International Atomic Energy Agency

INDC(SEC)-9/L

365

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

OFFICIAL MINUTES OF THE SECOND MEETING

Brookhaven National Laboratory, USA

2 - 6 June 1969

Compiled by

J.J. Schmidt (Kernforschungszentrum Karlsruhe)
(Executive Secretary)

Aided by

R.E. Chrien (Brookhaven National Laboratory)
(Local Secretary)

and

A. Lorenz (IAEA)

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

Contents

Appendices

There were present

1. Members

A.I. Abramov, Obninsk, USSR
A.S. Divatia, Trombay, India
G.C. Hanna, Chalk River, Canada
G.H. Kinchin, Dounreay, UK (Chairman)
O. Kofoed-Hansen, c/o CERN, Geneva, Switzerland
G.A. Kolstad, USAEC, Washington, USA
T. Momota, JAERI, Japan
J.J. Schmidt, Karlsruhe, Germany (Executive Secretary)
M. Souza-Santos, Sao Paulo, Brazil
Z. Sujkowski, Swierk, Poland
J.L. Symonds, Lucas Heights, Australia

2. Representatives of International Organisations

J. Spaepen, BCMN, Geel, Belgium
V.J. Bell, ENEA/CCDN, Saclay, France

3. Technical Advisers

W.W. Havens, Jr., Columbia University, New York, USA
E.R. Rae, AERE, Harwell, UK
R.F. Taschek, LASL, USA

4. Others Participating

R.E. Chrien, Brookhaven, USA (Local Secretary)
A. Morales Amado, Mexico University, Mexico

5. IAEA Nuclear Data Unit Participants

W.M. Good (Scientific Secretary)
A. Lorenz (Scientific Secretary)

As part-time observers Goldstein from the Columbia University, New York, and Goldberg from Brookhaven attended session 8, Pearlstein from Brookhaven sessions 8 and 9, Higinbotham from Brookhaven and Sanatani from the IAEA session 6b. Joly, France, was absent excused.

Summary of the main Conclusions and Recommendations of the Second Meeting of the Committee

1. Highlights in nuclear data research

$\alpha(Pu^{239})$. The latest available measurements (Gwin et al. /Oak Ridge, Schomberg et al. /Harwell, Czirr/Livermore) show an improved agreement, discrepancies remain around 6 keV and above 10 keV. New preliminary Dubna results by Ryabov et al. will be made available to the Winfrith specialists meeting on $\alpha(Pu^{239})$ end of June 1969.

$\sigma_f(Pu^{239})$. The committee was informed on the status of the Karlsruhe Van de Graaff measurements of the Pu^{239}/U^{235} fission cross section ratio by Pfletschinger and Käppeler in the energy range 5 keV to 1 MeV and on the measurement program of Pönitz with a particular focus on the resolution of the discrepancies of about 15% between capture cross sections measured absolutely and those measured relativeto σ_f of U^{235} in the 150 to 500 keV range.

$\sigma_\gamma(U^{238})$. The only new available results are those due to Moxon from Harwell in the energy range 0.5 to 100 keV. The data agree very well with the earlier measurements of Moxon and Rae, but are still lower than the results of other measurements, in agreement, however, with present expectations from integral measurements.

$\bar{\nu}_{Sp}(Cf^{252})$. A recent NPL measurement by Axton yielded the low value of 3.692 ± 0.023. De Volpi recently obtained an intermediate value of 3.736 ± 0.013. The discrepancies in existing $\bar{\nu}_{Sp}(Cf^{252})$ values are still not resolved.

$\bar{\nu}(Pu^{239})$. Block reported on relative $\bar{\nu}$ measurements in Pu^{239} resonances which reveal on the average 2.5% higher $\bar{\nu}$ values in 0+ than in 1+ resonances. It is planned to extend these measurements up to several keV. Regarding the reliability of the present knowledge of $\bar{\nu}(Pu^{239})$, the thermal value is known to about ± 1%, considering the inaccuracy spread in the $\bar{\nu}$ standard; in the range most important for fast reactors below about 2 MeV $\bar{\nu}(Pu^{239})$ is known to only about ± 2%.

2. Meetings and Panels

a. CODATA meeting 1968

The field of nuclear data was represented by Gove/ORNL, Hjärne/IAEA/NDU and Schmidt/Karlsruhe. The Committee was informed on the highlights of the Conference and felt that it should continue to be represented at CODATA meetings (recommendation in appendix 1.1).

b. Second Conference on Nuclear Data for Reactors, Helsinki, June 1970

The Committee was informed on the progress in the preparation of the Second Conference on Nuclear Data for Reactors to be held in Helsinki in 1970, and in particular on the program and preliminary list of invited speakers for the Conference worked out by the program committee. The proposed program reproduced in appendix 3 was felt to reflect the ideas and discussions at the last INDC meeting. The Committee approved a recommendation to publish all of the papers accepted for the Helsinki Conference (appendix 1.2).

c. Panel topics for 1971, 1972

The Committee agreed on the recommendation to hold a Panel on Methods of Evaluation in 1971. For later the Committee proposes a Second Panel on Standards, possibly to be foreseen for 1972, and a Panel on Resonance Parameter Statistics (appendix 1.3).

3. Dissemination of INDC information

A large subcommittee dealt in substantial detail with this item and formulated a draft report with proposed modifications to the "Methods of Work" for consideration at the next INDC meeting (appendix 6).

4. World request list for nuclear data measurements

The Committee took note of a letter of Weinzierl, present Chairman of the EANDC, to the Chairman of the INDC, which formulates the attitude and the expectations of the EANDC in the question of extending the EANDC request list to a world-wide

request list (appendix 4). The NDU had requested in spring 1969 for contributions to a Non-EANDC request list from member states within its service area and received a few contributions from Brazil, Finland, Bulgaria and Taiwan. For later more definite considerations of this matter the Agency was asked to produce as soon as possible a Non-EANDC request list.

5. Data compilation and evaluation

The Committee was informed on the main conclusions and recommendations of the IAEA Panel on Neutron Data Compilation at Brookhaven in February 1969 which are summarized in the "Report of the Panel on Neutron Data Compilation" published by the IAEA. It is now the task of the four world data centres to consider in more detail the reasonable implementation of these rather diverging recommendations in their work.

Gratifying progress was noted in the inter-centre cooperation. In particular the last four-centre meeting in December 1968 in Vienna succeeded in defining a format for the exchange of data and auxiliary information between the four centres. The next four-centre meeting is planned to be held in the Soviet Union in the fall of 1969; it will deal with problems of putting the exchange format into effect, of the quantity classification and of the physical documentation of experimental data.

Goldstein gave an extensive account on the present status and problems concerning CINDA. The Committee recommended that the Agency assume the responsibility for the printing and distribution of CINDA from January 1, 1971 onward (appendix 1.4).

Several Committee members gave progress reports on recent evaluation activities in their countries. Regarding the exchange of evaluated neutron data the Committee felt that the initial ad-hoc exchanges of evaluated data which were agreed at the last INDC meeting had been successful. It recognized the large demand for evaluated nuclear data for reactor calculations and looks forward to a similar increase in the exchange of evaluated data as in the exchange of experimental data.

6. Standards

The Committee was informed of the present status of the revision of the previous 2200 m/sec evaluation of the thermal constants for the four main fissionable nuclei. The work will be finished about in the middle of July 1969 and then get to be published by the IAEA. Regarding other evaluation possibilities reference was made e.g. to the recommendations of the Brussels Panel on Standards; the NDU was asked for a working paper on evaluation activities to be submitted to the next meeting of the Committee.

7. Foil and target material exchange

The Committee agreed that the establishment of a pool of samples would not be worth-wile because of the impossibility to anticipate the kind of samples actually needed. The gathering by the IAEA of a pool of information on available targets and materials, however, was felt valuable and a corresponding recommendation made to the Agency (appendix 1.6).

8. Safeguards

Sanatani from the IAEA gave a short review of IAEA safeguards activities, Higinbotham from Brookhaven commented on the connection between nuclear data and safeguards. The discussion revealed the discrepancy between the accuracies in cross sections needed for safeguards and the actual very inaccurate knowledge of those data. Referring in particular to the merits of the existing data request lists, the Committee is interested in more specific definitions and priorities of the actual data needs for safeguards, in order to get a clearer idea of the scope of the safeguards data problems and of the help the INDC could offer to solve these problems.

9. Nuclear structure data, Hollander proposal

The Committee took note of the proposal made by Hollander from LRL Berkeley concerning the possible cooperation of the IAEA in the world-wide coordination of the work of the various groups compiling nuclear structure data (appendix 5). The general feeling was that it may be premature for the IAEA to undertake specific responsibilities in this field at the present time. The Committee

agreed on the recommendation that the IAEA plan to sponsor a small symposium no later than 1973 on the collection, compilation, indexing, evaluation and distribution of nuclear (including neutron) data (appendix 1.7).

10. Topical Conference

The Topical Conference was concerned with various contributions on the subjects of neutron capture cross sections and gamma-ray spectra. The program and abstracts of the individual contributions are given in appendix 7.

1. Organization and announcements

1(a). Opening and announcements

Dr. Goldhaber, Director of the Brookhaven National Laboratory, welcomed the participants and expressed his best wishes for a successful meeting of the Committee. The Chairman thanked Dr. Goldhaber for the hospitality of the Brookhaven National Laboratory acting as host for the Committee Meeting.

1(b). Adoption of NNDC minutes

With very minor amendments the edited, but unapproved informal minutes of the first meeting in Vienna in May 1968 were adopted as final. The report of the Scientific Secretary to the Director General of the IAEA on the first meeting was adopted without changes.

1(c). Adoption of agenda

The draft agenda submitted by the chairman was adopted by the Committee with a slight reordering of discussion of the individual items.

1(d). Election of Chairman for next term

From January 1, 1970, on the chair will be transferred to Dr. Kolstad with Dr. Hanna as Executive Secretary. In November 1969 J.J. Schmidt will take over the Nuclear Data Unit from W. Good. He will continue as Executive Secretary up to January 1970. A new German member of the Committee replacing Schmidt will be appointed in due course. Kinchin will prepare the Chairman's report before the end of the year and submit it to the next Committee Meeting for final approval.

2. Meetings and Conferences

2(a). Report on CODATA meeting

The First International CODATA Conference took place in Arnoldshain/Taunus near Frankfurt/Germany from 30 June to 5 July 1968. The field of nuclear data was presented by Gove, Oak Ridge National Laboratory, Hjärne, IAEA/NDU, and Schmidt, Karlsruhe. Schmidt reported briefly on the highlights of the Conference.

The Committee on Data for Science and Technology, also known as CODATA, was established in 1966 upon the suggestion of the International Council of the Scientific Unions (ICSU) to have a Committee taking the lead in providing international coordination and guidance in the field of compilation of data for science and technology. The Committee has met three times, 1966 in Paris, 1967 in Moscow, 1968 in Frankfurt and is now consolidated. For the first two years its Central Office was located in Washington with Dr. Guy Waddington as Director, from 1 July 1968 on it moved to Frankfurt with Dr. Christoph Schäfer as Director.

The Conference last year at Arnoldshain was entitled "On Generation, Collection, Evaluation and Dissemination of Numerical Data for Science and Technology"; it was the first occasion to bring a variety of data compilers from all over the world together. The data fields covered concerned mostly chemical, physico-chemical, thermodynamic, crystallographic data, data on atomic spectra and also nuclear data. All presentations at the Conference were informal and no proceedings were issued, somewhat in the manner of the Gordon Conferences in the US, with which the present Conference had close similarities. Only the opening talk of Professor Rossini, chemist from the University of Notre Dame, on "Data for Science and Technology , from the Past into the Future", an introduction to the activities and organisation of CODATA and a brief review of the Conference both by Dr. Waddington have been published in the First CODATA-Newsletter.

The Conference concerned itself first with review reports on various data compilation activities on international, national and individual laboratory scales. The main contributing countries were the US, USSR, UK, France, Germany, Japan, Canada, Poland and Israel. Among the more important institutions deserving particular mention are

The National Standard Reference Data System (NSRDS) of the National Bureau of Standards in the US, headed by Dr. Brady,

The Thermophysical Properties Research Centre (TPRC) at the Purdue University in the US, headed by Dr. Touloukian,

The Tables Annuelles de Constantes Selectionées in France,

The Crystallographic Data Centre in Cambridge in the UK, headed by Mrs. Kennard,

The Landolt-Börnstein tables edited in the Springer-Verlag by Professor Hellwege,

The Thermophysical Properties Institute at Moscow headed by Professor Gurevich.

All of these reports gave the impression, that there are many activities in data compilation going on in many places, but that there also still exists a lack of coordination and rather much duplication of work. Therefore at the Conference itself, in addition to these review reports, several panels and task groups were formed and met to explore the possibilities of worldwide cooperation in selected areas, in particular

a panel on infrared spectra,
a panel on data for chemical thermodynamics,
a task group on key values for thermodynamics,
a task group on computer use in data compilation.

Furthermore one of the first tasks of the Frankfurt Central Office of CODATA will be to compile and edit a compendium directory survey of continuing data compiling projects and related work.
In the minds of many of the experts present the nuclear data field appeared as a prototype example of good international organisation and cooperation, which has not yet been reached in the other data fields. Therefore, these other data fields for the moment receive much stronger attention from CODATA than the nuclear data field. Schmidt concluded by recommending that both the IAEA and the INDC always be represented by observers at CODATA Conferences. These would be expected as the nuclear data representatives at this Conference, to give a short account of the present state of the nuclear data activities.
This last point was discussed by the Committee and it was generally felt that at least the INDC should continue to be represented at CODATA meetings. A subcommittee consisting of Good, Iavens and Symonds worked out a recommendation which found the approval of the Committee and which is reproduced in appendix 1.1. Schmidt was asked to inform Dr. Schäfer from the CODATA Central Office about this recommendation and to extend to him the formal request to distribute CODATA-Newsletters and the compendium directory survey of CODATA also to INDC members. Bill Iavens also volunteered to relay to the CODATA US Representative to put all INDC members, observers and advisers on the distribution of CODATA publications.

2(b). Future meetings

Good first gave a survey of meetings which are sponsored by the IAEA but which do not arise directly from recommendations of the INDC. This concerns in particular

1. Panel on New Uses of Neutron Generators, held in Budapest, Hungary, 5 - 9 May, 1969,
2. Second Symposium on the Physics and Chemistry of Fission, Vienna, 28 July - 1 August 1969,
3. International Symposium on Neutron Capture Gamma-ray Spectroscopy, Sweden, 11 - 15 August 1969.

The first two meetings are organized by the Physics Section of the IAEA, the third by the Swedish Government with some support of the Physics Section of the IAEA. For 1970 the Physics Section is interested in holding one ore at most two of the following Panels: a Panel on Neutron Instrumentation for Thermal Neutron Inelastic Scattering Research or a Panel on Pulsed Neutron Research or perhaps a Panel on the On-line Application of Computers and Data Handling in Nuclear Physics Research. There was strong "criticism" that the INDC members were not earlier informed on the nuclear-physics data reactor meetings planned by the IAEA, to be sponsored by its Physics Section. So far no major symposium is foreseen in the 1970 Physics Section program. Further possibilities for 1970 are study groups on neutron generators (depending upon the results of the Budapest panel), on the IPA project, or on a regional research collaboration in South America. Good also mentioned the 14th International Summer Meeting of Physicists on "Fast Neutrons and the Study of Nuclear Structure" jointly organized by the Federal Nuclear Commission of Yugoslavia and the Institute "Rudjer Boskovič", Zagreb, to be held in Duilovo, near Split, Yugoslavia, 8 - 20 September 1969.

In the discussion Taschek pointed out the general need of more information on the scope of IAEA Panels. He also expressed some criticism as to the suppression of papers for the Fission Conference, which, according to Rae, might be due to the neighbourhood of the Helsinki Conference. Concerning the selection of Panel members the Chairman recommended that INDC members make proposals to the IAEA after having received more detailed information.

Turning to meetings of direct concern to the INDC Good reported on the progress in the preparation of the Second Conference on Nuclear Data to be held in Helsinki, Finland, in 1970. As date 15 - 19 June is now scheduled. The program and paper selection committee consists of Good (IAEA, Secretary), Rowlands (UK), Schmidt (Germany), Sukhoruchkin (USSR) and Taschek (USA). At the time of

the Brookhaven Panel on Neutron Data Compilation in February 1969 this committee met in New York and Brookhaven and worked out a program and a preliminary list of invited speakers for the Conference. Details of the proposed program are given in appendix 3. The Committee felt this program to be consistent with the ideas and discussions at its last meeting. In particular the program aims at a closer relationship between nuclear data and reactor physics aspects than has been the case at the Paris Nuclear Data Conference in 1966. The Chairman recommended that the title of the Conference be changed to "Nuclear Data for Reactors" in order to better express this relationship. The Committtee felt that the normal IAEA procedure to restrict the proceedings page number to 600 was not appropriate to the Helsinki Conference and approved a recommendation to publish all of the papers accepted for this Conference; this recommendation is given in appendix 1.2. Concerning Panel topics for 1971 and 1972 the Committee agreed on the recommendation to hold a Panel on Methods of Evaluation in 1971. The IAEA is asked to send a proposal for the agenda to INDC members for comments. Further proposals concern a Second Panel on Standards possibly to be held in 1972 and a Panel on Resonance Parameter Statistics. These recommendations are given in appendix 1.3.

3. Dissemination of INDC information

A large subcommittee was set up consisting of Holstad (Chairman), Hanna, Abramov, Kofoed-Hansen, Souza-Santos, Rae, Lorenz, Taschek and Havens, which dealt in substantial detail with this item and formulated a draft report with proposed modifications to the "Methods of Work" for consideration at the next INDC meeting. This report is reproduced as appendix 6 and in the following only brief additional remarks are given.

3(a). Liaison officers

Lorenz commented on the revision of the Liaison Officer system proposed in Appendix A to the NDU progress report. Kofoed-Hansen brought out complaints he had received from OR countries of not being well informed on INDC activities which illustrates the necessity of having liaison officers also in countries not belonging to the NDU service area. Particular approval was given to the proposals put forward by Lorenz to post the Liaison Officers at more frequent

intervals and to use them more efficiently in their capacity of providing the NDU with nuclear data information.

3(b). Distribution and numbering of INDC documents

The present numbering of INDC documents was generally felt to be much too complicated; the subcommittee was asked to simplify the numbering and to try to adopt a scheme similar to that used by the EANDC. Appendix B of the NDU progress report put forward by Lorenz was found to be a good basis for the discussion of the subcommittee on documents distribution.

3(c). NDU information letters

Lorenz drew the attention of the Committee to section C of the NDU progress report as a basis of the subcommittee's discussion on this matter.

