information Center	DSA (DOD)	150,000
	OSRD	30,000
C. Materials Utilization Data		
1. Crystal Data Center	OSRD	80,000
2. Diffusion in Metals Data Center	OSRD	24,000
3. Superconductive Materials Data Center	OSRD	9,000
4. Rare Earth Information Center	Industry	20,000
D. Physical Science Data		
1. Microwave Spectral Data Center	OSRD	56,000
2. Berkeley Particle Data Center	OSRD	22,000
	ERDA	200,000
	NSF	35,000

[a]ERDA is now part of the Department of Energy.

APPENDIX E

SUMMARY OF PUBLICATION ACTIVITIES

1. Fay Ajzenberg-Selove, University of Pennsylvania

The evaluation of A=18-20 has been published in Nuclear Physics. A draft of A=5-10 is being circulated and the evaluation will be sent to North-Holland for publication before the end of the year.

2. P.M. Endt and C. van der Leun, Fysich Laboratorium Rijksuniversiteit

The evaluation of A=21-44 has been sent to North-Holland for publication in Nuclear Physics.

3. International Commission on Radiation Units and Measurements

The commission publishes on a regular basis compilations and evaluations of data relevent to dosimetry. These are cited in BNL-NCS-50702.

4. Kernforschungszentrum Karlsruhe, Institut für Radiochemie

Karlsruhe will continue to publish the Nuklidkarte on a four-year cycle. Publication of the fifth edition will be in the latter part of 1980.

The Karlsruhe Charged Particle Data Group is preparing a publication of experimental integral (i.e., angle integrated) charged-particle nuclear data (see Appendix G). It will be a loose-leaf publication allowing easy updating. No date has been set for publication, but it will probably be produced by the Zentralstelle fur Atomkernenergie Dokumentation.

5. Knolls Atomic Power Laboratory

The G.E. Chart of the Nuclides will be updated on a four-year basis interleaved with the Karlsruhe effort. The current chart (12th edition) is available to DOE and U.S. educational organizations free, to students and scientists for $4.00, and to others for $7.00.

6. Medical Internal Radiation Dose Committee

The committee supports on a regular basis the compilation and evaluation of data relevent to internal radiation dose. BNL-NCS-50702 indexes some of these pamphlets.

7. National Bureau of Standards

The Photonuclear Data Index 1973-1977 (NBS Special Publication 380, Supplement 1) has been published and is available from the Superintendent of Documents for $2.75.

Work is continuing on a joint OSRD and AAPM dosimetry handbook. Other work with which the Office of Standard Reference Data is connected include a pocketbook of data produced by the Medical Physics Group of the AAPM and an evaluation of depth-dose curves for gammas and electrons up to 4 MeV by the Mellancrot Institute of Radiology. The pocket book should be in final form before the end of the year.

Gimm and Hubbell have produced NBS Technical Note 968 (1968) on the theoretical analysis and evaluation of total photon cross section measurements above 10 MeV. Hubbell, et al., will have ready by the end of the year a new paper on photon attenuation coefficients and cross sections.

8. National Nuclear Data Center, Brookhaven National Laboratory

BNL-NCS-50740, the third edition of the Bibliography of Integral Charged Patticle Nuclear Data will go to press in March, 1979.

BNL-NCS-50702, the second edition of A Source List of Nuclear Data Bibliographies, Compilations and Evaluations goes to press in October, 1978.

BNL-325, Volume I, Part 1, Z=1-60, of the fourth edition of the Resonance Parameters will go to press by June, 1979, followed by Part 2, Z=61, in early 1980.

BNL-325, Volume II. Work is scheduled to begin on the fourth edition of the "Book of Curves" in January, 1980.

DOE-NDC Status Report, the annual report covering experimental nuclear physics performed for the Department of Energy, continues.

9. Nuclear Data Project, Oak Ridge National Laboratory

Approximately thirty mass chains have been published in the Nuclear Data Sheets in the last year, as well as three issues of Recent References.

NCRP-58, including radionuclide data provided by the NDP is in press.

10. Radiopharmaceutical Research Group, Department of Chemistry, Brookhaven National Laboratory

Two volumes of "Accelerator Produced Nuclides for Use in Biology and Medicine, A Bibliography" (BNL-50448) have been published, covering the literature through June, 1976. Preparation for a third volume is continuing.

11. Table of Isotopes Group, Lawrence Berkeley Laboratory

The seventh edition of the Table of Isotopes is available from John Wiley and Sons ($40.00, cloth; $26.25, paper). DOE Contractors should contact John Wiley and Sons about a possible discount.

The Table of Moments by U.S. Shirley and C.M. Lederer, LBL-3450 (1974), has been updated to early 1977 and included as Appendix VII of the seventh edition of the Table of Isotopes. There may also be a separate reprint of the Table of Moments available from John Wiley and Sons.

12. The U.S. Nuclear Data Network

The Network has undertaken the responsibility to publish on a four-year cycle the Nuclear Wallet Cards. The current edition is being prepared by the Table of Isotopes Group. When published, they will be available from the NNDC at no cost.

The network has also undertaken to produce a Handbook of Nuclides on a four-year cycle (See Appendix F for a proposed outline of the publication). The planning is in the early stage with publication scheduled for the latter part of 1982.

13. Zentralstelle fur Atomkernenergie-Documentation

The Center continues to sponsor a series of bibliographies, compilations, and evaluations entitled Physics Data. Those publications relevant to nuclear data are indexed in BNL-NCS-50702. The Atomic Energy Documentation Service, Larchmont, New York, distributes this series in the United States.

