EUROPEAN-AMERICAN NUCLEAR DATA COMMITTEE

TECHNICAL MINUTES OF THE HARWELL MEETING (18 - 21 July 1961)

EANUC-14(T)

compiled by

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aided by

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Chalk River, Ontario, Canada

8 November 1961

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Preface to the Technical Minutes

This version of the minutes of the third meeting of the European-American Nuclear Data Committee is produced for general distribution to those concerned with measurement programmes in the nuclear data field. The conclusions are, however, of an interim nature in many cases, and the document is therefore marked "Not for Publication" and should neither be quoted in publications nor listed by abstract journals. Pages common to this document and the complete minutes may bear double page-numbers, the number followed by (T) applying in this volume.
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(ii) The discussions under §§9(b), 9(c)(i) (double-spaced section) are by element in order of increasing Z; these are not indexed below. The table on p. 26 is also not indexed by element.

References are to page numbers, and part of page. (α, β, γ, λ, µ, i.e. γ = about middle of page.)

Boron 2β, 4λ, 13λ
Caesium 13λ
Dysprosium 13λ
Gold 13λ
Hafnium 13λ
Oxygen 47
Plutonium (isotopes) 10-11γ, 13λ
   Pu-239 6α, 15α, 26λ-µ, 37-38
Protactinium-233 35-36
Silver 13λ
Sodium 15γ
Thorium 6α
Uranium-233 37-38
   U-235 4µ-5γ, 6α, 12γ, 37-38
   U-238 6α, 25λ
Water 15λ
Zirconium 15β
AGENDA FOR THE THIRD MEETING OF THE
EANDC, HARWELL, ENGLAND
18-21 July, 1961

1. a. Consideration of Minutes of Second Meeting: EANDC-10.
   b. Notification of changes of membership of committee.
   c. Adoption of final form of agenda for the Third Meeting.
   d. Admission of observers and experts.

2. Matters arising from EANDC-10. The items in Appendix XIV have been dealt with as follows:
   c. Matters to be discussed at this meeting:
      (i) Samples and facilities; standards - 44, 47-52, 54.
      (ii) Other matters - 1, 4, 6-7, 14, 17, 40, 45.

3. General Problems
   b. Nomenclature, symbolism, definitions and compilations.
      (i) Compilations - IAEA Participation - Kolstad.
      (ii) Resonance Integrals - sub-committee report. Westcott et al. (EANDC-12).
      (iii) Other compilations.
   c. Possible exchanges and mutual use of equipment.
   d. Exchange of personnel for specific projects.
4. Information on Facilities and Programmes.
   a. Programme status reports from each representative organization - EANDC-(US)19, (US)20, (CAN)9, (E)23, (UK)10.
   b. Documents submitted on specific research activities - EANDC- (CAN)10, (CAN)11, (OR)12, (OR)15, (E)18, (E)19, (US)21.

5. Integral Data and Techniques.
   b. Neutron spectra in lattice assemblies
      (i) Chopper method - Sjöstrand (EANDC-(OR)17)
      (ii) Pulsed source method - Beckurts (EANDC-(E)22)
   c. Neutron beam source experiments to be sponsored by EANDC. EANDC-(UK)12.

   a. Reports from Laboratories
      (i) Euratom - Spaepen. EANDC-(E)24.
      (ii) NBS - Kolstad.
      (iii) NPL - Bretscher. EANDC-(UK)11.
   b. Exchanges of standards dictated by the foregoing.

7. Foil and Target Preparation and Exchange.
   b. Facilities for Target and Foil Preparation.
      (i) At ORNL - Kolstad, Harvey.
      (ii) Euratom - Spaepen. EANDC-(E)27.
   c. Plutonium facilities in preparation at Karlsruhe.
8. Consideration of Discrepancies
   a. Cross section discrepancies - Goldstein. EANDC-(US)22.
   b. Non-cross section discrepancies.

9. Requests for Measurements.
   b. Detailed consideration of combined request list EANDC-13. Priority I items only. EANDC-(E)20, (CAN)9,(OR)14, (OR)16.
   c. General consideration of fields of particular interest to the committee.
      (i) $Z > 92$ isotopes
      (ii) Other fields ($E_n > 1$ MeV)
      (iii) Other fields ($E_n < 1$ MeV)

    a. Specific recommendations for implementation of desired measurements.
    b. Personnel exchange.
    c. Exchange of samples or mutual use or exchange of equipment. EANDC-(E)25.

11. Production of Special Isotopes.
    b. Siebersdorf - requests for isotopes. EANDC-(OR)11.
    c. Status of problem of obtaining pure Pu-239.
    d. Depleted U-238.
    e. Contribution in this field from Saclay.

12. Symposia.
    b. Comments, further suggestions for sponsorship.
13. Any other business.
   a. Proposal for the transfer of items on the Agenda of the Tripartite Nuclear Cross-sections Committee to the Agenda of EANDC.

14. Date and Place of Fourth Meeting of EANDC.
   a. Introduction of new chairman, executive and corresponding secretaries.

15. Adjournment.
Minutes of the Third Meeting of EANDC

held at
A.E.R.E., Harwell, England,

There were present:
R.F. Taschek, LASL, USA (Chairman)
C.H. Westcott, AECL, Canada (Executive Secretary)
R. Joly, CEA, Saclay, France (Corresponding Secretary)
K.H. Beckurts, Karlsruhe, Germany
A. Bracci, Ispra, Italy
E. Bretscher, AERE, UK
H. Goldstein, NDA, USA
J. Harvey, ORNL, USA
O. Kofoed-Hansen, Risø, Denmark (Observer)
G.A. Kolstad, USAEC, Washington, USA
L. Kowarski, ENEA, Paris (mornings of 19th and 20th July only)
R. Meier, EIR, Würenlingen, Switzerland
E.B. Paul, AERE, UK
N.G. Sjöstrand, AB Atomenergi, Sweden
J. Spaepen, Euratom, Mol, Belgium
J.S. Story, AEE, Winfrith
R.P. Perret, ENEA, Paris (Observer and acting document assistant)
A.T.G. Ferguson, AERE, Harwell (Local Secretary)

Observers for specific agenda items (as indicated):
G.H. Debus, BCMN, Geel, Belgium - items 6 and 7
P.A. Egelstaff, AERE, UK - item 5.b
M.J. Poole, AERE, UK - item 5.c
P.J. Campion, NPL, Teddington, UK - item 6.a.iii
F.C. Hobbs, USAEC Liaison, London - item 5.b.1 only
INTRODUCTION

The Chairman brought the meeting to order by introducing Dr. Ferguson as local secretary and Dr. Kofoed-Hansen who was to be present as an observer throughout the meeting, since he would be nominated a committee member to replace Sjöstrand before the next meeting.

2. MATTERS ARISING FROM THE PREVIOUS MINUTES

Spaepen reported that he had visited the Argonne National Laboratory (Dr. Ringo). He was informed that the boron stock at the ANL was so small that they had now decided to make a new one. It was agreed that there should be collaboration between the Argonne and his Laboratory, and that his Laboratory would make up 100 kilograms of standard boron, of which 50 kilograms would be supplied to the Argonne; this will be completed in about three months. Spaepen also reported that he had received samples of the existing boron standards from the Argonne and also from Saclay. At present these were being analysed chemically and by mass spectrometry.

3. 3(b) Nomenclature, Symbolism, Definitions and Compilations

(ii) Report from the Sub-Committee on Resonance Integrals (notation) (EANDC-12 in draft)

Story introduced the draft document prepared by the Sub-Committee and summarised its contents briefly. Some technical discussion, particularly with regard to the energy limits proposed, followed. Westcott pointed out that the two spectrum method which had been used by Tattersall at Harwell and Hellstrand's method (Sweden) produced a $1/v$-excess type of integral which could be fairly directly introduced into reactor calculations. When there was good information on the shape of the cross-section as a function of energy and knowledge of the reactor spectrum, it was fairly easy to correct from the $1/v$-excess to the complete integral. Story stated that there was still some question what to choose for the lower limit of the integral in the epi-cadmium type of measurement: the appropriate value depends somewhat on the conditions of the measurement, for example, whether the measurement is done in a beam
or using an isotropic neutron flux, e.g. inside a reactor. There was some discussion of the relative merits of beam experiments and experiments in isotropic flux, and Sjöstrand pointed out that when a beam method was used the beam spectrum could fairly readily be measured using a chopper. Story stated that the Argonne National Laboratory proposed 0.625 eV on the grounds that this was the lower energy limit in their MUFT computer programme. It was not felt that this was a very cogent reason for adopting this limit for our purposes, but it might be worth while to canvas opinion more widely in the U.S. and elsewhere.

