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INDC-19/U

International Atomic Energy Agency

INDC **INTERNATIONAL NUCLEAR DATA COMMITTEE**

TECHNICAL MINUTES

OF THE SEVENTH INDC MEETING

Lucas Heights, 7-11 October 1974

Compiled by

V. Benzi (CNEN Bologna, Italy)
(Executive Secretary)

Aided by

W. Gemmell (AAEC Lucas Heights, Australia)
(Chairman)

J.J. Schmidt (IAEA)
(Scientific Secretary)

September 1975

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

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Introduction

The International Nuclear Data Committee (INDC) at its Sixth Meeting in Vienna in October 1973 decided to issue "Technical Minutes" of each of its meetings for distribution to scientists interested in the production, evaluation and use of nuclear data. These minutes contain information of a technical nature which was presented and discussed at the INDC meeting. The numbering of items in the table of contents is in accord with the item numbers on the INDC agenda.

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LIST OF PARTICIPANTS

1. INDC members

W. Gemmell, AAEC/Lucas Heights, Australia (Chairman)
V. Benzi, CNEN/Bologna, Italy (Executive Secretary)
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W.G. Cross, AECL/Chalk River, Canada
T. Fuketa, JAERI/Tokai-Mura, Japan
R. Joly, CEA/Saclay, France
M.K. Mehta, A.R.C./Trombay, India
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2. Scientific advisers

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H.T. Motz, LASL/Los Alamos, USA
A.B. Smith, ANL/Argonne, USA
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3. Observers

1. B.J. Allen, A.A.E.C./Lucas Heights, Australia
2. J.R. Bird, A.A.E.C./Lucas Heights, Australia
3. J.W. Boldeman, A.A.E.C./Lucas Heights, Australia
4. B. Clancy, A.A.E.C./Lucas Heights, Australia
5. J. Coombs, A.A.E.C./Lucas Heights, Australia
6. M.J. Kenny, A.A.E.C./Lucas Heights, Australia (Local Secretary)
7. H. Liskien, BCMN/Geel, Belgium, Euratom

I. INTRODUCTORY ITEMS

Mr. K.F. Alder, Commissioner and Head of the Nuclear Science and Technology Branch of the A.A.E.C. and himself a former Director of the AAEC Research Establishment for over a decade, welcomed the participants to the Seventh INDC meeting on behalf of the Australian Atomic Energy Commission and the staff of Lucas Heights Research Establishment. After a brief outline of the Research Establishment work in nuclear applications, Mr. Alder pointed out the importance of the IAEA and INDC in advising the smaller and developing nations in the planning of research and development. "We feel - said Mr. Alder - that in giving this type of help to the smaller and developing nations, it is important to avoid making the choice for them: the aim should be to ensure that the choice is relevant". In particular, in advising developing countries whether or not to participate in the field of nuclear data measurements and compilation, the INDC should help them to ensure that their projects are both manageable and relevant, in order to avoid the creation of groups of frustrated scientists having inadequate access to modern facilities.

Mr. Alder also pointed out that there are many expensive and sophisticated machines for physics research around the world, which apparently are underutilized. The distribution of these facilities, and problems of funding, restricts their greater use and the possibility for small or developing countries to send people to work on them. A more even geographical distribution of facilities would assist in making better use of the talents available and hence assist in training and real collaboration and cooperation. Since these are primary abjectives of the IAEA, these problems are undoubtedly worthy of consideration by a body such as INDC, which, while it has scientific objectives, has also aims and responsibilities in connection with international collaboration and understanding.

The Scientific Secretary, Dr. J. Schmidt, thanked Mr. Alder for his pertinent remarks on behalf of the Agency and participants, and the Australian Government for its financial support in holding this INDC meeting at Lucas Heights. The association between the NDS and the AAEC Research Establishment has been a long and fruitful one, (he only needed to mention the fission product data library as an example),and he hoped this meeting would cement and continue the association. Schmidt thanked the previous Chairman, Professor Usachev, for his efforts during the 1972/73 calendar years and welcomed the new members and participants (M.K. Mehta, A.H. Wapstra, T. Fuketa, D. Berenyi and Y. Le Gallic).

Dr. Schmidt outlined some of the roles the IAEA expected the INDC to fulfill, particularly as this was the beginning of a new 3 year's period in which increased attention was being given to non-neutron nuclear data. The main function of the INDC lay in the policy advisory field, in advising, and directing recommendations to, the Director General of the IAEA on all aspects of nuclear data, both short and long term, in advising him on NDS activities in the field of data for nuclear reactions, nuclear safety, safeguards, environmental protection, and programs for developing countries, and, in the longer term data for fusion, life sciences and industry. These fields had been clearly brought out at the last General Conference of the IAEA to be the important areas of IAEA activity.

Dr. Schmidt hoped that the INDC would and could sustain improving and increasing contact with NDS activities in between INDC meetings, and members of INDC should show initiative in

1. soliciting support for fellowships and research contracts for nuclear data studies by developing countries (he mentioned the Romanian contract to measure thermal fission cross sections as an example);
2. stimulating and suggesting regional cooperative projects on nuclear data requested in the WRENDA lists.

Other roles for the INDC suggested by Schmidt included

- timely recommendations for meetings on special topics, and assistance with the preparation and organisation of such meetings. A very successful recent meeting was that on Fission Product Nuclear Data at Bologna in 1973;
- assessing the adequacy of NDS' staff and resources for fulfilling its growing tasks in relation to the Agency's overall programme;
- act as a dissemination source for nuclear data by various means, such as establishing regional and national data committees which could collect and screen data requests. A number of such committees have already been formed;
- open up communication channels to data users. He noted that this would become more difficult as the scope of work envisaged by the committee widened away from classical reactor data.

Schmidt drew attention to the experience of the INDC in the reactor physics data field where the reactor physicist needing the most accurate basic information had bridged the gap with the nuclear physicist, making the measurements. He expressed the hope that the INDC would continue to help bridge the gap between the pure and applied sciences. In this context Schmidt pointed out how appropriate it was to meet in a laboratory where the research in progress is both basic and applied.

In conclusion, Dr. Schmidt thanked the AAEC and the Australian Government for the opportunity of holding this INDC meeting in Australia.

The introductory speech of the Chairman for the 1974/1975 period, W. Gemmell, was mainly devoted to an analysis of the present situation in the field of nuclear data. There are many signs that, since many of the data objectives have been realised or are within sight of realisation, the manpower, effort and funding in the area of the measurement and compilation activities associated with neutron nuclear data have decreased.

In the area of nuclear power, in particular, the number of IAEA Memeber States active in fission reactor design has decreased, and as experience develops, data requirements here with their stringent accuracies are likely to recede. However, most member countries are potential or actual consumers of nuclear power and they will want to be self-sufficient in their analysis of fuel cycles, fission products, actinide waste and radiation shielding. There is, therefore, much still to be accomplished here, but possibly with less frequent major reviews.

Continuing his analysis, the Chairman said that as a consequence of the above mentioned expected reduction in neutron data requirements for nuclear fission reactors, there would appear to be an excess of experimental capability. Therefore, the INDC or IAEA might examine the possibility of using its good offices to assist in the utilisation of some of this excess capacity.

A consequence of possible reduction in experimental data output - said the Chairman - could be a questioning of the need for the Four Data Centre concept. Without weakening the cooperation between the various groups which is a major strength of the NDS and INDC, the possibility of achieving some degree of specialisation and avoidance of duplication should be considered.

The Chairman also pointed out that the INDC has been innovative in its support of small specialist meetings and in experimenting with their format. New approaches could also be suggested in order to establish the need for data in atomic energy application areas. For example, two INDC members (or INDC nominations) might be sent to attend IAEA meetings on nuclear applications and report back to the INDC with a critical review of what the data problems are likely to be.

The last point examined by the Chairman was the widening of the NDS scope. In looking for areas of diversification - said the Chairman - it would be useful to have agreed guidelines for new endeavours. The choice must be made carefully, but not so widely that it overextends the resources of NDS.

A.B. Smith (USA) expresses G.L. Rogosa's apologies for being unable to attend this particular meeting. Rogosa, who recently had assumed increased responsibilities as Assistant Director to the Division of Physical Research, had expressed his confidence in the success of the meeting.

II . PROGRESS REPORTS ON NUCLEAR DATA MEASUREMENTS AND FACILITIES (°)

II .A. Short Additions from Participants to Submitted Progress Reports

AUSTRALIA

Gemmell apologised for the lateness of the Australian 1973 progress report. He had hoped that the report to July 1974 would be available for this meeting. Indeed, the report was with the printer but not yet available. He asked Allen and Clancy to deal with various aspects of the Australian program.

A) Measurements

Allen indicated that $\bar{\nu}(E)$ for ^{233}U showed fine structure in accord with theoretical expectation, while none had been found for ^{235}U. The progress report would show mass yields and fission product angular distributions for ^{233}U and ^{235}U in addition to $\bar{\nu}_{Cf252}$ as a function of fission fragment charge and mass.

Analysis of high resolution neutron capture cross sections in collaboration with Oak Ridge has concentrated on light nuclei and those with near closed shell configurations. The ^{90}Zr analysis indicated a high valence neutron contribution and a high correlation between neutron and gamma resonance parameters. The study showed major disagreement with earlier RPI results.

In Fe the valence model calculations did not account satisfactorily for all the gamma ray intensities observed with Ge(<0.5 MeV) and NaI (<1 MeV) detectors.

The two lowest Si resonances found in the total cross section had been found to be asymmetric and the capture gamma ray intensities indicate that valence neutron effects are strong.

Capture gamma ray studies in the keV neutron region have been performed at 0.5 MeV for a variety of nuclei across the periodic table in a search for anomalous features as a function of mass number. These are of relevance to the systematic study of capture cross sections for fission products.

B) Evaluation

Clancy highlighted two areas in the forthcoming report, namely,

(°) Discussed on Wednesday

(i) A revision of AAEC/E277 on neutron strength functions including data to January 1974 and the preparation of similar information on neutron resonance parameters.

(ii) The more recent and more hopeful prediction of fission product mass and charge distributions - an extension of work reported at the Bologna fission product meeting.

CANADA

The Canadian Progress Report was distributed as G-document INDC(Can)-14/G. Cross restricted then his presentation to the following points:

A) Measurements

- The cross section measurements for the $^{103}Rh(n,n')^{103}Rh^{m}$ and $^{115}In(n,n')^{115}In^{m}$ reactions in the energy range from 0.122 to 14.74 MeV have been analysed. The results obtained by different methods of measuring neutron flux were found to be consistent.
  The number of gamma rays per disintegration of ^{115}In is uncertain. A six year old Chalk River unpublished value of gammas per disintegration is probably the most accurate available.

- From measurements at a neutron energy of 0.0551 eV, a cross section of 18.0 ± 1.6 b at 2200 m/sec was deduced for the $^{59}Ni(n,\alpha)^{56}Fe$ reaction. This value compares with 13.7 ± 0.6 b reported by Eiland and Kirouac.

- ^{235}U thermal fission yields of Palladium isotopes were measured at McMaster University. The obtained preliminary values suggest that the data for the 105 fission yield (cumulative) are about 50% higher than the expected value from the fission yield curve.

B) Facilities

- The NRU reactor at Chalk River is operating again after modifications that improve the experimental facilities. A number of beam holes have been increased in size and the emerging flux increased about 2-8 times. Two new holes have been added. The central hole in the thermal column has been enlarged to permit installation of a cold neutron source.

- The TRIUMF accelerator at Vancouver is expected to have its first beam (5 MeV) in the middle of October 1974. If start up goes according to plan, the energy will be increased from 5 MeV to 450 MeV within a few days. Experiments using polarized beams will start immediately using the low (1μA) beam available. Medical experiments are scheduled to start in a few months. The beam current will gradually be increased to 100 μA over the next year.

- In the Chalk River 13 MV Tandem Accelerator, the installation of a Pelletron charging system reduced the ripple on the terminal from 25 KeV to 500 eV at 10 MeV. It appears that further reduction of the ripple is possible; while the Pelletron system works very well electrically there are still mechanical problems.
- A new 14 MeV neutron generator with an expected output of $4x10^{12}$n/sec is under construction. It will be used for dosimetry and medical studies.
- A new Bremsstrahlung monochromator has been installed on the electron LINAC at the University of Toronto. The tagged gamma rays have a measured resolution better than 20 KeV at 7 MeV. A preliminary test is described in the progress report.

FRANCE

Joly mentioned that after the consolidated EURATOM report for 1973, the 1974 report would be issued nationally to speed its publication.

A) Measurements

The following activities were mentioned by Joly:

i) Saclay - The 60 MeV linac at Saclay would cease neutron cross section work after 1974. The analysis of the ^{241}Am σ_f and σ_t measurements from this machine in the resonance region was now complete and the high resolution (9 keV at 1 MeV) fission cross section ratio measurements for ^{235}U and ^{238}U in the energy range 0 to a few MeV were in progress. A similar measurement will be made with ^{243}Am relative to ^{235}U. Other projects were examining intermediate structure at low energies, the study of vibrational states near the fission barrier and the neutron capture cross section of gold in the energy range to 30 KeV with resolved Γ_γ to 600 eV.

ii) Cadarache - The group at Cadarache were continuing the EANDC cooperation project on absolute neutron flux measurements with the 5 MeV Van de Graaff and were working on ^{6}Li as a neutron standard reaction. A C_6F_6 liquid scintillator (Maier-Leibnitz detector) was used in a series of capture cross section measurements: Cr, Ni, Fe, Rh from 10 to 65 KeV; Na, Ta, Au from 10 to 160 KeV; Mn, ^{238}U from 10 to 550 KeV.

In addition to the above, a summary report on the experimental activities carried out at Bruyères-le-Chatel (Nuclear Physics Division) was presented by Michaudon.

The progress report included:

$\bar{\nu}$ and $\overline{E_\gamma}$ in the slow neutron resonances of ^{241}Pu using the Saclay 60 MeV linac (joint experiment with the Saclay group).
In contrast to what has been observed for ^{239}Pu and ^{235}U, no variation of $\bar{\nu}$ and $\overline{E_\gamma}$ has been detected in the ^{241}Pu resonances.

$\bar{\nu}.^{235}U$ from 200 KeV-1 MeV. Due to high background, the existence of structure in the $\bar{\nu}$ variation with E cannot be confirmed at present.

(n,2n) cross sections from threshold to 15 MeV have been measured for the following nuclei:
^{45}Sc, Fe, ^{59}Co, ^{89}Y, ^{169}Tm, ^{175}Lu, ^{181}La, ^{197}Au and ^{209}Bi
(additional points have been obtained at 14.5 and 15 MeV).
- W, Pt, Ni, Nb, Rh (data obtained).
- separated isotopes of Sm and Se (in progress).

(d,n) angular distributions of the emitted neutrons have been measured for:
- ^{56}Fe (good agreement with (^3He,d) data)
- ^{26}Mg, ^{30}Si, ^{31}P, ^{69}Ga, ^{71}Ga, ^{140}Ce.

(n,n), (n,n') and (n,x):
- separated isotopes of Se (76-78-80-82)
- separated isotopes of Sm (148-150-152).

$^{239}Pu(d,pf)$ measurements of anisotropy, mass distribution and kinetic energy of the fission fragments emitted in this reaction, combined with data on spontaneous fission of ground state and the isomeric state seem to show that two modes of fission appear in the ^{240}Pu system depending on the energy and damping on the fissioning state:
- superfluid motion for the ground state, the isomeric state, and the vibrational state at 4.65 MeV.
- viscous motion for states above 4.65 MeV excitation energy.

B) Evaluation

Joly mentioned that 3 laboratories were engaged in fission product work involving decay schemes and mass distribution of fission products from various fissile isotopes at different energies. This is part of the support for CEA file on fission product recommended data ($T_{\frac{1}{2}}$, E , E , yields, etc..) being established in ENDF/B-III format and in the process of translation into ENDF/B-IV format to allow introduction of accuracy.

Michaudon mentioned that a description of several model calculations has been made at the Topical discussion of the NEANDC meeting in Tokyo. These calculations include:

- Neutron-Nucleus Cross Sections in Heavy Nuclei with a Coupled Channel Model from 10 KeV to 20 MeV. (These calculations are extended to medium-mass nuclei such as ^{93}Nb, ^{89}V).
- Effects of Nuclear Deformations on Neutron Total Cross Sections (especially for Sm isotopes in the transition region).
- Calculations of (n,n') Cross Sections from 2 MeV to 7 MeV neutron energy for light nuclei (Cr,Ni).
- Evaluation of the (n,xn) and (n,xnf) Cross Sections for Heavy Nuclei with the Statistical Model - Results are obtained from 2 MeV to 15 MeV for Uranium Isotopes (^{232}U to ^{239}U).
- Statistical Model Evaluation of Neutron-Induced Fission and Capture Cross Sections of Heavy Nuclei from 3 KeV to 2 MeV. Results for ^{232}U, ^{235}U, ^{238}Pu and ^{240}Pu are available.

GERMANY

Cierjacks reported that besides the activities included in the European Progress Report NEA-NDC(E)/161"U", the following work in progress or recently completed had to be mentioned.

A) Measurements (Karlsruhe)

a) At 3 MV VdG accelerator

- measurements of ^{238}U capture cross section in the energy range 10-500 KeV relative to capture cross section of Au and fission cross section of ^{235}U.

  Complementary measurements are underway to normalize the relative data at about 500 KeV.

- the measurements of γ-production in resonance capture of Fe and Ni using a Ge(Li) detector were completed.
  The results have been reported at the Petten Conference.
- measurements of $\bar{\nu}$ and α for ^{239}Pu are in progress.
- capture cross section measurements for ^{240}Pu, ^{242}Pu and ^{241}Am with a Moxon-Rae detector are in preparation.

b) At FR 2 reactor

- in the framework of the Safeguards program, decay schemes and transition probabilities of ^{240}Pu and ^{242}Pu have been measured and published.

c) At the cyclotron

- measurements of (n,n',γ) cross sections on Ni and Cr have been completed, and the analysis of the experimental results is underway.
- elastic scattering cross section measurements on C , O , Si and Ca at 10 scattering angles with high resolution have been completed.
  Measurements on Fe and Pb are in progress.

B) <u>New facilities</u>

- Hamburg: the variable energy cyclotron has come into full operation with the following characteristics:

Projectile type	Energy range (MeV)	Beam current (μA) Internal	Beam current (μA) External
p	3-28	100	30
d	2-17	100	30
^{3}He	10-44	25	5-10
α	10-32	25	5-10

- Bochum: the new dynamitron of the University was put into operation at the beginning of 1974.

- Braunschweig: the compact cyclotron is expected to be installed in the very near future at the PTB.

- Darmstadt: the Heavy-ion accelerator UNILAC will go into operation at the beginning of 1975. The machine will accelerate ions up to U with an energy of $\sim$10 MeV/nucleon.

C) Evaluation

The evaluations of σ_f for ^{235}U and ^{238}U between 1-20 MeV, relative to H(n,p) are almost completed. Results are expected to be available at the end of 1974.

HUNGARY

Nuclear Data activities in Hungary in 1973 were described in the INDC(HUN)-11/L document.

Berenyi indicated that two universities and two research institutes were engaged in production of nuclear data and that increased collaboration was occurring with other branches of science.

INDIA

In addition to the Progress Report from India published as INDC report INDC(SEC)-42/L which covers the work performed during 1973, the following points were underscored by Mehta.

A) Measurements

i) Charged Particles - At Trombay, the major effort concerns the absolute measurement of (p,n) cross sections. Measurements are underway for the (p,n) reaction in ^{55}Mn from near threshold to about 5 MeV. Apart from this, there is a programme of studying elastic alpha scattering from light nuclei in which $^{6}Li(\alpha,\alpha)^{6}Li$ work is completed and data have been measured for ^{24}Mg and ^{26}Mg isotopes.

ii) Fission - Fission studies at Trombay have included determination of fragment isotopic yields in the case of spontaneous fission of ^{252}Cf accompanied by the emission of light charged particles (LCP). These measurements utilised high resolution detection of prompt gamma rays emitted from fragments in case of LCP fission relative to binary fission. An experiment was in progress - with encouraging preliminary results - to measure the cross section for the excitation of fission isomers of ^{238}U by inelastic scattering with 14 MeV neutrons.

B) Facilities

Mehta mentioned that the variable energy cyclotron (Calcutta) should be operational in 1975 and that a Li(p,n) facility would be installed for neutron data work. The 100 MW research reactor will provide 2.10^{14} n cm^{-2} s^{-1} in 1979 and will be equipped with hot and cold neutron sources.

C) Evaluation

The theoretical reactor physics group had calculated total, elastic, inelastic cross sections with optical and statistical models for fissile and fertile materials used in the fast breeder reactor thorium fuel cycle over the energy range 0.1 to 20 MeV. For multigroup cross section sets 1020 energy point values over the energy range 0.4 eV to 10 MeV scattering matrices have been prepared for various light and medium mass nuclides. These were now on magnetic tape in ENDF/B format.

ITALY

A summary of the Italian contribution to the European Progress Report NEA-NDC(E)/161"U" was circulated by Benzi. He underscored the following points:

A) Measurements

The following work was carried out by the Trieste group using the Padua VdG:

i) Elastic scattering of neutrons from carbon in the incident neutron energy range 1.98 to 4.64 MeV. Angular distributions were obtained by means of a neutron time-of-flight spectrometer. Data were taken for eight energies and for thirteen scattering angles. A phase-shift analysis was carried out and a set of phase angles capable of reproducing the elastic data was obtained.

ii) Angular distributions of the neutrons scattered by ^{6}Li , which have been measured by means of a neutron time of flight spectrometer for eight values of the incident neutron energy in the interval from 1.98 MeV to 4.64 MeV. The angular distributions have been determined at thirteen angles in the interval from 30° to 140° , in the laboratory frame of reference. The differential and the total elastic cross--sections have been then deduced from the angular distributions.

B) Facilities

The fast-thermal RB-2/TV reactor went critical at the beginning of September 1974 in Bologna.

In the framework of a joint CNEN-AGIP/N-CCR/ISPRA-CEA agreement, integral measurements based on the zero-reactivity method will be carried out during 1975 in order to have experimental values of capture integrals of Fe, Ni, Cr in neutron fluxes having energy spectra similar to those of large fast reactors.

JAPAN

In addition to the Japanese Progress Report INDC(JAP)23"L" the following activities were mentioned by Fuketa.

A) Measurements

R.C. Block et al. at Kumatori Linac (Research Reactor Institute, Kyoto University) performed iron filtered beam, t.o.f. transmission measurements on C , Be and O near 24 KeV. The obtained total cross section values are supposed to have very high precision.

B) Facilities

In reply to Joly, Fuketa said that the JAERI Linac is fully operational, but the repetition rate had yet to meet specification. The achievement of high currents would require installation of a new gun.

C) Evaluation

Fuketa highlighted the fission product evaluation for fast reactors in the recently issued progress report INDC(JAP)22/G. This was a preliminary evaluation and a preliminary benchmark integral experiment has been established to test this work.

NETHERLANDS

The progress report is included in INDC(SEC)-43/L. Wapstra highlighted these subjects:

A) Measurements

(a) The use of polarised neutrons and polarised targets to determine the spins in ^{235}U neutron capture. A better polarised neutron source was being developed using a better mirror and should be ready in 1975. The neutron capture gamma rays in rare isotopes such as ^{50}Cr were being studied as was the circular polarisation of gamma rays following capture of polarised neutron.

(b) Table 24 in the report on fission product cross sections and reactivity should be available soon and an evaluation of cross sections for fission products for 60 isotopes be completed by late 1975.

B) Evaluation

Regular adjustements to and evaluation of nuclear masses. An up to date file was maintained and data would be provided to those interested. A broad overall review would show:

(i) substantial improvement in masses of Th, U and Pu isotopes. This improvement over earlier compilations was due mainly to new mass spectrometry results from Minnesota.

(ii) vast improvement in masses of extremely neutron deficient isotopes ($150<A<220$) arises from better knowledge of α active chains.

(iii) very interesting information on neutron-rich light isotopes ($A<50$) , partly obtained at Orsay through mass spectrometry on very unstable isotopes.

(iv) Little improvement in masses of neutron rich isotopes, particularly fission nuclides. Measurements are still poor, but prospects have been improved by the recent developments in mass spectrometry of unstable nuclides.

SWEDEN

A) Measurements

Conde reported continuation of the scattering (elastic and inelastic) work at Studsvik. For elastic scattering, the angular representation had been refined, and the energy range increased up to about 10 MeV. The inelastic measurements were intended to check nuclear theories. Inelastic scattering measurements at KeV energies were being undertaken for ^{238}U. In addition to the neutron fission spectrum measurements, new experiments were in progress on delayed gamma rays from fission in the range 1 to 1000 s. The reactor physics group at Studsvik was measuring calorimetrically the fission decay heat of fission products 20 to 30 seconds after irradiation.

At the Chalmers University of Technology measurements were planned in the KeV-region using a neutron filter constructed for the R 2 reactor at Studsvik giving 10^6 neutrons $cm^{-2}\ s^{-1}$. The measurement of the $^{59}Ni(n,\alpha)$ cross section gave a slightly higher value than previously reported by Eiland and Kirouac.

The Lund University had measured the activation cross section of $^{115}In(n,\gamma)^{116m}In$ at 15 MeV and obtained values an order of magnitude lower than previous measurements. These would be repeated using an improved target system to decrease the contribution of low energy neutrons.

At the Research Institute of National Defense, measurements have been made of fission cross section ratios and gamma-ray production cross section ratios in the neutron energy region above 5 MeV.

The Swedish Research Council Laboratory had continued the measuring program on fission products by an on-line mass spectrometer allied with the R 2 reactor and was obtaining half lives and other decay properties.

B) Facilities

The 6 MeV tandem-pelletron installation at Lund has been delayed until spring 1975.

U.K.

Rose underlined the following activities among those described in the U.K. Nuclear Data Progress Report for the period April 1973 - March 1974:

A) Measurements

a) The natural isotopes of hafnium were the subject of thorough investigation of total and capture cross sections from a few MeV to 100 KeV and a resonance analysis has been done up to 40 eV.

b) Cunninghame has measured the absolute yield of five fission products from the fission of ^{235}U and ^{239}Pu, at six energies between 130 KeV and 17 MeV. The yields on the peak are constant to uncertainties of 4 per cent in the case of ^{235}U and yields in the valley and wings of the distribution increase with initiating neutron energy.

c) The measurements of the half lifes of ^{237}Np and ^{239}Pu previously reported should be complete this year and the measurement of ^{244}Cm production cross section from ^{243}Am is proposed for a ZEBRA fast reactor spectrum.

B) Evaluation

Rose indicated the major changes in Sowerby's simultaneous evaluation of ^{238}U capture, ^{235}U fission and the ratio of ^{238}U capture to ^{235}U fission in the energy range 100 KeV to 1 MeV. It is thought that incompatibility between them arises from errors in the ratio measurement.

The possibility that the experimental and calculated neutron spectra in fast ceramic fuelled reactors could be reconciled by invoking the $^{238}U(n,\gamma n')$ reaction as an additional moderating mechanism has been discussed by Lynn, who has found the cross section to be two orders of magnitude too small. (Smith later confirmed that Moldauer has reached similar conclusions in Nucl. Sci. and Eng. The reaction has a μb cross section).

U.S.A.

Smith and Motz confined their remarks mainly to highlights of USNDC-11 Progress Report.

A) Measurements

Smith mentioned that a paper had been produced on fast neutron capture in uranium between 500 and 3500 KeV and other fast neutron capture studies on gold, nickel and niobium. Inelastic scattering work for ^{238}U and heavily deformed nuclei had continued and a major effort into intermediate structural materials had occurred. Smith reported also papers on molybdenum and zirconium in which the physics of isospin and shell closure had been investigated for elastic and inelastic scattering over a wide range.

At Ohio University a new group has commenced work on neutron scattering in light nuclei (B, Li, etc..) at energies greater than 1 MeV and using R matrix theory to interpret the study. Progress was being made in (n,p) and (n,α) reactions.

Important neutron polarisation scattering experiments with light elements (Li, He, Be and C) were in progress at Yale.

Motz indicated the potential significance of the ^{233}U fission work at Columbia. The partial σ_f was correlated with the energy bin of the lower peak of the fission fragment distribution, taking 10 slices on this lower peak. Subtle but significant changes in the apparent resonance structure are found for all three nuclei (^{3}U, ^{5}U and ^{9}Pu) as the gating is changed. Resonances appear and disappear, double, and have a skew effect with bias. This indicates a new complication to fission which might require an additional quantum number.

The ^{235}U fission cross section relative to H(n,p) over the energy range 3 MeV to 20 MeV is being measured at Livermore as mentioned in the sub-committee. Also at LLL measurement of the ratios of fission cross sections of ^{233}U, ^{238}U, and ^{239}Pu to the fission cross section of ^{235}U is in progress over the energy range of a few hundred KeV to 30 MeV.