APPENDIX F

HANDBOOK OF NUCLIDES - A FORMAT OUTLINE

I. GENERAL

1. Data:
   Only evaluated data from existing evaluations to be given.

2. Uncertainties:
   To be given, if available.

3. References:
   Only for the original evaluations.

4. Coverage:
   All nuclides - radioactive and stable.

5. Data Arrangement:
   Data to be arranged by A and then Z.

6. Contents:
   a. Genetic relationship between different elements (Z's) for a given A, giving their decay modes, Q-, n- and p-separation energies, $T_{1/2}$, J^{π}-values..

   b. For each Z, within an A,
      i. Decay scheme(s) for A_Z decay.
      ii. Level properties - levels in A_Z not shown in the decay scheme(s) are presumed to be seen in nuclear reactions.
      iii. Radiations emitted by A_Z.

7. Production:
   To be computer produced from existing evaluated data files, e.g., ENSDF, ENDF, ISOCOM (Abundances), MASSES (Wapstra's Mass Table), THALF (Half-lives), BNL325, MOMENT (Shirley's Moments Table).

8. Revisions:
   Every four years.

II. SPECIFIC

1. Level Properties:

A. Ground State Properties:

	Property	Source File
i	Abundance	ISOCOM
ii	Mass Excess	MASSES
iii	Half-life	THALF/BNL325
iv	Spin-parity	ENSDF/MOMENT
v	Magnetic Dipole Moment	MOMENT
vi	Electric Quadrupole Moment	MOMENT
vii	Th Neutron Cross Section	ENDF/BNL325
viii	Fission Yields	ENDF
IX	Other	ENSDF

B. Isomeric Levels ($T_{1/2}$ > 1s)

i	Level Energy	ENSDF
ii	Half-life	THALF/BNL325
iii	Magn. Dipole Moment	MOMENT
iv	El. Quad. Moment	MOMENT
v	Spin-parity	ENSDF/MOMENT
vi	Other	ENSDF

C. Other Levels

i	Level Energy	ENSDF
ii	Half-Life	ENSDF
iii	Spin-parity	ENSDF
iv	Other	ENSDF

2. Radiations:

A. Types:

- i Alphas
- ii Betas
- iii X-rays
- iv Electrons: conversion, Auger
- v Gammas
- vi Other

B. Quantities:

i. Energy - for betas end point and average
ii. Intensity - in per 100 decays of parent (if possible). Log ft in decay scheme.
iii Gamma Multipolarity, total conversion coefficient (if known)
iv Coincidence information in decay scheme

C Sources:

MEDLIS (Using ENSDF) for i and ii
ENSDF for iii and iv.

3. Appendices:

Formulae, Tables, graphs, conversion factors, etc., of everyday use.

P
$^{40}_{20}Ca$
$^{38}_{19}K$

562.003

(G) $^{40}_{20}Ca(P,{}^{3}He)^{38g}_{19}K$

EXPERIMENTAL CROSS-SECTION

+ PRECURSOR

THE CONTRIBUTION FROM 20-CA-40 (P, N+2P) 19-K-38-G IS ASSUMED TO BE SMALL AS WAS STATED BY THE AUTHORS.

(M) $^{40}_{20}Ca(P,{}^{3}He)^{38m}_{19}K$

EXPERIMENTAL CROSS-SECTION

THE CONTRIBUTION FROM 20-CA-40 (P, N+2P) 19-K-38-M IS ASSUMED TO BE SMALL AS WAS STATED BY THE AUTHORS.

(R) $\dfrac{^{40}_{20}Ca(P,{}^{3}He)^{38g}_{19}K}{^{40}_{20}Ca(P,{}^{3}He)^{38m}_{19}K}$

EXPERIMENTAL CROSS-SECTION RATIO

EXPERIMENTAL CROSS-SECTION
+ PRECURSOR

EXPERIMENTAL CROSS-SECTION

(M) DATA DEPENDENT FROM VALUES ON SHEET 62.003

BIBLIOGRAPHY:

TITLE:	(P, HE-3) AND (P, T) CROSS-SECTION MEASUREMENTS
AUTHOR:	G. H. MCCORMICK, H. G. BLOSSER, B. L. COHEN, E. NEWMAN
INSTITUTE:	OAK RIDGE NATIONAL LAB., TENN., UNITED STATES OF AMERICA
REFERENCE:	J. INORG. NUCL. CHEM. 2, 269, 56

EXPERIMENT AND ANALYSIS:

FACILITY:	CYCLOTRON (OAK RIDGE NATIONAL LAB., TENN., UNITED STATES OF AMERICA) IRRADIATION WITH INTERNAL BEAM; CHEMICAL SEPARATION BEAM CURRENT WAS MEASURED USING A MONITOR FOR WHICH NO FURTHER DETAILS WERE GIVEN
SAMPLE:	SEPARATED CA-40 TARGET OF 5 MG/CM * * 2 THICKNESS
DETECTOR:	GEIGER-MUELLER COUNTER
RADIATION DET.:	(G) 19-K-38-G, β+ (M) 19-K-38-M, β+
DECAY-DATA:	(G) 19-K-38-G, $T_{1/2}$: 7.7 MIN, β+: 2.79 MEV 73.1% γ: 735.1 KEV, 21% (M) 19-K-38-M, $T_{1/2}$: 930 MSEC, β+: 5.0 MEV, 100%
MONITOR:	20-CA-44 (P, HE 3) 19-K-42 EXPERIMENTAL CROSS-SECTION
REFERENCE:	C. COLLE + PHYS. REV. C1, 327 (1969), SEE SUBENTRY B 0057004
- DEC.-DATA:	19-K-42, $T_{1/2}$: 12.5 HR, β-: - MEV, 100%
ANALYSIS:	THE RESIDUAL NUCLEI WERE IDENTIFIED FROM A GRAPHICAL ANALYSIS OF THE COMPLEX DECAY-CURVE

ADDITIONAL INFORMATION:

