USNDC-5
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STATUS OF MEASUREMENTS FOR THE U.S. NUCLEAR ENERGY PROGRAM

Reports of the USNDC Subcommittees February 1973

H. E. Jackson, Secretary, USNDC

Argonne National Laboratory

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ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

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INTRODUCTION

In accordance with its operating guidelines, the U. S. Nuclear Data Committee periodically reviews the status and needs of microscopic neutron and other nuclear cross section measurements in the U. S. These status reviews are included in a document entitled "Compilation of Requests for Nuclear Cross Section Measurements." These reviews are handled by the thirteen disciplinary subcommittees which provide technical support to the USNDC. Because of their general interest, these subcommittee reviews are being issued separately in the present document, in much the same form in which they were presented at the USNDC meeting of October 1972, at the National Bureau of Standards. They are reproduced from copies of individual reports subcommitted to the meeting; hence in some cases they are fragmentary and incomplete. In some cases these reports also contain comments on the overall programs within the subcommittee disciplines and guides to future needs. With the object of inexpensive and quick distribution, no editing or retyping has been done. Where request numbers are cited in these reviews, the reference is to the previously issued request list, NCSAC-35, LA-4652-MS.

These reports include contributions from the following subcommittees: Standards, Scattering, Fission, Biomedical, Resonance Parameters, Total Capture Cross Sections, Gamma Ray Production and Fast Neutron Reactions.

Robert E. Chrien, Chairman
USNDC
February 1973

REPORT OF THE USNDC SUBCOMMITTEE ON STANDARDS

by

R. S. Caswell
W. W. Havens, Jr.
B. R. Leonard
W. P. Poenitz
L. Stewart

Final Report, February 12, 1973

I. FUNCTIONS OF THE USNDC STANDARDS SUBCOMMITTEE

1. To know the status of nuclear standards work in progress and planned, to review proposals submitted to the USNDC for standards measurements, and to try to foster meaningful standards studies.

2. To originate nuclear standards requests for applied purposes and to establish priorities for them and for other requests for nuclear standards submitted to the USNDC.

3. To answer specific questions on nuclear standards referred by the USNDC, in particular, to review requests for measurements of standards cross sections submitted for publication in the USNDC Request List.

4. To supply current information on what is being done and what needs to be done in the area of nuclear standards. In the past this has chiefly meant standard neutron cross section measurements, but the broadening scope of the USNDC requires the inclusion of other types of nuclear standards work.

5. To foster topical conferences or symposia in the area of nuclear standards such as the Symposium on Neutron Standards and Flux Normalization held at Argonne in October 1970 under EANDC sponsorship,

6. To be aware of instrumentation developments which might relate to standards measurements.

7. To be cognizant of the activities of other standards working groups and subcommittees, especially within the United States.

II. ACTIONS OF THE SUBCOMMITTEE

Assuming that the functions listed above are the responsibility of this Subcommittee, we have summarized a few general comments which bear on several of the Subcommittee's functions and then described the individual actions taken at the last meeting.

1. General Conclusions

The Subcommittee recognizes that to definitively establish a standard cross section, it is essential that all the physics relative to the cross section be understood and give a consistent picture. Thus many kinds of information can contribute to our complete understanding and confidence in a standard cross section: the total and all the other partial cross section (if the standard is a partial cross section), nuclear level parameters, polarization effects, consistency with inverse cross sections, etc.

Nevertheless, after considerable discussion, the Subcommittee decided to be quite selective in the designation of priority neutron standards requests. In order to encourage work which can be expected to make major improvements in nuclear standards in the near future, we have eliminated many requests which have less bearing or only long-term impact on standards questions. For example, the measurements of a total cross section which does not give new or better information on an (n,α) standards cross section might be perfectly well-justified as a total cross section request and may eventually contribute to checking the standard cross section, but we might very well not consider justified as a present priority standard cross section request. Such a request would be referred to the subcommittee having cognizance over total cross sections. However, if a measurer proposes to measure the (n,α) cross section in question by a careful total cross section measurement combined with some improved way of determining the scattering cross section, so that the goal of the measurement is the (n,α) standard cross section, then this would be considered a valid response to a standard cross section request. The Subcommittee feels that in this way work will be better directed towards the goal of improving standards. This would avoid the problem of laboratories continuing to measure total cross sections under the justification of standards work if the work does not so contribute. It often occurs that in the determination of a standard cross section from a total cross section large uncertainties are introduced which result in no improvement in the standard cross section.

The Subcommmittee also believes that it is not sufficient for the United States to rely only on data from Europe and other countries in the area of standards. It is necessary that good standards work be done in the United States, and consistency among United States laboratories involved in cross section measurements be established and maintained.

2. Review of Proposals for Standard Cross Section Measurements

Two proposals were reviewed at the request of the main committee of the USNDC. Both measurements were proposed for hydrogen, one on the total cross section, and the other on both the total and scattering cross sections. Our recommendations are summarized below.

A. Measurement of total cross section of hydrogen by Wilson

The Subcommittee was asked to investigate the question of the (n,p) cross section. In particular the Subcommittee was asked to comment on a proposal by Richard Wilson for new measurements of the scattering length of hydrogen at thermal and epi-thermal neutron energies, and to determine if there is a need for additional measurements from the standpoint of neutron cross section standards. The Subcommittee has reviewed this proposal and feels that, while interesting and valuable basic physics may be learned from implementing this proposal, there is not likely to be any immediate direct impact on the (n,p) cross section as a standard. This experiment may be expected to contribute to the physical understanding of the (n,p) cross section standard, and would become of greater interest if accuracies at the 0.1% level become necessary in the future and if recoil detection techniques are improved.

B. Measurement of total cross section and elastic angular distributions of hydrogen. (Western Michigan)

This proposal, prepared by Robert E. Shamu, consists of two parts: (1) measurement of the total hydrogen cross section to an absolute uncertainty of 0.3% at about 2.5 MeV and at a number of energies between 5 and 20 MeV; and (2) measurement of the angular distribution of hydrogen elastic scattering to an accuracy of from 1 to 2 percent at neutron energies of 7, 10, and 20 MeV. As discussed later, the Subcommittee feels that the accuracy of the total cross section is at worst 0.5% to 1% from 100 keV to 10 MeV, and that the limit on the accuracy of standards measurements is the knowledge of the angular distribution of hydrogen scattering. Therefore, we cannot endorse the total cross section measurement proposal on the basis of standards. The angular distribution measurements proposed are appropriate to Request #2 (see below) and very much needed. The proposal seems technically appropriate to the cross section request; however, we have not compared this proposal with any others. It is most essential that this measurement be done carefully by competent workers.

3. Review of the Standards Requests for the USNDC Request List.

In the following, cross section requests by number refer to Compilation of Requests for Nuclear Cross Section Measurements, NCSAC-35 (LS-4652-MS) 1971. Some new information and comments have become available to us (for example, from the November 1972 Second IAEA Panel on Neutron Standard Reference Data) since the writing of the previous version of this report on which the request list priorities were based. Such information is included below, but changes in priorities and addition of new requests to the list is deferred for consideration by the Subcommittee and inclusion in the next report. Priorities given below are therefore consistent with the request list.

HYDROGEN-1

Request #1 includes a USNDC request for the total neutron cross section of ^{1}H from 100 keV - 20 MeV with an accuracy of 0.5%. The Subcommittee feels the accuracy of the total cross section is at worst 0.5% to 1% from 100 keV to 10 MeV, and that the total cross σ_T is not the limit on the accuracy of standards measurements (the limit is the lack of precise information on the angular distribution of the hydrogen scattering). The Subcommittee considers this request satisfied. It should, therefore, be deleted from the list. The Subcommittee recommends reconsideration of the requests by Avery, Hemmig, and Maienschein (DRDT) for the same cross section.

Request #2 is for the ^{1}H elastic scattering angular distribution, $\sigma(\theta_n)$. This USNDC request with priority I is for angular distribution measurements from 3 to 20 MeV with 0.5% accuracy. The calculations of Hopkins and Breit indicate an asymmetry of 5%, at 8 MeV, whereas earlier experimental measurements were analyzed by Gammel to indicate symmetry. Hydrogen is used as a standard cross section in two ways in the MeV range: (1) in a flux-measuring counter telescope where the protons are typically measured at forward angles near 0^{o}, corresponding to neutron scattering at 180^{o} in the center-of-mass system (for which higher accuracy is greatly needed); and (2) as a standard in neutron scattering angular distribution measurements where scattering angles of $\leq 50^{o}$ are of primary interest. The request should be changed to ask for full angular distribution at 2 or 3 widely spaced energies to check the Hopkins-Breit calculations in the energy region from 8 to 20 MeV, accuracy requirement of 2% or better. It is felt by some that one can simply extrapolate angular distributions downward from higher energies where the asymmetries are larger to check Hopkins-Breit in this energy region; however, the Subcommittee feels direct experimental measurements are needed for the high degree of certainty required.

Request #3 is for $^{1}H\ \sigma_{n,\gamma}$ from 1-15 MeV to an accuracy of 2%, priority II. This request is an impossible request to fill. Request #3 should be deleted, and the inverse reaction D(γ,n) should be measured instead. This request has been referred to the Photonuclear Subcommittee.

Request #6 is for the total cross section of ^{3}He from 1 keV - 3 MeV to an accuracy of 1%, priority I. The comments accompanying this request read: "As a standard cross section for ^{3}He detectors. Absolute values are required." The comment "absolute values required" makes no sense. The Subcommittee doubts the importance of the total cross section as a standard cross section since measurements are usually based on the ^{3}He(n,p) cross section. We have asked the requestor for a re-evaluation of this need.

Request #8 is for the ^{3}He(n,p) cross section from 1 keV - 3 MeV to an accuracy of 3%. This is an USNDC request for which the Subcommittee feels the priority should be II rather than I. Although the cross section is important for use in various ^{3}He detectors, it is less important than other standards such as ^{10}B(n,α), ^{6}Li(n,α), and $^{1}H(n,\alpha)$. The status comment is inconsistent with Costello's report at the Argonne meeting on Neutron Standards and Flux Normalization where the cross section above 100 keV is considered known to 10%. However, CSEWG considers the cross section known to 5 - 8%.

LITHIUM-6

Request #10 for the total ^{6}Li cross section should be withdrawn because many measurements of the total cross section have been made but they have not resolved the $^{6}Li(n,\alpha)$ standard cross section problem (e.g., Duke, Argonne, Harwell), and because the uncertainties in the scattering cross section prevent better total cross section measurements alone from improving the knowledge of the (n,α) cross section. This is not to discourage total cross section measurements if made in connection with $^{6}Li(n,\alpha)$ cross section measurements.

Request #14 for measurements of the $^{6}Li(n,\alpha)$ cross section from thermal to 14 MeV for the USNDC, priority I, should be changed to indicate an energy range from 10 keV - 14 MeV since satisfactory measurements exist below 10 keV. An accuracy of 3% is useful, 1% desired below 100 keV and 3% above. This cross section request continues to be of highest priority. Los Alamos would be interested in the angular distribution in order to use the tritons at a fixed angle as a flux monitor. Absolute cross sections would be required.

Request #15 for measurement of the ratio of $^{6}Li(n,\alpha)$ to $^{10}B(n,\alpha)$ from thermal to 100 keV is considered satisfied based on measurements from Harwell. It should be removed from the request list.

Request #17 for ^{7}Li total cross section from 0.1 keV - 3 MeV to check Van de Graaff measurements has been satisfied by measurements by RPI and Argonne and should be deleted.

Request #20 is a USNDC request for the $^{7}Li(\alpha,n)$ cross section measurement from 4 - 6 MeV with 1% accuracy. This reaction is the inverse reaction to $^{10}B(n,\alpha_o)$. The energy corresponds to 10 keV - 1 MeV in the $^{10}B(n,\alpha_o)$. The request for accuracy is changed from 1% to 2%, which is felt to be a more realistic value.

BORON-10

Request #26 is for measurements of the total ^{10}B cross section with priority I from thermal to 100 keV and with priority II from 100 keV to 1 MeV with 1 - 3% accuracy. This USNDC request is changed to be from 10 keV to 1 MeV with 1% accuracy, priority II. This measurement is desirable for "assessing" the $^{10}B(n,\alpha)$ cross section.

Request #27 is for the elastic scattering angular distribution $\sigma(\theta_n)$ for ^{10}B. The old USNDC request is priority I from 1 - 100 keV with an accuracy of 1 - 5%, and priority II from 100 keV - 1 Mev, accuracy 1 - 3%. Since the elastic scattering together with the total presents a method of checking the $^{10}B(n,\alpha)$ reaction cross section measurements, it is felt that priority II is more appropriate than priority I for this request.

Request #28 is a USNDC request for the $^{10}B(n,\alpha)$ cross section with priority I from thermal to 100 keV and priority II from 100 keV - 1 MeV, with errors of 1 and 4%, respectively. Subcommittee proposes to delete these two requests and replace them by a priority I request from 1 keV - 1 MeV, with an accuracy of 2%. The data of Friesenhahn, Carlson, Orphan, and Fricke, GULF-RT-A12210 (1972) applies to this request up to 100 keV.

Request #29 is for the $^{10}B(n,\alpha\gamma)$ cross section for production of the 478 keV gamma ray from 50 keV to 1 MeV. This request should have priority I, since this reaction leading to a gamma ray is used as a standard in linac neutron cross section measurements. The request accuracy is improved from 4% to 2%. It is understood the GRT (Friesenhahn et al) is measuring this reaction to good accuracy.

These preliminary results of Friesenhahn et al may be combined to yield a measurement of branching ratio $^{10}B(n,\alpha_1\gamma)/^{10}B(n,\alpha)$. The Friesenhahn et al results for the ratio are then significantly lower than the results of Macklin and Gibbons (Phys. Rev. 165, 1147 (1968)) and Sowerby, Patrick, Uttley, and Diment (J. Nucl. Energy 24, 323 (1970)) above about 40 keV. The Subcommittee will consider in its next report whether a priority request needs to be made for this branching ratio.

Request #30 is for total alpha production from ^{10}B, priority II from 1 - 18 MeV. The request is from McElroy (HEDL). The cross section is used as a standard for dosimetry. The Subcommittee believes that this request should be priority I in view of its importance to reactor dosimetry.

CARBON-12

Request #32 is for ^{12}C elastic scattering angular distribution $\sigma(\theta_n)$ with priority I from 1 keV to 2 MeV. This request is deleted as it appears that improved accuracy is not required for Van de Graaff measurements since satisfactory data by Langsdorf (Argonne), Cox (Argonne), and BCMN (Geel) are in agreement up to 1.5 MeV.

GOLD-197

Request #336 is for the $^{197}Au(n,\gamma)$ cross section, priority II, with energy range from 1 - 100 keV, 2% accuracy requested. This request is changed to the energy 10 keV to 1 MeV. In view of the use of gold activation as a standard in environments where other methods cannot be used, we feel that priority I would be justified.

URANIUM

Request #360 for ^{233}U fission ratio to ^{235}U, Request #362 for $^{233}U\ \bar{\nu}$, and Request #389 for $^{235}U\ \sigma_{n,s}$ are not USNDC Subcommittee requests and are referred to the Fission Subcommittee.

Request #390 for $^{235}U\ \sigma_{n,f}$ for measurements with 1% accuracy from 10 keV - 14 MeV is reaffirmed with priority I. Energy resolution of 3% is desired and energy calibration to 1%.

Request #391 for $^{235}U\ \sigma_{n,f}$ measured with respect to hydrogen above 1 MeV and with respect to ^{10}B below 1 MeV, priority I, with 1% accuracy from 10 keV - 14 MeV is established as a USNDC standards request. Intermediate accuracy of 3% would be useful. This measurement is needed to check out consistency between standards.

The following requests are referred to the Fission Subcommittee as being requests for fission information, not particularly related to standards. We assume high-accuracy requests are not necessarily standards (perhaps this question should be considered by USNDC).

Request No.	Target	Quantity	Variable
392	^{235}U	Eta	
395	^{235}U	Nu bar	
418	^{238}U	Fission ratio	wrt ^{239}Pu
419	^{238}U	Nu bar	

PLUTONIUM

The following requests are referred to the Fission Subcommittee:

Request No.	Target	Quantity	Variable
436	^{238}Pu	Fission ratio	wrt ^{235}U
451	^{239}Pu	Fission ratio	wrt ^{235}U
252	^{239}Pu	Nu bar	
265	^{240}Pu	Fission ratio	wrt ^{235}U
475	^{241}Pu	Fission ratio	wrt ^{235}U
476	^{241}Pu	Nu bar	

CALIFORNIUM-252

Request #534 is a USNDC standards request for ^{252}Cf $\bar{\nu}$ with priority I and 0.25% accuracy. There has existed a 2% discrepancy between liquid scintillator methods on the one hand, and manganese sulfate bath and other moderation methods on the other. However, new studies by Boldeman with the scintillator tank reported at the November 1972 IAEA Panel on Neutron Standard Reference Data, and corrections to other experiments, are claimed to give a value of $\bar{\nu}$ = 3.733 with an uncertainty of 0.3%. However, some people feel that it is not clear that the uncertainty is less than 1%. If the new $\bar{\nu}$ value is adopted, then there is a discrepancy with η values. In this connection the proposal to have J. R. Smith make new measurements of $\bar{\nu}$ is most interesting since he is one of measurers of η. The Subcommittee proposes to let the request stand until this situation can be carefully reviewed. $\bar{\nu}$ for ^{252}Cf is very important as a primary standard for $\bar{\nu}$ measurements, and also as a fission-like reference neutron field.

A new USNDC standards request is made for the ^{252}Cf fission spectrum, with priority I above 10 keV. There are worse discrepancies in the ^{252}Cf spectrum than in the ^{235}U fission spectrum. Accuracy desired for $P(E_{n'})$, the shape of the spectrum, is 5%. Also the uncertainty in the energy scale, $\Delta E_{n'}$, should be held to 5%. The situation has been reviewed by Conde in EANDC(OR) 102L. This problem has also been discussed in the recommendations of an IAEA Panel on Fission Spectrum. The shape of the californium spectrum is most important for use of californium as a standard reference neutron field and for cross section validation.

To determine the amount of ^{235}U in fission foils from α-ray counting and mass spectrometric mass ratios, the half-life of ^{234}U is needed. Extensive work reported on the half-life of ^{234}U was reported by BCMN (Geel) at the November 1972 Second IAEA Panel on

Neutron Standard Reference Data yielding a value of $T_{1/2} = 2.446 \pm 0.3\%$ (3σ error) $\times 10^5$ years. Further measurements of ^{234}U half-life are apparently not needed. However, for ^{233}U the half-life is only known to 2%, and for ^{239}Pu there is a discrepancy between calorimetric and counting methods of half-life determination of 1.3%. Priorities for fissionable nuclide half-life determinations will be considered in the next Subcommittee report.

