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NUCLEAR DATA REQUESTS FOR SAFEGUARDS TECHNICAL DEVELOPMENT

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PREFACE

Due to the considerable increase in Safeguards Research and Development over the past couple of years and the fact that nuclear materials Safeguards is a relatively new field of activity, this report (INDC(NDS)-21/G), which is intended to serve as a Working Document for the Third Meeting (22-26 June 1970) of the International Nuclear Data Committee (INDC), has been prepared with the view of presenting the INDC with the latest information that has been made available to the IAEA on the role of nuclear data in the development of Safeguards instrumentation and techniques.

So as to provide a framework for the report, as well as convey some typical impressions of the complex hierarchy of problems encountered in developing and implementing an effective Safeguards System, a rather extensive Introduction appeared to be necessary. This is followed by a short résumé of some of the non-destructive measurement techniques and methods, either in practical use at present or under development, for measuring the flow of fissile material throughout the nuclear fuel cycle. The question of determining the process inventories of continuous flow facilities has not been considered in this report. In Section 3 a detailed analysis is presented of the response to a Circular Letter (Appendix I), dispatched by the Nuclear Data Section to nineteen Member States and two International Organizations, to ascertain from their individual experts "what improvements, if any, in existing nuclear data should be undertaken for safeguards purposes?" This is followed by the Summary and Conclusions of the report, in which due emphasis is placed on questions such as, the scope of nuclear data needs, as well as the priorities and status associated with individual nuclear data requests.

1. INTRODUCTION

Prior to any examination of the impact of nuclear data on the technical development of Safeguards instrumentation and techniques, it is important to establish the scale of Safeguards activities so as to enable one to locate the place which inaccurate or inadequate nuclear data occupy when one examines the technical elements of Safeguards activities, as a whole.

A. Safeguards Systems

The basic elements of a Safeguards System designed to detect diversion or restrain potential diversion of Special Nuclear Material (SNM) to non-peaceful uses, may be divided into three categories:

I. Containment procedures - involving the use of locks, tags and seals, or it may involve physical restraints in the sense of guards or monitoring devices.

II. Surveillance procedures - which involve not only direct observation and monitoring but also the verification of plant operation and the certification of plant data.

III. Material Balance Accounting - which is a basic tool of the control system and involves records, reports and source data obtained from the safeguarded nuclear facilities, as well as independent measurements performed by the controlling Agency so as to achieve an independent material balance.

Whereas both the Containment and Surveillance procedures provide direct evidence of diversion, or rather provide a means of detecting a very recent or present diversion, Material Balance Accounting determines whether or not a diversion could have taken place over some time in the past, or whether or not material has been added. The tools of Material Balance Accounting are measurement and accounting procedures, such as establishing the "prescription of the points (the so-called "key"(1) or "strategic"(2) points) at which measurements must be taken, the methods of measurements and the manner in which the data are summarized into accounts"(3). In general, the sensitivity with which the Material Balance Accounting procedures can detect diversion depends on the accuracy (i.e. the bias) and the precision (i.e. the random error) in

the measurement system, the validity of the source data, the nature of the facilities and the inventory practices. Over a long period of time, however, the accountability function can be no more sensitive than the accuracy, precision and validity of the measurement system. In addition, it is worth noting that the strategy required to safeguard different types of facilities will necessarily be different, for on the one hand, in facilities such as power reactors, the inventory is large but the ratio throughput/inventory is very small, and on the other hand, for the reprocessing and conversion plants the ratio throughput/inventory is very large.

The essence of Material Balance control is the measurement of all inputs to and outputs from a system during a given period of time, and the inventory of the system at the beginning and end of the period, with the end result being the determination of the quantity MUF (Material Unaccounted For). The quantity MUF is arrived at by using the equation:

$$MUF = (BI + R) - (S + D + EI)$$

where

BI is the quantity of SNM material on hand at the beginning of the inventory taking period.

R is the quantity of SNM material received during the inventory period.

S is the quantity of SNM material shipped, as product, during the inventory period.

D is the amount of SNM material measured as scrap and waste discards during the inventory period.

EI is the quantity of SNM material on hand as determined by a complete physical inventory at the end of the inventory period.