COMMENT:	THE MAIN PURPOSE OF THIS WORK WAS A TEST OF THE ORDER OF MAGNITUDE OF THE CROSS-SECTIONS FOR A COMPARISON TO THEORY
RELATED REF.:	CRITICAL REMARKS BY COLLE + PHYS. REV. C 1 479 (1969) IN THIS REFERENCE A CORRECTION FACTOR OF 1.015 IS RECOMMENDED DUE TO A CHANGE IN THE β+ ABUNDANCE
ADDITIONAL RESULTS	COMPARISON TO THEORY TOTAL REACTION CROSS-SECTIONS WERE CALCULATED AND COMPARED TO THEORETICAL PREDICTIONS

ERROR ANALYSIS:

NO INFORMATION ON APPARATIVE OR SYSTEMATICAL ERRORS IS GIVEN
ONLY STATISTICAL ERRORS ARE QUOTED

P
$^{40}_{20}$Ca
$^{38}_{19}$K

562.003

E_{lab}	σ * G ($^{40}_{20}$Ca(P,^{3}He)$^{38g}_{19}$K)	σ * M ($^{40}_{20}$Ca(P,^{3}He)$^{38m}_{19}$K)	RATIO R	FOOTNOTE	MISCELLANEOUS
[MEV]	[MB]	[MB]	[NO-DIM]		[MEV]
21.0	1.5 ± 0.2	0.3 ± 0.01	5.0 ± 1.		20.2
22.0	2.7 ± 0.3	0.6 ± 0.02	4.5 ± 1.		21.3
23.0	3.8 ± 1.0	1.2 ± 0.1	3.1 ± 0.8		22.3
25.5	10.1 ± 2.0	2.9 ± 0.9	3.1 ± 0.8		25.1
30.	15.	4.	4.	1.	29.

DATA OBTAINED FROM A CURVE
* ATTENTION. SEE PREVIOUS PAGE FOR SPECIFICATION OF QUANTITY
Ⓖ Ⓜ Ⓡ SEE CORRELATED INFORMATION EQUALLY MARKED IN THE SECTIONS ABOVE
1. THE CROSS SECTION GIVEN IS AN UPPER LIMIT
+ CENTER OF MASS ENERGIES

Entered: 77/12/18

APPENDIX H

Department of Nuclear Engineering

Rensselaer Polytechnic Institute Troy, New York 12181

October 4, 1978

TO: Robert L. Heineman, Chairman
Reactor Physics Division, ANS

FROM: D. R. Harris, R. C. Little, J. M. Ryskamp

SUBJECT: Results of Survey to Assess Nuclear Data Needs of RPD Members

A questionaire to assess nuclear data needs was mailed to RPD members as part of a recent RPD Newsletter. There were 64 responses, largely from government-supported laboratories (27), from universities (13), and from utilities or EPRI (7). There were only 2 responses from reactor vendors.

The questionaire follows with entries showing the number of responses of high need (1), moderate need (2), and low need (3) for the indicated types and forms of data. Also shown is a weighted response determined by weighting by 1, 1/2, and 0 the responses of high, moderate, and low needs, respectively.

The dozen items with largest weighted responses are, for data types,

Capture Cross Sections for Neutron-Induced Reactions
Fission Cross Sections for Neutron-Induced Reactions
Fission Neutron Yields and Distributions
Half-lives of Radioactive Nuclei
Fission Product Yields and Distributions
Scattering Cross Sections for Neutron-Induced Reactions
Isotopic Abundances
Gamma Yields and Spectra for Radioactive Nuclei

and for data forms,

Chart of the Nuclides
Table of Isotopes
ENDF/B, ENDL, or Other Basic Data Set
Uncertainties in Recommended Data

At the other extreme little need was expressed for charged-particle-induced and photoneutron-induced reaction data, and for nuclear spins and moments.

QUESTIONAIRE RESULTS

Responses indicate high need (1), medium need (2), low need (3),

		1	2	3	Weighted Response
1.	Rate your need for the following nuclear data.				
A.	Isotopic abundances	30	21	8	.69
B.	Nuclear Masses	20	23	16	.54
C.	Nuclear spins and moments	11	10	36	.26
D.	Nuclear level schemes	24	11	22	.52
E.	For radioactive nuclei:				
	Half-lives	37	15	4	.80
	Gamma yields and spectra	33	14	13	.67
	X-ray yields and spectra	15	15	28	.39
	Electron yields and spectra	10	18	29	.34
	Alpha yields and spectra	13	20	25	.40
	Neutron yields and spectra	32	15	12	.67
	Other yields	9	9	26	.31
F.	For neutron-induced reactions:				
	Scattering cross sections	36	15	6	.77
	Scattering vs. angle and energy	18	24	14	.58
	Capture cross sections	49	9	3	.88
	Capture gamma spectra	23	24	13	.59
	Excitation functions	14	13	30	.36
	Fission cross sections	46	9	4	.86
	Fission neutron yields and distributicns	42	11	6	.81
	Fission gamma yields and distributions	20	28	13	.56
	Fission product yields and distributions	36	20	4	.77
	Other neutron data	12	18	16	.46
G.	For gamma-induced reactions:				
	Photoneutron cross sections	17	25	20	.48
	Photoproton cross sections	8	10	41	.22
	Other photoreaction data	5	13	38	.21
H.	For charged-particle-induced reactions:				
	Reaction cross sections	13	15	30	.35
	Reaction product distributions	10	10	36	.27
	Nuclear elastic data	7	8	43	.19
	Other charged-particle-reaction data	8	4	48	.17
2.	Rate your need for the following:				
A.	Reported and compiled measured data	25	24	13	.60
B.	Single-valued detailed data recommended from analysis (evaluation) of differential measurements and theory	23	20	17	.55
C.	Data recommended from analysis of integral measurements as well as differential data	30	15	14	.64
D.	Energy-group-averaged data	23	26	9	.62
E.	Uncertainties in recommended data	28	25	7	.68
F.	Data recommended after peer review	24	24	11	.61
G.	ANSI Standard Data Sets	18	24	15	.53