4. NEUTRON STANDARDS CROSS SECTION MEASUREMENTS IN PROGRESS AND PLANNED

Table I

Nuclide	Measurement	Energy Range	Resolution	Expected Accuracy	Measurements Underway	Completion Date	Laboratory
^{6}Li	σ_T	1 keV-1 MeV	0.5%	1%	Yes	9/72	NBS
^{6}Li	σ_{SC}	1 keV-1 MeV	-	< 3%	No	5/74	NBS
^{6}Li	$\sigma(n,\alpha)$	1 keV-1 MeV	-	2%	No	1/75	NBS
^{6}Li	$\sigma(n,\alpha)$	1 keV-1 MeV	~ 2%	1%	Yes	12/73	GRT
^{6}Li	$\sigma(n,\alpha)$	90 keV-600 keV	-	3%	Yes	12/73	ANL
^{10}B	$^{10}B(n,\alpha_o)^{7}Li+^{10}B(n,\alpha_1)^{7}Li^*$	1 keV-1 MeV	~ 2%	1%	Yes	5/72	GRT
^{235}U	σ_f rel to H	1.5 MeV-7 MeV	5%	≤ 3%	Yes	9/72	LASL
^{235}U	σ_f rel to H	50 keV-16 MeV	< 3%	< 2%	Yes	9/73	LLL
^{235}U	σ_f rel to H	20 keV-15 MeV	1 nsec/m	2%	No	/75	ORNL
^{235}U	σ_f rel to H	6 MeV-15 MeV	5%	≤ 3%	No	9/73	LASL
^{235}U	σ_f rel to $^{6}Li(n,\alpha)$	.01 eV-100 keV	< 3%	< 2%	Yes	6/73	LLL
^{235}U	σ_f rel to $^{6}Li(n,\alpha)$	30-150 keV	5-15 keV	-	Finished	12/72	ANL
^{235}U	σ_f rel to $^{10}B(n,\alpha)$	Up to 100 keV	1 nsec/m	.6%	Yes	6/73	ORNL
^{235}U	σ_f rel to $^{10}B(n,\alpha)$	10 kev-1.5 MeV	1 nsec/m	6%	Yes	/74	ORNL
^{235}U	σ_f rel to $^{197}Au(n,\gamma)$	30,150,500 keV	15,15,50 keV	3%	Finished	12/72	ANL
^{235}U	σ_f rel to Gray Neutron Detector	0.15 to 3.5 MeV	15-150 keV	2%	Finished	12/72	ANL
^{235}U	σ_f rel to Black Neutron Detector	2-5 MeV	20-50 keV	1-2%	Finished	12/72	ANL
^{235}U	σ_f absolute ^{51}Cr	500-650 keV	80-100 keV	2%	Finished	12/72	ANL
^{235}U	σ_f absolute Na Be	966 keV	-	2-3%	Yes	12/72	ANL
^{235}U	σ_f absolute ^{51}V Bath	500 keV	50 keV	2-3%	No	12/72	ANL
^{235}U	σ_f ^{235}U rel to σ_γ ^{238}U	Thermal and 24 keV	8%	< 1%	No	1/74	RPI

Table I (Continued)

Nuclide	Measurement	Energy Range	Resolution	Expected Accuracy	Measurements Underway	Completion Date	Laboratory
^{235}U	σ_f absolute	Avg. over ^{252}Cf spectrum	-	4%	Finished	9/72	NBS
^{235}U	σ_f absolute	Avg. over ^{252}Cf spectrum	-	2%	Yes	6/73	NBS
^{235}U	σ_f absolute	Avg. over $^{235}U(n,f)$ spect.	-	4%	No	12/73	NBS
^{252}Cf	Neutron age in H_2O	Avg. over ^{252}Cf spectrum	-	2%	Yes	12/72	NBS

LABORATORY

ANL	Argonne National Laboratory
GRT	Gulf Radiation Technology
LLL	Lawrence Livermore Laboratory
LASL	Los Alamos Scientific Laboratory
NBS	National Bureau of Standards
ORNL	Oak Ridge National Laboratory
RPI	Rensselaer Polytechnic Institute

5. Relation to CSEWG and CSEWG Activities with Respect to Standards.

Overlapping membership is held with the Cross Section Evaluation Working Group (CSEWG), which is responsible for the U.S. evaluation program of neutron cross sections. CSEWG and the USNDC have different functions, the former being primarily concerned with ENDF/B cross section evaluations and the latter being concerned with fostering measurements and improving measurement standards. However, CSEWG does recommend measurements needing to be made to the Division of Reactor Development and Technology of AEC and this function does overlap one of the purposes of the USNDC Subcommittee on Standards.

Estimates of all the major standard cross sections have been reviewed in the past year by CSEWG, except for the ^{238}U and ^{235}U fission cross sections. For example, six of the evaluated neutron files from ENDF/B, Version III have already been adopted as primary standards and approved by the AEC for world-wide distribution. These are identified as follows: hydrogen scattering, $^{3}He(n,p)T$, $^{6}Li(n,t)\alpha$, $^{10}B(n,\alpha)$, ^{12}C scattering, and $^{235}U(n,f)$. Complete files for each isotope on the ENDF/B were released. These data were extensively reviewed by both the Normalization and Standards and the Data Testing Subcommittees of CSEWG. Both internal and external consistency checks could be made since CSEWG has established a complete file on each isotope which covers a wide range of energies (from 10^{-5} eV to 15-20 MeV). The total cross section had to be the sum of all the partials and absorption and fission ratios were checked against experimental measurements. For calculational models, all cross sections for each isotope must be given along with the energies and angular distributions of all the emitted neutrons and the ENDF/B files satisfy these criteria.

Although the primary objective of CSEWG has been to construct and constantly update complete neutron files, expansion to other areas is underway and some of the areas are related to standards. For example, CSEWG currently has under review by the Non-Neutron Induced Data Subcommittee the problem of establishing a charged-particle evaluated library which could then contain the standard neutron source reaction cross sections. Already underway are: a partial cross-section file for specific dosimetry applications; some of which will be denoted as primary and secondary standards, and the preparation of photon production and photon interaction cross section files.

Although the USNDC and CSEWG have different functions, their interests and responsibilities naturally overlap with respect to the U.S. standards program. Since the primary objective of the USNDC is to foster new experiments and to improve measurement standards, such effort can contribute significantly to the national ENDF/B evaluation program which is sponsored by the DOD and three divisions of the USAEC. Therefore, close contact will be maintained with CSEWG with respect to the standard cross section evaluation program.

November 15, 1972

Report of:

The USNDC Subcommittee on Scattering.[a]

Subcommittee Members:

H. Goldstein
J. Hopkins
F. Perey
A. Smith, Chr.

I. Introduction.

The Subcommittee has the explicit responsibility of reviewing the request compilation in the areas of Elastic and Inelastic Scattering and of Nu-bar and Fission Neutron Measurements. The latter charge is ad-hoc. Responses to these reviews are given explicitly in Tables II and III, respectively. Some impression of the distribution of priorities and accuracies is given in Table I. In addition, consideration is given to: the character of the requests, the status of the field and the subcommittee organization. Subjective opinions as a consequence of these considerations are outlined in subsequent sections. They are consistent with individual subcommittee opinion, where expressed, and particularly reflect the impressions of the chairman.

II. Scope of Requests.

The scattering requests are grouped into the major areas: a) standards, b) shielding materials, c) structural components and d) fissile and fertile materials--largely relevant to fission reactors. Desired accuracies range from qualitative to fractional per cent and there appears to be a trend to both higher energies and higher priorities. In particular, the number of priority-III requests is relatively small. This may reflect some lack of interest in speculative and/or long term endeavors. There are some significant omissions. Only one request has as its primary motivation physical understanding. Such areas as deformed nuclei remain largely ignored and yet the physical interpretation of direct interactions in these nuclei is a continuing problem in the applied use of fissile, fertile and fission product nuclei and direct processes will become far more important in the higher energy range of CTR applications. Even in the context of fission reactors long term needs may not have been given proper consideration and it is noted, for example, that there is no request for

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[a]These remarks are based primarily on the comments and opinions of J. Hopkins, F. Perey and A. Smith.

scattering from Pu^{241} and higher isotopes that will inevitably appear in long term fuel cycles.

There is concern that the request list is not representative of needs for: physical understanding, long term requirements of current programs (e.g. fission reactors) and new areas of endeavor which are on the threshold of conceptual decisions.

III. Resources: Programs, Facilities and Manpower.

During the period of this review the major United States scattering effort was largely centered at four facilities as follows:

a. ORNL.

Final reduction of data obtained using 6 MeV VDG and new work at ORELA.

b. Ohio University

8 MeV tandem Van de Graaff working primarily in light-nuclei region.

c. University of Kentucky

5.5 MeV Van de Graaff (HVEC-CN) working in medium-nuclei region.

d. ANL

8 MeV tandem Dynamitron working primarily in medium- and heavy-nuclei.

During the past 18 months the ORNL program has utilized the VDG for studies in the energy range 4.2-8.6 MeV acquiring data on: C,N,O,Ti,^{52}Cr,Cr,^{60}Ni, Ni,^{63}Cu,^{65}Cu,W,^{206,207,208}Pb and U^{238}. Results have been formally reported and further reports are in preparation.[c] The results generally include both elastic and inelastic neutron scattering processes. These reports will terminate the ORNL-VDG program and the manpower will be shifted to ORELA for elastic and inelastic (primarily n:n'γ) studies using the white source. The schedule goal for operation is January 1973.

The Ohio University work is well summarized in "Structure Studies of Light Nuclei with Neutrons" presented at the recent Budapest Meeting (EANDC (US)-172AL) and includes scattering from ^{6}Li, ^{7}Li, ^{10}B, ^{11}B, ^{12}C and ^{14}N. The work is continuing and will include both differential scattering cross sections and scattered neutron polarizations in the light nuclear region.

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c. See notations on pertinent requests.

The University of Kentucky program has emphasized elastic and inelastic scattering from nuclei in the mass region A $\sim$ 100 to energies of $\sim$ 8 MeV. Results for $^{92,94,96,98,100}Mo$ are in press and studies of $^{92,94,96}Zr$ are in progress. In addition recent results of a study of scattering from ^{12}C from $\sim$ 3-6 MeV have been published.

The Argonne program has emphasized the final reduction and reporting of data obtained with the previous VDG accelerator ($E_n \lesssim$ 1.5 MeV) and a new measurement program at the Fast Neutron Generator currently emphasizing the energy range 1.5-4.0 MeV. The program stresses elastic and inelastic neutron scattering measurements from structural and core materials (eq. A$\sim$45-90 and A$\sim$232-240). All measurements are by time-of-flight and currently employ a unique 10-angle detection system with flight paths to 7 meters at angles of 20-160 degrees.

Only operation of a) and d), above, are AEC supported. Manpower associated with these activities is difficult to assay due to conflicting commitments. However, an average of 1-3 man/yrs per facility seems a reasonable estimate. Certain other facilities work in special problem areas: e.g. small-angle scattering at the Aberdeen Center. In any event, the manpower applied to this problem area is grossly inconsistent with the requests for information. It is noted that the facilities generally represent good-to-top quality technology for this type of work and that more manpower could be effectively utilized.

There is very little United States activity in nu-bar studies. The ANL bath measurements have been terminated. RPI studies of nu-bar in the resonance region are near completion. There is some new work at LLL. Generally, in the immediate future, most United States knowledge of nu-bar may well come from foreign sources.

Microscopic studies of prompt fission spectra are apparently not in progress within the United States and none are planned.[d] NBS (Grundl) continues studies of threshold (and other) index responses in such spectra.

An extensive program of delayed neutron yield measurements is in progress at ANL. Work is proposed at LASL and spectral measurements are underway at the University of Washington. Accuracies in total yield of better than 5% for U^{233}, U^{235}, U^{238} and Pu^{239} are a reasonable near-term expectation. The higher Pu isotopes will be more difficult.

IV. Experimental Practice and Quality.

In providing for many of the requests in this area there is no substitute for quality and it is not necessarily synonymous with quantity or newness. It should be a matter of concern that some recent results are not appreciably better than those obtained a decade ago with more modest facilities and that some of the current "flaps" tend to be due to premature or inaccurate new information. If many of the more difficult and more precise requests are to be fulfilled there must be a return to more careful experi-

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d. Subsequent to the preparation of this report LASL studies of fission neutron spectra have been described (See USNDC Status Reports - 1972).

mental procedures. These must be carried out within a rational physical framework and the results fully analyzed before transfer to the data center files. Too often physical reality and analysis are ignored with a consequent waste of experimental effort. Inherent in many of the measurements are large experimental perturbations. In the context of precise data requests, these cannot be ignored. Far more careful attention must be given to such things as multiple scattering corrections if success is to be achieved.

What is needed for success is a "disciplined physical approach" to the measurement program.

V. Subcommittee Structure.

The somewhat moribund status of United States neutron scattering activities is reflected in the Subcommittee, only two members of which spends more than one half of their time actively engaged in scattering studies. This may, unfortunately, be representative of National activity in the area but it does not result in a comprehensive grasp of the problem area without an inordinate amount of work on the part of subcommittee members. Consideration should be given to restructuring the subcommittee. One alternative is to place it on an ad-hoc stand-by basis or incorporate its activities within another subcommittee; neither likely to improve the situation. A more attractive option is an enlargement/or change of membership to include personnel actively working in the field. The latter are very limited and must include individuals outside direct USAEC support. This may require some changes in policy. These are recommended and not inconsistent with the recent restructuring of the parent committee. With such changes, one can hope for an improved cooperative and coordinated approaches to the respective nuclear data problems and even the stimulation of the field by the active physical-research orientation it so badly needs for new life.

IV. Review of Request List.

The Subcommittee has explicitly reviewed the Request Compilation in the pertinent areas. The results are given in the Tables I through III. Table I summarizes the number of requests by priority and by "high" ($\lesssim$ 3%) accuracy. Table II is responsive to scattering requests item-by-item. Table III is responsive to nu-bar and fission property requests item-by-item. These are not a comprehensive bibliographies but rather a current commentary emphasizing new results. It is presumed the requester is familiar with the formally reported literature as, for example, indexed in CINDA. Where appropriate, it is suggested that the requester review his requirements in the light of new information.

TABLE I.

Distribution of Priorities

Reaction	No. of Requests, Priority 1	2	3
Scattering[b]	73	62	12
Total Req.[a] = 147			
Nu-bar + fission Prop.[c]	14	17	2
Total Req.[a] = 33			

a. summed by priority designation.

b. No. of Reqs. with accuracies $\leq$ 3% = 6.

c. No. of Reqs. with accuracies $\leq$ 3% = 14.

Table II. Review of Neutron Scattering Requests.

NCSAC-35 No.	DIST. No.	Request Statement
2	2	$_1H^1$ Elastics 3-20 MeV Change status to: LASL-Hopkins + Briet, Nucl. Data A9 - 137 (1971)
New	3	$_1H^2$ Elastic th-1 keV Status-Quo.
4	4	$_1H^3$ Elastic 14 MeV Change status to: LASL-Seagrave has data, LA-DC-8859.
7	7	$_2He^3$ Elastic 1-14 MeV Change status to: LASL-Seagrave has data, LA-DC-8859 LASL-Drosg *et al*., Data at 14 angles and five energies 8-24 MeV
11	11	$_3Li^6$ Elastic 1-100 keV Status-Quo.
New	12	Elastic ∿ 14 MeV This request is likely satisfied to 15% accuracy. See BNL-400 and CINDA
12	13	Emission 8-14 MeV Add to status: AWRE-Cookson *et al*. have data at 10 MeV, LA-DC-8023

NCSAC-35 No.	DIST. No.	Request Statement
New	22	$_3Li^7$ Elastic ∿ 14 MeV
		Probably satisifed to required 15% accuracy.
		See CINDA and BNL-400
New	23	Inelastic thr - 14 MeV
		Add to status:
		AWRE-Cookson et al., data at 10 MeV-LA-DC-8023
18	24	Emission 5-16 MeV
		See status of #23, above
22	30	$_4Be$ Elastics 7-20 MeV
		Status-Quo.
23	31	Emission 1.8-5 MeV
		Status-Quo.
27	36	$_5B^{10}$ Elastic 1-1000 keV
		Add to status:
		Ohio U.-Lane - Review of Status.
33	39	$_6C$ Elastics 6-15 MeV
		Add to status:
		Ohio U.-Lane et al., data at 6 MeV, Budapest Conf.
		ORNL-Perey et al, data to 8.7 MeV, ORNL-4441.
		U.Ky-Galati et al, data to 7.0 MeV
32	40	Elastics 1-2.5 MeV
		Change status as follows:
		Delete Lane etc: too old.
		Retain Knitter Ref.
		Delete Nikolaev
New	41	Elastics 2-14 MeV
		Combine status of #39 and #40, above.

NCSAC-35 No.	DIST. No.	Request Statement
		6^{C} (Contd.)
34	42	Emission 7-15 MeV Change status to: ORNL - Perey et al., Data to 8.7 MeV, ORNL-4441
New	45	Inelastic(1st) 4.4-14 MeV Add to Status: ORNL - Perey et al., Data to 8.7 MeV, ORNL-4441
37	47	Polariz 4-5.5 MeV Status: Ohio U. - Lane Report to Budapest Conf. Detail Analysis
39	48 & 49	7^{N} Elastic 7-15 MeV ORNL - Perey et al. have new data See NS+E 46 428 (1971)
70	50	Emission 7-15 MeV See #48, above
43	53	8^{O} Elastic 0.01-15 MeV Add to status: ORNL - Kinney et al., Data in Range 4.3-8.5 MeV, ORNL-4780
44	54	Emission 7-15 MeV Add to status: ORNL - Kinney et al., Data in Range 4.3-8.5 MeV, ORNL-4780 Sweden - Lundberg et al., Associated gamma rays at 7.5 MeV, EANDC(OR)-104
50	59	9^{F} Elastics 3-20 MeV Status: Chalk River - Clarke and Perrin have 14 MeV data ANL - Smith et al. have preliminary results to 3.0 MeV.