(iii) Other compilations

Taschek enquired about an AWRE compilation of data which had come to his notice and in particular whether the basis of this compilation was experimental data or whether any serious amount of adjustment had taken place to fit integral experiments. Story reported that this compilation was a print-out of a library of data stored on cards or tape at AWRE; as far as he was aware, experimental data had been used when available, but wherever such data were lacking calculations using, for example, the optical or statistical models had been used to fill in the regions not actually measured. The compilation was backed up by a very extensive series of surveys of nuclear data for particular elements. Goldstein stated that he had seen one of these surveys and that it appeared to be very thorough. Kolstad reported that at General Atomics a similar compilation had been made covering only a few elements. Spaepen reported that Prof. Neuert at Hamburg was preparing a compilation of 14 MeV neutron data, with Euratom support. Westcott asked about changes which he had heard of in the organisation at Brookhaven connected with BNL-325. Harvey gave a summary of the organisation at Brookhaven both with regard to the production of BNL-325 and its successors, also with regard to the cross-section evaluation group. It was not clear whether another supplement to the second edition of BNL-325 would be produced, which could perhaps be ready early next year, or whether more extensive changes of format and perhaps of content would be made and a third edition produced. In the latter case all data would be in the new version,
with fuller documentation, but the work would take longer. Goldstein pointed out that both BNL-325 and the cross-section evaluation group were now part of the same division at Brookhaven and therefore under the same management. Taschek enquired about the status of BNL-400, a compilation of angular distributions of scattered neutrons. He wondered whether this would now be included in the revised BNL-325. Story stated that he had heard that this document (BNL-400) was being revised separately and it was a task of much smaller magnitude than the revision of BNL-325 and that the document could therefore be issued very much sooner. Taschek enquired further as to whether any compilation was envisaged of fast neutron inelastic scattering data. Story stated that as far as he was aware it had not been decided how to display this information and this was clearly a problem of quite some difficulty. Goldstein stated that Dr. Howerton had recently published a table of angular distributions as a UCRL report. Westcott stated that he had no immediate plans to revise his tables of g and s factors, but a number of minor errors had been found and he was issuing an erratum sheet; the errors were minor and did not affect the main tables.

4. INFORMATION OF FACILITIES AND PROGRAMMES

4(a) Programme Status Reports

Taschek raised some queries about the measurement proposed of the Boron$^{10}$ (n,$\alpha$) cross-section described on page 5 of EANDC-(UK)$^{10}$, pointing out that for elastic scattering the energy of the scattered neutrons would change by up to 20%; since the detector used would be a fission counter a correction would have to be made for its change in efficiency with energy. Since the knowledge of fission cross-sections in this energy region was extremely poor he was somewhat doubtful as to whether the accuracy aimed at could be achieved by this method. Taschek also enquired about the measurements $\bar{V}$, as a function of energy described on page 6 of EANDC-(UK)$^{10}$, comparing $\partial\bar{V}/\partial E = 0.1$ (MeV)$^{-1}$ found by Moat et al. with a value of

$$0.122 \pm 0.008 \text{ (MeV)}^{-1}$$

found by Diven et al. at Los Alamos (details of Diven's results are given in Appendix VIII of these minutes). There was some discussion as to the origin of this discrepancy, Taschek wondering whether this was due to the absolute value obtained
at AWRE at 3 MeV being somewhat lower than the absolute values obtained at similar energies at Los Alamos. However, as Story pointed out, the measurements at Aldermaston formed a consistent set in that while there might be errors in the absolute values, the slope was derived only from the ratios of $\bar{\nu}$ at the higher and lower energies. Paul stated that since this report (EANDC-(UK)10) was written further work had been done on this subject and that the slope quoted was now established by 5 or 6 points. There was some discussion centering around the fact that the slopes quoted by both sets of experimenters coupled with the well known thermal values of $\bar{\nu}$, did not pass through the well established data for $\bar{\nu}$ at 14 MeV. Joly pointed out that with the onset of the process $(n,nf)$ at around 6 MeV one would expect a step in the value of $\bar{\nu}$ at that energy and it was probable that there would be another step at around 12 MeV. Bretscher called the attention of the Committee to the description of a semi-conductor recoil spectrometer which he thought was promising for making measurements of fast neutron spectra in integral assemblies. Taschek asked Paul about the progress of the measurements of total cross-sections in the energy range 8-14 MeV using the Harwell Tandem generator. Paul replied that neutrons from the $(d,d)$ reaction were to be used but the programme was just getting under way and the problem being defined.

4(b) Specific Research Activities

Westcott drew the attention of the Committee to a recently published document CRRP-1006 in which some measurements relating to the "$1/E$ component" of reactor spectra were described. Bretscher raised the question of Chalk River measurements of alpha (made in an assumed thermal spectrum) the results of which had differed considerably from the world's best values, and asked how sensitive this measurement was to deviations from the assumed spectrum. He suggested that in general such measurements were better done in such a way that the variation of the quantity with energy was measured rather than using integral spectrum. Westcott stated that he did not altogether approve of the way in which the world's best values had been obtained from an over determined set of data, and pointed out that there had been omitted from this set carefully measured ratios
of fission cross-sections, for example, the ratio of the fission cross-section of Pu-239 to that of U-235, these cross-sections having been measured simultaneously under the same conditions. Referring to paper EANDC-(OR)12 entitled "The measurement of \( \bar{\nu} \) in Fast Neutron Fission of Th-232 and U-238", Bretscher asked whether the variation in sensitivity of the detector with possible changes in the fission neutron spectrum had been taken into consideration. Sjöstrand stated that difficulty had been experienced in this matter and that in fact a last minute revision had to be made of the published values. The tank was only 50 cm in diameter. Initially the efficiency of the tank had been determined by calculation but later doubt had been cast on this and some measurement had been made.

5. INTEGRAL DATA AND TECHNIQUES

5(b) Neutron Spectra in Lattice Assemblies

(i) Choice of method

Beckurts presented a resume of his paper EANDC-(E)22 in which the relative merits of pulsed sources and choppers for the study of spectra in D\(_2\)O moderated assemblies were discussed. It was concluded that the minimum size of a subcritical assembly which would give a representative spectrum would be in the vicinity of 1 metre cube. For a resolution of 12 \( \mu \)s/m the flight path needed with a pulsed source would be 100 m, and the report favoured the alternative of using a chopper. The fuel contamination would only be a factor of five lower with the pulsed source system but with a chopper, arrangements would be much more flexible. Dr. Poole agreed generally with these calculations but thought that the disadvantages of the long flight path were not as great as had been suggested, pointing out that on most existing reactors it was difficult to get several flight paths in different directions for spectral measurements. Poole also stated that at present they were not studying D\(_2\)O lattices but with poisoned D\(_2\)O solutions there were advantages in using the pulsed source. The important problem in all lattice work was how to get out a representative beam. The other key problem was what resolution was needed and Poole felt that useful resolutions for D\(_2\)O lattices could be obtained with a pulsed
source and a 60 meter flight path. Answering another question on the intensity of neutrons which could be obtained from a DT flash tube, Beckurts stated that tubes with intensities of $10^{10}$ to $10^{11}$ neutrons per burst would be available soon, but there was a question whether, using 14 MeV neutrons, sufficient neutrons were trapped in the system. With systems of the dimensions considered there were about two mean free paths between the neutron source and the outside of the system and this appeared adequate to moderate a sufficient number of neutrons.

Later, Poole cited curves in his Saclay Symposium paper; he also said the resolution needed to give a $\sim 1\%$ error in the $\sim 0.25$ eV region depended on the $\lambda$ (or $r$) of the spectrum, but for a "hard" spectrum a lower resolution suffices. Westcott also remarked that usefulness of these measurements would depend very greatly on the proposed time scale; from the practical point of view, (that is as making a contribution to the design of this type of reactor) it was most desirable that such information should be available next year or sooner, and in any case before the maximum burn-up of $D_2O$ moderated power reactors was established by experience. On the other hand from the academic point of view the measurement of spectra and the comparison of these spectra with calculations based on cross-sections would continue to be of interest for many years.

5(c) **Suggestion for Beam Source Experiments to be Sponsored by EANDC (EANDC-(UK)12)**

Summarising his paper, Dr. Egelstaff pointed out that certain methods might be devised for increasing the neutron intensity in certain spectral regions, or, alternatively, for reducing the neutron intensity in other spectral regions which was forming a background in a proposed experiment; in a few cases, e.g. for "hot" or "cold" neutrons, an enhancement factor of the order of 30 might be achieved, but in most cases the likely enhancement factor was $\leq 2$. However, even the latter factor would be of great value for experimental work. The Committee in general appreciated the technical merits of the proposal in particular cases but it found difficulty in seeing a general approach to the problem; the scope of the problem might be too great if one took into consideration
possibilities internal to an actual reactor. Harvey stated that in his opinion in many cases the cost of experimental studies of this nature might outweigh the financial advantages gained by the application of these methods; at Oak Ridge quite a lot of effort had already been put in to the design of holes to give optimised flux from their HFIR reactor. Bretscher stated that while modern applications of this technique might be new, similar considerations had been applied by Dunning in the very early days of neutron physics to provide more intense neutron beams from radioactive neutron sources in the design of his "Howitzer". Beckurts also considered that these studies might lead to improved performance of pulsed sources. Taschek summed up by stating that while he felt that there was matter in Egelstaff's paper which was of great interest to the Committee, he himself felt unable to formulate any course of action which the Committee might adopt, and therefore proposed a Sub-Committee consisting of Beckurts, Goldstein, Sjöstrand and Egelstaff to meet and attempt to formulate the problem and to report back at a later stage in the meeting.