		1	2	3	Weighted Response
3.	Rate your need for the following forms of data.				
	A. Wall charts	26	22	10	.64
	B. Journals, books	26	26	7	.66
	C. Magnetic tape	26	18	14	.60
	D. Retrievable on line at computer terminals	11	20	27	.36
4.	Rate your need for the following data sources.				
	A. Table of Isotopes	36	18	6	.75
	B. Nuclear Data Sheets and Nuclear Data B	24	20	17	.56
	C. Chart of the Nuclides	44	12	3	.85
	D. Table of Nuclides from Handbook of Chem. & Phys.	16	19	26	.50
	E. Gamma Ray Spectrum Catalogs, NaI(Tℓ) and Ge(li)	18	12	32	.39
	F. Energy Levels of Light Nuclei	11	16	33	.32
	G. ENDF/B, ENDL, or other basic data set	35	15	9	.72
	H. Charged Particle Cross Sections, LA-2014	5	14	39	.21
	I. CASK, Hansen-Roach, LEOPARD, CINDER, or other working data set	26	17	18	.57

APPENDIX I

THE RADIOPHARMACEUTICAL SCIENCE COUNCIL
SOCIETY OF NUCLEAR MEDICINE
475 PARK AVENUE SOUTH
NEW YORK, NEW YORK 10016
TELEPHONE: (212) 889-0717

August 2, 1978

James E. Cline
Nuclear Environmental Services
3 Choke Cherry Road
Rockville MD 20850

Att: Panel on Reference Nuclear Data

Dear Mr. Cline:

As the new representative from the Radiopharmaceutical Science Council on the Panel on Reference Nuclear Data, I look forward to bringing to the panel radiopharmaceutical expertise.

The three items identified in your letter of 19 July 78:

1. wall chart of the nuclides
2. table of isotopes
3. reference source list

are all of considerable importance to scientists in the radiopharmaceutical field. However, all three items <u>may</u> benefit our constituency by including the following:

1. chemical reactivity
2. dosimetry
3. clinical indications:
    a. external or internal administration
    b. diagnostic
    c. therapeutic
4. organ or part of body studied
5. radionuclides used in medicine:
    a. conventional (n,γ), fission, accelerator
    b. generator - radionuclide pairs
        (1) parent-offspring-grandoffspring
        (2) transient or secular equilibrium
        (3) equilibrium times (t_{eq})
        (4) method of separation

(a) column
(b) sublimation
(c) solvent extraction

c. photon energy used for imaging

6. imaging

a. gamma camera
b. positron (tomographic)
c. patient dose (mCi; MB_q)

7. critical organs

a. highest dose (RAD, Gy)

I look forward to our meeting on the 5 Oct 78.

Sincerely,

Frank P Castronovo

Frank P. Castronovo, Ph.D.
Assistant Professor in Radiology
Harvard Medical School -
Massachusetts General Hospital
Boston MA 02114

cc: Thomas W. Burrows, Ph.D.
Leona Stewart, Ph.D.
Dennis R. Hoogland, Ph.D.

Appendix J

Major Biomedical Users of Nuclear Data (Specifically for Radiation Therapy)

J.C. McDonald
for the American Association of Physicists in Medicine

October 5, 1978

Location	Radiation Type	Production Method	Common Problems Requiring Nuclear Data
Univ. of Wash.	Neutrons	21 MeV d → Be	Shielding Collimation Activation of components
Naval Res. Lab.	Neutrons	35 MeV d → Be	
Texas A. & M.	Neutrons	50 MeV d → Be	
Fermilab	Neutrons	67 MeV p → Be	
Harvard	160 MeV Protons	Cyclotron	Attenuation of various materials
LAMPF	170 MeV/C π^-	800 MeV p → C	Interactions and secondary charged-particle production in tissue-like media
TRIUMF	170 MeV/c π^-	600 MeV p → C	
Lawrence Berkeley Lab.	600 MeV ^{4}He 5 GeV ^{12}C	Synchrocyclotron or Bevalac	

NOTE: All of these centers are currently treating cancer patients. There are strong indications that more neutron facilities will be built. There are also some centers in Europe and Japan.

APPENDIX K

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Proceedings Of The

Magnetic Fusion Energy Blanket & Shield Workshop

A Technical Assessment

Edited By
J.R. Powell (BNL), J.A. Fillo (BNL)
B.G. Twining (ERDA) & J.J. Dorning (U of Illinois)

Systems & Applications Studies Branch

Division Of Magnetic Fusion Energy

August 1975

STUDY SESSION ON NEUTRONICS

D.J. Dudziak, Chairman (LASL)
J.D. Lee, Co-Chairman/Secretary (LLL)
R.G. Alsmiller (ORNL)
M.A. Abdou (ANL)
B.R. Leonard (PNL)
B. Twining (ERDA)
P.G. Young (LASL)
C.W. Maynard (U. of WISC.)
T. Parish (UT-AUSTIN)
W.G. Price (PPPL)
J. Dorning (U. of ILL.)
M. Stauber

1. Introduction and Summary

The Neutronics Working Group (WG) discussions occurred in the framework of two constraints:

(1) Requirements for EPR were assigned top priority because of the extremely short time period until a possible design freeze (1980-1981).

(2) Anticipated budget limitations led the WG to consider only high priority items, leaving many potential development efforts of importance to commercial designs undiscussed. Time constraints also forced the WG to address only the highest priority items. Thus, some areas of concern may have been missed, but hopefully not items of urgent necessity. Unfortunately, few long-term R&D planning judgments could be made under this constraint.

As a general conclusion, the WG considers neutronics R&D to be a low-risk item in terms of success, but an R&D program must commence soon to allow confident design of the EPR. That is, most of the theoretical methods required for neutronics exist in principle, but a low-risk/high payoff effort is required on an accelerated time scale to make these tools available to designers. Present deficiencies in nuclear data and codes affect equally all EPR designs. It is clear that with present data and codes, a viable final blanket/shield neutronic design is not possible. No differentiation between DEMO and commercial reactor nucleonics requirements can be made at this time.