NCSAC-35 No.	DIST. No.	Request Statement
		9^{F} (Contd.)
New	60	Inelastics 10-14 MeV
		Status: See Chalk River of #59, above.
51	61	Emission 0.5-20 MeV
		See Status remarks of #59, above.
55	66	11^{Na} Elastics 8-15 MeV
		Status:
		ORNL - Perey _et_ _al_., Data to 8.5 MeV, ORNL-4518
56	67	Inelastics 2-10 MeV
		Status-Quo
57	68	Emission 4-15 MeV
		Status-Quo.
60	72	13^{Al} Elastics. 8-16 MeV
		Add to Status:
		U. Ky. - Brandenberger has data at 8 and 9 MeV
		ORNL - Kinney _et_ _al_., data to 8.5 MeV, ORNL-4516
		Sweden - Holmqvist _et_ _al_., data at 8 MeV, AE-430
New	75	Inelastic Thr - 14 MeV
		Status:
		ORNL - Kinney _et_ _al_., ORNL - 4516, data to 8.5, also
		ORNL - TM-3284
		U. Ky. - Brandenberger, data at 8 and 9 MeV
		NOTE: Great number of older measurements should satisfy 15% accuracy of request to 3 or 4 MeV. Lower limit should be raised.
61	76	Emission 8-15 MeV
		Add to status same items as #75, above (i.e. ORNL, U.Ky.)

NCSAC-35 No.	DIST. No.	Request Statement
65	85	14^{Si} Elastics 8-15 MeV Add to status: ORNL - Kinney et al., Data at 8.5 MeV,ORNL-4517
66	86	Emission 8-15 MeV Status as of #85, above
71	91	20^{Ca} Elastics 8-15 MeV Add to Status: ORNL - Perey et al. have data to 8.5 MeV, ORNL-4519
72	92	Emission 8-15 MeV Add to Status: ORNL - Perey et al. have data to 8.5 MeV, ORNL-4519
84	104	23^{V} Elastic 1.4-10.0 MeV Add to Status: Sweden - Holmqvist data to 8.0 MeV, AE-430
85	107	Inelastic 1.5-10 MeV Add to Status; Sweden - Almen et al., Helsinki Conf.
New	108	Inelastic Thr - 15 MeV Same Status as #107, above
88	117	24^{Cr} Elastic 2-14.0 MeV Add to Status: ORNL - Perey et al. have data to 8.6 MeV
89	118	Inelastics 0.5-10.0 MeV Add to status as per #117, above
New	119	Inelastics Thr - 14.0 MeV Add to status as per #117, above

NCSAC-35 No.	DIST. No.	Request Statement
97	135	26^{Fe} Elastics 0.5-14 MeV Revise Status to: ANL - Smith et al., Data available satisfying intermediate resolution requirements to 3.8 MeV ORNL- Perey et al., ORNL - 4515, data 4.19-8.56 MeV Sweden - Holmqvist et al., AE-337, and Helsinki Conf., Data to 6 MeV. TNC - Williams et al., NCSAC-33, Data 9-11 MeV
98	136	Elastics 6-16 MeV Status-Quo
99	137	Inelastic .85-10 MeV Request satisfied to 2 MeV by ORNL, ANL, PEL work. This is priority 1 region. Revise Status to: ANL-Smith et al., Preliminary results to 3.8 MeV ORNL-Results 0.85-2, 4-8.5 MeV, Knoxville Conf. (Perey et al.) and ORNL-4515 (Dickens et al.). CEA-Naouat et al., Knoxville Conf. 2-14 MeV Sweden-Almen et al., Helsinki Conf. to 4 MeV TNC-Williams et al., NCSAC-33, 9-11 MeV
New	138	Inelastics thr - 14 MeV Change status to that of #137, above.
100	141	Emission 5-15 MeV Status: TNC-Williams et al., NCSAC-33, Results at9,11 MeV
101	142	Emission 7-16 MeV Status as per #141, above.
118	170	28^{Ni} Elastic 1.5-14 MeV Change Status to: ANL-Smith et al., Preliminary data to 3.0 MeV, work continues. ORNL-Perey et al., ORNL-4523, 6.5-8.6 MeV also new data available AE-Holmqvist et al., Helsinki Conf. 1.8-8 MeV. Delete other remarks of former status.

NCSAC-35 No.	DIST. No.	Request Statement
		$_{28}Ni$ (Contd.)
119	171	Inelastics 1-10 MeV Change Status to: ANL-Smith et al., Preliminary data to 3.0 MeV, work continues. ORNL-Perey et al., ORNL-4523, 6.5-8.5 MeV, also new data available.
New	172	Inelastics thr - 14 MeV Same status as #171, above.
New	189	$_{189}Cu$ Inelastics thr - 14 MeV Status: ANL-Preliminary data 0.3-3.0 MeV. Work continues, Smith et al. ORNL-Perey et al., work in progress
137	207	$_{32}Ge$ Emission 1-15 MeV No Change
139	209	$_{33}As$ Elastic th - 14 MeV No Change
140	210	Emission thr - 14 MeV No Change
153	223	$_{40}Zr$ Elastic 0.2-1.5 MeV 7-14.0 MeV The 0.2-1.5 MeV is available to $\sim$ 10% as required. Request should be dropped for E<1.5 MeV. Revise status to: ANL-Working above 1.5 MeV.
New	224	Inelastics thr - 14. MeV Change status to: ANL-Working to $\sim$ 5.0 MeV with even isotopes-90-92-94 (Smith et al.) U.Ky.-Working with even isotopes 90-92-94 to 6 MeV (McEllistrem et al.).

NCSAC-35 No.	DIST. No.	Request Statement
		$_{40}Zr$ (Contd.)
154	227	Emission 2-14 MeV
		Status should change to that of #224, above.
166	244	$_{40}Zr^{90}$ Elastic 100 keV-10 MeV
		Replace status with:
		U.Ky.-McEllistrem *et al*.
		Preliminary results 1.5-6.0 MeV.
		ANL- Smith *et al*., preliminary results. 1.5-3.0 MeV.
167	245	Inelastic 14 MeV
		Delete status remark and replace with "None".
		Is only the 14 MeV point wanted?
New	246	Inelastic 5-15 MeV
		Update status to that of #244, above.
168	247	Emission 1-15 MeV
		Change status to that of #244, above.
174	251	$_{40}Zr^{91}$ Elastic 0.1-10 MeV
		Change status to:
		ANL-Work in progress
175	252	Inelastic 2.5-14 MeV
		Change status to that of #244, above.
183	257	$_{40}Zr^{92}$ Elastic 0.1-10.0 MeV
		Change status to that of #244, above.
184	258	Inelastic 14 MeV
		Change status to "None"
New	259	Inelastic 2.5-10 MeV
		Change status to that of #244, above.

NCSAC-35 No.	DIST. No.	Request Statement
190	263	$_{40}Zr^{94}$ Elastics eV-10 MeV Add to status: U. Ky. - Working on problem.
191	264	Inelastics 14 MeV Change status to "none"
199	269	$_{40}Z^{96}$ Elastics 0.1-10 MeV This remains a sample problem.
203	272	$_{41}Nb$ Inelastic thr - 14 MeV Status: ANL-Data to 4.0 MeV in detail. AWRE-Data from 1.5-5.0 MeV. AWRE-0-66.71, R. Coles AE-Almen _et al_., Helsinki Conf.
204	273	Inelastic thr - 15 MeV (isomeric State) Status: None
205	274	Emission 1.5-15 MeV Status should be revised to that of #272, above.
220	295	$_{42}Mo$ Inelastic 1.5-3.0 Change status to: AWRE-Coles, AWRE-69/70, Data to 5.0 MeV. ANL-Smith _et al_., all even isotopes to 1.6 MeV, working to > 5 MeV. KY-McEllistrem _et al_., Data on even isotope 1.5-6.0 MeV.

NCSAC-35 No.	DIST. No.	Request Statement
		42^{Mo} (Contd.)
New	296	Inelastic th - 14.0 MeV
		Status should be same as #295, above.
221	299	Emission 1.5-15 MeV
		Status should be same as #295, above.
273	352	64^{Gd} Elastic 1.5-10 MeV
274	353	Emission 1.5-10 MeV
		Revise status of both to:
		1. Delete ANL-Sherwood. It is out of energy range.
		2. Status: None. (Apparently no active work).
311	388	72^{Hf} Elastic 1.5-10 MeV
		Delete ANL - Sherwood.
		Add to status:
		AE-Holmqvist et al., Helsinki Conf.
312	389	Emission 1.5-10 MeV
		Delete ANL - Sherwood.
		Current status: None.
320	397	73^{Ta} Emission 1.5-15.0 MeV
		No Change.
323	400	74^{W} Emission 4-16 MeV
		Add to status:
		ORNL-Perey et al. have data 4.3-8.6 MeV.

NCSAC-35 No.	DIST. No.	Request Statement
338	415	$_{82}$Pb Emission 3-16 MeV
		Change status to:
		ORNL-Perey _et al_. have data to 8.6, work in progress.
341	418	Isom. State th-15 MeV
		Change status as per #338, above.
344	421	$_{90}$Th Elastic 1-5 MeV
		No Change.
345	422	Inelastic 1-4 MeV
		No Change.
355	431	$_{92}U^{233}$ Inelastic 0.04-7.0 MeV
356	432	Emission 5-7 MeV
		Status of both unchanged.
381	453	$_{92}U^{235}$ Elastic 1-7 MeV
		Revise Status to;
		BCMN-Coppola and Knitter have data to 5.5 MeV.
		ANL-Measurements to 3.5 MeV. (Smith)
382	454	Inelastics 1.5-6.0 MeV
		Revise status to that of #453, above.
383	455	Emission 5-15 MeV
		Status;
		BCMN-Coppola and Knitter have data at 5.5 MeV.
384	456	Emission 1-20 MeV
		Status:
		Same as #453, above.

NCSAC-35 No.	DIST. No.	Request Statement
412	487	$_{92}U^{238}$ Elastics 0.001-10.0 MeV Statement "Factors of 2 lower accuracy would be useful on short term" should be deleted as this value has been achieved at many energies. Revised status: ANL-Smith et al. (NS+E 46 356, 1971) Data to 1.7 MeV and measurements underway to 5 MeV. BCMN-Ahmed has data to 2.3 MeV. ORNL-Perey et al. have data to 8.6 MeV, work in progress.
413	488	Inelastics 0.1-10 MeV "Useful" 20% accuracy is met to ∿ 1.2 MeV and possibly higher. This 20% useful accuracy should be deleted from the Req. Com. Revised status: ANL-Smith et al. (NS+E 46 356, 1971) to 1.7 MeV work in progress to 5 MeV. BCMN-Ahmed has data to 2.3 MeV. ORNL-Perey et al. have data to 8.6 MeV, work in progress.
414	486	Emission 5-15 MeV Add to status: ORNL-Perey et al. have data to 8.6 MeV, work in progress.

NCSAC-35 No.	DIST. No.	Request Statement
444	517	$_{94}Pu^{239}$ Elastics 1-7 MeV Request is satisfied to 2.5-3.0 MeV within the scope of the broad Resolution Requirements of ΔE = 500 keV. Status: ANL-Data to 3.0 MeV and work to 4.0 MeV in progress. (Smith et al.) BCMN-Data to 5.5 MeV Coppola and Knitter ZP-232 286, (1970).
445	518	Inelastics 0.010-10 MeV Replace old status with: BCMN-Data to 5.5 MeV, temp. Distributions, Zp-232 286 (1970). ANL-Work in progress to 4.0 MeV.
446	519	Emission 5-15 MeV Status: BCMN-Coppola and Knitter, Data to 5.5 MeV, ZP-232, 286 (1970).
463	538	$_{94}Pu^{240}$ Inelastics 1.5-10 MeV Revised status: ANL-Smith et al., Data to 1.5 MeV, (NS+E 47 19, 1971), work planned to higher energies.

Table III. Review of Nu-bar and Fission Neutron Requests.

NCSAC-35 No.	DIST. No.	Request Statement
341	437	$_{92}U^{233}$ Nu-bar th - 30 keV
		Add to status:
		AWRE-Mather et al., Review of U^{233} data to 4.0 MeV,EANDC(UK)49S
362	438	Nu-bar 30 keV-3 MeV
		See status of #437, above.
New	441	Nu-bar 7-20 MeV
		Status-Quo.
380	452	$_{92}U^{234}$ Nu-bar 0.5-20 MeV
		Status-Quo.
395	467	$_{92}U^{235}$ Nu-bar th - 3 MeV
		Add to status:
		AWRE-Mather et al. Review AWRE-0-55/71.
396	468	Fission Neuts. th - 3 MeV
		Note: Reg. Com. does not make sense.
		Status:
		(Delete old one)
		IAEA-Consults meeting proceedings to be published. Sweden-Holmqvist et al., to be published, data to E_n'> 10. MeV
		BCMN-Knitter et al., Detailed results for E_{in} = 40 keV.
397	470	Delayed Neuts. th - 5 MeV
		Replace ANL in status with ANL-Cox, work in progress Also add AERE-See review of Tomlinson, AERE-6993

NCSAC-35 No.	DIST. No.	Request Statement
		$_{92}U^{235}$ (Contd.)
New	471	Delayed Neuts. 5-14 MeV
		Add to status:
		AERE-See review of Tomlinson, AERE-6993.
407	480	$_{92}U^{236}$ Nu-bar 0.5-14 MeV
		Change status to:
		Sweden-Conde et al. Results to 7.0 MeV, EANDC (or) 105, to be published in J. Nucl. Energy.
New	481	Fis. Spect. > Thr
		Status-Quo.
419	494	$_{92}U^{238}$ Nu-bar 1-10 MeV
		Status-Quo.
New	495	Delayed Neuts. 5-14 MeV
		Add to status:
		ANL-Cox, work in progress.
420	496	Delayed Neuts. Thr - 5 MeV
		Add to status:
		ANL-Cox, work in progress.
437	512	$_{94}Pu^{238}$ Nu-bar 0.01-15 MeV
		Status-Quo.
452	525	$_{94}Pu^{239}$ Nu-bar th - 10 MeV
		Add to status:
		RPI-Block et al., studying resonance region.
		AWRE-See review of Mather et al. AWRE-0-86/70

NCSAC-35 No.	DIST. No.	Request Statement
		$_{94}Pu^{239}$ (Contd.)
453	526	Delayed Neuts. th - 5 MeV
		Add to status;
		ANL-Cox, working on problem.
		AERE-See Tomlinson review AERE-6993.
New	527	Delayed Neuts. 3-14 MeV
		Add to status:
		ANL-Cox, working on problem.
		AERE-See Tomlinson review, AERE-6993
466	541	$_{94}Pu^{240}$ Nu-bar Thr - 10 MeV
		Status-Quo.
New	542	Delayed Neuts. 0.7 - 14 MeV
		Delete old Diven status.
		Add:
		ANL-Cox, studying problem.
476	550	$_{94}Pu^{241}$ Nu-bar 0.001-10 MeV
		Status-Quo.
477	551	Nu-bar 0.5-14 MeV
		Status-Quo.
481	555	Delayed Neuts. th - 14 MeV
		Add to status:
		ANL-Cox, May measure at lower energies.
486	558	$_{94}Pu^{242}$ Nu-bar 0.5-10 MeV
		Status-Quo.

NCSAC-35 No.	DIST. No.	Request Statement
		$_{94}Pu^{242}$ (Contd.)
487	559	Nu-bar 0.5-14 MeV
		Status-Quo.
488	560	Delayed Neuts. 3-14 MeV
		Status-Quo.
535	603	$_{98}Cf^{252}$ Nu-bar Spon.
		Add to status:
		ANL-DeVolpi final value = 3.729 ± 0.015.
535	604	Nu-bar Spon.
		Drop request and add Alter to #603, above.
		Request is redundant.
New	605	Fis. Spec. Spon.
		Add to status:
		NBS-Grundl has new threshold-index values.

REPORT OF THE USNDC SUBCOMMITTEE ON FISSION

M. S. Moore, Chairman

C. D. Bowman
W. G. Davey
G. de Saussure
R. W. Hockenbury
E. Melkonian
J. A. Grundl

A review of current status of requests for nuclear data measurements on fissionable materials has been carried out. Preliminary, updated status comments are enclosed as Table I. In accordance with the ground rules for status comments to be included in the Request Compilation, comments relating to published data which will be referenced in CINDA are deleted, and only work planned or in progress is referenced.

While the status comments reflect primarily U.S. effort, some attempt has been made to include comments on measurements being carried on outside the U.S. These are often neither complete nor up to date, since the documentation used is not always current or complete. In general, those documents with limited distribution are not referenced in the status comments. In constructing the present report, the following documents were found to be useful:

1. "Current and Planned Fission Measurements in the U.S.," USNDC Report Submitted June 23, 1972, by C. D. Bowman. (Limited Distribution)

2. "Experimental Neutron Cross Section Status Survey for the Heavy Actinides - the ^{252}Cf Chain," DPST-72-426, July 21, 1972, by R. W. Benjamin. (Private Communication)

3. "Report to the AEC Nuclear Cross Sections Advisory Committee," and Reports to the U.S. Nuclear Data Committee," NCSAC-42, USNDC-1, USNDC-3, November 1971, May 1972, October 1972, respectively; Compiled by H. E. Jackson.

4. "Status of the Energy Dependent $\overline{\nu}$ Values for the Heavy Isotopes ($Z \geq 90$) from Thermal to 15 MeV, and of ν Values for Spontaneous Fission," INDC-(NDS)-34/G, July 1972, by F. Manero, V. A. Konshin. (Limited Distribution)

5. "UK Nuclear Data Progress Report, Mid 1971-March 1972," EANDC(UK)140 AL, INDC(UK)15G, June 1972, by M. G. Sowerby. (Limited Distribution)

6. "Progress Report on Nuclear Data Research in the Euratom Community," May 1972, EANDC(E)150/U. Unfortunately, this report includes no contributions from the Federal Republic of Germany, such as Munich, Julich, Kiel, or Karlsruhe.

7. "Compilation of Fission Product Yields, Vallecitos Nuclear Center - 1972," NEDO-12154, January 1972, by M. E. Meek and B. F. Rider.

8. "Experimental Neutron Cross Section Status Survey for the Heavy Actinides - the ^{238}Pu Chains," DPST-72-470, by R. W. Benjamin, September 8, 1972. (Private Communication)

Table I. Status Comments, Involving Active and Planned Work Relating to the U. S. Request List.

358 $^{233}U(n,f)$ 0.001 eV-1 keV

LLL Behrens+ have measurements in progress above 0.01 eV, see NCSAC-42.

BCMN Deruytter+, relative to ^{10}B, from 0.01-45 eV, in progress. EANDC(E)150/U

SAC Blons, NSE, to be published, data at LN temperature.

359 $^{233}U(n,f)$ 1-30 keV

LLL Behrens+ have measurements in progress; NCSAC-42.

RPI Block+ plan measurements

SAC Blons, NSE, to be published, data at LN temperature

360 $^{233}U(n,f)$ 1 keV-15 MeV, rel. to ^{235}U

LLL Behrens+ have measurements in progress; NCSAC-42.

