International Atomic Energy Agency

INDC(NDS)-45/L

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

REPORT OF THE NUCLEAR DATA SECTION

TO THE INTERNATIONAL NUCLEAR DATA COMMITTEE

JUNE 1971 TO MAY 1972

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

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A. INTRODUCTION

The following progress report of the Nuclear Data Section (NDS) of the IAEA to the International Nuclear Data Committee (INDC) covers the period from June 1971 to May 1972. This period saw an unusually large turnover in the staff of the Section. Bak (Korea) and Koster (South Africa) who left the Agency in the first half of 1971 were replaced by Lemley (Los Alamos, USA) and Calamand (Saclay, France) in August and October 1971, respectively. For budget reasons both posts had to be held vacant for about six months. During the second half of 1971 Konshin (USSR), Lorenz (USA) and Kaas (Austria) left NDS and were replaced by Vlassov (Academy of Sciences, Kiev, USSR) in March 1972, Dunford (Atomics International, USA) in April 1972, and Lammer (Seibersdorf, Austria) in October 1971. Due to the excellent cooperative spirit within the Section and the hard working of every staff member this deficiency of staff could be overcome and the objectives of this period be attained, although in some cases meeting these objectives was delayed. At present, NDS is again fully staffed with ten physicists, three programmers, two data-processing clerks and four secretaries; NDS was allocated a fourth secretary because of the increase in typing workload.

During the past year, EXFOR has matured to a fully workable state such that operation is routine and responsibilities are clearly defined. A revised EXFOR compilers manual for physicists was prepared by NDS and approved by the three other neutron data centres. A comprehensive checking programme for EXFOR entries has been developed by NDS and implemented also by CCDN/ENEA. The EXFOR data scope will be expanded in the near future to include fission product data.

In May 1972, CINDU-10 was published; it contains an up-to-date catalogue of experimental and evaluated neutron nuclear data available from NDS data files.

The publication of CINDA was continued with two supplements to CINDA-71 published in June and December 1971 and the new total volume CINDA-72 published in May 1972. CINDA-72 contains 75 000 entries; this represents an increase of 20 000 entries over CINDA-71.

The reviews on Pu-239 α, Pu-239 fission and on $\bar{\nu}$ data for all heavy isotopes were completed and will be published in Atomic Energy Review in the second half of 1972. They represent a substantial progress over similar work in the past and will be of particular benefit to national fast reactor projects.

Following recommendations by INDC, NDS organized a Specialist Meeting on the Status of Prompt Fission Neutron Spectra and a Panel on Neutron Nuclear Data Evaluation in consecutive weeks end of August/beginning of

September 1971. The fission meeting attracted much interest and reviewed comprehensively the existing problems in the knowledge and description of fission spectra. The Evaluation Panel produced a comprehensive international review of neutron evaluation activities and evaluated data files.

One of the major achievements during the past year was the production, jointly with CCDN/ENEA, of the Draft First World Request List (RENDA 72) for Neutron Data Measurements for Reactors. This document is submitted to the Fifth INDC Meeting for discussion and approval. With more than 1400 requests it represents a comprehensive picture of the international requirements for neutron nuclear data for the development of nuclear reactors and nuclear reactor shields. Furthermore an official list of nuclear data requests for the development of safeguards techniques was compiled from contributions from the USA, the USSR and the FRG. A similar request list for thermonuclear fusion is under preparation.

A number of official requests for targets and samples were received from eight research groups in seven countries. They are abstracted and categorized in a separate document which is submitted to the Fifth INDC Meeting for consideration and recommendation.

In the field of non-neutron nuclear data NDS organized the First Meeting of the International Working Group for Nuclear Structure and Reaction Data (IWGNSRD) in March this year. The Meeting started a review of nuclear data requirements for various applied purposes. As a first step, it defined the major fields of nuclear data application and linked these to the existing compilations.

After the IWGNSRD Meeting a programme committee met in Vienna to prepare a draft detailed programme for the Nuclear Data Symposium planned by NDS for March 1973 and hosted by the French CEA at Saclay or in Paris. The data scope of the meeting will cover both neutron and non-neutron nuclear data. The full title of the Symposium, "On Intercommunication between Users, Compilers and Evaluators of Nuclear Data for Applications in Science and Technology" points to the primary objective of the Symposium, i.e. to confront nuclear data compilers and evaluators with the requirements of nuclear data users.

B. INDC SECRETARIAT

B.1. Liaison Officers

The current list of Liaison Officers to the INDC comprizes scientists from 36 countries and is given in Appendix A. Taiwan is no longer included in this list as of January 1972, since Taiwan is no longer a Member State of the Agency. The new state Bangla-Desh is left out from the list as long as it has not yet joined the Agency.

As in 1971, the individual progress reports submitted by those countries within the service area of NDS which are not directly represented on INDC, will be combined into one single document and issued as such after the Fifth INDC Meeting.

B.2. List of Correspondents

The current list of "INDC Correspondents for the Exchange of Nuclear Data Information" has been distributed as INDC(SEC)-23/U in May 1972. The next issue will be distributed in November 1972.

B.3. List of Documents

The current list of INDC documents received and distributed by NDS/INDC Secretariat has been distributed as INDC(SEC)-22/U in May 1972. The next issue will be distributed in November 1972.

B.4. Translation of Documents

During the past year the following documents of Soviet and Hungarian origin were translated by the IAEA into English and distributed as INDC documents with the following numbers:

INDC(CCP)-15/U	Collection of Abstracts, Volume 10
INDC(CCP)-17/U	Nuclear Data Requirements for the Calculation of Fast Reactors, S.M. Zaritsky et al.

INDC(CCP)-19/U	Planning an Optimum Set of Microscopic Experiments and Evaluations to Obtain a Given Accuracy in Reactor Parameter Calculations, L.N. Usachev and Yu.G.Bobkov
INDC(CCP)-21/L	Absolute Measurements of Alpha for U-235 and Pu-239 in the 10 keV - 1 MeV Neutron Energy Range, V.N. Kononov et al.
INDC(CCP)-22/L	Radiative Capture-to-Fission Cross-Section Ratio for Pu-239 in the Neutron Energy Region below 50 keV, A.A. Bergman et al.
INDC(CCP)-23/G	Automation of the Procedure for Checking Information Contained in the Library of Evaluated Nuclear Data: the "Pososhok" Programme, V.E. Kolessov et al.
INDC(CCP)-24/G	Format of the Evaluated Nuclear Data Library for Reactor Calculations, V.E. Kolesov and M.N. Nikolaev
INDC(HUN)-7/U	Unfolding of Neutron Spectra from Activation Data Using the RFO1 and RFO7 Codes, L.Turi and A.Fischer
INDC(HUN)-8/U	The RESP Programme for Unfolding Neutron Spectra from Activation Data, A. Fischer and L. Turi

C. MEETINGS

C.1. Past Meetings

C.1.1. IAEA Panel on Reactor Burn-Up Physics, Vienna, July 1971

Coincident in time with the Fourth INDC Meeting in Bombay, the Agency convened a panel on Reactor Burn-up Physics in Vienna. The primary objective of the panel was to review and summarize the changes in the state-of-the-art in burn-up physics since the previous IAEA Burn-up panel in Vienna in April 1967. Following a presentation of a review report on thermal cross sections for the main fissile nuclides by H.D. Lemmel from NDS, the panel also discussed improvements in the knowledge of thermal nuclear data for heavy isotopes and of fission product data needed in order to improve the reliability of burn-up predictions in thermal reactors. The corresponding detailed recommendations of the panel are listed in Appendix B. NDS plans to review some of the requested data in 1973, following the completion of the second update of the 2200 m/sec constants for the main fissile nuclei.

C.1.2. IAEA Consultants Meeting on Prompt Fission Neutron Spectra, August 1971

At the recommendation of the INDC, the Agency convened an experts meeting on Prompt Fission Neutron Spectra on 25-27 August 1971, at its Headquarters in Vienna. This topic was selected for a consultants meeting because of the persistent discrepancy (of the order of ten percent) between macroscopic and integral measurements (activation cross sections or fission averaged cross sections) on one hand and the differential measurements on the other. Recent measurements had also indicated that the Maxwellian distribution of fission neutrons was a poorer representation of the spectrum than was previously assumed.

The meeting did not resolve the discrepancies. The meeting did, however, discuss the possible sources of errors in considerable detail, and a set of eighteen recommendations were formulated (see Appendix C). These recommendations could form the basis for a programme for an effective resolution of the discrepancies in the near future. The considerable success of the meeting was due to the high quality of the papers which the participants prepared and to contributions of the two chairmen A.B. Smith and A.T.G. Ferguson.

The recommendations reflect the accomplishments of the meeting quite well. The introduction of Cf-252 as a second standard spectrum on a level with U-235, and the observation that the Maxwellian can no longer be regarded as a satisfactory approximation are the two salient features in the recommendations. However, many participants consider that the most useful parts of the recommendations are those which describe needed measurements. These recommendations include: Spectrum measurements should use techniques that specifically identify observed neutrons as being of fission origin. Better knowledge is needed for the following:

(1) Angular distributions of fission neutrons;

(2) The most important integral fission cross sections;

(3) The fission cross sections of ^{238}U above 500 keV, ^{235}U and ^{239}Pu above 100 keV;

(4) Inelastic scattering of ^{238}U above 1.5 MeV;

(5) The age of ^{252}Cf fission neutrons in water.