Specific recommendations for nuclear data assessment, measurement, theoretical modeling, and evaluation were proposed. Even though top priority was assigned to EPR, some data uncertainties which can impact on DEMO feasibility or design choices were identified.

Most recommendations for code development involved improvements and adaptation of existing methods and codes to problems unique to fusion reactors. Participation of the CTR neutronics community in a code standardization effort currently underway in the fission community was strongly urged (i.e., to avoid duplication of effort and avail ourselves of a wealth of developed codes and data).

Specific experiments to confirm EPR blanket/shield material choices were assigned top priority among integral experiments. A final verification of the design will, however, require an actual mockup. Very simple clean integral experiments are essential for establishing a long-term basis for confidence in some nuclear data. A well-conceived program of neutron and gamma-ray dosimetry in the TFTR cell, beam tubes, etc., will be an invaluable aid in assessing EPR shielding problems.

Additionally, the WG identified some generic nucleonic questions regarding EPR and DEMO designs presented at this Workshop. While detailed analysis was not possible, judgments were made to help focus on possible crucial blanket/shield uncertainties.

In summary, the WG strongly recommends an agressive, EPR-priority oriented development effort to rectify large uncertainties in key nuclear data, to provide useable and design-oriented computational tools, and to verify design choices by means of selected integral experiments. Further, due to the limited consideration of longer-term R&D requirements at this Workshop, a subsequent review should be devoted to such programs.

2. Nuclear Data (EPR and DEMO/commercial)

A. Assessment of Needs

Quantitative data assessment studies using perturbation theory have been done for TFTR and EPR designs. Although extremely useful, such studies suffer from lack of error data in general, and specifically from lack of methods to conveniently quantify and format secondary energy distribution uncertainties in the ENDF. These secondary energy distribution errors are often as important as the cross-section errors (e.g., ^{7}Li and ^{9}Be), yet the effects of these errors on nucleonic design parameters are much more difficult to analyze in sensitivity studies.

Recommendations

1. The WG thinks documented assessments are essential to identify unacceptable data deficiencies, and to guide a program of nuclear model calculations, differential and integral measurements, and new evaluations. These assessments

should include qualitative review of existing evaluations for obvious deficiencies, as well as quantitative sensitivity studies.

2. Top priority should be given to principal EPR materials, but some effort must be devoted to identifying long-range needs for DEMOS. The latter needs must be identified now to (1) provide guidance to the long-range DPR program of measurements, (2) provide data to analyze prototype DEMO blanket modules in the EPR, and (3) provide data for analyzing radiation damage experiments.

B. Processor Code Development

Processing codes now exist for neutron and gamma-ray cross-sections, gamma-ray production matrices, kerma factors, multigroup error (covariance) data, dpa data, etc. These codes are judged to be generally adequate, except perhaps as to inconsistencies among codes which can lead to non-conservation of energy. Some of these problems are due to data evaluation deficiencies.

Recommendations

1. The required codes in existence or in development should be maintained, updated, and kept consistent. This is not a major effort, and identifiable inconsistencies are being removed. Constant maintenance is required to keep up with modifications of ENDF formats, some of which have come about at CTR request, and to incorporate CCCC data output formats.

2. The processing methods are codes under development appear adequate for EPR and DEMO design, as compared to data uncertainties.

C. CTR Library

The CTR multigroup library has just been distributed. No evaluation of the adequacy of the library for EPR conceptual designs or DEMO system studies has been done yet.

Recommendations

1. This CTR Library should be tested by benchmark type calculations. Comparison with design studies using previous data sets should also be carried out. As new materials are needed, they should be added.

2. On a high priority basis, kerma factor and dpa response functions should be added to the library and distributed to the CTR community. This should not involve a major effort.

3. Eventually, all response functions should be placed in the library as they become available (e.g., breeding and activation cross sections, decay data, gas productions). The library will then at least be complete, if not accurate enough for EPR calculations.

4. In the next iteration of the library (ENDF-V in ∿3 yrs.) these data should be provided by a self-consistent processing system.

D. Nuclear Data Measurement Needs

1. Assessment of Task

Nuclear data measurement needs were discussed by a sub-group consisting of M. Abdou, R.G. Alsmiller, M. Bhat, B. Leonard, and P.G. Young. It was generally agreed that, although the data needs of the CTR program are vast, the measurement request from this group should be kept to a bare minimum in order to have maximum effect. Accordingly, only the few most obvious needs were addressed. In all cases, experimental data at additional incident neutron energies would be welcome.

2. Priority I Recommendations (mainly for EPR (a))

a. neutron emission spectra (>5 angles, E_n' >500 keV)

^{7}Li $_{n,Nem}$ (Θ_n', E_n') Accuracy = 10%, E_n = 11, 14 MeV

^{11}B " " " "

C " " " "

Fe " " " "

b. gas production

$^{7}Li\,\sigma_{n,n't}(E_n)$ Accuracy = 10%, E_n = thres. - 15 MeV (1-MeV increments)

$^{11}B\ \sigma_{n,xp}(E_n)\&\sigma_{n,x\alpha}(E_n)$ Accuracy = 15%, E_n = 14 MeV

$^{12}C\ \sigma_{n,x\alpha}(E_n)$ " "

$^{56}Fe\ \sigma_{n,xp}(E_n)\&\sigma_{n,x\alpha}(E_n)$ " "

3. Priority II Recommendations (mainly for DEMO)

a. neutron emission spectra (>5 angles, E_n' >500 keV)

$^{6}Li\ \sigma_{n,Nem}(\theta_n', E_n')$ Accuracy = 10%, E_n = 11, 14 MeV

Al (b) " " "

Mo " " "

Ni " " "

Cr " " "

(a) Although extensive use of Li is not envisioned for the EPR, it is sufficiently important to the CTR program that ^{7}Li measurements are listed under priority I

(b) Al could be priority I if a FERF program is pursued.

b. gas production

Al[(a)] $\sigma_{n,xp}(E_n)$ and $\sigma_{n,x\alpha}(E_n)$ Accuracy = 15%, E_n = 14 MeV

Mo " " " "

Ni " " " "

Cr " " " "

^{6}Li $\sigma_{n,t}(E_n)$ Accuracy = 15%, E_n = 1-15 MeV (a few energies)

4. Priority III Recommendations

   a. neutron emission spectra for Be, Cu, Ti, V, Nb

   b. gas production cross sections for Be, Cu, Ti, V, Nb

   c. proton and alpha spectrum measurements (b) at E_n = 14 MeV for Fe, Ni, Cr

   d. selected measurements on isotopic data (for nuclear heating and activation calculations) for important elements; e.g., Ni, Cr, and Mo.