RPI Block+ plan measurements below 200 keV.

ANL Poenitz+ have measurements in progress, 150 keV-3.5 MeV.

361 ^{233}U $\bar{\nu}$ 0.001 eV-30 keV

RPI Reed+ have measurements in progress, thermal to 200 eV and 24 keV.

362 ^{233}U $\bar{\nu}$ 30 keV-3 MeV

AUA Walsh+ JNE 25, 321, find evidence for structure (~2 per) below 1 MeV.

LLL Howe+ plan measurements; NCSAC-42.

363 ^{233}U alpha 0.001 eV-1 keV

No active work. Data of Weston+, NSE 42, 143, have estimated uncertainties in eta of 1/2 per below 0.2 eV up to 1 per at 1 eV. The 2 per discrepancy with older data of Smith+ at 0.15 eV appears to be resolved; see INC Smith+ NCSAC-33, p. 87. Data of Weston+ NSE 34, 1, below 2 keV give est. uncertainty of ~2 per integral eta.

(Table I, cont.)

364 ^{233}U alpha 1 keV-3 MeV

No active work.

365 ^{233}U $\bar{\nu}$ prompt 7-20 MeV

LLL Howe+ plan measurements to 15 MeV; NCSAC-42.

367 ^{233}U res. param. Th-5 keV

COL Felvinci+ have analysis in progress, USNDC-1.

LASL Keyworth+ have measurements of J,K in progress at ORELA.

SAC Blons+, single-level analysis completed to 100 eV, 100-150 eV in progress, EANDC(E)150/U

370 ^{233}U Fiss. prod. Y. of ^{135}Xe, Th
371 ^{233}U Fiss. prod. Y. of ^{137}Cs, Th
372 ^{233}U Fiss. prod. Y. of ^{147}Nd, Th
373 ^{233}U Fiss. prod. Y. of ^{149}Sm, Th

GE Meek and Rider compilation summarizes status; NEDO-12154.

380 ^{234}U $\bar{\nu}$ prompt 0.5-20 MeV

No active work.

387 $^{235}U(n,f)$ 1 eV-1 keV

LLL Czirr+ have measurements in progress rel. to $Li(n,\bar{a})$; NCSAC-42.

BCMN Theobold+ in progress, to 2 keV; EANDC(E)150/U.

BCMN Deruytter+ in progress, rel. to ^{10}B, EANDC(E)150/U.

SAC Blons+, NSE, to be published.

388 $^{235}U(n,f)$ 1 eV-10 MeV at isolated values

LLL Czirr+ have linac measurements in progress, NCSAC-42, covering this range.

ANL Poenitz+ have completed measurements, 30, 150, 500 keV.

(Table I, cont.)

389 $^{235}U(n,f)$ 1 keV-14 MeV
390 $^{235}U(n,f)$ 10 keV-15 MeV
391 $^{235}U(n,f)$ 1 keV-14 MeV rel. to H, ^{10}B

LASL Barton+ have measurements in progress, 1.5-7 MeV, and plan measurements 6-15 MeV.

LLL Czirr+ have measurements in progress, rel. to H above 50 keV, rel. to $^{6}Li(n,\bar{a})$ below 100 keV.

ANL Poenitz+ have completed measurements rel. to $^{6}Li(n,\bar{a})$, 30-150 keV; rel. to $^{197}Au(n,\bar{g})$, at 30, 150, 500 keV; rel. to Grey neutron detector above 150 keV; rel. to Black neutron detector 2-5 MeV; absolute (^{51}Cr)500-650 keV. Absolute points at 500, 966 keV planned or in progress.

ORNL Gwin+, rel. to ^{10}B to 200 keV, find agreement with Lemley+ data to ~2 per.

ORNL de Saussure+ have measurements in progress rel. to $^{10}B(n,\bar{a})$ and $^{6}Li(n,\bar{a})$ up to 1.5 MeV.

ORNL Peele+, measurements rel. to H planned, to 15 MeV, USNDC-3.

ORNL de Saussure+ have measurements in progress rel. to $^{10}B(n,\bar{a})$ up to 1.5 MeV; measurements rel. to H planned, to 15 MeV.

AERE Gayther+ have measurements in progress, 1 keV-1 MeV to <5%.

BCMN Deruytter+ to 100 keV, rel. to ^{10}B, EANDC(E)150/U.

CEA Szabo finds older results should be renormalized downward by 2-4 per EANDC(E)150/U.

392 ^{235}U eta Th-50 keV

No active work; however, see alpha, nubar.

393 ^{235}U alpha 0.001 eV to 7 MeV

ORNL de Saussure, to 100 keV, in progress, USNDC-1.

394 $^{235}U(n,f)$ and $(n,\bar{g})$ at 77°K, Th-1 keV

SAC Blons, NSE, to be published

(Table I, cont.)

395 ^{235}U $\bar{\nu}$ Th-3 MeV

RPI Reed+ have measurements in progress, thermal to 200 eV and 24 keV.

LLL Howe+ have measurements in progress, NCSAC-42, see also USNDC-3.

ORNL Peele+ plan measurements to 1.5 MeV.

396 ^{235}U Fission Neutron Y. Th-3 MeV

ANL Smith+ have measurements in progress below 1.6 MeV.

AERE Rose+ find evidence for nonlinearity above 6 MeV, at E_n = 130 keV.

LASL Auchampaugh+ have verified spectrum linearity to 12 MeV at E_n = 1.85 MeV, USNDC-3.

CEA Abramson+ have data to be analyzed at E_n = 8-50 keV, EANDC(E)150/U.

397 ^{235}U Delayed Neutron Y. Th-5 MeV

LASL Evans+ report corrected data, USNDC-3.

ANL Cox, work in progress.

New ^{235}U Delayed Neutron Y. 5-14 MeV

ANL Cox, work in progress.

400 ^{235}U Res. Par. Th-200 eV

ORNL de Saussure+ to 60 eV, plan to extend to 200 eV, USNDC-1.

LASL Keyworth+ measuring J,K in progress, USNDC-3.

ANC Smith+ in progress, single- vs multi-level comparison studies, USNDC-1.

COL Felvinci+ in progress, NCSAC-42.

SAC Blons+ in progress, EANDC(E)150/U, to 150 eV.

401 ^{235}U Fiss. prod. Y. of ^{135}Xe, Th
402 ^{235}U Fiss. prod. Y. of ^{137}Cs, Th
403 ^{235}U Fiss. Prod. Y. of ^{149}Sm, Th
404 ^{235}U Fiss. prod. Y. of ^{147}Nd, Th

GE Meek and Rider compilation summarizes status, NEDO-12154

(Table I, cont.)

407 ^{236}U $\bar{\nu}$ prompt

Data of Conde and Holmberg, JNE 25, 331 (1971), extend from 0.8-6.7 MeV, quoted accuracy <2 per.

New ^{236}U Fission spect., at one point above threshold

BCMN/CNEN Coppola+ have data at 1.5, 1.9, 2.3 MeV, to be analyzed, EANDC(E)150/U.

New ^{236}U Delayed Neutron Y. 3, 14 MeV

None

408 ^{236}U RI to 10%

No active work. Existing measurements agree to within requested accuracy.

409 ^{236}U(n,γ) Th-1 keV

BCMN Rohr+, in progress to 3 keV, rad widths reported by Carlson+ NP A141, 577, have accuracy within 10 per.

410 ^{237}U(n,f) 100 eV-16 MeV

LASL McNally+ to 1.8 MeV, to be published; see LA-4420. Accuracy requested not met.

411 ^{237}U Destruction of Target 1 keV-15 MeV

LASL McNally+ have fission data to 1.8 MeV, LA-4420.

LASL Barr+ have critical assembly core and reflector integral fission measurements.

417 ^{238}U Fission ratio to ^{235}U, 500 keV-15 MeV

ANL Meadows+ have data to 5.3 MeV, to be published. See USNDC-1.

ANL Poenitz+ have points at 2, 2.5, 3 MeV, with quoted accuracy ~2 per. USNDC-1.

LLL Behrens+ have measurements in progress, NCSAC-42.

(Table I, cont.)

418 ^{238}U Fission ratio to ^{239}Pu 500 keV-14 MeV

ANL work planned.

419 ^{238}U $\overline{\nu}$ 1-10 MeV

LLL Howe+ have measurements in progress.

New ^{238}U Delayed Neutron Yield 5-14 MeV

ANL Cox+, work in progress.

LASL Evans+ have recorrected older work, see USNDC-3, NSE to be published.

420 ^{238}U Delayed Neutron Yield, P(E$_n$') Th-5 MeV

ANL Cox planning work.

424 ^{238}U(n,γ) wrt ^{235}U(n,f) or ^{239}Pu(n,f) 10 keV-10 MeV

ORNL de Saussure+ have measurements rel. to ^{235}U and ^{6}Li in progress to 100 keV, plan to extend to 800 keV.

LLL Czirr+ plan measurements rel. to ^{235}U to 1 MeV, USNDC-1.

429 ^{237}Np(n,f) 1 keV-5 MeV

NBS Bowman+ plan measurements rel. to ^{235}U(n,f) to 2 MeV.

430 ^{237}Np(n,f) 20 eV-15 MeV

NBS Bowman+ plan measurements 10 keV-2 MeV.

435 ^{238}Pu(n,f) 1-10 MeV

LASL Silbert+ data to be published Phys. Rev., see USNDC-3.

436 ^{238}Pu(n,f) 10 keV-5 MeV

None that satisfy accuracy requirements.

438 ^{238}Pu $\overline{\nu}$ prompt

LLL Howe+ have measurements in progress, see NCSAC-42.

(Table I, cont.)

439 ^{238}Pu(n,γ) Th-10 MeV

LASL Silbert+ data to be published Phys. Rev., 18 eV-200 keV, see USNDC-3.

441 ^{238}Pu(n,γ) 0.1-300 keV

LASL Silbert+ to be published Phys. Rev., to 200 keV, see USNDC-3.

443 ^{238}Pu Destruction of Target 1 keV-15 MeV

LASL Silbert+ capture and fission data to be published Phys. Rev., see USNDC-3.

449 ^{239}Pu(n,f) Th-1 keV

LLL Behrens+ have measurements in progress, NCSAC-42.

RPI Block+ plan measurement rel. to ^{235}U, Th and 24 keV.

BCMN Theobold+ in progress to 2 keV, EANDC(E) 150/U.

SAC Blons, NSE, to be published.

450 ^{239}Pu(n,f) 1 eV-10 MeV

LLL Behrens+ have measurements in progress, NCSAC-42.

ORNL Gwin+ to 1.5 MeV, in progress, see NCSAC-42.

ANL Poenitz+, 0.15-5 MeV rel. to ^{235}U in progress.

NBS Bowman+ plan measurements 0.1-2 MeV.

RPI Block+ have measurements in progress, 1-200 keV.

AERE Gayther+ have measurements in progress, show agreement with evaluation by Sowerby+ AEREM 2497, to 5 per.

SAC Blons, NSE, to be published, to 30 keV.

ORNL Peele+, rel. to H, ^{10}B, and ^{235}U, plan measurements to 15 MeV, USNDC-3.

(Table I, cont.)

451 ^{239}Pu Fission ratio wrt ^{235}U 10 keV-15 MeV

NBS	Bowman+ plan measurements 0.1-2 MeV, 2-5 per.
ANL	Poenitz+ in progress 0.15-3 MeV, 1 per.
LLL	Behrens+ in progress, expect 2 per, see NCSAC-42.
ORNL	Gwin+ in progress to 1.5 MeV, expect 2 per, see NCSAC-42, USNDC-3.
RPI	Block+ in progress to 200 keV, expect 1 per.
CEA	Szabo+ have completed new measurements 17 keV-1 MeV, EANDC(E)150/U.
ORNL	Peele+ plan measurements, USNDC-3.

452 ^{239}Pu $\bar{\nu}$ Th-10 MeV

RPI	Reed+ plan measurements, Th-200 eV.
ORNL	Weston+ in progress, Th-200 eV, plan to extend to 1.5 MeV.
LLL	Howe+ in progress rel. to $\bar{\nu}$ ^{252}Cf, see NCSAC-42.
SAC	Trochon and Ryabov find no evidence for spin correlation, EANDC(E)150/U.
AAEC	Boldeman and Walsh have data below 2 MeV, to be published.

453 ^{239}Pu Delayed Neutron Yield 3-14 MeV

LASL	Evans+ report recorrected older work, NSE, to be published, USNDC-3.
ANL	Cox, in progress.

454 ^{239}Pu eta Th-1 eV

No active work; however, see alpha and nubar.

455 ^{239}Pu alpha 100 eV-10 MeV

RPI	Block+ plan measurements, 1-200 keV.

458 ^{239}Pu Fission Product Yield of ^{135}Xe at Thermal
459 ^{239}Pu Fission Product Yield of ^{137}Cs at Thermal
460 ^{239}Pu Fission Product Yield of ^{147}Nd at Thermal
461 ^{239}Pu Fission Product Yield of ^{249}Sm at Thermal

GE	Meek and Rider compilation summarizes status, NEDO-12154.

(Table I, cont.)

464 $^{240}Pu(n,f)$ 500 eV-10 MeV

LLL Behrens+ have measurements in progress, see NCSAC-42.

ORNL Weston+ have measurements in progress to 250 keV.

AERE Belcher+ have measurements in progress rel. to ^{235}U to 1 MeV.

465 ^{240}Pu Fission ratio to ^{235}U, 1 keV-15 MeV

LLL Behrens+ have measurements in progress, see NCSAC-42.

AERE Belcher+ have measurements in progress to 1 MeV.

467 ^{240}Pu Delayed Neutron Yield 750 keV-14 MeV

ANL Cox will try, if sample is available.

470 ^{240}Pu alpha 150 keV-7 MeV

ORNL Weston+ have measurements in progress to 250 keV.

474 $^{241}Pu(n,f)$ Th-10 MeV

ORNL Weston+ in progress, rel. to $^{10}B(n,\alpha)$, to 200 keV.

LLL Behrens+ in progress, rel. to ^{235}U, NCSAC-42.

CEA Szabo+ have completed measurements 17 keV-1 MeV, EANDC(E) 150/U.

SAC Blons+ report data taken at LN temperature to 30 keV, NSE, to be published.

475 ^{241}Pu Fission ratio to ^{235}U 10 keV-15 MeV

LLL Behrens+ in progress, NCSAC-42.

476 ^{241}Pu $\overline{\nu}$ 1 keV-10 MeV

LLL Howe+ plan measurements above 10 keV, see NCSAC-42.

477 ^{241}Pu $\overline{\nu}$ prompt 500 keV-14 MeV

LLL Howe+ plan measurements, see NCSAC-42.

478 $^{241}Pu(n,\gamma)$ Th-30 keV

ORNL Weston+ in progress.

(Table I, cont.)

479 ^{241}Pu alpha 1 keV-2 MeV

ORNL Weston^{+} in progress to 250 keV.

480 ^{241}Pu Res. Par. Th-400 eV

SAC Blons^{+}, least squares multilevel analysis in progress, EANDC(E) 150/U.

481 ^{241}Pu Delayed Neutron Yield Th-14 MeV

ANL Cox may attempt if sample is available.

485 ^{242}Pu(n,f) Th

None

486 ^{242}Pu $\bar{\nu}$ 500 keV-10 MeV

None

487 ^{242}Pu $\bar{\nu}$ prompt 500 keV-14 MeV

None

488 ^{242}Pu Delayed Neutron Yield 3,14 MeV

LASL Evans^{+} report recorrected older data, to be published NSE, see USNDC-3.

489 ^{242}Pu(n,γ) Th-7 MeV

RPI Block^{+} plan measurements 20 eV-30 keV.

490 ^{242}Pu(n,γ) 0.1-300 keV (Oct)

RPI Block^{+} plan measurements to 30 keV.

BCMN Rohr^{+} to 1 keV, in progress, EANDC(E) 150/U.

496 ^{241}Am(n,γ) Th-10 MeV

ORNL de Saussure^{+} in progress, to 250 keV.

497 ^{241}Am(n,γ) 0.1-300 keV

ORNL Weston^{+} in progress, to 250 keV.

(Table I, cont.)

499 $^{242}Am(n,f)$ Th-10 keV

LLL Browne+ plan measurement, see NCSAC-42.

500 $^{242}Am(n,\gamma)$ Th-10 MeV

No active work.

505 ^{243}Cm Total Th-10 keV

No active work.

506 $^{243}Cm(n,f)$ Th-100 keV

LASL Diven has data to be analyzed from Physics 8.

LLL Browne+ plan measurements, see NCSAC-42.

507 $^{243}Cm(n,\gamma)$ Th-10 keV

No active work.

508 ^{244}Cm Total Th-10 keV

SRL Benjamin+ have data to be analyzed.

510 $^{244}Cm(n,f)$ 10-100 keV

No active work in this energy region.

512 $^{244}Cm(n,\gamma)$ Th-10 MeV

No active work.

513 $^{244}Cm(n,\gamma)$ 0.1-300 keV

No active work.

514 ^{245}Cm Total Th-10 keV

No active work.

515 $^{245}Cm(n,f)$ Th-100 keV

LLL Browne+ plan measurements, NCSAC-42.

(Table I, cont.)

516 $^{245}Cm(n,\gamma)$ Th-10 keV

No active work.

518 $^{246}Cm(n,f)$ 10-100 keV

No active work in this energy region.

519 $^{246}Cm(n,\gamma)$ Th-10 keV

No active work.

520 ^{247}Cm total - Th-10 keV

No active work.

521 $^{247}Cm(n,f)$ Th-100 keV

LLL Browne[+] plan measurements, NCSAC-42.

522 $^{247}Cm(n,\gamma)$ Th-10 keV

No active work.

523 ^{248}Cm total Th-10 keV

SRL Benjamin[+] plan measurements at ORELA.

524 $^{248}Cm(n,f)$ 10-100 keV

No active work in this energy region.

525 $^{248}Cm(n,\gamma)$ Th-10 eV

SRL Benjamin[+] will try to infer from total cross section measured on ORELA.

528 $^{249}Cf(n,f)$, 10-100 keV

LASL Silbert has data to be published, see USNDC-3.

LLL Browne[+] plan measurements, NCSAC-42.

(Table I, cont.)

533 ^{252}Cf(n,f) 10-100 keV

No active work.

538 ^{253}Es(n,f) 10-100 keV

No active work in this energy region; see LASL, Silbert, USNDC-3.

541 ^{257}Fm(n,f) 10-100 keV

No active work in this energy region.