C.1.3. IAEA Evaluation Panel, August/September 1971

The panel was held in Vienna from 30 August to 3 September 1971 and consisted of 25 specialists from 11 countries, the ENEA and IAEA. A total of 26 papers were submitted to the panel and a list of the titles and authors of these papers, as well as the list of participants and the agenda of the panel are given in document INDC(NDS)-42/G. The agenda is also given in Appendix D of this report. Because of the fact that the panel proceedings will not be published before the last quarter of 1972 the main highlights of the panel have been summarized for the benefit of INDC members in document INDC(NDS)-42/G. These include:

1. The paper by Byer and Schmidt which reviewed the evaluation activities and evaluated data needs in 23 Member States.

2. The Status and contents of the following evaluated neutron data libraries:

   UKNDL
   ENDF/B-III
   LLL (Lawrence Livermore Laboratory)
   SPENG (Sweden)
   KEDAK
   Italian and Australian Fission Product Libraries
   the USSR Evaluated Nuclear Data Library
   the USSR Catalogues of 26-Group Constants, and
   the Evaluations of French Origin in the UKNDL Format.

3. A summary of the panel's deliberations on international co-operation in and co-ordination of evaluation activities.

C.1.4. IAEA Neutron Inelastic Scattering Symposium, Grenoble, March 1972

The fifth in the series of IAEA symposia on this subject was held 6 -10 March 1972 in Grenoble, France, the site of the new high-flux reactor. The meeting topics were

1. Experimental Techniques and Instrumentation
2. Molecular Crystals
3. Polymers
4. Phonons
5. Liquids
6. Magnetic Systems.

A high quality of reported results and excellent review papers characterized this symposium.

The conclusions concerning status in the various technical areas are as follows:

1) The investigation of phonons in solids, and the studies of magnetic systems are characterized by high accuracy of the results when compared with the previous Agency Symposia. The theory is well developed.

2) Little progress is observed in studies of liquids; particularly the theory is in an inadequate shape.

3) The work on molecular crystals, polymers and liquid crystals has only started but offers a wide spectrum of interesting problems in fundamental and applied research.

C.1.5. First Meeting of the International Working Group on Nuclear Structure and Reaction Data, Vienna, March 1972

At the recommendation of the IAEA Consultants Meeting on Non-Neutron Nuclear Data and endorsement of the INDC, this working group was formed and held its first meeting in Vienna on 13-17 March 1972.

The meeting is the subject of a separate report, INDC(SEC)-27/G, and will be summarized only briefly here.

The Working Group made a rather comprehensive survey of existing compilations, as well as of the various fields of applications. With regard to the basic compilation of nuclear level schemes, it was felt that the situation had improved somewhat since the time of the IAEA Consultants Meeting on Non-Neutron Nuclear Data in November 1970, although the task to cope with the tremendous backlog has not been solved yet. It was a particular concern of some participants that the situation might very soon deteriorate again, when the two-year "crash" programme of the U.S. National Science Foundation (NSF) has been concluded. Of more immediate nature is the question of the use of repackaged data, that is, the compilations extracted uncritically from more basic compilations to meet the special requirements of certain users fields. It would seem that many users of data are relying on tables with rather obsolete content.

Other recommendations of the Working Group were concerned with a nuclear data compilation newsletter, with the desired improvement of the information content of scientific papers in journals and with various ways to improve the information feedback from users through, for example, request lists or questionnaires.

C.1.6. Meeting of the International Working Group on Fast Reactors (IWGFR), April 1972

As usual, the meeting reviewed the current status of the national fast breeder reactor development in the major developed countries. NDS gave a short description of its current related neutron nuclear data activities (e.g. data compilation and reviews, RENDA). IWGFR wants NDS to perform a review of delayed neutron yield data for Pu-239 in view of the recent discrepancies found between measured and predicted β_{eff}-values for Pu-239.

C.1.7. NDS Participation in Other Meetings Outside Vienna

In October 1971 J.J. Schmidt attended the 15th EANDC Meeting in Lisbon, Portugal with discussions on the joint ENEA/IAEA production of the Draft World RENDA List as particular highlight.

In January 1972 T.A. Byer participated in a meeting of the Joint EANDC/EACRP Subcommittee on Evaluation at Harwell, U.K., which compared current evaluations of U-235, U-238 and Pu-239 cross sections. In another meeting of this Subcommittee in June 1972 in Bologna, in which

Mrs. Attree is participating, the computer conversion programmes for translation of formats of the main Western evaluated neutron data libraries will be compared and difficulties discussed.

In January 1972, J.J. Schmidt attended the 22nd National Conference on Nuclear Spectroscopy and Structure of the Atomic Nucleus in Kiev and presented a paper on "International Cooperation in the Field of Nuclear Data" by L. Hjärne and J.J. Schmidt, INDC(NDS)-40/U. Consecutive visits during about two weeks to various scientific institutions in Kiev, Minsk, Moscow, Dubna and Leningrad conveyed a good survey on neutron physics measurement facilities and programmes (including computers), on neutron compilation and evaluation activities and on achievements, interests and plans in the field of non-neutron nuclear data.

End of June 1972, Hjärne will take part in the Third International CODATA Conference on Generation, Compilation, Evaluation and Dissemination of Data for Science and Technology and in the 7th Annual Meeting of CODATA after the Conference, both to take place at Le Creusot in France.

C.2. Future Meetings

C.2.1. International Conference on the Study of Nuclear Structure with Neutrons, Budapest, August 1972

This Conference is organized by the Central Research Institute of Physics and the Eötvös Loránd Physical Society, Budapest, and sponsored by IUPAP, the Hungarian Academy of Sciences and the Hungarian Atomic Energy Commission. The programme of the plenary sessions and the names of invited speakers and rapporteurs as contained in the 3rd circular of 15 April 1972 are reproduced in Appendix E.

C.2.2. International Summer School on Nuclear Data for Reactors and Reactor Physics, Romania, September 1972

In the beginning of September 1972 the Institute for Atomic Physics in Bucharest, Romania, is organizing a summer school on nuclear data for reactors and reactor physics with mainly Romanian participation and invited lecturers from abroad. The subjects of the summer school are listed in Appendix F. NDS is invited to give lectures on the subject "Present Status of Nuclear Data and the Effect of Evaluation Uncertainties on Reactor Design".

C.2.3. Fourth International Conference on Reactor Shielding, Paris, October 1972

OECD/ENEA and the French CEA, in collaboration with IAEA, are organizing the Fourth International Conference on Reactor Shielding to take place in Paris, 9-13 October 1972. The purpose of the Conference is to present and discuss recent developments in reactor shielding in all parts of the world; both the physics aspect in theory and experiment and the engineering aspect of the subject will be covered. The Conference is centered around the following subjects:

- General Approach to Reactor Shield Design;
- Development of Theoretical Methods and Shielding Computer Codes;
- Engineering Solutions to Shielding Problems;
- Nuclear Data;
- Test of Exact Computational Methods and Data.

In addition, a panel is envisaged on nuclear data requirements for shielding design. A joint paper by NNCSC, LLL, AWRE, KFK, CCDN and NDS will be prepared on neutron and photon production data for shielding available in the major evaluated data libraries.

C.2.4. Second Panel on Standards, Vienna, November 1972

The second IAEA Panel on Neutron Standard Reference Data will be held in Vienna from 20-24 November 1972. The official invitations to the Government of nine Member States requesting them to nominate participants to the panel were dispatched during April and it is expected that by the end of June a provisional list of participants and observers would be available. In addition, three international organizations, ENEA, Euratom and JINR, have been invited to send observers to the panel. It is estimated that about 20-25 participants will attend the panel, for 11 of whom (apart from the Scientific Secretaries) the Agency will bear the total costs of attendance. The draft agenda for the panel as well as the proposed organization of the meeting are discussed more fully in a working paper being presented for discussion at the July INDC meeting. The panel information sheet and agenda is attached as Appendix G.

C.2.5. Nuclear Data Symposium, Paris/Saclay, March 1973

A programme committee for the IAEA Symposium on the Intercommunication Between Users, Compilers, and Evaluators of Nuclear Data for Applications in Science and Technology was convened on 20-21 March with participation of G.A. Bartholomew, B. Grinberg, D.J. Horen and V. Kulakov. The pro-

gramme was designed to emphasize the applications of compiled and evaluated data, and particularly the cost penalties for the various inaccuracies and omissions which occur in all compilations. The major fields of application were identified as follows:

(1) Fission Reactors,
(2) Activation Analysis,
(3) Applications of Radioisotopes (e.g. in Nuclear Medicine)
(4) Safeguards,
(5) Fusion Reactors,
(6) Space and Accelerator Shielding, and
(7) Astrophysics.

A list of topics for this symposium is given in Appendix H.