Continuing thermal neutron capture experiments at Los Alamos have shown new weak transitions in Be with 4 μb cross sections, which gives an indication of the sensitivity of the experimental system.

Oak Ridge work on capture gamma rays from capture of neutrons in the 100 KeV to 20 MeV region continued with the gamma rays in the range of a fraction of MeV to the binding energy, of great interest in shielding. A new ^{238}U capture measurement was planned with new detectors because of the discrepancies which existed and could not be understood.

B) Facilities

a) At Duke University, the Cyclo-Graaff (a 15 MeV cyclotron injecting into a Model FN tandem Van de Graaff) has been in operation for six years. A neutron time of flight system was obtained from the Aereospace Laboratory at the Wright Patterson Air Force Base. This system is completely devoted to fast neutron cross section measurements.

b) The 100 m flight path at NBS was now operational.

C) Evaluation

In addition to the experimental work, a number of activities on evaluation were mentioned. Smith reported that a revision of Nb for CTR applications was completed. He drew attention to the effort devoted to the conversion of the fission product file at NRTS into ENDF/B-IV format. Referring to the above mentioned experimental work, Smith noted the uncertainties in model calculations and drew attention to a forthcoming paper at the American Physical Society's October 1974 meeting, entitled "How and Why the Hauser-Feshbach Formula Works". He suggested there were many serious unresolved problems associated with the compound nucleus process.

Smith tabled a number of Argonne reports which might not otherwise come to members' attention.

The National Bureau of Standards has issued NBS 138, a comprehensive graphical summary and guide to total cross section measurements.

An R matrix study of the $^{6}Li(n\alpha)$ reactions was mentioned by Motz in which 19 individual reaction observations over various energy regions had been fitted and all charged particle information had been correlated simultaneously in the fit.

The delayed neutron spectra from ^{235}U was also mentioned, as was the NSE paper from the University of Washington on the same topic, giving similar results, but which compared their work with the 1952 Batchelor data and made comments on the corrections necessary to both.

Discrepancies have been found in the decay scheme and branching ratios of ^{241}Pu which are of importance in safeguards work.

Motz drew members attention to a review paper by de Saussure (ORNL) at the recent ANS Topical Meeting on Reactor Physics, September 1974, which was in effect a critique of evaluations.

USSR

Several papers on experimental neutron studies (Ya.F.I. collected papers 17 and 18) and a collection of nuclear constants (Ya.K. 13 and 15) have been sent to the IAEA. Yankov dealt with some aspects of these compendia.

At the Energy Physics Institute (Smirenkov group), the neutron spectrum from the spontaneous fission of ^{252}Cf, ^{244}Cm and ^{240}Pu were found to take a Maxwellian form. For ^{252}Cf, T=1.42±0.03.

Kozansky et al. were continuing alpha measurement in ^{239}Pu at the following energies: 2, 24.5 and 140 KeV and the Kononov group were measuring α , σ_f and $\sigma_{n\gamma}$ for ^{235}U and ^{239}Pu from a few to 100 KeV. Papers from this group were presented to the sub-committee on Discrepancies.

Measurements of $\bar{\nu}$ for ^{240}Pu, ^{241}Pu and ^{232}U were being made by the Kusminov group also.

At the Experimental Reactor Institute, Yenatin is investigating $\bar{\nu}$ for the curium isotopes ^{244}Cm, ^{246}Cm and ^{248}Cm and Smirenkin the fission cross section of ^{249}Cf.

Maksyutenko (Atomic Energy Institute) is measuring neutron resonance parameters for fission products, including those of ^{101}Tc.

Salnikov at the Physics Energy Institute is studying the secondary neutron spectrum from inelastic scattering on Fe, Co, Ni, Cu, Nb, Sn, Bi at a variety of angles for 9.1 MeV initial neutron energy.

CBNM - EURATOM (Geel)

A) Measurements

As many of Geel's activities were concerned with standards and as these have been discussed in the Standards Sub-committee report, Liskien restricted himself to complementary issues.

On the linac, resonance parameters for ^{238}U were being measured from 10 eV to 4 KeV and average capture cross section below 100 KeV. Other resonance parameter or $\sigma_{n\gamma}$ measurements were available on ^{91}Zr and ^{96}Zr(E<15 KeV) and for ^{237}Np(<250 eV).

The VdG was in use in measuring (n,2n) cross sections for Au and ^{66}Zn in the 12-20 MeV energy range. The neutron fission spectrum of ^{239}Pu was being measured for neutron fission with 300 KeV neutrons. The laboratory had participated in the first round of neutron flux intercomparison between five laboratories.

B) Facilities

Liskien reported that the two existing machines were being modernised:

- the linac upgraded with new sections to 120 MeV with a 4 ns pulse capability;

- the Van de Graaff will be replaced (1975/1976) with a 7 MV machine with a klystron buncher instead of the Mobley buncher.

II .B. Short Report on Nuclear Data Measurements in Countries Not Represented on INDC

Schmidt reported a substantial increase in the number of countries providing information on their neutron and non-neutron nuclear data activities. This was reaching the stage of being a useful survey of nuclear physics activity and of increasing importance and use to other Agency bodies. The report, INDC 43(L) indicated substantial international cooperation, particularly between East European countries and Dubna. He drew attention to a report from the Tehran University Nuclear Centre (late arrival) and the Brazilian investigation of the resonance fluctuation factor in Hauser-Feshbach theory - a topic already suggested for inclusion in the agenda of the forthcoming IAEA Consultants Meeting in the use of Nuclear Theory for Neutron Rata Evaluation at Trieste.

III. NUCLEAR DATA MEASUREMENT REQUIREMENTS

IIIA. Targets and Samples Program (°)

Smith distributed copies of the US electromagnetically enriched isotope inventory as of March 1974 (°°), and indicated that the US policy on loans and sales was that announced by Rogosa at the last NEANDC meeting. He indicated that samples were available by sale for all research purposes and loans are judged on their specific merit. Both OECD and non-OECD countries have recently benefited from these arrangements. The IAEA had access to this inventory. Schmidt sought the views of Rose, Usachev and Liskien on the availability of samples from the UK, USSR and CCDN loan pool. Usachev's informal enquiries indicated that loans were available at 5 per cent of cost per annum and mentioned that both France and Germany had availed themselves of this service. A catalogue of USSR isotopes available for loan, or sale was available from Techno Export. (Liskien indicated that it was better to write to the Techno Export agent in the member's own country. He had the name and address of the German agent). Schmidt was told that it was best if IAEA wrote directly to Techno Export on IAEA letter head.

(°) Discussed on Wednesday.

(°°) See Appendix XI.

IV. NEUTRON NUCLEAR DATA

IV.A. Additional Information from Neutron Data Centres

Attention of members was drawn to the publication of:

BNL-325 3rd Edition, Vol. 1. Resonance Parameters

NEANDC95(U) Compilation of special neutron reaction cross sections for neutron reactor dosimetry. Of special note is the abstracts of experiments in EXFOR-like format suitable for evaluations.

IAEA Handbook on Nuclear Activation Cross Sections. (See actions n. 12 and 13)

NEANDC 97(U) Computer programs available at CPL for neutron cross section calculations and evaluations.

Benzi noted that the latter was intended to indicate selected, most widely used codes to form the basis of CPL library, but to his knowledge no action to get them had commenced.

Smith drew attention to recent US activities (USNDC-INDC 65(U), p. 61) dealing with planning for the fifth version of ENDF/B and thought that the Standards file would probably be available to IAEA/NDS in due course. Volume 2 of BNL-325 was in press and consisted of cross section curves. Usachev outlined recent developments in USSR activities. In addition to basic compilation and evaluation of microscopic cross sections, they had the task of generating nuclear constants for reactor studies. This included a library of integral benchmark experiments with associated sensitivity coefficients and derivation of group constants from evaluated data. Comparison of evaluated data with the integral quantities in the benchmark library allowed a unification of the data - adjustment of constants and consideration of the integral experiments set down the data requirements in terms of accuracy to be achieved in experiments - in a planned program as already outlined. This presented an iterative approach to nuclear data and improved the effectiveness of the work.

IV.B. Evaluated Data and Evaluated Data Exchange (°)

Usachev reported that Konshin's ^{239}Pu evaluation presented at the Kiev conference was now complete and available on punched tape. Transfer to magnetic tape - unusual in current USSR practice - was being actively pursued and should be available for distribution by the end of 1974. Currently, a 500 page report on the evaluation would be available on request to those active in the evaluation field, but would not be published in the usual sense. It was intended to present in "Nuclear Constants" a 10 to 20 page statement on this evaluated file in a manner based on similar USA standard file description.

A similar file for iron would also be available on magnetic tape soon. Several papers had been published over the years on various aspects of iron evaluations (cross sections above 2 MeV, cross section in the resonance range) and this had been completed with complementary studies.

An evaluation of ^{235}U by Konshin was mentioned by Usachev as being almost complete and would be accompanied by a 700 page report setting out details of the evaluation. The deuterium evaluation by the Nikolaev group was also being transferred to magnetic tape. He hoped that both of these items would be available shortly.

Russian studies having a bearing on evaluations were:

- Tolstikov's evaluation of $(\sigma_{n\gamma}\ ^{238}U)/\sigma_{nf}\ ^{239}Pu$ has been published this year in Nuclear Constants 13. It was hoped that it would be issued soon as an INDC 'G' distribution. Usachev had two copies with him.

- Lukyianov and Sukhoruchkin's theoretical study describing the Salnikov group's measurements of angular scattering at six angles and at 9.2 and 14 MeV by a direct reaction involving a physical excitation by the neutron of a nuclear nucleon. This was the simplest model possible and provided a good description of the process. This should enable the gap between experimental points to be filled by interpolation.

- Usachev noted the publication of cross section calculations based on coupled channel theory for iron, and

- the compilation of evaluated activation cross sections for threshold reactions, considered in an earlier discussion on reactor dosimetry. This covered 20 isotopes and provided curves averaged over all exis-

(°) Discussed on Friday

ting results. These are given in Nuclear Constants 15.

Schmidt queried how much of this evaluation was based on original USSR work and having consulted the references in the Nuclear Constants report brought to the meeting, found only few. He wondered whether this indicated a lack of interest in the reactor dosimetry field. Usachev was unable to confirm or deny the non existence of USSR work in this area, but felt that this was the purpose of international cooperation - that it was possible to exchange information and avoid always measuring the same quantities.

Finally, Usachev drew attention to Nuclear Constants 12, Part 2, containing a survey by Abramov on photoneutron reactions close to threshold and the collection of constants and decay schemes for gamma emitting radioisotopes in the appendix to Nuclear Constants 14. The latter was a reference work by physicists active in activation analysis generally, and reactor coolant circuits specifically. It contained gamma spectra data on 72 isotopes of practical interest to them.

Schmidt introduced the Working Paper n. 6 (see Appendix XII), indicating what evaluated files were available at NDS.

Smith drew Schmidt's attention to the fact that it was ENDF/B-IV Standards Reference Files that were available at NDS and hoped that version V would be available soon. He then addressed himself to the problem of documentation. He felt this was a serious problem because, without adequate description, the file could not be read. He then outlined his problems with the USSR evaluations available at NNCSC. These were the Nikolaev elastic scattering angular distribution and the ^{238}U evaluated file on file tapes 715 and 700. Only the ^{238}U evaluated file was complete in the ENDF/B sense and although he had some success in untangling it, he found many critical items, particularly in the resonance region, undocumented. He thought it impossible, without a massive effort, completely understand to what the file contained or meant. If the transfer and exchange of evaluated data was to be treated as a serious matter, then documentation of the format was an absolute essential. He would like to propose the following guidelines:

- That evaluated data being exchanged should be considered to be implemented and effective only when there was a common language documentation on format, definition, on file production and some mechanism for converting the file from one format to another in anautomated manner.

He drew attention to the meeting arranged by Benzi at Bologna on format conversion and suggested increased attention should be given to:

(i) programs which were capable of converting one format to another, and

(ii) the scope of the files.

He personally felt that certain parts of the USSR files were superior to US files, because they agreed with his own measurements, but was unable to check USSR files with benchmark calculations.

The INDC should give its attention to the comprehensive nature of file exchange and not just exchange of numbers on magnetic tape. This meant definition of formats, documentation and a mechanism for transformation between systems.

Finally, he reiterated his plea for feedback information from those who were using the standards files. Information on errors and corrections were sought. Smith provided Usachev with some plots resulting from his work on the USSR file.

Benzi indicated that they were considering the possibility of accepting the Sokrator format in their "Four Aces" program, which at present accept KEDAK, UK and ENDF/B files to produce group cross section libraries.

They were held up by the absence of adequate documentation, e.g. whether treatment of resonances was single or multilevel.

Usachev expressed surprise that documentation on the ^{238}U file was lacking because everything had been written in English and the tape contained complete indications of its content at the beginning of the file. He felt there must be some misunderstanding and suggested that Smith and Benzi should write to the authors, either directly or via the data centre. Usachev added that he hoped feedback would not be restricted to US files as everyone would benefit from feedback which indeed was one of the main purposes of international exchange and publication.

Schmidt indicated that the USSR "Sokrator" format was detailed in English in INDC reports CCP-13L and CCP-23G and that these were manuals in sufficient detail to run the program. He indicated that it was the responsibility of member states and not the IAEA to translate the back-up documentation (i.e. the 500 to 700 page reports mentioned earlier).

The following actions were agreed upon:

1. on CJD. To ensure that adequate documentation is included to make reading of the evaluated file on magnetic tape possible (action n.14);

2. on Four Centres. To encourage users of standards files to supply feedback information to the centres and originators of the evaluation (action n.15).

V. NON NEUTRON NUCLEAR DATA

V.A. Additional Information on Existing and Projected "Non-Neutron" Nuclear Data Centres and Groups

Bird presented his personal views on a Nuclear Data Committee in Australia involving the universities, to foster communication with the IAEA and other overseas groups. Most measurements made in Australia are reported in the open literature and a move into evaluation and compilation will only occur when a clear demonstration of need exists. Compilation for applications was taking place in n and p capture gamma rays. Better and more coordinated information is required than is currently available and indeed intensities of gamma lines was a problem. The Rasmussen (MIT) catalogue had been computerised with gamma intensities as a function of energy and element. This was a consistent set from one set of measurements by one person in 1967. Although various capture experiments had been published since then with greatly improved precision on energy and intensity, there had been no attempt to incorporate them into a unified scheme like Rasmussen's and when it was done in calibrating Ge(Li) detectors, the result was not a smooth curve and variations of 20 per cent were found.

Motz suggested the Rasmussen data was neither the best, the most up to date, nor reliable. In application it was best to try the experiment out to see how well it worked with approximate intensities and as a function of signal/noise, etc.. Complete gamma spectra were not available on a coarse mesh and very few experiments gave lines all the way from X-rays to binding energies with all the necessary information. He thought Groshev's data was most complete and reliable, although it did not have high resolutions. There was a need to improve the correlation of the data, for Groshev gave intensities as a function of energy and then table of lines as he resolved them.

While Bird did not disagree with this, he indicated that specific lines were used to identify specific elements in chemical analysis and not only was an accurate answer required, but also the accuracy of the answer. Gamma line intensities seldom have confidence levels. Schmidt drew an analogy with classical photometry, and felt that with many laboratories possessing research reactors it would be possible to achieve standardisation of gamma lines from various elements by a comparison program between laboratories. Schmidt thought this could be considered for action at this or the next INDC meeting. Bird thought that the existing newsletter on gamma ray compilation would enable quick action and a speedy solution.

Mehta said although India had no activities in this area at present and had little work in the (n,γ) field, he hoped to commence some charged particle work in a selected area and hoped this INDC meeting might provide some ideas for work.

Schmidt introduced a Working Paper Note on the Jülich work "Gamma Rays of all Radionuclides" which has been published as JUEL-1003-AC. This contains over 1000 nuclides and covers data published up to 1972. It is a continuing activity and lists gamma rays by Z and A , and energy. The intensities of the gamma lines from about 10 KeV to 7 MeV are listed. Although exact accuracies are not given, accuracy ranges are given by a code (x and a) for intensities. He felt that energy accuracies achievable with Ge(Li) detectors were well established and known. (See Appendix XXIV).

In view of the many groups active in this area, he proposed an action on all INDC members to draw this work to the attention of others in this field and keep NDS informed for coordination purposes. (Action n. 19).

Motz drew the meetings' attention to the forthcoming publication of a similar, but different type of study by Heath (Idaho), namely, ANCR-1000-2, 3rd Ed. 1974, "Gamma Spectrum Catalogue - Ge and Si Detectors". It contained pictures of Ge and Si detector gamma ray spectra on a large format size page for easy recognition with accompanying tables of energies and intensities in a consistent fashion, from a common detector used in standard geometry. Another feature was a selection of fission product spectra following a variety of irradiation and decay periods with decay schemes.

Smith returned to the question of coordinating activities from several laboratories and/or countries and indicated the type and magnitude of costs involved. Thus for the Oak Ridge Nuclear Data Project on mass chains, the compilation and evaluation for $A > 44$ would take 40 manyears of effort in updating the work to 1970. About 20 A chains were evaluated each year and the computerised keyword system is now finding increasing acceptance. Much effort was being applied to special evaluations for applications and this was being made available by Lederer's group at Berkeley to users by teletype automatic access. It was felt that a generalised data bank could be implemented, but was held back by funds and man-power. They were convinced of the soundness of the system, but were now surveying the user' data needs.

He referred to the impending 7th Edition of the Table of Isotopes release in 1976. This was commenced by Lederer's group in 1971 with full time effort of 5 evaluators, 1 computer programmer and 1 reference secretary. Automated and graphical production methods are being used. He noted that a review committee in the USA had recommended that Berkeley and Oak Ridge Centres produce interchangeable data files - which currently do not exist - and proposed the eventual establishment of a standardised nuclear data base for the USA.

Wapstra said the updating work done was a Herculean task and he was not surprised at the effort involved, but thought that future revisions by trained staff would be twice as quick. Smith agreed.

VI . TOPICAL DISCUSSION

The abstracts of the papers presented at the topical discussion on "Gamma rays from Nuclear Reactions" are given in Appendix XIII.

VII . REPORTS OF SUB-COMMITTEES AND DISCUSSIONS

VII .A. Nuclear Standard Reference Data

ii) Gamma-detector calibration

Liskien and Le Gallic discussed the sub-committee's views on the first non neutron standard quantities to be raised in the sub-committee, namely, gamma ray standards for calibration of detectors. Le Gallic indicated that most metrology laboratories were aware of the need of such items and that the sub--committee was seeking moral support for laboratories working to provide decay schemes for such standards and that wider recognition and use be made of the multi gamma ray emission standards, e.g. ^{152}Eu. Rose felt that INDC should indicate to metrology laboratories that as users INDC value this work. Berenyi, while in agreement with the report, felt it had not given adequate consideration to the calibration problems at energies less than 100 KeV and that it should be expanded. In answer to Schmidt, both Liskien and Le Gallic indicated that no other body took responsibility for directing work in this area. Liskien pointed out that the sub-committee's report (in fact all sub-committee reports) were directed to the INDC which could take action on sub-committee recommendations as it deemed fit. He said INDC had been given responsibility in this area and it had a legitimate responsibility to advise the Director General on current issues. Schmidt was worried that INDC might be covering ground already covered by other committees. Liskien believed measurements rather than evaluation was the major need.

iii) ^{237}Neptunium

Although the sub-committee is prepared to take up ^{237}Np as a threshold standard for cross sections in reactor dosimetry (2nd Standards meeting) it felt that it should weight the considered views of the EWGRD and IWGRRM as to whether this would improve the dosimetry situation. This was discussed less than two weeks before the INDC meeting by the EWGRD without a final decision being reached. Liskien was prepared to examine this question again when a decision had been reached by the reactor dosimetry specialists.

(°) These, and more general issues, are outlined under XII.A. below.

iv) (n,p) Total Scattering Cross Section

In discussing the status of (n,p) scattering data, Smith drew attention to the absence or unsatisfactory use being made of the evaluated files as circulated at NDS on such standard data. He was unaware of any feedback, but hesitated to draw the obvious conclusion that this was because the file was perfect. Smith sought Rose's view as to progress being made by Fowler at AERE on (n,p) scattering. Rose indicated it was at a very early stage and no results would accrue for quite some time.

v) ^{3}He(n,p)

Liskien noted that no measurements were being made on ^{3}He(n,p) reaction or being made relative to this reaction since the 2nd Panel meeting. He suggested this was because its uses were confined to:

(a) proportional counters which are slow,

(b) high pressure gas scintillators which have poor energy resolution.

It was proposed to reduce the emphasis given to ^{3}He(n,p) reaction by this sub-committee.

vi) ^{6}Li(n,α)

Michaudon dealt with the ^{6}Li(n,α) reaction, pointing out the variety of new information which has become available, but not yet fully analysed. He noted measurements since 1972 by Fort and Marquette, Clement and Rickard, Poenitz, Overley, Stephany and Knoll and Friesenhahn. Below 0.5 MeV Friesenhahn's values were significantly higher than the others. Above 0.5 MeV, even if the high values of Friesenhahn were omitted and the values of Clement and Rickard removed (as suggested by Rose), the factor of 2 variation would be reduced to 25% and this was still quite unsatisfactory.

The progress made in energy determination of the resonance was noted with most measurements coming close to the Harwell/Columbia values at 299 KeV. The Li content of glass scintillators was still subject to correction, but if new Cadarache values were 12% lower as suggested, this would go some way to resolving discrepancies with Friesenhahn. New measurements were proposed and the signs were that the previous discrepancies could be resolved. He felt that within 1 to 2 years the Li standard situation could be satisfactory.

vii) ^{12}C total cross section

Smith had asked the sub-committee to re-examine the total cross section of ^{12}C justified by its use as

- a reference for angle integrated secondary distributions in elastic and inelastic scattering studies at energies distant from the dip at 3 MeV and below 5 MeV;
- energy reference scale because of its clearly defined sharp resonances at high energies.

He pointed out the uncertainties in the resonance structure and energies which he felt prevented its wider use and acceptance, mentioning discrepancies of 4 to 6 per cent above $1\frac{1}{2}$ MeV in the smooth cross section region away from resonances - a discrepancy greater than one wanted for the angle integrated scattering.

It was agreed that the sub-committee should act on the sub-committee's recommendations on carbon.

viii) $^{197}Au(n,\gamma)$

It seemed likely to the sub-committee that when all the new measurements on ^{197}Au had been thoroughly evaluated, a significant improvement in the accuracy and status of this standard would result.

Le Rigoleur was reported to be extending his measurements below 75 KeV and the Livermore results of Czirr need to be normalised to the more recent evaluated $^{235}U(n,f)$ values.

It was felt by the sub-committee that the recent gold results of Macklin and of Poenitz considerably improved this standard. This is particularly so as Poenitz also measured the U-238/Au-197 ratio with results consistent with those previously reported. Liskien felt that Poenitz' data could not be off by as much as 55% as he had also measured the gold-uranium-238 ratio which was unlikely to be in error by 10%. The degree of freedom was limited in the linkage between these results.

ix) $^{235}U(n,f)$

At high energies ($<$ 6 MeV) Smith indicated that Livermore relative measurements of good definition and relative accuracy normalised at 3 MeV, gave accuracies of 3 to 4% and were consistent to 6 MeV. At higher energies discrepancies increased with energy to 15 to 20%. Discrepancies at 14 MeV were found with the new relative Livermore values in both shape and magnitude. Compared to White's measurements at 2.5 and 14 MeV, the Livermore results were lower at 2.5 MeV and at 14 MeV. If normalised to the White figure at 2.5 MeV then agreement is still just acceptable at 14 MeV. Shape measurements and an absolute value are required. Motz indicated that these Livermore measurements were shape measurements normalised to the Poenitz value of 1198 mb at 3 to 4 MeV.

Cierjacks indicated that similar problems had been encountered at Karlsruhe. Normalisation at 14 MeV gives cross sections much too high at 2 MeV, although in their progress report these results had not been published because they were not understood. Smith felt it likely that the target accuracy of 3 to 4% would be met, but that the ultimate objective of 1% was still far off.

x) Miscellanea

Smith urged that laboratories working in the area of neutron standards be advised of the availability of the evaluated standards data on file at NDS. He suggested that the availability might be published in journals with computer graphic output, or that the Agency publish a curvebook. (Action n. 25) He said it was essential that these files be used and feedback produced for further progress.

He indicated that knowledge of the ^{197}Au evaluation on file would have cleared up this sub-committee's doubts as to the normalisation of the Livermore data and Liskien would have come up with different values. All members were requested to send comments on the report of the Standards Sub-committee by November 30, 1974 (Action n. 26).

VII .B. Discrepancies in Important Nuclear Data and Evaluations

The report of this sub-committee (Appendix XV) was presented by its Chairman, Joly. The Sub-committee had worked to its original agenda and felt for the moment unable to undertake the additional work suggested by Schmidt-fission products, reactor dosimetry and thermal fission constants. In particular they felt that so many discrepancies exist in fission product that it was impossible to adequately deal with them. It was agreed to await the crucial items to be highlighted by the fission product nuclear data panel and to deal with those.

The Standards Sub-committee had agreed to examine σ_f of ^{235}U above 100 eV and in view of this the paper prepared by Nishimura and submitted by Fuketa had been given to Liskien. Like the Standards Sub-committee, the Discrepancies Sub-committee had agreed to share its work load with individual members being responsible for investigating given discrepancies. Joly thanked Cierjacks for undertaking the major part of the report. Cierjacks introduced the report, but indicated he would not deal in detail with those items contained in the report.

Cierjacks reported new measurements on plutonium fission cross sections by Gayther and Käppeler at energies less than 1 MeV and by Szabo and Poenitz above 1 MeV. Sowerby had additionally completed his evaluation and Sowerby's conclusions appeared to be that the present discrepancies could only be resolved by new measurements.

The fission cross section of ^{238}U was now believed to have the following relative accuracies: 3% between 0.6 and 1.8 MeV; 5-8% in the plateau between 1.8 and 6 MeV; 6% above 6 MeV. The latest measurements from Karlsruhe (final values) and Harwell (preliminary) seemed to indicate agreement over the complete energy range of 1-20 MeV except at 7 MeV where Karlsruhe measurements were 2-3% higher than those from Harwell, and above17 MeV where an energy shift was apparent. These two new measurements were in agreement with Stein's (Los Alamos), but were $\sim$3% lower than Poenitz' measurements. Discrepancies still exist in the 0.6 to 1.8 MeV region and the new measurements, when integrated over a ^{235}U fission spectrum, give rise to only a 0.5% change and hence the discrepancy against integral measurement remains unresolved.

Joly announced that the sub-committee had agreed to two actions:

1. That Conde, Cierjacks and Motz would undertake an intercomparison of ^{238}U fission experimental data against the Sowerby evaluation as base and exchange this information before 1st January 1975. (Action n. 27).

2. That Joly, Cierjacks and Motz would undertake a similar comparison for ^{239}Pu fission. (Action n. 28).

For both actions he was hoping that Rose would provide Sowerby's evaluation in graphical form.

Joly also indicated that this 1974 report should be taken in conjunction with the 1973 sub-committee's report as interim and he hoped to combine both into one document and seek comments from INDC members by the end of the year. (Action n. 29).

Cierjacks mentioned that new information about sub-threshold fission in ^{238}U suggests that the phenomenon might be important for some reactor spectra.

Usachev indicated he would like to see a general action by INDC on data centres to give first priority to the compilation and exchange of data dealt with by INDC sub-committee on Standards and Discrepancies, and that this should include evaluated data wherever possible. He felt that this would spur effort on these items and help resolve discrepancies more propitiously. A similar action had been taken on ^{252}Cf fission spectrum, but unfortunately centres had not yet been able to collect and/or exchange the data.

Schmidt indicated thata similar action had been agreed upon at the last Four Centres meeting. Joly said to be effective it must encompass measured and evaluated data. (see Action n. 30)

In discussing recent evaluations on ^{238}U capture, Smith made a plea for precision as to documentation of evaluations and values used being specifically stated. He objected strongly to such phrases as "relative to previous evaluations". To suggest Poenitz' measurements were in significant discrepancy with evaluations was quite meaningless when Poenitz data lay within 2% of ENDF/B-IV.

Examination of the ^{238}U capture to ^{235}U fission ratios indicated things were much as at the previous meeting with disagreements of up to 7% for energies less than 600 KeV. The conclusion reached from various evaluations was that differences in evaluated data sets arose chiefly from the philosophy adopted. The discrepancy could not be resolved by further evaluations, but rather by new measurements and this the sub-committee highly recommended.