REPORT OF THE USNDC SUBCOMMITTEE ON RESONANCE PARAMETERS, RESONANCE INTEGRALS AND TOTAL CROSS SECTIONS

August 31, 1972

(R. Block, Chairman, A. Carlson, J. Farrell, W. Havens, M. Kalos and O. Simpson)

This subcommittee was charged with the review of all requests involving the measurement of resonance parameters, resonance integrals, and total cross sections. A summary of the request type, number, number satisfied, and estimate of man-years of scientific effort required to complete these requests is contained in Table I. A total of 68 requests were reviewed, and to date 9 of these requests have been confirmed as satisfied by direct consultation with the requestor (or his delegated representative). The Estimated Scientific Man Years Required to Complete the Requests represents our best guess at what would be necessary to carry out these requests, assuming (as in the case of the transplutonic nuclei) that suitable samples can be provided. The lower limit represents the minimum time it would take to satisfy all or the bulk of the request, with today's facilities, while the upper limit is a much cruder estimate of the maximum time required. However, the (+) indicates that for some of the requests it is about impossible today to provide the required accuracy over the indicated energy range and that considerable more time will have to be spent to get the request satisfied. A typical request in this (+) category is Request Number 533 for the resonance parameters of ^{239}Pu in the keV region; a large number of reasonably good measurements have already been made and a considerable amount of additional work will have to be expended to improve the status of these parameters. It is also not clear how many confirmation measurements will have to be carried out at different laboratories before the requestor is satisfied that his accuracy has been obtained; the estimated man years only represent a thorough measurement by <u>one group at one laboratory</u>.

The requests were reviewed in detail by the committee. The following questions were answered for each request: (i) Is the request satisfied? If so, the requester was contacted for his confirmation, (ii) Does the request make sense? Should it be modified? (iii) Can it be carried out with present day facilities, samples? (iv) How many scientific man-hours are needed to complete the request? (v) Is there any active work on the request? Specific comments upon the requests relating to these questions are contained in Tables II and III.

A few general comments can be made about our review. Most of the requests contained in Table II on Resonance Integrals and Resonance Parameters also appeared in the previous (January 1971) review of these requests by this committee. Since most of the comments pertinent at that time still apply today, these were generally not repeated in the comments in Table II. In fact, it is the opinion of the Chairman that many of these previous comments were never reviewed by the requester, since it appears that they have had little effect one-way-or-the-other on the current request list. Perhaps the personal contact between reviewer and requester this time will have a more tangible impact on updating requests. In the previous report we recommended that a dE/E facility be set up at at least two laboratories to carry out resonance integral measurements, and that for the most part existing U.S. pulsed accelerator and nuclear explosion facilities are adequate for the resonance energy measurements; this recommendation applies again for this review. Again, as for the previous report, we recommend that a task force type of approach be carried out when measurements of total, capture, resonance parameters, resonance integrals, etc. upon a particular set of isotopes have been requested (as in the case of Zr).

TABLE I

REQUEST TYPE	NUMBER OF REQUESTS				NUMBER OF REQUESTS SATISFIED OR WITHDRAWN	ESTIMATED SCIENTIFIC MAN-YEARS REQUIRED TO COMPLETE REQUESTS
	Priority I	Priority II	Priority III	Total		
Resonance Integral	12	4	0	16	3	15 to 22 (+)
Resonance Parameter (non-fissile)	11	5	0	16	0	24 to 38 (+)
Resonance Parameters (fissile)	2	5	0	7	0	16 to 32 (+)
J,π	1	3	2	6	0	11 to 20 (+)
Total Cross Section	15	7	1	23	6	16 to 34 (+)
TOTAL	41	24	3	68	9	82 to 146(+)

TABLE II
RESONANCE INTEGRALS AND RESONANCE PARAMETERS

REQ. NO. 70 Na (Γ_n and Γ_γ of 3 keV res.)

(i) Γ_n is already known to be better than 10%. The problem is in Γ_γ.

(ii) BNL Chrien finds significantly different capture spectra at resonance and thermal energies which could lead to larger Γ_γ than predicted by thermal capture cross section.

(iii) COL Rahn+, USNDC-1(1972): Γ=388 eV, J=1, 1=0.

(iv) ORNL Macklin and Allen, NCSAC-42(1971), pg. 185: report $\sigma(n,\gamma)$ measurement.

REQ. NO. 128 Cr (capture RI)

(i) KFK Beer+, KFK-1271, 117 (1971) have measured par. of 15 res in ^{50}Cr and 19 res. in ^{52}Cr.

REQ. NO. 131 ^{53}Cr (Γ_γ)

(i) It is extremely doubtful that Γ_γ will ever be determined for the resonances near 600 keV.

(ii) KFK Müller and Rohr, NP A164, 97 (1971), report J, Γ_n for 30 res. in ^{53}Cr from 17 to 250 keV.

(iii) KFK Plan measurements on separated isotope.

REQ. NO. 154 Fe (capture RI)

(i) An accurate 0.0253 eV to 1 keV capture cross-section measurement would help in clearing up discrepancy between the calculated thermal capture cross section and the measured value. The shape of the capture cross section over this energy range should help in determining the effect of negative energy levels.

TABLE II(cont'd)

REQ. NOS. (155 Fe (Γ_n and Γ_γ)
(160 ^{57}Fe (Γ_n)

(i) COL Rahn+, NSE 47, 372 (1972): measured total cross section-minima.
(ii) RPI Block+, USNDC-1(1972): measured total cross-section minima.
(iii) ORNL Harvey+, USNDC-1(1972): measured total cross-section minima.
(iv) ORNL Harvey+, measured transmission of separated isotopes and should obtain Γ_n's.

REQ. NO. 156 Fe(J,π)
(i) No active work.

REQ. NO. 162 Co (res. par.)
(i) LUCAS HTS. Bird+, AAEC/PR33, pg. 14(1970): Γ_γ

REQ. NO. 168 ^{58}Co (J,π)
(i) Unique determination of the spins and parities of all levels in ^{58}Co from 25 keV to 3 MeV is a very big job (if it is possible at all.) For many levels it is known that only a few values of J^π are possible. It may be worthwhile for the requestor to try various possible combinations in his calculations in order to determine the sensitivity of the calculations to the J^π values.
(ii) Xenoulis, NP A170, 369 (1971).

REQ. NO. 182 Ni (capture RI)
(i) KFK Ernst+, Proc. of Helsinki Meeting, Vol. 1, 633 (1970), Γ_γ of 14 resonances between 7 and 37 keV.
(ii) RPI Hockenbury+, USNDC-1(1972), capture measurements on ^{61}Ni.
(iii) KFK Beer+, KFK 1271/3, parameters for 15 res. in ^{60}Ni, 13 res. in ^{62}Ni and 19 res. in ^{64}Ni.

TABLE II(cont'd)

REQ. NO. 188 ^{61}Ni (Γ_n)

(i) RPI Hockenbury+, USNDC-1(1972), capture measurements of separated isotope and will obtain Γ_γ and Γ_n; will make transmission measurements to several hundred keV.

REQ. NOS. (249 ^{90}Zr (Γ_n and Γ_γ)
(255 ^{91}Zr (" " ")
(261 ^{92}Zr (" " ")
(266 ^{94}Zr (" " ")

(i) ORNL Macklin has finished capture measurements from 2.5-500 keV. He is in the process of analyzing the data. Resonance parameters should be obtained up to ~100 keV for the even isotopes and ~25 keV for the odd isotopes.
(ii) ORNL Good is waiting for samples and will make a total measurement in the energy region of 0.5-500 keV. The total and capture data will be combined to yield the best set of resonance parameters, E_o, Γ_n, and Γ_γ for the resolved resonances above 2.5 keV.
(iii) There are still bad discrepancies among the existing data sets for some of the levels below 2.5 keV. Capture and total measurements should be made covering these resonances.
(iv) A complete evaluation should be done incorporating all earlier measurements plus the new measurements at ORNL and the results submitted to ENDF/B.
(v) BNL Mughabghab, BAPS 17, 18AE17(1972) and USNDC-1 (1972), deduced J for 7 resonances in ^{91}Zr.

REQ. NOS. (230 Zr (capture RI)
(248 ^{90}Zr (capture RI)
(254 ^{91}Zr (" ")
(260 ^{92}Zr (" ")
(265 ^{94}Zr (" ")
(271 ^{96}Zr (" ")

TABLE II(cont'd)

(i) Requests 265 and 271 are satisfied.
(ii) KAPL Fullmer Nuc. Sci. and Engr. 45, 314 (1971) for isotopes of 94 and 96.
(iii) ORNL Macklin's capture and Good's total data will produce resonance parameters for levels above 2.5 keV.

REQ. NO. 250 ^{90}Zr (J,π)

(i) The evaluation by K. Way indicates that this request is essentially satisfied. Only a few levels are uncertain as to J^{π}.
(ii) The requestor should perform calculations to see if these uncertain levels are significant.
(iii) Ball, Phys. Rev. C4, 196 (1971).
(iv) Glenn, NP A165, 533 (1971)

REQ. NO. 256 ^{91}Zr (J,π)

(i) This is an extremely difficult task. The level spacing is very small. The requestor should decide if the maximum excitation energy could be lowered.
(ii) Glenn, NP A165, 533 (1971).

REQ. NO. 262 ^{92}Zr (J,π)

(i) No active work.

REQ. NO. 267 ^{94}Zr (J,π)

(i) The spins and parities of the levels are fairly well known at lower excitation energies (up to ~2.6 MeV). The requestor should determine if the 4 MeV upper limit is necessary.
(ii) Ball, Phys. Rev. C4, 196 (1971).

REQ. NOS. (356 Gd (capture RI)
(357 ^{154}Gd (Γ_n and Γ_γ)
(359 ^{155}Gd (capture RI)
(360 ^{155}Gd (Γ_n and Γ_γ)
(362 ^{156}Gd (capture RI)

TABLE II(cont'd)

REQ. NOS. (363 ^{156}Gd (Γ_n and Γ_γ)
(365 ^{157}Gd (capture RI)
(366 ^{157}Gd (Γ_n and Γ_γ)
(368 ^{158}Gd (capture RI)
(369 ^{158}Gd (Γ_n and Γ_γ)
(370 ^{160}Gd (capture RI)
(371 ^{160}Gd (Γ_n and Γ_γ)

(i) COL Rahn+, NSE 48, 219(1972): Resonance capture integrals for ^{154}Gd, ^{158}Gd, ^{160}Gd.
(ii) COL USNDC-1(1972), Res. par. up to 1 keV for ^{154}Gd and to 10 keV for $^{158,160}Gd$.
(iii) Req. No. 366: SAC Ribon (Ph.D. Thesis).

REQ. NO. 442 ^{233}U (res. par.)
(i) If 10% accuracy on parameters is required, this does not make sense as multilevel parameters of fissile nuclei are not unique. It is, however, possible to obtain parameters which reproduce the observed cross section to 10%.
(ii) Keyworth will measure spins at ORELA. Combining this data with cooled-sample cross-section data should give parameters to 100-190 eV with perhaps 10% accuracy. This is probably the best that can be done at present.
(iii) It appears that average parameters could be obtained in the higher energy region by measuring the average cross sections as a function of sample thickness and temperature.
(iv) COL Rahn+, USNDC-1(1972), deduce parameters for 38 resonances.

REQ. NO. 474 ^{235}U (res. par.)
(i) If 10% accuracy on parameters is required, this does not make sense as multilevel parameters of fissile nuclei are not unique. It is, however, possible to obtain parameters which reproduce the observed cross section to 10%.

TABLE II(cont'd)

(ii) Keyworth will measure spins at ORELA. Combining this data with cooled-sample cross-section data should give parameters to 100-190 eV with perhaps 10% accuracy. This is probably the best that can be done at present.
(iii) LASL Keyworth+, NCSAC-42(1971) will measure spins by polarization to ~100 eV at ORELA.
(iv) BNL Chrien+, NCSAC-42(1971), deduced J,π for 7 resonances.

REQ. NO. 483 ^{236}U (RI)
(i) Request satisfied
(ii) GEEL Theobald+, NP A181, 639 (1972), deduced Γ_f for 16 resonances below 415 eV.

REQ. NO. 502 ^{238}U (res. par.)
(i) There is a vast amount of data available (especially with recent Columbia measurements). Additional measurements seem pointless unless significant improvements can be made.
(ii) Perhaps this request is now as satisfied as it is likely to be for some time.
(iii) COL Rahn+, NCSAC-42(1971) and USNDC-1(1972) Trans. and self-indication measurements.

REQ. NO. 533 ^{239}Pu (res. par.)
(i) The Saclay data are probably as good as can be obtained with current techniques. There appears to be no point in repeating the considerable amount of work for a slight improvement of the parameters.

REQ. NO. 546 ^{240}Pu (res. par.)
(i) Apparently satisfied by recent RPI results and renormalized Geel results.
(ii) RPI Hockenbury+, NSE (1972); capture, fission and total measurements to 30 keV. Deduced res. par. for 35 resonances below 500 eV.

TABLE II(cont'd)

(iii) Geel Weigmann (private communication), renormalized their data to revised Harwell results and are now in agreement with RPI Γ_{ν} results.

(iv) ORNL Weston (private communication), measured capture in ^{240}Pu and is in agreement with RPI results.

REQ. NO. 554 ^{241}Pu (res. par.)

(i) Accuracy of 5% does not seem possible, especially need 400 eV.

(ii) Need to assign spins before it will be possible to do much better than currently available data. Even if this is done, the multilevel fits are not unique.

REQ. NO. 574 ^{242}Cm (res. par.)

(i) Suitable samples can probably be obtained.

(ii) Sample is rather hot for present day accelerators, but perhaps measurement could be done. A measurement could be done easily with a bomb shot, but none are planned at present.

TABLE III
TOTAL CROSS-SECTION REQUESTS

REQ. NO. 1 ^{1}H (total)
(i) Probably satisfied (see USNDC Standards Subcommittee Report, Aug. 8, 1972).

REQ. NO. 6 ^{3}He (total)
(i) RPI/LASL Stoler and Seagraves: have data from 0.7 to 30 MeV.
(ii) Validity of this request is questionable (see USNDC Standards Subcommittee Report, Aug. 8, 1972).

REQ. NO. 10 ^{6}Li (total)
(i) RPI Goulding+, USNDC-1, pg. 572, (1972): have data from 0.7 to 30 MeV.
(ii) Request withdrawn.

REQ. NO. 21 ^{7}Li (total)
(i) Request withdrawn.

REQ. NO. 34 ^{10}B (total)
(i) No active work.

REQ. NO. 65 Na (total)
(i) No active work.

REQ. NO. 116 Cr (total)
(i) No active work.

REQ. NO. 134 Fe (total)
(i) COL Rahn+, NSE 47, 372, (1972) Measured transmission of thick samples (to obtain data near cross-section minima).

TABLE III (cont'd)

(ii) RPI Alfieri+, USNDC-1, pg. 178,(1972) Measured transmission of thick samples (to obtain data near cross-section minima).
(iii) ORNL Harvey+, NCSAC-42, pg. 183,(1971) Measured transmission of thick samples (to obtain data near cross-section minima).

REQ. NO. 169 Ni (total)
(i) No active work.

REQ. NO. 211 ^{83}Kr (total)
(i) No active work.

REQ. NO. 243 ^{90}Zr (total)
(i) No active work.

REQ. NO. 479 ^{236}U (total)
(i) Request satisfied.

REQ. NO. 564 ^{241}Am (total)
(i) No active work.

REQ. NO. 568 ^{242}Am (total)
(i) No active work.

REQ. NO. 571 ^{243}Am (total)
(i) Request satisfied.
(ii) ANC Simpson+, ANCR 1060 (Feb. 1972), meas. trans. from 0.5 to 1000 eV.

TABLE III (cont'd)

REQ. NO. 575 ^{243}Cm (total)
(i) INC Berreth+, BNL-50298 (1971), meas. trans. and deduced res. par.

REQ. NO. 578 ^{244}Cm (total)
(i) Request satisfied.
(ii) ANC Simpson+, meas. trans.

REQ. NO. 583 ^{245}Cm (total)
(i) LLL Bowman and ORNL Dobbs plan to make meas. (probably fission)

REQ. NO. 586 ^{246}Cm (total)
(i) LASL Moore+, Phys. Rev. C3, 1656 (1971), report res. par. above 20 eV.

REQ. NO. 589 ^{247}Cm (total)
(i) LLL Bowman plans to make meas. (probably fission)

REQ. NO. 592 ^{248}Cm (total)
(i) ORNL Halperin plans to make integral meas.
(ii) SRL MacMurdo, has data on capture integral.
(iii) SRL/ORNL Benjamin+, plan to make res. energy meas.
(iv) SRL/ORNL Benjamin+, NSE 47, 203 (1972), meas. thermal and res. int. fission.

REQ. NO. 595 ^{249}BK (total)
(i) LLL Bowman plans to make meas. (probably fission)

REQ. NO. 598 ^{250}Cf (total)
(i) ORNL Halperin, ORNL 4706, has res. int. data.

REPORT OF THE USNDC SUBCOMMITTEE ON TOTAL CAPTURE CROSS SECTIONS

Status Comments

R. L. Macklin, ORNL, Chairman
R. C. Block, RPI
M. P. Fricke, GRT
W. Poenitz, ANL
J. B. Czirr, LLL

Revised November 14, 1972

New Request	Old NCSAC-35	Target	Status
32	24	4Be	See CINDA
62	52	9F	Nystroem PS 4, 95-99, 1971
77	--	13Al	Macklin data above 2.5 keV, Nystroem PS 4, 95-99, 1971
87	67	14Si30	See CINDA
88	68	16S34	See CINDA
90	70	19K41	Stet
95	75	20Ca44	Macklin data above 2.5 keV
97	77	21Sc	See CINDA
109	--	23V	See CINDA
110	86	23V	See CINDA
122	90	24Cr	See CINDA
123	--	24Cr	No News
132	95	25Mn55	See CINDA
143	--	26Fe	See CINDA, Kenny AUJ 24, 805 (1972), Moxon plans
144	--	26Fe	No News
157	107	26Fe54	See CINDA, KFK Ernst+, Kenny AUJ 24, 805 (1972), RPI Hockenbury+, USNDC-1 (1972): have capture data from 0.1 to 200 keV on separated isotope (no data given).
161	111	26Fe58	See CINDA, Hockenbury+, USNDC-1 (1972): have capture data from 0.1 to 200 keV on separated isotope (no data given), Beer-KFK plans.