C.2.6. Third IAEA Symposium on the Physics and Chemistry of Fission

This symposium is currently in the early stages of preparation. No site has been selected for the meeting which is planned for the summer of 1973. Topics covered will be approximately the same as the previous two conferences in the series. However, important new developments in the area of fission isomers and ternary fission are expected to be discussed.

C.2.7. IAEA Consultants Meeting on Fission Product Data, 1973

As demonstrated by the numerous requests contained in RENDA 72, the subject of fission product data has attained considerable importance in modern reactor and shielding design. To a lesser extent it is also important for safeguards purposes, e.g. for the establishment of rough burn-up estimates. As a consequence the four neutron data centres have recently been asked to incorporate fission product data into EXFOR.

NDS therefore plans to convene a Consultants Meeting on Fission Product Data at a suitable date in 1973 with the following specific topics:

- Fission product yields for thermal and fast neutrons;
- Fission product neutron capture cross sections;
- Fission product half life data;
- Fission product γ-ray spectra and intensities;
- Delayed neutron precursors and their data (half lives, emission probabilities, decay schemes);
- Integral fission product measurements (Idaho, Petten, Studsvik).

The matter of eventual cosponsoring of this meeting by other relevant divisions of the Agency will be investigated during the second half this year. Place and date of the meeting have still to be fixed. The views of INDC on the subjects of this meeting are sought.

C.2.8. Third IAEA Conference on Nuclear Data, 1974

A working paper has been prepared for the INDC's consideration concerning the theme and outline of this third conference to be held in 1974.

D. COORDINATING ACTIVITIES AND SURVEYS

D.1. Draft World and Non-EANDC RENDA Lists

Requests for inclusion in these lists were received from the following countries in the Nuclear Data Section service area:

Australia	(15 requests)	Hungary	(12 requests)
Brazil	(7 requests)	India	(10 requests)
Bulgaria	(5 requests)	Pakistan	(15 requests)
East Germany	(5 requests)	South Africa	(6 requests)
Finland	(4 requests)	Taiwan	(3 requests)

In addition there were 16 requests originating from the Nuclear Data Section in connection with current review work, and 36 requests were received from the USSR.

All these requests were prepared for entry into the system by Schmidt, who added appropriate comments, based on reviewers reports, to bring the requests into line with those from the EANDC countries.

In January/February Mrs. Attree spent two weeks at CCDN working with Dr. Lesca on the updating of the RENDA file, including the non-EANDC requests, and studying the RENDA system. After the updating, subject retrievals were made by Dr. Lesca and sent to the subject reviewers for a final control. This was necessary because a number of inconsistencies arose in the comments due to the simultaneous inclusion of new and

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* Note that Finland is now an EANDC country, but is included in the non-EANDC list as the requests were sent to NDS.

revised requests from the countries with the separate reviewers comments. The latter also produced inconsistencies because of an overlapping of subjects in some cases. Finally the draft world RENDA, INDC(SEC)-25/G, and the draft non-EANDC RENDA, INDC(SEC)-24/L, have been printed as requested by the INDC. (Reference: Informal minutes of Fourth Meeting of the INDC, held in Bombay, 12-16 July 1971, Item VII.A, page 36). It should be noted that some requests for fusion applications are included in the world list (e.g. Request numbers - 5, 19, 507, 519). These were submitted by individuals in several countries.

D.2. Proposal for Future Production and Publication of RENDA

The Nuclear Data Section will undertake the operation of the RENDA system and the publication of the document following the publication of RENDA-72. A proposal for future publication and scheduling has been distributed to INDC members for their consideration.

CCDN has kindly agreed to supply NDS with the computer programmes for the current RENDA system. On the basis of Mrs. Attree's experience while at CCDN this year and because of the installation of a new computer at IAEA in July 1972 many of the programmes will be rewritten to optimize the system. At the same time it is proposed to include a cross-referencing system for comments which will decrease the bulk of RENDA by removing endless repetition of identical comments by reviewers.

It is expected that a 4-centre operation can be implemented, and during the summer NDS will send to the other centres a proposal for the transmission of RENDA data, taking due account of the different computers and character-sets available at each centre.

D.3. Nuclear Data Request List for Safeguards

In accordance with the procedures established at the Fourth INDC meeting for the submission of requests for nuclear data needed for safeguards development purposes, officially screened and sanctioned requests have been received from the U.S.A., USSR and the Federal Republic of Germany. The list of data needs have been merged on the basis of increasing atomic number and are presently being examined by the Agency's Department of Safeguards and Inspection. The merged international request list, which now appears to be of a quality for publication, is presented in document INDC(NDS)-44/G.

D.4. Nuclear Data Requirements for Controlled Thermonuclear Research

The NDS has prepared for submission to the INDC meeting in July 1972 a preliminary draft of a report on nuclear data requirements for controlled thermonuclear research (CTR). Data requirements enumerated in this report were derived from the following sources:

1) Replies to a letter of October 1970 from A. Lorenz to members of the International Fusion Research Council (IFRC);

2) Agency-sponsored meetings in which members of NDS participated in discussions of nuclear data;

3) Requests from RENDA 1972 which specified CTR;

4) Relevant papers from conference proceedings and the literature.

Members of the NDS participated in discussions of nuclear data at two meetings:

1) Consultants Meeting on Fusion Power and the Environment, Vienna, 15-17 December 1971, and

2) International Working Group on Nuclear Structure and Reaction Data, Vienna, 13-17 March 1972.

From experience with previous request lists assignment of priority to data requests has been of great value. Extraction of priority information in replies to Mr. Lorenz' letter was difficult. First, some letters contained no priority assignments. Second, priority information was meaningful only in the context of an individual letter and was lost when data requests were placed together in a common list. Third, relative priority assignments did not always reflect the relationship of nuclear data needs to other problems in CTR.

For these reasons NDS prepared a list of "Priority Criteria for Nuclear Data Requirements in CTR". These criteria were submitted for review and comment to members of the IFRC and INDC and to others with whom the Agency has corresponded concerning CTR. A revised version of the criteria which incorporates as far as possible the comments received appears in the draft of the report on nuclear data requirements (Appendix I). It is recognized that the priority criteria must evolve with developments in CTR and should probably be rewritten when the feasibility of fusion power has been demonstrated.

A first draft of the report will be submitted at the end of May 1972 to the IFRC, INDC and other correspondents for comment particularly on the following:

1) Content and completeness
2) Consistent priority assignment
3) More precise specification of requested data as to specific nuclei, reaction type, etc.
4) Complete documentation with regard to energy range, precision, justification, status.

D.5. Targets and Samples

A modest amount of money (max.US$15 000) has been budgeted for the present year to assist laboratories in IAEA Member States in the procurement of targets and samples. A total of eight official requests have been made by member states for assistance. The proposals have been analyzed according to conditions recommended by the INDC. A report, INDC(NDS)-43/G, has been prepared summarizing the requests and NDS recommendations for the present and future of the programme.

The proposals varied with respect to quality and completeness. Materials requested were mostly of the rare or fissile type. Only a small part of the recommended samples can be provided without material loans from the member states.

D.6. A Survey of Neutron Data for Reactor Radiation Measurements

At the meeting of the International Working Group on Reactor Radiation Measurements, 19-21 April 1971, in Vienna, the subject of cross section data for neutron reactions used in reactor radiation measurements was discussed.

It was concluded that

- there are discrepancies and gaps in the experimental information,
- different values for evaluated data are used in various laboratories,
- at present, no reference set of nuclear data has found general acceptance.

The Working Group recommended that the IAEA (Nuclear Data Section) take appropriate steps in order to arrive at internationally acceptable reference values for those neutron reactions of primary importance for radiation effects investigations in nuclear reactors.

As a first step towards the fulfilment of this recommendation NDS is preparing a status report on neutron cross section data commonly used in reactor radiation measurements and on investigations of irradiation effects, for submission to the next meeting of IWGRRM (October/November 1972). This survey report shall serve as a basis for the preparation of specific recommendations and for establishing priorities for further experimental and evaluation work.

A list of reactions to be covered in this status report has been selected by agreement between a member of IWGRRM, Mr. P. Mas (Grenoble, France), Mr. W. Zijp (Petten, Netherlands) and NDS. This list is contained in Appendix J.

Because of the short period of time before the next meeting of IWGRRM the report will not be an evaluation in the true sense, but rather a compilation of the more recent experimental data and evaluated data used at different laboratories and a first attempt to assess the status of these cross sections, i.e. the confidence level, discrepancies and gaps in the available information and in outline of most urgent needs for improvement.

D.7. INIS and UNISIST

The International Nuclear Information System has been expanded to its full scope on a trial basis since the beginning of 1972. At the beginning of 1973 the full scope is planned to be covered on a routine basis, and "Atomindex" will from then on include references for one whole field of nuclear science and technology.

The Intergovernmental Conference on UNISIST was held as planned in 1971. It was encouraging to note in the final report of the Conference that subjects of most of the NDS comments to the UNISIST proposals were touched upon by delegates at the Conference. The final decision on UNISIST will be taken by the UNESCO General Conference during 1972. The report has been sent to INDC members.