Usachev drew attention to an evaluation to this ratio by Tolstikov, which he would distribute soon. The comparison with the "old" Sowerby evaluation (UKNDL file) was good, above 25 KeV/and up to several hundred KeV.

There was little progress to report on alpha measurements except for the Karlsruhe work in progress in the 15-400 KeV energy range and the Kononov results which are 18% higher compared with Kononov's earlier results. Usachev was unaware of the reasons for this discrepancy. Smith felt that the alpha measurements were not discrepant, but of low accuracy and wondered whether they should still be considered by this sub-committee. The measurements were consistent within their accuracy. Cierjacks and Rose felt that the measurements were far from satisfactory and whether they were described as inaccurate or discrepant was really a question of whether the errors were internal or external ones. They felt that it might be more appropriate to change the name of the sub--committee and let it continue to review alpha measurements. Rose suggested that sub-committee's name be changed to include "Important Data". This was accepted.

Joly hoped to include a review by Ribon on resonance parameters of ^{235}U, ^{238}U and ^{239}Pu which would indicate substantial discrepancies and have some recommendations. No new information was available on ^{238}U resonance parameters, but he mentioned an evaluation by Moxon which was heavily weighted towards mathematics. He disagreed with Moxon as to the correctness of including superseded data, e.g. Moxon had included the 1954 Garg (Columbia) data in addition to the 1972 Columbia results.

Motz reported on inelastic scattering in ^{238}U the difficulties in resolving the first inelastic level at 44 KeV from the elastic component, particularly at forward scattering angles. Nuclear models were being used to calculate this level based on comparison with other rotational nuclei such as ^{186}W whose first level was at a sufficiently high energy to be resolved. The experimental values quoted for the first level in ^{238}U were discrepant by a factor of 2 and this was serious for fast reactors. Theoretical values and shapes used were unable to resolve this. Condé and Rose mentioned that measurements are in progress at Studsvik and Harwell.

New measurements of Cr, Fe and Ni above 100 eV were reported.

Values for Ni by Poenitz were in agreement with higher Cadarache values. The care required in correcting adequately for elastic scattering in liquid scintillators was noted. Measurements at Karlsruhe covered the range 10 to 200 KeV. The Cadarache measurements were made with a Maier-Leibnitz detector. The evaluation scene was still bad with the three main files (UKNDL(71), KEDAK-II and ENDF/B-IV) in dispute by a factor of 2, and this should be compared with user accuracy requirement of 10%. The differential data are not consistent with large integral critical experiments and new measurements were recommended.

Smith reiterated the need for adequate scattering corrections to scintillator tank measurements and expected that neutron leakage in small tanks could be considerable. He would be happy to supply an Argonne general Monte Carlo code for calculating tank efficiency for anyone who wished to use it. Cierjacks looked favourably on the agreement in the Ni case between two methods using different detectors - scintillator tank and Maier-Leibnitz.

Although the sub-committee had not discussed delayed neutron emission, a short discussion ensued between Schmidt and Smith on this subject during which it became evident that serious discrepancies existed in total yield of delayed neutrons in the higher plutonium isotopes and this influenced large fast breeder reactors with a 5% uncertainly in breeding ratio. Smith and Schmidt were asked to prepare papers on this subject for sub-committee by 31st December 1974. (Action n. 31)

VIII. MISCELLANEOUS ITEMS

VIII.A. Participation of Trieste Centre in Nuclear Data Workshops (°)

The NDS submission on this topic is contained in Working Paper 7 (Appendix XVI) and was introduced and reviewed by Schmidt. A main objective of the centre was said to be the advancement of theoretical physics in developing countries through research and training programs conducted at the centre. In the past decade there had been four very successful seminars on nuclear structure and theory. The manner in which the centre implements its work is by way of seminars, fellowships, associateships and federation agreements. These are described in summary detail in the appendix. Rose and Lynn (UK) have talked to the Director of the centre, Dr. A. Salam, about hosting a consultants meeting on "Nuclear Theory for Nuclear Data Evaluation" and about the feasibility of seminars and work originating from this consultants meeting being held within the framework of the centre. Rose mentioned that costs would be the major problem. Schmidt indicated that he had advised Salam of INDC actions and the steps NDS had taken to plan the consultants meeting and found Salam keen to host the consultants meeting.

Various suggestions of suitable topics had been submitted by INDC members and liaison officiers, all listed in the working paper, and Schmidt reviewed some of them. They ranged from rather pure through longer term to some which were extremely relevant to evaluators today. He felt, for instance, that increased understanding and knowledge of fission was not enough being put into practice by evaluators. Schmidt felt that development of a unique deformed optical model code may be a timely asset in countering the lack of consistency in the many optical model codes in existence and valuable in comparing them. He would like to see INDC take the following actions:

(i) Produce a short list of two or three well defined topics for workshops.

(ii) Recommend to Director General.

(iii) Identify sources of financial support for the workshops.

(iv) Identify scientists with potential interests in the topics and nominate nuclear physicists of high standard who might be prepared to undertake tuition at such a workshop.

Definite ideas and plans should be available within the year to evaluate them to be confirmed at the consultants meeting in Trieste in November/December 1975.

(°) Discussed on Friday

VIII .B. Nuclear Data Programs in Developing Countries (°)

Rose presented the report of the "ad hoc" sub-committee on this matter (Appendix XVII). It summarised the situation from the limited INDC point of view, and indicated how regional programs could be organised and depended greatly on IAEA regional cooperation agreements. The sub-committee felt that the initiative was with the regions to make specific proposals on which INDC could act and advise as set out in the sub-committee's report. The "ad hoc" sub-committee recommended that all members advise NDS of any existing or new project as and when they became aware of them. Rose believed that unofficial bilateral agreements were as useful as any other.

An action was placed on NDS to complete its information survey on men and equipment in developing countries. (Action n. 33). Rose felt that this was necessary, but not sufficient. The main drive lay in proposals from the regions themselves, taken in conjunction with this information. Schmidt felt that a case could be made for outside proposals such as those by Smith (elastic scattering, angular distribution from 14 MeV neutrons) and himself. Rose was unconvinced and indicated he would await the response to those with interest, while Smith had a feeling that the response from developing countries was zero.

Schmidt would discuss these proposals with those developing countries he intended to visit during his Asian trip following the meeting; he will submit a report on the response and findings to INDC. (Action n. 34)

It was agreed that all INDC members should report to NDS on any discussions with developing countries and the response. (Action n. 35)

Fuketa indicated that Japan would cooperate in such an assistance program, (e.g. cooperation with Korea) provided a suitable specific project arose of interest to the developing country and which fitted into the national research program. Mehta welcomed such collaborative projects, but indicated they depended very much on facilities being available. Gemmell believed the projects had a much better chance of success if generated within the developing country rather than being imported from an external source. The developing country must have a major interest and say in the project, and he agreed with the conclusion of the sub-committee that short term projects with a quick return were to be preferred.

(°) Discussed on Friday

IX . MEETINGS AND CONFERENCES

IX .A. Publication of IAEA Meeting Proceedings (°)

A short report was made by Schmidt on the publication procedures within the Agency and the lack of control over publication by NDS. It became clear that many problems arose because of papers presented at meetings were not being received in the IAEA publication format. Members were asked to encourage this practice. The type of meeting determined the type of publication and INDC was asked to give serious consideration to this matter so that neither the number of meetings nor meetings and meeting proceedings were curtailed. It was agreed that the Chairman should write to the Director General on the time taken to publish proceedings and the need for topicality. (see action n. 24)

IX .B. Future Meetings

Schmidt indicated that NDS proposals were outlined in INDC(NDS)-63 pages 16 to 21. Members were aware of preparations for the Actinide Data meeting which has been delayed for manpower reasons arising out of the total of 1½ year delay in getting replacements. Final preparations for this meeting, to be held along the lines of the successful Fission Product Data meeting, would begin when he returned to Vienna. Like the Actinide meeting, the proposed "Nuclear Theory in Neutron Nuclear Data Evaluation" meeting had been approved at the previous INDC meeting. It had been agreed earlier at this meeting that it would now be held at Trieste after the 1975 INDC meeting and there was an action on all members to submit proposals for subject topics to NDS by 15th November, 1974. (Action n. 45)

The shielding community felt the necessity for a meeting dealing with calculational methods and sensitivity studies prior to a data meeting. This meeting on methodology would possibly be held in 1975 under the aegis of IAEA's reactor division. It was agreed to defer a potential Nuclear Data for Shielding meeting to 1976.

The first proposed meeting for compilers in the area of non-neutron nuclear data had been discussed earlier and a meeting agreed to for 1975.
Earlier discussion had covered meetings on "Integral Cross Sections in Standard Neutron Fields" for Reactor Dosimetry, "The Third Standard Neutron Data Meeting,

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(°) Discussed on Thursday; see Appendix XXV

1976" and a Symposium on "Nuclear Research Materials" in 1976 sponsored by EURATOM and co-sponsored by the IAEA.

In view of proposed USA (Washington Conference on Nuclear Cross Sections and Technology, March 1975, and International Conference on Interaction of Neutrons with Nuclei, Lowell University 1976) and USSR (3rd Kiev Neutron Physics Conference, June 1975) meetings, the INDC could see no place for the IAEA's Third Nuclear Data Conference.

Michaudon felt that if USA and USSR held International Nuclear Data conferences every two years, there was no place for an IAEA meeting. He sought Usachev's view of the biennial continuation of the USSR meetings, to which Usachev replied that each meeting proposed was discussed and approved on its own merits.

It was agreed to place the general problem of IAEA nuclear data conferences on the agenda for the next INDC meeting.

A P P E N D I C E S

TENTATIVE AGENDA

7th INDC Meeting, Lucas Heights, 7-11 October 1974

(Detailed topics, guidelines and background report references are listed in Attachment B)

MONDAY SESSION A	**I.**	**Introductory Items**
9:00 - 9:30		Opening of the meeting (30 m).
MONDAY SESSIONS A + B	**II.**	**Committee Business (Part I)**
9:30 - 9:45	A.	Consideration and approval of complete minutes of the 6th INDC meeting (15 m.)
9:45 - 10:00	B.	Consideration and adoption of agenda for 7th INDC Meeting (15 m.)
10:00 - 10:15	C.	Attendence of observers (15 m.)
10:15 - 10:30	D.	Biannual report of 1972/1973 INDC Chairman (15 m.)
10:30 - 11:00		Coffee break (30 m.)
11:00 - 11:30	E.	Review of actions arising from the 6th meeting (30 m.)
11:30 - 12:00	F.	INDC Programme Review (30 m.) (Appointment of ad-hoc subcommittees 1, 2 and 4)
12:00 - 12:30	G.	INDC Secretariat (30 m.) (Appointment of ad-hoc subcommittee 3)
12:30 - 13:30		Lunch break (60 m.)
MONDAY SESSIONS C + D		**Meetings of Standing Subcommittees**
13:30 - 17:30		
TUESDAY SESSION A	**III.**	**Progress Reports on Nuclear Data Measurements and Facilities**
9:00 - 10:00	A.	Short discussion (no presentation) of submitted progress reports (60 m.)
10:00 - 10:30	B.	Short reports on nuclear data measurements in countries not represented on INDC (30 m.)
10:30 - 11:00		Coffee break (30 m.)
TUESDAY SESSIONS B + C	**IV.**	**Nuclear Data Measurement Requirements**
11:00 - 11:45	A.	WRENDA and other request lists (45 m.)
11:45 - 12:15	B.	IAEA targets and samples programme (30 m.)
12:15 - 12:30	C.	Nuclear data measurements in developing countries (Part I) (15 m.)
12:30 - 13:30		Lunch break (60 m.)
13:30 - 15:00	D.	Review of recommendations from 1973/74 NDS meetings (90 m.)
15:00 - 15:30		Tea/Coffee break (30 m.)
TUESDAY SESSION D		**Meetings of Standing Subcommittees**
15:30 - 17:30		
WEDNESDAY SESSION A	**V.**	**Neutron Nuclear Data**
9:00 - 9:15	A.	Report on the 10th Four Centre Meeting (15 m.)
9:15 - 9:30	B.	Additional information from neutron data centres (15 m.)
9:30 - 10:15	C.	New evaluated data and evaluated data exchange (45 m.)

10:15 - 10:30	D.	International newsletter on evaluation (15 m.)
10:30 - 11:00		Coffee break (30 m.)

WEDNESDAY SESSIONS B + C	VI. "Non-Neutron" Nuclear Data	
11:00 - 12:00	A.	Reports on the Consultants' Meeting on Charged Particle and Photonuclear Reaction Data and on the Specialists' Meeting on Nuclear Data for Applications (60 m.)
12:00 - 12:30	B.	Additional information on existing and projected "non-neutron" nuclear data centres and groups (30 m.)
12:30 - 13:30		Lunch break (60 m.)
13:30 - 15:00	C.	Discussion of recommendations from "non-neutron" nuclear data meetings (VIA)
15:00 - 15:30		Tea/Coffee break (30 m.)

WEDNESDAY SESSION D	VII. Topical Discussion
15:30 - 17:30	

THURSDAY SESSIONS A + B	VIII. Reports of Subcommittees and Discussions	
9:00 - 10:30	A.	Nuclear standard reference data (90 m.)
10:30 - 11:00		Coffee break (30 m.)
11:00 - 12:30	B.	Discrepancies in important nuclear data and evaluations (90 m.)
12:30 - 13:30		Lunch break (60 m.)

THURSDAY SESSION C	IX. Miscellaneous Items	
13:30 - 14:00	A.	Nuclear theory for evaluation: Trieste Centre participation (30 m.)
14:00 - 14:40	B.	Nuclear data measurements in developing countries (Part II) (Report of ad-hoc subcommittee # 4) (40 m.)
14:40 - 15:00	C.	INDC Correspondents and documents distribution (Report of ad-hoc subcommittee # 3). (20 m.)
15:00 - 15:30		Tea/Coffee break (30 m.)

THURSDAY SESSION D	AAEC Laboratory Visit
15:30 - 17:30	

FRIDAY SESSIONS A + B	X. Reports of Subcommittees and Discussions	
9:00 - 10:30	A.	Energy applications of nuclear data (90 m.)
10:30 - 11:00		Coffee break (30 m.)
11:00 - 12:30	B.	Non-energy applications of nuclear data (90 m.)
12:30 - 13:30		Lunch break (60 m.)

FRIDAY SESSION C	XI. Meetings and Conferences	
13:30 - 14:00	A.	Reports on past meetings (30 m.) (other than NDS meetings)
14:00 - 14:30	B.	Publication of IAEA meeting proceedings (30 m.)
14:30 - 15:00	C.	Future meetings (30 m.)
15:00 - 15:30		Tea/Coffee break (30 m.)

FRIDAY
SESSION D

XII. Committee Business (Part II)

15:30 - 16:30	A.	Relationship between INDC and EANDC (Report of ad-hoc subcommittee # 1). (60 m.)
16:30 - 17:00	B.	IAEA policy regarding INDC (30 m.)
17:00 - 17:15	C.	Modification of INDC Methods of Work and responsibilities and working procedures of standing subcommittees (Report of ad-hoc subcommittee # 2) (15 m.)
17:15 - 17:25	D.	Review of actions arising from this meeting (Exec. Secretary) (10 m.)
17:25 - 17:29	E.	Next (8th) INDC Meeting (4 m.)
17:29 - 17:30	F.	Adjournment of the meeting (1 m.)

APPENDIX II

CHAIRMAN'S REPORT ON THE INDC FOR 1972 AND 1973

by

L.N.USACHEV

Development of international cooperation on Nuclear Data in the frameworks of the International Atomic Energy Agency (IAEA) has begun 10 years ago. During this period there has been created an operating world-wide system of cooperation.

The International Nuclear Data Committee, the advisory body of the IAEA, continued the activities on expansion and deepening of this international cooperation during 1972-1973.

MAIN RESULTS OF INDC ACTIVITIES FOR THE TWO-YEAR PERIOD. EXPANSION OF THE INDC RESPONSIBILITIES

The INDC responsibilities were expanded for the development of international cooperation for the data on nuclear structure and nuclear reactions along with the neutron data to meet demands in nuclear data of all the branches of science and technology being of interest for the IAEA. The necessity in such broadening of the activities was clearly shown at the Symposium on Applications of Nuclear Data in Science and Technology held by the IAEA, according to recommendations of the INDC, in March 1973 in Paris. An important role in this was played by the International Working Group on Nuclear Structure and Reaction Data, organized by the IAEA, that was self-dissolved recommending the INDC to take the functions of coordination of international cooperation in this field.

REORGANIZATION OF THE INDC

For solving new problems the structure of the INDC standing subcommittees was reorganised. The policy in the field of nuclear data should be determined by the needs in them.

Therefore, at determining the responsibilities of the subcommittees the methodical principle of separation the data into neutron and non-neutron data was rejected. It should be noted that the dividing of responsibilities on the methodical basis is likely to be reasonable when organizing the data centers, as far as their methodical specialization should result in increasing the data reliability.

The first standing subcommittee "Nuclear Data for Nuclear Energy" should give the recommendations on policy concerning the generation and satisfaction of the request list in the whole area of the nuclear energy industry to monitor the interfaces between producers and users of nuclear data. It was suggested that the nuclear energy area be divided into the number of fields: e.g.: Reactor Cores, Fuel Processing, Waste Disposal, Shielding, Safeguards, Inpile Radiations Measurements, Fusion. It is meant that the subcommittee's major attention at certain time should be concentrated in one or two mentioned fields.

The subcommittee "Nuclear Data for Non-Energy Application" should cover wide and various fields of nuclear data application. Its role is to make recommendations on the policy concerning the generation and satisfaction of requirements in compilations and evaluations of nuclear data as well as to maintain the interfaces between the producers and users of nuclear data in all the applications relevant to the business of the IAEA except the nuclear energy area, i.e. biomedical sciences, industrial and agricultural uses, etc.

To accomplish these ends it should be still necessary to decide on a workable breakdown into areas to identify the corresponding national and international organizations and to find appropriate methods of cooperation with these organizations.

Along with this it was decided that for realization of technical functions of compilation and dissemination of non-neutron data there should be developed a network of centres analogous to the four neutron centres.

For promotion in this direction it was decided to gather in April 1974 in Vienna the "Meeting of the X-Centres" with the final title "IAEA Study Group Meeting on Nuclear Data for Applications".

Standing subcommittees on "Standards" and "Discrepancies in Important Nuclear Data and Evaluations" are retained as technical subcommittees, i.e. the subcommittees considering specific problems of measurement and evaluation of specific values, mainly, of neutron ones. By retainment of these subcommittees the INDC again stressed the importance of its traditional activities on neutron data.

TRADITIONAL ACTIVITIES ON NEUTRON DATA

This activity in its structure is rather logical, but there is still much work to do in detail. The operating mechanism of cooperation is characterized by three concepts: WRENDA, CINDA and EXFOR. One more concept, corresponding to the world library of evaluated data, is absent.

WRENDA, the world-wide request list for neutron data, naturally, is the beginning of the structure of this activity. According to the INDC recommendations this list as a compilation of requests from different countries revised every year. The INDC made the recommendations on working out a unique definition of a tolerated uncertainty and on engagement to reviews of WRENDA evaluators for whom it is not difficult to characterize the state of the knowledge of the values evaluated by them. In this case it is supposed to use in future in the reviews the unique definition of the uncertainty. When these recommendations are realized, WRENDA becomes the most valuable document compactly representing the state of the knowledge of neutron data, that is characterized by their uncertainty, as well as of the uncertainty tolerated from the viewpoint of the data application. From the comparison of the achieved and needed accuracies it would be clear whether it is necessary to carry out new measurements.

The activities were also carried out on improvement or request lists for nuclear data on fusion and the safeguards.

On the base of the coordinating efforts of the 4 Centres the following systems are working: CINDA - the bibliographic computerized catalogue, of all the neutron works published in the world, being updated twice a year and EXFOR - world computer library of numerical experimental neutron data. To function the latter system important is the exchange between the 4 Centres of data on magnetic tapes in the common exchange format EXFOR.

Any library is valuable for its completeness. EXFOR includes the half of all the works published after 1970 - about 1 million of experimental points. There is a quarter of works more in the centres' own formats and the problem of their translation is a matter of time. But numerical data on the number of very important works, even published at the Helsinki Conference in 1970, have not yet been obtained by the data centres. It was accepted by the INDC that the problem of non-availability of data from experimentalists should be solved. In this connection CINDA was discussed as an EXFOR catalogue. Even now the works, the numerical material on which is available at the centres, is denoted in CINDA by a flag. A more developed system of flags, that would denote not only the presence of information but its preliminary or final character, and not only its nonavailability but its cause, should have a stimulating significance in solving the problem of data nonavailability.

ILEND - international library of evaluated neutron data. Such a concept does not still exist. This word is being pronounced here for the first time with the hope that if the name is given, the library, as well as the activities for its creation, should appear.

An agreement about a broad international cooperation in the field of neutron data evaluation and exchange has not yet still been reached. The discussion of this problem is being carried out at each INDC meeting. Some countries have not yet developed the works on evaluation in rather a full scale, other countries and their organizations have not yet determined their position in the solution of this problem. Nevertheless, the IAEA has a considerable set of evaluated data files. Those are English, French, West-German, Soviet files, American files on seven standards, Italian, Australian files of fission fragments, etc. Just this is the beginning of ILEND.

The problem of evaluated neutron data is extremely urgent for the INDC activities, because it is just the evaluated data that are needed by the users.

OTHER IMPORTANT PROBLEMS

For promotion of works on nuclear data in developing countries the program on Samples and Target (17,000 dollars for 1974) is of great importance. The fulfilment of this program and the ways of increasing its efficiency were discussed at INDC. With the same purpose, an "Ad Hoc Subcommittee on Nuclear Data Measurement Programs for Developing Countries" was formed. The program to be developed should meet WRENDA requirements. In support of such measurements bilateral cooperation with developing countries was recommended as well as finding in other international organizations of funds for supporting works in accordance with the program being elaborated keeping in mind the use of these works from the point of view of training the specialists for developing countries.

MEETINGS, CONFERENCES

Two IAEA Panels were successfully carried out: on 20-24 November 1972 in Vienna on neutron standard reference cross sections and on 26-30 November 1973 on "Fission Product Nuclear Data", and the Paris Conference in March 1973 about which it was said above.

NDS - THE INDC SECRETARIAT

The IAEA Nuclear Data Section is working with efficiency, successfully fulfilling ever increasing volume of works. A contribution of NDS into all the achievements mentioned can hardly be overestimated.

CONCLUSION

The cooperation in the frames of the International Nuclear Data Committee is being successfully developed. Numerous important projects have been already realized and bring now much use. The solution of a number of the above-mentioned problems in future work of INDC should approach the organization of the activities to the ideal. This would contribute much to increasing efficiency of a number of science and technology fields, needing nuclear data, in all the countries-members of the IAEA.

APPENDIX III. Members of the four standing Sub-Committees of INDC

1. Sub-committee on nuclear standard reference data.

Liskien, BCMN Geel, CEC, Chairman	
Boldeman, Australia (*)	
Le Gallic, France	
Lemley, IAEA/NDS	ex-officio member
Michaudon, France	
Rose, UK	
Smith, USA	
Yankov, USSR	
Wapstra, Holland	

2. Sub-committee on discrepancies in important nuclear data and evaluation

Joly, France	Chairman
Cierjacks, FRG	
Fuketa, Japan	
Kenny, Australia (*)	
Koncin, USSR	corresponding member
Lemmel, IAEA/NDS	ex-officio member
Motz, USA	
Rowlands, UK	corresponding member
Smith, USA	

3. Sub-committee on energy application of nuclear data

Motz, USA	Chairman
Allen, Australia (*)	
Benzi, Italy	
Cierjacks, FRG	
Condê, Sweden	
Fuketa, Japan	
Gemmell, Australia	
Metha, India	
Michaudon	
Rowlands, UK	corresponding member
Schmidt, IAEA/NDS	ex-officio member
Yankov, USSR	

p.t.o.

(continued)

APPENDIX III. Members of the four standing Sub-Committees of INDC

4. Sub-committee on non-energy application of nuclear data

Rogosa, USA	Chairman
Berenyi, Hungary	Acting Chairman
Bird, Australia (*)	
Cross, Canada	
Fröhner, NEA/CCDN	corresponding member
Le Gallic, France	
Lorenz, IAEA/NDS	ex-officio member
Metha, India	
Rose, UK	
Usachev, USSR	
Wapstra, Holland	
Zelenkov, USSR	corresponding member

(*) Observer

APPENDIX IV. List of Ad-Hoc Sub-Committee Members

i) Ad-hoc Sub-committee on Relationship of INDC and EANDC

Cross, Canada	Chairman
Cierjacks, FRG	
Condé, Sweden	
Fuketa, Japan	
Metha, India	
Michaudon, France	
Rose, UK	
Smith, USA	
Usachev, USSR	

ii) Ad-hoc Sub-committee on Modification of INDC Methods of Work

Gemmell, Australia	Chairman
Le Gallic, France	
Motz, USA	
Yankov, USSR	

iii) Ad-hoc sub-committee on Nuclear Data Measurements in developing countries.

Rose, UK	Chairman
Condé, Sweden	
Coombs, Australia (*)	
Metha, India	
Motz, USA	

(*) Observer

Agenda item IIC a

13 September 1974

NDS Working Paper 3

Extension of the List of Correspondents and List of Documents to include non-neutron nuclear data.

by

A. Lorenz

A. List of Correspondents

It is proposed to extend the existing INDC documents distribution, currently consisting of the C,L and U categories, by creating two new distribution categories N and W to facilitate the distribution of documents and reports generated by/for the INDC in the field of "non-neutron"* nuclear data.

This "non-neutron" distribution would consist of the following three categories:

C - Distribution (same as for the neutron nuclear data document distribution)

N - Distribution (equivalent to the neutron data L distribution) consisting of the C distribution, INDC Liaison Officers, heads of nuclear data centers, members of national nuclear data committees and other recipients concerned with the development of programmes and international cooperation in the measurement, compilation, evaluation, dissemination and application of "non-neutron" nuclear data, and the INDC Secretariat.

W - Distribution (equivalent to the neutron data U distribution) consisting of the N distribution and of additional selected measurers, evaluators and users of "non-neutron" nuclear data.

At this stage of "non-neutron" nuclear data consideration by the INDC, the N distribution is deemed to be the most important inasmuch as documents requiring such distribution have already been generated by IAEA/NDS this year (e.g. the reports on the "non-neutron" nuclear data meetings held by NDS in April-May 1974). The W distribution is one primarily oriented toward the users of "non-neutron" nuclear data; although no current document requires such a distribution at the present time, a number of them are foreseen for the coming year, such as the results of the analysis of the nuclear data use survey, the compendium of "non-neutron" nuclear data compilations etc.

Members of the INDC are requested to review the proposed N distribution list attached herewith, and to give consideration to the formulation of a W distribution and supply the INDC Secretariat (NDS) with a suggested list as soon as possible after the meeting, preferably not later than December 1974.

B. List of Documents

It is anticipated that with the expansion in the scope of nuclear data considered by INDC, to include "non-neutron" nuclear data, the number of documents received by the INDC Secretariat will increase considerably.

Inasmuch as the existing system for INDC documents distribution by the INDC Secretariat (see INDC(SEC)-41/U) does not depend on subject matter classification, all "non-neutron" nuclear data documents generated by or for the INDC could be incorporated into the existing procedures of document distribution in accordance with the N and W distribution categories proposed in A above.

In order to implement this system for "non-neutron" nuclear data documents and reports, it will be necessary to inform all producers of "non-neutron" nuclear data documents in every participating member state to comply with the INDC document distribution instructions (i.e., as to the method of nomenclature to be used and the number of copies to be sent to the INDC Secretariat) given in the "List of Documents Received by the INDC Secretariat" (INDC(SEC)-41/U) and the "List of INDC Correspondents" (INDC(SEC)-39/U

"Non-neutron" nuclear data reports received as single (or few) copies by NDS or the INDC Secretariat, for which no INDC distribution is provided for, will be listed in the annually published "List of Documents Received by the INDC Secretariat", together with the neutron data documents received as single copies.

C. General Comment

The INDC Secretariat is concerned that many nuclear physics reports related to the measurement or evaluation of nuclear data such as laboratory reports generated in participating Member States do not get the adequate dissemination they should have. It therefore urges INDC participants to distribute more documents through the established INDC channels (L,U,N and W distributions).

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*) "Non-neutron" nuclear data is used here to mean nuclear structure, decay and charged particle and photonuclear reaction data.

APPENDIX VIII

DISTRIBUTION LIST BY CODE/COUNTRY/NAME

N DISTRIBUTION TO MEMBER STATES
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ARGENTINA

RICABARRA, DR. G.

AUSTRALIA

ALLEN, MR. B.J.
BIRD, DR. R.
GEMMELL, MR. W.