When this Sub-Committee reported, Sjöstrand stated that they had met and come to the conclusion that there were a great number of instances in which the techniques suggested could produce useful improvements over the presently available facilities; they had in fact in their brief session been able to enumerate 10 items coming into this category which were listed as follows:

1. Spectra with wavelengths in excess of 6 Å, i.e. very cold neutrons
2. Spectra in the range 2 - 6 Å
3. Spectra with wavelengths less than 1 Å for the study of neutron diffraction and energy levels
4. Spectra in which fast neutrons and gammas were suppressed in a thermal beam
5. Moderators for Linacs
6. Spectra with a high 1/E content with a low gamma-ray background
7. Spectra with a high 1/E content with a low fast neutron background
A fission spectrum with a small non-fission gamma and neutron component.
The extraction of beams from reactors and lattices without distortion of the spectrum.
How to modify fission spectra so that they will be suitable for shielding studies, e.g. how to produce hardened fission spectra.

It was concluded that there was a need for studies of this type. It was proposed that the members of the Sub-Committee should prepare a fairly general survey of the problems in this field in somewhat greater detail and circulate this to people whom they thought might be interested, and from whom comments would be invited. It was hoped by this means that one might unearth much unpublished data and calculations in this field, for example, calculations relevant to reactors which had not actually materialized. When these comments had been received it was proposed that the Sub-Committee (with Egelstaff) should write a report making more specific proposals to present to the next meeting. This proposal was accepted by the Committee. Kolstad suggested that the Sub-Committee should draw some help from experts in their own laboratories. Goldstein stated that even to publish a list of problems would stimulate activity in this field. He was well aware of the difficulties experienced in providing an adequate supply of problems for students working for research degrees.

6. **STANDARDS**

6(a) **Reports from Standards Laboratories**

(i) **Euratom - Bureau Central de Mesures Nucléaires (EANDC-(E)24)**

Spaepen reminded the Committee of the way in which mass spectrometry was used in connection with problems of burn-up of nuclear reactor fuels, pointing out that the mass spectrometers were not in general absolute instruments and that for the purposes of calibration it was necessary to have available a standard material whose isotopic composition was well known. For a number
of materials such as uranium, boron, and heavy water, work already completed in the United States had provided satisfactory standards. There were, however, to his knowledge no standard isotopic mixtures of plutonium available. In this paper it was proposed that EANDC should set up a scheme to establish plutonium standards. This programme would consist of:

1. The obtaining of samples of separated plutonium isotopes in a state of high chemical purity and the manufacture of accurately-controlled mixtures of these isotopes.

2. The mass spectrometry of these mixtures in different laboratories, and

3. The distribution of the results to participating laboratories.

Enlarging point 1, Debus and Spaepen indicated that quantities of the order of 0.1 gm of each plutonium isotope from 238 to 242 of 99.5% isotopic purity, or preferably near 99.9%, would be desirable for carrying out this programme. The BCMN laboratories at Geel would take part in the measurements and would act as a clearing house for the samples; a more detailed proposal could not be drawn up until the contributing laboratories were known. A number of members pointed out the very considerable effort involved in supplying the plutonium isotopes requested particularly in view of the high degree of isotopic purity which was demanded; the requested amounts of some of the plutonium isotopes would not become available for months or years and > 99% was not available at all yet in some cases. Bretscher asked whether it would not be sufficient to provide samples of Pu-239 and Pu-238, both of which could be obtained in a state of very high purity by purely chemical means. Dr. Debus did not think that these two isotopes would be adequate on the grounds that the variation of the efficiency of mass spectrometers depended critically on the masses of the isotopes being separated, and that it would be necessary to cover the range of plutonium isotopes up to 242 in order to calibrate a mass spectrometer properly. Debus also stated that the quantity of material required for this exercise would depend considerably on the number
of laboratories who were willing to participate; it was also true
that chemical assay imposed a larger minimum quantity limit, in
general, than mass spectrometric requirements. He pointed out also
that the accuracy of the measurements would, of course, increase in
proportion to the number of laboratories participating in the measure-
ments. In view of the high cost of the isotopes involved it was
suggested that Spaepen and Debus should prepare a brief summary of
the minimum quantities of the isotopes with which they thought they
could manage, and the matter could then be further considered by the
Committee. Some Committee members asked Spaepen and Debus also to
consider whether the high isotopic purity of source material which
they specified was in fact justified by practical considerations of
the accuracy with which measurements would ultimately be required
for reactor programmes and justified the elaborate work required in
preparation of the starting material. Spaepen proposed that in the
meantime they should attempt to contact various laboratories who
might be willing to participate in the programme, of exchanging
samples for the purpose of inter-comparison; the setting up of exact
standards could occur at a considerably later date.

(iii) National Physical Laboratory (U.K.)

Dr. P.J. Campion, briefly introducing his report on the
work in progress and proposed at the National Physical Laboratory,
stated that at NPL experience was sadly lacking in the nuclear
energy field. In order to improve this position they had now
ordered a 3 MV Van de Graaff (to be applied mainly to neutron dosi-
metry); it was hoped that at a later stage this machine might be
applied to certain aspects of the cross-section measuring programme.
They also had considered acquiring an electron linac but this would
not be ordered for a year or two. Spaepen asked what the specifi-
cation of this accelerator would be and Campion replied that its
energy would be 10 MV, this limit being derived from the maximum
energy of gamma-rays associated with reactors since the instrument
would be used to a considerable extent for the standardization of
reactor instrumentation. This machine would include facilities for
neutron studies in addition to the gamma-ray work referred to. In reply to a further question from Spaepen, Campion stated that there was no mass spectrometry group at NPL, but that the National Chemical Laboratory (nearby) had sometimes helped in mass-spectrometry work in the past. Kofoed-Hansen commented on the great difficulty of some of the problems of dosimetry; for example, there were many requests for "in-pile" dosimetry involving problems which were as yet completely unsolved.

7. FOIL AND TARGET PREPARATION AND EXCHANGE

7(a) Fission Foil Exchange Scheme (EANDC-(E)26)

Spaepen reported that arrangements for the Bureau Central de Mesures Nucléaires to take over this scheme from Oak Ridge had been agreed and that he had now contacted laboratories in the Euratom area with the view to asking them to participate in the fission foil exchange. So far only the Belgian laboratory at Mol and BCMN (Euratom), Geel, have shown an interest in this scheme. The Belgian laboratory had in fact prepared U-235 foils, both on standard platinum discs provided and also on aluminum. There might be a few months delay in comparison of these foils due to a reactor shutdown necessitated by a Wigner release. This comparison will be carried out by BCMN (Euratom). Fission foils required for exchange in the general fission foil exchange scheme had been prepared and within a period of three to six months should be ready for exchange with other laboratories.

7(b) Foil and Target Preparation Centre

(i) At ORNL

Harvey stated that it was not quite true to say that in the past the Oak Ridge Laboratory had not engaged in any target preparation; although preparation facilities were on a small scale there had been some work in which, for example, material stored as oxides had been reduced to metals and in which foils and evaporated targets had been prepared. Kolstad presented material on the proposed improvement in this target and foil preparation facilities at Oak Ridge National Laboratory (see Appendix XI). The actual costs
of preparing targets and foils would be borne in general by the customer and therefore this aspect of the activities would be self-supporting. On the other hand, these activities would be backed up by a research and development programme which had a budget of between fifty to a hundred thousand dollars per annum.

(ii) **Euratom - EANDC-(E)27**

Spaepen then introduced EANDC-(E)27. The proposals in this document had been made after discussion in the Euratom data group where the plan had been received well. The proposal was based on the assumption that the feed material in the form of separated isotopes could be obtained in the United States and the United Kingdom. The facilities of stage I, it was thought, would certainly be adequate for Euratom and probably for all European users. The facilities proposed in stage II were designed to be sufficient to cover EANDC users. The main reasons for having this centre at Geel was that this laboratory was already well equipped for high precision measurements in the fields of chemistry, mass spectrometry, and optical spectroscopy. The Euratom Commission had approved an expenditure (purely on equipment) of £360,000 and a staff of 24 people. The laboratory had already made plutonium samples and also thin foils of gold, boron and dysprosium. Standard solutions were also being prepared of gold, hafnium, silver, and caesium. Thin foils of organic material of large diameter have been coated with uranium by cathodic sputtering. A special evaporation unit was being developed for the preparation of thin foils of plutonium. At the moment there were six members of the staff engaged in the preparation of samples and five on the assay work. Spaepen continued that the decision on whether to start stage II would depend on the results of the questionnaire sent out to members of the EANDC by Taschek. Taschek asked Spaepen what would be the Euratom attitude of the target preparations facilities at Oak Ridge were greatly expanded; would they, for example, drop or curtail stage II? Spaepen said that while stage II would not be dropped altogether it would in all probability be somewhat reduced. Bretscher stated that the United Kingdom might be able to reduce its own efforts on
foil and target fabrication if some firm commitment were available regarding the ability of the proposed foil target preparation centre to meet the needs of the United Kingdom. Taschek thought that without experience it was very difficult to say with what volume of work the staff proposed could cope. The planning of stage II should be deferred at least until the replies of various countries which were to state their requirements were received and perhaps until stage I was functioning smoothly. Spaepen also stated that a proposal to build a very high resolution mass separator was being considered, but would not be yet a firm project. It would upgrade already-separated materials. Questions were then asked about methods of payment for foils and targets prepared both at Oak Ridge and at Euratom Foil and Target Preparation Centre.