E. DATA CENTRE ACTIVITIES

The data centre activities continued much the same as outlined in last year's report (INDC(NDS)-31, pp 23-39). The present report can therefore be brief although it concerns most of the manpower of the NDS.

E.1. NDS Area Service

Political events changed the geography of the NDS service area. The Republic of China (Taiwan) and East Pakistan (Bangla Desh) are no longer members of the IAEA and the NDS can no longer keep contacts with scientists in these areas. This is most regrettable since institutes in Dacca, Taipeh, and others, were among the most active customers of the NDS data centre.

E.1.1. Compilation Within NDS Service Area

In fall and winter 1971/72 the compilation work was delayed due to the Agency's policy to leave posts vacant for six months whenever a staff member is to be replaced. Meanwhile the posts of H.I. Bak and A. Koster have been refilled by J.R. Lemley and A. Calamand, who do now most of the compilation work.

All experimental data are now compiled in EXFOR format. The compilation of new data has the first priority. Here completeness is achieved by
(1) contacting the authors on the ground of progress reports, and
(2) by regular scanning of all publications from the NDS service area and of the most important international journals.

Second priority is given to the compilation of older data of important nuclei. This consists of converting DASTAR-entries to EXFOR format and of detecting and filling gaps in earlier compilations. Completeness of compilation is assured by comparison with CINDA. Special emphasis is given to the compilation of old data, when the data centres agree on a new data-type to be compiled, e.g. gamma-spectra following neutron capture. Third priority is given to the compilation of older data of less important nuclei.

Available manpower allows that the first priority compilation is well done, the second priority satisfactorily but with interruptions, and the third priority not at all.

E.1.2. CINDU

CINDU-10 was published in May 1972 and distributed to various institutes and scientists in the NDS service area, to INDC members and to other data centres.

CINDU is an index to all experimental and evaluated neutron data now stored at the NDS. An introductory part informs scientists how to make use of the NDS services and activities. An annex gives detailed descriptions of available evaluated data libraries.

It is hoped that in the not too distant future CINDA will have developed such that CINDU can be included in CINDA.

E.1.3. Data dissemination and exchange

The statistics of data requests received and data sets distributed are given in the two tables overleaf, which are organized in the same way as in last year's report (INDC(NDS)-31, p.31).

Table I gives the request statistics, which is organized in three groups: (1) "Incoming" requests received at NDS, (2) "Follow-up" requests, which are initiated when data needed for an "incoming" request are not yet available at the centre, (3) "NDS origin" requests which were sent out for the purpose of NDS data reviews or completion of files. Each request group is sub-divided by service area, where area 1 is the NNCSC area (North America), 2 is the NDCC area (West Europe and Japan), 3 is the NDS area and 4 is the CJD area (USSR).

Table II gives the statistics of data sets disseminated on request. This excludes the routine exchange of EXFOR data between the centres.

Data requests include requests for experimental data, evaluated data, documents or CINDA retrievals. Most frequent request-types are: send me <u>all</u> existing data on specified reactions, or send me <u>best</u> existing data on specified reactions. <u>All</u> data are requested for data reviews and comparison with own experiment or theory. <u>Best</u> data are requested for applied purposes. Both request-types include experimental <u>and</u> evaluated data, for example: latest evaluated data plus more recent experimental data.

TABLE I

SUMMARY OF NDS REQUEST STATISTICS AS OF MAY 1972

REQUESTS FOR --	EXPERIMENTAL DATA		EVALUATED DATA		DOCUMENTS		CINDA RETRIEVALS		TOTALS	
REQUEST ORIGIN	Cumulative totals	71-72* period	Cumulative totals	71-72* period	Cumulative totals	71-72* period	Cumulative totals	71-72* period	Cumulative totals	71-72* period
Incoming from Area 1	23	1	1	0	22	8	0	0	46	9
" " " 2	33	2	2	2	48	19	1	0	84	23
" " " 3	66	16	40	21	49	14	15	1	170	52
" " " 4	37	3	13	1	9	1	7	0	66	5
Incoming: Subtotal	159	22	56	24	128	42	23	1	366	89
Follow-up to Area 1	56	10	1	0	0	0	0	0	57	10
" " " 2	52	10	13	7	2	1	16	2	83	20
" " " 3	46	0	1	1	0	0	0	0	47	1
" " " 4	29	3	1	0	3	1	0	0	33	4
Follow-up: Subtotal	183	23	16	8	5	2	16	2	220	35
NDS origin: sent to Area 1	24	8	1	1	2	1	0	0	27	10
" " " " " 2	30	5	6	4	3	0	4	0	43	9
" " " " " 3	110	9	0	0	1	1	0	0	111	10
" " " " " 4	11	1	0	0	0	0	0	0	11	1
NDS origin: Subtotal	175	23	7	5	6	2	4	0	192	30
TOTALS:	517	68	79	37	139	46	43	3	778	154

* This column gives number of requests which have been either received at, or originated by NDS in the course of the last period: May 1971 - April 1972

TABLE II

Experimental Data Dissemination*

(as of April 30, 1972)

	Number of data sets		Number of data lines	
	Cumulative total	1971-1972 period	Cumulative total	1971-1972 period
To Area 1	531	0	34.921	0
" " 2	253	0	15.639	0
" " 3	1.178	599	181.836	64.155
" " 4	146	0	94.808	0
Total:	2.108	599	327.204	64.155

Evaluated Data Dissemination

(as of April 30, 1972)

	Number of data sets		Number of data lines	
	Cumulative total	1971-1972 period	Cumulative total	1971-1972 period
To Area 1	601	576	209.770	207.325
" " 2	617	578	211.374	207.772
" " 3	2.609	1.817	1.365.964	570.449
" " 4	792	419	460.324	69.351
Total:	4.619	3.390	2.247.432	1.054.897

* Excluding EXFOR transmissions

E.2. CINDA

The production of CINDA, the computer index to the literature on microscopic neutron data, has continued as described in last year's report INDC(NDS)-31, p.30.

E.2.1. CINDA Publication

The new cumulative issue, CINDA 72, was published in June 1972. It is envisaged to publish a cumulative issue of CINDA annually around June, followed by a supplement around December. The rate of literature relevant to CINDA is still growing: CINDA-72 (cut-off date May 1972) has 87 000 entries as compared to 75 000 entries in CINDA-71 (cut-off date November 1970) and 55 000 entries in CINDA-69. This volume increase demanded that CINDA-72 had to be published in two volumes of about 800 pages each. The partition was done by elements: vol. 1 including 1-H to 54-Xe, and vol. 2 from 65-Cs up. For technical reasons this partition was preferred, although there are valid arguments in favour of a partition by reference-date.

The economics of the CINDA production by IAEA is based on the bulk orders by ENEA (500 copies) and by USAEC (previously 400 copies). Additional copies are sold to the USSR, to countries in the NDS service area and through the Agency's sales agents. For the continuation of CINDA it is essential that the bulk orders remain at the present level !

E.2.2. CINDA Coverage

The number of CINDA-entries mentioned above illustrates that all CINDA-centres and individual CINDA-indexers performed a huge job, and the completeness of CINDA can be regarded as satisfactory. Nevertheless it must be noted that the coverage of laboratory-reports needs further improvement. In particular it had been pointed out that the CINDA-bibliography to the evaluated data files UKNDL and ENDF/B was insufficient. It is hoped that this can be improved during the next year.

The list of references included in CINDA contains about 250 scientific journals, 200 report-series, 120 books and conference proceedings, as well as many private communications.

E.2.3. CINDA Development and International Data Index

The re-programming of CINDA at NDCC has made much progress and is almost completed. Parallel programming was done at Oak Ridge. It is hoped that the CINDA operations will start under the new system in fall 1972. The reprogramming was done for two reasons: a) the fast increasing file-size of CINDA required greater sophistication in the file-manipulation, which took intolerably much computer-time under the old system; b) several new features will be introduced, two of them are of particular interest to CINDA users: accession-numbers to numerical data files will be given together with the relevant bibliographic references, and unimportant references (e.g. progress-reports after the appearance of the final publication) will be excluded from the book though not deleted from the internal file. The introduction of these new features to old entries will proceed gradually.

NDS had been in continuing consultation with NDCC on the development of the new CINDA-system.

E.3. Inter-Centre Cooperation

E.3.1. Status of EXFOR System and Data Transmission

The scope of EXFOR remains unchanged. The compilation of fission-fragment data is not yet started. Crouch (Harwell) is preparing a fission-product classification scheme. In cooperation with NDS this will be transformed into a definite coding scheme for EXFOR and will be submitted to the next Four-Centre Meeting in October 1972.

The quality of EXFOR entries is being carefully controlled by all centres. Regular dictionary transmissions take place which helps to ensure consistency of compilation in all centres.

The table below shows the total number of exchange tapes and the total number of entries transmitted as of 10 May 1972.

	Centre	Tapes	Entries	(as of May 71)
1.	NNCSC	5	63	(17)
2.	CCDN	5	113	(16)
3.	NDS	3	109	(82)
4.	CJD	2	23	(15)

E.3.2. EXFOR Manual and Four Centres Agreement

The EXFOR system is now laid down in the following documents:

1. Protocol for cooperation between NNCSC, NDCC, NDC and CJD for the systematic exchange of neutron data information. The version as amended at the last Four-Centres meeting is included at the end of INDC(NDS)-41. This "protocol" gives the general guidelines for the data-exchange through the EXFOR system.