It is therefore evident that MUF consists of two major components, the first of which is the total overall uncertainty in the value of MUF due to the biases and imprecisions in the measurement and/or estimation of each of the five basic quantities above, and the second of which causes the expected value of MUF to deviate from zero. This second component arises from unmeasurable process losses or a real diversion, with the net

result being that a non-zero MUF could represent a genuine process aberration, unaccounted measurement system errors or a real diversion. The establishment of accurate estimates of the normal operating or process losses for continuous flow nuclear facilities, is regarded as "one of the most difficult safeguards problems for which a solution is not apparent"(4). As a result of these factors, it therefore emerges that the total error (σ_{MUF}) in MUF is directly related to the effectiveness of the Safeguards System, if one accepts that "perhaps the best indication of effectiveness is some estimate of the frequency, or probability, with which a diversion of a given size would be detected"(5). In other words, for a given cost and size of inspection effort, one of the parameters which plays a dominant role in arriving at an effective Safeguards System is the accuracy and precision with which measurements can be made to determine both the flow of SNM material throughout the entire fuel cycle and the process inventories at strategic points in the fuel cycle. This is clearly seen from Fig. I(6) where, by assuming that MUF is a random variable, the effect of different σ_{MUF}'s on the diversion detection probability is shown for varying amounts of material diverted; the larger σ_{MUF}, the lower is the probability of detecting diversion.

B. The Nuclear Fuel Cycle

From what has been outlined above, it becomes clear that the development and improvement of instruments and techniques for measuring both the amount and the isotopic content of SNM in the multitude of forms encountered in the nuclear fuel cycle is an exceedingly important aspect of Safeguards development. It would therefore be beneficial to briefly outline the various forms in which SNM are to be found in the fuel cycle, using as a simple illustration the low enriched U-235 cycle beginning with the receipt of UF_6 at the conversion facility. (Fig. II shows a sketch of this cycle). It is important to emphasize that a detailed review of the many "Safeguards problems" encountered at different points of this fuel cycle is not being attempted here. The purpose however, is to draw attention to the types of problems encountered in assessing the flow of SNM in the fuel cycle, as a whole; on the one hand, the points

at which the Containment and Surveillance procedures may be expected to dominate and on the other hand, the points at which measurements of high accuracy and precision appear important.

I. Conversion

Fig. III(7) indicates the principal intermediate compounds and products at the conversion plant. At this part of the cycle UF_6 is received (from the diffusion plants) and stored in 2½ ton or larger cylinders in which the SNM content can be measured with very high precision and accuracy (better than 0.25%(8)) by sampling and chemical analysis at the enrichment plants. Since these containers are such large and opaque systems none of the non-destructive measurement methods appear to be useful. The cylinders are withdrawn from their storage area, connected to the process system where the UF_6 is hydrolized in an ammonia solution to ammonium diuranate (ADU), and this is in turn reduced to UO_2 with hydrogen and subsequently milled and blended to UO_2 powder. The UO_2 powder is then passed onto the fabrication stage. It is evident that as the SNM moves through the several conversion (fabrication and reprocessing) processes Material Balance Accounting becomes increasingly difficult due to the dilution of the SNM with additives, the generation of scrap and wastes and the genuine loss of materials. As a result of these factors it appears "preferable to attempt material balances only at the periphery of (continuous flow) plants"(5), and it is for this reason that the strategic points at which measurements appear necessary to establish a material balance are shown in Fig. III at the feed-point (I), product point (II), the recoverable (IV) and irrecoverable (III) scrap* and waste* points.

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*Scrap material is defined(9) as that part of fissile material from a process stream which is chemically pure but because of some physical defects (density, etc.) cannot be used in the subsequent process steps in the production line; whilst waste is that part of the fissile material in a plant in which the chemical purity or concentration of the fissile material has been degraded to such a degree that it has either to be discarded or recovered at an economic cost higher than the value of the material.

In general, the process yield at the conversion stage is rather high (about 97%(10)) with about 2-3% of input appearing as recoverable scrap, about 0.5%(7) of input as irrecoverable scrap and waste, and about a further 0.5%(7), under normal conditions, being attributed to unmeasured normal operating losses.