8. CONSIDERATION OF DISCREPANCIES

8(a) Cross-section Discrepancies

Goldstein complained that so far he had had very little response to the request to bring to his notice cross-section discrepancies. Spaepen stated that his laboratory was making surveys of the existing data in the field of \((n,p)\) \((n,a)\) and other threshold reactions. This project was being carried out for twelve elements, it was well advanced and it was hoped to circulate the material to members within a period of the order of a month. The survey already existed but had to be translated yet into English. It was agreed to supply a copy to Goldstein in its original language. In reply to a question concerning the list of cross-sections contained in the Chalk River report AECL-1181 (cited in EANDC-(CAN)9, page 2 (top)) Westcott agreed that the list covered rather a similar field. The document quoted had already had a wide circulation ("standard AECL distribution") but he agreed to supply a copy personally to Goldstein. Goldstein also stated that he had discovered that there was an AWRE report on this topic and asked whether this could be circulated to the Committee. After some discussion Spaepen agreed that he would write up and send to Goldstein discrepancies which arose in studies in his laboratory of the available data. Beckurts mentioned that a number of discrepancies were discussed in Schmidt's EANDC-(E)21 and
in earlier versions of this document. He agreed to recheck these discrepancies and to send a list of them to Goldstein.

Taschek pointed out that in general, before raising a matter as a discrepancy, it was probably worth while to enter into correspondence with the original authors of the data. He cited the discrepancy pointed out in EANDC-(E)21 on page 10 with regard to $\alpha$ and $\bar{\nu}$ for Pu-239, quoting Diven as saying that the way these measurements had been made the discrepancy between them might lie within the possible range of error. Sjöstrand pointed out that the recent measurements of the resonance integral of zirconium described in EANDC-(OR)15, in which they had gone down to sample thicknesses as small as 0.2 mm, had largely removed the discrepancies in this quantity. Westcott expressed interest (he had not yet received his copy) but cited the Canadian report CRRP-1006 and asked how well the departures from the $1/E$ law of the spectrum in the measuring location were known. He agreed to send Sjöstrand a copy of CRRP-1006, so that the point could be considered. In connection with the total cross section of sodium, Meier said that he would check and see what corrections should be made to his measurements due to the angular distribution of the scattered neutrons and due to the gamma rays from inelastic scattering.

8(b) Non-Cross Section Discrepancies

Beckurts pointed out a new discrepancy which resulted from recent measurements of the diffusion length of thermal neutrons in water. Measured values of this quantity now ranged all the way from 2.68 to 2.86 cm. This was all the more disturbing since previously this quantity had seemed to be settling around 2.7, but a new measurement at KAPL gave a value of 2.86 while De Juren obtained a value of 2.80.

9. REQUESTS FOR MEASUREMENT

9(a) Philosophy Underlying Requests ("Background" Documents): EANDC-(CAN)9 (Part II), EANDC-(E)21

Dr. Beckurts introduced EANDC-(E)21 (Nuclear data needs for fast and intermediate reactor calculations) emphasizing that this
document represented primarily background information only and not their request list. Requests originating at Karlsruhe were included in the joint Euratom request list (EANDC-(E)20). The requests related to the (E)21 background document were much the same as those of other fast reactor groups, but differed somewhat in placing a greater emphasis on resonance region data; for calculating the Doppler effect, fission and radiation widths in the kilovolt region were needed.

9(b) Detailed Consideration of Combined Request List
(EANDC-13) - Priority I Items Only

The corresponding secretary (Joly) and Perret have undertaken to produce shortly a revised version of EANDC-13, incorporating information notified at the meetings; these minutes therefore include only main points in the discussions, not mere facts (additional to or amending those in the document) brought out at the meeting.

D : $\sigma_{n,2n}(E)$. Request met by work (in Phys. Rev.) by Livermore Radiation Laboratory.

H$_2$O, D$_2$O, Be, BeO and UO$_2$: $\sigma_{n,n'}(E,E')$ and $\sigma_{n,n'}(E,E',\theta)$.

Measurements are under way at Chalk River (Egelstaff, A.E.R.E., or contact via Westcott).

D$_2$O: $\lambda_{tr}$ as a function of T. Kolstad agreed to ask whether the Savannah River group could measure this.

Li$^6$: $\sigma_{n,n}$. See Phys. Rev. 115, 1959 (Murray and Schmidt).

Be: $\sigma_{n,2n}(E,E')$. See Livermore paper (Phys. Rev. 1961) for $\sigma(E)$; Goldstein cited Levin and Cranberg for $\sigma(E,E')$ measurements and Meier work at Basel University.

Be: $\sigma_{nD}$ is needed to know whether further purification of Be is needed.
Bonner’s data were stated to be fragmentary.

Phillips had now made measurements at energies of between 3 and 4 MeV at intervals of 100 KeV. Sayres (Columbia University) had measured angular distribution with very fine energy steps using an ion chamber. Owing to some difficulties in the energy calibration of the Columbia Van de Graaff he wishes to repeat this measurement. Goldstein pointed out that measurements of elastic scattering angular distributions made using ion chambers or proportional counters, suffered from the disadvantage that small angle scattering corresponded to low energy recoils so that the distribution could not readily be measured at recoil angles less than $\sim 50^\circ$. Goldstein cited an apparently quite large discrepancy in this quantity; so far he had received the data but had not yet completed his review. Taschek pointed out that the request for an angular distribution with one-degree angular steps would take an inordinate amount of experimental time. Goldstein doubted very much if measurements at such small angular steps were required; if angular distributions were expressed in terms of Legendre polynomials, orders up to 10 could be obtained (mathematically at least) from data taken at steps of between 0.1 and 0.2 in $\cos \theta$.

Taschek stated that Dr. DeJuren at Los Alamos had measured this quantity for energies from 10.5 MeV to 17 or 18 MeV; these measurements were in the course of completion and he thought that they would probably meet the request (v. Appendix XVII).

Goldstein cited the angular distribution measurements of Lane, Langsdorf et al; extending in energy up to 2.3 MeV; the first term in their series of Legendre polynomials gave the total
cross section. Also Towle and Gilboy (AWRE) had measured this to 3%. It was concluded that this request could be deleted.

Na: $\sigma_{n,n}'(E,\gamma')$. Paul stated that Towle and Gilboy data were available at 1, 1.5, 2.5, and 4 MeV.

Na: $\sigma_{n,\gamma}(E)$, epithermal. Joly asked for a detailed knowledge of the resonance parameters (especially $\gamma$) up to 1 MeV.

Mg: $\sigma_{n,p}(E)$. Spaepen remarked that measurements existed in the range of 12.5 to about 19 MeV. Taschek stated that to cover the region requested (8 to 12 MeV) a Tandem Generator would be necessary.

Paul stated that the Aldermaston Tandem Generator group had measured the cross-section for Sc(n,2n) for 13 to 15 MeV (this is the first element in their programme).

S: $\sigma_{n,p}(E)$. Spaepen noted that there was a considerable discrepancy near threshold. Taschek questioned the need for accuracy near threshold where the cross-section was extremely small and where resonances made high accuracy difficult to obtain. He felt that accuracy requested in such cases should be expressed $\pm \times\%$ or alternatively $\pm n$ milli-barns. Paul also felt that lower accuracy should be demanded in the higher part of the energy range, on the grounds that high accuracy was difficult to obtain at higher energies (except at 14 MeV) and there were not many fast neutrons in the fission neutron spectrum.

Fe: $\sigma_{n,n}(E,\theta)$. Goldstein pointed out that the requests from Livermore Radiation Laboratory should have been attributed to Dr. Murrey Goldberg. He again pointed out that the one-degree steps requested under sub-heading (d) were unnecessary. Paul pointed out that
elastic scattering measurements were in progress at AWRE and so far had been done up to 2 KeV.

Fe: \( \sigma_{n,\gamma} \). The Harwell results cited were to be published in Nuclear Physics shortly; the delay in publishing had been due to the computation of a multiple scattering correction. Paul stated that the results of Montague and of Day at Los Alamos now agree well. Paul further stated that in general very few inelastic scattering results had been corrected for multiple scattering and those not so corrected might be up to 30% high, the exact magnitude of this correction depending on the details of the experimental geometry.

Fe: \( \sigma_{n,\gamma} \). Columbia would study resonances in the KeV region.

Co: resonance parameters. Dr. Harvey stated that for the 130 eV resonance in cobalt (Dr. Jain of BNL at Chalk River) \( \Gamma_\gamma \) had been measured to accuracy of about 6%.

Ni-58: \( \sigma_{n,p}(E) \). Paul stated that this cross-section had been measured at AWRE at 9 energies between 2 and 14 MeV. (EANDC-(UK)10, p. 5). CEA, CBN, and KFK wished to add the request \( \sigma(n,2n) \) for Ni-58 for threshold to 14 MeV to an accuracy of \( \pm 5\% \).