2. The Systems Manual, consisting of

   a) the "EXFOR Manual" containing conventions, codes, and formats basic to the programming system;

   b) "LEXFOR", a lexicon-type collection of instructions to the compilers including physics definitions and rules how to use the EXFOR system in specific examples.

The documents 2a and 2b are unpublished and intended for centre-internal use only. They are currently updated by exchangable pages, following four-centres agreements reached at meetings or by exchange of "4C-Memos". Although the system has been in full operation for almost two years, it is still developing as new data-types require new definitions and as more refined programmes for checking and data processing are developed.

An example of an EXFOR-entry is shown and discussed in the introductory pages of CINDU-10.

E.3.3. Seventh Four Centres Meeting, Brookhaven, October 1971

The agenda of the 7th Four Centres Meeting at Brookhaven, 25-29 October 1971, reproduced in Appendix J, showed a broad scope ranging from detailed discussions of experiences with the EXFOR neutron data exchange to discussion of long-term trends such as future expansion of the present four centres cooperation to non-neutron data centres. Highlights of the meeting are:

- EXFOR has matured to a fully workable state with clearly defined responsibilities. NNCSC is responsible for maintaining and updating the full EXFOR manual, NDS for maintaining and updating the EXFOR dictionaries and protocol.

- A thoroughly revised EXFOR compilers manual for physicists (LEXFOR) which was prepared by NDS (Lemmel) was approved by the meeting. The comprehensive checking programme for EXFOR entries developed by NDS (Attree) was adopted by CCDN; also CJD is greatly interested in it.

- The EXFOR data scope will be expanded in the near future to include fission product data. A proposal for EXFOR coding is to be worked out in cooperation between Harwell specialists and NDS.

- In the framework for coordination of evaluation activities the meeting supported the NDS proposal of a world-wide evaluation newsletter.

- Regarding future four-centre cooperation on RENDA, NDS was asked to submit a detailed technical proposal to the other centres (see section D.2. of this report).

- For the first time a representative of a non-neutron nuclear data centre (Dr. Horen, director of the Oak Ridge Nuclear Data Project) took part in the four centres' deliberations. Non-neutron nuclear data needs for reactors, safeguards and fusion were discussed.

The next Four-Centres Meeting will take place in Vienna, 16-20 October 1972.

E.4. Data Reviews

E.4.1. 2200 m/sec Fission Constant Review

The IAEA will perform a third evaluation of the 2200 m/sec values in 1972 which will supersede those published in Atomic Energy Review in 1965 and 1969. The new recommended values will be prepared during the fall of 1972. The experimental data and their accuracies which will be used as input in the evaluation will be reviewed by consultants. Four consultants have been tentatively proposed: Drs Axton, Deruytter, Leonard, and Story, Dr. Lemmel (IAEA) will be responsible for the coordination and Dr. Dunford (IAEA) for the computer aspects of the review. All final detail will be completed at a meeting of the consultants preceding the November 1972 Standards Panel.

The most important change will be U-235 fission cross section. Deruytter's result, which is based on the confirmed lower value of the U-234 half-life, has such an accuracy that it would greatly influence the fit and raise σ_f U-235 from 580.2 barns (1969) by a few barns, probably not exceeding 587 barns. The U-233 fission cross section, which is strongly influenced by ratio measurements, will also be raised. The Pu-239 fission cross section may not be seriously affected since the 1969

recommended value has been experimentally confirmed. However, Deruytter pointed out that a recent experiment has indicated a low value of the Pu-239 α half-life and this could therefore lead to a change in σ_f Pu-239.

It is difficult to predict the influence of the increased U-235 fission cross-section on the other fitted data, but the correlation matrix of the fitted data shows that the $\bar{\nu}$ values will go down "a bit". However, $\bar{\nu}$ will not change as much as to leave the product $\bar{\nu}\sigma_f = \eta\sigma_a$ unchanged, as De Volpi assumed. Instead, η and σ_a of U-235 are both likely to go up "a bit". Here "a bit" means the order of magnitude of a tenth or a few tenth of a percent.

With respect to experimental data of $\bar{\nu}$ (Cf-252) the situation has not yet changed. Nevertheless, a new least-square fit is likely to yield a value of $\bar{\nu}$ (Cf-252) "a bit" lower than previously due to the following consideration: one can deduce from fission cross-sections, η and α values of the uranium and plutonium isotopes, and from $\bar{\nu}$ -ratios versus Cf-252 an "indirect" value of $\bar{\nu}$ (Cf-252) which is independent of absolute measurements. In 1969, this "indirect" value of $\bar{\nu}_t$ (Cf-252) was 3.784 ± 0.014. This value, which has an accuracy comparable to the best absolute measurements, will go down "a bit" due to the higher uranium fission cross-sections. Thus, the preference that was found in the 1969 evaluation for higher $\bar{\nu}$-values, will no longer be as strong.

A more general "least squares" fitting programme has been obtained from Chalk River and made operation here in Vienna. It will be possible to increase the number of variables considered with no major reprogramming effort. Attempts have been made to quantify confidence level and not just statistical errors.

E.4.2. Review of Fast Pu-239 Alpha Data

This review jointly undertaken by M.G. Sowerby (Harwell) and V.A. Konshin (formerly NDS, now at Minsk-Sosny) which was described in the last NDS progress report to INDC is nearing completion and will be published in the Atomic Energy Review in the second half of 1972. It represents a real evaluation, as a serious attempt has been made to detect and discuss systematic errors in the individual experiments and to assign weights reflecting not only the statistical but also the systematic errors in each of them. The recommended "best" values of alpha can be taken to have an average confidence level of about ± 10% at energies where α is important.

E.4.3. Pu-239 Fast Fission Cross Section Evaluation

A simultaneous evaluation of the Pu-239 fission cross section and the fission cross section ratio, σ_f Pu-239/σ_f U-235, has been performed from 1 keV - 10 MeV, and detailed comparisons of the results of this evaluation with those of Davey, Sowerby et al., Greene et al. and Hart have been made. It is expected that this work will be published in Atomic Energy Review in the second half of 1972, as soon as the refereeing of this evaluation (by Dr. M.G. Sowerby (Harwell)) is completed. The draft report on this work is presented in INDC(NDS)-33/G. The major conclusions of this review are:

First, that the ratio data of Gilboy and Knoll and the two ratio points of White et al. at 40 and 67 keV cannot be reconciled with recent σ_f Pu-239 and σ_f U-235 data. Second, the old 1968 σ_f U-235 data of Poenitz is inconsistent with the absolute σ_f Pu-239 data of Szabo et al. and all the available fission ratio, σ_f Pu-239/σ_f U-235, data between 300 - 800 keV. Third, there appears to be a fundamental inconsistency between the data for the following six data types: σ_f Pu-239 and σ_f Pu-239/σ_f U-235, σ_c Au-197 and σ_c Au-197/σ_f U-235, σ_c U-238 and σ_c U-238/σ_f U-235. This is suggested by the fact that the first two data types above support the "high" White, Szabo and Käppeler σ_f U-235 between 300 - 800 keV, whilst the last four data types above tend to support the lower σ_f U-235 data of Poenitz.

Finally, the estimated systematic errors of the recommended values σ_f Pu-239 and σ_f Pu-239/σ_f U-235 are:

σ_f Pu-239		σ_f Pu-239/σ_f U-235	
1-10 kev	6%	1-10 kev	8%
10-30 kev	5%	10-30 kev	4%
30-600 kev	4%	30-100 kev	3%
600-1000 kev	5%	100-600 kev	2.5%
1-2 Mev	8%	600-1000 kev	3-3.5%
2-10 Mev	8-10%	1-2 Mev	4.0%
		2-10 Mev	6-7%

E.4.4. Status of $\bar{\nu}$ Data

Following the recommendations of the IAEA Consultants Meeting on $\bar{\nu}$ held in Studsvik, Sweden, in June 1970, which were affirmed at the last INDC Meeting in Vienna, NDS has completed a thorough compilation of all measurements on $\bar{\nu}$ published up to the end of January 1972, which includes

not only the numerical data but also the essential physical information related to the measurements; i.e. method of measurement, type of detector and standard used, analysis and corrections carried out as well as errors considered.

The data taken into consideration in this review are:

i. Absolute $\bar{\nu}$ value for the spontaneous fission of Cf-252.

ii. Thermal values.

iii. Prompt-$\bar{\nu}$ values for spontaneous fission.

iv. Energy dependent $\bar{\nu}_p$ values for the heavy isotopes ($Z > 90$) from thermal to 15 MeV.

v. Delayed-neutron yields.

vi. Neutron multiplicity measurements for resonance fission.

All experimental data have been renormalized to recommended standards. A weighted least-squares orthogonal polynomial fitting analysis was applied to the $\bar{\nu}_p$ renormalized data and "best fits" deduced for the energy dependence of the $\bar{\nu}_p$ values of each isotope. Tables of recommended values of $\bar{\nu}_p$ and $\bar{\nu}_t$ as function of the incident neutron energy are included.