New Request	Old NCSAC-35	Target	Status
163	113	27Co	No News
164	114	27Co	See CINDA, Elgart OA-328 (NTU-pile act), Beer-KFK plans
166	--	*27Co58	See CINDA
167	--	*27Co58	See CINDA
176	--	28Ni	No News
192	--	29Cu	See CINDA Supp.
198	128	29Cu63	Stet
199	129	29Cu63	Macklin data above 2.5 MeV
202	132	29Cu65	Stet
205	--	30Zn64	See CINDA
212	142	36Kr83	See CINDA
214	144	*37Rb83	No News
217	147	*37Rb84	No News
228	155	40Zr	See CINDA, Poenitz, Czirr (USNDC-1, 8 & 94), ANL Poenitz, measurements, 400-1500 keV started
229	--	40Zr	No News
238	160	*40Zr88	See CINDA Supp.
241	163	*40Zr89	See CINDA Supp.
268	196	*40Zr95	See CINDA Supp.
270	200	40Zr96	.020 $\pm$ .003 B NSE 46, 312 (1971)
278	207	41Nb	Data Harlow+; Poenitz; plans Macklin
288	211	*41Nb91	No News
291	214	*41Nb92	No News
293	216	*41Nb93	No News
294	218	*41Nb95	See CINDA
300	222	42Mo	See CINDA, data Weigmann; Macklin; ANL Poenitz measurements started 400-1500 keV

New Request	Old NCSAC-35	Target	Status
301	--	42Mo	See CINDA
309	225	*42Mo99	See CINDA Supp.
310	226	*44Ru103	See CINDA Supp.
311	227	45Rh	See CINDA, Carlson, Glass+ data
312	228	*45Rh105	See CINDA & Supp.
313	229	*46Pd107	See CINDA Supp.
314	230	47Ag109	See CINDA Supp.
315	231	*52Te127	No News
316	232	*52Te132	See CINDA Supp.
317	233	*53I133	See CINDA Supp.
318	234	54Xe131	See CINDA Supp.
319	235	*54Xe133	See CINDA Supp.
320	236	*54Xe135	See CINDA Supp.
322	238	55Cs	See CINDA & Supp.
323	239	55Cs	See CINDA & Supp.
324	240	60Nd143	Add Macklin data
325	241	60Nd145	Add Macklin data
326	243	*60Nd147	See CINDA Supp.
327	244	*61Pm147	See CINDA Supp.; Harker (USNDC-1, 1) 1972
328	245	*61Pm148	Stet
329	246	*61Pm148	See CINDA, Pile activation
330	247	*61Pm149	See CINDA
331	248	*61Pm151	See CINDA
332	250	62Sm150	See CINDA Supp.
333	251	*62Sm151	See CINDA Supp.
334	253	62Sm152	See CINDA Supp.; Harker (USNDC-1, 1) 1972
335	254	*62Sm153	No News
336	255	63Eu	See CINDA

New Request	Old NCSAC-35	Target	Status
339	258	*63Eu148	See CINDA Supp.
341	260	*63Eu149	See CINDA Supp.
343	262	*63Eu150	See CINDA Supp.
345	264	63Eu151	See CINDA Supp.
346	265	63Eu151	See CINDA & Supp.
347	266	*63Eu152	See CINDA
348	267	63Eu153	See CINDA & Supp.
349	269	*63Eu154	See CINDA & Supp.
350	270	*63Eu154	See CINDA & Supp.
351	272	*63Eu155	See CINDA & Supp.
354	275	64Gd	See CINDA & Supp.
358	279	64Gd155	See CINDA & Supp.
361	282	64Gd156	See CINDA & Supp.
364	285	64Gd157	See CINDA & Supp.
367	288	64Gd158	See CINDA & Supp., Hacken (NCSAC-42, 61) 1972RI
372	293	66Dy	See CINDA & Supp., Slaughter data
375	298	*69Tm167	See CINDA Supp.
377	300	*69Tm168	See CINDA Supp.
379	302	69Tm	See CINDA & Supp., Czirr (USNDC-1, 94)
380	303	*69Tm170	See CINDA Supp., Miyano JPJ <u>31</u>, 1304 (1971)
381	304	*69Tm171	Stet
383	306	*71Lu173	See CINDA Supp.
385	308	*71Lu174	See CINDA Supp.
387	310	71Lu175	See CINDA & Supp., Hacken+ (NCSAC-42, 61) 1972
390	313	72Hf	See CINDA & Supp.
391	314	72Hf174	See CINDA Supp.
392	315	72Hf176	See CINDA & Supp.

New Request	Old NCSAC-35	Target	Status
393	316	72Hf177	See CINDA & Supp., Rohr data-Budapest Conf.
394	317	72Hf178	See CINDA & Supp.
395	318	72Hf179	See CINDA & Supp.
396	319	72Hf180	See CINDA & Supp.
398	321	73Ta	See CINDA & Supp.; ANL Poenitz, measurements in 400-1500 keV range started; Czirr+, Block+ (USNDC-1, 94 & 176) 1972, and paper to be presented at ANS Topical Mtg., Kiamesha Lake, N.Y., Sept. 1972: determined capture cross section at ~24 keV (with filtered beam). Plan to extend to ~80 keV and above.
403	326	74W180	See CINDA & Supp.
405	328	74W182	See CINDA & Supp.; ANL plans; COL Camarda+, to be published in Phys. Rev. C (1972): measured trans. (& self indication) and determined resonance parameters
406	329	74W183	See CINDA & Supp.; ANL plans; COL Camarda+, to be published in Phys. Rev. C (1972): measured trans. (& self indication) and determined resonance parameters
407	330	74W184	See CINDA, ANL plans; COL Camarda+; to be published in Phys. Rev. C (1972): measured trans. (& self indication) and determined resonance parameters
408	331	74W184	See CINDA, ANL plans
410	333	74W186	See CINDA & Supp.; ANL plans; COL Camarda+; to be published in Phys. Rev. C (1972): measured trans. (& self indication) and determined resonance parameters
411	334	76Os186	See CINDA & Supp.
412	335	76Os187	See CINDA & Supp.
413	336	79Au	See CINDA & Supp., Moxon; Froehner; Macklin data; Czirr (USNDC-1, 94); Moxon-revisions in progress, and new data; RPI Block+, USNDC-1 (1972) and paper to be presented at ANS Topical Mtg., Kiamesha Lake, N.Y., Sept. 1972: determined capture cross section at ~24 keV (with filtered beam), plan to extend to ~80 keV and above.
414	337	*81Tl204	See CINDA
420	343	82Pb208	Allen+, preprint in preparation.

New Request	Old NCSAC-35	Target	Status
424	347	90Th	Stet, Moxon revisions in progress; ANL Poenitz, measurements, 200-2000 keV in '73
429	353	91Pa231	See CINDA & Supp.
430	354	*91Pa233	See CINDA & Supp.
451	378	92U234	See CINDA & Supp., RPI Block+, plan to make capture measurements
484	409	92U236	See CINDA & Supp., Rohr-Geel data
497	421	92U238	See CINDA & Supp., Block+, Czirr+ (USNDC-1, 176 and 94 resp.) 1972; Moxon revisions in progress, Beer-KFK data; Pearlstein-Harwell plans; Ryves, Nat. Phys. Lab., UK, measured in 150-650 keV range; ANL Poenitz, measurements in 400-1500 keV range started.
498	422	92U238	See CINDA & Supp., Czirr+ (USNDC-1, 94) 1972; Moxon revisions in progress and new data; Beer-KFK data; Pearlstein-Harwell plans; Ryves, Nat. Phys. Lab., UK, measured in 150-650 keV range; ANL Poenitz measurements in 400-1500 keV range started; RPI Block+, paper to be presented at ANS Topical Mtg., Kiamesha Lake, N.Y., Sept. 1972: determined capture cross section at ~24 keV (with filtered beam), plan to extend to ~80 keV and above.
500	424	92U238	Stet
506	431	93Np237	See CINDA & Supp.
507	432	*93Np238	See CINDA & Supp.
513	439	94Pu238	See CINDA & Supp.
514	441	94Pu238	See CINDA & Supp.
543	468	94Pu240	See CINDA & Supp.; RPI Hockenbury+, accepted for publication in NSE: measured capture and fission cross section up to 30 keV, transmission up to ~1 keV and obtained resonance parameters.
544	469	94Pu240	See CINDA & Supp.; Froehner+ plans, Beer-KFK plans
552	478	94Pu241	See CINDA & Supp.; Smith+; Moat+ data
561	489	94Pu242	See CINDA & Supp.; James NP A123, 24; Beer-KFK plans; RPI Hockenbury+, capture measurements up to 30 keV are in progress

New Request	Old NCSAC-35	Target	Status
562	490	94Pu242	See CINDA & Supp.; James NP A123, 24; Czirr (foil available, exp. planned); Beer-KFK plans; RPI Hockenbury+, capture measurements up to 30 keV are in progress.
566	496	95Am241	See CINDA & Supp.
567	497	95Am241	No News
570	500	95Am242	See CINDA
572	502	95Am243	See CINDA & Supp.
573	503	*96Cm242	See CINDA & Supp.
577	507	96Cm243	See CINDA & Supp.
581	512	96Cm244	See CINDA & Supp.; Berreth+ (NCSAC-42, 4) 1972 THR
582	513	96Cm244	See CINDA & Supp.
585	516	96Cm245	See CINDA & Supp.
588	519	96Cm246	See CINDA & Supp.
591	522	96Cm247	See CINDA & Supp.
594	525	96Cm248	See CINDA & Supp.
596	527	97Bk249	See CINDA & Supp.
600	531	98Cf250	See CINDA & Supp.
601	532	98Cf251	See CINDA & Supp.
606	536	98Cf252	See CINDA & Supp.
607	537	*98Cf253	See CINDA & Supp.

REPORT OF THE USNDC SUBCOMMITTEE ON GAMMA RAY PRODUCTION

H. E. Jackson, Chairman
R. E. Chrien H. T. Motz
J. K. Dickens V. J. Orphan

September 1972

The sub-committee on Gamma Ray Production has completed its review of the status of requests for gamma ray production measurements on stable nuclei contained in the current USNDC request compilation. Attached is a listing of the results of this review by individual request. For each entry the request number, appropriate target, request reviewer, and status comment is included. Also attached is a listing of the results of a review of requests for measurements requiring radioactive samples. In the area of gamma ray production progress since the last review of the request compilation (1970) has not been substantial. All of the requests for gamma ray production cross section contained in the previous compilation (NCSAC-35) have been carried over in the new request retrieval. Where thirty-six requests for gamma ray production data were considered in the previous review seventy-six requests are listed in the new tabulation. A large majority of these requests involve measurements for incident neutrons in the range of 1—15 MeV, and this energy region continues to be the area of greatest difficulty and most limited progress. In spite of the continuing shift in emphasis to requests for production cross sections at higher neutron energies, the national capability for meeting this need has at best remained a constant and most likely has diminished. In the USA at the present time, the only active programmatic efforts in the area of MeV gamma-ray production cross section are at ORELA (ORNL) and Gulf Radiation Technology.

Some progress has been made in the past several years in developing new techniques for measuring gamma-ray production cross sections. The use of white sources of neutrons (usually produced with a linac or cyclotron) and time-of-flight techniques allow $(n,x\gamma)$ cross sections to be measured continuously as a function of neutron energy over a wide range in an efficient manner. This technique provides data in an important energy range, approximately 9—14 MeV where measurements with monoenergetic neutron sources are quite difficult because clean neutron sources from Van de Graaff accelerators are not generally available. The success of the linac technique in providing (n,xγ) cross sections in the 9—14 MeV range may relieve the urgency for developing clear neutron sources at these higher energies. However, cases remain where measurements of angular distributions of resolved or discrete gamma rays from (n,xγ) reactions are important. For these nuclei measurements with Van de Graaff and tandem facilities will likely be necessary. In addition the use of pulsed monoenergetic sources and time discrimination allows effective elimination of troublesome scattered neutron backgrounds from (n,xγ) measurements. In this regard the committee wishes to affirm its earlier recommendation: <u>a substantial research effort should be directed toward adapting the $T(p,n)^3He$ and $D(d,n)^3He$ reactions as accurate and reliable sources of neutrons above 10 MeV and developing target collimation and shielding materials which will alleviate the severe backgrounds characteristic of their use.</u> Substantial neutron backgrounds <u>may</u> continue to be the major failing of white source experiments on linacs at higher neutron energies, but efforts to determine the possibilities for linac experimentation with 10—20 MeV neutrons should be actively pursued.

The number of man-years of experimental effort required to meet GRP requests reviewed by the committee is difficult to assess because development of experimental techniques remains an important element. In addition to the study of appropriate sources of high energy neutrons considerable effort is currently focused on developing Ge(Li) detectors and associated methods of analysis as tools for measuring discrete and continuum gamma-ray spectra. For observation of discrete lines high resolution Ge(Li) systems are currently preferable, and their use in systematic studies of line intensities as a function of neutron energy will be necessary for relating observed production spectra to nuclear level schemes and for developing calculational techniques for generating production spectra in the absence of experimental data. On the other hand at higher neutron energies line broadening impairs the usefulness of Ge(Li) systems. At these energies and also for those specific requests where spectral cross sections for broad energy groups are sufficient, NaI spectrometers may continue to provide a major portion of the information if proper care is taken in shielding and data analysis. If we assume ~1.0 man-years of effort per request and allow approximately 20 man-years of effort for development of experimental techniques outlined in this discussion, then approximately 90—100 man-years of experimental effort will be required to meet current cross section requests in the area of gamma-ray production.

Requests for Gamma-Ray Production Measurements

No. 9 Li Reviewer-Dickens (NCSAC-35 No. 9)

Status — BYU + MIT, Rogers+, Integral E_n = 5-10 MeV, Trans. Am. Nucl. Soc. 13, 864
(Frankfurt), Presser+Bass, E_n = 1-9 MeV, Nucl. Phys. A182, 321

No. 37 B-10 Reviewer-Orphan (NCSAC-35 No. 29)

Status — GRT, Friesenhahn+, Gulf-RT-A12210, 4 to 1000 keV, Accuracy 1.5% to 4.5%
Harwell, Coates+ preliminary data from ~1-240 keV

No. 43 C Reviewer-Dickens (NCSAC-35 No. 35)

Status — ORNL, Morgan+, E_g = 4.43 MeV E_n = 5-20 MeV
θ_g = 90, 125 deg ORNL-TM-3702

No. 52 N Reviewer-Dickens (NCSAC-35 No. 42)

Status — BYU + MIT, Rogers+, Integral E_n = 5-10 MeV E_g = 2.317 MeV, Trans. Am. Nucl. Soc. 13, 864
ORNL, Dickens+, θ_g = 125 deg E_n = 2-20 MeV in progress
ORNL, Dickens+, E_n = 8—11 MeV, Nucl. Sci. Eng. 40, 346. Lund, Nyberg+, E_n = 15 MeV, Phys. Scri. 4, 165.

No. 56 O Reviewer-Dickens (NCSAC-35 No. 46)

Status — Lund, Nyberg+, E_n = 15 MeV, Phys. Scri. 4, 165
ORNL, Dickens+, θ_g = 125 deg E_n = 6—20 MeV in progress,also Nucl. Sci. Eng. 40 283, E_n = 6.7—11 MeV
GRT, Orphan+, Nucl. Sci. Eng. 42 352, E_n = 6.4—16.5 MeV

No. 71 Na Reviewer-Chrien

Status — Unpublished data on 3 keV spectrum exist at BNL (Chrien), Harwell (Lynn), and ORNL (Slaughter). Some differences between resonance and capture spectra are noted; measurements may not be of required accuracy.

No. 81 Al Reviewer-Orphan (NCSAC-35 No. 62)

Status — Strecher-Rasmussen+, NP A181, 225
Orphan+, GGA Report GA-10248

No. 80 Aℓ   Reviewer-Orphan

Status — GRT, Orphan+, Gulf-RT-A10743, Line + Continuum
γ-rays, E_n = 0.86-16.7 MeV
ORNL, Linac + NaI E_n = 1 — 20 MeV in progress
Nyberg+, Physica Scripta 4, 165 (1971), E_n = 15 MeV
Dickens , PR C5, 100 (1972), E_n = 3.53-9.0 MeV
TNC, Buchanan+, ORO-2791-32, E_n = 3.6-4.6 MeV, 14.8 MeV
Kravcov+, USSR, 72 Kiev, Gamma-Spectrum with Ge(Li)
Young+, LASL, Complete Reeval., LA 4726

No. 82 Aℓ   Reviewer-Orphan   (NCSAC-35 No. 63)

Status — GRT, Orphan+, Gulf-RT-A10743, Line + Continuum
γ-rays, E_n = 0.86-16.7 MeV
ORNL, Linac + NaI E_n = 1 — 20 MeV in progress
Nyberg+, Physica Scripta 4, 154 (1971), E_n = 15 MeV
Dickens , PR C5, 100 (1972), E_n = 3.53-9.0 MeV
TNC, Buchanan+, ORO-2791-32, E_n = 3.6-4.6 MeV, 14.8 MeV
Kravcov+, USSR, 72 Kiev, Gamma-Spectrum with Ge(Li)
Young+, LASL, Complete Reeval., LA 4726

No. 83 Aℓ   Reviewer-Orphan

Status — Stecher-Rasmussen+, NP A181, 225
No suitable data for non-thermal capture

No. 93 Ca   Reviewer-Dickens   (NCSAC-35 No. 73)

Status — ORNL, Dickens+, E_n = 5.9 MeV Conf-710301, 235 (Knoxville)
ORNL, Dickens, E_n = 4.8-8 MeV, θ_g = 125 deg., Nucl. Sci. Eng. 48, 78

No. 98 Ti   Reviewer-Dickens   (NCSAC-35 No. 78)

Status — ORNL, Dickens, E_n = 5-6 MeV in progress

No. 99 Ti   Reviewer-Dickens   (NCSAC-35 No. 79)

Status — ORNL, Dickens, E_n = 5-6 MeV in progress

No. 114 V Reviewer-Dickens

Status— AWRE, Porter+, E_n = .3-4 MeV Ge(Li) Detector (n, n') gamma-ray data AWRE-0-78/70

No. 100 Ti Reviewer- (NCSAC-35 No. 80)

Status—ORNL, Dickens, E_n = 5-6 MeV in progress

No. 115 V Reviewer-Dickens

Status—ORNL, Bird+, ORNL-TM-3379 E_n = 20-60 keV

No. 126 Cr Reviewer-Dickens

Status— Tagesen + Hille, Öster Akad Wiss Math 174, 85 spectrum for $\theta_\gamma = 90^\circ$ E_γ = 1-2 MeV

No. 127 Cr Reviewer-Orphan

Status— ANL, Thomas+, USNDC-1, 18
Orphan+, GGA Report GA-10248

No. 129 Cr Reviewer-Orphan (NCSAC-35 No. 92)

Status— Degtjarev+, IZV 35 2341, E_n = 1.0-3.4 MeV

No. 130 Cr Reviewer-Orphan (NCSAC-35 No. 93)

Status— Degtjarev+, IZV 35 2341, E_n = 1.0-3.4 MeV

No. 133 Mn Reviewer-Chrien (NCSAC-35 No. 96)

Status— Spectra for first four resonances known (Chrien, BNL). 2 keV capture spectrum from MTR, IN-1317, p. 116 (1970).