AUSTRIA

BREUNLICH, DR. W.
BURTSCHER, DR. ALFONS
EDER, DR. O.J.
RIEHS, MR. P.
SELIGMAN, DR. H.

BANGLADESH

ISLAM, DR. M.

BELGIUM

NEVE DE MEVERGNIES, DR. MARCEL

BOLIVIA

PAZ LORA, SR. F.

BRAZIL

GERBASI DA SILVA, DR. A.
HERDADE, DR. S.B.
SUAREZ, DR. A.A.

BULGARIA

NADJAKOV, DR. E.

CANADA

BARTHOLOMEW, DR. G.A.
CROSS, DR. W.G.
HANNA, DR. G.C.
LEWIS, DR. W.B.
WALKER, DR. W.H.

CHILE

MARTENS COOK, DR. P.

COLUMBIA

THE DIRECTOR (IAN)

CZECHOSLOVAKIA

RIBANSKY, DR. I.
ROCEK, DR. J.

DENMARK

BURAS, PROF. B.
CHRISTENSEN, DR. C.J.

ECUADOR

MUNOZ, ING. RICARDO

EGYPT

EL-NADI, PROF. DR. M.

FINLAND

SILVENNOINEN, DR. P.

FRANCE

BLACHOT, DR. J.
GRINBERG, PROF. B.
JOLY, DR. R.
LAUBUGE, DR. R.
LEGALLIC, DR. Y.
LEGRAND, DR. J.
MICHAUDON, DOCTEUR A.
RIBON, DOCTEUR P.
SCHMITT, DR. A.P.

GERMANY,FED.REP

CIERJACKS, DR. S.
EBEL, DR. G.
MATTAUCH, PROF. J.H.E.
MICHAELIS, DR. W.
MUENZEL, DR. H.
PFENNIG, DR. G.
RITTBERGER, DR. W.
SCHULT, DR. O.
SEELMANN-EGGEBERT, DR. W.

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APPENDIX X

UNIQUE DEFINITION OF NUCLEAR DATA ACCURACY

L.N.Usachev

Abstract

An approach to development of the unique definition of evaluated nuclear data accuracy suitable for reactor and other applications is proposed. In this connection the nature of experimental nuclear data errors is discussed and recommendations for the representation of the error components in publications are given.

A general algorithm is given for the calculation of the "unique" error important in applications - the error in the integral under the curve and in its general slope - on the basis of the representation of errors by a covariance matrix being obtained at the parametrization of experimental data by the least square method.

INTRODUCTION

Nuclear data the most important for fast reactors have been repeatedly measured and evaluated for more than a quarter of the century by many groups of authors but the measurements and evaluations of these values are being continued up to now and planned for the future.

This is caused by the dissatisfaction with the uncertainty value of obtained quantities. Besides, an increase in the accuracy of an experiment demands an increase of costs which are inversely proportional to the square of a tolerable uncertainty according to some estimations. Therefore quantitative determination of satisfactory accuracy is of great importance. There exists also a mathematical apparatus -

- "experiment planning" - which allows to find quantitatively the required data accuracy. To the problem being discussed this apparatus is applied in [1], [2], [3], [4]. It is necessary only to come to an agreement about the unique representation of the error based on the understanding of its structure, i.e. the nature of its components of various origin which have a different effect on the accuracy of calculated reactor parameters.

The great majority of reactor parameters depends on wide neutron spectra. Therefore the error components correlated over wide energy ranges and over some isotopes in a reactor are of great importance. Unique representation of these error components is of great concern because the most rigid requirements deduced in [1] - [4] are imposed just on the accuracy of these components. It is clear that all the considerations mentioned above will be also valid for the blanket of a fusion facility and in general for all cases when wide neutron spectra are important.

The question being considered here arose in connection with the discussion of the world-wide request list for neutron data (WRENDA) [7] at INDC. In particular, the discussion concerned the problem of reviews of state-of-the-art in the knowledge of some definite values by the evaluators which had performed corresponding evaluations. The point is that the errors indicated by them and characterizing the attained state of knowledge must be compared with the error value tolerated by users and shown in the same document. Comparison of attained and required accuracies must show if the efforts in refinement of the value under consideration should be continued or stopped. Naturally, this is possible only at the unique definition of quantities being compared. Formulation of the problem was discussed earlier in document [8].

ERROR STRUCTURE IN AN EXPERIMENT

An experimentator investigating the dependence of a function on an argument measures it usually at the argument values being successively selected. In this case the dependence is obtained as a set of experimental points each of which has an error. Now we consider components of this error.

The first error component - the statistical one - shows itself directly in an experiment in the fact that the scatter is observed in the results of various sets of measurements.

This scatter is caused by the finiteness of the number of registered events and perhaps by other random factors. The experimentators consider that it is necessary to eliminate these random factors and they are satisfied if the scatter of some measurement sets is fully explained by the finiteness of the number of registered events, N, when the relative dispersion is equal to $\frac{1}{\sqrt{N}}$.

Irrespective of whether the scatter of measurement results is caused by the finiteness of the events number or not we denote this first error component by Δ statistical $\equiv \Delta_1$.

The second error component goes over to the measured value from the error of the standard used in measurements. Let us denote it by Δ standard $\equiv \Delta_2$.

The third error component is connected with possible disadvantages of the experimental set-up itself which results in a shift of the value under measurement. If the experimentator understands the causes of this shift or its part he introduces a calculational correction and evaluates a possible inaccuracy of this correction which is the third error component.

We denote it by Δ systematic $\equiv \Delta_3$.

This error can not stochastically vary from point to point because it results from the cause remaining constant or varying very slightly. Thus, this error component being correlated characterizes the error not of each point, but of the whole curve. The same considerations apparently can be attributed to Δ_2 or at least to its part and also to the next unknown error component.

The unknown error component is connected with disadvantages of the experimental set-up itself which result in the shift of the value under measurement what the experimentator himself does not know. We denote this component by Δ unknown systematic $\approx \Delta_x$.

The existence of Δ_x is just the reason of frequent discrepancies of the results of experiments performed with the use of various methods by values exceeding the errors declared by the experimentators.

The existence of Δ_x and its order of magnitude are revealed only when comparing the results in the process of evaluation. An important and a delicate task of an evaluator when revealing these discrepancies is the attribution of various values of Δ_x to the results of different authors. Fortunately, in some experimental works several various methods are used and in this case one can consider that for these works Δ_x is determined from the experiment.

The total error of an experimental point the authors of measurements usually calculate according to the formula

$$\Delta^2_{teep} = \Delta^2_1 + \Delta^2_2 + \Delta^2_3$$

because usually nothing is known about the last summand Δ_x. This representation is correct because three error components are not correlated with one another and the error of one point is characterized by this value correctly.

But it would be incorrect to form the table: argument, function, Δ_{teep}.

The fact is that at this representation one would like to draw a curve through the points with errors by the least square method but this assumes the errors of neighbouring points to be non-correlated. But in reality there is no correlation between neighbouring points only for the component Δ_1. On the contrary, for all remaining error components taking into account their origin one assume in the first approximation that there exists the total correlation between the points. In other words, all the components with the exception of Δ_1 shift the whole curve completely upwards or downwards and Δ_1 affects its form. If we draw the curve by the least square method using Δ_{teep} the form of this curve will be smoothed because some its peculiarities will be wrong treated as statistically unstipulated. It would not take place when using Δ_1 instead of Δ_{teep}. On the other hand, the error of an integral under the curve at a great number of points. Can be highly lowered because the total error is considered as the statistical one, decreased by $\sqrt{N}$ times with the increase of the "N" - number - points on the curve. At the correct treatment only the contribution to the integral from Δ_1 will be decreased with the increase of points number. The growth of the experimental points number in the given experiment can not affect other error components but Δ_1.

RECOMMENDATION FOR REPRESENTATION OF ERRORS OF EXPERIMENTAL VALUES

The error component Δ_1 non-correlated in various points and following directly from the measurements should be represented point by point. All other error components obtained as a result of the analysis of the experimental set-up and corresponding calculation or from literature should be represented separately with the specification of correlative properties, either with the help of formulae, either by algorithms description or in the table form. The total error of an experimental point can be presented in some characteristic points.

UNIQUE DEFINITION OF ERROR AND THE EVALUATION ALGORITHM AT WHICH IT IS REALIZED

The unique definition of error is necessary for establishing a common language between users, evaluators and measurers of nuclear data in the process of planning the work on data refinement.

When the user is speaking about a tolerable value of error, the evaluator - about a decrease of error achieved in the last experiments, and the experimentator - about his ability of measuring a value to a certain error, it is necessary that the same word "error" have the same meaning. Search of this meaning should be started from considering the aim of activities, i.e. ensuring an assigned accuracy of reactor calculation. From general considerations on the breadth of neutron spectra in fast reactors it is clear that the error components correlated over a broad energy range, i.e. affecting the integral under the cross-section curve and, may be, the general slope of this curve, should affect the calculation accuracy. And, on the contrary, the error component determining the inaccuracy of the curve detailed trend cannot influence significantly.

In accordance with this, for a unique definition of error of a function we take the errors of several functionals of this function which would characterize its normalization, general large-scale trend, etc. In the simplest case such functionals are the integral for characterizing the normalization and the first moment for characterizing the slope.

What are the requirements to the evaluation procedure to determine correctly the errors of the evaluated data and, specifically, of the above functionals?

First of all, the following remark should be made.

The commonly used programs of the least-squares method, for example, the program of the curve representation with the use of polynoms, assume the errors to be non-correlated, statistically independent. Therefore, with the use of these programs it is quite justified to draw a curve through the points of a single experiment assigning to those points the error Δ_i . But an attractive possibility to draw a curve through the points of several works at once, with assigning a total error to each point, should be rejected as an incorrect one. Let us explain this. There are two groups of experimental points from two works carried out by different methods and presenting the same function. They differ from one another by some value characterizing the systematic error value Δ_s . Now by assigning total errors to the points of both experiments according to the formula $\Delta^2_{iexp} = \Delta_i^2 + \Delta_s^2$ and drawing a curve through them by the least-squares method we obtain an error in the integral of this curve equal on its order of magnitude to $\Delta_{iexp}/\sqrt{N}$, where N is the number of points in both experiments. But it is obviously an erroneous conclusion because this error is determined by Δ_s and cannot decrease with the number of points on the curve.

Therefore, taking into account this remark, the evaluation process should consist of the following stages: 1) Reduction of results to one standard, introduction of corrections for systematic errors found out by the time of evaluation, rejection of works not satisfying some criteria or assigning a considerable systematic error Δ_s to them.
2) Parametrization by the least-squares method of experimental curves of separate works or groups of works performed by the same method. In this case information about uncertainties resulting from statistical uncertainties of each experimental work is presented, in corresponding covariance matrices.
The algorithm for obtaining the error of the functional of the parametrized curve from the covariance matrix is described in Appendix. Let us denote these errors by Δ_{ip} .
3) The procedure of obtaining a single evaluated function from several parametrized curves will not be discussed here. If such a method keeping information about errors exist, then it would be sufficient to apply the algorithm described in Appendix to a correspondingly parametrized function and to its covariance matrix to obtain a "unique" error. But irrespective of the method used for obtaining the evaluated curve the information on uncertainties of its functionals can be obtained by considering a statistical ensemble of functionals of the curves taken from separate works. When considering this ensemble we can consider it as an ensemble of measuring methods, systematic errors of each method being now considered as random ones. Therefore, to obtain the mean functional

and its dispersion let us use the formulae of the least-squares method:

$$F = \frac{1}{N}\,\frac{\sum F_i/\Delta^2_{iF}}{\sum 1/\Delta^2_{iF}} \quad ; \quad \Delta^2_F = \frac{1}{\sum 1/\Delta^2_{iF}} \qquad \text{(a)}$$

In this case the condition of $\frac{1}{N}\sum (F-F_i)^2/\Delta^2_{iF} = 1$ (b) will not be satisfied if we take $\Delta_{iF} = \Delta_{1iF}$. It is necessary to include in Δ_{iF} the known systematic errors Δ_{3iF} and, may be, to assign the unknown Δ_{xiF}. Assuming all the curves to be reduced to one standard, we do not take into account the component Δ_{2iF} at this stage. Thus,

$$\Delta^2_{iF} = \Delta^2_{1iF} + \Delta^2_{3iF} + \Delta^2_{xiF}$$

Strictly speaking, Δ_{xiF} should be assigned in accordance with the quality of methods but so that the condition (b) is satisfied.

From the point of view of applications the correctness of the evaluated curves should be verified by comparison of their functionals with the values obtained by formulae (a). As for the "unique" errors, they are also determined by the latter formulae (a) and (b).

In conclusion it should be noted that for the functionals considered we may take not the integral and the first moment but, for some important reactor parameter, the integral of the product of a cross-section by flux and importance of neutrons. In some cases it may prove that important is not an error within a broad energy range, as it has been said above, but an error in parameters of some resonance, for example, of the 3 keV sodium resonance. Functionals determining blocking coefficients, i.e. sensitive to the detailed trend of a curve can be also considered.

From the above it is clear that the proposed approach to the unique definition of the error is a sufficiently general one.

A P P E N D I X

The Error of the Parametrized Curve Functional

Let $f(x, a_0, a_1 \ldots a_n)$ be a function the parameters of which are determined from the condition of the best, in the sense of the least-squares method, description of the experimental points set. $F(a_0, a_1 \ldots a_n)$ is the functional of the "f" function, and D_{ij} is the covariance matrix characterizing dispersions - squares of parameter errors (diagonal terms) and covariances of parameter errors (non-diagonal terms).

To calculate the functional F dispersion it is necessary, first of all, to find the sensitivity coefficients of the functional to parameter variation, i.e., partial derivatives of the functional over the parameters $\partial F/\partial a_i \quad i = 0, 1, \ldots n$, the set of which forms the vector $\{\partial F/\partial a_i\}$.

The dispersion of the functional F, i.e. the square of its error, is expressed by the formula:

$$\Delta^2_{1F} = \left|\frac{\partial F}{\partial a_0}\ \frac{\partial F}{\partial a_1} \cdots \frac{\partial F}{\partial a_n}\right| \times \begin{vmatrix} D_{00} & D_{01} & \ldots & D_{0n} \\ D_{10} & D_{11} & \ldots & D_{1n} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ D_{n0} & D_{n1} & \ldots & D_{nn} \end{vmatrix} \times \begin{vmatrix} \frac{\partial F}{\partial a_0} \\ \frac{\partial F}{\partial a_1} \\ \vdots \\ \frac{\partial F}{\partial a_n} \end{vmatrix} \qquad \text{(p.1)}$$

where the sign "x" denotes matrix multiplication. Thus, this algorithm extracts from the detailed information about the error the component we are interested in.

As a simple example let us consider a function presented by a series over the Legendre polynomials in the range of arguments from -1 to +1, i.e. in the range of orthogonality of those polynomials. In case of the energy dependence of the functions in the interval E_1 to E_2, by transformation of the argument:

$$x = -\frac{E_2 - E}{E_2 - E_1} + \frac{E_1 - E}{E_1 - E_2} .$$

we will get into the above mentioned interval of arguments.

So, let

$$f(x, a_0, a_1 \dots a_n) = \sum_{i=0}^{n} a_i P_i(x)$$

then

$$F_0 = \int_{-1}^{1} f(x, a_0, \dots a_n)\,dx = 2a_0 \quad . F_1 = \int_{-1}^{1} x f(x, a_0 \dots a_n) = \frac{2}{3} a_1$$

$$\frac{\partial F_0}{\partial a_i} = 2\delta_{0i} \quad i = 0, 1 \dots n \qquad \frac{\partial F_1}{\partial a_i} = \frac{2}{3} \delta_{1i} \quad i = 0, 1 \dots n$$

$$\Delta^2_{1F_0} = 4 D_{00} \qquad \Delta^2_{1F_1} = \frac{4}{9} D_{11}$$

If the polynomials were not orthogonal, or the functionals had weight, or parametrization were more complicated, e.g., presentation of the resonance curve by a multilevel formula, then such simplification of the algorithm would not take place and calculations should be carried out by the general formula (p.1).

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APPENDIX XI

ORNL ELECTROMAGNETIC ISOTOPES INVENTORY
AND REQUIREMENTS AS OF MARCH 31, 1974

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Sb-121	>98		4,543		5,000	40,100		1,994	42,094		120	78
Sb-123	>96		5,232		3,500	49,920			49,920		120	70
Ba-130	<55		68			1,414			1,414			
	>55				1,000	80			80			
	>50										1.0	1.0
Ba-132	5-15		196									
	15-35		1,797		1,000							
	35-45		4		500	768			768			
	>45					210			210			
	>50										1.0	0.8
Ba-134	<55		2,804			1,436			1,436			
	55-70		2,094			30,000		10	30,010			
	>70		336		} 2,000	17,171			17,171			
	>85					4,452			4,452		30	25
Ba-135	50-70		8,209			10,000			10,000			
	70-90		3,842			39,966			39,966			
	>90		2,299		3,500	20,865		2,875	23,730			
	>95										100	76
Ba-136	30-60		7,071			52,262			52,262			
	60-90		1,729			49,063			49,063			
	>90		11,075		4,000	24,374			24,374			
	>95										100	76
Ba-137	<80		12,529			120,572			120,572			
	80-90		16,492		3,500	45,494			45,494			
	>95										100	100
Ba-138	>95		13 237		25,000	228,256	6,000		234,256		100	None
B-10	>99		8,410		500						50	50
B-11	>98		500		500							
Br-79	90-98		2,266									
	>98		5,549		4,000	186,733			186,733		50	None

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Br-81												
	>97		4,200		5,000	168,584			168,584		50	None
Cd-106	70-85		255			4,958			4,958			
	>85	17,000	411	2,000	2,000	4,011			4,011	6,000		
	>80										15	6
Cd-108	60-75		318			5,131			5,131			
	75-85	13,000	15	6,000	6,000					7,000	10	5
	>75											
Cd-110	>95	186,000	5,312	10,000	15,000	40,807	43,735	3,389	87,931	13,000	100	13
Cd-111	>90		19,428		12,500	79,174		3,640	82,814		100	17
Cd-112	>95	368,000	17,798	132,000	150,000	24,087	74,398		98,485	2,000	100	2
Cd-113	>90		10,683		10,000	87,018			87,018		100	13
Cd-114	>98	450,000	4,033	400,000	400,000	55,008		5,895	100,903	40,000	100	39
Cd-116	>94	120,000	3,419	12,000	15,000	36,801		7,353	44,154	6,000	50	6
Ca-40	99.97		45,109*		52,000	284,648	140,000		424,648		570	106
Ca-42	65-90		742									
	>90		31,748		6,000	1,000	52,823		53,823		55	1
Ca-43	60-80		11,318									
	>80		2,685		2,500	4,901	7,880		12,781		10	None
Ca-44	75-98		4,437			84,244		42	84,286		40	None
	>98		27,246		20,000	209,978	15,024		225,002		160	None
Ca-46	<40		386		400							
	>40				200	181			181		0.5	0.3
Ca-48	>94		424		8,000	15,697	9,504	6,502	31,703		50	18
C-12	>99.9		3,532		1,000	4,000			4,000		100	95
Ce-136	<25		821		1,000	5,000			5,000			
	25-40				100	1,453			1,453			
	>40					134			134		} 10	4
Ce-138	<14		403			1,951			1,951			
	14-25		4,444		1,000	12,783			12,783			

*Includes 5,215 mg on loan.

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Ce-138	>25					2,244			2,244			
	<20										10	8
Ce-140	>98		20.755		50,000		550,000		550,000		200	None
Ce-142	>83		9,847		6,500	63,850	92,435	9,000	165,285			
	>99										100	100
Cl-35	85-98		112			2,007			2,007			
	>98		2,963		40,000	178,293			178,293		100	None
Cl-37	75-95		10,896		15,000	31,938			31,938			
	>95		124		7,500	7,259			7,259		50	43
Cr-50	88-95		4,471				2,872		2,872			
	>95		4,223		25,000	30,722	29,763		60,485		55	None
Cr-52	99-99.9		9,865		18,000	95,279	49,981	1,740	147,000		147	None
Cr-53	85-95		1,052									
	>95		6,925		15,000	83,927	50,000		133,927		134	None
Cr-54	87-95		8,510		1,500	1,844	19,705		21,549			
	>95				2,000	14,804	3,000		17,804		50	11
Cu-63	91.33		9,072									
	>99		32,956		50,000	443,115		109,885	553,000		553	None
Cu-65	>95		76,537*		25,000	55,832	173,818	70,046	299,696		300	None
Dy-156	<20		198		100	615			615			
	20-30		398		150	1,148			1,148			
	>30				50	69			69		1.5	1.5
Dy-158	10-25		706		300	2,159	400		2,559			
	25-35				200	250			250			
	>40										3.0	3.0
Dy-160	<60		4,281									
	60-70		3,212			20,278			20,278			
	70-80		356		3,000	1,939			1,939		20	18
	>80					342			342			

*Includes 59,103 mg on loan.

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Dy-160	>75										20	18
Dy-161	>90		11,175		10,000	100,000			100,000		100	None
Dy-162	>90		13,314		17,500	51,993	95,607		147,600		150	None
Dy-163	>90		4,430		3,000	92,112	59,184		151,296		150	None
Dy-164	>95		9,140		25,000		159,590		159,590		150	None
Er-162	20-25		172		300	3,449			3,449			
	>25		770		200	2,527			2,527		10	7.5
Er-164	60-70		2,628		1,000	24,641			24,641			
	>70		264		750	5,607			5,607		30	15
Er-166	80-95		2,300		2,500		100,000		100,000			
	95-99		3,601		7,500	170,000			170,000		170	None
	>99					2,683			2,683			
Er-167	85-95		13,039		12,500	170,000			170,000			
	>95										170	None
Er-168	>90		13,952		20,000	170,000	100,000		270,000		170	None
	99.9		1,030			440			440			
Er-170	96-97		16,966		25,000	68,543	169,125		237,668		170	None
Eu-151	90-99		22,813		25,000	60,163	88,388		148,551		150	1.5
Eu-153	90-99		23,947		25,000	5,555	94,437	50,000	149,992		150	None
Gd-152	<25		1,833		1,000							
	25-35		1,740		500	2,000			2,000			
	35-45					1,269			1,269			
	45-55					183			183		3.0	1.5
Gd-154	60-75		2,770		4,000	30,433			30,433		} 30	None
	>98		344			1,818			1,818			
Gd-155	74-80		498			1,509			1,509			
	80-90				} 9,000	26,046			26,046			
	90-95		124			27,269	34,866	2,440	64,575			
	99.82		2,994		1,000							
	>95										150	85

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Gd-156	80-95		19,207		18,000	30,000	116,428		146,428			
	95-99		15,813			9,967			9,967		150	29
	99.82					1,591		400	1,991			
Gd-157	69-80		1,692			1,778		479	2,257			
	80-90		6,991			49,954	93,074		143,028			
	90-95		150		10,000	24,344		6,598	30,942		150	None
	99.7		2,281									
Gd-158	80-90		25,180		5,000	79,915			79,915			
	90-95		16,528		15,000	2,919			2,916			
	>95					171,462			171,462		170	None
Gd-160	90-99		90,437*		47,500	100,000			100,000		150	None
	>99.99		1,024				50,170		50,170			
Ga-69	>99		4,055		10,000		70,000		70,000		70	None
Ga-71	>99		1,833		6,000		72,886		72,886		70	None
Ge-70	80-90		42,886		7,500	32	125,483		125,515			
	90-95		26									
	>95		100		2,500	8,326			8,326		75	67
Ge-72	90-95		88,373			2,763	177,951		180,714			
	>95		9,167		15,000	14,032			14,032		75	None
Ge-73	70-85		4,977		10,000	41,459	6,000		47,459			
	85-95		7		5,000							
	>95										75	75
Ge-74	90-95		26,685		} 40,000	49,902			49,902			
	>95		2,210			24,098			24,098		75	None
Ge-76	70-85		1,734		5,000	24,882			24,882			
	85-95		100		5,000							
	>95					272			272		75	75

*Includes 50,000 mg on loan.

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Hf-174	<10		1,019		500							
	10-15	1,000	63	200		492			492	800		
	20-25		61		5,000	209			209		100	100
Hf-176	68-70		250				8,629		8,629			
	70-85	10,000	241	2,000	5,000	634		3,000	3,634	8,000	100	88
Hf-177	70-85		3,064		5,000	4,999	20,000	14,683	39,682			
	85-95	75,000	7,311	3,000	10,000	5,163		1,600	6,763	72,000	100	79
Hf-178	89-95	110,000	18,328		15,000	67,844	20,000		87,844	110,000	100	12
Hf-179	<70		114			11,983			11,983			
	70-85	50,000		10,000	10,000		13,170		13,170	40,000		
	>85		3,624		10,000	3,541			3,541			
	>90										100	100
Hf-180	90-99	115,000	994	444	27,500	50,937	22,000		72,937	90,000	100	20
In-113	45-70		830		1,000	994			994			
	85-95				500							
	>95		18			4,668	138		4,806		30	25
In-115	>99.5		29,635		7,500	199,680			199,680		120	None
Ir-191	85-90				300							
	90-96				500	156			156		50	None
	>96	56,000		1,000						55,000		
Ir-193	85-95		123		300							
	>95		7		500						50	None
	>98	95,000	84	1,000		556			556	94,000		
Fe-54	>90		28,755		35,000		369,386		369,386		160	None
Fe-56	98-99.8		16,700		20,000	129,550	181,054		181,054		} 960	None
	>99.8		69,998		80,000	900,000	60,000		960,000			None
Fe-57	40-70		704		} 25,000							
	80-90						234,960		234,960 }		{ 250	None
	>90		4,503		50,000	64,874	37,326	10,000	112,200 }		50	None
Fe-58	25-70		9,411			15,592			15,592			
	70-90		6,022		7,500	92	18,883	50	19,025			
	>90										10	

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
La-138	1.23		419		300							
	7-8		159			2,000			2,000		2.0	None
La-139	>99.9		1,000		1,000	30,000			30,000		30	None
Pb-204	20-80		30,638			7,188	99,424	1,178	107,790			
	80-99		16		10,000							
	>99		2,181		1,000	15,000			15,000		20	5
Pb-206	99-99.95		30,872		40,000	95,264	84,081		179,345			
	>99.95		1,287			10,000			10,000		} 263	74
Pb-207	80-90						309,373		309,373			
	90-98		49,370		60,000	395,166	433,529		828,695		750	None
	>98		5,141		2,000							
Pb-208	95-99						1,498,000		1,498,000			
	99-99.9		49,195		100,000	65,208	547,463	67,094	679,765		245	None
	>99.9		154		1,000	6,490			6,490		10	3.5
Li-6	>99.9		1,000		1,000	10,000			10,000		10	None
Li-7	99.99		1,000		1,000	8,591			8,591		10	1.5
Lu-175	>99.8		7,575		10,000	180,953	50,000		230,953		200	None
Lu-176	70-80		50		500	4,206	50		4,256		20	16
Mg-24	>99		44,542		50,000	200,000	51,937	196,200	448,137*		200	None
Mg-25	>99		14,219		15,000	79,404		43,340	122,744		100	None
Mg-26	>95		25,106		30,000	13,714	106,286		120,000		120	None
Hg-196	20-30	1,450		850				216		600		
	33.79	179		179								
	48.18		771		5,000	742			742			
	49.13	39		39							} 50	49
	73.16					121			121			
Hg-198	50-80		29			5,627	2,500	3,702	11,829			
	80-90					4,662			4,662			
	90-99				2,000	2,065			2,065			
	>99										50	50

*Includes 200,000 mg sample borrowed from Reserve.