II. Fabrication,(10),(11)

Fig. IV(7) sketches the process steps within the fabrication plant and is essentially self-explanatory. The process yield at this stage is high, but a larger fraction (about 5-6% of input(7)) of material appears as recoverable scrap, with the irrecoverable scrap and waste, as well as the unmeasured normal operating losses each being about 0.5% of input(7). One of the most important measurement points (point II, Fig. IV) at this stage of the cycle is to determine with high accuracy and precision the amount and isotopic content of the UO_2 pellets just prior to their being loaded into tubes and surrounded by cladding material. This point (II) is the last stage at which the SNM is directly accessible, until the fuel elements have been dissolved at the dissolver tank of the reprocessing plant following reactor irradiation and cooling; i.e. until at least one year after fuel element fabrication.

III. Reactor irradiation,(12),(13),(14)

Fig. V depicts the essential aspects of the flow of SNM at the reactor and in contrast to other branches of the fuel cycle the application of Safeguards at this juncture appears to be very much less complex. It would appear that Containment procedures dominate at this point in the cycle since the fissile material is well contained in the fuel pins and sub-assemblies of heterogeneous reactors. Furthermore, these fuel elements move between the three discrete areas shown in Fig. V, the dry storage area, the reactor vessel and the wet storage area, which lend themselves almost naturally to the application of strict Containment and Surveillance procedures. The fuel elements would be identified and counted in the dry and wet(15) storage areas and by registering the movements of the fuelling machines and the reactor bay crane as well as the activity in the reactor bay area(12), the movement of the fuel elements could be established.

As a result of this, detailed records of reactor power output and other operational data may be regarded as being "redundant information"(12), though useful as a Safeguards "back-up" measure. The problem of accurate U-235 burn-up and Pu production calculations on discharged sub-assemblies may therefore be viewed as being of secondary importance for Safeguards. This is a somewhat fortunate situation since burn-up and production calculations still leave much to be desired from a Safeguards standpoint, due to the very large computer costs and the inaccuracies in predictions (up to 10% for local Pu concentrations(12)).

IV. Reprocessing,(16),(17),(18),(5)

Fig. VI(16) gives an outline of the complexed stages at the reprocessing plant. The irradiated fuel elements, after at least three months 'cooling' in the reactor 'cooling pond', are stored and subjected to piece identification. They are then removed from their shielded shipping containers and the head and bottom ends of the sub-assemblies are separated, with the rest of the sub-assembly being chopped into pieces and the superfluous non-nuclear material in the cladding discarded to waste. The chopped pieces are subsequently dissolved in thermally hot nitric acid and this solution is then fed to the accountability tank, which is the first point in the fuel cycle after the pellet and fuel pin stages of the fabrication plant at which measurements of high accuracy and precision may be attempted. The subsequent steps in the process are depicted in Fig. VI. At measuring points I, II and III, Fig. VI, the amount and isotopic content of the SNM is at present established by means of chemical analysis (isotopic dilution and mass spectrometric (I), volumetric titration (II),(III) and gravimetric (III) methods) of samples of the solution. Due care must be exercised in the sampling procedures, particularly at the accountability tank due to the presence of solids and undissolved fuel. The importance of strict Containment and Surveillance procedures at the product points (particularly for Pu) is evident, since the Pu solution has very high concentration (about 200 gms/liter(5)) and is shipped in small 10 liter bottles.

In conclusion, it is worthwhile pointing out that though the question of assessing the relative importance of different strategic measurement points in the fuel cycle is a complexed systems analytic problem, it

appears(19) to be related to the range of uncertainties in the integrated amount of SNM obtained at each such point and these uncertainties are, in turn, a function of the integrated amount of SNM passing through the point, the accuracy and precision of measurements executed at that point and the number of samples [illegible].

2. NON-DESTRUCTIVE MEASUREMENT TECHNIQUES AND METHODS

The necessity of measurements being made at strategic points in the cycle so as to determine the amount and isotopic content of the SNM flowing through the fuel cycle, may be inferred from what has been stated above. The methods of performing these measurements may function on the basis of nuclear reactions, ordinary physical properties, or chemical properties, with the latter only being capable of application to samples of the population to be tested (since the form is changed), whilst the two former methods may, in principle, be applied to the entire population. Destructive or non-destructive techniques for measuring the amount and isotopic content of SNM which has either been unirradiated (cold) or irradiated (hot) may be divided into two main categories:

A). Passive Assay - which involves the measurement of the natural radioactivity of SNM; such as, the measurement of neutrons from spontaneous fission, (α,n) and (γ,n) reactions; of γ-rays following β-decay of fission products; of X-rays and α-particles.