3(d). Other Committee business

The Committee was furthermore concerned in particular with the definition of observers and scientific advisers. The conclusions on these questions are also set out in detail in appendix 6.

4. Standards activities

4(a). Report on 2200 m/sec evaluation

Hanna said that the revision of the earlier 2200 m/sec evaluation of the thermal constants for the four principal fissile nuclides actually took more time than anticipated before, but should now be finished about in the middle of July 1969 and then get to be published by the IAEA. One of the major problems was a complete revision of the g-factors of the four nuclides effected by Westcott. Troubles were mainly caused by the continuing discrepancies in the measurements of $\bar{\nu}(Cf^{252})$ and in the α half lives of the specific activities of the α-emitting nuclides. According to Hanna more serious changes compared to the earlier evaluation are to be expected only for Pu^{241}. Good pointed out that the fact that measurements are still continuing would necessitate future revisions. The Chairman said that probably after the report has come out there would not be a large exercise within the next year so that the question of a further revision of the present evaluation could be left to decide upon at the next meeting of the Committee.

4(b). Other evaluation possibilities

Regarding other evaluations Good referred to the recommendations advanced by the Brussels Panel on Standards that an evaluation activity in the area of standard cross sections should be considered as a possibility. Spaepen pointed out that this might be an interesting activity for the IAEA. Schmidt said that because of the turn-over in November 1969 of the head of the NDU no specific commitments would be possible at present and that the whole question of further evaluation activities of the NDU would have to be considered according to the interest profiles of the centre users. For the moment the interestsof the nuclear community, mainly of reactor physicists, seemed to be most strongly focussed on the cross sections of the main heavy fertile and fissile nuclides and on standard cross sections. Also the recommendation of the Brookhaven Compilation Panel that the centres should publish review articles on well defined topics of use for the user community would have to be considered in this context. In conclusion Kinchin asked the NDU for a working paper on evaluation activities to be submitted to the next meeting of the Committee.

4(c). Reports on standards activities from members

Abramov pointed out that the Obninsk Centre does not work in the field of standards, because it belongs to the State Committee on Utilization of Atomic Energy. In the USSR there is another special State Committee on Standards by which all the standards work is done. However, Obninsk is much interested in the results of such work and e.g. has therefore sent a delegate to the 2200 m/sec Evaluation Panel.

Hanna mentioned the Canadian participation in the fall of 1968 in the international intercomparison of Mn^{56}. This was basically a comparison between NPL and AHL techniques which are both involved in Mn-bath measurements of $\bar{\nu}(Cf^{252})$. Actually no systematic discrepancies showed up, and the agreement reached is of the order of 1/2 %.

Symonds mentioned some neutron standards intercomparison between Australia and some other countries which is going to be published e.g. by the National Bureau of Standards.

Ree said that the scattering cross section measurements on B^{10} by Asami and Moxon are now available as Harwell report AERE-R5980 and are being submitted for publication in JNE. The results of these measurements combined with earlie

transmission measurements suggest a deviation from 1/v of the $B^{10}(n,\alpha)$ cross section between 5 and 6% in the region between 10 and 20 keV. - None of the Li^6 cross sections work is so far published. Uttley made a careful σ_T measurement of Li^6 up to 10 MeV and has fitted the region up to about 2 MeV with resonance parameters both of observed resonances and of states known to exist in the Li^7 compound nucleus. The scattering cross section generated from these parameters is in good agreement with published scattering data, the total absorption cross section derived at low energies shows a clear 1/v behaviour, its thermal value is more accurate than previously published work. Around the 250 keV resonance, however, the derived σ_a values are about 20% higher than any of the measured values obtained with Li^6 glasses. The parameters derived from the latter measurements do not fit the scattering cross section. - A B^{10}-Vaseline sphere grey detector is now constructed and will hopefully be used in experiments in the fall of 1969.

Spaepen reported first on Deruytter's 2,200 m/sec measurements for σ_f^{25}. Unfortunately these could not yet be made final because of uncertainties in the determination of the half life of U^{234} on which it is based. New measurements of the U-quantity using isotopic dilution techniques indicate provisory values 1.5 - 2% higher than those found by ordinary chemical methods. Work is continuing, but better sample material is required. Also the results of a round robin for chemical analysis of U-layers, in which the Idaho Laboratory is participating, might help to clarify the situation. Other laboratories could still join this round robin, for which layers could be provided by CBNM. - Comparisons were made of the neutron-induced counting rates of precisely known Pu^{239}-layers prepared by electrospraying and evaporated absolute boron-layers to deduce the fission cross section of Pu^{239} at 2200 m/sec. The amount of Pu^{239} on the layer is obtained from low geometry α-counting and is based on the knowledge of the Pu^{239} α halflife, which seems to be quite well known. A final precision on σ_f (2200 m/sec) of about 0.5% is hoped for. - CBNM participated in an international intercomparison of Mn^{56} and the results confirmed what Hanna has said about it. - The preliminary results (Wash.1968) on the normalisation of the relative U^{235}-fission cross section in the resonance region were considerably improved

by using a solid state detector with much less detector material. Also counting statistics were improved and the normalisation of relative measurements to the absolute values obtained with a chopper was made in a larger energy-region. - Neutron fluxes of the $T(p,n)^3He$ reaction were measured at 1 MeV using the associated particle method, the recoil telescope and the methane proportional counter. The results agreed within 2%. Preliminary results at 500 keV also agree to 2%. - A Li^6-glass-scintillator calibrated by CEN at Cadarache was compared at CBNM at 100 and 400 keV to a hydrogen proportional counter. Results are being evaluated. - Initiated by a publication from Hvehuss and Czibok (Phys. Letters 28B, 585, 196a) a check was performed on the angular distribution of the scattered protons as a function of neutron energy. The authors indicate that a ± 5% variation of the total n-p-scattering cross section may be due to a considerably fluctuating anisotropy at proton scattering angles near 0°. Recoil protons were observed in a telescope counter at several angles. Preliminary results do not confirm the anisotropy. - Accurate determinations of the differential elastic scattering cross sections of carbon from 0.5 to 2 MeV in steps of 50 KeV have been made. Correction calculations have been started. - A stock of natural lithium is being established by calibrated mass spectrometric measurements (for calibration 4 different chemical methods established blends precise to 0.02%). - The measurement of the Be^7 branching ration continues.

Concerning the Hungarian measurements Taschek mentioned recent HBS work with no indication at all of oscillations. Schmidt mentioned recent σ_T measurements of Cierjacks et al. at the Karlsruhe cyclotron between 0.5 and 30 MeV with a statistical accuracy of 0.3 which show the smooth energy dependence as known before. Also Pae confirmed that in recent cyclotron measurements at Harwell no fluctuations could be found.

Divatia said that the standards activity at Trombay is undertaken in the Electronics Division (see Indian progress report, BARC-401, p. 15-17). He mentioned in particular the establishment of a standard thermal neutron flux density for the calibration of thermal neutron detectors, a new method to determine the source self absorption, the comparison of the flux standard with standards maintained at the NBS in Washington and at the Electrotechnical Laboratory in Tokyo by exchanging irradiated gold foils. - Then he mentioned the participation of BARC in the international intercomparison of Co^{60} which was organised by the Bureau International des Poits et Mesures (BIPM) in France.

Havens called the attention to the standardization work done at ANL in the Van de Graaf group of A.B. Smith (see US progress report WASH-1127, p. 5f.). This concerns measurements on σ_T (Li^6), σ_T (C) and on the Li^7 (p,n) reaction. There is also some work done by Pönitz on the measurement of the efficiency of its grey neutron detector.- At Brookhaven a measurement of the parahydrogen cross section is going on in order to improve the scattering parameters of the (n, p) interaction.

Souza-Santos mentioned the fabrication of ionisation chambers filled with known quantities of gaseous UF_6, which will provide the possibility of absolute (γ, f) cross section measurements. Taschek and Hanna drew the attention to the stoechiometric difficulties with UF_6.

Homota reported on the status of the evaluation work on σ_T (C) below 2 MeV by Nishimura et al. and of the review work on σ_T (Fe) below 100 keV by Nakasima and Schwarz/CCDN. The σ_T (C) evaluation work takes into account most of the comments received earlier and is now submitted for publication in an CCDN Newsletter. The σ_T (Pb) review is still incomplete and, after completion, will also appear in a CCDN Newsletter.

5. Progress reports

5(a). Reports from members

Only the more important items will be reported here except those covered under 5(c). For further items and detail we refer to the individual progress reports.

USSR (INDC(CCP) - 3/G)

Since the last INDC meeting the Sixth progress report as a collection of abstracts has been issued and already distributed. The Seventh progress report is in preparation and will be distributed in a few weeks. During this time also the fourth NDIC Bulletin has been issued, translated by the IAEA and distributed. Abramov reported briefly on the experimental work carried out in the USSR in the last year.

Institute of Physics and Energetics, Obninsk: The main work was carried out for fast neutrons above 1 keV. Particular studies were concerned with the measurement of the angular anisotropy of fission fragments originating from U^{238} fission near threshold between 0.8 and 3.4 MeV, the measurement of the

ratio $\bar{\nu}(Pu^{242})/\bar{\nu}(Cm^{244})$, some theoretical work particularly on $\sigma_f(Pu^{239})$, σ_γ measurements on 12 different nuclides ranging from Cu^{63} to Ir^{193} between 10 and 350 keV and for 8 of these nuclides in addition between 0.2 and 3.0 MeV and finally still continuing measurements of inelastically scattered neutrons in the angular range 30 - 150° on Fe, Cu, Mo, Th^{232} and U^{238}.

Kurchatov Institute, Moscow: The main work is concentrated on the resonance range. Muradian carried out σ_T, σ_γ and σ_n measurements on Sn and Ag. Some $\sigma_f(U^{235})$ measurements were performed with samples cooled down to liquid nitrogen temperatures in order to reduce the Doppler effect.

Institute of Theoretical and Experimental Physics: $\sigma_f(Pu^{239})$ is investigated in the thermal energy region. In ternary fission studies yields for masses >4 (Li, Be, B, C) are measured. $\sigma_T(Th^{230})$ has been measured up to 600 eV and average resonance parameters derived.

Joffe Institute, Leningrad: $\sigma_f(U235)$ is measured in the thermal energy region. Furthermore the dependence of the anisotropy of fission γ-rays upon the total energy of the two fragments and the light/heavy fragment mass ratio is studied.

Khlopin Institute, Leningrad: Radiochemical determinations of the yields of 19 rare earth elements between La and Yb from slow neutron fission of Pu^{239} and Pu^{241} were carried out. In ternary fission the emission of long-range particles was studied. Furthermore the neutron spectra from spontaneous fission of Pu^{242} and Cm^{244} were measured.

Ukrainian Institute, Kiev: Angular distribution of polarised neutrons were measured on Mg, Al and Si at 1.5 MeV in the angular range 20 - 143°. Activation measurements were carried out on various isotopes of Cu and W in the energy range from 200 keV up to 3.1 MeV.

Kiev University: (n, 2n) reactions are investigated.

JINR, Dubna: Resonance parameters for various nuclei are studied.

As the translation of USSR documents into English by the IAEA usually takes considerable time, the Committee expressed its desire to have Russian language copies well in advance of the translated documents.

Mexico

Morales first described briefly the measurement facilities available in Mexico. At the National Polytechnic Institute of the Mexico University there are two subcritical reactors. The National University in Mexico City has used a 2 MeV Van de Graaf for some time for σ_T measurements. Recently the Government and the National Nuclear Energy Commission have installed a Nuclear Centre outside Mexico City, which has a Triga Mark III reactor which went critical in

November 1968, and a 12 MeV Tandem accelerator. The Tandem group plans to continue the σ_T measurements at higher energies and to make angular distribution measurements. The reactor group is going to install before the middle of 1970 a double-axis time-of flight spectrometer from Japan for cross section measurements on solids and liquids. Within the National Nuclear Energy commission there is a standards group which deals mainly with energy standards for calibrating counting equipments, pulse height analysers etc. Finally Morales pointed out that outside documents, for the most appropriate dissemination among the people concerned, are best sent to the Library of the Nuclear Centre.

Canada (INDC(CAN) - 4/E, EANDC(CAN)- 38)

Hanna said that recent results of fast neutron activation cross section measurements are going to be written up shortly. The moderator scattering law measurements were sent to all interested parties including the NDU. The fission product program is being pursued by Walker and Mowatt. Preliminary results on Pr^{147} are in good agreement with previous Aldermaston results, but disagree with values deduced from time-of-flight studies which are higher. Durham just finished a re-measurement of the U^{233} half life resulting in a value of about 1.58 to $1.59 \cdot 10^5$ y with an accuracy of better than ±1% which is significantly below the old accepted value of $1.62 \cdot 10^5$ y, but is definitely higher than the value $1.55 \cdot 10^5$ y reported by Keith a few years ago. The program of mass spectrometric measurements of fission product yields at the McMaster University continues. Recently data were obtained for Sn isotope yields from U^{233} thermal and fast fission. In the study of spontaneous fission of Cf^{252} Horvick's previous observation of the anomalously high yield of Xe^{135} was confirmed.

Australia (INDC(AUL)- 5/G)

Symonds reported that the statistical studies of neutron resonance parameters were continued and a number of reports published, the latest one covering average resonance parameters derived from measured capture cross sections in the keV range. Measurements of $\bar{\nu}(E)$ were continued e.g. for U^{235} between 0 and 2 MeV at closely spaced intervals showing no fine structure as reported by other authors and fitting well into a linear energy dependence. More sophisticated measurements on neutrons originating from individual fragments are planned. The studies of keV neutron γ-ray spectra on all elements from Ca to Zn are now completed. While the spectra resemble those for thermal

neutron capture additional γ-rays are observed probably coming from d-wave resonances which are being particularly studied for information on the behaviour of d-wave strength functions. The data are now being compiled and results will be presented at the forthcoming Studsvik and Montreal Conferences. The bright-line scattering measurements at Melbourne University have been completed; the results will come out shortly and will be circulated. Γ_γ measurements on the 132 eV resonance of Co are completed and will be published in a few months.

UK (INDC(UK) - 9/E, AERE - PR/NP 15 and EANDC(UK) - 110)

Rae reported that at Aldermaston work has recently been started on $\bar{\nu}$ measurements for Pu^{239} between 100 keV and 1 MeV. The Harwell Chemistry Division work is concerned interalia with the determination of product yields coming from fast neutron fission with a neutron spectrum resembling that of a fast reactor and being generated by the Harwell booster within the framework of the prototype fast reactor program. Recently in addition to U^{234}, subthreshold fission studies have also been carried out on Pu^{242} and on Th^{230} which latter shows an anomalous spike shape near the threshold. The natural width of this spike with very good energy resolution on the Ibis accelerator could be determined as about 20 keV, the spike itself being explained as a single vibrational level in the second fission barrier minimum predicted by Strutinsky with a rotational band built on it. Measurements with the "black" detector are expected for the fall of this year. For the measurements of capture γ-ray spectra two time-of-flight paths of 10 and 20 m respectively are now available. The Ge detector resolution has been improved to about 8 keV, neutron energies up to a few keV are covered.

BCMN/Geel (INDC(EUR) - 2/E, EANDC(E) 115 U)

Spaepen reported on measurements performed at BCMN/Geel since the last Euratom progress report EANDC(E)115 which covers the activities in 1968. The evaluation of the resonance parameters from the σ_γ measurements on U^{233} using the multilevel shape fit program of F.T. Adler and D.B. Adler was continued. The first run (65 eV - 800 eV) on $\sigma_m(Pu^{241})$ was completed. After separation of the grown-in Am^{241} a second run (0.7 - 100 eV) was started in the beginning of May. In further measurements σ_γ for U^{232} has been determined between 750 eV and 2.4 keV and between 2.5 and 14 keV. The analysis using the area program of Atta and Harvey is made for the range 65 eV to 800 eV; data reduction and analysis for the other runs are in progress. Subthreshold fission

on ^{241}Am and ^{237}Np is being examined. The modified multilevel program "Codilli" of the Adlers has been applied to the $\sigma_f(U^{233})$ cross section data by Cao et al. obtained with the spark chamber fission fragment and the liquid scintillator neutron detectors. For comparison a single level shape analysis is underway. Measurements of $\sigma_f(Pu^{241})$ with the neutron detector started in May 1969. For the study of neutron scattering on fissile isotopes a detector consisting of a boron-10-loaded liquid scintillator with pulse shape discrimination surrounded by a big scintillator tank as anti-fission detector is still under test. Scattering measurements on U^{235} have been performed with the He^3 scattering detector in order to determine the spin of resonances below 100 eV. The analysis of the data is in progress (joint program with CEN-SCK, Mol). Analysis of U^{238} cross section data is in progress. σ_γ measurements on $Mo^{95,97,98}$ and 100 are started between 50 eV and 5 keV. Prompt γ-ray spectra from individual resonances in U^{235} +n have been measured. By comparison of the spectra from resonances with strongly different capture to fission ratios a decision is possible between γ-rays associated with capture or fission. Resonance spin assignments are made on the basis of the relative strength of the 642 keV γ-ray. A paper is presented to Nuclear Physics. Measurements on γ-ray spectra from Mo^{98} resonances are underway. The experimental data for neutron scattering on Pu^{239} (190 to 380 keV) have been completely analysed and other experimental results (1.5 to 5.5 MeV) are available.

<u>OR countries (Austria, Denmark, Greece, Spain, Sweden, Switzerland, Turkey)</u>
Kofoed-Hansen said that the OR countries have skipped one progress report in order to save work during the present change in EANDC meeting frequency (phasing in with the INDC frequency) and thus he could not present an OR progress report this time. He then told that he had a Danish progress report at hand, most of the contents concerns solid state physics. For this reason he only wanted to report on two items: A re-measurement by E. Warming of the asymmetry parameter in the angular distribution of capture γ from the capture of polarized neutrons in Cd. The preliminary result is $A = (-0.6 \pm 1.8)10^{-4}$ and thus it gives no evidence for a non-zero effect in contrast to the results obtained by Abov et al. Secondly he mentioned the use of position sensitive He^3 filled proportional counters by J. Kjems with 1.2 cm space resolution for the detection point permitting at the same time angular and time-of-flight resolution in scattering experiments.

USA (INDC(US) - 10/U, WASH - 1127, EANDC(US) 120 U)

Kolstad reviewed the facility situation in the U.S. At Argonne the new building for the 8 MeV Tandem accelerator headed by A.B. Smith is occupied and the beam handling equipment is being installed. It has a fast critical assembly located externally which can be pulsed with the neutron beam. A large bending magnet delivers beams to any of the following three different flight paths: a scattering chamber at 8 m, an evacuated flight path 50 m long with a 1.5 m diameter large liquid scintillator tank at its end, and one to a total cross section station and a polarization solenoid. Machine delivery is scheduled for June 30; acceptance tests will be finished by September 1, and they will be running by October 1, 1969.