A study of the systematics of the thermal and spontaneous fission $\bar{\nu}_p$ values was carried out and relationships given which allow the prediction of the thermal $\bar{\nu}_p$ value of any nuclei, either from the corresponding $\bar{\nu}_p$ value for spontaneous fission or as a function of Z and A.

Attention has been also paid to the problem of the energy dependence of the delayed neutron yields. Their dependence on Z and A was also analysed.

This review will be distributed by NDS as report INDC(NDS)-34/G, and will be published in "Atomic Energy Review" by the middle of 1972.

APPENDIX A

List of Current Liaison Officers to the INDC

May 1972

Austria	Weinzierl, P.
Belgium	Nève de Mevergnies, M.
Bolivia	Paz Lora, F.
Brazil	Herdade, S.B.
Bulgaria	Nadjakov, E.
Chile	Martens Cook, P.
Colombia	Director, Instituto de Asuntos Nucleares
Czechoslovakia	Rocek, J.
Denmark	Moeller, H.B.
Ecuador	Munoz, R.
Egypt	El-Nady, M.
Finland	Saastamoinen, J.
Greece	Dritsa, S.
Hungary	Kluge, G.
Iran	Rouhaninejad, H.
Iraq	Abdulla, Ali Attiyah
Israel	Ben-David, G.
Jamaica	Chen, A.A.
Kenya	Gacii, P.
Korea	Cho, M.
Mexico	Graef Fernandez, C.
Netherlands	Bustraan, M.
Norway	Andersen, E.
Pakistan	Ghani, A.
Philippines	Navarro, Q.O.
Poland	Sujkowski, Z.
Portugal	Carvalho, G.F.
Romania	Rapeanu, S.N.
South Africa	Reitmann, D.
Spain	Velarde Pinacho, G.

- continued

Switzerland	Hürlimann. Th.
Thailand	Nimwanadon, Th.
Turkey	Enginol, T.
Uruguay	Azziz, N.
Viet-Nam	Vo-Xuan-Bang
Zaire	Pollak, H.

APPENDIX B

Nuclear Data Recommendations of the IAEA Panel on Fast Reactor Burn-Up Physics

Since the last panel was held on fuel burn-up physics, knowledge of basic nuclear data has significantly improved, in particular, with respect to plutonium data. The precision of certain data and data evaluation, however, require further improvements. The panel believes that the efforts of the IAEA and other nuclear data evaluation centres is providing best-value thermal neutron data for the fissile isotopes should be continued in order to resolve certain indicated discrepancies and to include more comprehensive and accurate data in the evaluated data sets. The INDC and other request lists are reasonably complete. The panel attempted to identify the data requirements which are of greatest significance for burn-up physics predictions. In particular, panel members note:

1. Comparison of theoretical predictions with isotopic measurements and critical experiments indicate that possible inaccuracies in the thermal and resonance cross sections of the plutonium isotopes may be responsible for some of the observed discrepancies. Some comparisons which indicate a consistent tendency to overpredict reactivity, suggest that the 0.3 eV Pu-239 resonance capture cross section should be increased. The 2200 m/sec normalization and the energy dependence of the Pu cross sections should be re-evaluated to 4 eV. The accuracy of the Pu-242 cross sections also should be improved.

2. Accuracy of the thermal cross sections and fission yields should be improved where needed, and standard values should be tabulated for the following nuclides that are most important in burn-up physics measurements and analysis for thermal reactors: Xe-135, Nd-143, Sm-149, Rh-103, Xe-131, Pm-147, Rh-105, Sm-151, Sm-152, Cs-133, Eu-153, Pm-148, Eu-155, Tc-99, Ag-109, Nd-145, Sm-150, Eu-154, Ru-103, Pd-108, Cd-113, In-115, I-127, Gd-157, Kr-85, and H_3. Increased accuracy is required for the nuclides that are used in measurements: Nd-148, Ba-140, Cs-137, Zr-95, Sr-90, Ce-144, Nd-146 and Nd-150. The preceding is a list of the isotopes that are important in burnup calculations. The accuracy of the nuclear data for some isotopes is better than for others and the order is of no significance.

3. Recommended values for the energy released in fission for Th-232 and the uranium and plutonium isotopes should be developed. The discrepancies between solid state surface barrier and velocity measurements of fission fragment energies should be resolved. Also, there is little reliable data for some nuclides such as Pu-241 and additional measurements are needed.

4. More accurate energy dependent cross-sections are needed for Am-241, Am-243, Cm-242, Cm-244, Pu-238, Np-237, and Pu-236. The accuracy of the n-2n cross sections for Np-237 should be improved.

The preceding are listed in order of estimated priority. It is recommended that the Agency undertake appropriate action to establish best values for these nuclear data.

The panel made special note of the data and standard requirements for improvement of burn-up determination and concluded that improved data determinations would contribute to improvement of the accuracy of burn-up measurements.

For fission product monitor methods of burn-up determination the accuracy of the fission yield values for the thermal fission of U-235, Pu-239 and Pu-241 should be improved to increase the overall accuracy. For fast flux irradiations and for the fission of other heavy element nuclides much improvement is needed. Increased information is needed on the variation of fission yield with neutron energy and fissile nuclides. Fluence monitor activation nuclides require more accurate energy dependent neutron capture cross section values. Improvement also is required in the accuracy of the decay schemes for nuclides used in gamma spectrometric techniques. It is recommended that the Agency take necessary action to establish best values for this data.

Standards of known isotopic composition and purity are available for uranium and neodimium but not for plutonium. This requirement is very important for calibration of mass spectrometric measurements. Two standards should be made by mixing high purity separated isotopes of mass 239, 240, 241, and 242 to give isotopic compositions of about (50%, 25%, 13%, 12%) and (65%, 20%, 12%, 3%) respectively. It is suggested that the IAEA look into the provision of gram quantities of this standard to Member States.

Consultants Meeting on
PROMPT FISSION NEUTRON SPECTRA

APPENDIX C

Recommendations

Recommendation no. 1:

We recommend that the fission neutron spectrum of ^{235}U arising from fission induced by neutrons below 150 keV should be regarded as a standard. High priority should be given to its precise determination over an energy range from below 150 keV up to above 10 MeV. The experimental data should be made available in tabular form including estimated errors. We suggest it would be valuable to make strictly comparable measurements of the fission neutron spectra of other elements such as Pu^{239} at the same incident neutron energy and under essentially identical experimental conditions to those used for the "standard" measurements. The point by point ratios of the unknown to the standard would constitute valuable data.

Recommendation no. 2:

High priority should be given to the determination of the ^{252}Cf fission neutron spectrum to the best possible precision over an energy range from a few keV up to at least 10 MeV, and to relate this to the U^{235} standard. The quality of the results should be such as to make it a "standard" fission neutron spectrum.

Recommendation no. 3:

It is recognised that a simple Maxwellian form does not satisfactorily fit all observed fission spectra.

Recommendation no. 4:

The shape of the fission neutron spectra of ^{235}U, ^{238}U, ^{239}Pu,-and if possible, higher Pu isotopes - as a function of incident neutron energy should be studied. The fission neutron spectra should be measured over the entire fission neutron energy range from 200 keV to $\sim$10 MeV. Techniques that specifically identify the observed neutrons as being of fission origin should be used in order to

avoid distorting the fission neutron spectrum by elastically and inelastically scattered neutrons. The experimental data should be made in tabular form including the estimated errors.

Recommendation no. 5:

Measurement systems employed in microscopic-fission spectrum experiments should be well calibrated using a controlled monoenergetic neutron source and a standard such as hydrogen or carbon or other methods of equivalent accuracy, e.g. associated radioactivity or associated particle counting manganese bath, etc. The calibration should be inclusive of corrections for multiple processes and other perturbations.

Recommendation no. 6:

Angular distribution measurements of fission neutrons relative to the direction of the incident neutron seem necessary as anisotropies of unknown magnitude may arise from a number of underlying causes viz.

a) effect of anisotropic fission fragment angular distribution
b) effect of a possible anisotropy in emission of neutrons from the fission fragments in the centre-of-mass systems.
c) to discover some possible systematic errors in the neutron spectrum measurements.

Recommendation no. 7:

Particular attention should be paid to measurements of the low energy parts of the ^{252}Cf, ^{235}U and other fission spectra where, in some experiments, the major departures from a simple Maxwellian shape have been suggested. In order to carry out time-of-flight measurements in the low energy part of the ^{252}Cf spectrum, a detector of well known efficiency and smooth energy dependence from 1 keV - 200 keV, insensitive to gamma-rays below 2 MeV, is required.

Recommendation no. 8:

It is recommended that a theoretical understanding of the shape of fission spectra and that of $\bar{\nu}(E_n)$ are very desirable in the long-term. To achieve this, multiparameter investigation of neutron spectra versus fragment mass, $\bar{\nu}(A)$ and fission fragment mass distributions as a function of incident energy should be encouraged.