B). Active Interrogation Assay - which employs an external source of highly penetrating photons or neutrons to induce characteristic nuclear reactions (such as fission, (n,γ) capture, $(n,n'\gamma)$ scattering) in the SNM being assayed, which in turn, produce observable and measurable signatures of the specific fissile isotopes present in the material.

Whereas Passive Assay methods are in general simple and inexpensive and the equipment is fairly easily transported (though as yet not for Ge(Li) detectors), the Active Interrogation methods possess(20),(21) high penetrability (thereby allowing measurements to be made on fissile materials in bulk media), environmental insensitivity (so that operation

may be performed in high background radiation fields), very high isotope discrimination power and tend to be inherently more "tamper resistant".

For any measuring technique to be applicable in assaying either hot or cold material it must fulfil a number of basic criteria, some of which are outlined in Table I,(9),(19), and a brief description of some of the Passive and Active Non-destructive assay techniques will now be summarized.

A. Passive Techniques

I). Gamma-Ray Spectrometry

The concentration of a given long-lived fission product in irradiated fuel elements or sub-assemblies gives a measure of the total number of fissions (U-235 and Pu-239) that have occurred in the fuel and led to the formation of that product during neutron irradiation. Such fission products may therefore serve as indicators of total fissions (U-235 and Pu-239). Apart from the long half-life, these fission products, should also have(22) low neutron capture cross section (to reduce burnout), high fission yields which are rather independent of the neutron energy spectrum, negligible diffusion as a function of temperature and, above all, emit high energy gamma rays, so as to reduce the absorption corrections and increase the gamma ray penetrability through the fuel and cladding material. By direct measurement of the γ spectrum using Ge(Li) detectors and multichannel analysers it appears that a considerable amount of information on burn-up can be extracted from the γ spectra. Amongst the fission products which have received particular attention to-date are:

Ce-Pr-144, Ru-Rh-106 (for Pu-239 fissions), Cs-137,
Zr-Nb-95, Ba-La-140, Cs-134 (produced by Cs-133 (n,γ)),
Eu-154 and Ag-110m.

Heath has however pointed out(23) that the most important limitation is "the lack of high-quality basic information (e.g. fast-fission yields and precision values for capture cross sections of certain nuclides)." Amongst the areas of basic study which he proposed were:

1. Extend accurate fission yield data to epithermal and fast regions.

2. Measure decay characteristics of selected nuclides.
3. Obtain improved primary and secondary capture cross section data for selected fission product nuclides and heavy elements.
4. Study gamma-ray branching ratios of selected fission product nuclides.

Gamma ray spectrometry of cold SNM is also worthy of mention. The main problem which arises, however, is that the gamma rays from cold material have low energy (a few hundred Kev) and therefore possess limited penetrability, thereby only yielding information about the surface layer of sample. For low and highly enriched U-235 material, measurement of the difference between the count rates at the 185 Kev peak and another arbitrary energy (143 Kev) enables the U-235 enrichment level to be established.

II. Calorimetry

The radio calorimeter having thin walls (to minimize γ-ray absorption) utilizes the heat generated by α-decay of the Pu isotopes (by far the largest contributor being Pu-238) in Pu containing fuel elements. If the isotopic composition of the Pu is known, the total amount of Pu can be deduced from the heat generated by the Pu isotopes and the Am-241 present. The technique can be made tamper-proof by simultaneously measuring the spontaneous fission neutrons (from Pu-240 and Pu-242) and determining the ratio neutrons/watt(9),(19). Ultimately, the total percentage error in determining the amount of Pu present is expected to be around 0.4-0.5%(19), and it is envisaged that this technique could be used for the determination of Pu content in fuel pins at the product end of Pu fabrication facilities, as well as at the feed points of such plants where the Pu is contained in bird cages.

III. Neutron Counting

Neutron counting is used primarily for Pu determination by detecting in coincidence the neutrons emitted from spontaneous fission of Pu-240, Pu-242 and any Cm-244 which may be present. The total amount of Pu present can however not be determined unless the isotopic composition of the Pu is known. This technique could be useful for Pu

determination of heterogeneous Pu containing wastes at reprocessing and fabrication facilities.

IV). X-ray Fluorescence

This technique relies on measuring the characteristic X-rays of the atoms near the surface of highly radioactive samples. Its use is limited due to the low energy (high attenuation) of the X-rays, thereby only yielding information about the quantity of U and Pu in the surface layer of the sample, however, for homogeneous solutions containing U or Pu the method could be applied, though it is of limited versatility.