The Brookhaven Double Emperor Tandem is almost complete and will be used for studies of nuclear structure. Completion of acceptance tests is scheduled by December 1969, the begin of operation by July 1970.

The 440 MeV Synchrocyclotron at Carnegie-Mellon University is scheduled to be shut down by June 30, 1969.

The 30 MeV Cyclograaff at Duke University has so far obtained an observed resolution of 29 keV at 15 MeV. By the use of internal cyclotron slits and improved regulation of power supplies even more improvement in the energy resolution is expected. The objective is a maximum proton energy >30 MeV with a spread of 6 keV FWHM. The first neutron experiments will probably be (p,n) measurements of nuclear temperatures as a function of target charge and mass.

The 100 MeV electron linear accelerator under construction at LRL/Livermore will be utilized in at least two basic programs, photonuclear and neutron physics research. The construction phase will be complete about the end of July 1969. The facility will be operational about the end of December 1969.

For the Meson Physics Facility at Los Alamos the basic site work and utility installations are complete. LASL expects 10^{13} neutrons per burst in each 5μsec burst; peak neutron intensities will be 10^{21} neutrons per second. Beginning of operation is scheduled for about spring 1973.

The University of Maryland cyclotron will e.g. accelerate protons to about 140 MeV and alpha particles up to about 190 MeV. So far it has been operated with an internal beam; an extracted beam is scheduled for early June. For the first year the research program will be focussed on (p,2p), (p,pα), (α,2α) and (p,pn) reactions and on π^0 production by the proton and He^3 beams.

For the 400 MeV electron linear accelerator of the MIT full energy operation is scheduled for some time after February 1971. The research program will initially emphasize electron scattering studies. Longer range interests are on expanding

the facilitiy to allow for nuclear structure studies.
The 68 MeV proton linear accelerator at Minnesota University was shut down in January 1969.
For the electron linear accelerator ORELA at Oak Ridge final reliability runs are now in progress; the first measurements will begin by the middle of June 1969. The accelerator has met the following specifications: 30 to 140 MeV electrons, 15 A peak current (2.3 to 24 nsec), 2.3 to 1000 nsec pulse width, 5 to 1000 pulses/sec and 50 MW at 1000 pulses/sec for 24 nsec pulses. ORELA is designed for neutron cross section measurements in the few keV to a few 100 keV energy range mainly for the AEC fast reactor program (LMFBR). In particular measurements of σ_f and α for U^{233}, U^{235} and Pu^{239} and of σ_γ for U^{238} are planned. Three techniques will be used to measure the fission yields: detection of fissic neutrons, fission fragments and fission gammas. Further plans concern high resolution σ_n measurements on enriched isotopes up to about 100 keV, high resolution γ-ray spectral measurements from neutron capture in individual resonances below about 10 keV, σ_γ measurements upon nuclides of interest to nucleosynthesis and of importance to reactors between 5 and 500 keV, fission measurements with aligned nuclei, and transmission and fission measurements with polarized neutrons and polarized nuclei.
With the 50 MeV Cyclotron at Princeton University the program emphasis will be on nuclear reaction studies.
The 220 MeV Synchrocyclotron of Rochester University was shut down in September 1968.
Havens reported on low energy neutron cross section work in the US, referring to the last US progress report WASH-1127. He drew particular attention to the Argonne fast chopper work on capture γ-ray widths and average cross sections. De Volpi and Forges will perform η measurements on U^{235} and Pu^{239} on the Argonne CP-5 reactor after its restarting; furthermore they have a new absolute measurement of $\bar{\nu}_{sp}$ (Cf^{252}) for which no final results are as yet available; a preliminary value is 3.722 ± 0.015. Moldauer/Argonne is conducting a theroretical program on the statistical model trying to match up theory and experiment over the whole energy range of investigation.
V. Sailor/ Brookhaven is working on the magnetic orientation and scattering from magnetic reoriented materials.
At Columbia an enormous amount of resonance results is available, most recently particularly for Eu^{151} and Eu^{153}. As most striking feature in recent fission

studies on U^{235} the most probable number of neutrons emitted by a fission fragment was found to be zero. In recent studies of spontaneous fission of Pu^{240} and neutron induced fission of Pu^{239} the difference in the (average) kinetic energy of the fission fragments was obtained to 0.75 MeV which is about consistent with the neutron numbers emitted in both kinds of fission. A recent redetermination of the 2200 m/sec capture cross section of H yielded the particularly accurate value 332.5 ± 0.9 mb.

From the Los Alros nuclear explosion work an enormous amount of data is available. The Livermore linear accelerator is working particularly on time-of-flight spectroscopy, bright-line and scattering measurements. Havens drew finally the attention to the extensive work going on at RPI being all of direct concern to the INDC.

Taschek reported on fast neutron work in the US and referred mostly also to the recent WASH-1127 report. He first mentioned particularly precise transmission work around the O^{16} inverted resonance at about 2.3 MeV.

At ORNL $\sigma_T(Ca^{40})$ has been remeasured with much higher resolution than in the past at energies up to 2 MeV; due to the high resolution about twice as many resonances were detected than previously. There is also quite a lot of inelastic γ-excitation and elastic scattering work going on between 4 and 8 MeV.

At GGA the $He^3(n,p)$ cross section has been measured up to about 1 MeV with rather poor resolution, but high accuracy. Also a number of σ_γ measurements up to about 700 keV is available; usual statistical theories seem not to fit the data above 200 keV, and a more rapid change of $\bar{\Gamma}_\gamma$ with excitation energy seems to be inferred by the data. Also good resolution σ_T measurements were performed with the electron linac up to about 9 MeV on H and Fe. Furthermore $(n,n'\gamma)$ measurements were made on H and O up to about 16 MeV.

At Idaho Nuclear the wellknown interference dip below the 28 keV resonance in Fe was used to extract a well collimated 3 1/2 ' diameter beam of 25 ± 1 keV neutrons with a flux density of $3 \cdot 10^5$ n/cm^2 sec; this would allow an accurate Mn bath calibration and absolute measurements as with the Sb-Be source.

At Case-Western Reserve University elastic and inelastic neutron scattering is studied on separate isotopes of Fe and Ni up to about 6 MeV. At Texas Nuclear $(n,n'\gamma)$ work is going on; recently H and O were studied at 14 MeV, B^{10} $(n,\alpha\gamma)$ up to 5 MeV, Si and W between 8 and 11 MeV. At RPI Al $(n,n'\gamma)$ was measured up to about 20 MeV.

At the National Bureau of Standards σ_T was measured up to about 4 MeV for Ca, Ti, Fe, Ni and Pb. The use of crosscorrelation and selfcorrelation methods is of particular interest here. At Lockheed σ_T work is done on oriented nuclei

for fast neutrons, in particular on Ho^{165}, in order to study deformation effects.

At Livermore there is at present particular emphasis on integral type measurements, e.g. high sensitivity determination of average energies in various geometries by use of measured reatios Ni(n,p)/Ni(n,2n) or Al(n,α)/Ni(n,2n). Other integral experiments concern the pulsing of spheres filled with liquid O or liquid $(CH_2)_n$, the measurement of time spectra and their comparison with Monte Carlo calculations. The fits obtained are very good inspite of the fact that the calculated response functions of the detectors used might differ from the actual ones. Furthermore photoneutron cross sections on B and H were studied from threshold to about 30 MeV.

At Argonne elastic and inelastic scattering work up to 1.5 MeV on Th^{232}, U^{238} and Pu^{239} is continuing with particular increase in accuracy. Pönitz is emphasizing ratio measurements like $\sigma_\gamma(U^{238})/\sigma_f(U^{235})$ and $\sigma_f(Pu^{239})/\sigma_f(U^{235})$ up to about 1 MeV. This is coupled with measurements of the sensitivity of the grey neutron detector and of the $Au(n,\gamma)/U^{235}(n,f)$ ratio in an attempt to resolve the still existing discrepancies in the available σ_f measurements. Also prompt neutron fission spectra as a function of incident energy are studied on U^{235} and Pu^{239}. Between 0.3 and 8 MeV the spectra obtained are identical. Delayed neutron yields for Th^{232}, U^{235} and U^{238} were investigated as a function of incident neutron energy; no changes have been found up to 2.4 MeV. Also σ_T of carbon has been measured with a resolution of 1 keV between 0.1 and 1.5 MeV with ±1% precision in σ_T.

At Rice elastic scattering measurements on D were repeated at 5, 7 and 9 MeV; further work is planned for H and O.

At Los Alamos McNelly and Shunk found in the bomb results for $\sigma_f(Cm^{244})$ the same intermediate structure as observed for other nuclides, getting clusters of sharp resonances below 5 keV. There is evidence for a change in the fission fragment angular distribution above about 0.6 MeV. Farrel completed the analysis of $\sigma_f(U^{232})$ up to about 6 keV a detailed account of which is given in the LA progress report; there is no conclusive evidence of intermediate structure in U^{232}. Good agreement between theory and experiment and very good correspondence between neutron induced and (d,pf) and (t,pf) studies was recently obtained when the double-hump fission barrier shape is taken into account. Taschek finally commented on the recent discrepancies in the U^{235} prompt neutron fission spectrum, referring back to the wellknown measurements by Grundl. The

discrepancies are really large as can be seen e.g. from a comparison of observed and computed spectral indices. For fission spectrum neutrons a $\bar{\sigma}_f(U^{235})/\bar{\sigma}_f(U^{238})$ ratio of 3.85 ± 6% is observed, whereas the computed value using the older accepted fission spectrum and ENDF/B σ_f data is 20% larger, i.e. 4.60 ± 4%. Similar discrepanices are observed for the same spectral index in bare (13%) and reflected U^{235} critical assemblies (14%) and also in Pu^{239} critical assemblies. As reason for these discrepancies it is claimed, particularly by Grundl, that the old measurements of the fission spectrum e.g. by Cranberg, Moreson, Stewart, Rosen and others are not correct and should be harder with an average energy of about 2.2 MeV instead of the earlier 1.94 MeV. Taschek pointed out, that it is rather unlikely that the fission spectrum is wrong at high energies, because the comparison of three "best" sets of data obtained with different methods due to Barnard et al. from Harwell (E_n =100 keV) Cranberg (time-of-flight, E_n=5-90 keV) and Rosen (photoplate, thermal), with arbitrary, but consistent normalization to the Harwell data, between 200 keV 8 MeV shows very good agreement. Thus it might be, that the fission cross sections are wrong; Taschek underlined strongly the necessity of reconciling the presently available partly discrepant fission cross section measurements. He also said that Grundl is going to the National Bureau of Standards in particular to repeat some of his fission plate work with the HBS reactor. Good pointed out that the INGFR had suggested a panel on the fission spectrum question. Symonds said that they also observe similar discrepancies between measured and computed fission ratio values; but suggested as alternative reasons incorrect inelastic and elastic scattering cross sections used in the calculations leading to incorrect neutron spectra. Taschek pointed out that the discrepancies are not only observed for critical assemblies, but also in "clean" measurements, in which the same fission plates were used for the measurements of the fission spectrum and of the fission cross section ratios.

Brazil (INDC(BZL)-2/G)

Souza-Santos pointed out that the last year's contribution of Brazil to DASTAR and CINDU was about 3200 data points. These pertain e.g. to time-of-flight σ_T measurements on polycrystalline Fe in the wave length range between 0.75 Å and 5.44 Å. Further work concerns the influence and elimination of the effect of contamination due to second order reflection neutrons in transmission measurements with the crystal spectrometer; for this purpose σ_γ(Au) was measured between 0.01 and 1 eV using monochromatic Al and Ge crystals. With the slow chopper and time-of-flight spectrometer measurements were made on slow neutron

scattering in H_2O, polyethylene and several methyl compounds for neutron wave lengths between 0.8 and 10 Å at room temperature. The resolution changed from 0.03 Å at 1 Å at 10 Å. H_2O σ_T results were found to be in good agreement with previous results. With the same apparatus also σ_T measurements were performed on UO_2 between 1 and 8 Å; the obtained data were about 10% higher than previously accepted values due to impurities. Souza-Santos mentioned this example in order to underline the need of developing countries for high purity samples. He also mentioned calculations of the efficiency of a long counter used for measurements of the ratio of the number of neutrons emitted in photofission of natural and enriched uranium and thorium and in the (γ,n) process. Furthermore Monte Carlo methods were used in order to calculate the resolution of a magnetic spectrometer with due consideration of second and higher orders of approximation; this spectrometer is used for internal capture studies.

Finally photofission cross section studies are performed on Th^{232} and U^{238} near threshold. Previously these were mainly determined by using the bremsstrahlung from betatrons and synchrocyclotrons. Analysis of the existing data shows large discrepancies between different measurements of the order of 50% and more. In the last year some $\sigma_{\gamma f}$ results for U^{238} were published by Manfredini et al. from Casaccia and Zürich obtained by using monochromatic capture γ-rays. In Sao Paulo similar measurements were performed; the results compare favourably with previous betatron work published at the 1958 Geneva Conference, but show large disagreement with the results of Manfredini et al. Souza-Santos emphasized the importance of further photofission work in the interest particularly of fission theory and safeguards.

Japan (INDC(JAP)-3U and Annex, JAERI-Memo 3305

Momota distributed a listing of the CINDA entries relating to recent Japanese neutron research described in the above progress report. An appendix to this report summarizes more recent work at Tokai. Momota mentioned in particular direct measurements of nuclear reaction times by use of the blocking effect in single crystals, scattering studies on Fe between 1.5 and 3 MeV, analysis of angular distributions of fast neutrons scattered by Al, Si, S, Cu and Zn, studies of γ-rays from the $Cs^{133}(n,n'\gamma)$ reaction, neutron total cross section measurements on La, Pr and Re, studies of the decay scheme of I^{134} and, empirical correlation for the spontaneous fission half-lives.

Regarding new facilities two HVEC Van de Graaff accelerators have been installed The two-MV machine at Nagoya University will mainly be used for reactor physics

studies. The four-MV machine at the Tokyo Institute of Technology will partially be used for nuclear data studies. The JAERI electron linac has become so old that it is going to be replaced by a (nearly) new machine of 32 MeV and 500 mA within 10 months.

India (INDC(IND)-8/G, BARC-401)

Divatia commented first briefly on the participation of India in the IAEA activities regarding CINDA, DASTAR and the submission of progress and other reports. He also mentioned a request received through the IAEA to join the ENEA Computer Program Library at Ispra and to nominate a liaison officer for this purpose. Regarding the measurement program in the Nuclear Physics Division the measurements of K x-rays emitted from U^{236} fission fragments were recently completed. The number of x-ray yield per fission is found to be 0.08 ± 0.01 for the light fragment and 0.30 ± 0.02 for the heavy fragment group. At the Van de Graaff Laboratory the (α,n) and (p,n) reaction work using a 4π counter has been continued, S^{32}(n,α) cross section data have been obtained from results on the inverse reaction. (p,n) cross sections have been measured for Ca^{48} between 1.940 and 2.040 MeV in 0.5 keV steps; the resonance seen in this range can be interpreted as the analog of the Ca^{48} ground state. Also the V^{51}(p,n) cross section has been measured; the absolute values obtained have an accuracy of only ± 13%, which will be improved by recalibration of the neutron counter used. At the Radiochemistry Division work has been done on the measurement of recoil ranges in thermal neutron induced fission of U^{233} and Pu^{239}.

Regarding new facilities the project of the variable energy cyclotron which was approved in January 1968 has been continued. The main contracts for the magnet and the coils have been almost finalized with Indian industrial firms. Most of the design studies necessary for the ion source, the deflector, the RF-system done at Trombay are almost completed. It is planned to install an on-line computer built at Trombay named TDC-12 (Trombay Data Computer), whose specifications are somewhere between a PDP-7 and a PDP-9. In the Indian Institute of Technology at Kanpur a 2 MeV Van de Graaff is going to be installed. The Punjab University at Chandigarh has acquired the 6 MeV cyclotron of the Rochester University.

Federal Republic of Germany (INDC(GER)-6/E; see also EANDC(E)115U)

The progress report submitted by Schmidt is largely the same as that making part of the last Euratom progress report (EANDC(E)-115"U"). Concerning the Van de Graaff at Karlsruhe the high resolution resonance spectroscopy work was continued with measurements on Sc^{45} between 20 and 300 keV with a resolution <0.2 nsec/m; the data are in the process of being analysed. The analysis of the former data on Fe^{57} and Cr^{53} is not yet completed. In the case of Fe^{57} inelastic scattering competition to the 14 keV level had to be taken into account in the multilevel analysis of the measured total cross section. The computer program for the analysis of the Van de Graaff σ_γ results in terms of s,p and d wave strength functions has been modified in order to take into account inelastic scattering competition; revised p and d wave strength function values for 8 materials are given in the progress report. Very recently σ_γ measurements on Tl and Ce of interest in nucleosynthesis work have been completed in the energy range 10 - 200 keV. The experimental data have still to be corrected for multiple scattering and selfshielding and will afterwards also be analysed in terms of S_o, S_1 and S_2.

Concerning more recent work of Cierjacks et al. with the cyclotron the 190 m path is now completed. First measurements with a resolution of 5 nsec/km have just been completed on O and Al in the energy range 0.5 to 30 MeV. Particularly in Al the high resolution revealed about three times as many resonances than were known before. Also recently the first σ_γ measurements on a separated isotope in the above energy range were performed, namely on a 30g sample of N^{15}. These measurements are complemented by angular distribution and polarization measurements performed by Zeitnitz et al. on the Hamburg 3 MeV pulsed Van de Graaff in the energy range 0.5 to 3 MeV. These measurements will permit a complete analysis of the resonance structure of the cross section below 3 MeV and thus a comparison with microscopic theory and shell model predictions e.g. by Weidenmüller et al. at Heidelberg.

Taschek pointed out systematic discrepancies between the Karlsruhe cyclotron data and previous work, noticeably that of A.B. Smith and Barschall, the cyclotron data being found systematically higher than previous results. Schmidt promised to find out about these discrepancies with Cierjacks.

Schmidt then mentioned the measurements of the mass and time dependence of the number of delayed neutrons by Armbruster et al. from KFA Jülich. Basing on Keepin's values for the total number of delayed neutrons per fission (1.58 ± 0.05 n/100 f) they could assign yields of 1.05 ± 0.06 and 0.53 ± 0.04 n/100 f

to the light and heavy fission products respectively. A still unidentified fraction of the delayed neutron yield might originate from Y^{98} and Y^{99} as precursors.