Recommendation no. 9:

The limited validity of Terrell's T ($\bar{\nu}$) formula must be recognized concerning the possible differences in connection with:

a) the different type of fission reactions, and
b) the different excitation energies.

Notwithstanding this, however, in the absence of any empirical data the broad predictions of Terrell's formula must be regarded as the best available for applied use.

Recommendation no. 10:

It is recommended that data on fission neutron spectra should be transmitted by the experimenter to his local nuclear data centre in numerical form as measured. A hard copy should be sent to the Nuclear Data Section of the IAEA who should correlate them and, at an appropriate time, issue a compilation and review. A detailed technological description of the experimental apparatus should be given and the environment described. A tabulation of the important parameters of the experiment should accompany the data. A clear account should be given of the corrections already applied to the data.

Recommendation no. 11:

Fundamental microscopic integral cross sections (χ_A is the thermal fission spectrum of isotope A)

1. $\bar{\sigma}_f(\chi_{235}, {}^{238}U)$, $\bar{\sigma}_f(\chi_{235}, {}^{235}U)$
   $\bar{\sigma}_f(\chi_{252}, {}^{238}U)$ and $\bar{\sigma}_f(\chi_{252}, {}^{235}U)$

should be determined to an accuracy of $\pm$ 2 - 3%, preferably at more than one laboratory.

2. $\bar{\sigma}_f$ (χ_{235}, ^{238}U) and $\bar{\sigma}_f$(χ_{235}, ^{235}U) should be determined in an alternative approach, using pulsed-source and fast timing technique for background reduction.

Recommendation no. 12:

In order to enable a more reliable interpretation of important integral measurements, absolute fission cross section measurements are required for the following:

a) ^{238}U; E_n = 500 keV - 1.3 MeV; $\Delta\sigma = \pm 10$mb

E_n = 1.3 - 2.0 MeV ($\Delta E = \pm$ 25 keV); $\frac{\Delta\sigma}{\sigma} = \pm$ 3%

$E_n \geq$ 2.0 MeV; $\frac{\Delta\sigma}{\sigma} = \pm$ 2%

b) ^{235}U; $E_n >$ 100 keV; $\frac{\Delta\sigma}{\sigma} = \pm$ 2%

In view of the fact that the ^{235}U fission cross section serves as basic standard for the majority of fission and capture cross section measurements it is highly recommended that the second IAEA Panel on Neutron Standard Reference Data (planned for the second half of 1972) consider the ^{235}U fission cross section as one of the main discussion items.

c) ^{239}Pu; $E_n >$ 100 keV; $\frac{\Delta\sigma}{\sigma} = \pm$ 2%

Recommendation no. 13:

Measurements on ^{238}U inelastic scattering should be extended above 1.5 MeV. Cross sections for individual levels should be reported wherever possible; otherwise cross sections over small energy intervals (250 - 500 keV) would be acceptable. If the degree of angular anisotropy is shown to be small ($\sim$10 - 20%), then energy spectra at one angle (preferably 55°) would suffice.

Recommendation no. 14:

It is recognized that in some circumstances it will be necessary to use detectors based on the ^{6}Li (n,α)T reaction, e.g. Li glass, or sandwich detectors. The group is concerned that this cross section is still inadequately known above 100 keV. For some applications especially below 100 keV, it is necessary to know the triton angular distribution.

Recommendation no. 15:

The age of ^{252}Cf fission neutrons to indium resonance in H_2O should be determined to at least $\pm$ 0.5 cm^2 using an ideal point source.

Recommendation no. 16:

In fission-neutron studies, careful attention should be given to spectral purity and a controlled environment.

Recommendation no. 17:

Wherever possible, detectors employed for both differential and integral measurements should be carefully calibrated with a controlled mono-energetic neutron source. Foils used should be retained and made available for subsequent study and exchange.

Recommendation no. 18:

More detailed information on the experimental equipment and the environment should be provided together with the assumptions used for the analysis of the experiments and (including) the assessment of the corresponding corrections and errors.

APPENDIX D

Agenda
for the IAEA Panel
on Neutron Nuclear Data Evaluation

1. Evaluation activities in Member States, important evaluation needs and the assessment of these needs

2. Status and quality control of evaluations:

   A. Status of existing evaluated data libraries

   B. Quality control - format, consistency and physical checks - influence of macroscopic experiments and adjustments to evaluated data sets

3. Basic rules of neutron nuclear data evaluation:

   A. Comparison of experiments and the criteria used to characterize agreement

   B. Handling of discrepant experimental data

   C. Weighting and fitting procedures

   D. Reference standards used in evaluation

   E. Documentation of evaluations

   F. Assessment of the errors of evaluated data

4. Establishment of computer libraries of evaluated data and associated computer programmes:

   A. Formats, editing and user programmes

   B. Practical problems of representation of evaluated data

   C. Technical problems connected with the exchange of evaluated data libraries - conversion from one format to another

5. Role and efficiency of nuclear theory in evaluation

   I. <u>Resolved and Unresolved resonances:</u>

      A. Present status and formalisms used

      B. Experiences, limitations and achievements in the application of theory to resolved resonance evaluation

      C. Energy and spin dependence and systematics of average resonance parameters

D. Importance of resonance interference and intermediate structure in fission on the Doppler effect

E. Representation of resolved and unresolved resonance data

II. Statistical, Optical and Direct Interaction Models:

A. Availability, quality of and estimated computer time for computer codes

B. Physical adequacy and convenience of data representation

C. Comparison of computer codes - possible reasons for discrepant results

6. International cooperation in evaluation, coordination of evaluation activities and possible improvements in the international exchange of evaluated data.

APPENDIX E

CONFERENCE ON NUCLEAR STRUCTURE STUDY WITH NEUTRONS HUNGARY, 1972.

Organizing Committee
Chairman: Professor L. Jánossy
Secretary: Professor D. Kiss

BUDAPEST
July 31 - August 5

Secretariat:
Department of High Energy Physics
Central Research Institute
of Physics
Budapest, 114. POB 49, Hungary
Telephone: 166-547
Telex: 3673

3rd circular

April 15, 1972

organized an sponsored by the Central Research Institute of Physics and Eötvös Loránd Physical Society,
sponsored by the International Union of Pure and Applied Physics, Hungarian Academy of Sciences, Hungarian Atomic Energy Comission

The Conference will consist of plenary sessions of general interest in the morning and of a few, probably three parallel specialized sessions in the afternoon. The preliminary program of the plenary sessions is given below. The program of the afternoon parallel sessions will be established after the reception of the contributed papers /deadline: 1 May, 1972/.

PROGRAM OF THE MORNING PLENARY SESSIONS

Monday, 31 July /afternoon/

Opening address - L.Jánossy, Vice-president of the Hungarian Academy of Sciences

Introductory talk: I.M.Frank /Dubna/

Nuclear spectroscopy with neutrons
invited speakers /IS/: R.O.Lane /Ohio/ and Yu.P.Popov /Dubna,
summary of contributed papers /SCP/: H.H.Bolotin /Melbourne/

Tuesday, 1 August

Optical model IS: G.R.Satchler /Oak Ridge/
SCP: N.Cindro /Zagreb/
Nuclear fission IS: V.M.Strutinsky /Kiev/
Ultra cold neutrons IS: F.L.Shapiro /Dubna/

Wednesday, 2 August

Statistical model and intermediate structure
IS: H.H.Barschall /Livermore, pending/ and C.Mahaux /Liége/
SCP: H.A.Weidenmüller /Heidelberg/

Thursday, 3 August

Trip to the Lake Balaton

Friday, 4 August

Neutron capture mechanism and non-statistical effects
IS: R.E.Chrien /Brookhaven/ and S.F. Mughabghab /Brookhaven, pending/
SCP: I.Bergqvist /Lund/ and L.M.Bollinger /Argonne, pending/

Saturday, 5 August

New high intesity neutron sources
IS: S.W.Cierjacks /Karlsruhe/, R.Fullwood /Los Alamos, pending/, E.Moll /Grenoble/, Yu.S.Yazvitsky /Dubna/

Closing lecture: Neutron physics, present and future E.Lynn /Harwell, pending /

APPENDIX F

SUBJECTS

for the International Summer School on Nuclear data for reactors and Reactor physics. Bucharest, Romanie, September 1972

Nuclear data for reactors

1. The present stage of neutron nuclear data for reactors and the effect of evaluation errors on the accuracy of reactor parameters calculations.

   - requirement of nuclear data
   - check up and comparison between nuclear data;
   - status of nuclear data libraries;
   - exchange and distribution of nuclear data.

2. The role and efficiency of nuclear models in evaluating neutron nuclear data:
   - nuclear models;
   - the calculation-experiment consistency
   - extrapolation methods.

3. Present stage of knowledge regarding nuclear data for moderators and reactor structural materials :
   - evaluation of data for thermal neutrons, resonance and fast neutrons;
   - isotopes and cross-sections of particular interest.

4. Evaluation of cross-sections for fissionable materials:
   - evaluation methods;
   - comparison with existing data;
   - discordant points;
   - relationships between microscopic and integral sizes.