E. Nuclear Data Evaluation Needs

1. Assessment of Task

The most important materials for the EPR design are B, C, SiC, Cu, Al, LiH, Pb and stainless steel (Fe, Ni, Cr). Additional materials that are possible major constituents of the DEMO include ^{6}Li, ^{7}Li, Be, F, Mo, Ti, V, and Nb. Clearly, the nuclear data evaluations for these materials should be maintained and improved as new measurements become available, and any serious deficiencies should be remedied. The CSEWG is requested to pay particular attention to (n,n'), (n,2n), (n,n' particle, and (n,xγ) cross sections and spectra for $E_n \leq$ 15 MeV in the Version V evaluations for these materials. This request is being communicated to CSEWG in a memo (See Addendum No. 1). Specific recommendations involving these evaluations are given below.

2. Specific Recommendations

a. The existing Version IV evaluation for ^{11}B is based on a 1966 U.K. data set and does not include gamma-ray production data or a realistic representation of secondary neutron spectra. A new ^{11}B evaluation is recommended.

b. Re-evaluations incorporating new experimental data and more accurate representations of secondary neutron spectra are needed for ^{7}Li and ^{9}Be.

c. Correlated error files in ENDF format for all partial cross sections and secondary energy spectra are needed for the EPR and DEMO materials listed above.

(a) Al could be priority I if a FERF program is pursued.

(b) These measurements for additional materials such as Nb, V, and Mo might become important as DEMO designs evolve.

d. Gas production and activation data evaluations are needed for Mo isotopes. Model calculations and existing experimental data should be adequate for a first evaluation

e. The gas production and activation data for all the above EPR and DEMO materials should be examined for adequacy.

f. An evaluation of the $T(t,2n)^4He$ reaction is needed.

3. General Recommendations

a. continued vigorous ENDF/B activity

It is essential to maintain a supply of accurate evaluated data in order to meet EPR and DEMO data needs. In addition to maintaining and supplying high quality data, CSEWG must continue its effort to improve and devise formats and reaction types that are needed in CTR applications. In addition, there are special CTR data needs for ENDF-formated isotopic data and partial evaluations, some of which only require nuclear model calculations. These special needs might be satisfied by having a separate evaluated data file for CTR applications, or by having CSEWG emphasize CTR problems more in the general purpose ENDF/B files.

b. extension of data files to 30 MeV

The decision on whether to build a D-Li neutron source will have a large impact on nuclear data needs. Because of the possible use of E_n>20 MeV neutron sources for radiation damage studies, the extension of ENDF/B data files up to incident neutron energies of 30 MeV or so should be investigated. The data required include neutron, charged-particle, and gamma-ray production cross sections and secondary spectra. It is likely that nuclear model codes can be utilized to a large extent in this task, but experimental data for light elements, calculational verification, etc., will be required.

3. Transport and Nucleonic Methods and Codes

A. Transport Codes (1-, 2-, and 3-D S_n)

Transport codes (not including Monte Carlo here -- see 3-B below) in 1- and 2-D are production design tools, as well as analysis tools for integral experiments, etc. Several codes in these categories (ANISN, DTF-IV, ONETRAN, TWOTRAN, DOT, TRIDENT) exist. Only one experimental 3-D S_n code (THREETRAN) exists. A concern was expressed over long computer time requirements for some 2-D problems with existing codes. Current acceleration methods are ineffective in some instances. Ray effects have not been evaluated for CTR cases. No need for diffusion-theory codes could be identified.

Recommendations

1. The 1-D codes are adequate for the 1-D class of problems of interest in EPR and DEMO design.

2. The principal concern for 2-D codes is for accurate geometrical representation of the cross section of a torus. The emphasis should be on convenience of geometric modeling (e.g., with a triangular mesh). Such a code should be available by 1977. Also, some members recommended that a vigorous effort be made to develop methods which will minimize the number of spatial mesh intervals required for accurate solution of realistic fusion reactor engineering designs.

3. Some members of the WG were not optimistic about improving acceleration techniques in 2-D codes, with the possible exception of coarse mesh rebalance.(a)

4. No major new code development beyond the present triangular mesh developments can be identified at this time. Studies of potential ray effects or other computational anomalies in 2-D calculations should be conducted.

5. The general consensus was that there is no pressing need for explicit toroidal-coordinate 2-D S_n codes (i.e., in r-θ). However, some members thought such codes may be quite useful and thus a small effort could be devoted to their development.

6. No effort should be expended on diffusion-theory codes.

7. One member of the WG thought long-range development of multi-dimensional integral transport methods was warranted by their potential payoff in treating void streaming.

B. Monte Carlo Codes

Presently several MC codes, both continuous-energy and multigroup, exist and are generally adequate. Some include toroidal region specifications.

Recommendations

1. Some members thought that no major MC code development, including toroidal geometry capability, need by pursued. Others would like to have toroidal geometry capabilities (such codes exist, e.g., MCNG, but not in combinatorial geometry). However, the WG felt strongly that input specifications need to be simplified for the existing codes; i.e., the input for approximating tori should be specialized and simplified. This effort would be modest and provide a great convenience for EPR/DEMO designers. Although not directly related to calculational accuracy, such simplifications will enable more routine Monte Carlo calculations of essential transport problems.