At Frankfurt University the $Li^6(n,p)$ reaction has been studied by Bass et al. between threshold (3.2 MeV) and 9 MeV and the $Li^6(n,n'\gamma)$ reaction for E_γ = 3.562 MeV between threshold (4.2 MeV) and 7 MeV.
At Hamburg University Bormann et al. are continuing the study of energy and angular dependent excitation functions for the (n,α), (n,p) and $(n,2n)$ processes; recently obtained data are given in the progress report.

At Geesthacht recent fast chopper total cross section work of Jung et al. was concerned with resonances of Cs^{133} and natural Ru. Runs on the isotopes Ru^{100}, Ru^{101}, Ru^{102} and Ru^{104} are planned.

Poland (INDC(POL)-2/G)

Sujkowski first reported on (n,n') and $(n,2n)$ work performed with a 2.5 MeV Van de Graaff accelerator at the Institute for Experimental Physics of the Warsaw University and at the Institute of Nuclear Research in Warsaw. Particular studies were concerned with the (n,n') and $(n,2n)$ reactions on Y^{89} and with the $(n,2n)$ reaction and isomeric cross section ratios for Se^{74}, Zr^{90} and Mo^{92} in the neutron energy range of about 13 to 18 MeV. Systematic deviations between experiment and statistical theory calculations were observed which may be due to the fact that in the calculations gamma decay competition was not taken into account.

The ternary fission studies at the Institute of Nuclear Research, Swierk were continued first with the investigation of prompt neutrons accompanying spontaneous ternary fission of Cf^{252}. It was found that the angular distribution of prompt neutrons are very similar in binary and ternary fission, the ratio of the number of prompt neutrons emitted from the light fragments to that emitted from the heavy ones was determined to 1.1 ± 0.1. Further ternary fission studies were concerned with the measurement of the relative yields of protons and tritons with respect to the α-particle yield in coincidence with prompt neutrons from thermal neutron induced fission of U^{235} and spontaneous fission of Cf^{252} and, with the measurement

of the relative intensities and energy spectra of H^1, H^2, He^3, He^4, He^6 and He^8 particles from thermal neutron induced fission of Pu^{239}.

Regarding progress in solid state physics Sujkowski mentioned the development of a computer program for the calculation of the frequencey distribution function of crystals based on the so called "sampling method" in a cooperative effort of the Institute of Nuclear Research, Swierk and the Institute of Emerimental Physics of the Warsaw University.

5(b). Reports from other countries (NDU)

Good mentioned first a letter sent out in March 1969 to about 17 liaison officers of IAEA member states not direcly represented in the INDC which asked in particular to forward progress reports on research going on in the respective areas concerned. Answering reports were received only from South Africa (INDC(SAF)-1/G), Israel (INDC(ISL)-1/G), Pakistan (INDC(PAK)-1/G) and Bulgaria. The reports from the first three countries have been distributed. The Bulgarian report lists briefly measurements of diffusion constants for heterogeneous water lattices, plans for new facilities and experiments for investigation of neutron diffusion and thermalization constants in heterogeneous water lattices and crystalline moderators at low temperature by pulsed methods and compilation activities on nuclear levels.

5(c). Reports on important cross sections

$\alpha(Pu^{239})$

Abramov mentioned new preliminary Dubna results by Ryabov et al. which would be made available to the Winfrith specialists meeting on α spc sored by the IWGFR.

Taschek mentioned that the most recent results of Gwin et al. differ slightly from the previous ones. They are normalized to α = 0.357 at thermal and α = 0.66 at 0.3 eV. The internal normalization of fission foils against fission chamber yields a standard error of about 3% in σ_f/σ_a. The data of Czirr from Livermore are still less certain than those of Gwin et al. Integral α measurements performed at Argonne by Till et al. to be reported at the forth-

coming BNES Conference on Fast Reactor Physics in London support mainly Gwin's α results.

Rae pointed out that the α curves in the progress report do not represent the latest state of the art. More recently the apparatus has been improved, the ratio of the detector sensitivities for γ-rays from fission and from capture has been lowered, the whole experiment has been rerun with three sample thicknesses and with greater care in the background determination. The agreement now between the Harwell and ORNL/RPI data is improved except for energies around 6 keV and above 10 keV in the latter region the Harwell data being still systematically much higher than the ORNL/RPI data.

Kinchin pointed out that at Winfrith from the analysis of quite a number of critical assemblies (k_{eff}, reaction rates and spectrum) the Pu α values should be higher than in the unadjusted FGL4 data set.

Schmidt referred to a recent review of the α(Pu) problem he had to prepare for the German Atomforum Reactor Conference at Frankfurt in April. The conclusions were, that below about 2 keV the various existing data sets are in rather good agreement, whereas between 4 and 7 keV and above 10 keV there are still systematic discrepancies. He also outlined briefly that the systematic fluctuations observed in the energy dependence of α below about 2 keV are clearly correlated to inverse fluctuations observed in σ_f measurements at Saclay and Harwell and can quantitatively be understood as being due to intermediate structure in the 1+ s wave fission cross section component.

Hanna drew the attention to a slight disagreement between Gwin's thermal normalisation value of 0.357 and the present least squares best value of 0.3646 ± 0.0046 obtained in the IAEA's 2200 m/sec work.

$\sigma_f(Pu^{239})$

Schmidt reported on the measurements of the Pu^{239}/U^{235} fission cross section ratios by Pfletschinger and Käppeler with the Karlsruhe Van de Graaff in the energy range 5 keV to 1 MeV. In this experiment fissions were recorded by coincidence measurements of the two fission fragments. The fission foils used were as thin (100 μg/cm^2) as to reduce the α pile-up from the radioactive decay of the isotopes involved, to separate clearly α and fission fragment pulses, to suppress wrong coincidences and to be able to registrate more than 90% of the actual fission events. For the final results the chemical determination of the total amount of fissionable material contained in the

sample by BCMN/Geel has still to be awaited. The accuracy of the final results is expected to be between ± 2 and ± 3%.
Muschek reported on recent work of Pönitz which is partly focussed on measurements to resolve the discrepancy of about 15% observed between capture cross sections measured absolutely and those measured relative to σ_f of U^{235} in the 150 to 500 keV energy range. A recent check of the efficiency curve of the grey neutron detector yielded agreement with the calculated curve within 3%. The detector has been applied also to measurements of the $Li^7(p, n)$ cross section the results being in good agreement with the graphite sphere results of Macklin and Gibbons. A measurement of the Be^7 branching ratio has been carried out; data are presently being evaluated. A change of this quantity would affect Pönitz's absolute values. The $\sigma_\gamma(Au)/\sigma_f(U^{235})$ cross section ratios have been checked for energies above 150 keV. Preliminary results are in agreement with previously reported ratios. $\sigma_f(U^{235})$ has been measured by two independent methods, a) the flux integration method using a vanadium-bath to obtain the shape of the cross section and $MnSO_4$-bath calibrated Sb-Be (23 keV) and Na-Be (960 keV) sources to obtain absolute values, b) the associated activity method, using a spherical counter and the $V^{51}(p,n)\ Cr^{51}$ source as well as a 4π fission counter and the $Li^7(p,n)\ Be^7$ source. Some other check measurements have been carried out relative to H(n,n) (shape only) and relative to $Li^6(n,\alpha)$. Data will be available within one year.

$\sigma_\gamma(U^{238})$

Rae pointed out that the results of the recent measurements of Moxon between 0.5 and 100 keV had been written up (AERE-R6074, EANDC(UK)-113"AL"). The measurements used highly depleted U^{238}. The data agree very well with the earlier measurements of Moxon and Rae, but are still lower than the results of other measurements, in agreement with present expectations from integral measurements.

$\bar{\nu}_{Sp}(Cf^{252})$

Rae mentioned the recent NPL measurement by Axton which yielded the low value of 3.692 ± 0.023 which is to be compared e.g. with the old boron pile value of 3.713 ± 0.015. De Volpi recently obtained an intermediate value of 3.736 ± 0.013. The discrepancies in existing $\bar{\nu}_{Sp}(Cf^{252})$ values are still not resolved.

$\bar{\nu}(Pu^{239})$

Schmidt mentioned that Condé had plans for measurements of $\bar{\nu}$ averaged over various fast neutron spectra of the Swedish FRO facility. Block reported on relative $\bar{\nu}$ measurements in Pu^{239} resonances which reveal on the average 2.5% higher $\bar{\nu}$ values in 0+ than in 1+ resonances. It is planned to extend these measurements up to several keV. Symonds asked whether the existing information is felt to be adequate or whether more measurements are needed, e.g. from the keV range upwards. Schmidt pointed out that to the best of his knowledge the thermal value is known to about ± 1%, considering the inaccuracy spread in the $\bar{\nu}$ standard, and that in the range most important for fast reactors below about 2 MeV $\bar{\nu}$ (Pu^{239}) is still known to only about ± 2%. This situation is still unsatisfactory in view of the fact that the k_{eff} of a reactor is directly proportional to $\bar{\nu}$.

6. INDC related activities

6(a). Foil and target material exchange

Hjärne from the NDU outlined the situation of the IAEA regarding the question of samples for nuclear data measurements (see NDU progress report, appendix C, for details) underlying particularly the importance of this question to developing countries and asked for specific recommendations of the Committee. There was general agreement that the establishment of a pool of samples would not be worth-while, because it can not be anticipated what kind of samples will actually be needed; a pool of information on available targets and materials, however, produced by the IAEA was felt valuable. It was also felt advisable that the target item be only taken up again at the next INDC meeting, provided that specific requests with backing-up information are submitted to the Committee for consideration. The final recommendations of the Committee to the IAEA in this matter are set up in appendix 1.6.

6(b). Safeguards

Sanatani from the IAEA first gave a short review of IAEA safeguards activities. Since the last INDC meeting there has been some reorganisation and expansion in these activities. Dr. Rudolf Romatsch, Managing Director of Eurochemic at Mol, Belgium, has been appointed the new Inspector-General for the Department of Safeguards and Inspection. There are now two Divisions in this De-

partment, the Division of Operations and the Division of Development, each comprising a few sections. The Division of Operations has the responsibility of implementing the safeguards agreements entered into by the Agency on the one hand and different member states on the other. This includes carrying out of inspections and examination of records and reports. The Division of Development is concerned with the improvement of methods and techniques of safeguards and systems analysis. There are at present about 25 to 30 inspectors approved by the Board of Governors. The Agency at present is very seriously trying to find new procedures for safeguards as well as improve the existing ones which will be effective, credible, economic and unobtrusive. Sanatani mentioned three problem areas where there might be common interest between nuclear data specialists and people interested in developing safeguards techniques.

1) The amount of plutonium produced in operating power reactors can be calculated by various burnup codes. These codes use neutron cross sections over the entire energy range for uranium and plutonium isotopes. For accurate prediction of plutonium buildup as a function of irradiation, there is a need for improvement of methods of calculation as well as in the fundamental cross section data, e.g. σ_a and σ_f for Pu isotopes in the kilovolt range.

2) Non-destructive assay of nuclear materials for practical cases is still one of the outstanding problems of safeguards and various old and new techniques are constantly being tried out. Some of the new methods (active interrogation techniques) involve the study of delayed neutrons produced as a result of neutron and gamma fissions, in order to identify and estimate the different isotopes of interest. Therefore, improvement in the existing data on delayed neutron yields, energy spectra and decay time, would facilitate the assay of materials by these methods.

3) In passive gamma assay of samples with the help of sensitive Ge(Li) detector coupled to multichannel analysers, one encounters a very large number of γ-lines (peaks). One of the ways of making their interpretation more reliable, would be to improve the existing data on γ decay schemes of at least all of the heavy isotopes likely to be found in the sample.

Higinbotham from Brookhaven commented on the connection between nuclear data and safeguards. He mentioned first a small group at Brookhaven working on technical studies and providing technical advice to the USAEC Office of Safeguards at Washington. The importance of safeguards is illustrated by the rapid growth of nuclear industry, which in the US in 1975 will lead to about 16 000 kg of Pu retrieved from the fuel reprocessed in that year. Three problems are pursued on national and international scales, i.e. containment, maintenance of material balance by appropriate measurements and surveyance of the heavy materials concerned, the second point being the most technical problem. At present almost all measurements are made by taking samples and performing chemical or mass spectrometry analysis. This is difficult and time consuming, it might be even impossible to take samples representative of the material concerned. This underlines the need for non-destructive or physical types of measurements of the γ-rays or neutrons emitted. These, however, depend heavily on a better knowledge of the physical properties of the heavy isotopes and their fission products. For neutron and γ-ray interrogation in particular many more epithermal and fast neutron cross sections and fission product distributions and capture properties have to be known. For details of such needs Higinbotham referred to the report WASH-1122, which represents a collection of abstracts on research and development work in the field of safeguards taking place at a number of institutions, e.g. at the IAEA and at Karlsruhe, under the auspices of the USAEC.

The following discussion revealed the discrepancy between the accuracies in cross sections needed for safeguards and the actual very inaccurate knowledge of those data. Higinbotham pointed out that the reprocessing in the US would be going through three or four reprocessing plants; thus each material stream is very large and one would like to know the throughput through any major plant to at least 1%. Kolstad and Kinchin expressed a general feeling of the Committee, when they asked for more specific definitions and priorities of the actual data needs for safeguards, referring in particular to the merits of the existing data request lists, in order to get a clearer idea of the scope of the safeguards data problems and of the help the INDC could offer to solve these problems.

6(c). Hollander proposal: properties of nuclear states

Good introduced the proposal made by Hollander from Lawrence Radiation Laboratory, Berkeley, concerning the possible cooperation of the IAEA for establishing closer communication among the major worldwide groups compiling data on nuclear level schemes and radioisotopes. This proposal and the pertinent letters are reproduced as appendix 5. Long discussions brought out the general feeling that it may be premature for the IAEA to undertake specific compilation or coordination responsibilities in this field at the present time. The conclusions and recommendations set out by a Subcommittee consisting of Kolstad, Abramov, Lorenz and Kjärne and listed in appendix 1.7 reflect very well the main points of the discussions and render further remarks on these discussions unnecessary.

7. Topical Conference on neutron capture cross sections and γ-ray spectra

The Topical Conference was held on Wednesday, June 4, in the Berkner-Hall at Brookhaven. Abstracts of the various contributions are given in appendix 7.

8. Compilation

8(a). Report on Brookhaven Compilation Panel

Good reported briefly on the IAEA Panel on Neutron Data Compilation at Brookhaven in February 1969. As the data centres so far had no explicit terms of reference nor had been recognized in any formal way, the Panel served a particular purpose of providing guidelines for the future development of the centres. The results of the Panel are being reproduced in two forms. All papers submitted are published as technical IAEA report IAEA-111. In addition there is the "Report of the Panel on Neutron Data Compilation" also published by the IAEA which summarizes the conclusions and recommendations of the Panel. One of the main purposes of the Panel was to serve as a spring-board for publicizing the existence and achievements of the four data centres. Lorenz drew attention to the recommendations contained in the Panel report which had to be looked into in more detail regarding their implementation in the work of the centres. Schmidt underlined the diverging nature of these recommendations reflecting in particular the diverse interests of the centre users. He pointed out that the recommendations had to be considered with different weights of importance; the most important recommendations concerned

improvements and reasonable unification in the CINDA and SCISRS quantity classification, the development of a scheme of physical characteristics of the experiments underlying the data stored in the data files, the appropriate publicizing of the centres' activities and a definition of those data fields considered by the centre users as being most important for compilation at present and in the near future, among these in particular heavy element cross sections and standard data.

8(b). Report on "four-centre" activities

8(b)(i) Inter-centre cooperation

Good first commented on the gratifying progress in the inter-centre cooperation. He mentioned especially a workshop on SCISRS-II soft ware programs in June 1968 at Brookhaven. Unfortunately Obninsk was not represented, but was kept fully informed of the results. This workshop was a good preparation for the four-centre meeting in December 1968 in Vienna which succeeded in defining a format for the exchange of data and auxiliary information between the four centres and submitted a paper to the Brookhaven Compilation Panel which found good acceptance. The next four-centre meeting is planned to be held probably at Obninsk in the fall of 1969 and will deal with problems of putting the exchange format into effect, of the quantity classification and of the physical documentation of experimental data.

8(b) (ii) CINDA

Goldstein commented on the present status and problems concerning CINDA. CINDA 68 was printed through the efforts of CCDN, and appeared during the Summer of 1968, delayed to some extent by the civil disturbances in France. A supplement, containing only new entries, was issued in January, 1969; the actual printing being done in the U.S. DTIE facilities. The most recent cumulation, CINDA 69, represents the status of the library as of April 15, 1969. It has again been printed in France, and should be ready for distribution soon.
The major problem confronting CINDA remains the consolidation of the numerous entries representing various stages of one and the same experiment. No method has yet been proposed for performing this consolidation.

that does not require the intervention of people knowledgeable in cross section work. The most promising procedure yet turned up is to distribute to the various cross section measuring groups those entries relating to their own experiments. They have been asked to indicate which entries should be consolidated or eliminated. On the whole, the cooperation has been excellent, considering the magnitude of the task. CINDA 69 reflects some of the "cleaning up" resulting from these efforts, and further reviews along these lines will be exploited intensively for the next cumulation.

The Division of Technical Information, which has the responsibility for the operation of the U.S. share of CINDA, has generously provided suppor for an extensive overhaul of the computer handling of the CINDA library in FY 1970. One of the goals of the overhaul is to convert from 7094 to 360 operation. But it is proposed to take advantage of the process to consider expansion and modifications of the format. Above all, it is desired to provide for greatly speeded-up and expanded sorting and retrieval capability. It is hoped in this manner to provide for automatic linkages with data libraries, and for indications in the printed output that the indexed data are in the libraries.

It is clear the the new version of CINDA will call for more information to be displayed per line of entry. Further, despite the best efforts at "cleaning-up", the number of entries will continue to grow. To ease the consequent expansion of the size of the printed volume, the possibilities of a computer-composed output are being examined through the kind offices of NBS. Using computer-composing machines at the U.S. Government Printing Office, promising experiments have produced printed output looking very much like standard "hot-type" printing even though the input was from the restricted 48 character BCD set. The greatly increased readability opens the possibility of putting more characters in a line and more lines on a page. Some sort of development on this line seems imperative for CINDA to accomplish the functions expected of it. However, computer-composing requires access to very specialized machines, a circumstance which may cause difficulties when the responsibility for printing CINDA is transferred to IAEA.

The results of the following discussion on CINDA printing can be summarized as follows. The Committee is appreciative of the Agency's careful study of the proposal that it print and distribute CINDA.

After considering various new developments in regard to CINDA and

in particular the purpose it is designated to serve, the Committee concluded that:

a) Given the fact that the application of automatic type-setting is being investigated, the choice of page size is premature at this time.

b) The Agency should make budgetary provision to subsidize reprinting and distribution of CINDA to the extent of a free distribution to each member state, and to cover the contribution in kind made by each compilation centre.