No. 148 Fe Reviewer-Dickens

Status— ORNL, Dickens+, E_n = .85-20 MeV ORNL-4798

No. 149 Fe Reviewer-Chrien

Status—keV capture work of Kenny Aust. J. Phys. 1961, 24, 805-19 Energy dependence of branching ratios known from thermal to 1 keV from BNL work, see BNL 12268

No. 151 Fe Reviewer-Chrien (NCSAC-35 No. 103)

Status — No additional work beyond that noted in status comments.

No. 152 Fe Reviewer-Chrien

Status — Redundant request, covered by 149 and 151.

No. 153 Fe Reviewer-Orphan (NCSAC-35 No. 105)

Status — GRT, Orphan+, Gulf-RT-A10743, Line + Continuum γ-rays, E_n = 0.86-16.7 MeV
ORNL, Dickens+, E_n = .85—20 MeV ORNL-4798
TNC, Buchanan+, ORO-2791-32, E_n = 14.8 MeV
Kravcov+, USSR, 72 Kiev, E_n = 14 MeV

No. 165 Co Reviewer-Chrien (NCSAC-35 No. 115)

Status —Additional measurements noted in CINDA 71 Suppl. 2.

No. 180 Ni Reviewer-Motz

Status — ORNL Dickens+, NCSAC-42, p. 195, have Ge(Li) data at 6 MeV, not yet reduced.
ORNL Dickens+, priv. comm., Aug. 7, 1972, have NaI data at ORELA 47 m station; E_γ 0.7 to 10 MeV, E_n 7 keV to 20 MeV, not yet reduced.
MIT Rasmussen+, GA-10248/DASA-2570, Thermal neutron capture spectrum.

No. 181 Ni Reviewer-Motz

Status — ORNL Dickens+, priv. comm., Aug. 7, 1972, have NaI data at ORELA 47 m station; E_γ 0.7 to 10 MeV, E_n 7 keV to 20 MeV, not yet reduced.
MIT Rasmussen+, GA-10248/DASA-2570, Thermal neutron capture spectrum

No. 183 Ni Reviewer-Motz (NCSAC-35 No. 122)

Status — ORNL Dickens+, NCSAC-42, p. 195, have Ge(Li) data at 6 MeV, not yet reduced.
ORNL Dickens+, priv. comm., Aug. 7, 1972 have NaI data at ORELA 47 m station; E_γ 0.7 to 10 MeV, E_n 7 keV to 20 MeV, not yet reduced.

No. 183 (cont'd.)

MIT Rasmussen+, GA-10248/DASA-2570, thermal neutron capture spectrum.

No. 184 Ni — Reviewer-Motz (NCSAC-35 No. 123)

Status — ORNL Dickens+, NCSAC-42, p. 195, have Ge(Li) data at 6 MeV, not yet reduced.
ORNL Dickens+, priv. comm., Aug. 7, 1972, have NaI data at ORELA 47 m station; E_γ 0.7 to 10 MeV, E_n 7 keV to 20 MeV, not yet reduced.

No. 195 Cu — Reviewer-Dickens

Status — ORNL, Dickens+, E_n = 0.7-20 MeV in progress.

No. 196 Cu — Reviewer-Dickens

Status — ORNL, Maerker+, ORNL-4382 E_n = thermal
Idaho Nuclear Greenwood+, E_n = 2 keV, TID-4500 (IN-1407) UC-80
ORNL, Bird+, ORNL-TM-3379 E_n = 20-50 keV
ORNL, Macklin+, E_n = 3-500 keV in progress

No. 197 Cu — Reviewer-Dickens (NCSAC-35 No. 127)

Status — ORNL, Dickens+, E_n = .7-20 MeV in progress

No. 203 Zn — Reviewer-Dickens (NCSAC-35 No. 133)

Status — ORNL, Maerker+, ORNL-4382.

No. 204 Zn — Reviewer-Dickens (NCSAC-35 No. 133)

Status — (Russian) Konobeevski+, E_n = 1-1.6 MeV IZV Akad Nauk (Physics) 35, 2345
ORNL, Dickens, E_n = 5-6 MeV in progress

No. 208 Ge — Reviewer-Chrien (NCSAC-35 No. 138)

Status — None

No. 233 Zr — Reviewer-Motz (NCSAC-35 No. 157)

Status — MIT Rasmussen+, GA-10248/DASA-2570, thermal neutron capture spectrum.

No. 234 Zr | Reviewer-Dickens

Status — BET Blickstein+, E_n = 2.8-6 MeV ^{90}Zr Phys. Rev. C4, 1818
BET Glickstein+, E_n = 1.2-2.4 MeV ^{91}Zr Conf-710301 241 (Knoxville)

No. 235 Zr | Reviewer-Motz

Status — MIT Rasmussen+, GA-10248/DASA-2570, thermal neutron capture spectrum.

No. 236 Zr | Reviewer-Motz | (NCSAC-35 No. 158)

Status — BETTIS Glickstein+, Phys. Rev. 4C, 1819 (71). Discrete gammas for 8 levels, E_n 2.8 to 6 MeV.

No. 282 Nb | Reviewer-Motz | (NCSAC-35 No. 208)

Status — MIT Rasmussen+, GA-10248/DASA-2570, thermal neutron capture spectrum.

No. 283 Nb | Reviewer-Motz

Status — ORNL Dickens+, NCSAC-42, p. 195, have Ge(Li) data at 6 MeV, not yet reduced.

No. 284 Nb | Reviewer-Motz

Status — MIT Rasmussen+, GA-10248/DASA-2570, thermal neutron capture spectrum.

No. 285 Nb | Reviewer-Motz | (NCSAC-35 No. 209)

Status — ORNL Dickens+, NCSAC-42, p. 195, have Ge(Li) data at 6 MeV, not yet reduced.

No. 286 Nb | Reviewer-Motz

Status — ORNL Dickens+, NCSAC-42, p. 195 have Ge(Li) data at 6 MeV, not yet reduced.
MIT Rasmussen+, GA-10248/DASA-2570, thermal neutron capture spectrum.

No. 304 Mo   Reviewer-Orphan   (NCSAC-35 No. 223)

Status—Orphan+, GGA report GA-10248, Line + Continuum γ-rays
Barchuk+, USSR, 72 Kiev, Ge(Li) data for MO-94, 96, 98, 100

No. 305 Mo   Reviewer-Orphan

Status— None

No. 306 Mo   Reviewer-Orphan

Status— For THR capture same as for 304
Wasson+, USNDC-1 134, 6-50 keV
Wasson+, USNDC-1 27-up to 100 keV
Cole+, NCSAC-42, 185, 10-100 keV
Chrien+, NCSAC-42, 40, 12-48 keV

No. 307 Mo   Reviewer-Orphan

Status— For capture, same as for 306
None

No. 308 Mo   Reviewer-Chrien   (NCSAC-35 No. 224)

Status— Resonance capture spectra available to ~20 keV from ORELA; Wasson and Slaughter, for Mo-92 and Mo-98.

No. 321 Xe-135   Reviewer-Motz   (NCSAC-35 No. 237)

Status—None

No. 337 Eu   Reviewer-Motz   (NCSAC-35 No. 256)

Status— None

No. 355 Gd   Reviewer-Motz   (NCSAC-35 No. 276)

Status—None

No. 373 Dy | Reviewer-Motz | (NCSAC-35 No. 294)

Status — None

No. 399 Ta | Reviewer-Motz | (NCSAC-35 No. 322)

Status — ORNL Yost+, NSE 47, (72) claim calculated gamma yields for Ta-181, E_γ 1-6 MeV, E_n thermal to 900 keV, in agreement with reactor spectrum data.
ORNL Morgan+, ORNL-TM-3702, Feb. 8, 1972. Cross sections and spectra from E_γ 1 to 10.5 MeV, E_n 7 keV to 20 MeV observed at 90 and 125 degrees.

No. 401 W | Reviewer-Orphan | (NCSAC-35 No. 324)

Status — Tucker+, TNC report DASA 2333, 5-11 MeV
Orphan+, GGA report GA-9121, 2 eV-100 keV

No. 402 W | Reviewer-Orphan | (NCSAC-35 No. 325)

Status — Tucker+, TNC report DASA-2333, 5-11 MeV
ORNL Morgan+, E_n = 1 — 20 MeV, in progress

No. 416 Pb | Reviewer-Orphan | (NCSAC-35 No. 339)

Status — Dickens+, NCSAC 42-194, 4.9-8.0 MeV
Buchanan+, TNC report ORO-2791-32, Pb-206, 207, 208 (1-5 MeV, 14.8 MeV)

No. 417 Pb | Reviewer-Orphan | (NCSAC-35 No. 340)

Status — Dickens+, NCSAC-42 194, 4.9-8.0 MeV
Degtjarev+, USSR, IZV 35 2341, 0.1-3.4 MeV
Buchanan+, TNC report ORO-2791-32, Pb-206, 207, 208 (1-5 MeV, 14.8 MeV)

No. 426 Th | Reviewer-Orphan | (NCSAC-35 No. 349)

Status — None

No. 427 Th | Reviewer-Chrien | (NCSAC-35 No. 350)

Status — Resonance spectra for first 4 resonances + thermal, BNL fast chopper - von Egidy et al. Phys. Rev. C6, 266 (1972).

No. 428 Th Reviewer-Chrien (NCSAC-35 No. 352)

Status — No additional comments.

No. 443 U-233 Reviewer-Chrien (NCSAC-35 No. 368)

Status — Delete present comment.

No. 444 U-233 Reviewer-Chrien (NCSAC-35 No. 369)

Status — No additional comments.

No. 469 U-235 Reviewer-Chrien

Status — Eliminate present comments. Add "γ-rays to 1 μsec after fission for U-235, Pu-239, Sund et al.; GRT: quoted in USNDC-1 p. 79 (May 1972)."

No. 472 U-235 Reviewer-Chrien (NCSAC-35 No. 398)

Status — Graves et al. (BNL) have data for 6 resonances NCSAC-42 p. 48; low energy γ-ray data recorded by Coceva et al., Geel, reported at Aix-en-Provence June 1972 — 14 spin assignments made. BNL transmission data with polarized neutrons and polarized sample are now available up to 9 eV for U-235. Resonance spins have been assigned for nine resonances by Reddingius and Postma

No. 473 U-235 Reviewer-Chrien (NCSAC-35 No. 399)

Status — No change in status comments.

No. 499 U-238 Reviewer-Chrien (NCSAC-35 No. 423)

Status — Average capture spectrum results available; Bollinger, Argonne; to be published in Phys. Rev. 1972; thermal capture spectrum by Jurney Los Alamos NCSAC-42.

No. 501 U-238 Reviewer-Chrien (NCSAC-35 No. 425)

Status — Delete status comments.

No. 530 Pu-239 Reviewer-Chrien (NCSAC-35 No. 456)

Status — No change in status comments.

No. 531 Pu-239 Reviewer-Orphan

Status —Kimhoft, NCSAC 42 142, 4 min-24 hrs.

No. 532 Pu-239 Reviewer-Motz

Status — None

No. 547 Pu-240 Reviewer-Chrien (NCSAC-35 No. 472)

Status — Thomas (Harwell) has resonance (n, γ) data from Pu-240 in eV region, shows delayed component, UKNDC (72) p. 37.

Requests for Measurements Requiring Radioactive Samples

No. 327 Pm-147 Reviewer-Jackson (NCSAC-35 No. 244)
Status — Codding, Nucl. Sci. Eng. 43, 58 has total, 0.01-1000 eV and RI

No. 347 Eu-152 Reviewer-Jackson (NCSAC-35 No. 266)
Status* — LASL Harlow & Wash-1127 prelim data to 6 keV

No. 351 Eu-155 Reviewer-Jackson (NCSAC-35 No. 272)
Status — Can. Jour. Physics 48, 1933 gives eff. sig. thermal = 4040 ± 125 b

No. 381 Tm-171 Reviewer-Jackson (NCSAC-35 No. 304)
Status* — Inc Simpson has some res. par. to 60 eV

No. 430 Pa-233 Reviewer-Jackson (NCSAC-35 No. 354)
Status — Bet, Connor, WAPD-TM-837, gives RI and sig. thermal

No. 485 U-237 Reviewer-Jackson (NCSAC-35 No. 410)
Status — LASL, McNally, LA 4420, data for 44 eV-1.8 MeV

No. 573 Cm-242 Reviewer-Jackson (NCSAC-35 No. 503)
Status — ANC, Schuman, Wash-1136, gives Res. Int = 150 ± 40 b

No. 607 Cf-253 Reviewer-Jackson (NCSAC-35 No. 537)
Status — Nucl. Sci. Eng 41, 146 gives sig. eff = 17.6 b

No. 608 Es-253 Reviewer-Jackson (NCSAC-35 No. 538)
Status* — LASL, Silbert, Wash-1136, has data 30 eV up

No. 611 Fm-257 Reviewer-Jackson (NCSAC-35 No. 541)
Status* — ORNL, Bemis, ORNL-4581, 6100 ± 600 b σ_{abs}, pile neutrons
LRL Wild, NCSAC-33, 3080 ± 200 b thermal neuts.

*Status comment from 19 May 1972 retrieval

For each of the following requests:

Status — None Reviewer-Jackson

No.'s 29, 166, 167, 168, 213, 214, 215, 216, 217,
218, 219, 220, 221, 222, 237, 238, 239, 240, 241,
242, 268, 287, 288, 289, 290, 291, 292, 293, 294, 309,
310, 312, 313, 315, 316, 317, 319, 320, 321, 326, 328,
329, 330, 331, 333, 335, 338, 339, 340, 341, 342, 343,
349, 350, 374, 375, 376, 377, 380, 382, 383, 384, 385,
414, 507, 574, 609, 610

Please note that in some cases the above entry represents a deletion of information reported earlier.

The above request list corresponds to requests listed in NCSAC-35 as follows:

No.'s 21, new, new, 116, 143, 144, 145, 146, 147
148, 149, 150, 151, 152, 159, 160, 161, 162, 163,
164, 196, 210, 211, 212, 213, 214, 215, 216, 218, 225,
226, 228, 229, 231, 232, 233, 235, 236, 237, 243, 245,
246, 247, 248, 253, 254, 257, 258, 259, 260, 261, 262,
269, 270, 297, 298, 299, 300, 303, 305, 306, 307, 308,
337, 431, 504, 539, 541

REPORT OF THE USNDC SUBCOMMITTEE ON FAST NEUTRON REACTIONS

H. Alter
D. G. Barr
J. Brownlee
G. Butler
D. E. Gardner

The subcommittee has completed a review of that portion of the cross section measurement request compilation pertinent to fast neutron reactions. One-hundred-twenty-nine (129) requests were reviewed. Of these it was determined that one (1) has been essentially satisfied; twenty-seven (27) have been withdrawn; thirty-seven (37) have had modifications made to their status comments; and sixty-four (64) remained unchanged with respect to status. Modifications reflected in the comments include the upgrading and/or downgrading of specific requests with respect to priority and changes in the energy range over which a measurement was requested.

Of the 129 requests reviewed, not including the 27 withdrawn requests, 45 fall into the priority 1 category, 59 into the priority 2 category, and 12 are classed as priority 3. Note that the sum of the above exceeds 102, since several of the requests have more than a single priority category assigned.

A breakdown of requests by organization is given below:

Organization	No. of Requests	% of Total
DCTR	42	36
DMA	35	30
DRDT	21	18
DNA	9	7.7
DNR	5	4.2
Misc.	6	5.1

It is apparent from a review of the status comments that there is a somewhat less than total dedication being applied to satisfy the fast neutron cross section requests for measurement. Some effort is being expended for nuclides with mass less than 10. However, for the major portion of the request compilation, the measurement effort in this country appears minimal. Since more than 3/4 of the total number of requests are from the DCTR, DRDT, and DMA organizations, it would be reasonable to expect these organizations to assume the lead in the effort to satisfy their requirements. It is recommended that this need for guidance be brought to the attention of appropriate personnel within these organizations.

Request Number	NCSAC 35 Number	Target Z A	Reaction Type	Status
5	5	$_1H^3$	(n, 2n)	1972 Status: None.
8	8	$_2He^3$	(n, p)	Change priority of Caswell's USND request to II. (USND Caswell, private communication 1972) 1972 Status: Costello + Nuc. Sci. Eng. 39, 409, 0. 3-1. 1 MeV, 10 per.
14	13	$_3Li^6$	(n, 2n)	1972 Status: AWRE Mather AWRE-0-47/69, data at 14 MeV, 5 per.
15A	New	$_3Li^6$	(n, n'd)	1972 Status: No data to required accuracy.
16	New	$_3Li^6$	(n, t)	1972 Status: No data to required accuracy.
17	14	$_3Li^6$	(n, α)	Change Caswell's USND request to indicate an energy range from 10 keV-14 MeV since satisfactory measurements exist below 10 keV. (USND Caswell, private communication 1972) Also change last Requestor Comment to read as follows: Accuracy 1 per below 100 keV, 3 per above NCSC. Change LASL Motz request to cover an energy range of 100 KeV to 13 MeV. (LASL Stewart, private communication 1972). 1972 Status: AERE Uttley CONF 710301, 551 (Knoxville Conf.) reviews data below 1. 7 MeV.
18	15	$_3Li^6$	(n,α) Ratio wrt B^{10}	This request should be removed from the request list since it is considered satisfied based on measurements from Harwell. (USND Caswell, private communication 1972)
19	16	$_3Li^6$	Tot α prod.	1972 Status: None.
25	19	$_3Li^7$	(n, 2n)	1972 Status: None.
26	New	$_3Li^7$	(n, n't)	1972 Status: Present accuracy is 25 percent at 8 MeV, 15 percent at 14 MeV.
27	New	$_3Li^7$	(n, n't $\theta_{n'}$)	1972 Status: None.
29	21	$_4Be^7$	(n, p)	1972 Status: None.