(a) Comment added in review: The synthetic method[1] has recently been modified to improve stability and implemented in 1D by R. Alcouffe.[2] This method has proved to be 2-10 times more efficient than coarse mesh rebalance. LASL is working now on its implementation in 2D.

2. Again as a matter of usability and convenience to designers, specialized input routines are desired to simplify specification of streaming problems. This would also be a modest effort, and its importance to designers cannot be over-emphasized.

3. Special biasing (e.g., adjoint flux) methods for streaming calculations should be examined and developed in the long term.

4. Suitable processing codes exist for supplying continuous-energy Monte Carlo libraries. However, storage limitations restrict the number of data points that can be handled. Improved representations are needed, therefore, to fully account for resonance self shielding.

C. Non-Monte Carlo Streaming Methods

No development needs in this area have been identified. Monte Carlo has been the method of choice. (But cf. recommendation 3.A.7). However, existing analytic approximations should be surveyed and evaluated for applicability to fusion reactors (e.g., compared with Monte Carlo calculations).

D. Sensitivity Codes

Both 1-D and 2-D sensitivity codes based upon perturbation theory are very useful for cross section sensitivity studies. Similarly, they are useful for design optimization, although one member of the WG questioned the computer time requirements of doing 2-D design optimization.

Recommendations

1. Modest but urgent development is required to represent secondary energy distributions, and hence perform sensitivity studies. These are essential for assessment of EPR data needs.

2. Modest developmental effort is required for 2-D sensitivity codes. This is a no-risk effort using present perturbation theory methods.

E. Advanced Sensitivity Methods

Other than incorporating secondary energy and angular distribution uncertainties in the codes (by developing methods as discussed in 3.D), strong incentive was identified for developing advanced sensitivity methods for the EPR. Longer range development, however, should be pursued starting now at a low level.

F. S_n and Monte Carlo Coupling

This is now a state-of-the-art method in forward-forward calculations, and simply needs to be implemented with existing codes. It is anticipated that CTR designers (EPR & DEMO) will require such methods for efficient calculation of many blanket and shield problems, and they should be made available for existing codes (modest effort). Forward-adjoint coupling should be developed in a longer-range program.

G. Radioactivity and Afterheat Methods and Codes

An assortment of codes have been applied on an *ad hoc* basis to calculate radioactivity and afterheat. However, these have used libraries of activation cross sections and decay data (λ, E_γ, $\bar{E}_\beta$, B.R.) varying in degree of accuracy.

Recommendations

1. A multigroup activation cross section library should be added to the CTR library with high priority. This is a minor effort.

2. An interim library of decay data should be added to the CTR pointwise (ENDF-format) library on an urgent basis. This requires a moderate level of effort. ENDF formats exist for decay data and some such data will be in ENDF-IV, but for fission products and actinides only. Waiting for the normal ENDF mechanism would not be acceptable for the EPR design requirements. The CTR library of decay data is also essential for computing delayed kerma factors.

3. A radioactivity code should be developed which has the following characteristics:

   a. Access ENDF via an intermediate processor which prepares the radioactivity code library. (Assumed to be a minor development).

   b. Calculate spatial distributions and spatial integrations of radioactivity, afterheat, BHP, IHP, and many other weightings of the basic radioactivity value.

This code needs to be developed for the EPR analysis. It may be needed in the very near future for the environmental impact statement and safety analysis. Though of high priority, the amount of effort should be moderate because the code can be developed as a modification and extention of an existing code.

H. Radioactive corrosion products (CRUD)

Standard shielding methods can be used to handle the radiation problems associated with deposition of activated coolant impurities and structure. To do this we will need information on the rate of material transport by the coolant, and deposition distributions in the blanket coolant loop.

I. Shield Optimization Methods and Codes

A strong incentive exists to optimize shield arrangements and materials so as to achieve a given effective attenuation in minimum thickness. Such optimization is especially important on the inboard side of the torus in Tokamaks. One-and two-dimensional perturbation theory codes can be used for such optimization, after a relatively modest and zero-risk development effort.

Recommendations

1. Because of the high potential payoff, shield optimization codes based upc perturbation theory should be developed for 1-and 2-D. One member thought that th 2-D could be done for about 1 man-year of effort, and may prove useful in guiding 3-D streaming calculations. The need for these codes is not urgent for EPR, but will have a large payoff in all future design studies.

2. Advanced methods such as linear programming models with constraints were discussed. They were not considered to be worth a high priority development effor but some members thought such methods may prove valuable for DEMO/commercial reactors and should be developed at a low level of effort.

J. Code and File Standardization (CCCC)

There was general agreement in the WG concerning the desirability of the CTR community establishing a cooperative effort in code standardization and standard file definition. It was noted that we will continue to use codes developed in the fission programs, and a cooperative effort could be mutually beneficial. However, it will require modification of existing interface data files and thus a modest level of effort. The payoff is high.

Recommendations

1. A liaison should be established immediately with the existing Committee on Computer Code Coordination (CCCC) for CTR representation.

2. Modifications to standard files (mainly cross section and flux files) should be agreed upon among the CTR neutronics community and then proposed to the CCCC.

3. Future development of exportable codes for CTR neutronics should be unde CCCC standards if agreements can be worked out as in 2 above. Slight modificatio of existing codes to accommodate CTR standard files should be performed.

K. CTR Computer Useage

At present the CTR computer has a rather limited amount of peripheral equipment which is inhibiting its use for large scale nucleonics calculations.

The CTR computer uses the LLL CHATR compiler with LRLTRAN, which is almost ANSI FORTRAN 4 compatible. The system has no interactive graphics.

When the CTR computer service centers are operational and storage space is available, we propose placing data files, processing codes, libraries, 1-,2-, & 3-D transport codes on the system for use by the CTR community. Perhaps RSIC could undertake some of the transfer of data.