Ni-60: \( \sigma_{n,p}(E) \). It was agreed to delete this request, which is not priority I.

Zr: \( \sigma_{n,\gamma} \), also resonance integral. It was agreed by Dr. Sjöstrand that these requests could be withdrawn (cf. EANDC-(OR)15).

In-115: resonance integral. Swedish work will be described in the (OR) progress report, and Spaepen will intercompare results (also for activation request, p. 6 of EANDC-13) in preparing his compilation.
Westcott considered this a difficult request and was also in some doubt as to whether it should be priority I. The thermal discrepancy was almost within experimental errors and for a reactor value see Can. J. Phys., 27, 531, 1959.

**Xe-135: Yield (from U-235 fission).** It was agreed to delete this request.

**Xe-135: Yield (from U-238 fission).** Westcott doubted whether this ought to be priority I as the effect was quite a small one in thermal reactors. It was agreed to reduce the priority of this to delete it from the compilation of priority I requests.

**Pb-206, 208: $\sigma_{n,n'}(E,E' \gamma)$**. Taschek stated that Day at Los Alamos had almost completed these measurements using enriched samples of these lead isotopes. He understood that these samples on the completion of these measurements were to be transferred to Harwell where further measurements would be made using the pulsed Van de Graaff facility.

**Th-232: $\sigma_{n,\gamma}(E)$**. Certain people in the reactor field in the United States were worried about the uncertainty of this important cross-section, especially below 100 eV. They had presented their case to Professor W.W. Havens who had written to Dr. Rae asking him if he could measure this quantity on the AERE Linac. Bretscher stated that Rae was making these measurements in the energy range 300 eV to 2 KeV, and resonance parameters were at present being deduced.

**Pa-233: $\sigma_{n,\gamma}(E)$, 0.025 eV to 500 eV.** Taschek stated that the sample required for this measurement would have to be produced by the irradiation of thorium, but the shielded chemical facility
needed was not yet completed. However, a preliminary measurement had been made using the MTR fast chopper by using the irradiated thorium as a sample and comparing its transmission with that of unirradiated thorium. Harvey added that using this method, five resonances had been observed and their parameters measured. He understood that the data obtained in this measurement would be communicated to the requestors, asking them whether it would suffice for their purposes and pointing out that it would be more than a year before separated Pa-233 would be available for a better measurement.

(i) Elements Z ≥ 92

$U_{\text{nat}}: \sigma_{n,T}(E)$. Beckurts stated that they now considered this request should be for U-238.

$U-233: \bar{\nu}$. Measurements of this quantity would be made at AERE; at present absolute measurements to 1-1/2% are available (Sowerby and Colvin).

$U-233: \eta$. Paul stated that the ratio of $\eta(U-233)$ to $\eta(U-235)$ had been measured using the boron pile at Harwell giving the result $1.091 \pm 0.015$. Taschek stated that U.S. requests for $\eta(U-233)$ had been withdrawn.

$U-233: \sigma_f$, Thermal. Paul stated that Maslin at AWRE was intending to measure this.

$U-233: \sigma_f$, (5 eV to MeV region). Bretscher stated that this quantity had been measured at AERE between 0.7 and 700 eV. AWRE is also to do this and at Saclay (preliminary) results are almost complete.
Taschek stated that Dr. Diven (Los Alamos) was making measurements of $\eta$ for U-233 at energies up to 1 MeV; in this energy region separate measurements had to be made of $\overline{\nu}$ and $\alpha$ to give a computed value of $\eta$. Replying to Beckurts, Taschek stated that an upper energy limit not far above 1 MeV neutron energy was dictated by the shielding of the large scintillator tank used in these measurements. When the apparatus was moved to the large Van de Graaff, the opportunity would be taken to improve the shielding and measurements might then be extended to higher energies.

**U-235: $\overline{\nu}$**. Paul stated that absolute measurements to 1.5% had been made by Sowerby and Colvin (AERE); with another technique, Moat (AWRE) had also measured this quantity and his results now agreed with those of Sowerby and of Diven. (Values quoted in meeting were 2.41 and 2.416).

**U-235: $\eta(E)$, thermal to 150 KeV.** It was stated that Brooks' (AERE) measurements were now finished and were being written up. (v. EANDC-(UK)10 p. 9 Sec. 6A4).

**U-235: $\sigma_{nf}$**. It was stated that Maslin (AWRE) was making this measurement at thermal energy. Kofoed-Hansen stated that at his laboratory they were considering using a slow chopper to make absolute measurements of the cross-section for the reaction He$^3$(n,p) and it was felt that once this measurement had been made it would be possible to derive a measurement of the fission cross-section of U-235 at the same energies. Beckurts proposed that a request be added for $\alpha(E)$ in the energy range 10 eV to 10 KeV with an accuracy of 5% (requested by KFK).
U-235: $\sigma_T$. Beckurts added a request (from KFK) for this quantity within the range 100 eV to 10 KeV to an accuracy of 5%. Goldstein asked whether this request required good or poor resolution, pointing out that at 1 KeV he had estimated that Doppler effect was of the same order of magnitude as the level separation. Below 1 KeV older measurements had too poor a resolution to resolve resonances. In discussion Joly pointed out that the reduction of the Doppler effect by cooling the sample was limited by the Debye temperature (e.g. for metallic uranium, at 100 eV: half width of the resolution function for 1 ns/m is 27 mV; half width of the Doppler effect at room temperature is 350 mV, and is reduced only by a factor about 2 at helium temperature).

U-235: $\sigma_{n,f}(E)$. This quantity will be measured at AERE in the energy range 10 eV to 30 KeV.

U-238: $\sigma_{n,T}$. Harwell results (Uttley, Saclay symposium paper) may have satisfied this request.

U-238: $\sigma_{n,n}$. Beckurts said (cf. - (E)20) $\sigma(E)$ was wanted for 2-10 MeV and $\sigma(E,E_j)$ with 10% accuracy to 1 MeV.

The action (unnumbered in EANDC-10, but see p. 23 (middle) of that document) was also discussed at this point. Dresner had written to Harvey as follows:

"1) The measurements of Cranberg and Levin (Phys. Rev. 102, 2063 (1958) and Smith (EANDC-(US)15) check with Dresner's calculations up to 1 MeV, with the exception that at one MeV the experimental cross-section for the $2^+$ level at 44 KeV seems a little low. This discrepancy probably arises because the energy resolution is not sufficient to resolve this neutron group from the elastically scattered neutrons."
2) There are several levels in U-238 at an excitation of 700-800 KeV, which have not as yet been experimentally resolved. It would be desirable to have experimental data for these different levels to compare to his theoretical calculations.

3) However, it appears that the inelastic cross section data up to 1 MeV are sufficient to satisfy reactor requests."

Beckurts said he still felt they needed the data listed in -(E)20; he also noted that in EANDC-13, last U-238 item, \( E_\gamma \) (which occurs twice) was a misprint for \( E_j \), the energy of level \( j \).

\( \text{UO}_2: \sigma_{n,n} (E,E') \), thermal. This item should be for U-238 oxide and the U.K. request should be to 1500°C. Work on this has been started at Chalk River.

\( \text{Pu-239}: \gamma,\alpha,\sigma_f \). AWRE also plans to measure \( \sigma_f \) (v. p. 17, EANDC-(UK)10) as well as \( \alpha \) (ibid., p. 1; this is for Maxwellian neutrons).

Spaepen said BCMN is also continuing Pu-239 work with the 4\( \pi \) fission chamber (EANDC-10, p. 23). The problems of measuring \( \gamma(E) \) for Pu-239 on the Linac at AERE were being studied, but the amount of material needed presents a hazard. See also -(UK)10, Sec. 8 B2.2; after U-233 and U-235, James will attempt Pu-239; Diven has suspended \( \alpha(>1 \text{ MeV}) \) work for a time which will probably last another twelve months.

Pu-239: \( \sigma_T \) and \( \sigma_f \). Discussion centred on the requestors' comments, where \( \pm 5\% \) accuracy was asked for. Beckurts will check what resolution (\( \mu s/m \)) would suffice. These may be measured on AERE Linac after U-233, U-235. Westcott asked why the U.K. request for \( \sigma_f \) (< 0.05 eV) was \( \pm 3\% \) when 1/2 to 1\% was asked for at 0.0253 eV.

\( \text{Pu-240}: \sigma_{n,\gamma}(E) \) is a sample problem; 10 gm needed for tank method and background may render method impossible. Activation is also
difficult (very soft $\beta$). $\sigma_T$ is probably also a sample problem (above Bollinger's maximum energy).

Pu-241: $\sigma_{n,f}$ and $\sigma_{n,\gamma}$. Beckurts said the KFK request was to 120 KeV, not 12 MeV and was for $\sigma_{n,f}$ only (not $\sigma_{n,\gamma}$). MTR and AECL are measuring $\sigma_T$, and MTR $\sigma_f$ also. See also - (UK)10, p. 15 (James, 3 eV - 20 KeV).