Request Number	NCSAC 35 Number	Target Z A	Reaction Type	Status
33	25	$_4Be^9$	(n, p) $Li^9 \beta \rightarrow Be^{9*} \rightarrow n$	1972 Status: Measurements planned at LASL.
36	28	$_5B^{10}$	(n, α)	Oates, AERE-FR/NP 18 (1972). Fricke, New Measurements, GRT (1972)
38	30	$_5B^{10}$	Tot α prod.	Change the priority to I. (USND Caswell, private communication 1972). 1972 Status: None.
44	36	$_6C$	Absorption	1972 Status: None.
46	New	$_6C^{12}$	(n, n'3α)	1972 Status: Grin, Helv. Phys. Act. 42, 990 (1969) get 190 + 20 mb for $E_{n'}$>1 MeV at 14. 1 MeV.
51	41	$_7N$	Absorption	1972 Status: None.
55	45	$_8O$	Absorption	1972 Status: None.
63	New	$_9F$	Absorption	1972 Status: None.
64	53	$_9F^{19}$	(n, α)	Crumpton, Nucl. Instru. Methods 92, (1971) 533.
69	58	$_{11}Na^{23}$	Absorption	Measurements at Columbia and ORNL underway (1972)
73	New	$_{13}Al$	(n, 2n)	1972 Status: No data to required accuracy.
74	New	$_{13}Al$	(n, 2n $\theta_{n'}$, $E_{n'}$)	1972 Status: None.
78	New	$_{13}Al$	(n, p)	1972 Status: Partington, Analyst 95, 257 (1970) get 80+5 mb at 14 MeV. See also Husain, Phys. Rev. C1, 1233 (1970); and Salaita, Nucl. Phys. A170, 193 (1971) at 14. 8 MeV.
79	New	$_{13}Al$	(n, α)	1972 Status: Bresesti, Nucl. Sci. Eng. 40, 331 (1970) reviews previous experimental work. LASL Prestwood gets 122. 6+ 3 mb at 14. 1 MeV, (private communication 1972).
84	64	$_{13}Al$	(n, p) Act.	1972 Status: FRK Bass + EUR 119c have data 6-9 MeV. ANL has measured values WRT U235 fission between 3 and 6 MeV. (1972)

Request Number	NCSAC 35 Number	Target Z A	Reaction Type	Status
89	69	$_{16}S^{36}$	(n, 2n)	Request withdrawn.
94	74	$_{20}Ca^{40}$	(n, α)	Request withdrawn.
96	76	$_{20}Ca^{46}$	(n, 2n)	Request withdrawn.
101	81	$_{22}Ti^{46}$	(n, p)	Ghorai, Diss. Abstracts 32B (1971) 1138 and J. Nucl. Energy 25 (1971) 319. ANL measured values WRT U235 fission between 4 and 6 MeV. (1972)
102	82	$_{22}Ti^{47}$	(n, p)	Meadows, NCSAC-42, 10 (1972). Ghorai, Diss. Abstracts 32B (1971) 1138 and J. Nucl. Energy 25 (1971) 319
103	83	$_{22}Ti^{48}$	(n, p)	Ghorai, Diss. Abstracts 32B (1971) 1138 and J. Nucl. Energy 25 (1971) 319. ANL measured values WRT U235 fission between 4.5 and 6 MeV. (1972)
105	New	$_{23}V$	(n, 2n)	1972 Status: None.
106	New	$_{23}V$	(n, 2n) ($\theta_{n'}$, $E_{n'}$)	1972 Status: None.
111	New	$_{23}V$	(n, p)	1972 Status: None.
112	New	$_{23}V$	(n, α)	1972 Status: None.
120	New	$_{24}Cr$	(n, 2n)	1972 Status: None.
121	New	$_{24}Cr$	(n, 2n) ($\theta_{n'}$, $E_{n'}$)	1972 Status: None.
124	New	$_{24}Cr$	(n, p)	1972 Status: None.
125	New	$_{24}Cr$	(n, α)	1972 Status: None.
139	New	$_{26}Fe$	(n, 2n)	1972 Status: None.
140	New	$_{26}Fe$	(n, 2n) ($\theta_{n'}$, $E_{n'}$)	1972 Status: None.
145	New	$_{26}Fe$	(n, p)	ANL has measured values WRT U235 fission between 4 and 6 MeV. (1972)
146	New	$_{26}Fe^{56}$	(n, α)	1972 Status: None.
147	New	$_{26}Fe$	(n, α)	1972 Status: None.
150	102	$_{26}Fe$	Absorption	1972 Status: None.
158	108	$_{26}Fe^{54}$	(n, p)	Paulsen measuring from 1.5-6 MeV and from 12-20 MeV, Gel. (1972) ANL has measured values WRT U235 fission between 2 and 6 MeV. (1972)

Request Number	NCSAC 35 Number	Target Z A	Reaction Type	Status
159	109	$_{26}Fe$	(n, 2n)	1972 Status: None.
173	New	$_{28}Ni$	(n, 2n)	1972 Status: None.
174	New	$_{28}Ni$	(n, 2n) (θ_n, E_n)	1972 Status: None.
175	120	$_{28}Ni$	Absorption	Measurements underway in keV region, AAEC (1972)
177	New	$_{28}Ni$	(n, p)	Paulsen, Measurements in progress, 12-20 MeV, Gel. (1972)
178	New	$_{28}Ni$	(n, α)	1972 Status: None.
179	New	$_{28}Ni$	(n, α)	1972 Status: None.
185	New	$_{28}Ni^{58}$	(n, p)	Paulsen, Measurement in progress 1-6 MeV, Gel. (1972). ANL values WRT U235 fission 1-6 MeV. (1972)
186	124	$_{28}Ni^{58}$	(n, p)Act.	Paulsen, Meas urement in progress 02-20 MeV, Gel. (1972)
187	125	$_{28}Ni^{60}$	(n, p)	1972 Status: None.
190	New	$_{29}Cu$	(n, 2n)	1972 Status: None.
191	New	$_{29}Cu$	(n, 2n) $(\theta_{n'}, E_{n'})$	1972 Status: None.
193	New	$_{29}Cu$	(n, p)	1972 Status: None.
194	New	$_{29}Cu$	(n, α)	1972 Status: None.
200	130	$_{29}Cu^{63}$	(n, α)	Bormann, Nucl. Phys. Galley Proof 3429, 3/28/72.
201	131	$_{29}Cu^{65}$	(n, 2n)	Kanda, At. Energy Research Inst., Tokyo (1972) 1207.
				Qaim, Nucl. Phys. A185 (1972) 614. Mogharrab, Atomkernenerie 19 (1972) 107.
206	136	$_{30}Zn^{66}$	(n, 2n)	Qaim, Nucl. Phys. A185 (1972) 614.
213, 215, 143, 145 216, 218, 146, 148 219, 220, 149, 150 221, 222, 151, 152				Requests withdrawn.

Request Number	NCSAC 35 Number	Target Z A	Reaction Type	Status
225	New	$_{40}Zr$	(n, 2n)	Bari, U. of Ark., Activation Cross Section at 14.8 MeV. (1972) Nethway, LLL, has data to 5% for Zr^{90} at 14.1 and 14.8 MeV (Relative to Al^{27} (n, α). (1972).
226	New	$_{40}Zr$	(n, 2n) (θ_n, E_n)	1972 Status: None.
231	New	$_{40}Zr$	(n, p)	Bari, U. of Ark., Activation Cross Section at 14.8 MeV (1972)
232	New	$_{40}Zr$	(n, α)	Bari, U. of Ark., Activation Cross Section at 14.8 MeV (1972)
237, 239, 159, 161 240, 242, 162, 164				Requests withdrawn.
253	177	$_{40}Zr^{91}$	(n, α)	1972 Status: None.
275	New	$_{41}Nb$	(n, 2n)	Häring, et al, Quotes 1.35±.25 Z, Physik 244, 352 (1971) Bari, U. Ark., Act. Cross Section at 14.8 MeV. (1972) Nethway, LLL, Data to 5% at 14.1 and 14.8 MeV (1972)
276	New	$_{41}Nb$	(n, 2n) (θ_n, E_n)	1972 Status: None
277	206	$_{41}Nb$	(n, 2n) Act.	Haering, Z. Physik 244 (1971) 352. Blow, J. Nucl. Energy 26(1972) 9. Bari, U. of Ark. Activation Cross Section at 14.8 MeV (1972).
280	New	$_{41}Nb$	(n, p)	1972 Status: None.
281	New	$_{41}Nb$	(n, α)	Bari, U. of Ark. Activation Cross Section at 14.8 MeV (1972). Bormann, U. Hamburg, Angular Distribution, Energy Spectrum at 14.2 MeV (1972)
287, 289, 210, 212 290, 292, 213, 215				Requests withdrawn.
297	New	$_{42}Mo$	(n, 2n)	1972 Status: No data to required accuracy.
298	New	$_{42}Mo$	(n, 2n $\theta_{n'}$)	1972 Status: None.

Request Number	NCSAC 35 Number	Target Z A	Reaction Type	Status
302	New	$_{42}Mo$	(n, p)	1972 Status: None.
303	New	$_{42}Mo$	(n, α)	1972 Status: None.
338, 340, 342,	257, 259 261			Requests withdrawn
344	263	$_{63}Eu^{151}$	(n, 2n)	1972 Status: None.
374, 376	297, 299			Requests withdrawn
378	301	$_{69}Tm$	(n, 2n)	Druzhinin, Yad. Fiz. 14 (1971) 682.
382, 384	305, 307			Requests withdrawn.
386	309	$_{71}Lu^{175}$	(n, 2n)	1972 Status: None.
404	327	$_{74}W^{182}$	(n, 2n)	1972 Status: None.
409	332	$_{74}W^{186}$	(n, 2n)	1972 Status: None.
419	342	$_{82}Pb^{206}$	(n, α)	Request withdrawn
423	346	$_{90}Th$	(n, 2n)	1972 Status: None.
425	348	$_{90}Th$	Absorption	Rahn, Columbia, Resonance Parameters to 2.9 keV (1972)
433	357	$_{92}U^{233}$	(n, 2n)	1972 Status: None.
449	376	$_{92}U^{234}$	(n, 2n)	1972 Status: None.
450	377	$_{92}U^{234}$	(n, 3n)	1972 Status: None.
457	385	$_{92}U^{235}$	(n, 2n)	1972 Status: None.
458	386	$_{92}U^{235}$	(n, 3n)	1972 Status: None.
490	415	$_{92}U^{238}$	(n, 2n)	1972 Status: None.
491	416	$_{92}U^{238}$	(n, 3n)	1972 Status: None.
503	428	$_{93}Np^{237}$	(n, 2n)	1972 Status: None.
508	433	$_{94}Pu^{238}$	(n, 2n)	1972 Status: None.
509	434	$_{94}Pu^{238}$	(n, 3n)	1972 Status: None.
515	442	$_{94}Pu^{238}$	(n, p)	1972 Status: None.
520	447	$_{94}Pu^{239}$	(n, 2n)	1972 Status: LASL Barr gets 150 mb ± 20 per at 14 MeV, priv. comm. Measurements with lower accuracy not helpful, LLL.

Request Number	NCSAC 35 Number	Target Z A	Reaction Type	Status
521	448	$_{94}Pu^{239}$	(n, 3n)	1972 Status: LASL Barr gets 1.5±0.5 mb at 14 MeV, priv. comm.
556	484	$_{94}Pu^{242}$	(n, 2n)	1972 Status: None
563	492	$_{94}Pu^{242}$	(n, p)	1972 Status: None.
565	495	$_{95}Am^{241}$	(n, 2n)	1972 Status: None.
579	509	$_{96}Cm^{244}$	(n, 2n)	1972 Status: None.

REPORT OF THE USNDC BIOMEDICAL SUBCOMMITTEE

Prepared by
James S. Robertson, BNL
E. M. Smith, U. Miami

November 1972

NUCLEAR DATA NEEDS

I. Radionuclide Production

Some potentially useful cyclotron-produced radionuclides are listed below. Optimum production techniques using the selected reaction modes can be evaluated provided the excitation functions are known. The required energies are up to 15 MeV for deuterons, 27 MeV for protons, 30 MeV for α-particles, and 39 MeV for He-3.

Fluorine-18

1. a. $^{16}O(^{3}He,n)^{18}Ne \xrightarrow{\beta+} {}^{18}F$
   b. $^{16}O(^{3}He,p)^{18}F$
2. a. $^{16}O(\alpha,2n)^{18}Ne \xrightarrow{\beta+} {}^{18}F$
   b. $^{16}O(\alpha,pn)^{18}F$
3. $^{20}Ne(d,\alpha)^{18}F$
4. $^{22}Ne(p,\alpha n)^{18}F$
5. $^{18}O(p,n)^{18}F$
6. a. $^{19}F(p,2n)^{18}Ne \xrightarrow{\beta+} {}^{18}F$
   b. $^{19}F(p,pn)^{18}F$

Potassium-43

7. $^{40}Ar(\alpha,p)^{43}K$
8. a. $^{44}Ca(d,^{3}He)^{43}K$
   b. $^{44}Ca(d,\alpha)^{42}K$

Gallium-67

9. $^{66}Zn(d,n)^{67}Ga$
10. $^{67}Zn(d,2n)^{67}Ga$
11. $^{65}Cu(^{3}He,n)^{67}Ga$
12. $^{65}Cu(\alpha,2n)^{67}Ga$
13. $^{67}Zn(p,n)^{67}Ga$
14. $^{67}Zn(p,2n)^{67}Ga$

Strontium-82

15. $^{82}Kr(^{3}He,3n)^{82}Sr$
16. $^{80}Kr(\alpha,2n)^{82}Sr$
17. $^{84}Sr(p,3n)^{82}Y \xrightarrow{\beta+} {}^{82}Sr$

Iron-52

18. $^{50}Cr(\alpha,2n)^{52}Fe$

19. $^{52}Cr(^{3}He,3n)^{52}Fe$

Yttrium-87 $\xrightarrow{\beta+}$ Strontium-87m

20. $^{87}Rb(^{3}He,3n)^{87}Y$

21. $^{87}Sr(p,n)^{87}Y$

22. $^{88}Sr(p,2n)^{87}Y$

Indium-111

23. $^{109}Ag(\alpha,2n)^{111}In$

24. $^{109}Ag(^{3}He,n)^{111}In$

25. $^{111}Cd(p,n)^{111}In$

26. $^{112}Cd(p,2n)^{111}In$

27. $^{110}Cd(d,n)^{111}In$

28. $^{111}Cd(d,2n)^{111}In$

Iodine-123

29. $^{122}Te(d,n)^{123}I$

30. $^{122}Te(^{3}He,2n)^{123}Xe \xrightarrow{\beta+} {}^{123}I$

31. $^{123}Te(p,n)^{123}I$

32. $^{123}Te(d,2n)^{123}I$

33. $^{123}Te(^{3}He,3n)^{123}Xe \xrightarrow{\beta+} {}^{123}I$

34. $^{124}Te(p,2n)^{123}I$

Cesium-129

35. a. $^{130}Ba(p,2n)^{129}La \xrightarrow{\beta-} {}^{129}Cs$

b. $^{130}Ba(p,2p)^{129}Cs$

36. $^{132}Ba(p,\alpha)^{129}Cs$

37. $^{127}I(\alpha,2n)^{129}Cs$

38. $^{127}I(^{3}He,n)^{129}Cs$

Dysprosium-147

39. $^{159}Tb(p,3n)^{157}Dy$

40. $^{156}Gd(^{3}He,2n)^{157}Dy$

41 $^{155}Gd(\alpha,2n)^{157}Dy$

II. Radiation Detection

Radioactive materials are administered to patients for diagnostic, therapeutic and research reasons. In all of these it is important to be able to measure quantitatively the radioactivity in a given location of the body or in samples of tissue or fluids from the body.

Since many aspects of radiation detection such as attenuation in tissue are dependent on radiation type and energy, an accurate knowledge of the decay schemes of the nuclides in use is essential. In particular, it is necessary to know the absolute fraction of disintegrations that involve a particular gamma ray. This is mentioned because often the abundance of gamma rays is given relative to each other rather than to the disintegration rate. Of course many other features of the decay scheme such as the energies and half lives are important but in general these do not involve a problem of the user not being able to find the information.

III. Activation Analysis

Activation analysis is applied in medicine both for *in vitro* and *in vivo* measurements. In the *in vitro* applications it is used principally for the determination of the amounts and location of tracer elements. The *in vivo* applications also include studies of substances such as calcium, which are present in the body in relatively large quantities but which are difficult to determine quantitatively by other methods because they are in locations such as bone which are inaccessible and do not turn over rapidly enough to be studied by exchange methods for example.

Here, of course, the essential nuclear data are the neutron capture cross sections as functions of neutron energy.

IV. Biological Effects of Radiation

In therapy, but also in all uses of radioactive materials, it is necessary to be able to measure or compute the radiation dose associated with the procedure. In some situations dose calculations may become quite complex because a variety of factors in addition to the physical decay characteristics such as biological localization and turnover are also involved.

For internally distributed nuclides, again a knowledge of the decays scheme is essential. In addition to the gamma ray components, for dose calculations it it also necessary to have full information on beta-ray energies, Auger electrons, x-rays and any other component that can contribute to the dose. One difficulty in the use of available data that may be singled out as being most important (or at least annoying) is the specification of β energies. In general only the E_0 is given, whereas what is needed for dose calculations is the E_{AVE}. In some cases, where E_{AVE} has been determined experimentally, as by calorimetry, it is given but otherwise it is omitted. It is recognized that E_{AVE} can always be computed from E_o, but the computation is a not-so-simple function of Z as well as E_o, is different for β^- and β^+, and is dependent on whether the transition is allowed or forbidden. In the case of some of the forbidden spectra (for example Ra E, or $^{210}_{83}Bi$) the experimentally determined spectrum is substantially different from the hypothetical allowed spectrum. It would therefore be more reliable if an expert in the field would make the necessary calculations and make the E_{AVE} available along with E_o in the nuclear data compilations.

It may be mentioned that there is a committee of the Society of Nuclear Medicine, known as MIRD (Medical Internal Radiation Dose Committee) that evaluates decays schemes and presents the data in a form useable for internal radiation dose calculations.

Future applications in medicine may involve neutron, proton and π meson beams directly, and all of the nuclear data pertinent to these particles and their reactions with tissue and other target materials will become of interest in this field.

It should be emphasized that for users in the Medical area the nuclear data requirements are usually incidental to other principal problems and these users cannot keep up to date by the method of referring to the physics literature. Compilations are necessary for these users to have ready access to the required information. At present the principal references in use are the Lederer, Hollander, and Perlman Table of Isotopes, the K. Way et al, Frequent Use Tables, and the MIRD publications.

<u>NOTE</u>: <u>Section I</u> is the contribution of E. M. Smith, Division of Nuclear Medicine, U. Miami School of Medicine

<u>Sections II, III and IV</u> are by James S. Robertson, Medical Department, Brookhaven National Laboratory