Therefore the Committee recommends that the Agency assume the responsibility for the printing and distribution of CINDA from January 1, 1971 onward. The present arrangements for printing CINDA should continue until that time. A detailed breakdown of the total CINDA cost, including details of the proposed free distribution, and the estimated overall distribution figures will be circulated to members as soon as possible.

The specific recommendation of the Committee regarding the transfer of the printing of CINDA to the IAEA worked out by a Subcommittee consisting of Bell, Goldstein and Good is set out in appendix 1.4.

8(c). Reports from Brookhaven, Obninsk, Saclay and Vienna

Brookhaven NNCSC

Pearlstein first gave some background information on the work of the Brookhaven NNCSC. The NNCSC represents the second largest federally supported information centre in the US. It consists of about 25 people divided into three groups, compilation (Goldberg), evaluation (Drake) and computer application (Cullen). The NNCSC has an advisory committee consisting of Hanna, Goldstein, Greebler, Lazarus, A.B. Smith (Secretary) and Ehrlich (Chairman) fairly well balanced in terms of their interests. This Committee helps in two major ways, commenting on NNCSC's technical program and providing a stable background for the centre's development in the last two years.

Regarding data compilation strong emphasis is given to the establishment of a proper relationship between experimental data, compilation and evaluation with the particular emphasis on providing services in preparing and sending tapes, listings, plots etc. in response to written and phone requests. At

present almost all old data have been entered into SCISRS-I tapes. Data are now being prepared for SCISRS-II using the transrission (or exchange) format. An author-proof procedure for new incoming data has now been instituted since January 1969. Some work has been done towards automatic publication of data. Most advances have been on BNL-400 and on least squares Legendre polynomial fits of experimental angular distribution data.
The long range emphasis of the NNCSC is on completion of the experimental bibliographic information and files, on having analysis programs and the ability of simultaneous display of experimental data and model and least squares fits to these data, and on achieving a better compatibility between CINDA and SCISRS data file index.

Obninsk NDIC

Abramov pointed out that a general description of the activities of the Obninsk NDIC has been made in a report by Zolotukhin submitted to the Brookhaven Compilation Panel (IAEA-111, p. 133). The main work in the last year was concerned with the development of an internal neutron data storage and retrieval format for magnetic tape together with an automatic checking program and with the translation from IBM to Russian standard and vice versa in order to enable data exchange on magnetic tape between NDIC and NDU. In the latter respect the recent visit of Attree and Lemmel from the NDU at Obninsk was very useful. The NDIC internal format will be close to the exchange format and both formats will be used by the NDIC. A catalogue of the data held in the NDIC will be prepared before the end of this year. Work on CINDA has been continued; since the last INDC meeting 676 CINDA entries were sent to Vienna which refer to 70 reports from the Anglo-Russian Seminar in June 1968 and 72 reports from a conference held in Yerewan in January 1969. Attempts to improve the Russian request list are continuing, the final list will be close to the REXDA format. The work of the Obninsk NDIC is guided by a council of the Obninsk Centre which consists of experimentalists and reactor physicists and, which meets about two or three times per year. Regarding the relationship between the NDIC and the various laboratories the measurers are approached by representatives in each institute. Letters with requests are sent to the laboratories, the laboratories in turn send abstracts of their work and data in form of numerical tables.

Saclay CCDN(INDC(ENEA)-2/G)

Bell outlined that during the past period the work of the CCDN has been concentrated heavily on the development and implementation of an adequate data storage and retrieval system. During the first half of 1968, the ECSIL system was implemented at the CCDN, and is now working with the Livermore data and bibliographic library dated March 1968. The NEUDADA system has been developed at the CCDN which enables the centre to work with the SCISRS-I data library. This system makes full use of the direct access storage media on the IBM 360/30 The development of this program and the subsequent translation and implementation of the full SCISRS-I library for use with NEUDADA was completed by the end of 1968; the dissemination of data from NEUDADA was started in January 1969. CCDN Newsletter 8 lists the data content of NEUDADA as of March 15, 1969 A number of large data sets of wider interest have recently been translated and entered into the data library (Cierjacks and Rohr: σ_T data (KFK); Brunner: σ_T data (Nürenlingen); σ_γ, σ_f and σ_n data from various measurers at Geel; Patrick, Sowerby: η and σ_f for Pu^{239} (Harwell)).
Bell then mentioned the cooperation of the CCDN in the Brookhaven workshop last year. As a result of this programs to translate the SCISRS-I data library into SCISRS-II format with disc storage and programs to make limited retrievals from these files were developed and have been implemented at the CCDN. Most of the last year's work on CINDA at the CCDN has been devoted to filling gaps in the coverage before about 1962. In addition necessary groundwork has been performed for automatic checking of CINDA against the data file in connection with the CCDN Newsletter 8.
The recommendations of the Brookhaven Compilation Panel were discussed at the recent Centre Committee Meeting at Paris. It was the general feeling of this Committee that these recommendations were rather broad and that it would be necessary, before agreeing on these recommendations, to have a better idea of what work the CCDN actually could undertake. In this context before the next Centre Committee Meeting the CCDN will try to assess the total compilation level of the CCDN, so that realistic decisions can be made on how many of these recommendations can be undertaken. The CCDN makes efforts to get the most up-to-date data into its data files and continues the policy of sending people to the principal laboratories within its service area encouraging these laboratories to, as far as possible, prepare the data in a form which can be rapidly entered in the centre's data files.

IAEA/NDU

Lorenz reviewed some of the work of the NDU since the last INDC meeting; this is covered more comprehensively in the NDU progress report (INDC(NDU)-10).
In the compilation of data from the NDU's service area last year particular emphasis was given to South America and a considerable amount of data could be gathered in this time. T. Dyer from the NDU is presently on a mission to about six South American countries; he will also attend two meetings in Brazil and Chile respectively to advertise the activities of the Vienna data centre and to encourage the scientists to send their data and make use of the centre's services. Shortly the NDU will have two new members from Korea and South Africa respectively which will help to improve the feedback between the NDU and Asian countries and South Africa. The list of liaison officers in the NDU service area has been extended.
The present content of DASTAR is estimated to about 150 000 data lines, this is about 25% of the total amount of compiled data all over the world excluding transmission data. About 40% of the data sets contained in DASTAR originated from the NDU service area. A long range program foresees the collection of a roster of names of all scientists involved in the neutron physics field and the preparation of profiles of the interests of these people.
Concerning the inhouse development of the NDU a computer program system for data compilation is being prepared which will be based on the exchange format. It will be very similar to DASTAR and allow automatic retrieval of bibliographic information from it. The NDU has a coordinating function in the development of the exchange format and the new quantity classification scheme.
In the discussion afterwards Goldberg and Goldstein briefly commented on the present status of the new quantity classification scheme. Differences in views had caused some slipping in the time scale, but they hoped to have agreed proposals for the forthcoming four-centre meeting at Obninsk. Abramov proposed that the IAEA publish the results of the discussions between Obninsk people and Attre and Kermel from the NDU during their recent workshop before the next four-centre meeting.

9. Evaluation

9(a). Progress reports

Kinchin outlined that work is currently in progress on a revision of the U^{235} data file following the discovery of errors in the low energy data in DFN 345,

also data for $\bar{\nu}(E)$ for Pu^{239} are being revised. Revision of the Zr data and comparison with measured resonance integrals has been completed and a new file for Nb is being checked. Work on B10 has been resumed. Finally improved files for thermal scattering from H_2O, D_2O and C have been prepared. In the field of adjustment of data to fit integral experiments, reaction rate ratios, k_∞, and measured neutron spectra have been introduced in addition to the already widely used information on criticality. By adjusting data all of the integral measurements from a wide range of assemblies can be reproduced with the exception of the low energy spectrum measured in ZEBRA. Further attention is being given to the accuracy of the experiments and to other important data. Most of the adjustments to the FGL 4 data set are not individually significant but some examples are: 10% increase of Pu^{239} alpha, 21% reduction of carbon moderation above 821 keV, 40% reduction of Fe capture, 16% reduction of U^{238} moderation above 821 keV.

USSR

Abramov gave a short resumé of Russian evaluation work which is described in more detail in a report by Nikolaev submitted to the Brookhaven Compilation Panel (IAEA-111, p. 141). The work is concentrated in different groups in different institutes, the results of these activities are collected by the NDIC. Probably in the future some reorganisation will take place. Some results of NDIC's evaluation work were sent to Vienna and through the IAEA to different laboratories. Particular examples are the report of Popov and Nikolaev on neutron scattering sent to the UK last year and an evaluation of capture cross section for U^{238}, the preliminary results of which are reported at the Topical Conference at the present INDC meeting.

Canada

Hanna mentioned that Walker is revising his evaluation of fission product data; this will be available as an AECL-report in a couple of months.

Australia

Symonds outlined that the fission product evaluation is being resumed. Also some integral experiment analysis is performed in order to find out the difficulties in particular in reproducing U^{238} capture reaction rates in D_2O-U_{nat} systems; results will be available in a few months.

USA

Pearlstein briefly commented on the evaluation effort in the US. The evaluated data system as such is in quite a good shape; a complete revised description of the format, data specification etc. will come out in the next few months. The first iteration of the ENDF/B library has been out since July 1967. In the reevaluation of the data a task force technique is assumed. Thus last summer a revision of 2200 m/sec data for non-fissile materials was prepared at Brookhaven by Goldman, Aline, Sher and Stehn. For resonance and fast cross sections of the main fissile and fertile materials a reevaluation is planned for the fall of 1969 in a cooperative effort of a group of experimental and evaluation physicists. In this reevaluation particular emphasis will be given to take into account ratio measurements and to establish consistency between the data sets for the mentioned nuclei. The first meeting of this task force will take place at Brookhaven in the week after the INDC meeting. With ENDF/B there are quite a few processing, checking and plotting routines available, the checking codes being at present enlarged.

Japan

In addition to the evaluation work on C and Pb Momota mentioned the recent evaluation on Pu^{239} data in the resolved and unresolved resonance regions by Katsuragi in collaboration with Durston at Winfrith. This work is described in a JAERI report and will be distributed as an INDC document.

India.

Divatia said that there is no major effort in evaluation in India. In the Theoretical Physics Section of the Trombay Reactor Engineering Division computer codes for checking and updating of evaluated data have been adapted. The programs available are: CHECKER, CRECT and DAMMET.

Federal Republic of Germany

Schmidt said that in addition to KFK 120 / part I a new (compared to the first edition, KFK 120 / part II in 1962) improved and enlarged volume with tables of evaluated "best" microscopic cross sections and related nuclear data for the most important reactor materials was edited as KFK 750 report. Being essentially a copied print-out of the Karlsruhe evaluated nuclear data file KEDAK it simultaneously serves as documentation of the content of KEDAK.

The first phase of the evaluation of all microscopic cross sections and related nuclear data needed in reactor calculations for the higher Pu isotopes Pu^{240}, Pu^{241} and Pu^{242} performed by the group of Prof. Yiftah in collaboration with Karlsruhe as part of a contract between the TECHNION, Haifa, and the Gesellschaft für Kernforschung Karlsruhe is finished (see report IA-1152). Before entering these data into the KEDAK file capture cross sections and resonance parameters for Pu^{240} were still improved by taking into account the recent comprehensive resonance results obtained at Geel. As part of a new two years contract the present evaluations for Pu^{240}, Pu^{241} and Pu^{242} will be still improved particularly regarding fission, capture and inelastic scattering cross sections.

For Cd an existing GGA evaluation has been improved and incorporated into KEDAK. 26-group cross section sets (ABN-group structure) have been calculated from these data with ABN and Na prototype reactor spectrum weighting, respectively.

In order to enable the transfer of the KEDAK file to the IBM-360/65 recently installed at Karlsruhe and to the Saclay CCDN computer, a card image format has been developed for KEDAK (KFK 880). In this format the KEDAK file has been sent to the Saclay CCDN together with the necessary documentation of its present content.

As one of the main points of the Karlsruhe evaluation work a systematic comparison and evaluation of recent discrepant absorption and fission cross section measurements particularly for U^{233} and Pu^{239} has been started, in close interaction with integral experimental results obtained at the Karlsruhe facilities SNEAK and SUAK. First results of these investigations together with the feedback on reactor physics calculations were reported at the International Winter Meeting of the American Nuclear Society at Washington, November 1968 (KFK 793).

The treatment of inelastic scattering within the reactor physics computer programs was improved over the hitherto used ABN scattering matrices by making use of the evaluated excitation cross section data from KEDAK in the region of resolved rest nucleus levels and of the evaporation model in the so-called "continuum" range.

In the framework of theoretical safeguard investigations the methodically still simple derivation of five-group cross section sets for σ_γ σ_f, σ_{2n} and $\bar{\nu}$ for a series of Pa, U, Np, Pu, Am and Cm isotopes was started using typical thermal and fast reactor spectra as weighting spectra.

At several occasions reviews were given on the technical principles and the

organizational aspects in the field of neutron nuclear data evaluation (KFK 772, KFK 791).

9(b). Exchange of evaluated data

Lorenz first pointed out that since the last INDC meeting the NDU has received a number of evaluated data sets. The importance of the exchange of evaluated data was demonstrated by the fact that the distribution frequency for evaluated data since the last INDC meeting has been about five times as high as for experimental data reflecting a considerably larger demand within the NDU service area for evaluated than for experimental data. Lorenz pointed out that there are considerable variations in the documentation of the various evaluated data sets. As future action he suggested the development of an exchange format for evaluated data similar to that for experimental data, which would standardize the desired amount of documentation.

Schmidt mentioned a request for the Karlsruhe KEDAK Library received recently from Dr. Rastogi from the Bhabha Atomic Research Centre Reactor Engineering Division. As Karlsruhe imposes no restriction on the distribution of KEDAK data, a copy of the file held at Saclay was sent to the NDU upon Karlsruhe request. The Committee now agreed that the NDU keep these data in their files and forward another copy of the KEDAK file to Dr. Rastogi.

The Committee in general felt that the initial ad-hoc exchanges of evaluated data which were agreed at the last INDC meeting had been successful. It recognized the large demand for evaluated nuclear data for reactor calculations and looks forward to a similar increase in the exchange of evaluated data as in the exchange of experimental data.

10. Request list

10(a). Communication from EANDC Chairman

Kinchin brought first to the attention of the Committee a letter directed to him by Weinzierl, present Chairman of the EANDC regarding the question of a world-wide request list for nuclear data measurements. This letter is reproduced in appendix 4.

10(b). REHDA and world request list

Lorenz pointed out that in March 1969 the NDU received a number of copies of REHDA, and distributed these together with an accompanying explanation of REHDA and a request for contributions from member states within the NDU service area. As a result of this the NDU received a few contributions from Brazil, Finland, Bulgaria, Chile (only acknowledgement) and Taiwan. Promised contributions from Poland are still not worked out.
In view of the different emphasis of different countries placed on the same data and for strengthening of the importance of certain requests the maintaining of the multiplicity of requests which appear in REHDA was generally felt desirable. Kolstad mentioned a new procedure adopted recently in the reports to the NCSAC, i.e. that the reporting laboratories make reference to items in the REHDA list. Symonds pointed out the usefulness of adding comments to the REHDA list on work going on or planned. Kolstad suggested that the NDU prepar a request list from Non-OECD countries for September this year such that it be availble for consideration at the next EANDC-meeting in October this year. Good felt that this time was too short and proposed that the establishment of a Non-EANDC REHDA list be an objective for the next INDC meeting. The Chairman concluded by requesting the Agency to produce as soon as possible such a request list.

11. Next meeting

The next meeting will take place in Vienna, June 22 - 26. In view of the neighbourhood of the Helsinki Conference the "Discrepancies in Nuclear Data" will be made an item of the agenda and not an item for topical discussion. It is recommended to the DG of the IAEA that Dr. Weinzierl be invited as an ad-hoc member to the next meeting (see appendix 1.5).

Appendix 1

Recommendations of the Committee

1.1. Representation on CODATA Conferences

The Committee notes the efforts of the CODATA to bring about a common international meeting ground for the data compilation activities of diverse technical disciplines, and that the Agency has been represented by a member of the INDC as well as by the Agency itself.

INDC is of the opinion that it should continue to be represented at CODATA meetings. Because of CODATA's bread spectrum of disciplines, it is probable that in due time, the Agency may wish occassionally to be directly represented in areas other than nuclear data.

The INDC recommends that a member of the Committee or a suitable alternate attend as an observer at CODATA meetings to keep the Committee informed on CODATA activities. If the Director General proposes an INDC member, rather than a suitable member of IAEA staff, the INDC further recommends that the Director General delegate to the Chairman of INDC the selection of the INDC member and that this member attend, preferably at no cost to the IAEA.

1.2. Publication of Helsinki Nuclear Data Conference Papers

The Committee strongly recommends that the IAEA publish all of the papers accepted for the Helsinki Conference on Nuclear Data for Reactors. If sufficient funds are not available to subsidize the publication of all papers accepted, the Committee recommends that the IAEA investigate other means of obtaining the funds, such as charging each delegate a registration fee for the meeting or charging delegates a suitable price for a copy of the proceedings.

1.3. Panel topics for 1971 and 1972

The Committee recommends to held a Panel on Methods of Evaluation in 1971 and asks the IAEA to send a proposal for the agenda to INDC members for comments. For later the Committee proposes a second Panel on Standards, possibly to be foreseen for 1972 and a Panel on Resonance Parameter Statistics.

1.4. Printing of CINDA

The Committee recommends that the Agency assumes the responsibility for the printing and distribution of CINDA from January 1, 1971, onward. The present arrangements for printing CINDA should continue until that time.

1.5. Ad-hoc members at next INDC-meeting

The Committee recommends to the DG of the IAEA that Dr. Weinzierl be invited as an ad-hoc member to the next INDC meeting.

1.6. Foil and target material exchange

The Committee notes that revised arrangements have been agreed for the safeguarding of small quantities of nuclear material. The Committee notes further that there are requests from developing member states for the provision of targets, foils and other special materials, for nuclear data measurements. The INDC recommends that the IAEA consider making budgetary provision for the supply of material and fabrication of such samples, especially for the developing member states. The Committee would be willing to advise the Director General on the merits of specific proposals.

1.7. Nuclear Structure Data Compilation

The Hollander Proposal to establish international cooperation in the compilation of data on radioactive isotopes and nuclear levels constitutes a constructive step toward the recognition of the importance of this activity within the framework of the IAEA. The Committee believes that such nuclear data compilation constitute an important resource for many applied activities (e.g., medicine, engineering, biology, agriculture) especially in developing countries.