4. Integral Experiments

A. Assessment of Needs

Integral experiments can be classified in three basic categories, according to the nature of the information which is to be extracted.
There are experiments:

(I) to evaluate and improve the understand of basic cross sections, and to a lesser extent calculational methods;

(II) to test the feasibility of generic design concepts; and

(III) to verify the performance of detailed designs.

The Type I (Fundamental) experiments should be "clean", so as to allow the highest confidence in interpreting subsequent analysis in terms of basic cross sections. Presumably data would be collected from homogeneous mixtures, about 2 to 20 mean-free-paths thick, in very simple spherical or cylindrical assemblies. Information developed would be made available to cross-section evaluators for use in improving the contents of ENDF. These experiments could also provide well documented "benchmarks" for code validation. They would be primarily for single elements, with the singular exception of stainless steel, which warrants special attention for the EPR.

The Type II (Feasibility) experiments would be "simple", but each would incorporate geometrical or compositional complexities to test generic engineering design approaches. The emphasis would be on determining real design parameters such as heating, dose, and damage (although analysis in terms of spectra, etc., might also be valuable in interpreting results). These experiments would provide directly usable design information (e.g., thick shield attenuation factors) and provide tests of the codes used in real engineering designs (e.g., for thick primary magnet shields and for beam tubes through blankets).

The Type III (Mockup) experiments are for final design verification. They would incorporate all the important features of a proposed real machine, and would be performed (as insurance) just before the design was to be frozen. It could be rather difficult to trace the actual source of any poor performance, and very few such (expensive) experiments would normally be performed.

B. Recommendations

1. Top priority should be given to Type II experiments checking the feasibility of important generic EPR blanket/shield design approaches. In particular a test of the effectiveness of the bulk shield material (currently, laminations of

stainless steels and various combinations of boron and carbon) is of great importance in establishing basic reactor dimensions. Type II geometric experiments, to validate methods for computing streaming through ducts, will also be of great importance. Clearly, experiments of this type must be completed before the EPR design is frozen.

2. A long-range program of more fundamental Type I experiments should be established. This effort should be coordinated with a differential cross section measurement program and a continuing evaluation effort to ensure that the CTR-ENDF data are kept adequate to the calculational needs. First priority within this program should be deep penetration checks of the basic EPR materials (stainless steel, boron-11, and perhaps copper) to identify seriously deficient data, possibly even in time to improve it for the EPR designers.

3. Blanket mockup experiment(s) must be performed for the final design configuration. If the shield proves inadequate in the mockup, a major design fault could be avoided. The probability of shield inadequacy is determined principally by the Type II experimental program.

4. If at all possible, all integral experiments should use materials which are as homogeneous as possible; i.e., no unnecessary heterogenieties should be introduced. Heterogeneities can make analysis of experimental results extremely difficult, if not impossible in some cases.

5. A well-planned program of measurements should be undertaken on the TFTR during and after DT operation. The WG agreed that an invaluable contribution to design of the EPR shielding could result. Extensive neutron and gamma-ray dosimetry should be performed in the TFTR reactor cell, beam injectors, vacuum ports, etc. Such a program could have an enormous payoff in identifying unanticipated streaming problems in the EPR.

5. Design Reviews

A. Status of EPR Nucleonics

Nuclear data on the proposed EPR shielding materials (stainless, boron, carbon) and copper magnet are uncertain. This uncertainty limits the usefulness of present shielding design studies. Experiments and/or evaluations are needed to reduce these uncertainties to acceptable levels.

Although only 1-D calculations have been performed to date, 3-D calculations are needed to develop shield designs around streaming paths. Streaming can have large effects on the magnets and cryropanels. Poloidal variation of fluxes must also be examined by multidimensional methods. Also, the effects of neutron source spectrum may be important in assessing coil damage rate. The net effect of all these uncertainties could well be an underestimate of the bore size of the toroidal field coils needed to accommodate the required shielding, as well as a severe impact on vacuum pumping requirements, beam injector design, etc.

B. Comments on Demonstration/Commercial Blanket Designs

The use of solid lithium compounds for tritium breeding will in most cases require the use of a neutron multiplier to overcome the loss of $^{7}Li(n,n't)^{4}He$ breeding. The use of lithium enriched in ^{6}Li may also be necessary or advantageous. The choice of a neutron multiplier is a function of reactor system economics. From an ergonic point of view, beryllium appears to be the best choice. Lead and other materials can provide the necessary neutron multiplication, but neutron energy multiplication suffers. In low and modest Q systems (mirror and theta pinch) the use of beryllium gives the best economics when compared with other (non-fission) multipliers. Of course, much better economics is achievable if ^{238}U, or to a lesser degree ^{232}Th, is used as the multiplier.

One-dimensional transport codes are very useful for doing blanket calculation but care must be exercised when radial streaming through relatively large voids or different materials is possible. Self-shielding effects may be important so care should be exercised in this regard also.

6. Response to "Questions for Neutronics Workshop Sessions"

A set of questions (1 through 12 in Addendum No. 2) were addressed to the participants in the Neutronics working group before the meeting at BNL. Additional questions (13 through 15 in Addendum No. 2) were formulated by D. J. Dudziak. Responses to the original and extended questions were contributed by D. J. Dudziak and P. G. Young (Addendum No. 2) and C. W. Maynard (Addendum No. 3). A compendium of 14 MeV neutron source experiments, contributed by B. R. Leonard is enclosed as Addendum No. 4.

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1. W. H. Reed, "The Effectiveness of Acceleration Techniques For Iterative Methods In Transport Theory," Nucl. Sci. Eng. 45, 245-254 (1971).

2. R. E. Alcouffe and E. E. Lewis, "Synthetic Acceleration Methods For The Neutron Transport Theory in Reactor Calculations, Bologna, Italy (November 1975).