The requests for Pu-241 fast neutron data were academic at present due to the sample position.

\((\text{Temperature}), \text{fissile isotopes}\). Hector may do when ready.

Spaepen introduced an additional request (post-deadline, from Delft), for values of $\xi$ and $\sigma_{\text{non-el}}$ for 0.01 eV to 10 MeV for Ca, Ti, Si, V and S (Goldstein said that some data existed except for V and Ti).

(ii) \textbf{On lower priority and other request items} \\
\textbf{(E}_n<1\text{ MeV)}

Westcott mentioned $\sigma_{n,\gamma}(\text{U-238}) - 2200$ m/sec, which was not well documented; Sjöstrand and Story promised to supply a copy of their study covering this point.

Westcott also pointed out the class of fission products (cf. requests in -(CAN)9, also -(CAN)3). Goldstein cited the Fe resonance integral (old value much larger than deduced from res. parameters). Rosen's (Columbia) p-wave resonance work was also mentioned as contributing to knowledge of total $(n,\gamma)$ reaction rate.

(iii) \textbf{(E}_n>1\text{ MeV)}

Goldstein said there were whole classes of requests in this field which were difficult, especially angular distributions and the energy range below 14 MeV. Mainly the shielding requests were category II; Paul said the U.K. had provided a II(a) category which comprises
11. PRODUCTION OF SPECIAL ISOTOPES

11(c) Status of Problem of Obtaining Pure Pu-239

The discussion centred round the problem of obtaining a quantity of the order of 500 grams of Pu-239 which contained less than 0.5% of Pu-240. Harvey stated that this material had originally been of interest to Egelstaff who wished to measure the total cross-section of plutonium in the region around 1 eV where Pu-240 had a very large resonance. It was for this projected experiment that the quantity of 500 grams was decided upon. In addition there were demands from Euratom Countries for quantities of the order of 100 milligrams. Three sources of possible supply of this material were suggested, namely, the Belgian reactor BR1, the fuel from the Halden reactor, and for small quantities, material deposited in the pockets of EM separators set up to give the higher isotopes of plutonium.
13. OTHER BUSINESS

13(a) Proposal for the Transfer of Items on the Agenda of the Tripartite Nuclear Cross-Sections Committee to the Agenda of EANDC

A letter, included as Appendix X to these Minutes, from Bretscher (Chairman of TNCC) had been received by Taschek (Chairman of EANDC) setting out in detail items recommended for transfer from the TNCC to become functions of the EANDC. Taschek drew particular attention to Items 4 and 5 of this note, namely the consideration of discrepancy lists and request lists; these matters, he said, were very basic to the whole functioning of the Committee. It was agreed to accept all the items at EANDC functions.

14. DATE AND PLACE OF 4TH MEETING OF EANDC

It was decided to hold the next meeting in Italy. The first two days of the meeting, the 5th - 6th April, 1962, being held in Casaccia, near Rome. The meeting would then adjourn for the weekend and reconvene at Ispra on the 9th - 10th April, 1962.

15. ADJOURNMENT

Votes of thanks were proposed by Sjöstrand to the Chairman and Secretaries for their efficient work during their period of office. Dr. Meier proposed a vote of thanks to Sjöstrand and Paul for their services during the past two years since both were now retiring from the Committee.
APPENDIX I

LIST OF GENERAL DOCUMENTS

submitted at the third meeting, Harwell

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<th>No.</th>
<th>Classification</th>
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<tr>
<td>EANDC-11</td>
<td>U</td>
<td>List of Facilities</td>
<td>R.P. Perret</td>
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<tr>
<td>EANDC-12</td>
<td>L</td>
<td>Report of Sub-Committee on Resonance Integrals</td>
<td>J.A. Harvey</td>
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<td>EANDC-13</td>
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<td>Compilation of EANDC Priority I Requests</td>
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APPENDIX II

LIST OF CANADIAN DOCUMENTS
submitted at the third meeting, Harwell

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<td>C.H. Westcott</td>
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<td>TNCC-(CAN)31</td>
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<td>Report and List of Requests for Measurements.</td>
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<td>EANDC-(CAN)10</td>
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<td>Elastic and Inelastic Scattering of 14 MeV Neutrons from Carbon, Magnesium and Sulfur</td>
<td>R.L. Clarke</td>
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<td>TNCC-(CAN)32</td>
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<td>EANDC-(CAN)11</td>
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<td>The Ratio of Neutron Capture to Fission in U-235</td>
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<td>TNCC-(CAN)33</td>
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### APPENDIX III

**LIST OF EURATOM DOCUMENTS**

submitted at the third meeting, Harwell

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<td>EANDC-(E)18</td>
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<td>A Survey of Neutron Cross Section Values for the Li(n,α) H(^3) Reaction</td>
<td>C. Beets, G. Gierts</td>
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<td>EANDC-(E)19</td>
<td>U</td>
<td>Measurement of the Capture Cross Section of Gaseous Neon</td>
<td>J.C. Carre, M. Robin, R. Vidal</td>
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<td>L</td>
<td>Compilation of Requests for Nuclear Cross Section Measurements from Euratom Countries</td>
<td>J. Spaepen</td>
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<tr>
<td>EANDC-(E)21</td>
<td>U</td>
<td>Nuclear Data Needs for Fast and Intermediate Reactor Calculations</td>
<td>J.J. Schmidt</td>
</tr>
<tr>
<td>EANDC-(E)23</td>
<td>L</td>
<td>Progress Report on Nuclear Data Research in the Euratom Community</td>
<td>J. Spaepen</td>
</tr>
<tr>
<td>EANDC-(E)24</td>
<td>U</td>
<td>Establishment of Precise Standards for Isotopic Analysis of Stable and Fissile Isotopes</td>
<td>J. Spaepen</td>
</tr>
<tr>
<td>EANDC-(E)25</td>
<td>A</td>
<td>Euratom Request List for Samples</td>
<td>J. Spaepen</td>
</tr>
<tr>
<td>EANDC-(E)26</td>
<td>L</td>
<td>TNCC - Fission Foil Exchange Scheme. Proposed Specifications for U-235 Foils</td>
<td>A. Prosdocimi</td>
</tr>
</tbody>
</table>
Installation at the Central Bureau for Nuclear Measurements, Euratom, OEEC, Belgium, of a Central Laboratory for the Development, Fabrication and Distribution of Foils, Targets and other Samples for Nuclear Measurements
### APPENDIX IV

**LIST OF OTHER OEEC COUNTRIES AND ENEA DOCUMENTS**

submitted at the third meeting, Harwell

<table>
<thead>
<tr>
<th>No.</th>
<th>Classification</th>
<th>Title</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>EANDC-(OR)11</td>
<td>U</td>
<td>The design of the electromagnetic isotope separator of the S.G.A.E.</td>
<td>F. Viehböck</td>
</tr>
<tr>
<td>EANDC-(OR)12</td>
<td>U (nfp)</td>
<td>Measurement of $\overline{\nu}$ in Fast Neutron Fission of Th-232 and U-238.</td>
<td>H. Conde, N. Starfelt</td>
</tr>
<tr>
<td>EANDC-(OR)13</td>
<td>A</td>
<td>Proposals for Sponsored Measurements in Certain European Countries</td>
<td>L. Kowarski</td>
</tr>
<tr>
<td>EANDC-(OR)14</td>
<td></td>
<td>Report not yet issued</td>
<td></td>
</tr>
<tr>
<td>EANDC-(OR)15</td>
<td>U</td>
<td>A Study of the Resonance Integral of Zirconium</td>
<td>E. Hellstrand, G. Lindahl, G. Lundgren</td>
</tr>
<tr>
<td>EANDC-(OR)16</td>
<td>L</td>
<td>List of Requests from Denmark and Sweden</td>
<td></td>
</tr>
<tr>
<td>EANDC-(OR)17</td>
<td>A</td>
<td>Status of Proposed Chopper Measurements of Neutron Spectra</td>
<td>N.G. Sjöstrand</td>
</tr>
</tbody>
</table>
APPENDIX V

LIST OF UNITED KINGDOM DOCUMENTS
submitted at the third meeting, Harwell

<table>
<thead>
<tr>
<th>No.</th>
<th>Classification</th>
<th>Title</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>EANDC-(UK)10</td>
<td>U (nfp)</td>
<td>Progress Reports to the U.K. Nuclear Reactor Data Committee A.E.R.E. Harwell, 9th May, 1961</td>
<td>A.T.G. Ferguson</td>
</tr>
<tr>
<td>NRDC 135</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EANDC-(UK)11</td>
<td>L</td>
<td>The programme of the National Physical Laboratory in the Radiological and Nuclear Energy Fields</td>
<td>P.J. Campion</td>
</tr>
<tr>
<td>EANDC-(UK)12</td>
<td>A</td>
<td>Suggestion for Neutron Beam Source Experiments to be Sponsored by EANDC</td>
<td>P.A. Egelstaff</td>
</tr>
</tbody>
</table>
### APPENDIX VI

**List of United States Documents submitted at the third meeting, Harwell**

<table>
<thead>
<tr>
<th>No.</th>
<th>Classification</th>
<th>Title</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>EANDC-(US)19 U</td>
<td>Report to the AEC Nuclear Cross Section Advisory Group</td>
<td>J.A. Harvey</td>
<td></td>
</tr>
<tr>
<td>WASH 1031</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UC 34 Phys.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EANDC-(US)20 U</td>
<td>Off-site Nuclear Cross Sections Measurement Program</td>
<td>USAEC</td>
<td></td>
</tr>
<tr>
<td>EANDC-(US)21 U</td>
<td>Stable Isotopes Cross Section Research Pool Inventory</td>
<td>USAEC</td>
<td></td>
</tr>
<tr>
<td>EANDC-(US)22 A</td>
<td>Tentative Changes in the Discrepancy Compilation (EANDC-9)</td>
<td>H. Goldstein</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX VII

POSSIBLE PA-233 MEASUREMENTS AT ORNL

BY

J. A. HARVEY

The main problem in the measurement of the Pa-233 neutron cross section, particularly in the thermal energy range, is the preparation of an adequate sample or samples. Attached is a memo from F. L. Culler on the feasibility of preparing such a sample at ORNL.