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Hg-199	65-80							235	235			
	80-90		373			600			600			
	>90				3,000	76	2,500		2,576		50	48
Hg-200	70-90	9,062	1,177		1,500			2,996	2,996	9,062		
	93.13	7,469		469						7,000		
	>95	5,368		368						5,000	50	50
Hg-201	81-90		3,385				25,995		25,995			
	90-95	17,000	729	1,000	2,500	5,034	2,500		7,534	16,000	} 50	37
	>95		507			4,422	1,000		5,422			
Hg-202	70-85	13,000	448	3,000						10,000		
	>95				7,500		2,848		2,848		50	47
Hg-204	44-80		12,639			329	2,400		2,729			
	80-90		276									
	>90		1,887	-	} 3,000							
	>98							4,052	4,052		} 50	46
Mo-92	90-98		24,651		35,000	-50,000	197,147	52,000	199,147		195	None
Mo-94	85-95		14,146		15,000		182,359	2,000	184,359		100	None
Mo-95	>96		14,071		15,000	147,000	50,000	6,000	203,000		203	None
Mo-96	>96		11,581		15,000		197,000	3,000	200,000		200	None
Mo-97	90-95		5,117		6,000	40,000	50,000	7,000	97,000		97	None
Mo-98	85-90		40,423	40,000 }	>1,000,000							
	92-99		358,967	497,000 }		46,402	151,010	9,000	206,412		206	None
Mo-100	95-99		21,416		15,000	31,025	265,584	10,735	307,344		100	None
Nd-142	90-95		316			4,257			4,257			
	>95		29,604		80,000	67,489	117,705	8,000	193,194		194	None
Nd-143	65-85						18,077		18,077			
	>85		4,716		6,000	93,235	56,000		149,235		150	None
Nd-144	94-99		15,040		17,500	39,090	38,000	67,788	144,878		140	None
Nd-145	55-75		4,302			1,861		20,000	21,861			
	75-85		1,474									
	>85		26,790		5,000	71,186		23,279	94,466		150	
Nd-146	85-95					74,000		5,000	79,000			
	>95		502		15,000	14,128	39,078		53,206		} 132	

			Sales			Research Materials Collection						
Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Inventory (mg)	To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Nd-148	87-90					20,699		6,000	26,699			
	>90		9,442		12,000	4,226	39,000	30,000	73,226		}100	None
Nd-150	>90		11,306		25,000	11,393	42,092	47,549	101,034		100	None
Ni-58	99		241,562		250,000		587,844		587,844		280	None
Ni-60	98-99.8		43,853		175,000	301,261	748,918		1,050,179		1,050	None
Ni-61	70-85		33									
	85-95		11,399		10,000	267	69,960	1,437	71,397			
	>99				2,000	3,912		424	4,336			
	>98										100	96
Ni-62	>95		26,763		100,000	14,462	3,404	1,444	139,310		138	None
Ni-64	>95		6,810		10,000	8,993	19,568	1,439	30,000		30	None
Os-184	2-3	50	37		100					50		
	> 5										0.02	0.02
Os-186	60-65		-30		2,000	125		59	184			
	75-80	2,200		200						2000		
	>90										2	2
Os-187	45-50				2,000	1	266		267			
	70-75	2,200		200						2000		
	>90										2	2
Os-188	>85	18,000		5,000	5,000					13,000	10	10
Os-189	>85	22,000	3	10,000	10,000	-1,399	3,974		2,575	12,000	20	17
Os-190	>95	35,000		10,000	10,000	-1,392	3,784		2,392	25,000	20	17.5
Os-192	>95	55,000		15,000	15,000					40,000	50	50
Pd-102	75-80	4,000	228	300	500					3,700		
	>80										100	100
Pd-104	55-70		516									
	70-85							633	633			
	>85	34,500	822	2,500	2,500			5,000	5,000	32,000		
	>90										100	95
Pd-105	<80		210									
	>90	46,600	330	2,600	2,500		9,990		9,990	44,000	100	90

			Sales			Research Materials Collection						
Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Inventory (mg)	To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Inventory (mg)	On Loan (mg)	Reprocessing (mg)	Total Inventory (mg)	To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Pd-106	<90		376			1,500			1,500			
	>90	80,200	1,432	4,200	5,000		1,493	10,500	11,993	76,000	100	88
Pd-108	85-95		882									
	>95	89,600	45	4,600	5,000	385	8,300	6,300	14,985	85,000	}100	85
Pd-110	85-95											
	>95	29,700	375	6,700	7,500			3,600	3,600	23,000	100	97
Pt-190	0.3-0.6		740		500							
	2.5-3.0											
	3.0-5.0	212		32						180	50	50
Pt-192	8.4-15		1,215		1,000							
	57	1,839		339						1,500		
	>90										50	48.5
Pt-194	40-60		3,961									
	60-70					9,582			9,582			
	>95	60,058		5,058	5,000					55,000	50	None
Pt-195	45-55		6,595			4,422			4,422			
	55-65		897		1,000							
	47-60										50	None
	>95	59,831		1,000	1,000					58,831		
Pt-196	40-50		65									
	50-60											
	>95	40,893		5,896	6,000					35,000	50	50
Pt-198	30-50					1,274			1,274			
	>95	13,519		1,519	2,000					12,000	50	50
K-39	>99		8,500		10,000	39,919	18,081		58,000		58	None
K-40	30-55		211*									
	55-60		36									
	60-80		261		2,500						}1.0	1.0
	>80		12									

*Includes 32 mg on loan.

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
K-41	>98		1,114		15,000	8,000	39,709		47,709		50	2
Re-185	>85		10,038		8,000	72,904			72,904			
	>98										100	26
Re-187	<98					54,460			54,460			
	>98		4,349		8,000	96,207			96,207		200	103
Rb-85	>98		15,743		25,000	94,000			94,000		94	None
Rb-87	85-99		49,920		} 50,000	90,000			90,000		90	None
	>99											
Ru-96	>98				1,500	327			327		100	100
Ru-98	<55		19									
	55-65		437									
	85-95		20		300	449			449			
	>95										100	100
Ru-99	75-90											
	>90				5,000						100	100
Ru-100	71-80		344									
	80-90		1			1,000			1,000			
	>95		478		1,000	2,942			2,942		100	97
Ru-101	85-95		21			1,500			1,500			
	>95		639		2,000	1,881	3,000		4,881		100	95
Ru-102	>95		42		10,000	9,918			9,918		100	90
Ru-104	>95		14		4,000	3,353	2,931		6,284		100	94
Sm-144	75-85		847									
	85-95				10,000		24,830		24,830			
	>95		227		15,000	1,000	23,836	24,870	24,836		50	25
Sm-147	90-99		16,650		15,000		219,452	4,000	223,452		150	None
Sm-148	80-95					10,270			10,270			
	95-99.9		20,811		15,000	89,594	40,000	2,500	132,094		} 150	16
	>99.9		30			1,723			1,723			

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Sm-149	>90		20,117		20,000	17,580	110,000	4,000	131,580		150	20
Sm-150	60-85		140			6,627			6,627			
	85-99.7		4,202		15,000	42,869	73,820	4,000	120,689		} 150	27
	>99.7		26			1,923			1,923			
Sm-152	>90		39,546		50,000	11,107	140,323	4,000	155,430		150	None
Sm-154	>96		67,931*		60,000	12,411	145,604		158,015		150	None
Se-74	25-40		60									
	>40			1,500							} 80	80
	>70		372		7,500	703						
Se-76	>95		5,207		5,000	40,000					40	None
Se-77	>90		1,013		5,000	40,000			40,000		40	None
Se-78	>95		4,630		5,000	60,000			60,000		60	None
Se-80	>94		13,060		20,000	80,000			80,000		80	None
Se-82	55-80											
	80-90		2,735				2,000		4,890			
	90-95				4,000							
	>95		1,182	2,512		38,000			38,000		40	2
Si-28	>98				15,000		2,000		2,000			
	>99		12,832			18,478	182,000		200,478		} 200	None
	99.99+										30	30

*Includes 50,000 mg on loan.

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Si-29	85-95					7,497			7,497			
	>95		10,293		7,500	4,299	12,873	78,990	96,162		100	3.9
	99.99+										1.0	1.0
Si-30	<90		19,109									
	90-94		776			1,304			1,304			
	>94		18,338		12,500	4,630	52,807		57,437		80	23
	99.99+										1.0	1.0
Ag-107	>98		10,632		12,000	100,000			100,000		100	None
Ag-109	>99		10,020		12,000			99,959	99,959		100	None
Sr-84	60-80		5,601									
	>80		11,572		15,000	20,000			20,000		20	None
Sr-86	75-95											
	>95		22,568		30,000	100,000			100,000		100	None
Sr-87	85-90		28,909		10,000	284,256			284,256		}100	None
	>90		7,168		6,000	67,418			67,418			
Sr-88	>98		126,328		100,000	116,000			116,000		126	10
S-32	>98		7,143		3,000	240,000	1,972	7,253	249,425		250	None
S-33	<30		27,359				2,000					
	45-75		553		}3,000		995				}5	3.9
	75-90		46				1,086		1,086			
	>90		81									
S-34	<70		70,277									
	70-85					3,323			3,323			
	>85		2,625		10,000	166	15,000	14	15,180		100	85
S-36	<2.0		14,556									
	2.0-4.0		63		1,000	104			104			
	}10										100	100
	55.8	12*		12								

*To be added to inventory when price approved by AEC.

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Ta-180	0.34-5.10		75		100							
	>5.1						164		164		1.0	1.0
Te-120	<50	1,000	556			408			408	1,000		
	50-60				1,000	1,100			1,100			
	>60										2.0	2.0
Te-122	>90	25,000	19	20,000	50,000	3,000				5,000	40	40
Te-123	<75	8,000	141			8,120			8,120	8,000		
	75-85		2,349		1,000	85		2,900	3,075			
	>85		1,756		2,000							
	>80										10	6
Te-124	70-95	45,000	10,717	10,000		27,369			27,369	35,000		
	>95				20,000	26,000			26,000		90	27
Te-125	<90					3,868			3,868			
	90-97		14,162		20,000	99,836			99,836		90	None
Te-126	85-90		-100		}15,000						}100	None
	>98		13,050			100,000			100,000			
Te-128	80-97		23,784									
	97-99+		131,055		60,000		110,000	7,000	117,000		103	None
Te-130	90-99+		13,281		30,000	186,286		7,000	193,286		101	None
Tl-203	>90		49,624		40,000	138,977	33,487		172,464		200	28
Tl-205	>95		14,998		30,000	977	250,614		251,591		200	None
Sn-112	>70		593		25,000	5,100		933	6,033		10	4
Sn-114	45-55		85									
	55-75		6,891		1,000	21,253		902	22,155			
	>75										10	10
Sn-115	<30		3,105			7,468			7,468			
	30-40				750			9,515	9,515			
	>40					148			148		4	4
Sn-116	>95		45,262		20,000	80,243	50,020	1,940	132,203		158	26
Sn-117	75-90		24,835		25,000	83,339	29,242	925	113,506		74	None
Sn-118	90-99		62,927		100,000	135,330	117,730	918	253,978		254	None
Sn-119	>80		37,282		50,000	22,575		66,425	89,000		89	None

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Sn-120	95-99		74,691		90,000	81,216	213,759	941	295,916		295	None
Sn-122	85-95		12,231		15,000	66,883	33.117	921	100,921		100	None
Sn-124	85-97		22,430		20,000	24,463	59,537	1,865	85,665		84	None
Ti-46	70-80		8,552			66,790			66,790			
	80-90		17,690		40,000	9,435	2,049		11,494			
	>90										40	40
Ti-47	<75		878			50,943		2,087	53,030			
	75-90		18,086		6,000	30,860	13,466		44,326			
	>90										40	40
Ti-48	>96.5		11,033		40,000	172,957	8,609	16,736	198,312		144	None
Ti-49	25-50		567			13,180			13,180			
	50-75		2,279			39,294			39,294			
	75-90		12,679		9,000	11,610	4,759		16,369			
	>90										40	40
Ti-50	65-75		4,962			52,370		1,536	53,906			
	75-85		873		15,000		6,712		6,712			
	>90										40	40
W-180	<12		3,786		1,500	20,177			20,177			
	>20										20	20
	92.62		123		150							
W-182	90-95		13,992		15,000	128,854	482,713	181,000	792,567		130	None
W-183	70-90		16,838		10,000	21,859	263,294	208,083	493,236			
	>90										100	;88
W-184	80-96		14,075		20,000	167,000	457,909	177,000	801,909			
	>94										167	None
W-186	>96		22,545		30,000	103,905	550,778	187,000	841,683		124	None
V-50	36-45		146		150	307			307		0.34	None
V-51	>99.95		50		500							

Isotope	Enrichment (%)	Proposed Separations thru Dec. 1974 (mg)	Sales: Inventory (mg)	Sales: To Be Added from Proposed Separations (mg)	5-Year Sales Requirements (mg)	Research Materials Collection: Inventory (mg)	Research Materials Collection: On Loan (mg)	Research Materials Collection: Reprocessing (mg)	Research Materials Collection: Total Inventory (mg)	Research Materials Collection: To Be Added from Proposed Separations (mg)	RMC Requirements (g)	Approx. Bal. RMC Requirements (g)
Yb-168	10-20		4,058		1,000							
	20-30		-3		4,000	2,000			2,000		2.0	None
Yb-170	60-85		16,506		5,000	46,495			46,495			
	85-90				1,000	1,801			1,801			
	>90										30	30
Yb-171	85-95		40,547		10,000	55,713	190,000		245,713			
	>95				5,000	4,173	5,000		9,173		100	90
Yb-172	85-98		8,791		10,000	16,761	87,461		104,222		105	None
Yb-173	75-95		14,114		12,000	1,959	235,000		236,969		98	None
Yb-174	85-99		19,057		35,000	189,000			189,000		189	None
Yb-176	85-99		11,331		15,000	114,839			114,839		115	None
Zn-64	85-99		321		20,000	11,279	15,000		26,279		} 64	None
	>99		28,013		10,000	169,459		3,766	173,225			
Zn-66	90-99		14,530		20,000	46,995		3,090	50,085		} 80	
	>99		57			4,423	20,000		24,423			6
Zn-67	50-95	53,000		15,000	15,000					30,000		
	75-95		171				11,051	1,990	13,041			
	>95										30	30
Zn-68	98-99+	175,000	2,907	145,000	200,000	50,785	10,000	3,384	64,169		60	None
Zn-70	<75	1,000	572	1,000	1,500	1,210			1,210			
	75-90	3,500	922	1,000	500	505			505	2,500		
	>90										3	3
Zr-90	97-99		91,878		50,000	9,922	267,700	21,386	299,008		217	None
Zr-91	<85		2,346									
	>85		4,035		15,000	11,485	85,495	5,132	102,112		100	None
Zr-92	85-95		23,412									
	>95		12,929		10,000	18,451	75,169	7,690	101,310		100	None
Zr-94	80-90		4,681									
	90-99		63,479		10,000	15,069	9,277	42,329	66,675		100	34
Zr-96	45-60		1,492		} 2,000		13,453	6,700	20,153			
	60-75		1,739									
	75-90	12,000	1,522*	4,000	10,000		211	1,235	1,446	8,000		
	>95										50	50

*Includes 1,235 mg on loan.

Agenda Item V.c(b)
27 September 1974

NDS Working Paper 6

Use of evaluated data files

The evaluated neutron data files stored at the IAEA Nuclear Data Section are listed in Annex I. These files are available free of charge on request, and can be supplied in the form of listings or on magnetic tape.

In addition to the evaluated data dissemination statistics given in INDC(NDS)-63/L (page 40, Table IIB) for the time period 1 September 1973 to 31 August 1974, Table I of this working paper gives an account of the frequency of evaluated neutron data file dissemination by NDS between May 1972 and September 1974. The cut-off date of May 1972 was chosen so as to have a representative time period during which the ENDF/B standards files have been available from NDS.

Table II gives a more detailed breakdown of the dissemination of the ENDF/B-III evaluated standards data files by NDS from May 1972 to September 1974. This summary does not include information on the latest ENDF/B-IV standards file which has been received by NDS in the middle of September 1974.

Annex I

Evaluated Neutron Data Files Available from the Nuclear Data Section on Magnetic Tape.

Description and Documentation

1. Australian Fission Product Library

Received: 17 December 1971

References: a) "Fission Product Cross Sections"
J.L. Cook, June 1970 AAEC/TM-549

b) "The AAEC Fission Product Cross Section Libraries FISPROD.POINTXSL and FISPROD.GROUPXSL."
E. K. Rose, March 1971, AAEC/TM-587

2. Australian Fission Product Group Cross Section Library

Received: 31 January 1972

Reference: "Fission Product Group Cross Sections Library", V.K. Bertram et al, 1971, AAEC/E-214

3. Australian Strength Function File

Received: 9 January 1974

Reference: "A Compilation of S- and P-wave Neutron Strength Function Data",
A.R. de L. Musgrove AAEC/E-277

4. Italian (Bologna) Fission Product Library

Received: several releases between 1968 and 1972

Reference: Newsletter CCDN/NW-10

5. Soviet BOYAD 1 file

(U-238 file # 2001: "Evaluated Nuclear Data Library for Reactor Calculations", V.E. Kolesov and M.N. Nikolaev)

Received: 17 July 1972

References: INDC(CCP)-13/L
INDC(CCP)-23/G

6. Soviet BOYAD 2 file

(Angular distribution of neutrons scattered from Deuterium to Pu-239, files 1001 to 1042 (by M.N. Nikolaev), file 1043 containing data for U-235 (by V. Konshin).

Received: 21 January 1974

References: a) "Anisotropy of Elastically Scattered Neutrons", M.N. Nikolaev and N.O. Bazazjants (1973) translated by A. Schett, NEA/CCDN; to be published

b) INDC(CCP)-13/L

7. ENDF/B-3 Standards File

Received: a) 6 Materials File: 4 May 1972
b) 7 Materials File: 16 October 1972

References: a) "Data Formats and Procedures for the ENDF Neutron Cross Section Library", M.K. Drake, Oct. 1970, Vols. 1 and 2, BNL-50274 (T-601)

b) "ENDF/B Summary Documentation" O. Ozer and D. Garber, May 1973, BNL-17541 (ENDF-201)

c) "Up-dated Documentation for ENDF/B-IV," S. Pearlstein, April 1974

Note: the ENDF/B-IV Standards file, superseding the ENDF/B-III files, was received by NDS on 15 September 1974.

8. Lawrence Livermore Laboratory ENDL File

Received: a) 2 sets received 25 January 1974
b) 72 sets received 8 April 1974

Reference: "The Lawrence Livermore Laboratory Evaluated Nuclear Data Library (ENDL) Translated into the ENDF/B Format", R.J. Howerton, Oct. 1973, UCID-16376

9. KEDAK - The Karlsruhe Evaluated Nuclear Data File

Received: 9 October 1970

References: a) "Neutron Cross Sections for Fast Reactor Materials - Part I: Evaluation", J.J. Schmidt, Feb. 1966, KFK-120 (EANDC-E-35U); and

"Tables of Evaluated Neutron Cross Sections for Fast Reactor Materials", I. Langner, J.J. Schmidt, D. Woll, KFK-750, September 1968

b) "Card Image Format of the Karlsruhe Evaluated Data File KEDAK", D. Woll, December 1968, KFK-880 (EANDC-E-112U)

c) "Status of the Karlsruhe Evaluated Nuclear Data File KEDAK as of June 1970", B.Hinkelmann et al, June 1970, KFK-1340 (EANDC-E-136U)

10. UK Nuclear Data Library (UKNDL)

Received: Several releases of this file since 1968, 62 files as of July 1974

Reference: "The Aldermaston Nuclear Data Library as of May 1963", K. Parker, AWRE Report O-70/63.

Table I

Evaluated Data Dissemination by NDS between May 1972 and September 1974

Evaluated Data File: File name	Total no. of material sets in file	Dissemination: No. of material sets	No. of times itemized	sub-totaled
Australian fission product library	192	whole file	5	
" " " "		4	3	
Australian fission product group cross section library	192	whole file	2	
Australian strength function file	199	whole file	1	
Australian files subtotal				11
Italian fission product library	246	whole file	5	
Italian file subtotal				5
Soviet BOYAD 1 file	1	whole file	8	
Soviet BOYAD 2 file	43	whole file	2	
Soviet files subtotal				10
ENDF/B-3 standards	6	whole file	2	
" " "		3	3	
ENDF/B-3 Standards	7	whole file	5	
" " "		3	3	
ENDF/B files subtotal				13
Laurence Livermore Laboratory ENDL file	72	2	2	
US file subtotal				15
FRG KEDAK file	41	whole file	4	
" " "		34	8	
KEDAK files subtotal				12
UK Nuclear Data Library	62	whole file	8	
" " " "		43	10	
UK files subtotal				18
Total number of evaluated data material sets sent ⟶				72

Table II

ENDF/B-III EVALUATED DATA DISSEMINATION (from May 1972 to August 1974)

NUCLIDE	Acc.No.	Sub Acc.no.	no. of material sets	no. of lines		LAB CODE	REQUESTOR	FORMAT	DATE
6 set standards *									
Li-006	1115								
He-003	1146								
H-001	1148		6	6590		4CCPINP	Konshin (USSR)	LD	720720
B-010	1155					4CCPCJD	Usachev (USSR)	TD	720522
U-235	1157								
Au-197	1166								
H-001	1148		1	444		4CCPKUR	Yankov (USSR)	LD	720607
H-001	1148		1	444		3SAFNIT	Bibby (South Africa)	L	721003
Subtotal 1			14	14068					
7 set standards **									
Li-006	1115					3INDKAL	Shankar Singh (India)	TD	731012
He-003	1146					3HUNFKI	Vertes (Hungary)	TD	730319
H-001	1148					3KORSEO	Mann Cho (Korea)	TD	730402
B-010	1155		7	9245		3RUMBUC	Mateescu (Romania)	T	730323
U-235	1157					3CSR	Kott (Czechoslovakia)	T	730321
C-012	1165								
Au-197	1166								
C-012	1165		1	2655		4CCPCJD	Manokhin (USSR)	T	730731
C-012	1165		1	2655		3SAFSLT	Pauletta (South Africa)	L	730921
U-235	1157		1	2995		3BZLSAO	Herdade (Brazil)	T	720830
Au-197	1166	3	1	59		3ISLNEG	Kushelevsky (Israel)	L	740104
Subtotal 2			53	73079			9		
TOTAL			67	87147			13		

* Tape received at NDS = 720504

** Tape received at NDS = 721016

L = Listing, D = Documentation, T = Magnetic tape

SEVENTH INTERNATIONAL NUCLEAR DATA COMMITTEE MEETING

TOPICAL SESSION - "GAMMA RAYS FROM NUCLEAR REACTIONS"

LUCAS HEIGHTS

OCTOBER 9, 1974

LIST OF PAPERS

J. R. BIRD (AAEA)	Review of Second International Symposium on Neutron Capture Gamma Ray Spectroscopy and Related Topics September 2-6, 1974, Petten, The Netherlands)
M. J. KENNY, B. J. ALLEN J. W. BOLDEMAN, A. R. de L. MUSGROVE (AAEC)	Non-statistical Effects in keV Neutron Capture
D. G. SARGOOD (Melbourne University)	(p,γ) Resonance Strengths in the (s,d) Shell
M. N. THOMPSON (Melbourne University)	De-excitation Gamma Rays from Residual States following Photonuclear Disintegration
B. M. SPICER (Melbourne University)	Recent Photoneutron Cross Section Measurements
R. H. SPEAR, et al. (Melbourne University)	Electromagnetic Transitions in ^{22}Na Gamma Rays from ^{22}Na
Presented by B. ROSE (UKAEA, Harwell)	Non-Statistical Effects in Neutron Capture in ^{93}Nb and ^{103}Rh
Y. TOMITA, S. TANAKA (JAERI, Japan)	The Level Structure of ^{50}V and the 5.255 MeV Isobaric Analog Resonance in ^{51}V Studied by the ^{50}Ti(p,n) and $(p,n\gamma)$ Reactions
C. NORDBERG, B. LUNDBERG, L. G. STROMBERG AND H. CONDE (RIND, Sweden)	Gamma-rays from Inelastic Neutron Scattering in Oxygen
L. NILSSON, A. LINDHOLM (TAL, Sweden) and I. BERGQVIST (University of Lu[illegible] Sweden)	Gamma Rays from Fast Neutron Capture in Silicon and Sulphur
A. LINDHOLM, L. [illegible]SSON (TAL, Sweden) I. BERGQVIST, [illegible]LSSON (University of [illegible]und, Sweden)	Gamma Rays from Fast Neutron Capture in ^{89}Y and ^{140}Ce

SEVENTH INTERNATIONAL NUCLEAR DATA COMMITTEE MEETING

ABSTRACTS OF PAPERS FOR TOPICAL SESSION

GAMMA RAYS FROM NUCLEAR REACTIONS, OCTOBER 9, 1974

J. R. BIRD (AAEC) - Review of Second International Symposium on Neutron Capture Gamma Ray Spectroscopy and Related Topics.

This symposium concentrated on a specific topic and provided quite a thorough review of progress since the first symposium in 1969. Some of the material presented was already well known, but a number of new developments and trends were also evident - from the papers and from private discussions.

There was considerable emphasis on reaction mechanisms with only one third, or less, of the time being spent on nuclear spectroscopy and structure. This meant that there was also more emphasis on epithermal rather than thermal capture. This presumably arose, in part at least, from the fact that there was to be an International Conference on Nuclear Structure in Amsterdam the following week.

M. J. KENNY, B. J. ALLEN, J. W. BOLDEMAN, A. R. de L. MUSGROVE (AAEC)

- Non-statistical Effects in keV Neutron Capture.

Neutron capture gamma ray spectra following capture of neutrons up to 1 MeV energy in silicon, calcium, iron and zirconium show strong high energy transitions indicating a departure from statistical decay. The data has been analysed in conjunction with high resolution cross section data obtained at ORELA. Valence model calculations give good agreement for zirconium, but not for iron.

D. G. SARGOOD (Melbourne University)

- (p,γ) Resonance Strengths in the (s,d) Shell

There is serious disagreement in the literature concerning absolute strengths of (p,γ) resonances in the (s,d) shell. These strengths are generally measured by determining the height of the step in a thick target yield curve. This method requires accurate knowledge of the isotopic composition of the target and its stopping power, the total beam charge collected, and the detection efficiency of the gamma ray detector.

An alternative method which was developed by the Utrecht group and which avoids these requirements, depends on the measurement of the resonant absorption of ground state gamma rays from a (p,γ) reaction, using a lump of the product isotope as absorber. The method is applicable only for resonances with strong ground state gamma decay and natural width ≥ the experimental resolution. It has therefore been applied to only two resonances, one in ^{30}Si(p,γ)^{31}P and one in ^{26}Mg(p,γ)^{27}Al, and the Utrecht group have then used these to calibrate relative measurements on resonances in other nuclei using chemical compound targets.

Disagreements between the two methods, as large as a factor of two, exist. The current status of the disagreement will be discussed.

M. N. THOMPSON (Melbourne University)

- De-excitation Gamma Rays from Residual States following Photonuclear Disintegration.

The talk will cover recent data obtained from the study of gamma rays from excited states in residual nuclei formed following nucleon emission from the dipole resonance of certain light nuclei.

The data lead to estimates of photonuclear cross sections to these residual states. Because the states so populated are generally the same as those populated following pick-up reactions on the same nuclei, a largely single particle interaction by the incident photon is inferred.

B. M. SPICER (Melbourne University) (paper by abstract only)

- Recent Photoneutron Cross Section Measurements

Recent precision measurements of the photoneutron cross sections of ^{45}Sc, ^{181}Ta and ^{208}Pb. Their relationship to, and interpretation in terms of inelastic scattering experiments with electrons, protons and deuterons on ^{181}Ta and ^{208}Pb targets will be discussed. The ^{45}Sc results will be discussed in terms of isospin effects.

R. H. SPEAR, R. A. I. BELL, M. J. ESAT, P. R. GARDNER, D. C. KEAN

A. M. BAXTER (ANU)

- Electromagnetic Transitions in ^{22}Na Gamma Rays from ^{22}Na.

Gamma rays from ^{22}Na states up to 4.6 MeV excitation have been studied using the ^{19}F(α,nγ)^{22}Na and ^{23}Na(^{3}He,αγ)^{22}Na reactions. The existence of several controversial weak transitions has been established and branching ratios measured. Angular correlation measurements have established, or restricted possibilities for, several level spins and decay mixing ratios. The electromagnetic properties of ^{22}Na levels are found to disagree significantly with predictions of the simple rotational model, but impressive agreement is obtained with recent shell-model calculations.

(Presented by B. ROSE, UKAEA, Harwell)

- Non-statistical Effects in Neutron Capture in ^{93}Nb and ^{103}Rh.

A search has been made by T. Haste and B. Thomas at Harwell for non-statistical effects in partial radiation widths following neutron capture in ^{93}Nb and ^{103}Rh in the neutron energy range up to about 5 keV. The only significant correlation observed have been with the widths of d-p transitions to the same final states.

Y. TOMITA, S. TANAKA (JAERI, Japan) (presented by T. Fuketa)

- The Level Structure of ^{50}V and the 5.255 MeV Isobaric Analog Resonance in ^{51}V Studied by the $^{50}Ti(p,n)$ and $(p,n\gamma)$ Reactions

The $^{50}Ti(p,n)$ and $(p,n\gamma)$ reactions have been studied at proton energies between 3.8 and 5.4 MeV. Excitation functions and angular distributions have been measured for both neutrons and γ-rays. The results have been analysed by the statistical theories. For most of the levels in ^{50}V below 1.9 MeV, spins have been determined. The branching ratios and the mixing ratios for the γ-rays deexciting these levels have also been obtained. The 5.255 MeV analog resonance has been observed in the (p,n) reaction and has been assigned to be $^{9}/_{2}^{+}$.