It is important in order to provide a sound basis for the establishment of IAEA policies and in order to promote the cross-fertilization among different kinds of nuclear data compilation activities, that meetings and/or symposia be held at an early date. Accordingly, the INDC recommends that the IAEA plan to sponsor a small symposium no later than 1973 on the collection, compilation indexing, evaluation and distribution of nuclear (including neutron) data. The INDC will be prepared at its next meeting to take further steps for organ-

ising the program and scope of the symposium.

Because of broad interest in this area of activity and need for increased international cooperation we also suggest that other means for promoting such cooperation be explored (e.g., IUPAP, informal contact at Montreal Conference, CODATA). In view of the foregoing, we suggest that it would be premature for the IAEA to undertake specific compilation or coordination responsibilities in this field at the present time.

Appendix 2

Actions arising from the Second INDC Meeting

Action No.	Page No. of Minutes	Action on	Action
1		Kinchin	prepare chairman's two years report and submit it to the next Committee meeting.
2	12	Schmidt	inform Dr. Schäfer from CODATA Central Office about Committee recommendations regarding the relationship between INDC and CODATA; ask him to distribute CODATA Newsletters and the compendium directory survey to INDC members.
3	13	NDU/ INDC Secretariat	request "Minutes of IWGFR Meetings" and proceedings or reports of meetings that it sponsors to be sent to the INDC Members.
4	14	IAEA	draft and send proposal for agenda of suggested 1971 Panel on Methods of Evaluation to INDC members for comments.
5	14	NDU/ INDC Secretariat	extend the membership of Liaison Officers to include all interested Member States not represented on INDC.
6	16	NDU	prepare working paper on evaluation activities for next INDC meeting.
7	33	NDU/ INDC Secretariat	request progress reports to the INDC from NON-INDC Member States at an early date.
8	36	IAEA	provide pool of information on available targets and foil materials.
9	42	IAEA	prepare a detailed breakdown of the total CINDA cost including details of the proposed free distribution and circulate it together with an estimate of the overall distribution figures to INDC members as soon as possible.
10	45	NDU	publish results of discussions of recent Obninsk workshop before next four-centre meeting.
11	49	NDU	provide Dr. Rastogi from Bhabha Atomic Research Centre with a magnetic tape copy of the Karlsruhe KEDAK file.
12	50	NDU	prepare as soon as possible request list for nuclear data measurements from Non-OECD countries.

Appendix 3

Proposed Program for the Second International Conference of the IAEA on Nuclear Data for Reactors, Helsinki, 15 - 19 June 1970

I. General Aspects of the Needs and Uses for Nuclear Data

- General Status of Nuclear Data Requirements
- Implications of Neutron Data Uncertainties to Reactor Design and Operation
- Nuclear Data Interests for Non-Reactor Purposes
- Contributed

II. Cross Sections and Techniques for High Precision Neutron Nuclear Data Measurements

- Introductory
- Contributed
- Evaluation

Special Paper: Nuclear Data Requirements for Controlled Thermonuclear Devices

III. Nuclear Data in the Thermal and Resonance Energy Regions: A > 220

- Introductory
- Contributed
- Evaluation

IV. Nuclear Data Above the Resonance Energy Region: A > 220

- Introductory
- Contributed
- Evaluation

V. Nuclear Data in the Thermal and Resonance Energy Region: A < 220

- Introductory
- Contributed
- Evaluation

VI. Nuclear Data Above the Resonance Energy Region: A < 220

- Introductory
- Contributed
- Evaluation

VII. Relationships of Microscopic and Integral Data

- Introductory
- Contributed

Special Paper: Progress in International Nuclear Data Compilation and Exchange (a report of the four Neutron Data Centres).

Special Paper: Progress in Understanding Neutron Interactions with Nuclei

VIII. Evaluation Problems and Methods

- Special Paper
- Contributed

IX. New Developments in Instruments and Methods

- Contributed

X. Summary Panel

Appendix 4

EANDC letter regarding world request list

Dear Dr. Kinchin:

At its 12th meeting the EANDC agreed to transmit to the IAEA the information contained in its current Request Compilation (EANDC-78) with the understanding that this compilation will not be merged into a broader document without the prior agreement of the EANDC. Sufficient copies are being made available to the IAEA to permit a limited distribution to non-EANDC states.

We hope that the IAEA will make available to the EANDC a sufficient number of a Request Compilation covering non-EANDC states. We prefer, however, to wait until after the next INDC meeting, and until a more representative Request Compilation from non-EANDC states has been prepared, before reconsidering the question of merging the EANDC Request Compilation into a single world wide document. We hope that this matter can be decided at the next meeting of EANDC.

Sincerely yours,

Weinzierl
(EANDC Chairman)

Appendix 5

Hollander Proposal

December 4, 1968

Dear Dr. Seligman:

For some time we have felt that it would be desirable to have a means for closer communication and liaison among the major worldwide groups who compile data on Nuclear Level Schemes and Radioisotopes. The need for such liaison and cooperation is becoming daily more evident as the "data explosion" continues, increasing the difficulty for each of the groups to keep up with the data in its area of activity.

We are aware of the interest that has developes in IAEA in the nuclear information field and we believe that the IAEA would provide an ideal milieu for such international liaison and cooperation as is needed in the nuclear data field.

We have, therefore, prepared the enclosed proposal for the creation of an IAEA Committee on Compilation of Nuclear Level and Radioisotope Data, which we wish to submit for consideration by IAEA. This proposal has the approval and encouragement of Chairman G. T. Seaborg of the United States Atomic Energy Commission, and its International Division (Dr. A. S. Friedman) and Technical Information Division (Dr. E. Brunenkant) have also given their full support to this effort. We have been in close touch with our colleagues in the Nuclear Data Group at Oak Ridge as this idea developed, and they wish to participate fully in the Committee's functions. Dr. L. K. Peker and Professor B.S. Dzhelepov of Leningrad (who direct the major nuclear data compiling effort in the Soviet Union) have warmly supported the idea of an international liaison group in verbal discussions held at Dubna in July 1968 with Dr. Lederer of our group, and a copy of this proposal is being sent to them as well as to Professor Indt in Utrecht.

We hope that IAEA can treat this as a formal proposal, to be acted on in the near future. If, however, it is necessary for us to follow a different procedure in this regard, please advise me as to how to proceed.

With thanks for your help, and with best wishes,

Sincerely yours,

Jack M. Hollander

PROPOSAL FOR ESTABLISHING INTERNATIONAL COOPERATION IN THE COMPILATION OF DATA ON RADIOACTIVE ISOTOPES AND NUCLEAR LEVELS

December 1968

Proposal:

It is proposed that a Committee on Compilations of Nuclear Level and Radioisotope Data be established under the auspices of the International Atomic Energy Agency (IAEA), with the purpose of establishing communication and cooperation between groups working actively in this field.

Background of the Proposal:

The uses of nuclear data have diversified greatly in recent years. More than ever nuclear physicists need to have complete, up-to-date information on all nuclear levels. In addition, such information, particularly information on the decay of radioactive nuclei, has become increasingly important for its applications in many branches of science and technology. For example, the recently-developed, high-resolution semiconductor gamma-ray spectrometers are rapidly finding use in such diverse fields as chemical analysis, archaeology, mining, medicine, and nuclear engineering. The effective use of such instruments depends heavily on the availability of detailed information about the gamma-ray spectra of many radioisotopes.

At present the task of compiling and interpreting such data is being carried on independently by several groups--predominantly those in Leningrad ("Decay Schemes of Radioactive Nuclei"), Oak Ridge ("Nuclear Data" journal), Utrecht ("Energy Levels of Light Nuclei"), and Berkeley ("Table of Isotopes"). The need for communication and cooperation among these groups, and for making their work readily available to the users of nuclear data, is accentuated by the dramatic and continuing increase in the amount and detail of data generated by the many laboratories engaged in nuclear research. It can realistically be hoped that the channels of communication opened by this Committee, and the cooperative efforts among compiling groups resulting therefrom, will ease the burden on the compilers by help-

ing to reduce duplications of effort, and will also improve the completeness and usefulness of nuclear data compilations.

Need for IAEA Sponsorship:

Since this proposal is directed toward a cooperative effort between groups in the U.S.A., Holland, and the USSR., it is desirable that such cooperation be sanctioned by an appropriate international organization. It is logical that this organization be the IAEA, since these countries are all members of IAEA, and since benefits would accrue from the proposed work to many of the IAEA member states. Furthermore, the IAEA, which has broad and active programs concerning the application of isotopes, is itself already involved in the compilation of other aspects of nuclear data.

For these reasons, this proposal is directed to the IAEA for its consideration.

Functions:

1) The most immediate function of the Committee would be to establish contact and to provide a mechanism for the exchange of information between compilers in different IAEA member states.

2) When requested by the Committee, the IAEA could arrange for exchange visits between persons from compiling groups in different member countries, or for joint projects to be undertaken by several such groups.

3) When requested by the Committee, the IAEA could assist in securing publication of data compilations so that the widestpossible distribution could be obtained.

4) The IAEA would sponsor infrequent (possibly annual) meetings of the Committee for the purpose of discussing and planning cooperative efforts in nuclear data compiling. It would be desirable for the first meeting to take place as soon as possible after the Committee is constituted.

It is not expected that the functions of the Committee will require special funding other than for travel expenses, which should be borne by IAEA.

Membership of the Committee:

Members of the Committee will include active compiling groups from IAEA member countries, which may be represented by one (or more) persons from each group. We would suggest that initial members be the Leningrad, Utrecht, Oak Ridge, and Berkeley groups. Additional members may be chosen by the initial Committee.

23 December 1968

Dear Professor Hollander,

Further to my letter of 16 December concerning your proposal for the creation of an IAEA Committee on Compilations of Nuclear Level and Radioisotope Data, I have now had the opportunity of discussing it at some length with the competent staff members of the Agency.

You may know that a similar suggestion had been made some time ago but it had been decided, at that time, to concentrate on neutron data, a field in which the Agency has a compilation programme and is collaborating with the world's four main data centres.

In the nuclear data field, the Agency is advised by a special committee called the "International Nuclear Data Committee". We think that this Committee should help us with your suggestion and, as a matter of fact, we would like to include your proposal as an agenda item for their next meeting which is scheduled in Brookhaven next June. However, before doing so, we would like to seek the opinions of the nuclear data centres which you mention and it is proposed that their answers together with your proposal be discussed at the June meeting.

I hope that you will not be under the impression that we are trying to be very formal about your proposal but you should realize that it involves an increase in staff for the nuclear data group, which means an increase in budget. As any budgetary increase has to be examined in competition with all the other activities of the Agency, we need to have the fullest support from the INDC before bringing this matter to the attention of our Board of Governors who have the final say on the Budget.

Yours sincerely,

Henry Seligman
Deputy Director General
Department of Research
and Isotopes

Appendix 6

Draft Report of Subcommittee on Committee Business

PROPOSED MODIFICATIONS TO "METHODS OF WORK"

The "Methods of Work", adopted as guidance for the INDC, provides the basis for Committee operation and is to be followed except in those cases where the Committee may decide otherwise. In accordance with Article X, the following are offered for adoption as amendments to "Methods of Work" at the next meeting of INDC.

Liaison Officers (Section III-5)

1. The IAEA may request a Member State or International Organisation not represented on the INDC to nominate a liaison officer to provide a communication link between the INDC and the scientists producing and/or using nuclear data in that state.

2. Liaison officers shall be provided with lists of all official Committee documents, copies of which he may request from the Scientific Secretary. The Scientific Secretary shall send the draft agenda to all liaison officers at the same time that it is sent to the Committee members.

3. Where active interest in items of an INDC meeting is indicated by a liaison officer, he may request approval from the Chairman of the INDC through the Scientific Secretary to attend that meeting as an observer at no expense to the IAEA.

Distribution and Numbering of Documents (Section V-6)

Member states submitting documents to INDC are advised strongly to assign an INDC number to the document in the manner described in the "Methods of Work" and to be sure that this identifying number is affixed to the upper right-hand corner of the document prior to dispatch. Unless this procedure is followed, it may be impossible to assure appropriate distribution.

There shall be three categories[1] of Committee documents (i.e. those documents originated by the INDC, by a member state or organization for the INDC, or by the IAEA for the INDC):

1) Category "C" - Committee Members and other continuing participants only

2) Category "L" - Committee Members and other continuing participants, Liaison Officers, Local Data Committees, Heads of Data Centres, IAEA Secretariat (X)

3) Category "U" - Same as "L" plus additional distribution requested by member states

Distribution lists shall be provided periodically to the Scientific Secretary by the Member States. A sufficient number of copies for the appropriate distribution will normally be provided by the originating country.

Observers (Section IV-3)

1) Observers are defined to include experts, specialists or other individuals who are invited on an ad hoc basis to attend all or specific portions of INDC meetings.

2) Any Member of the Committee may request the Chairman to invite an observer for a specified portion or the whole of the meeting. The Chairman, upon the advice and consent of the Committee, extends the invitation.

3) At the beginning of each meeting, the Chairman shall consult with the Committee to determine which session the observers shall attend.

Working papers (add to Section IV-4)

Substantive agenda items should be supported by appropriate working papers which should be submitted to Committee members 30 days in advance of the meeting.

---

[1] Because of the parallel operation of INDC and BANDC and to simplify documentation for those states belonging to both, the same categories are recommended for adoption by INDC.

Local Secretary (Add to Section IV-1)

The Local Secretary will be permitted to attend all except executive sessions of the Committee.

Observers and Scientific Advisers (Rewording of Article III-3)

Each member may be accompanied by advisers. Observers may, with the advice and consent of the Committee, be invited by the Chairman to attend all or specified portions of meetings. After consultation with the Chairman, the Director General of the IAEA may appoint additional observers or ad hoc Members to attend all or specified portions of meetings.

Respectfully submitted,

G.A. Kolstad (USA), Chairman
G.C. Hanna (Canada)
A.I. Abramov (USSR)
O. Kofoed-Hansen (Denmark)
M. Souza-Santos (Brazil)
E.R. Rae (U.K. Adviser)
A. Lorenz (IAEA Adviser)
R.F. Taschek (USA Adviser)
W.W. Havens (USA Adviser)

Appendix 7

TOPICAL CONFERENCE ON NEUTRON CAPTURE CROSS SECTIONS AND GAMMA-RAY SPECTRA

Wednesday, June 4

PROGRAM

9:00 a.m.	Radiative Capture Cross Sections in the keV Region	R.C. Block RPI
	Capture Cross Section Measurements at Karlsruhe	J.J. Schmidt Karlsruhe
	Capture Cross Section Standards (or the real life story of the Indian and the turkey)	J.H. Gibbons ORNL
	Capture Cross Section Measurements in ^{233}U, ^{235}U, and ^{239}Pu	R. Gwin ORNL
	Thermal Neutron Capture Cross Section Measurements	G.C. Hanna Chalk River
	Capture Cross Section Work in the USSR	A.I. Abramov Obninsk
12:30 - 1:30 p.m.	LUNCH	
2:00 p.m.	High Resolution Resonance Gamma-Ray Spectroscopy	O.A. Wasson BNL
	Resonance Capture Gamma-Ray Studies at Harwell	E.R. Rae AERE
	Capture Gamma-Ray Studies at Chalk River	E.D. Earle Chalk River
	Australian Studies in Neutron Capture Cross Sections and Gamma-Ray Spectroscopy	J.L.Symonds AAEC
	Gamma-Ray Production Measurements	I.L. Morgan Texas U.
	The Calculation of Neutron Capture Gamma-Ray Spectra and their Effect on Optimized Shield Design	K.J. Yost ORNL

Radiative Capture Cross Sections in the keV Region

Robert C. Block

Rensselaer Polytechnic Institute, Troy, New York

Neutron capture cross section measurements are reviewed in terms of the experimental capture yield, the ratio of number of captures to number of incident neutrons. From a study of the yield relation it is concluded that today's neutron time-of-flight spectrometers are capable of measuring capture cross sections over the entire keV energy range and with a resolution adequate to resolve much of the resonance structure. Examples are presented of high resolution capture measurements carried out at the Rensselaer electron linac laboratory upon medium and heavy weight nuclei and of time-of-flight measurements carried out at the Los Alamos Laboratory with the nuclear explosion method upon ^{238}U. It is concluded that such measurements provide useful information on radiation widths of the predominantly scattering resonances, the neutron widths of the weaker $\ell \neq 0$ resonances, and the p-wave strength function in the mass region at which it is at a minimum. Measurements of the capture cross section averaged over resonances were reviewed in terms of recent results upon W isotopes at Rensselaer, ^{238}U at Harwell, and heavy nuclei at Gulf General Atomics. The latter results have been interpreted in terms of the simple exponential level density formalism, but it turns out that agreement between experiment and theory requires a drastic variation of Γ_γ (or other formerly considered constant term) with neutron energy. It is finally concluded that from the experimentalists' point of view, the problem is going from raw counting data to SCISRS, rather than from SCISRS to ENDF.

Capture cross section measurements at Karlsruhe

J.J. Schmidt

Kernforschungszentrum Karlsruhe

In 1968 the computer program set up by Kompe and Ernst for the extraction of strength functions from average capture cross section data obtained with the Karlsruhe Van de Graaff were extended so that now open inelastic exit channels can be treated adequately. With the modified code one obtains p- and d-wave strength functions which differ in some cases, especially for the d-wave, from the preliminary results where inelastic scattering had been neglected. The revised values are given in the table below. Good fits were achieved without the necessity pointed out by Block in his contribution of introducing a stronger energy dependence of $\bar{\Gamma}_\gamma$ than normally assumed.

The linearity and count rate independence of the electronic equipment associated with the 800 l liquid scintillation detector were improved. Capture cross sections measurements on a number of separated isotopes are being prepared.

Element	$S_o \cdot 10^4$	$S_1 \cdot 10^4$	$S_2 \cdot 10^4$
Nb	0.4	11 ± 3.2	0.4 ± 0.3
Ag	0.45	7.5 ± 1.3	3.1 ± 1.3
Cs	0.7	3.9 ± 1.0	2.4 ± 1.5
Hf	2.5	0.13 ± 0.06	2.1 ± 0.7
Ta	2.1	0.1 ± 0.04	2.2 ± 0.5
W	2.1	0.32 ± 0.09	0.7 ± 0.15
Re	2.4	0.1	6.3 ± 1.0
Au	1.6	0.19 ± 0.04	1.4 ± 0.4

Capture Cross Section Standards (or the Real Life Story of the Indian and the Turkey)

J.H. Gibbons

Oak Ridge National Laboratory
Oak Ridge, Tennessee

Improvements in "standard" neutron cross sections are occurring at roughly the same rate as requested improvement in accuracy of reaction cross sections. Thus experimenters seem to be assured of continuing work! However, recent results have considerably clarified the picture, especially in the energy range from ten to a few hundred kiloelectron volts. The best candidate for a primary standard seems to be $^{6}Li(n,\alpha)$ with $^{3}He(n,p)$ and $^{10}B(n,\alpha)$ following close behing. Secondary standards such as $^{127}I(n,\gamma)$, $^{197}Au(n,\gamma)$ and $^{235}U(n,f)$ are going to continue to be used and are much better known than a couple of years ago, but they are subject not only to greater uncertainty in absolute value but are also susceptible to the vagaries of resolution-dependent cross section variations in the lower energy range ($E_n \lesssim 50$ keV). There is an unquestionable need for additional careful investigation of these cross sections, per se, as well as allied studies that can shed light on them.