The ORNL fast chopper spectrometer is not at present capable of handling highly radioactive samples and a hot sample changer would have to be built. Also, for measurements in the thermal energy range, it would be desirable to have a new rotor designed for thermal energy cross section measurements. This new rotor would also be designed to handle very small area samples ~0.01 cm². The present rotors are designed for transmission measurements for samples ~0.1 and ~1 cm².

The cost of a new rotor and hot sample handling facility would be small compared to the cost of producing the sample. Also, the time required for such chopper modification would be less than that required to produce the sample.

July 11, 1961
INTRA-LABORATORY CORRESPONDENCE
OAK RIDGE NATIONAL LABORATORY

July 10, 1961

To: J.A. Harvey
From: F.L. Culler

Subject: Preparation of Pa-233 Samples for Cross-Section Measurements

In answer to your request we have made a brief study of the feasibility of preparing 100 mg Pa-233 samples for cross-section measurements. It is possible with present facilities at ORNL to make the Pa-233 by irradiating small samples of thorium metal in the ORR. A hot cell could be made available for the necessary chemical separations and loading the sample holder. However, considerable development work and design effort will be necessary to devise a satisfactory method of loading the Pa-233 into the sample holder because of the intense radiation and thermal heating of this short-lived isotope.

At fluxes available in the ORR it will be possible to produce 100 mg of Pa-233 by irradiating 10-g samples of thorium metal for approximately one month. This will produce only small quantities of U-233 and fission products compared to the Pa-233. The sample can then be dissolved and the Pa-233 isolated essentially pure by anion exchange using chloride solutions. The chemistry of this separation has been worked out and would require little additional development. For instance, it should be possible to obtain the 100 mg of Pa-233 with less than 1% U-233, an equal amount of thorium, and no significant rare earths. However, the problem of obtaining the solid Pa205 and compacting it into the sample holder with the required geometry and homogeneity for the measurements will require some development work. The thermal heating, about 4 watts per 100 mg, and the radioactivity, 2000 curies per 100 mg, precludes ordinary methods of sample preparation. One possibility is to precipitate the protactinium from solution as the hydroxide and collect it on a filter built into the sample holder. The hydroxide could then be calcined to the oxide in the holder and compacted to a suitable density for the cross-section measurements. The development of such a method would require considerable experimentation to ensure its success, and a considerable amount of design would be required to provide facilities for safely transporting and handling the highly radioactive sample.

If sufficient interest exists for these samples, we will be happy to carry out the scouting work necessary to define the problems and prepare a cost estimate.

Original signed by
F.L. Culler
APPENDIX VIII

\( \bar{\nu} \) and \( \frac{d\bar{\nu}}{dE} \) as a Function of Energy for \( ^{233}U \), \( ^{235}U \), and \( ^{239}Pu \)

B.C. Diven and J.C. Hopkins

<table>
<thead>
<tr>
<th>Isotope</th>
<th>( E_n )</th>
<th>Prompt Neutrons Per Fission</th>
<th>Delayed Neutrons Per Fission</th>
<th>Total ( \bar{\nu} )</th>
<th>( \frac{d\bar{\nu}}{dE_n} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( ^{233}U )</td>
<td>Thermal</td>
<td>2.440 ± 0.041</td>
<td>0.007</td>
<td>2.447 ± 0.041</td>
<td>0.126 ± 0.014</td>
</tr>
<tr>
<td></td>
<td>4.0 MeV</td>
<td>2.943 ± 0.040</td>
<td></td>
<td>2.950 ± 0.063</td>
<td></td>
</tr>
<tr>
<td>( ^{235}U )</td>
<td>Thermal</td>
<td>2.414 ± 0.030</td>
<td>0.016</td>
<td>2.430 ± 0.030</td>
<td>0.122 ± 0.008</td>
</tr>
<tr>
<td></td>
<td>4.0 MeV</td>
<td>2.903 ± 0.048</td>
<td></td>
<td>2.919 ± 0.048</td>
<td></td>
</tr>
<tr>
<td>( ^{240}Pu )</td>
<td>-6.28 MeV</td>
<td>2.167 ± 0.036</td>
<td>0.009</td>
<td>2.176 ± 0.036</td>
<td>0.098 ± 0.005</td>
</tr>
<tr>
<td>( ^{239}Pu )</td>
<td>Thermal</td>
<td>2.785 ± 0.046</td>
<td>0.006</td>
<td>2.791 ± 0.046</td>
<td>0.158 ± 0.012</td>
</tr>
<tr>
<td></td>
<td>4.0 MeV</td>
<td>3.415 ± 0.063</td>
<td></td>
<td>3.421 ± 0.063</td>
<td></td>
</tr>
<tr>
<td>( ^{252}Cf )</td>
<td>Spont. 1</td>
<td>3.723 ± 0.051</td>
<td>0.032</td>
<td>3.755 ± 0.051</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spont. 2</td>
<td>3.722</td>
<td></td>
<td>3.754</td>
<td></td>
</tr>
</tbody>
</table>

* "U.S. Value", all other points normalized to this. D.J. Hughes et al. BNL 325 Supplement No. 1, p. 4 (1960)

1 \( ^{252}Cf \) Spontaneous fission \( \bar{\nu} \) normalized to "U.S. value" for \( \bar{\nu} \) of \( ^{235}U \)

2 \( ^{252}Cf \) Spontaneous fission \( \bar{\nu} \) obtained from our preliminary absolute measurement.

8th July, 1961
ABSOLUTE VALUES OF $\nu$
NORMALIZED TO THERMAL $U^{235}$ $\nu$ OF $2.43 \pm 0.03$
APPENDIX X

List of subject matters which the TNCC concluded could more profitably be placed before the EANDC.

(1) Fission foil interchange programme; it was recommended that its administration be transferred from ORNL to the Central Bureau of Measurements (Mol) if the parties concerned are agreeable.

(2) Cross section programmes with choppers and accelerators.

(3) Problem of building up supplies of pure Pu-239.

(4) Consideration of combined discrepancy list.

(5) Consideration of combined request list.

(6) Advice on the use of stable isotopes.

(7) General conferences; it is further recommended that the EANDC clear this topic with the International Atomic Energy Agency to prevent overlap.

(8) Publication and review of facility compilations.

(9) Personnel Exchange in general.
APPENDIX XI

UNITED STATES

ATOMIC ENERGY COMMISSION

WASHINGTON 25, D.C.

MEMORANDUM TO: EANDC Members

FROM: George A. Kolstad
Assistant Director for
Physics & Mathematics Programs
Division of Research

Attached is a notice on a target preparation facility which has been established at the Oak Ridge National Laboratory. The services of this facility will be available for EANDC programs. The procedure for requesting services will be the same as that required for loan of research samples from the United States. If possible, requests should be discussed at EANDC meetings for EANDC approval. When it is necessary to obtain services without waiting for an EANDC meeting, the procedure under "Appendix IX" EANDC-5 should be followed. Please note that the requests should be sent to the Division of Research, U.S. Atomic Energy Commission, Washington 25, D.C. (Attention: George L. Rogosa).

Attachment:

ORNL Target Preparation Facilities
ORNL TARGET PREPARATION FACILITIES

The Atomic Energy Commission has recently established a facility at ORNL which will concern itself primarily with the development of procedures and techniques for making targets of normal and isotopically enriched stable elements, uranium, and transuranic elements suitable for research use. The potential applications include the measurement of cross sections and other nuclear properties, studies of radiation damage, and studies of physical properties.

Up to the present time, there has been limited success in fabricating supported and unsupported foils of varying thickness of such elements as Ni, Fe, Sn, Ag, and Pb. In cases where sufficient starting material was available, targets of Mg, Si, Cd, Mo, Cr, and W also have been prepared. It is hoped that in the near future, targets of the rare earths, Hf, V, etc., will also be forthcoming.

The Oak Ridge National Laboratory is interested in receiving information on the requirements for potential uses of these targets—particularly with respect to shapes, forms, thicknesses, etc. For the time being, development work will be limited to AEC programs. In addition to the cost of the isotope involved, charges will include costs for chemical conversions where necessary and for the actual target fabrications.