Nuclear reactor physics

1. Present stage of calculation methods for the parameters of thermal and fast reactor lattices.

2. Experimental methods for the determination of integral data necessary for thermal and fast reactor calculations.

3. Theoretical and experimental problems concerning neutron thermalization and the calculation of thermal neutron spectra.

4. Methods for optimizing and observing the fuel burn up in power reactors.

5. Present problems in fast reactor physics.

 APPENDIX G

International Atomic Energy Agency

Second Panel on Neutron Standard Reference Data

Vienna, 20 - 24 November 1972

INFORMATION SHEET

1. Introduction.

The accuracy and priority requirements for neutron cross sections of structural and fuel element materials needed for the design and safe operation of fast breeder power reactors and for neutron flux dosimetry, necessitate precise knowledge of neutron standard reference data. Towards this end, the objectives of the panel are to quantitatively assess the progress in the field of neutron standard reference data since the first IAEA panel on this topic, define available precisions and identify and seek to resolve outstanding problems. The panel will be asked to report to the Director General of the Agency on the current status of the topics discussed and to recommend guidelines for future work in this field. It is estimated that the size of the panel will be about 20-25 participants.

2. Participation and Organization.

Upon receipt of the name of the participant recommended by your Government, the Scientific Secretaries of the panel, Drs. T.A. Eyer and J.R. Lemley, will then contact the participant from your country regarding the preparation of a written contribution for the panel discussions.

3. Agenda for the Panel.

The draft agenda for the panel (see Annex I) will be discussed at the forthcoming meeting of the International Nuclear Data Committee (INDC) and the provisional agenda will then be transmitted to the officially nominated participant after the INDC has completed its deliberations.

Annex I.

Draft Agenda for the Second IAEA Panel on Neutron Standard Reference Data

Vienna, 20 - 24 November 1972

I. Opening of the Panel.

II. Reports by participants on neutron standard reference data activities in their countries.

III. Review and detailed discussions of: -

A. Light Element Standards.

1. Li-6(n,α) cross section for fast neutrons.
2. B-10 (n,α) and B-10 (n,$\alpha\gamma$) cross sections for fast neutrons.
3. He-3 (n,p) cross section for fast neutrons.

B. Fission and Capture Standards.

1. U-235 fission cross section.
2. $\bar{\nu}$ for Cf-252.
3. Au-197 fast neutron capture cross section.
4. The 2200 m/sec fission and capture cross sections of the fissile nuclides.

IV. Formation of Working Groups to summarize the current status of the topics discussed and to draft recommendations and conclusions of the panel.

V. Discussion of the conclusions and recommendations of the panel and preparation of a draft report to the IAEA.

List of Topics for Nuclear Data Symposium, Paris/Saclay, March 1973.

(a) Nuclear Data for Fission Reactors

- Use and critique of neutron and non-neutron nuclear data evaluations in reactor technology including shielding
- Cost penalties in reactor technology due to inaccurate or inadequate evaluated data
- Services of the four neutron data centres to the reactor community
- Special compilations of practical importance, e.g., of fission product nuclear data

(b) Nuclear Data for Activation Analysis

- Critical judgement and needs for improvement of existing compilations of nuclear data used in the various applications of activation analysis with thermal and fast neutrons and with charged particles
- Economic consequences of deficiencies in nuclear data compilations in various applications of activation analysis
- Special compilations of nuclear data for use in neutron and/or charged particle activation analysis

(c) Status of Compilations and Evaluation of Nuclear Structure and Reaction Data

- Presentation by the Nuclear Data Project, Oak Ridge
- Contributions from compilation and evaluation groups

(d) Nuclear Data in Applications of Radioisotopes

- Use and critique of available compilations in medical (diagnostics and therapeutics), biological, industrial and any other application of radioisotopes

  Contributions on specific evaluations of radioisotope nuclear data (examples: tables by Martin and Blichert-Toft and by Dillman)

(e) Nuclear Data for Safeguards

- The role of nuclear data in destructive and non-destructive measurements in safeguards

- Contributions on the role of nuclear data in safeguards methods involving:

  a. neutron capture γ-rays and fission product γ-rays from spent fuel elements;

  b. delayed neutron interrogation;

  c. passive neutron and γ-ray scanning

(f) Nuclear Data for Thermonuclear Fusion Reactors

- Required nuclear parameters relevant to current fusion reactor conceptual designs

- Evaluation of nuclear data for fusion

(g) Nuclear Data for Space and Accelerator Shielding

- Use of nuclear data in space and accelerator shielding for energies less than 1 GeV

- Evaluation of nuclear data for space and accelerator shielding

(h) Nuclear Data for Astrophysics

- Availability of and need for improved compilations of neutron and charged particle nuclear reaction data for astrophysics

(i) Summary Panel

- What improvements of compilations and evaluations of nuclear data are really needed for applied sciences and technology ?

- How to improve the intercommunication between users, producers, compilers and evaluators of nuclear data ?

APPENDIX I

Proposed Priority Criteria for Nuclear Data Requests in Controlled Thermonuclear Research (CTR)

Priority 1

In general highest (first) priority shall be assigned to those nuclear data upon which some important aspect of CTR is immediately contingent. Specifically Priority 1 shall be assigned to requests for nuclear data which

1.) are required for evaluation of feasibility of a proposed CT reactor concept, or

2.) are required for immediate application of plasma phenomena in a fusion reactor context, or

3.) are related to materials of conceptual importance in CTR, e.g. Li cross sections for tritium breeding, or

4.) are required for an important decision involving allocation of resources or redirection of research effort in CTR programmes, or

5.) are necessary to develop some important aspect of current CTR programmes to a level consistent with progress in other aspects of these programmes.

Priority 2

Priority 2 shall be assigned to nuclear data which

1.) are required for evaluation of materials of high potential utility in current CT reactor designs, or

2.) are expected to contribute to significant progress in CTR or reactor design studies in the near future.

Priority 3

Priority 3 shall be assigned to nuclear data which

1.) are of use in current design studies but are not of crucial importance, or

2.) are not of immediate importance for CTR but which have probability of becoming important as CTR programmes develop, or

Priority 4

Priority 4 shall be assigned to nuclear data which

1.) fill out the body of information needed for fusion reactor technology, or

2.) are of potential interest for CTR but which cannot be assigned more definite priority at present. (This priority will allow the Agency to solicit opinion on specific data and to reflect diversity of response.)

Reactions Important for Study of Reactor Radiations

1. Thermal and intermediate neutron reactions

2000 m/s cross sections resonance integrals and, where it is possible, energy dependent cross sections for intermediate energies for the following reactions:

^{6}Li (n,α)*	^{55}Mn (n,γ)	^{175}Lu (n,γ)	^{139}La (n,γ)
^{235}U (n,f)*	^{103}Rh (n,γ)	^{23}Na (n,γ)	^{186}W (n,γ)
^{59}Co (n,γ)*	^{164}Dy (n,γ)	^{115}In (n,γ)	^{45}Sc (n,γ)
^{238}U (n,γ)*	^{10}B (n,α)	^{176}Lu (n,γ)	^{64}Ni (n,γ)
^{239}Pu (n,f)*	^{58}Fe (n,γ)	^{30}Si (n,γ)	^{98}Mo (n,γ)
^{197}Au (n,γ)*	^{109}Ag (n,γ)	^{63}Cu (n,γ)	^{151}Eu (n,γ)
			^{51}V (n,γ)

2. Fast neutron reactions

Energy dependent cross sections and cross section averages taken over the fission spectrum for the following reactions:

^{6}Li (n,α)*	^{93}Nb (n,n')*	^{46}Ti (n,p)	^{56}Fe (n,p)
^{232}Th (n,f)*	^{238}U (n,f)*	^{59}Co (n,α)	^{93}Nb (n,2n)
^{27}Al (n,p)*	^{58}Ni (n,p)*	^{47}Ti (n,p)	^{93}Nb (n,γ)
^{54}Fe (n,p)*	^{103}Rh (n,n')*	^{48}Ti (n,p)	^{31}P (n,p)
^{237}Np (n,f)*	^{58}Ni (n,α)*	^{55}Mn (n,2n)	^{32}S (n,p)
^{63}Cu (n,α)*	^{115}In (n,n')*	^{27}Al (n,α)	

The reactions marked by an asterisk are of particular importance.

APPENDIX K

A g e n d a

7th Four - Centre Meeting

Brookhaven, 25-29 October 1971

I. Organization and announcements

II. Working policies and coordination of centres
(Progress reports from centres; recommendations for nuclear data committees; use of centres; EXFOR status in general; responsibilities)

III. Trends and developments coming up to the centres
(extension of EXFOR data scope; coordination of evaluation activities; four centre cooperation on RENDA; cooperation with non-neutron nuclear data centres)

IV. EXFOR in detail
(experience with exchange tapes; checking programmes; dictionaries; EXFOR manual; LEXFOR manual for compilers)

V. CINDA in detail
(completeness of literature coverage; CINDA publication and distribution; new CINDA computer system developments; CINDA as EXFOR data index)

VI. Evaluated data in detail
(published index of evaluated data libraries; exchange of evaluated data in technical detail)

VII. RENDA in detail

VIII. Conclusions

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