Measurement of the Neutron Fission and Absorption Cross Sections of ^{239}Pu over the Energy Region 0.02 eV to 30 keV[1]

R. Gwin, L.W. Weston, G. de Saussure,
R.W. Ingle,[2] J.H. Todd,[2] F.E. Gillespie,[2]
R.W. Hockenbury[3], and R.C. Block[3]

The analysis of the ^{239}Pu experiments on the neutron fission and absorption cross section reported in the Neutron Physics Division Progress Report for 1968 has been extended. The main development in the analysis has been the reduction of the data to neutron cross sections.

The data obtained using the fission chamber were normalized at 0.025 eV to an absorption cross section of 1008 barns and a fission cross section of 742 barns. The normalization was completed by setting the value of $\alpha(\sigma_c/\sigma_f)$ in the 0.3 eV resonance to 0.66. The present normalization is consistent with that used previously.[4]

Figure 1.1.1. shows the experimentally derived values of α as a function of energy over the energy range from 0.1 to 30 keV. Also shown are α values calculated by Pitterle et al. [5]. The errors shown are standard deviation obtained from the experiments using the metal foils of ^{239}Pu (10- and 20-g samples). The various experiments differed in sample thickness and/or neutron filters used to measure the background. Below 1 keV the measurements with the fission chamber may be expected to have a smaller uncertainty than that for the metal foils. No errors are shown for normalization since this type of uncertainty usually produces a biased result. If the uncertainty in α at 0.3 eV is 0.66 ± 0.02 then an uncertainty in α of ± .05 is expected where α is unity.

Table 1.1.1 shows average values of the ^{239}Pu fission cross section for the neutron energy range from 1 to 30 keV. All of the values shown in Table 1.1.1 except the ORNL-RPI values were taken from a paper by James and Patrick[6] and included the results of experiment by Shunk,[7] Patrick,[8] and James[6].

In the evaluation of the data James and Patrick used for the $^{10}B(n,\alpha)$ cross section the relation

$$\sigma(n,\alpha) = \left(\frac{610.3}{\sqrt{E}} - 0.28\right) \quad \text{barns},$$

where E is in electron volts.

This relation was also used for the present work in obtaining the neutron flux from measurements made using a ^{10}B ionization chamber.

The agreement between the present results using the metal foils and the fission chamber is good. This agreement gives a measure of confidence in the α values obtained with the metal foils. The present experiments, fission chamber and metal foils, yield fission cross sections which are consistent with those of James while the results due to Patrick and Shunk are lower on the average than the present results.

1.1. References

[1]Abstract of ORNL-TM-2598 (in press).

[2]Instrumentation and Controls Division.

[3]Rensselaer Polytechnic Institute, Troy, New York.

[4]R. Gwin et al., Neutron Phys. Div. Ann. Progr. Rept. May 31, 1968, ORNL-4280.

[5]T. A. Pitterle, E. M. Page, and M. Yamamoto, "Calculation of Fast Critical Experiments using ENDF/B Data and a Modified ENDF/B File" Proceedings Neutron Cross Sections and Technology Conference, Washington, D. C., vol 2, March 4-7, 1968.

[6]G. D. James and B. H. Patrick, "Evaluation of the ^{239}Pu Fission Cross Section in the Energy Range 1 keV to 100 keV," AERE-M 2065, (amended) October 1968.

[7]E. R. Shunk, W. K. Brown, and R. LaBauve, "Fission Cross Section of ^{239}Pu, 20 eV to 2 MeV," Conf. on Neutron Cross Section Technology, Conf. 660303, March 22-24, 1966, Washington, D. C., p. 979. See also LA-3586.

[8]B. H. Patrick et al., Proc. of IAEA Conf. on Nuclear Data for Reactors, Paris (1966), vol. II, p. 117 and Ref. 3.

Table 1.1.1. Comparison of ORNL-RPI ^{239}Pu Fission Cross Section with Other Measurements

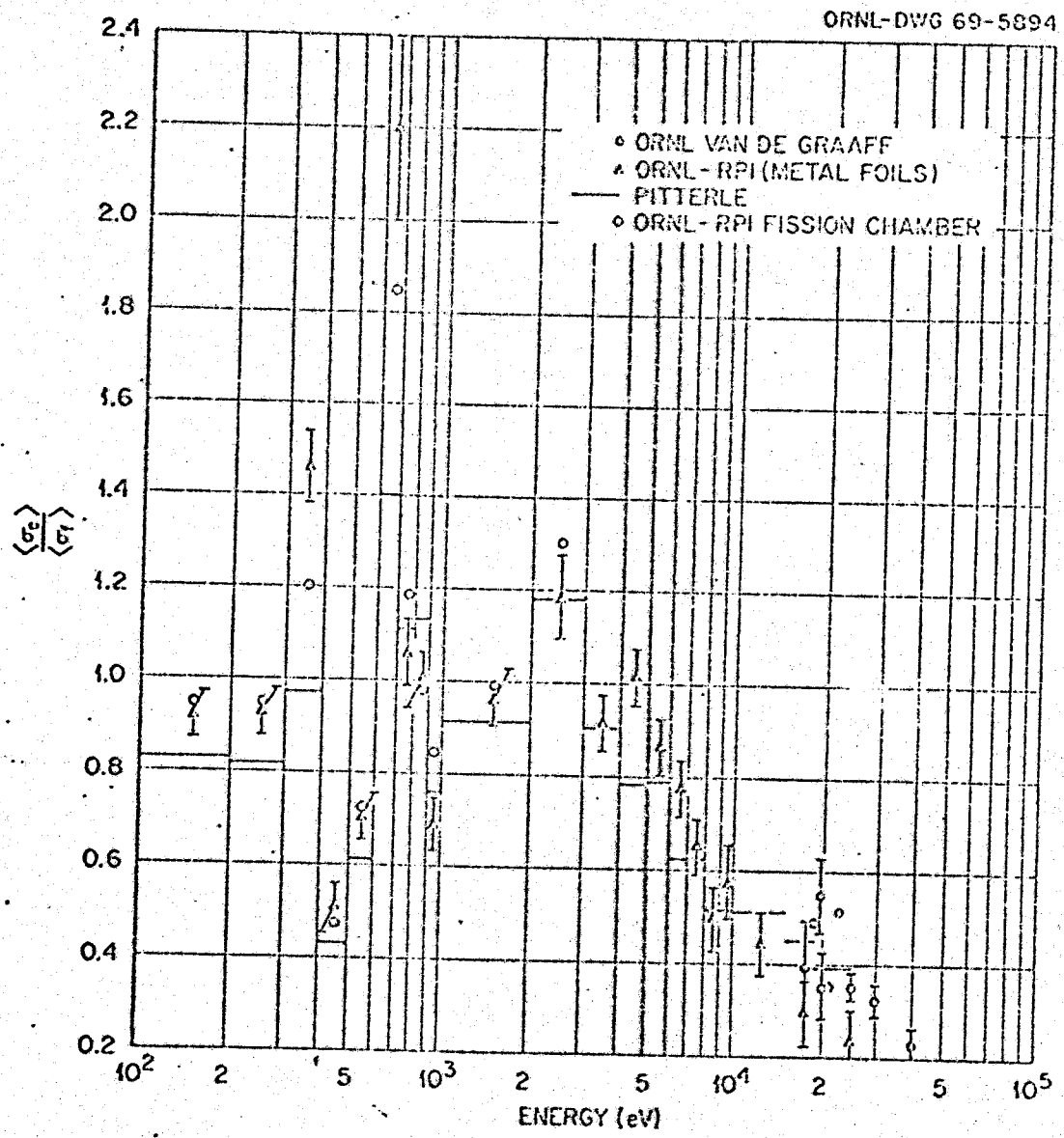
Energy (keV)	Fission Chamber	Metal Foils	Deduced Cross Section James and Patrick[a]	James[a]	Shunk[b]	Patrick[c]
1.5	4.49 ± .04	4.53 ± .08	3.85 ± .21	4.40	3.43	3.64
2.5	3.30 ± .30	3.30	3.07 ± .20	3.46	2.64	2.83
3.5	3.20 ± .30	3.05 ± .21	2.95 ± .17	2.86	2.74	2.73
4.5	2.39 ± .03	2.42 ± .06	2.45 ± .09	2.54	2.31	2.31
5.5	2.17 ± .06	2.36 ± .18	2.50 ± .13	2.41	2.71	2.17
6.5	2.16 ± .06	2.14 ± .11	2.19 ± .13	1.97	2.20	1.96
7.5	2.13 ± .08	2.13 ± .07	2.14 ± .07	2.27	2.24	2.17
8.5	2.23 ± .10	2.26 ± .12	2.25 ± .12	2.25	2.46	2.32
9.5	1.88 ± .07	1.88 ± .06	2.06 ± .10	1.85	2.14	1.99
15.0	1.79 ± .09	1.79 ± .12	1.71 ± .04	1.76		1.67
25.0	1.66 ± .10	1.68 ± .12	1.57 ± .08	1.62		1.53

[a]G. D. James and B. H. Patrick, "Evaluation of the ^{239}Pu Fission Cross Section in the Energy Range 1 keV to 100 keV," AERE-M 2065, (amended) October 1968.

[b]E. R. Shunk, W. K. Brown, and R. LaBauve, "Fission Cross Section of ^{239}Pu, 20 eV to 2 MeV," Conf. on Neutron Cross Section Technology," Conf. 660303, March 22-24, 1966, Washington, D. C., p. 979. See also LA-3586.

[c]B. H. Patrick et al., Proc. on IAEA Conf. on Nuclear Data for Reactors, Paris (1966), vol. II, p. 117 and Ref. 3.

List of Figures



Ratio of Capture to Fission vs Energy for ^{239}Pu.

The fast neutron capture cross section for ^{238}U

A.I. Abramov, V.A. Tolstikov

Institute of Physics and Power Engineering Obninsk

The analysis of the requests for fast neutrons sigma capture measurements for ^{238}U shows that the accuracy $\sim$4 - 5% in the energy region from 1 keV to 10 MeV would be sufficient for the solution of many problems. But at the present time the spread of the experimental results obtained by many authors is much greater. The results of the evaluations of the capture cross sections carried out during the last years also differ considerably from each other.

In the present work one more attempt is being done to evaluate the capture cross sections for ^{238}U by comparing the results of several measurements carried out at the Institute of Physics and Power Engineering with the results of other authors. The recommended curve obtained in the work, at energies above 0.1 MeV, practically coincides with other similar curves, but at energies below 0.1 MeV it goes lower. This fact seems to be consistent with the data obtained at the critical assemblies.

The Ratio of Capture to Fission in ^{233}U, ^{235}U and ^{239}Pu

G.C. Hanna
Chalk River

Measurements of α for ^{233}U, ^{235}U and ^{239}Pu at thermal energies have been made at Chalk River by Lounsbury, Durham, Kushneriuk, Bigham and Hanna in a special high-flux irradiation facility. Extensive thermalization calculations were carried out and the uncertainty in the neutron spectrum was equivalent to $\pm 3^{o}C$.

With a ^{233}U - ^{238}U mixture the change in the (233/238) ratio gives the 233 destroyed and that in (234/238) the 234 produced, from which $\alpha(233)$ can be calculated. Similarly a ^{239}Pu - ^{242}Pu mixture gives $\alpha(239)$. If they are mixed, so that they receive the same irradiation, the ratio of the fractions of ^{233}U and ^{239}Pu destroyed is equal to the ratio of the absorption cross sections. The experiment involved irradiating such a ^{233}U - Pu mixture, and a similar ^{235}U - Pu mixture, to 0.7 n/kb.

The 2200 m/s α values obtained for ^{233}U, ^{235}U and ^{239}Pu were 0.0899 ± 0.0004, 0.1702 ± 0.0007, and 0.3594 ± 0.0021 respectively. The mean value of σ_a for ^{239}Pu was 1017.7 ± 6.4 b, based on σ_a values of 575.6 ± 3.3 b for ^{233}U and 679.5 ± 2.5 b for ^{235}U. Values of $\sigma_\gamma = 96.1 \pm 2.0$ b for ^{234}U and 289.3 ± 1.4 b for ^{240}Pu were also obtained. The errors include experimental errors and the uncertainties in the neutron spectrum but not the g-factor uncertainties.

Resonance Radiative Neutron Capture Studies at Brookhaven

O.A. Wasson
Brookhaven National Laboratory

Low energy resonance neutron capture γ-ray experiments are performed at the HFBR at Brookhaven by both the fast chopper facility under R.E. Chrien and the neutron monochromator under W.R. Kane. The chopper in its three years of operation has provided useful data on over thirty elements including 45 different nuclei. The monochromator in its nine months of operation has produced final data on ten nuclei. The chopper is used primarily for studies of the neutron capture reaction mechanism while the monochromator is used for nuclear spectroscopy.

The chopper was also used to measure the spins of p-wave resonances in tin and molybdenum by measuring the angular distribution of γ-ray transitions to final states of known spin and parity. The facility is also useful in measuring lifetimes of isomeric states in the interval from 2 to 1000 μ sec. Numerous s-wave resonance spin assignments were deduced from the resonance capture γ-ray spectra. In addition, the partial capture cross section of twenty γ rays in iron were measured in the region below 1 keV.

The magnitude of the direct neutron capture cross section was deduced for several γ rays in Co^{60}, Tm^{170}, and U^{239}, and found to be in fair agreement with the predictions of Lane and Lynn. These results were obtained from an analysis of the interference between direct and resonance capture. Evidence for direct neutron capture at thermal energies for N-22 target nuclei was observed by the monochromator group for Ba, Ce, and Nd.

A large effort was spent on the statistical analysis of partial radiation widths. Variations form the purely statistical compound nuclear model are evidenced by the departures from a chi-squared

distribution with one degree of freedom of the distribution over capturing states of partial radiation widths in a significant number of nuclei. Further evidence is the observation of significant correlation of partial radiation widths with reduced neutron widths. However, the failure to observe a significant correlation of partial radiation widths with both capturing and final state reduced neutron widths in the same nucleus indicates that the departure from a purely statistical capture process is not due to the channel resonance capture process of Lane and Lynn. More complicated capture processes need to be included to explain the neutron capture reaction.

Resonance Capture Gamma-Ray Studies at Harwell

E.R. Rae

A.E.R.E., Harwell, Berks., England

The Harwell Electron Linac-Booster installation is used as a pulsed neutron source for the study of resonance capture gamma-ray spectra with Li-Ge spectrometers on two flight paths of 10 and 20 metres respectively. A photon energy resolution of ∿8 keV is available and the useful neutron energy range extends to several keV.

The principal object of the work has been to search for evidence of non-statistical behaviour in the radiative decay of the compound nucleus due to intermediate structure effects. So far results have been disappointing. The striking change in the capture spectrum of Hg-198 between the 23 and 90 eV resonances was vitiated by the study of the next three resonances, all of which produced spectra intermediate in character between the 23 and 90 eV cases, so that the complete set was not inconsistent with statistical behaviour. A careful study of the resonance capture spectra of the even tungsten isotopes (to be reported by J. Murray at the forthcoming Studsvik Conference) although equally tantalising in its suggestions of structure effects, likewise failed to establish conclusively the real existence of such effects. Work on the resonance capture spectra of U-238 in the neutron energy range up to ∿300 eV has so far failed to confirm the anti-correlation effects reported by Brookhaven, although there is, once again, a tantalising suggestion of a structure effect in the doublet at 3.98 and 3.99 MeV.

It would seem that the effects of intermediate structure on the capture gamma-ray spectra, if they exist, are weak and that much patient and accurate work will be necessary to reveal them.

Capture Gamma Ray Studies at Chalk River

E.D. Earle

CRNL, Chalk River, Ontario

The existing facilities for gamma ray studies at the CRNL reactors, i.e. the fast neutron chopper, the angular correlation and linear polarization, and the variable energy gamma ray irradiation facilities, were briefly described. Experiments recently executed on these facilities include ^{232}Th, $^{235,238}U(\gamma,f)$ cross-section and angular distribution measurements, $^{208}Pb(\gamma,\gamma)$ resonant scattering measurements, $^{199}Hg(n_{th},\gamma)$ angular correlation and linear polarization measurements, $Pt(n_{res},\gamma)$ and $In(n_{res},\gamma)$ measurements.

Anomalously intense radiations near 5.5 MeV first observed following thermal neutron capture (1) were found to be predominantly M1 in ^{200}Hg (2) and were found to be present following resonance capture in Pt. These anomalous radiations were studied further by $(d,p\gamma)$ and $(p,p'\gamma)$ experiments on the Chalk River Tandem. The gamma ray spectrum observed following the (d,p) reaction (3) was similar to that observed in the thermal and fast (4) (n,γ) reactions. It is independent of excitation energy and decreases in relative intensity as the target mass decreases from 208.

The experimental results are consistent with the hypothesis that the anomalous radiation following neutron capture is due to the decay of the doorway-state components in the wave function of the compound level. The primary gamma ray then corresponds to a transition of a single particle between orbits with $\Delta\ell = 1$, an energy of approximately 5.5 MeV.

The $(p,p'\gamma)$ experiments via isobaric analogue states in ^{208}Bi of ^{208}Pb particle hole states preferentially populating, in ^{207}Pb, states with 1p - 2h configurations were also performed. As expected the ^{207}Pb levels decayed strongly via the 5.5 MeV radiation.

(1) B.B. Kinsey, G. A. Bartholomew, Phys. Rev. 93 (1954) 1260

(2) G.A. Bartholomew, M.R. Gunye, and E.D. Earle, Can. J. Phys. 45 (1967) 2063

(3) G.A. Bartholomew, E.D. Earle, A.J. Ferguson, and I. Bergqvist, Phys. Letts. 24B (1967) 47

(4) I. Bergqvist and N. Starfelt, Nuc. Phys. 39 (1962) 353

A.A.E.C. studies in neutron capture cross sections and γ-ray spectroscopy

J.L. Symonds
A.A.E.C., Lucas Heights, Australia

Since the 3 MeV Van de Graaff accelerator was installed at Lucas Heights in 1963, a programme of measurements on gamma ray spectra following keV neutron capture has been in hand. The techniques used for these measurements have been refined steadily as firstly sectioned NaI crystals became available and later larger and larger Ge(Li) crystals were produced. Data collection usually limits the amount of information which can be handled so that early action was taken to introduce an on-line PDP-7 8K computer facility. This markedly improved the data output capability and permitted complex display of results. Human judgement in the analysis of results has been made possible through visual (CRT and light pen) and digital (typewriter keyboard) interfaces with the computer. The data analysis system is now used for two-thirds of the accelerator experiments as well as for programme development and other experimental analysis.