C. NORDBERG, B. LUNDBERG, L. G. STROMBERG and H. CONDÉ, (RIND, Sweden)

- Gamma-rays from Inelastic Neutron Scattering in Oxygen

The gamma-rays from inelastic neutron scattering in oxygen have been measured between 6.5 and 10.5 MeV. The measurement has been made in two parts covering the energy regions from 6.5 to 8.2 MeV and from 7 to 10.5 MeV, respectively. The gamma-rays were detected with a large NaI crystal using time of flight techniques. The differential cross sections at 90° were measured together with angular distributions at three different energies. Spins for the involved levels in the compound nucleus are proposed and the shapes of the angular distributions are compared with calculations based on the compound nucleus model. The results are also compared with previous reported measurements.

L. NILSSON and A. LINDHOLM (TAL, Sweden) and I. BERGQVIST (University of Lund, Sweden) (presented by H. Condé)

- Gamma Rays from Fast Neutron Capture in Silicon and Sulphur

Gamma-ray spectra from neutron capture in natural samples of silicon and sulphur have been measured at incident neutron energies between 4.7 and 10.9 MeV as well as at 15 MeV. A large NaI(Tℓ) scintillator was used as gamma-ray detector and time of flight technique was employed to reject undesirable background. The experimental results are compared with theoretical predictions of the semi-direct model.

A. LINDHOLM, L. NILSSON (TAL, Sweden), I. BERGQVIST and B. PÅLSSON (University of Lund, Sweden)

- Gamma Rays from Fast Neutron Capture in ^{89}Y and ^{140}Ce

Gamma-ray spectra from the reactions $^{89}Y(n,\gamma)^{90}Y$ and $^{140}Ce(n,\gamma)^{141}Ce$ have been recorded with a large NaI(Tℓ) scintillator for incident neutron energies between 6.2 and 10.9 MeV. Time of flight technique was used to reject undesirable background. The experimental results are compared with theoretical predictions of the semi-direct capture model.

REPORT TO THE 7TH INDC MEETING BY ITS SUBCOMMITTEE ON STANDARD REFERENCE DATA

J. W. Boldeman, Australia
Y. Le Gallic, France
J.R. Lemley, IAEA/NDS (*ex-officio member*)
H. Liskien, EC/CBNM (Chairman)
A. Michaudon, France
B. Rose, U.K.
A.B. Smith, U.S.A
A.H. Wapstra, Netherland
G.B. Yankov, U.S.S.R

A. GENERAL RECOMMENDATIONS

1. Third IAEA Meeting on Nuclear Standard Reference Data
2. Proposed Changes of the Subcommmittee's Method of Work

B. TECHNICAL REPORTS AND RECOMMENDATIONS

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2. Reactor Dosimetry Standards
3. n - p Scattering Cross Section
4. ^{3}He (n , p) Cross Section
5. ^{6}Li (n , α) Cross Section
6. ^{10}B (n , α) Cross Section
7. C Total Cross Section
8. ^{197}Au (n , γ) Cross Section
9. ^{235}U (n , f) Cross Section
10. $\bar{\nu}$ of ^{252}Cf ; Thermal Cross Sections for Fissile Materials ; Half - lives
11. Methods and Techniques for Flux Determination
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13. Neutron Energy Scales

APPENDIX XIV

A. GENERAL RECOMMENDATIONS

1. Third IAEA Meeting on Nuclear Standard Reference Data

The sub-committee has been informed by the IAEA Nuclear Data Section (NDS) about the steps taken towards a third IAEA-sponsored meeting on Nuclear Standard Reference Data in 1976 as recommended by the INDC during its 6th meeting . It agrees to the proposed two additional topics , namely γ-ray Standards and Reactor Dosimetry Standards , but would not like to see the list of topics already definitely closed . It suggests that INDC confirms its former recommendation but finds it very disturbing that from the 2nd IAEA panel which took place in November 1972 neither the presented contributions are available nor the " Summaries ,Conclusions and Recommendations " as a formal document . A not negligible part of the participants of such specialists'meetings organised by the IAEA is funded by their laboratories .

The participants themselves and their laboratories must necessarily become uninterested in such meetings if the outcome is not properly documented and published within a reasonable time.

2. Proposed Changes of the Subcommittee's Method of Work

a) The Sub-committee on Standard Reference Data proposes to change its method of working.

In future , responsibilities for keeping a status file on each topic of standards interest will be assumed by a country which is represented on the sub-committee. The responsibility will be discharged by nominating an individual who would normally carry out this task for three years. The various nominated individuals would prepare up-to-date status reports which could be sent to the chairman of the sub-committee two month before the next meeting of INDC , who would ensure the distribution of a combined report to members of the sub-committee to be received by them one month before the date of the meeting.

b) The list of topics and the corresponding responsibilities has been agreed as follows :

H (n , p)	U.K.
^{3}He (n , p)	AUS
^{6}Li (n , α)	U.S.A.
^{10}B (n , α)	E.C. - C.B.N.M.
^{12}C (n , n)	U.S.A.
^{197}Au (n , γ)	U.S.A.
^{235}U (n , f)	U.S.S.R.
$\bar{\nu}$, $T_{\frac{1}{2}}$ and thermal parameters	I.A.E.A. - N.D.S.
γ - ray calibration	F
neutron flux	F
neutron energies	U.K.
Cf fission spectrum	U.S.S.R.

c) The sub-committee is conscious of overlap with the corresponding sub-committee of NEANDC on this topic. It believes that , if a similar method of work could be adopted by that committee , the overlap would be reduced and the efficiency of working increased by requiring that the nominated individuals on any given topic co-operate fully in maintaining a joint status file on that topic and exchanging status reports at the approriate time. (It would clearly be advantageous in ensuring continuity that their periods of responsibility be staggered). The two sub-committees would then each deal with the status reports following their own methods of work.

d) The Sub-committee on Discrepancies could work in a similar fashion for a number of items.

e) We propose therefore that the NEANDC be approached to consider this recommendation , which we believe has the greater weight because of the INDC proposal to increase the interval between INDC (and NEANDC) meetings to 18 months.

B. TECHNICAL REPORTS AND RECOMMENDATIONS

1. γ - Detector Calibration

Working papers presented to the INDC at its last meeting by the NDS have opened the discussion on the need of promoting progress in connection with the calibration of Ge(Li) detectors with respect to both, energy scale and efficiency.

In the mean time NDS has drawn our attention to three further publications by W. Beer and J. Kern .

- Phys. Letters 47B (1973) 345
- IAEA panel " Charged particle induced radiation capture " p. 345 (1974) = INDC (SWT) - 5/L
- NIM 117 (1974) 125 = INDC (SWT) - 6/G

all dealing with " γ - energy standards " with accuracies in the order of 10 eV. In addition Wapstra reported that the Commission on Atomic Masses and Fundamental Constants of IUPAP has formed a sub-committee consisting of Drs. Van Assche (Mol) , Van der Leun (Utrecht) and Helmer (Idaho) which is charged to develop a set of energy standards to be officialy adopted. This set will be applicable to gamma rays of radionuclides , as well as emitted in charged particle reactions and in neutron capture. It is hoped that this list will be ready to be presented at the 5th International Conference on Atomic Masses and Fundamental Constants (AMCO V) to be held in June 1975 and organised by BIPM at the occasion of the centennial of the " Convention du Mètre " . Given these facts the sub-committee sees no need to become active in this field. However, the sub-committee realises the urgent need for practical " γ-efficiency standards ".

Efficiency curves of γ-detectors depend on many parameters and are not at all simple curves. Many examples exist where the absolute efficiency of such detectors must be known to the 1 % accuracy level . At present there is a large number of precise " γ-activity standards (Ci)" and γ-emmission rate standards (γ/s) known. However, the number of calibration points per such source is typically one or two. This implies that a determination of a complete efficiency curve requires the simultaneous availability of many sources. These tedious methods should be supplemented by the use of multi-γ ^{152}Eu " emission rate standards ".

Considering the fact that this source , though representing an important improvement , does not cover the whole energy range of interest, it is recommended to fill the gaps with other multigamma emission rate standards , possible candidates being ^{133}Ba (below 0.3 MeV) and ^{56}Co (above 1.5 MeV) . This implies :

(a) to study the involved decay scheme parameters
(b) to produce and distribute upon request accurate standard sources of the chosen radionuclides
(c) to develop computer programs simplifying the procedure of efficiency calibration of γ-spectrometers by correcting automatically for the possible effects of summing when multi-gamma emission rate standards are used.

The sub-committee will in the future draw its attention to the high energy part which can not be covered by radionuclides.

2. Reactor Dosimetry Standards

During the Second Panel on Neutron Standard Reference Data the need for rapid improvement of certain cross sections relevant to reactor dosimetry was pointed out. The panel suggested that the EURATOM Working Group on Reactor Dosimetry (EWGRD) should consider wether the adoption of the ^{237}Np (n, f) cross section as a primary standard would improve the situation and this suggestion was also brought to the attention of the Agency's International Working Group on Reactor Radiation Measurements (IWGRRM) . A definite answer from the EWGRD does not yet exist while according to J.R. Lemley the IWGRRM thinks that designation of one more cross section such as ^{237}Np (n, f) , as a standard would not help significantly.

The sub-committee is ready to take up this matter if a definite reply from EWGRD and IWGRRM is available .

The complete set of excitation functions (which include four of the acknowledged standards and ^{237}Np (n, f)) classified as category I by the IAEA Consultants' Meeting (INDC (NDS) - 56 U p.127) cannot be accepted as standards since it comprises a too large number (14) of reactions.

3. n- p Scattering Cross Section

Below 20 MeV the total n - p scattering cross-section is believed to be known to the 1 % accuracy level and there is general agreement that the results of the phase shift calculations by Hopkins and Breit (Nucl. Data Tables A9 (1971) 137) should be used. The sub-committee however, notes that this publication is of limited value because linear interpolation between given energy points introduce unacceptable errors. Users attention is drawn to the additonal calculations of Report LA-4574 , which are included in the ENDF Standard File .

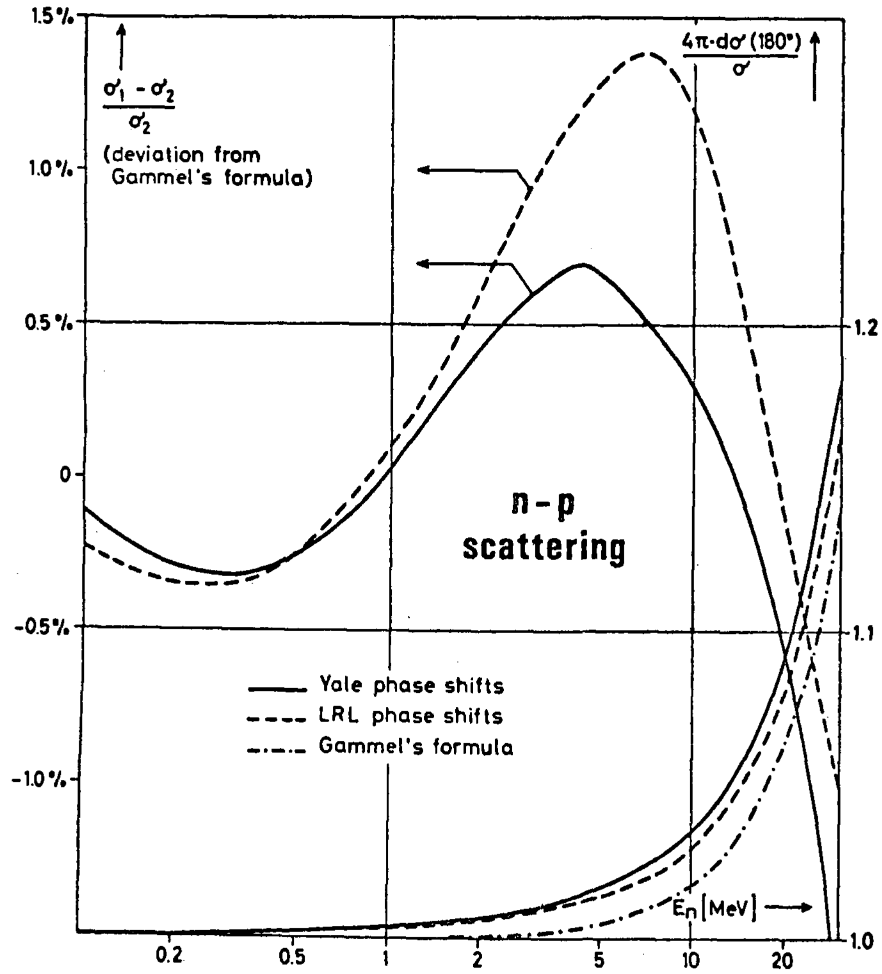


Fig. 1

Deviations between these phase-shift calculations and the semi-empirical formula of J. L. Gammel (Fast Neutron Physics Part II , p. 2209) do not exceed 1.5 % (see Fig. 1) . The points of attention are at present the differential cross-sections and especially the 180° cross-sections used in telescope-type recoil counters (see Fig. 1) .
At 14 MeV Gammel's semi-empiral formula yields a differential 180° cross -section which differs by 2.4% from the value calculated by Hopkins and Breit. Recent work by Shirato and Saitoh (J. Phys. Soc. Japan 36 (1974) 331) at 14.1 MeV and by Burrows (Phys. ReV 7C (1973) 1306) at 24.0 and 27.2 MeV support the phase shift calculations.

The situation has been reanalysed by two papers by Lomon and Wilson (Phys. Rev. 9C (1974) 1329) and by Voignier (Report CEA-R-4632 (1975), both concluding that the theoretical discrepancies are smaller than the actual experimental uncertainties for differential data and that therefore only very precise angular distribution measurements can improve our knowledge . The sub-committee however, would like to see these statements confirmed by proper error propagation from the input data to the calculated differential cross- sections.
At present experiments are being conducted in Harwell between 14 and 28 MeV and at Duke University between 8 and 15 MeV .

4. ^{3}He (n , p) Cross Section

No new information superseding that given at the 2nd IAED Panel on Neutron Standard Reference Data nor any active user of this standard could be identified. If one excludes some evaluation work then this period of stagnation can even be enlarged by several years.
This lack of interest over such an extended period is certainly due to the nonexistence of suitable detector systems and reduced emphasis should be given to this standard.

5. ^{6}Li (n , α) Cross Section

In Figures 2 and 3 the very recent data (1972 and later) are plotted :

Coates et al. , Proc. of Panel "Neutron Standard Reference Data"p. 105 (1972)
Fort and Marquette , Report EANDC (E) - 148 'U' (1972)
Clement and Rickard, Report AERE - R 7075 (1972)

Friesenhahn et al. , Report INTEL - RT- 7011 -01 (1974)
Poenitz , Z. Physik 268 (1974) 359
Overley et al. , Nucl. Phys. A221 (1974) 573
Stephany and Knoll , INDC (USA) - 62 "U" p. 129 (1973)

A general examination between 0.1 and 1.4 MeV shows that :

Below 0.5 MeV , i.e. across the 250 keV resonance , most of the data agree one with each other except for those of Friesenhahn which are much higher than the others . For example , at the peak of the resonance, Friesenhahn obtains 3. 7 b whereas the other data peak around 3 b. Let us note right now that some data, those of Cadarache for example , will probably have to be increased by 10 per cent ore more due to a modification of the estimated value of the ^{6}Li content in their glass (this will be discussed below) .
Above 0.5 MeV the data points are more scattered , with Friesenhahn points being on top and those of Clement and Rickard being the lowest ones. There is almost a factor of 2 between the extreme values. There is , therefore , a serious problem which could not be solved at present. Nevertheless, comments on a few things can be made :

a) energy calibration of the neutron spectrometer in the 100 keV range.

In order to determine more accurately the energy of the ^{6}Li (n,α) resonance near 250 keV , and thus avoid energy shifts when comparing the data , several laboratories have measured the energy of sharp and well defined resonances in other nuclei around 250 keV.
A general consensus seems to have been reached to study the Na resonances, especially that around 300 keV, which is easy to measure. The energy of the maximum value of the total cross section, as obtained by various laboratories is the following:

Karlsruhe:	299.5 keV ± 0.1 keV	cyclotron
Columbia:	298.5 keV ± 1.0 keV	synchrocyclotron
Saclay:	303.0 keV ± 3.0 keV	linac
Cadarache:	302.0 keV ± 4.0 keV	Van der Graaff
Harwell:	298.8 keV ± 2.3 keV	linac
	299.31 keV ± 0.12keV	synchrocyclotron

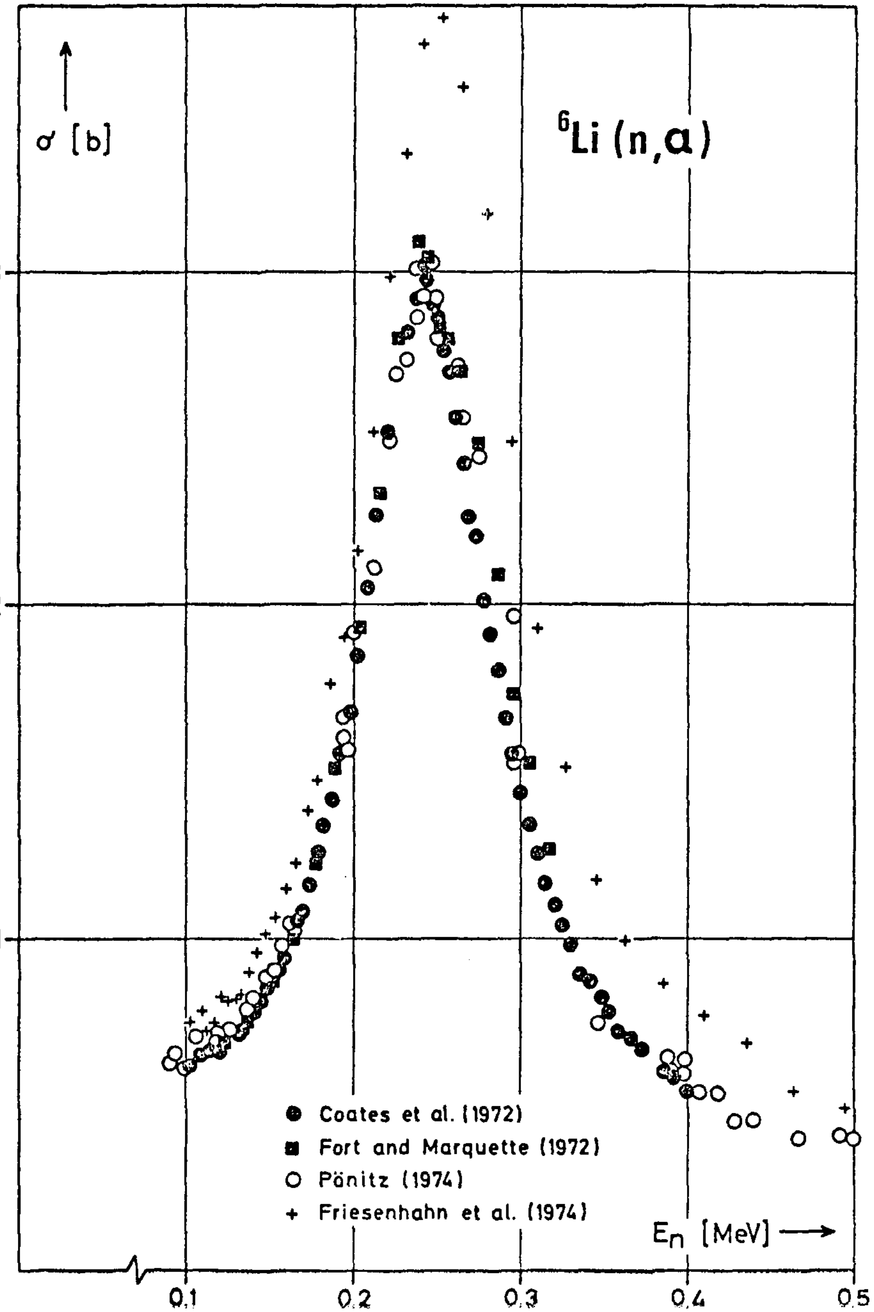


Fig.2

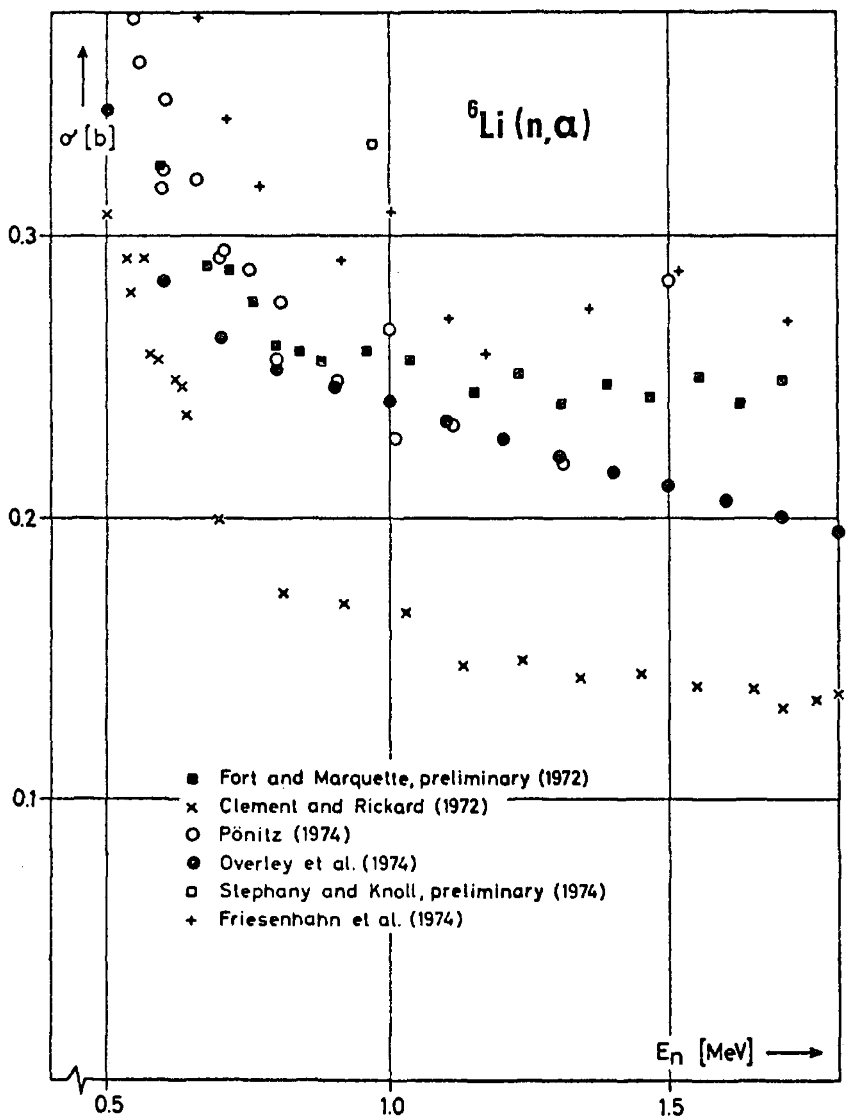


Fig. 3

Examination of the three most precise data (Karlsruhe, Harwell, Columbia) shows a very good agreement. In summary, energy calibration of different neutron spectrometers of different types has recently made great progress and overall agreement together with good accuracy seem to have been achieved.

b) determination of the ^{6}Li content in ^{6}Li-loaded glass scintillators

Some measurements of the ^{6}Li(n, α) cross section, such as those made at Cadarache, need to know accurately the ^{6}Li content in the ^{6}Li-loaded glasses used in the experiments. This content has been determined by several methods with conflicting results. Therefore, it is absolutely necessary to improve the precision and the reliability of the determination of the ^{6}Li content. Among the most recent results or proposals, let us quote:

The transmission method, using the time-of-flight technique with a white neutron source, assumes that the 1/v component of the total cross section is due to ^{6}Li only. Several measurements have been made already at Saclay (using the 60 MeV linac) for the glass used at Cadarache for the determination of the ^{6}Li(n, α) cross section. The value obtained for the ^{6}Li content is about 12 per cent lower than the value assumed previously by Fort and based on several other measurements (value given by Nuclear Enterprise, pile oscillation method and a previous linac experiment). This would mean that the Cadarache values of the ^{6}Li(n, α) cross section should be raised by 12 per cent.

A preliminary intercomparison of the Harwell and Saclay measurements carried out with the same Harwell glass does not lead to the same results yet. A difference of about 5 per cent is observed, the Harwell value being still lower than the Saclay one (a 2 per cent accuracy is claimed for both measurements). This intercomparison will continue between Harwell, Geel and Saclay. For example, similar measurements are now being carried out at Saclay on the following samples:

- the Cadarache glass (repeated)
- the Harwell glass (repeated)
- a calibrated sample of metallic Li provided by Geel

The boron content of the ^{6}Li glass scintillator used by Coates et al. to measure the ^{6}Li (n, α) cross section has been determined using the ^{11}B(p, α) reaction on a cullet of the glass. No counts due to this reaction were observed and the measurement gives an upper limit of six parts in 10, 000 parts natural boron by weight in the glass. A chemical determination of the boron content has given an upper limit of one part in 10, 000. These values are well below the level which could affect the cross section measurements. A transmission measurement on a ^{7}Li glass used for comparison has been made and showed no 1/v component, which-if present-could have contributed to overall errors in the measurement of the ^{6}Li cross section.

Measurements of the capture gamma rays induced in the sample by thermal neutrons have been proposed by H. Motz to determine the relative Li content and also to detect possible impurities in the glass through their characteristic capture gamma rays. We note that, with this method, the amount of ^{10}B can be determined by observation of the 422.6 keV line even though this is the same line as the one produced by neutron capture in ^{6}Li. This is due to the fact that the line is Doppler broadened in the case of ^{10}B, but not in the case of ^{6}Li. It would be of great interest to extend the range of intercomparison discussed above and to measure the thermal neutron gamma rays of the samples measured with the transmission method. The Cadarache group is quite willing to send their glass to Los Alamos for such an investigation after the Saclay measurements have been completed.

c) R-matrix approach

It has been shown that it is not possible to fit all ^{6}Li neutron cross sections in the 250 keV region with a single level Breit-Wigner formalism. A multilevel formalism is necessary to fit the data. But, in addition, it has been suggested by Motz to include in the data to be fitted, not only the neutron cross sections, but also all other data relevant to the formation of the ^{7}Li system by other channels, (α + t) cross sections, angular distribution, polarisation data, for example. Clearly, such a simultaneous fit to all these data will introduce new constraints on the possible values of the ^{6}Li(n, α) cross section. Calculations have been made already, but the conclusions can be obtained only if the errors are properly taken into account and if their impact on the ^{6}Li(n, α) cross section can be evaluated through sensitivity studies. Though such calculations do not replace direct neutron measurements, they can be very useful in bringing in other relevant data and help to find out possible internal inconsistencies.

d) measurements in progress

Euratom - Geel

Data analysis	^{6}Li σ_T	0.1 MeV to 3 MeV	VdG Monoenergetic
	^{6}Li σ_T	2 keV to 2 MeV	Linac
Measurement started	^{6}Li $(\frac{d\sigma}{d\Omega})_{el}$	0.25 MeV to 3 MeV	VdG
	^{6}Li σ_T	0.1 MeV to 0.5 MeV	White spectrum
In preparation	ratio $\frac{^{6}Li(n,\alpha)}{^{10}B(n,\alpha)}$	0.1 keV to 1 MeV	Linac

Italy (Trieste group)

^{6}Li $(\frac{d\sigma}{d\Omega})_{el}$ results obtained from 1.98 MeV to 4.64 MeV

Saclay and Harwell

Determination of the ^{6}Li content in ^{6}Li-loaded glasses by the transmission method.

U.S.A.

ORNL ^{6}Li σ_T results already obtained from 100 eV → 1 MeV (good agreement with Harwell < 10 keV)

ANL ^{6}Li (n, n) E_n > 1.5 MeV

NBS ^{6}Li (n, α) and σ_T

Yale, Ohio University, Livermore } work in progress

6. $^{10}B(n,\alpha)$ Cross Section

The only new piece of information are the Friesenhahn data. Spectrum shape has been determined in the 2.5 keV to 1.5 MeV range using a CH_4 filled proportional counter and also (in the 0.2 to 1 MeV range) by a BF_3 counter with an additive of CH_4. There are cross sections for the sum of both branches (ion chamber) and branching ratios (^{10}B slab + Ge(Li)). Results were normalised to absolute scale in the keV range where the 1/v behaviour is well established. It is not excluded that the observed discrepancy on Li(n,α) between the Friesenhahn set and other sets will have also some bearing on the $^{10}B(n,\alpha)$ data.