Delivery on routine items can be made 4 to 6 weeks after receipt of order. Developmental items will usually take somewhat longer, depending upon specific requirements.
APPENDIX XV

Neutron absorption cross-section of U238 at 2200 m/sec.

N.G. Sjöstrand and J.S. Story

The atomic abundance of U238 in natural uranium is 99.274%, and some of the uranium now available commercially contains an even higher proportion of U238.

According to MACKLIN & LYKINS (1951) \( \sigma_{F}[U238] < 0.5 \) millibarn with thermal neutrons. LEONARD & ODEGAARDEN (1960) tried to detect sub-threshold fission at the 6.8 eV resonance, using neutrons from a crystal spectrometer. They concluded that the fission width \( \Gamma_{F} < 0.18 \times 10^{-6} \) eV and inferred that

\[
\sigma_{F}[U238] < 0.02 \text{ millibarn}
\]

at 2200 m/sec. Since no long-lived isomeric state of U239 is known the slow neutron absorption cross-section of U238 should be equal to that for the prompt activation of the U239 ground state, which decays by beta emission with a half-life of 23.5 minutes.

The expected agreement is confirmed by the measurements which are listed in the table below. A variety of methods has been used, but most of the measurements were by comparative experiments in thermal neutron spectra, and we have revised the results as far as possible, using for the reference standards the values listed. For most experiments uranium containing very little U235 was employed (0.03 to 0.003 percent). SMALL (1955) used both natural and depleted samples so that the effect of the U235 could be eliminated. The activation measurement by CROCKER (1955) was corrected by RYVES (1959) who noticed that the small residue of U235 in the sample would give rise to fission-product activities of about the same half-life as U239. RYVES estimated that the original datum is about 0.04 barn too high.

The more recent measurements, since 1954, are in excellent agreement, with a mean value of 2.706 ± 0.025 barns. However two comments are in order:
(i) Most of these measurements were made at Harwell, the samples being drawn from a common stock; EGELSTAFF and colleagues (1954, 1955), CROCKER (1955), SMALL (1955).

(ii) The comparatively high values obtained by POMERANCE (1951) and by HARRIS et al. (1951) have not been explained; indeed POMERANCE records that no impurity could be found. It does not seem justifiable completely to reject these careful measurements. As a weighted mass of all the data we recommend the value

\[ \sigma_{\gamma[U238]} = 2.72 \pm 0.025 \text{ barns} \]

for neutrons of 2200 m/sec. Of this about 1.32 barns is due to the resonance at 6.68 eV, and the remainder is accounted for by more distant resonances at positive and negative energies. The mean resonance spacing D is about 18 eV and the strength function \( \langle \Gamma_n \rangle / D \approx 1.0 \times 10^{-4} \text{ eV}^{-1} \) for slow neutrons. For neutrons of about 0 to 1 eV we may write

\[ \sigma_{\gamma \sqrt{E}} \approx \sigma_{\gamma} \sqrt{E_0} \cdot [1 + a (E - E_0)] \]

with

\[ a = 0.18 \pm 0.01 \text{ eV}^{-1} \]

Hence \( g = 1.0023 \pm 0.0001 \) at 20°C, in the notation of WESTCOTT (1958, 1960).

The epi-cadmium resonance absorption integral is 280 barns, and is exceptionally large in relation to the thermal cross-section.
U238 capture cross-section for neutrons of velocity 2200 m/sec

<table>
<thead>
<tr>
<th>Reference</th>
<th>$\sigma_0^0$ barns</th>
<th>Weight</th>
<th>Method and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRUMMITT et al. (1944)</td>
<td>2.88 ± 0.18</td>
<td>0.03</td>
<td>Activation with Cd-differences, using a natural uranium sample in comparison with manganese. Revised assuming $\sigma_{act}[\text{Mn}] = 13.17$ barns at 2200 m/sec</td>
</tr>
<tr>
<td>HILL &amp; NAGLE (1944)</td>
<td>2.70 ± 0.09</td>
<td>0.1</td>
<td>Activation method using a very thin sample of natural uranium. The fission rate and Np239 activity were compared, giving $\delta_{act}[\text{Np239}]/\delta_F = 0.66 \pm 0.02$</td>
</tr>
<tr>
<td>ANDERSON et al. (1944)</td>
<td>2.77 ± 0.08</td>
<td>0.1</td>
<td>Reactivity measurement in a thermal well using uranium of low U235 content. Cd-ratios determined by activation. Revised using $\sigma_A[B] = 757.7$ barns for the standard</td>
</tr>
<tr>
<td>SEREN et al. (1944)</td>
<td>2.53 ± 0.25</td>
<td>0.01</td>
<td>Activation Measurement</td>
</tr>
<tr>
<td>POMERANCE (1951)</td>
<td>2.91 ± 0.10</td>
<td>0.16</td>
<td>Local oscillator, relative to Au, using samples of very low U235 content. Cd-ratio measured by activation was 29, so the resonance absorption effect $\ll 0.10$ barns. Revised assuming $\sigma_A[Au] = 98.4$ barns at 2200 m/sec</td>
</tr>
<tr>
<td>LEDDICOTTE (1951)</td>
<td>2.83 ± 0.29</td>
<td>0.01</td>
<td>Activation measurements with Cd-differences, using samples of very low U235 content. U239 and Pu239 activities were observed, respectively. Revised assuming $\sigma_{act}[\text{Mn}] = 13.17$ barns and $\sigma_{act}[\text{Co}] = 37.7$ barns at 2200 m/sec for the standards</td>
</tr>
<tr>
<td></td>
<td>3.04 ± 0.31</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>STUDIER et al. (1951)</td>
<td>2.62</td>
<td>0</td>
<td>No details available</td>
</tr>
<tr>
<td>HARRIS et al. (1951)</td>
<td>2.98</td>
<td>0.1</td>
<td>Reactivity measurement in CP3 using a sample of very low U235 content. Cd-ratio measurement by activation method used to correct for resonance absorption. Revised using $\sigma_A[B] = 757.7$ barns at 2200 m/sec for the standard</td>
</tr>
<tr>
<td>Reference</td>
<td>$\sigma_y^0$</td>
<td>Weight</td>
<td>Method and Comments</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------</td>
<td>--------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>HARRIS et al. (1954)</td>
<td>$2.71 \pm 0.05$</td>
<td>0.64</td>
<td>Reactivity measurement in CP3 using a sample of very low U235 content. Cd-ratio measurement by activation method used to correct for resonance absorption. Revised using $\sigma_A[B] = 757.7$ barns at 2200 m/sec for the standard</td>
</tr>
<tr>
<td>EGELESTAFF (1954)</td>
<td>$2.8 \pm 0.1$</td>
<td>0.16</td>
<td>Transmission measurements with a slow-neutron chopper at long wavelengths. Sample of very low U235 content was used</td>
</tr>
<tr>
<td>CROCKER (1955)</td>
<td>$2.71 \pm 0.10$</td>
<td>0.16</td>
<td>Activation in a thermal spectrum with $\sigma_{ct}[Au] = 98.4$ barns at 2200 m/sec as standard. Corrected by RYVES (1959) as described in the text</td>
</tr>
<tr>
<td>SMALL (1955)</td>
<td>$2.72 \pm 0.06$</td>
<td>0.45</td>
<td>Local oscillator in well moderated spectrum. Measurements with natural and depleted uranium allowed elimination of U235 effect. Revised assuming $\sigma_A[MnSO_4] = 13.73$ barns at 2200 m/sec for the standard</td>
</tr>
<tr>
<td>COCKING &amp; EGELESTAFF (1955)</td>
<td>$2.69 \pm 0.04$</td>
<td>1</td>
<td>Transmission measurements using cold neutrons from a Bi filter, extrapolated to 2200 m/sec. Sample was of very low U235 content</td>
</tr>
<tr>
<td>EGELESTAFF &amp; HALL (1955)</td>
<td>$2.69 \pm 0.04$</td>
<td>1</td>
<td>Transmission measurements at long wavelengths with a slow-neutron chopper. Sample of very low U235 content was used</td>
</tr>
<tr>
<td>PALEVSKY (1955)</td>
<td>$2.73 \pm 0.07$</td>
<td>0.33</td>
<td>Transmission measurements at long wavelengths with a slow-neutron chopper. Sample was of natural uranium corrections being made for the U235 contribution</td>
</tr>
<tr>
<td>Weighted mean value</td>
<td>$2.723 \pm 0.025$</td>
<td>For neutrons of 2200 m/sec</td>
<td></td>
</tr>
</tbody>
</table>
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SMALL V.G. (1955) J. Nucl. En. 1, 319

STUDIER M.H. et alii (1951) ANL 4667, unpublished. Quoted by POMERANCE (1951)

WESTCOTT C.H. (1958) AECL 670

WESTCOTT C.H. (1950) AECL 1101
APPENDIX XVII

The graph below was provided at the meeting as provisional results of the work of R.W. Stooksberry, J.A. De Juren and M. Wallis which has now appeared in abstract (Bull. Am. Phys. Soc. 6, p. 440, abstract P2, 1961).