This discussion of the activities can be no more than an outline of the programme and its results. Details of experiments will be presented at conferences in Studsvik and Montreal later this year. It would be unfair to steal the authors' thunder at this gathering. Measurements have now been completed for keV neutron capture gamma ray spectra in all elements from calcium to zinc. As you are aware, this mass region includes many commonly used materials for which nuclear effects such as closed shells and strength function peaks are particularly important. Nuclei with even atomic number in this region usually have a neutron resonance spacing sufficiently large to allow observation of individual resonances. The closer level spacing for odd atomic number nuclei usually results in the measurement of averaged resonance capture information. Nevertheless, it has been found that some structure can be observed in the neutron time-of-flight spectra even with close resonance spacings (1 keV) and three are associated changes in the gamma ray spectra. The interesting feature of the keV neutron capture gamma ray spectra is that, while the spectra resemble those for thermal neutron capture, additional gamma rays may be observed and intensities differ. Contributions from d-wave resonances are indicated, sometimes higher than expected, and these effects are being closely examined for information on the behaviour of d-wave strength functions.

The main features of the results analysed to date are as follows:

(a) Calcium. Resonances at neutron energies of approximately 20, 50 and 100 keV are observed, each with a different gamma ray spectrum. The ground state in ^{41}Ca is observed, particularly for a resonance near 90 keV. This transition to a $7/2^-$ state is absent from thermal capture and indicates a contribution from p- or d-wave resonances. Some evidence is also present for a transition to the $1/2^+$ second excited state which is not observed for thermal capture.

(b) Scandium. In spite of the close resonance spacing (1.5 keV) some structure is observed in the neutron time-of-flight spectrum and there are associated changes in the gamma ray energy spectrum. The latter is similar to that observed for thermal capture although additional gamma rays are observed and intensities differ.

(c) Titanium. Results have been published. (Bird, Kenny and Allen (1968) - Phys. Lett. 27B: 638).

(d) Vanadium. The Chief feature of the vanadium results is that the high energy gamma rays become stronger as neutron energy increases.

(e) Chromium. keV capture is dominated by the most abundant element ^{52}Cr. Three strong transitions are observed one of which is to a high spin final state. The shapes of the observed gamma ray peaks can be fitted by assuming two resonances at 30 and 50 keV, the former having a probable d-wave assignment. The observed energies and intensities for these and other gamma rays are tabulated and will be issued in a forthcoming A.A.E.C. Progress Report.

(f) Manganese. In spite of the close level spacing in ^{56}Mn, over 30 gamma ray peaks are observed for levels up to an excitation of 2 MeV. The seven highest energy gamma rays have relatively high intensities showing that this behaviour is a property of averaged s-wave capture as well as thermal capture. Several gamma rays which are absent in thermal capture are strong in keV capture.

(g) Iron. Gamma rays from capture in ^{56}Fe have been studied from 1 MeV to the binding energy (7.6 MeV). Individual resonance effects are observed and transitions to high spin final states show the presence of p- or d-wave capture. The ground and first excited state doublet dominates keV capture, but to a lesser extent than in thermal capture.

(h) Cobalt. Results for cobalt show similar trends to those for manganese.

(i) Nickel. Results for nickel have already been published. (Allen, Kenny and Sparks (1968) - Nucl. Phys. A122: 220).

(j) Copper. Results for copper have already been published. (Allen (1969) - Nucl. Phys. A111: 1).

(k) Zinc. Transitions to a number of final states have been observed which are not present in thermal capture (outline of results to be presented in the next A.A.E.C. Progress Report). Observed intensities do not agree with estimates which were based on previous values of resonance parameters and assumed a statistical capture mechanism. The results indicate that the d-wave is higher than expected and that configuration effects play an important role in determining gamma ray strengths.

Compilation of Data

The study of capture gamma ray spectra has two functions - to supplement neutron resonance studies, and to produce information on other aspects of nuclear physics. While these functions are not always separate, practically all resonance capture spectra work has been devoted to resonance studies whereas thermal neutron capture studies have usually involved various aspects of nuclear structures. It is not surprising therefore that resonance capture results tend to appear at conferences where neutron interaction data are discussed, with emphasis on neutron cross sections and resonance parameters. The actual details of capture spectra for this purpose do not assume the same importance. We feel that it would be reasonable for neutron data centres to compile only those aspects of cross section and resonance parameters that might be derived from capture gamma ray studies. The most appropriate

place for the details of spectra-transition rates, etc. - is in the compilation of information on nuclear energy levels, particularly in such a journal as "Nuclear Data"; the special issues of Nuclear Data devoted to the compilation of thermal capture spectra could well be emulated to present resonance capture spectra.

It is planned that an A.A.E.C. report will be produced covering all the data on keV spectra measured by Allen, Bird and Kenny using the Ge(Li) detectors available to them. It is our understanding, through Dr. Bird, that O.R.N.L. NaI spectrum measurements will also be assembled into a keV capture spectra report. It would seem that the time is close when consideration should be given to the combination of such reports with the information which has been produced by other laboratories, even though at this stage only one-third of the elements has been investigated. We would be interested to hear whether other laboratories are interested in such a compilation, even with the extension to eV capture spectra. We wish to indicate our willingness to play a part in such a venture.

$(n,n'\gamma)$ and $(n,G\gamma)$ Cross Sections

I.L. Morgan

The University of Texas

The statistical model of the nucleus has been rather successfully applied, in some cases, in predicting the gamma-ray production cross section due to neutron inelastic scattering. The formulations of Hauser and Feshbach,[1] Satchler,[2] and later modifications by Moldauer[3] tend to predict the cross sections and angular distributions in the region of medium- and heavy-weight nuclei, unless there are large width fluctuations or strong direct interactions.

Although the optical potentials successfully predict total and elastic cross sections, their success is not as apparent in predicting inelastic cross sections as multiple exit channels open for decay of the compound nucleus, i.e., $n,n'\gamma$, $n,p'\gamma$, $n,d'\gamma$, $n,\alpha\gamma$, and the n,xn process. The successfull application will require an experimental knowledge of the cross sections, angular distribution, spins, parity and mode of decay of the excited states.

The recent development of Ge(Li) gamma-ray spectrometers has provided a new emphasis to the study of $n,n'\gamma$ and $n,G\gamma$ reactions. In particular, a separation of the partial cross sections can be accomplished, as well as the determination of branching ratios, spins and parity of individual states.

Neutron time-of-flight techniques have combined with the new Ge(Li) gamma-ray spectrometers used, in a close and open geometry, as single crystals and Ge(Li) - NaI anti-coincidence spectrometers to study a wide range of nuclei. In particular, Orphan etal at GGA[4], Brandenburger etal at Kentucky[5], and Hopkins at LASL[6], Percy at ORNL[7], Condé in Sweden, and Tucker, Nellis etal at TNC[8] have active programs in progress.

Specifically, intensive research on light and heavy nuclei in the energy interval E_n = 6.0 to 12.0 MeV is being conducted with the observed gamma-ray energy interval being 0.250 MeV = $E_\gamma \leq$ 12.0 MeV. Many exit channels are

observed which show the gamma-rays generally to be anisotropic and in some cases Doppler broadened. The continuum of gamma-rays which lie within the resolution of the spectrometers are real and must be treated as a real part of the n,Gγ cross section.

In general, extensive experimental measurements are needed extending the incident neutron energies from the region of 5.0 MeV to 14.0 MeV and the observation of E_γ from 0.100 MeV to 12 MeV.

These data will provide an additional test to the predictions of the statistical model including all additional open channels, width fluctuations, competition due to direct interaction and optical model parameters. The inclusion of shell model predictions as to discrete and continuum level structure as well as the rotational-vibrational model of deformed nuclei may provide the needed corrections, combined with width fluctuation corrections, direct interaction corrections to the transmission coefficients in the Hauser - Feshbach [9] formulation.

---

1) W. Hauser and H. Feshbach, Phys. Rev. 87 366(1952)
2) G. Satchler, Phys. Rev. 104 1304(1954)
3) P. Moldauer, Rev. of Mod. Phys. 36 1079(1964)
4) V.J. Orphan et al (To be published Nuclear Instruments & Methods)
5) J. Brandenburger, Univ. of Kentucky (Annual Progress Report NSF GP-7707)
6) J.C. Hopkins (Private Communication) LASL
7) F. Percy (Private Communication) ORNL
8) W.E. Tucker, D.O. Nellis and I.L. Morgan, ORO-2791-27 Progress Report Texas Nuclear Corporation
9) Hauser and H. Feshbach, IBID

THE CALCULATION OF NEUTRON CAPTURE GAMMA-RAYS AND THEIR EFFECT ON OPTIMIZED SHIELD DESIGN

K. J. Yost
Oak Ridge National Laboratory

The requirement for gamma-ray data in nuclear technology is based upon the need for gamma-ray production cross sections which are used to represent gamma sources in gamma heating and dose calculations. Recent optimized shield design studies have shown that the secondary (capture) gamma dose rate dominates the primary (core) gamma dose rate in typical auxiliary space power reactor shield configurations. It has been further established that non-thermal capture gammas dominate the total secondary gamma dose rate. Thus, one requires neutron energy-dependent gamma yields for structural and shield materials in order to properly describe secondary gamma sources. With data requirements of this magnitude a combined theoretical and experimental approach to data generation seems most feasible. In this spirit a method for calculating gamma-ray production cross sections has been developed which is composed of essentially four parts: a) a series of nuclear models for the description of nuclear energy levels (wave functions, energies, spin, parity, etc.), b) a code for the calculation of radiative transition matrix elements with model wave functions, c) a gamma-ray cascade model which utilizes level energies, spin, and parities from the nuclear models as well as matrix elements generated in (b) to calculate capture (and inelastic scattering) gamma yields, and d) a routine which cross section weights gamma-ray spectra corresponding to capture states of spin and parity susceptible to excitation in s-, p-, and d-wave neutron capture. The latter is primarily applicable in the case of medium and heavy nuclei. Capture gamma yields have been calculated and compared with experiment for natural tungsten with excellent results.

Appendix 8

a. Progress reports submitted to the Second INDC Meeting

The list follows the same order as that in Section 5 of the Informal Minutes

USSR	- INDC (CCP) - 3/G	(Volume of Abstracts Nr. 6)
Canada	- INDC (CAN) - 4/E	(EANDC(CAN) 38 "L")
Australia	- INDC(AUL) - 5/G	
UK	- INDC(UK) - 9/E	(AERE-PR/NP 15)
BCMN/Geel	- INDC(BUR) - 2/E	(EANDC(E)115 "U")
USA	- INDC(US) - 10/U	(WASH-1127 = EANDC(US)120"U")
Brazil	- INDC(BZL) - 2/G	
Japan	- INDC(JAP) - 3/G	(JAERI-Memo 3305)
India	- INDC(IND) - 8/G	(BARC-401)
F.R.G.	- INDC(GER) - 6/E	(EANDC(E)115"U")
Poland	- INDC(POL) - 2/G	
South Africa	- INDC(SAF) - 1/G	
Israel	- INDC(ISL) - 1/G	
Pakistan	- INDC(PAK) - 1/G	

Appendix 8

b. List of IMDC documents received and distributed by the NDU between January and August 1969

INDC Document Designator	Date Received	Original Document Identification	Document title, author, other identification numbers, etc. ...	Accession number
INDC(CCP)-3/G	15 Jan 69	-	Nuclear Physics Research in the USSR (Collected Abstracts) No.6, 1968	260
INDC(CCP)-3/U	19 Mar 69	-	English translation of INDC(CCP)-3/G	260E
INDC(USA)-9/E	21 Jan 60	WASH-1124	Report of a Meeting held at Columbia University, New York, October 21-23, 1968 (also EANDC(US)-111)	261
INDC(AUL)-4/G	23 Jan 69	-	Neutron Capture; J.R. Bird (reprinted from The Australian Physicist, Vol.5, No.8, pp.111-115, Aug.1968)	262
INDC(NDU)-6/D	12 Feb 69	CINDU-8	CINDU-8 compilation	263
INDC(NDU)-7/G	6 Jan 69	-	Proceedings of the Panel on Neutron Measurement Standards, Brussels, 8-12 May 1967	264
INDC(GER)-3/E	10 Feb 69	KFK 1000	High Resolution Total Neutron Cross-Sections between 0.5 - 3.0 MeV; June 1968; S. Cierjacks et al. (also EUR 3963e, EANDC(E)-111)	265
INDC(SEC)-2/G,L	28 Feb 69	-	Report to the Director General of the First Meeting of the INDC, Vienna, May 1968	266
INDC(NDU)-8/U	6 Mar 69	-	Nuclear Data Unit Correspondents for the Exchange of Nuclear Data Information, March 1969	267
INDC(UNI)-4/C	10 Mar 69	CINDA-68 suppl.1	CINDA-68 compilation, supplement 1	268
INDC(CAN)-3/E	10 Mar 69	EANDC(Can)-37	Canadian List of Requests for Measurement; Oct.1968; G.C. Hanna	269
INDC(CAN)-4/E	10 Mar 69	EANDC(Can)-38	Progress Report to the EANDC (by Canada), Feb. 1968 to December 1968	270
INDC(EANDC)-2/L	18 Mar 69	EANDC-78	RENDA - Compilation of EANDC Requests for Neutron Data Measurements	271
INDC(SEC)-3/U	25 Mar 69	-	List of INDC Documents, March 1969	272

* * * *

INDC Document Designator	Date Received	Original Document Identification	Document title, author, other identification numbers, etc.	Accession number
INDC(NDU)-9/U	April 69	IAEA-111	Report of the Panel on Neutron Data Compilation, held 10-14 February 1969 at Brookhaven National Laboratory	273
INDC(IND)-7/G	2 Apr 69	BARC-363	Yield of K X-Rays emitted from U^{236} Fragments; S.S. Kapoor et al., BARC, Bombay	274
INDC(JAP)-3/E	14 Apr 69	JAERI-memo No. 3305	Progress Report January to October, 1968 inclusive; T. Momota (also EANDC(J)10"L")	275
INDC(NDU)-10/G	7 May 69	--	Report of the Nuclear Data Unit to the International Nuclear Data Committee, June 1968 to May 1969	276
INDC(NDU)-11/G	7 May 69	-	Report of the Panel on Neutron Data Compilation (final draft)	277
INDC(ISL)-1/G	8 May 69	-	Progress Report from Israel	278
INDC(GER)-4/E	9 May 69	KFK 793	Analysis of Fast Critical Assemblies and Large Fast Power Reactors with Group-Constant Sets Recently Evaluated at Karlsruhe; H. Kusters et al. (also EUR 3962e and EANDC(E)-113)	279
INDC(GER)-5/E	9 May 69	KFK 880	Card Image Format of the Karlsruhe Evaluated Nuclear Data File KEDAK; D. Woll (also EUR 4160e and EANDC(E) -112"U")	280
INDC(EUR)-2/E	15 May 69	EANDC(E)-115 "U"	Progress Report on Nuclear Data Research in the Euratom Community for the period January 1 to December 31, 1968	281

* * * *

INDC Document Designator	Date Received	Original Document Identification	Document title, authors, other identification numbers, etc. ...	Accession number
INDC(SAF)-1/G	20 May 69	-	Progress Report to the INDC, 1968; compiled by D. Reitmann	282
INDC(IND)-8/G	27 May 69	BARC-401	Nuclear Data Activities in India - V	283
INDC(PAK)-1/G	27 May 69	-	Progress Report from Pakistan; May 1969	284

* * * *

INDC Document Designator	Date Received	Original Document Identification	Document title, author, other identification numbers, etc. ...	Accession number
INDC(IND)-9/G	2 June 69	BARC-364	Van de Graaff Laboratory Progress Report, compiled by T.P. David	285
INDC(JAP)-2/G	16 April 68	JAERI-4043	Bibliography for Thermal Neutron Scattering (Japan Atomic Energy Research Institute; March 1968) - also EANDC(J)9'L'	286
INDC(GER)-6/G	2 June 69	-	Progress Report on Nuclear Data Research in the Federal Republic of Germany. Compiled by J.J. Schmidt	287
INDC(JAP)-4/G	2 June 69	-	Survey of the Total Cross Section of Lead below 100 keV by R. Nakasima and S. Schwarz	288
INDC(JAP)-5/G	2 June 69	-	A review of the Total Neutron Cross Section of Carbon up to 2 MeV. K. Nishimura, S. Igarasi, S. Tanaka and T. Fuketa	289
INDC(BZL)-2/G	2 June 69	-	Progress Report on Nuclear Data Research in Brazil for the Period May 1968 to May 1969	290
INDC(AUL)-5/G	2 June 69	-	Report on Australian Activities May 1968 - May 1969	291
INDC(AUL)-6/G	2 June 69	AAEC/E-198	Resonance Parameters for measured keV Neutron Capture Cross Sections, by A.R. de L. Musgrove	292
INDD(US)-11/G	2 June 69	-	The Nuclear Safeguards Research and Development Program of the Los Alamos Scientific Laboratory; A Program Review Covering Calendar Year 1968	293
INDC(US)-11/G	2 June 69	WASH-1122	Research and Development for Safeguards, Dec. 1968. G.M. Inman	294

* * * *

INDC Document Designator	Date Received	Original Document Identification	Document title, author, other identification numbers, etc. ...	Accession number
INDC(US)-10/U	2 June 69	WASH-1127	Reports to the AEC Nuclear Cross Section Advisory Committee Meeting at Oak Ridge, 15 - 17 April 69, compiled by M.S. Moore	295
INDC(UK)-9/E	2 June 69	AE/RE-PR/NP-15	Nuclear Physics Division Progress Report, 1 May 68 - 31st. Oct. 68. Editors: C.F. Coleman, C.A. Uttley	296
INDC(POL)-2/G	2 June 69	-	Progress Report on Nuclear Data Research in Poland May 1968 - April 1969, edited by T. Niewodniczanski	297
INDC(UNI)-5/G	July 69	CINDA 69	An index to the literature on microscopic neutron data	298
INDC(ENEA)-2/G	2 June 69	-	ENEA Neutron Data Compilation Centre Progress Report (presented by V.J. Bell at the 2nd. INDC Meeting) May 1968 - May 1969	299