7. Total Neutron Cross Section of Carbon

a) Justification and Use

This is one of the best reference checks for verifying angle-integrated scattering distributions and the performance of apparatus. The energy range of most interest is below 5.0 MeV and away from sharp resonance structure (e.g. 2.1 - 2.7 MeV).

The cross section is valuable in white-source and other energy-scale calibrations (e.g. ^{238}U fission cross sections). It is an easily used sample with some sharp structure in cross section at a number of energies. One of the best H(n,n) results depends upon the energy of the C(n,n) resonance at ≈ 2.08 MeV (PR C4, 1061 (1971)).

b) Status

There are a number of measurements but the most recent and more comprehensive sets are probably those of

S. Cierjacks et al., KFK-1000
R. B. Schwartz et al., NBS-138
F. Perey et al., ORNL-4823
J. Whalen, priv. communication

The first three use the white source technique.
ENDF/B-III and -IV apparently rely on the model fit as mentioned by N. C. Francis et al., (Proc. EANDC Symp. Neutron Standards and Flux Normalization, p. 166 (1970)).
There are discrepancies in both magnitude and energy scale. For example, the data of Cierjacks et al. are 4 to 6 % higher than those of Schwartz et al. and those of Whalen in the 2.1 to 3.0 MeV energy range and there are differences elsewhere. The evaluation of Francis et al. tends toward the lower values. Moreover, detail R-matrix polarization studies by Holt and Fink (priv. communication) make it difficult to accept the higher σ_t values. The recent measurements by Perey et al. indicate a 5 or more keV shift in the energy scale from some previous measurements and evaluations. The energy uncertainties are such as to negate the use of carbon as an energy-scale standard.

c) Recommendation

A working group composed of representatives from the major data sources and analysis groups should review the carbon total cross section with particular attention to the following issues:

The most recent, corrected, etc. data values from each source should be obtained, documented and set forth in a clearly identifiable file at the four Neutron Data Centers.

The working group should review this file and

i) formulate the best composite date set with associated uncertainties in both energy and magnitude;
ii) Recommend, if warranted, specific measurements to resolve discrepancies.

Working from the best composite data set (i, above) an evaluated standard file should be constructed from 0 - 20 MeV with scheduled revision as indicated by recommended measurements (ii, above). The evaluation should probably be based on an R-matrix fit to the available data including polarizations, partial neutron channels and charged-particle information (i.e. a "physical" model). However, the weighting for the interpretation should be such as to assure a good representation of the best contemporary neutron total cross section information. The results should be made available as a standard file through the four Neutron Data Centers.

8. $^{197}Au(n,\gamma)$ Cross Section

Renewed emphasis has been given to the $^{197}Au(n,\gamma)$ reaction as a capture standard. The reaction is attractive in combining the advantage of high resolution tank techniques with the potentially more accurate activation technique. Gold as sample material is easily available with high chemical purity. The previous concern for cross section structure at lower energies remains, but is now better defined (see below). This emphasis is manifested by work going on at various places to determine the cross section for this reaction with the highest achievable accuracy.

a) Using the direct capture γ detection method

1. Le Rigoleur et al. (Report CEA-N-1662 (1973)) analysed their results in the energy range 75 to 550 keV. Analysis for lower energies is in progress. Flux determination is obtained employing a calibrated "directional" counter.

2. Czirr and Stelts (NSE 52 (1973) 299) cover the energies between 7 and 530 keV and relate their results to the $^{235}U(n,f)$ fission cross section by observing fission neutrons in a deuterated benzene scintillator. Their absolute values are related to the evaluation of Davey (NSE 32 (1968) 35) and are partly more than 20 per cent higher than the Le Rigoleur values.

3. Macklin et al. (ORNL, to be published) took data in the 3 to 550 keV range using a ^{6}Li glass scintillator to determine the flux shape. Their results are normalised at the 4.9 eV resonance. Fluctuation intensity appears to indicate intermediate structure in ^{198}Au with $\sim$10 keV width and $\sim$40 keV average distance and has to be taken into account certainly below several hundred keV.

4. Poenitz (ANL, to be published) determined cross sections at 23 energies between 400 and 3500 keV employing his "black" and "grey" neutron detectors.

b) Using the activation method

5. Fort (CEN Cadarache) has preliminary data in the 20 keV to 500 keV range. For fluence determination he used the calibrated "directional" counter.

6. Paulsen and Liskien (CBNM Geel) have preliminary data in the 200 to 3000 keV range relative to the n-p scattering cross section employing a proton recoil proportional counter. Data are presented in Fig. 4.
There is good hope that our knowledge on this cross section will be improved significantly if all data are available in their final form and evaluated.

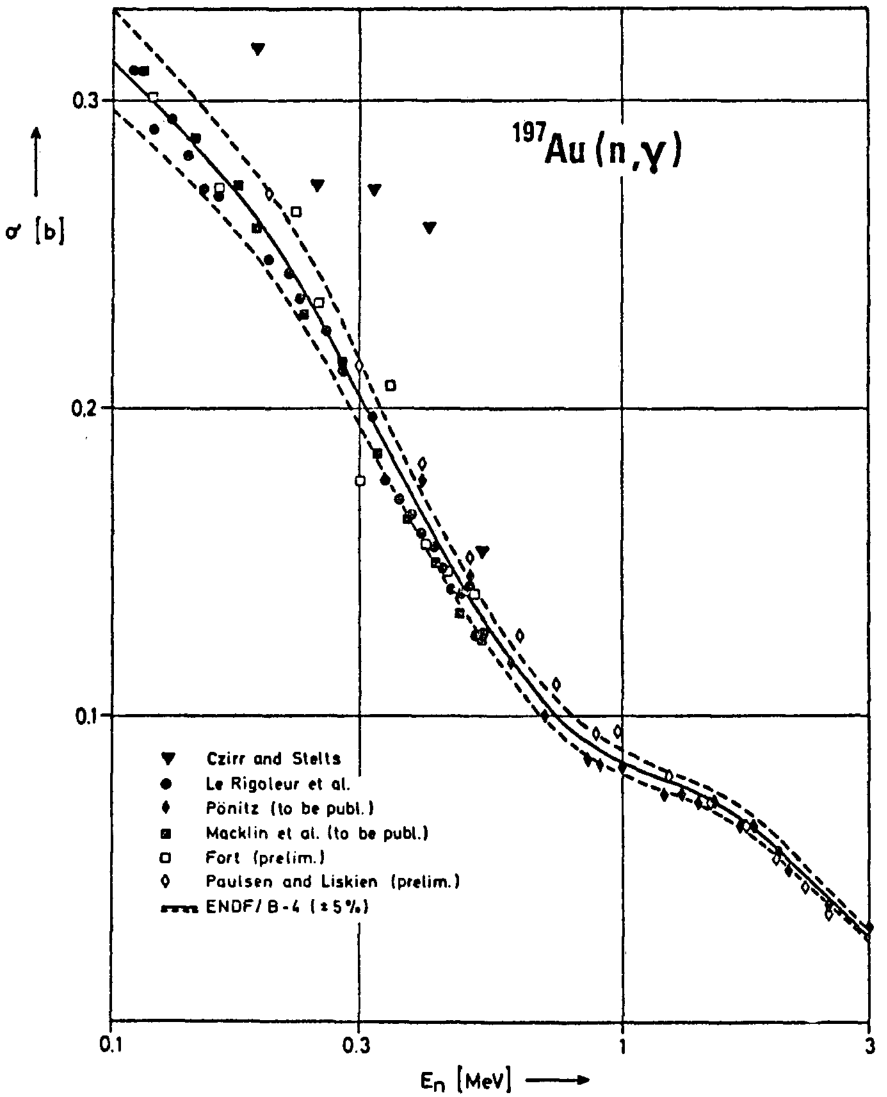


Fig. 4

9. ^{235}U(n,f) Cross Section

Care should be taken at energies below a few hundred keV to ensure against perturbations due to known energy dependent structure (Bowman, Proc. EANDC Symp. "Neutron Standards and Flux Normalization, p. 246 (1970).
It is doubtful if below 50 keV this cross section is at all useful. Nishimura has recently surveyed the field. His paper is attached as appendix.

a) Contemporary Status

A. 50 keV to 1.0 MeV

Results reported since 1965 are nicely converging over this energy range including the results of

W.P. Poenitz, NSE 53, 370 (1974)
D. Gilliam, Thesis, University of Michigan (1973)
F. Kaeppeler, Proc. of Panel "Neutron Standard Reference Data", p. 213 (1972)
D.B. Gayther et al., Proc. of Panel "Neutron Standard Reference Data", p. 201 (1972)
I. Szabo et al., CONF-710301 p. 573 (1971)
J. Lemley et al., NSE 43, 281 (1971)
G. Knoll and W. Poenitz, JNE 21, 243 (1967)
P. White, JNE A/B 19, 325 (1965)

Lesser weight should be given to earlier values as discrepancies may be as large as a factor of two. Optimistically, this standard is known to < ±3 per cent throughout this energy range and conservatively to ±5 per cent. The very lowest energy values of White tend to be a bit high as do the Kaeppeler results near 700 keV. The spread in the various results is well illustrated by Figure 16 of the recent paper by Poenitz. This agreement is encouraging, particularly as the results were obtained with differing techniques (e.g. mono-energetic and white source) and employed various methods of normalization.

B. 1.0 to 4.0 MeV

Primary results in this energy range are those of Poenitz Hansen et al. (LA), Pankratov (AE 17, 1017 (1963)), Smith et al. (BAPS 2, 196 (1957)) and Szabo et al. The consistancy is relatively good with overall uncertainties of 3 to 4 per cent over the energy range. The largest uncertainties are from 1 to 2 MeV where the Hansen et al. results are systematically higher than those of Szabo et al. and of Poenitz by 3 to 9 per cent. In addition to the above results, there have recently been reported preliminary results by Czirr and Sidhu (UCRL-74071 (1974). The latter is a "shape measurement" relative to the energy dependence of the H(n,p) cross section. Both definition and relative errors (± 1 %) are excellent and the results are consistent with the above uncertainties estimated from previously reported measurements.

C. 4.0 to 20.0 MeV

Recent values are those of White, Pankratov, Smith et al. and Czirr and Sidhu. The latter are "shape measurements" however. When normalised in the energy range of 3 to 4 MeV where reasonably known cross sections exist they give good definition and relative accuracy. These various sets are in reasonable agreement at 2.0 MeV. (e.g. 3 to 4 %) but become increasingly discrepant as the energy increases with differences amounting to as much as 10 to 15 % at energies of 15 to 20 MeV. For example, see Figure 9 of Czirr and Sidhu. These discrepancies are in both normalization and shape. Furthermore, there are apparently discrepancies between the results of Czirr and Sidhu and the widely used evaluation in ENDF/B-IV.

b) Summary Remarks

The ^{235}U standard fission cross section is known to ± 3 to 4 % from 50 keV to 1.0 MeV, to ± 3 to 4 % from 1.0 to 2.0 MeV with possibly lesser accuracy in the range 1 to 2 MeV, and becomes increasingly uncertain with increasing energy above 2.0 MeV amounting to possibly as much as ± 15 % uncertainties at 20 MeV. Major attention should be given to the energy range above 5.0 MeV using several methods including a precise reference value at 14 MeV. Work is known to be in progress extending from 0.3 to 20 MeV at LLL and NBS using white source techniques with results scheduled for April 1975. Additional programs planned elsewhere. It is reasonable to expect the fission cross section of ^{235}U to 3 to 4 % accuracy from 50 keV to 20 MeV by June 1975. Achieving the "ultimate objective" of ± 1 % accuracies over this energy range is a far more remote reality.

10. $\bar{\nu}$ of ^{252}Cf; Thermal Cross Sections for Fissile Material; Half-lives

Consistent values for the thermal and the 20° C averaged cross sections of ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu have been published by IAEA/NDS in 1966 and 1969. A third evaluation by NDS and a small group of specialists is underway. Final results are expected for spring 1975. Main difficulties encountered are:

- the assumption of a most probable value for $\bar{\nu}_t$ of ^{252}Cf,
- the establishment of best values for relevant half-lives, as very often sample assay depends on them,
- insufficient knowledge of cross section shapes below thermal energies for Westcott g-factor determination.

At NPL, work is going on to improve corrections relevant to the $\bar{\nu}$-determination. Results obtained so far indicate that while small changes may have to be made in the individual corrections, the overall effect on the NPL value for $\bar{\nu}$ will be negligible.
For this third evaluation $\bar{\nu}_t$ of ^{252}Cf is assumed to be (3.736 ± 0.008) and will yield for example for ^{235}U a thermal fission cross section of (587 ± 2)b assuming a half-life for ^{234}U of 244 600 ± 200 y.
According to information provided by the Nuclear Data Section to the INDC, the inaccurate knowledge of the 2200 m/s fission cross section of ^{233}U represents one of the main sources of uncertainty in the third IAEA review of the thermal neutron nuclear data of the fissile U and Pu isotopes. INDC therefore recommends strongly direct measurements of this quantity.

The fission cross section measurements by CBNM Geel at the BR2 in Mol for ^{233}U and ^{241}Pu are still in the phase of preparation. For the half-life of ^{233}U two new results became recently available:

- Jaffey et al., PR C9 (1974) 1991, published a value of $(1.591 \pm 0.0015^{*}) \cdot 10^{5}$ y. The measurement is based on titration and intermediate geometry α-counting (* statistical error only).
- Vaninbroukx et al., stopped their various measurements (since 1969) and end up with a value of $(1.592 \pm 0.0040) \cdot 10^{5}$ y. This result is based on coulometric methods and isotope dilution on one hand and on liquid scintillation, 4 π-proportional and low geometry α-counting on the other.

Final results from the half life determination of ^{237}Np and ^{239}Pu performed by Glover and Rogers at Harwell will be available early in 1975. Measurements for ^{238}Pu, ^{241}Pu and ^{241}Am, using the calometric method are performed by Jordan at Mound Laboratory. The following best values are quoted from report EUR 5194 e by R. Vaninbroukx:

Nuclide	Half-life
^{232}U	(72 ± 2) y
^{233}U	$(1.592 \pm 0.003) 10^{5}$ y
^{234}U	$(2.446 \pm 0.007) 10^{5}$ y
^{235}U	$(7.038 \pm 0.020) 10^{8}$ y
^{236}U	$(2.34 \pm 0.02) 10^{7}$ y
^{238}U	$(4.468 \pm 0.010) 10^{9}$ y
^{238}Pu	(87.8 ± 0.8) y
^{239}Pu	$(2.430 \pm 0.025) 10^{4}$ y
^{240}Pu	$(6.55 \pm 0.07) 10^{3}$ y
^{241}Pu	(14.5 ± 0.5) y
^{242}Pu	$(3.87 \pm 0.05) 10^{5}$ y
^{244}Pu	$(8.2 \pm 0.1) 10^{7}$ y
^{241}Am	(432 ± 4) y
^{252}Cf	(2.64 ± 0.02) y

11. Methods and Techniques for Flux Determination

The subcommittee is not aware about any major technical break-through or the application of new principles in flux determination devices. However, the attention given to this problem has obviously increased and is manifested by the construction, duplication or exchange of detectors based on the well known principles.

The outstanding event in this field is the termination of the first round of the intercomparison of fast monoenergetic fluences organised by BIPM. This first round is regarded as a learning experience in transfer instrument technology and therefore only five laboratories directly represented in the CCEMRI committee participated (CEN Cadarache, CBNM Geel, NRC Ottawa, BIPM Paris and NPL Teddington). Besides the foreseen energies 0.25, 2.5 and 14.8 MeV also the "optimal" energies 0.565 and 2.2 MeV were included. Deviations from the unweighted mean of the fluence results of all participants are typically 3 % except at 0.25 MeV where discrepancies up to 10 % exist. It is however, premature to go more into detail because at the very same moment a meeting at Paris is convened to discuss the results and future actions to be taken.

12. Fission Spectra

Besides the work of Alexandrowa et al. (AE 36, 282 (1974)) on ^{252}Cf no new final data are available. The ^{235}U measurements of Cadarache are not yet finalised. Work carried out at Harwell and Studsvik showed strong discrepancies between the two sets in the high energy part of the spectra. Therefore the work has been repeated jointly with Studsvik at Harwell and the results are still being analysed. It is certain that the new final results will show fewer high energy neutrons than the original Harwell data. Also the Harwell ^{252}Cf data have not yet been released because one expects that the uranium work will have some bearing also on the analysis of the californium data. Plans exist at Lucas Heights to measure the Cf-spectrum.

Results on prompt fission neutron spectra are typically known only in form of "average energy", "Maxwellian temperature", "deviation from a Watt form below (or above) a certain energy", etc. The 1971 Consultants'Meeting on Prompt Fission Neutron Spectra agreed that very sophisticated representations would be requested, but - because it was premature to suggest such models - supported a purely numerical representation and invited experimenters to transmit such data to their local neutron data center. Nevertheless, at present the available EXFOR data with respect to ^{252}Cf and ^{235}U are not at all complete. The subcommittee would like to see a special effort both from the experimenters' side and from the four neutron data centers to update the EXFOR files with respect to such data. Fig. 5 demonstrates (using a few ^{252}Cf data sets) how data could be presented for further discussion.

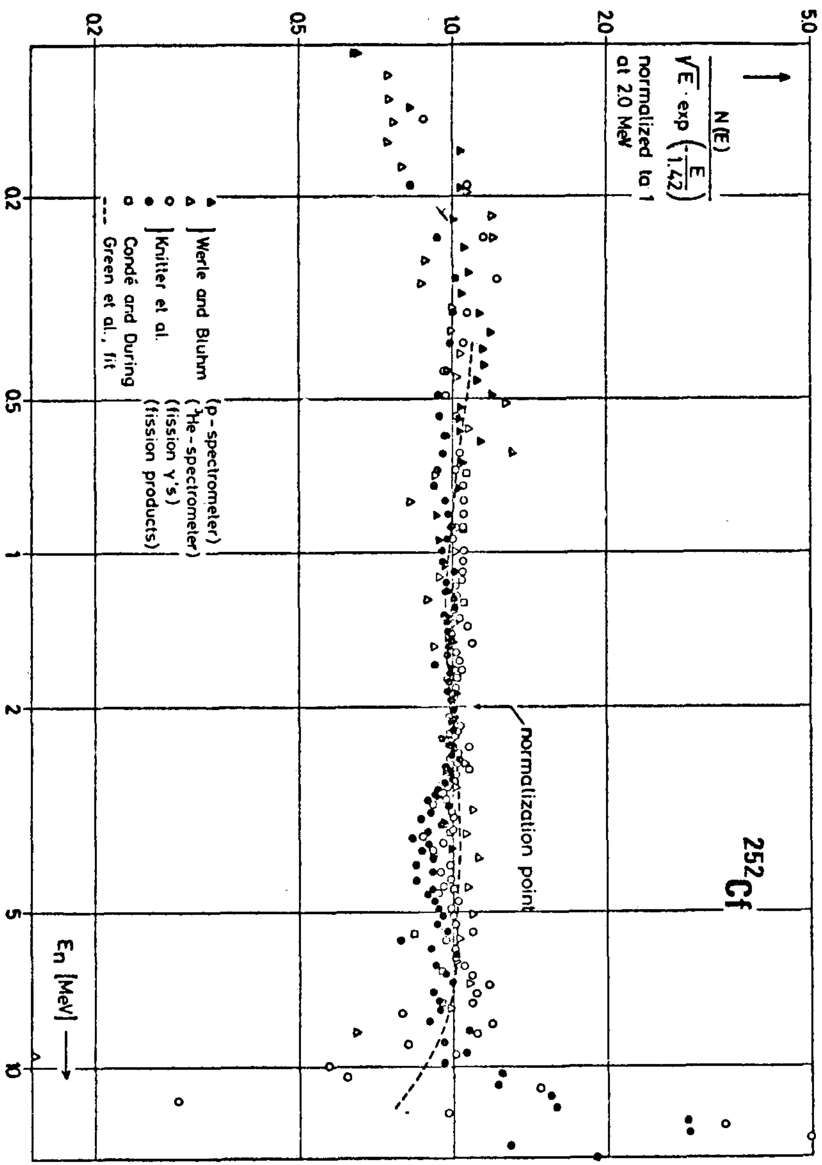


Fig. 5

13. Neutron Energy Scales

The Subcommittee recognizes continuing problems associated with an inability to accurately standardize energy scales at both white and mono-energetic neutron facilities. These uncertainties extend from the eV resonances region to 20 MeV and are apparent in such data discrepancies as the energy of the ^{6}Li (250 keV, p-wave) resonance, the energy of the ^{238}U fission threshold, and the exact value of a number of dosimetry-associated threshold reactions.

In view of the above, the subcommittee recommends that well defined total neutron cross section resonances be selected as standard reference energy values and that these standard values extend to energies of $\simeq$ 20.0 MeV. The selected resonances should be consistent with reasonable sample availabilities used at both mono-energetic and white source facilities and with "state-of-the art" resolutions achievable at both types of facilities. The subcommittee intends

a) to set up a working group and give it the responsibility to select these standard resonances; and

b) to stimulate the experimental determination of the recommanded resonance energies to be pursued by a number of laboratories in a cooperative manner including both mono-energetic and white source techniques.

FIRST DRAFT

INDC SUBCOMMITTEE ON DISCREPANCIES

(Draft report to the VII INDC Meeting)

The Subcommittee decided to restrict its review to the items listed under paragraph I of the proposed Agenda with the following modifications:

- item I-1 ("Fission cross section of ^{235}U above ~ 100 eV") will be transferred for consideration to the INDC Subcommittee on Standards.
- a new item on "Delayed neutron emitters" will be added at the request of the INDC Scientific Secretary. However, as this proposal was made in the course of the Subcommittee meeting, no information on this subjec t is included in this draft.

Concerning the 3 items of Paragraph II of the proposed Agenda, it was decided that the most important discrepancies must be selected by the INDC (and its Subcommittees on energy applications of nuclear data or on non-energy applications of nuclear data) before consideration of those items by the Subcommittee on Discrepancies.

I. Fission cross section of Pu-239, U-238 above 100 eV.

A. Pu-239 (n,f)

1. below 1 MeV

New data - Gayther et al (preliminary) agree with Szabo values above 200 keV. Discrepancies of ~ 3.5% remains still in the range 200 keV - 1 MeV.

Käppeler (preliminary) relative to H(n,p) no comparisons yet (0.5-1.2 MeV).

2. above 1 MeV

New data (Szabo (absolute) 3% lower than the earlier evaluations at about 1 MeV.

Poenitz (ratio measurement) up to 10% higher than earlier data in the range 1-2 MeV (σ_f U235, U238, Pu239, σ_c U238)

Simultaneous evaluation of Sowerby et al finalised (to be published in Jour. of Nucl. Sci. and Engineering): Standard deviation of Pu-239 σ_f increases with energy: 100 eV : ± 3%; 10 keV ± 1% 1 MeV ± 5%.

New measurements not included in Sowerby's evaluations are: Gayther (shape measurement), Kappeler U-239/U-235) (to be published) Weston (ORNL) absolute measurements not yet published.

B. U-238 (n,f)

New data - Meadows (NSE 49 (1974 p.310)

Poenitz Germany (JNE 26 (1972) 403)

Cierjacks et al (EURATOM Progr. Report)

Coates & Gayther (UK Progr. Report)

Preliminary results of Coates et al are generally consistent with Sowerby's evaluation. For the range 0.6-1.8 MeV, these measurements agree with measurements of Stein and Meadows and disagree with earlier values of Lamphere; above 1.8 MeV, ~3.5%, lower than Poenitz' and Meadows'. Agreements with new Karlsruhe data exists over the whole energy range except small differences in the peak region of 7 MeV and some energy shift above 17 MeV.

However, the difference in the change of microscopic data changes the fast reactor spectrum average values only by 0.5%.

Recent measurements of subthreshold fission are made by RPI (Block) et al (order of 0.1 mb) and Saclay relative to U-235) with better resolution. This can be significant in some reactor spectra:

Actions:

In order to try to clarify the existing discrepancies on ^{238}U and ^{239}Pu, it is decided to exchange, for intercomparison, the new data which were obtained after the Subcommittee reports to the VII meeting. This exchange will have to take place before December 31, 1974 and concern:

a) For ^{238}U

Conde for (NORDBORG data (Upsala))

Motz for BEHRENS data (LRL)

Cierjacks for KAPELLER data (KFK)

APPENDIX XV

b) For ^{239}Pu

Cierjacks for KAPPELER data (KFK)

Motz for WESTON data (ORNL)

Rowlands for GAYTHER data (Harwell)

Joly for SZABO data (Cadarache)

To facilitate the intercom parison, it is suggested to present these new data relative to the last evaluation of SOWERBY.

II. Capture cross sections σ_c (U-238).

A. Direct measurements

New results - Ryen et al (UK Prog. Report)

Moxon and Pearlstein (preliminary)

- Käppeler 20-500 keV relative to Au (shape measurement)

Poenitz, 20-1200 keV relative to gold

The Ryves data is about 10% lower than earlier evaluations at 231, 559 and 524 keV, and these new measurements have an accuracy of about 2%. The Moxon and Pearlstein measurements also support the lower values at these energies particularly above 400 keV.

B. Ratio of σ_c U-238 to σ_f U-235

The new evaluated data for U-238 (n,γ) are not in particularly good agreement with previous evaluations below 600 keV. The disagreement between the U.K. and the Davey and the Pitterle evaluations are e.g. up to 7%. At higher energies the agreement is better, because there are only limited data. The Harwell results are in general lower over the entire energy range, since they are based on lower U-238 (n,γ) / U-235 (n,f) data - and lower U-235 (n,f) - values over parts of the energy range. An outline of the existing discrepancies between the several evaluated data sets is contained in a Japanese Report by Y. Kanda, presented at the 3rd Seminar on Neutron Cross Sections at JAERI in November 1972 (JAERI-1228, p.13, 1973).

The major conclusion deduced from the Harwell evaluation is that the differences between recent evaluations are mainly due to differences in the philosophies adopted, since there is only little difference between the data, the various evaluators consider reliable. It appears to the U.K. evaluators that the discrepancies are not likely to be resolved by further evaluation work, but rather by additional new measurements. The particular problem envisaged is that all reliable data in the range above 100 keV, except those of Fricke et al which are not particularly accurate, have been carried out by or relative to an activation measurement.

It is, therefore, recommended that any new measurement of the absolute U-238 capture cross section or its value relative to U-235 (n,f) should preferably not use this technique. In absolute measurements of the capture cross sections, in addition, the use of intermediate standards (e.g. Au-197) should be avoided, as these only add to the overall uncertainties.

The U.K. recommendation concerning the avoidance of intermediate standards as Au-197 for absolute capture cross section measurements is a formidable problem which needs some further discussion in the Subcommittee before being adopted. It has been pointed out earlier that the use of other standards (e.g. U-235 (n,f)) might introduce new difficulties with respect to the accuracy of the absolute values.

New results - Filtered beam measurements at 24 keV, C. Block et al, (Japanese Progr. Report)

- Fuketa et al (JAERI, Progr. Report a few to 30 keV)

- Spencer, Beer, KFK, relative to σ_f U-238 between 20-500 keV.

- Tolstikov, 23 keV - 7 MeV, YaderniEnerg. 13

New Evaluation - Tolstikov, USSR, between 0.2 keV - 7 MeV; these are reported to be in agreement with the old Sowerby evaluation (UK NDL (1921)). 7+1)

III. α Values for ^{235}U and ^{239}Pu

A. α ^{235}U

Presently only thermal values are discrepant as documented in the recent US check list of important discrepancies. Values derived from irradiation experiments are higher than those from all other methods by 3 to 4 times the combined errors.

New results: Kononov (Obninsk Report 15, 1974)
in the range 10 to 80 keV. These are ~8% higher than the earlier results of this author. Measurements of α ^{235}U are in progress at the Karlsruhe Van de Graaff accelerator in the range from 15 to 400 keV.

B. α ^{239}Pu

New measurements: Varotnikov (Proc. Kiev Conf)
3 to 200 keV normalised at 30 keV to values of Lottin et al. and Kononov et al.
These results agree well with the shape of the evaluated curve from Sowerby and Konshin.

- Bergmann et al. (Proc. Kiev Conf.)
  thermal to 30 keV, total error ±15% in disagreement with Girin results by 15%.
- Kononov et al. (Obninsk Report 15, 1974)
  10 to 80 keV. No comparisons have been made yet
- Petrov et al. (Atomnaja Energia 32 1974, p.134 ff
  results with foil technique at E_n = 2.0; 24.5 and 140 keV.

Measurements in progress

- Kappeler, Beer, Ernst (KFK)
  for 15 to 400 keV with new experimental technique

IV. Resonance paramaters of ^{235}U, ^{238}Pu and ^{238}U

Status reports on the resonance paramaters of ^{235}U and ^{239}Pu are appended (Appendix II and III respectively).

Concerning ^{238}U, the subject was reviewed at a meeting held at Saclay on "Resonance parameters of fertile nuclei and ^{239}Pu". An evaluation of the ^{238}U resonance parameters was proposed by Moxon : the proposed values are based on an averaging of results from 16 experiments. The author decided to include all these results; his decision is based on χ^2 analysis of all individual data and this may be subject to some controversy.

V. Inelastic scattering data of ^{238}U

The ^{238}U (nn') cross section is not well known below a few hundred keV because of the difficulty of resolving the scattering of the first excited state at 45 keV from the elastic peak. Although some data are available at large scattering angles, they are discrepant and in some cases irregular. Theoretical shape estimates are of some help, especially when data from similar rotationally deformed nuclei are available as A.B. Smith has demonstrated for ^{186}W. This energy region is of great importance to any fast reactor system containing ^{238}U.

New measurements in this energy region are under way at Harwell, ORNL, Karlsruhe and at Studsvik. These should help considerably in normalising the lower energy range.

The situation above about 500 keV is similarly confused by lack of detailed, reliable measurements on the first few excited states, although the partial cross-section of the first excited state has decreasing importance since the energy loss is not so significant.

Preliminary new measurements at the Lowell Technical Institute and at ANL above 1 MeV demonstrate significantly improved resolutions. They indicate increased cross-section values in the 1 to 2 MeV ranges.

Clean integral experiments might be of value in verifying cross-section sets in this critical region. A highly depleted uranium system has been studied at Karlsruhe (Bluhm et al, Nuclear Sci. and Energ., 1974). A 10 percent ^{235}U, 90 percent ^{238}U system, called Big 10, is being used at Los Alamos. Neutron spectrum measurements can be compared to calculated values with a high correlation to the (n,n') cross sections used for calculations as indicated by Bluhm.

VI $\bar{\nu}$ values for ^{233}U, ^{235}U, ^{238}U and ^{239}Pu

1. The $\bar{\nu}$ value for the spontaneous fission of ^{252}Cf is relevant to $\bar{\nu}$ values for ^{233}U, ^{235}U and ^{239}Pu since it is the standard. It was agreed at the 2nd IAEA Panel on Neutron Standard Reference Cross Sections that no discrepancy exists between direct measurements of $\bar{\nu}$ for ^{252}Cf and this situation has not changed since then.

2. The apparent discrepancy between direct measurements of $\bar{\nu}$ for ^{252}Cf and the indirect value inferred from the 2200 m s^{-1} values has been a major consideration in the third IAEA review of thermal neutron data of the fissile isotopes by Lemmel et al. The report of this study is expected soon.

3. The discrepancy between earlier data on the correlation of $\bar{\nu}$ with resonance spin for ^{235}U and ^{239}Pu has been resolved by the four recent measurements of Shackleton et al., Reed et al, Theobald et al. and Howe. These measurements confirm that the correlation between $\bar{\nu}$ values and the spin of the resonances is very small although statistically significant and that the fluctuations have their origin in pre-fission gamma rays emitted in the (n,γf) reaction, (Shackleton).

4. The question of structure in the energy dependence of $\bar{\nu}$ for ^{235}U in the low MeV regions remains unresolved. The latest measurement of Savin suggests a step-like dependence in $\bar{\nu}$ in agreement with some, but not all, of the earlier measurements, suggesting structure. A recent measurement by Käppeler suggests a peak in $\bar{\nu}$ for ^{235}U between 200 to 400 keV. On the contrary, Boldeman finds no evidence of structure at all in measurements of $\bar{\nu}_p(E_n)$ and $\bar{E}_K(E_n)$. The latest measurement by Soleilhac also finds no evidence of structure.

A recent measurement by Volodin confirms the absence of structure in $\bar{\nu}$ for ^{239}Pu.

For ^{233}U two recent measurements of $\bar{E}_k(E_n)$ (Kuzminov and Boldeman) confirm a sharp rise in $\bar{E}_k$ between thermal and 200 keV and the minimum in $\bar{\nu}_p(E_n)$ that may be inferred from this data has been confirmed by Boldeman.

VII Capture Cross Sections of Cr, Fe and Ni above 400 eV

The situation of capture cross sections for structural materials was extensively reviewed at a Specialist Meeting held in May 1973 at Karlsruhe. The report is presently being presented as KFK-Report 2046, NEACRP-U-61, NEANDC-U-98, extra copies of which are distributed to INDC members.

The proceedings contain contributions on neutron capture in Fe, Co and Ni in the energy range from 1 keV to 1 MeV. In the first part experimental techniques and recent microscopic measurements of the elements and of separated isotopes are described. The second part is devoted to recent evaluations, while the third part deals with some users aspects. (Contents given in the Proceedings).

In the discussion of techniques and experimental results one major problem was soon encountered; The proper detection of scattered neutrons, which might lead to discrepancies in the experimental data of different groups by about 40 to 50 percent. (See the summary of this session provided by Dr. Frohner, CCDN). New results of the Ni capture cross sections were obtained by Poenitz. The preliminary data supports these values from Cadarache, which are ~20% higher than previous results.

The second session, devoted to recent evaluations discusses the large differences on the recommended data in the three major evaluated data files ENDF/B3, UKNDL (1971) and KEDAK, version 2. Major discrepancies exist in these data which can in some cases still exceed a factor of 2, e.g. the results for the Ni data in the energy range from 30 to 200 keV. Further information is given in the summary of the evaluation session, which was provided by Dr. Ribon, Saclay.

The users aspects were discussed in the last session. The required accuracy of e.g. stainless steel in the keV range was considered to be 10 per cent. This number is mainly based on the target accuracy for the breeding gain of large LMFBR systems. The influence of neutron capture data on uncertainties for physics quantities in zero power reactors was discussed. Data adjustment procedures seem to indicate that differential measurements on Co, Fe and Ni are not consistent with results from integral measurements in critical facilities. Further work, especially on iron neutron capture cross section measurements and on data testing is required.

VIII. Capture and total cross-sections in the 3 keV resonance

No new capture cross section measurement has been reported since the last meeting. A total cross section measurement and a resonance analysis have been made by Seltzer and Furk (N.S.W. 53, 415, 1974). The discrepancy of about a factor of 2 on Γ_γ for the 3 keV resonance is not removed.

IX. Fission neutron spectrum of ^{235}U, ^{239}Pu and ^{238}U

The joint experiment between Harwell and Studsvik on the fission neutron spectrum of ^{235}U aimed to settle the discrepancy between earlier reported measurements at these two laboratories is still not finalized. Studies of systematic errors due to energy and efficiency calibrations are in progress. Preliminary results indicate the absence of a high energy tail in the spectrum as was seen in the earlier Harwell measurement.

Further measurements of the fission neutron spectrum of ^{235}U were reported to be in progress at Cadarache and Studsvik and on ^{239}Pu at Geel and Studsvik. No new measurements were reported on ^{238}U.

APPENDIX I

VII INDC MEETING

PROPOSED AGENDA OF THE SUBCOMMITTEE ON DISCREPANCIES

I. Subjects to be considered according to the terms of reference adopted at the V INDC meeting :

1) Fission cross section of ^{235}U above $\sim$100 eV.

2) Fission cross sections of ^{239}Pu and ^{238}U above $\sim$100 eV.

3) Capture cross section of ^{238}U above $\sim$100 eV and the ratio to ^{235}U fission.

4) α values for ^{235}U and ^{239}Pu.

5) Resonance parameters data of ^{235}U, ^{238}U and ^{239}Pu.

6) Inelastic scattering data of ^{238}U.

7) $\bar{\nu}$ values for ^{235}U, ^{239}Pu and ^{238}U.

8) Capture cross sections of Cr, Fe and Ni above $\sim$100 eV.

9) Na capture and total cross sections in the 3 keV resonance

10) Fission neutron spectra of ^{235}U, ^{239}Pu and ^{238}U.

II. Subjects proposed by J.J. SCHMIDT for inclusion in the discussions of the Subcommittee

1) Discrepancies in fission product nuclear data. Conclusions and recommendations of the Bologna F P N D Panel.

2) Discrepancies in reactor dosimetry cross sections.

3) Draft conclusions of the third AIEA review on thermal fission constants.

N. B. : The decision for extending the Agenda of the Subcommittee to the items II above has to be discussed in INDC plenary session. -

Agenda item IX.A
2 October 1974

NDS Working Paper 7

Potential participation of the Agency's International Centre for Theoretical Physics at Trieste in the development of nuclear theory for nuclear data evaluation

The purpose of this working paper is to introduce, following requests, INDC participants briefly into history, purpose, fields of research, staffing and financing of the Agency's International Centre for Theoretical Physics at Trieste and to summarize the proposals and activities of INDC correspondents in the past year with regard to possible participation of the Trieste Centre in the development of nuclear theory for nuclear data evaluation.

1. Background information on the Trieste Centre

The first discussions on the creation of an international centre for theoretical physics under the auspices of the United Nations were held at the High-Energy Physics Conference in Rochester in 1960. More detailed plans and recommendations were formulated by a scientific panel of theoretical physicists convened by the IAEA in 1961 and by a three experts panel of the Agency in 1963 consisting of Professors R.E. Marchak (USA), J. Tiomno (Brazil) and L. Van Hove (CERN). On the basis of the reports and recommendations of these two panels the Centre was founded in October 1964 and, following an Italian offer, located at Trieste.

Currently the Trieste Centre is operated jointly by IAEA and UNESCO (with a yearly financial contribution of each of these two organizations of US $ 155.000,-). The administration is carried out by the IAEA on behalf of both organizations and the budget of the Centre forms, for administrative convenience, part of the budget of the IAEA. The Director of Budget and Finance of the IAEA is the liaison officer between the IAEA and the Centre. The Italian Government contributes US $ 250.000,- per year to its support. The rest of the budget (irregular, varied after 1970 from US $ 100.000,- in 1970 to 440.000,- in 1972) comes mainly from donations by the Ford Foundation, the United Nations Development Programme (UNDP, supports the Centre's condensed matter programme and the applied mathematics and computer science activities) and the Swedish International Development Authority (SIDA).

The basic objective of the Trieste Centre is, "to foster through research and training, the advancement of theoretical physics with special regard to the needs of developing countries so as to encourage theoretical physicists from those countries to continue and expand their research work".

More specifically the aims of the centre are defined to be the following:

"(a) to train young physicists from developing countries for research;

(b) to help in fostering the growth of advanced studies of theoretical physics, specially in developing countries;

(c) to conduct original research; and

(d) to provide an international forum for personal contacts between theoretical physicists from countries at all stages of development."

The fields of research covered by the centre have so far been

- elementary particles;
- high-energy physics;
- field theory;
- nuclear physics;
- solid state physics;
- plasma physics;
- astrophysics;
- general relativity; and
- applied mathematics.

To implement its training and research programme for the specific benefit of physicists from developing countries the Centre has set up the following four schemes:

(a) extended high level seminars;

(b) the fellowship programme;

(c) the associateship scheme;

(d) federation agreements.

The extended seminars last up to three months and are organized in specialized topics, mostly in the field of nuclear and condensed matter physics and more recently in atomic physics and applied mathematics. The following table gives an overview of the courses in nuclear physics so far organized by the Centre:

Subject	Date	No. of Lecturers	No. of Participants
Nuclear Reaction Theory	October - December 1966	32	102
Nuclear Structure Physics	January - March 1969	46	141
Nuclear Physics	January - March 1971	30	116
Nuclear Physics	September-December 1973	23	69

These seminars are designed to provide teachers, specially also from developing countries, with new contacts, with new knowledge and new research problems to pursue at home. They should bring as many young scientists as possible from developing countries in contact with leading experts in their field to update their knowledge, to encourage them to perform, under expert guidance, original and meaningful research and to carry out or initiate some research work during the courses.

Approximately 15 fellowships are awarded every year by the IAEA and UNESCO for post-graduate training and research to scientists from developing countries. The duration of the fellowships is usually about 6-9 months with possible extensions for a similar period. Applicants are expected to have a university degree (M.Sc. or Ph.D.) with a good background in quantum mechanics, methods of mathematical physics, relativity theory, atomic and nuclear physics etc. preference being given to those with research experience. Stipends are based on the rates of the United Nations Development Programme (UNDP) of US $ 400 per month.

The Associateship scheme was created for the benefit of senior physicists from and working in developing countries. It is complementary to the fellowship and visiting scientist programmes and gives those senior physicists the opportunity to spend six weeks to three months at the Centre, three times in a period of five years. The stay of associates at the Centre is designed to keep them in the main stream of modern physics and stimulate their research and teaching when they return home.

Openings are announced by a circular letter from the Directors General of IAEA and UNESCO to all Member States with copies to physicists on the Centre's mailing lists. Letters of recommendation from two eminent scientists are requested for applicants. The Centre's Scientific Council examines the applications and issues recommendations for appointments. No salary is paid to associates, the home institution being expected to grant them paid leave of absence. Travel expenses and a subsistence allowance are paid by the Centre. The associateship programme is financially supported e.g. from contributions by the Ford Foundation, the Swedish International Development Authority (SIDA) and UNDP.

The federation agreement scheme is aimed at building up relations of mutual co-operation between the Centre and scientific institutes or university departments in near- and/or developing countries. By these agreements, the institutes can send young scientists of their choice to the Centre for up to 40 (nearby countries) and 50 days (other countries). Normally the Centre pays a daily living allowance, while the federated institute provides for the travel cost. The number of federated institutes is at present 26 in 17, mostly Mediterranean and Near East, countries.

The Centre finally invites senior and junior research physicists from all Member States for periods ranging from a few weeks to nine months. Travel expenses are sometimes covered by the Centre. The intention is to bring together specialists and promising young scientists in some of the leading fields of theoretical physics for the specific benefit of the young fellows from developing countries.

The major research activity of the Centre is thus carried out by visiting and guest scientists, fellows and associate members, the core of the Centre's staff being rather small. It consists of its Director (Prof. Abdus Salam) and Deputy Director (Prof. P. Budini) and two other professional staff members, acting as administrative and scientific information officers. They are assisted by 15 general service staff and by 11 persons of the maintenance and operatives category provided by the Italian Government.

2. Proposals from INDC Correspondents

Following action 26 of the last INDC Meeting several INDC participants submitted proposals on nuclear theory subjects. A few suggestions were also received from INDC Liaison Officers which were approached in this matter by NDS. Altogether NDS got so far replies from INDC correspondents from 10 countries (Australia, Bangladesh, Bulgaria, India, Netherlands, South Africa, Sweden, Switzerland, UK and USA; five of them explained that they had no suggestions). In the following the suggestions are summarized item by item (including those coming from NDS):

1. Study of reaction mechanisms in radiative capture reactions;
2. Inelastic scattering (Hauser-Feshbach and Moldaner) calculations; Comment: we understand that the primary purpose would be to improve a theory, not to perform series calculations (see e.g. item 3)
3. More detailed investigations of the statistical behaviour of compound nucleus processes;

4. Systematic investigation of nuclear parameters, their distributions and averages, entering nuclear reaction theories, such as level densities, fission widths (for double-humped fission barriers) and capture widths as function of A, E, J, π (or ℓ);

5. A course or seminar on the current theories of nuclear fission;

6. Use of heavy-ion accelerator results to improve our understanding of the fission process; this will require extensive studies of the interrelation of single-particle and collective interactions;

7. Development of reliable and well-tested computational programmes, particularly for deformed optical models;

8. Development of quasi-particle, exchange etc. theories applicable to high energy (< 20 MeV) neutron induced processes with several secondary particles emitted (e.g. (n,np), (n, αn) etc.); this would be useful for future CTR work;

9. Investigation of the three-nucleon problem in coordinate representation.

In addition, Prof. J. Kern and coworkers from the Fribourg University in Switzerland indicated a strong interest in cooperation with theoretical physicists from the Trieste Centre in problems of interpretation of their level structure measurements on rare earth and actinide nuclides.

B. Rose and J.E. Lynn had informal discussions with Prof. Salam with the result that there might be some possibility for an international theoretical nuclear data workshop being hosted by the Trieste Centre and meeting there annually or biannually for a period of two to three months, provided that sufficient funds can be made available.

First conversations between J.J. Schmidt from NDS and Prof. Salam confirmed this. Prof. Salam was briefly informed on the actions INDC and NDS had taken so far, in particularly also on the planned Consultants' Meeting on the Use of Nuclear Theory for Nuclear Data Evaluation in the late fall of 1975. He immediately offered to host this meeting at his Centre which would be the ideal surroundings for it. Also this meeting could be very useful for developing further a concrete programme for a potential workshop.

3. Suggestions for procedure

To get a firm basis for further discussions of the project, NDS suggests that INDC

1. at the meeting consider the various suggestions made and select two or three topics of primary importance for applications,

2. submit a formal recommendation to the Director General stating the purpose of the project, the topics selected and formulating a suggestion to the Trieste Centre regarding their possible implementation in the Centre's workshop programme, in underlining the particular value of this project and its results for scientists and technicians in developing countries,

3. try to identify possible sources of financial support for such a workshop (or several workshops) and enquire into the liquidity of these sources in detail after the meeting,

4. approach after the meeting nuclear theorists of high standing and with interest in applications of nuclear theory to develop detailed working schemes for the treatment of the nuclear theory topics selected by INDC,

5. identify scientists with potential interest in the project, i.e. senior scientists for guidance of the work and other scientists, particularly also junior scientists from developing countries, for active participation,

6. keep NDS currently informed on the results of items 3,4, and 5,

7. NDS should approach INDC Liaison Officers particularly in smaller and developing countries on the issues of item 5.

The next meeting of INDC will take place before the Nuclear Theory Consultants Meeting. It would be extremely useful, if definite ideas and plans with a solid scientific and financial background for the project would have evolved by that time.

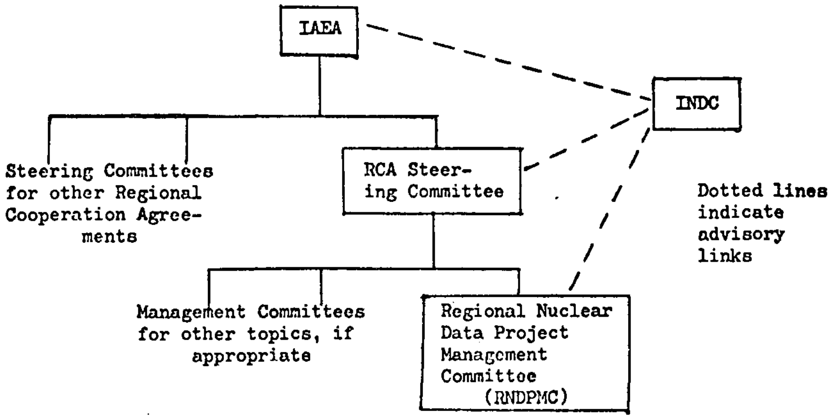
APPENDIX XVII

AD HOC SUB COMMITTEE NO. 4

NUCLEAR DATA IN DEVELOPING COUNTRIES

ORGANISATION

The committee discussed the way in which IAEA Regional Cooperation Agreements are expected to be organised and considers that within the expected arrangements, the following structure would be suited to the satisfactory development of nuclear data work.



The RCA may, of course, contain agreements on topics other than nuclear data. If, however, nuclear data is a clearly identifiable topic then a suitable Regional Nuclear Data Project Management Committee (RNDPMC) should be established to guide the work in this area.

The RNDPMC would be composed principally of experts from the region, together with one or two independent advisors selected by INDC, which would also be expected to offer advice to the RCA Steering Committee if requested to do so. The proposals concerning nuclear data from the RCASC to the IAEA would normally pass through the NDS which would need to satisfy itself of the technical merit of the proposals by reference to INDC, if they had not been effectively vetted by INDC at RCA Steering Committee level.

It became clear during the discussion that a number of formal and informal bilateral agreements are in existence or being considered and it will be important for the RNDPMC to be aware of these if it is to make the best use of its resources. We recommend therefore that all members of INDC report to NDS any of these of which they are, or become, aware.

PROGRAM

We did not attempt to discuss possible content of a regional program because this only makes sense if one has details of facilities (men and equipment) available in the region. However, one new general area of importance was mentioned briefly of particular interest to the Far Eastern area, namely, on capture gamma rays for applied purposes.

It should certainly be remembered that in many countries research work with a short term pay-off is likely to receive favourable reception from the national authorities and that we should consider rather carefully whether the non-energy program could present more opportunities for this sort of work than the energy program.

Agenda item VI.B
27 September 1974

NDS Working Paper 10

The attached summary sheet plus enclosures describe a continuing activity in the compilation of γ-ray lines from radionuclides which is being performed at the Nuclear Research Establishment (KFA) Juelich in the Fed. Rep. of Germany. We recommend the following action on the INDC Members concerned, i.e. to contact similar groups in their countries working on γ-ray compilations and inform them on the Juelich activities with the object to achieve coordination of compilation where possible and to keep NDS informed on this matter.

Title: "Gamma Rays of all Radionuclides"

Authors: Gerhardt Erdtmann, Werner Soyka

Address: Central Institute of Analytical Chemistry,
Nuclear Research Establishment, Post Office Box 365
KFA Juelich, Fed. Rep. of Germany
517 Juelich 1

This data compilation consists of all gamma-ray transitions (energies and intensities) observed in the decay of about 1300 known gamma-ray emitting nuclides. The radionuclide data are supplemented by data concerning their half life, parent and daughter nuclides and generating reactions. The work is based on literature published up to the end of 1971; some journals, such as Nuclear Physics A, Physical Review C, Bulletin of the Academy of Sciences of the USSR, Soviet Journal of Nuclear Physics and Nuclear Data B have been surveyed up to the middle of 1972.

The compilation is stored on magnetic tape which can be handled with appropriate programs on the IBM computer of the Central Institute of Applied Mathematics of the Juelich Nuclear Research Establishment (KFA). Copies of the magnetic tape can be purchased from the Institute (DM 100,— in 1974) and will also be made available to IAEA/NDS.

The compilation is also obtainable in the form of a tabulation printed as a three-volume Juelich report. ("Die γ-Linien der Radionuklide" Volumes 1-3, KFA Juelich report JUEL-1003-AC (Sep. 1973), G. Erdtmann and W. Soyka). The compilation is presented in two sorts: Volume 1 lists the data sorted by ZA, volumes 2 and 3 list γ-and x-ray lines of all nuclides in order of increasing energy.

To give an idea of content and format of this publication, we attach the table of contents and two sample pages of the compilation.

APPENDIX XXIV

Inhaltsverzeichnis - Contents

Inhaltsverzeichnis (Forts.) - Contents (cont.)

Inhaltsverzeichnis (Forts.) - Contents (cont.)

Tabellenteil - Section of tables

57 LA 136

HALF LIFE: 9.87M
GEN: NPA CE136
CHA BA136
DAU:
PAR:
REF: 68 JU 1,69 ME 1

0.03182			X
0.03219			X
0.03640			X
0.03730			X
0.51100	78.00000	A	
0.54150	0.00500	A	
0.73260	0.01200	A	
0.76040	0.36000	A	
0.76700	0.00400	A	
0.81850	2.50000	A	
0.89400	0.00500	A	
0.90680	0.00010	A<	
0.93500	0.00200	A	
0.98130	0.00010	A<	
1.26170	0.03300	A	
1.31050	0.11000	A	
1.32250	0.33000	A	
1.46600	0.00300	A	
1.49710	0.05300	A	
1.51450	0.00250	A	
1.55120	0.01200	A	
1.66690	0.01200	A	
1.71320	0.00025	A<	
1.79140	0.00700	A	
1.82200	0.00400	A	
1.95500	0.00200	A	
2.08060	0.02100	A	
2.12770	0.04300	A	
2.28600	0.00050	A	
2.33250	0.00250	A	
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57 LA 138

HALF LIFE: 1.09E+11A
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NPA CE138
NAT 0.089
DAU:
PAR:
REF: 72 EL 1

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0.03730	1.70000	A	X
0.41400	PAIR PEAK		
0.78800	33.00000	A	
0.92500	PAIR PEAK		
1.43600	67.00000	A	

57 LA 140

HALF LIFE: 40.27H
GEN: NTH LA139
NPA CE140
NFI 6.250
DAU:
PAR: BA 140 12.8D
REF: 70 MA 3,69 GU 1
70 KA 1

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0.03472	0.81000	A	X
0.03920	0.23400	A	X
0.04020	0.04800	A	X
0.06413	0.01000	A	
0.06892	0.06000	A	
0.10942	0.22000	A	
0.13112	0.53000	A	
0.17354	0.14000	A	
0.24196	0.56000	A	
0.26655	0.60000	A	
0.30690	0.03500	A	
0.32875	21.30000	A	
0.39780	C.10000	A	
0.43255	3.10000	A	
0.43850	0.02100	A	
0.44600	0.02500	A	
0.48703	45.70000	A	
0.51095	0.35000	A	
0.57420	PAIR PEAK		
0.61820	0.04000	A	
0.75179	4.50000	A	
0.81580	23.60000	A	
0.86786	5.60000	A	
0.91960	2.50000	A	
0.92525	6.80000	A	
0.93690	0.06000	A	
0.95102	0.60000	A	
1.08520	PAIR PEAK		
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1.41500	0.00600	A	
1.59620	96.00000	A	
1.90315	0.00600	A	
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2.34820	0.84000	A	
2.52183	3.25000	A	
2.53340	0.00400	A	
2.54770	0.10000	A	
2.89970	0.07000	A	
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3.31960	0.00500	A	

57 LA 141

HALF LIFE: 3.87H
GEN: NFI 5.730
DAU: CE141
PAR:
REF: 69 GU 1

1.37590	2.00000	A

57 LA 142

HALF LIFE: 92.0M
GEN: NPA CE142
NFI 5.800
DAU:
PAR:
REF: 71 LA 1,67, BA 2

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0.03472		
0.03920		
0.04020		
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0.14220	0.05000	A
0.16950	0.05000	A
0.17410	0.10000	A
0.29790	0.05000	A
0.33200	0.05000	A
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0.42790	0.05000	A
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0.89485	8.50000	A
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1.03920	0.10000	A
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1.10010	0.05000	A
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1.17430	0.15000	A
1.19090	0.40000	A

75-7516

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18.7H			0.49777 79.8 A	CHA HG202	
			0.57929 78.1 A		
			0.25587 77.3 A		
			0.75950 72.2 A		
KR 89	0.36880	2.0 A	0.22060 25.0 A	NFI 4.730	
3.18M			0.58640 21.0 A		
			0.49780 11.0 A		
			1.53340 11.0 A		
			1.47210 9.5 A		
LU 166	0.36900	41.0 R	0.22800 100.0 R	CHA TA182	PA:HF 166
3.3M			0.10200 60.0 R		6.0M
			0.33800 60.0 R		
			0.36900 41.0 R		
			0.27600 25.0 R		
HF 169	0.36930	10.0 A	0.49230 85.0 A	CHA YB170	
3.3M			0.05407 37.0 A X		
			0.51100 23.0 A		
			0.05297 20.0 A X		
			0.06130 12.0 A X		
PA 234	0.36980	3.4 A	0.09844 27.0 A X	NAT U 238	PA:TH 234
6.7H			0.13120 20.0 A		24.10D
			0.09466 15.0 A X		U 238
			0.88080 13.0 A		4.51E+09A
			0.88320 12.0 A		
GD 147	0.37050	13.2 A	0.22990 57.0 A	CHA SM147	
38.0H			0.76550 49.5 A	CHA SM144	
			0.39650 26.2 A		
			0.92800 16.2 A		
			0.37050 13.2 A		
J 136B	0.37050	19.0 A	1.31330 100.0 A	NPA XE136	
48.0S			0.38150 98.0 A	NFI 6.470	
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			0.37050 19.0 A		
BI 196	0.37100	48.0 R	1.04900 100.0 R	CHA TA181	
4.6M			0.68850 64.0 R	CHA RE185	
			0.37100 48.0 R		
			0.33650 15.0 R		
			0.13800 11.0 R		
HG 191	0.37100	11.0 R	0.25260 100.0 R	CHA AU197	
55.0M			0.42030 32.6 R		
			0.57870 30.9 R		
			0.24140 21.3 R		
			0.27470 15.0 R		
IR 190	0.37110	20.2 A	0.18670 51.0 A	NPA PT190	
11.0D			0.60530 34.5 A	NPA IR191	
			0.51840 31.2 A	CHA OS190	
			0.40720 26.5 A		
			0.55780 25.0 A		
RE 190	0.37150	25.5 A	0.18690 52.6 A	NPA OS190	
3.1M			0.55770 40.4 A	NPA IR193	
			0.82890 31.5 A	CHA OS192	
			0.56910 28.8 A		
			0.36140 27.7 A		