V). Alpha Spectrometry

Measurement of the characteristic energies of alpha particles emitted by the alpha emitting isotopes of Pu and U (e.g. Pu-239, Pu-238, Pu-240, U-232, U-233, U-234, U-235, U-236) may be used to determine the quantity of Pu and U in SNM. However, due to the very low penetrability even of high energy alphas the technique is limited, though it could be used to determine the Pu content in the highly active salt waste solutions from reprocessing plants, if due attention is paid to homogeneity of the solution.

B. Active Interrogation Assay

I). Neutron Interrogation Techniques.(24)

I-1. Capture Gamma Rays

Following thermal neutron capture by a nucleus, de-excitation occurs primarily to levels of low excitation energy where the level density is small, therefore the upper part of the high energy gamma spectrum shows a relatively simple structure. For fissionable materials, the capture gamma ray spectrum is masked by the prompt fission gamma-ray spectrum and by the delayed gamma-ray spectrum of the fission products. The prompt γ-ray spectra from U-235 and Pu-239 fission are essentially identical, however their capture γ-ray spectra are different and provide a means of discriminating and quantitatively establishing the isotopic composition of the material.

The prompt fission γ-ray spectra may be suppressed by detecting the fast-fission neutrons in anticoincidence and 4π geometry, whilst for short measuring times the delayed γ-ray component does not present series obstacles. The method may be extended to non-thermal neutrons by using neutrons from an electron accelerator and a Pu-239 or U-235 target, with an upper limit of about 5 Kev being set on the neutron energy. Extension from thermal to resonance energies is advantageous since the capture-to-fission ratio (α) is on the average larger in the resonance range than at thermal energies. The technique depends on the use of high resolution Ge(Li) detectors and is still at the early developmental stage since more capture γ-ray data is required.

I-2. Delayed and Prompt Neutrons and Gamma Rays

Neutrons produced by pulsed neutron sources (e.g. the D-D and D-T reactions) interrogate the SNM in which delayed and prompt neutrons and gamma rays result from fission. The delayed neutron regime can be time-separated easily from the interrogating pulse and the characteristic difference in the absolute yields and kinetic (time-dependent) response of the delayed neutrons from the different fissionable isotopes provides a means of quantitatively discriminating between the Pu-239 and U-235 content in SNM. By using variable energy external neutron sources it is possible to shift the primary source neutrons to the range below the fission threshold of U-238 and Th-232, thereby increasing the relative response of the fissile isotopes (U-235, U-233, Pu-239) in low enriched fuels. Another signature which may be exploited arises from the delayed gamma rays from fission products which are characteristic of the fissioned isotope.

These techniques should be applicable in determining the isotopic abundance and absolute amounts of fissile material in fuel pins and UO_2 pellets at the fabrication plant, as well as in scrap and non-hydrogeneous wastes from reprocessing and fabrication plants.

I-3. Slowing Down Time Spectrometer

Fast monoenergetic neutron bursts from a pulsed 14 Mev neutron generator are passed through a lead pile surrounding a fuel pin containing

U or Pu in this technique. A simple relation exists between the slowing down time and the average neutron energy in the lead pile, with the result that almost mono-energetic neutrons in the energy range from ~ o - 30 Kev impinge on the fuel pin thereby inducing fission events. The time - dependent fission neutron counting rate (measured with proton recoil counters) is proportional to the neutron flux and the macroscopic fission cross section of the fissionable material. When this is related to the neutron counting rate of reference fuel pins with known masses of fissionable material, the fissionable material content of the investigated pin is obtained.

Discrimination between U-235, Pu-239 and the higher Pu isotopes is achieved by making use of the different fission cross sections as a function of neutron energy in the resonance region. This technique could be used at the product end of fabrication plants to determine the isotopic abundance and absolute amounts of fissile material in fuel pins.

II. Gamma Ray Interrogation Techniques

II-1. Prompt and Delayed Neutron and Gamma Rays, (25)

Using a small LINAC, high intensity continuous energy bremsstrahlung gamma rays are produced, which then impinge on the SNM being investigated, thereby producing the characteristic photon reactions of photofission, photoneutron production and photoactivation. The prompt-neutron yields resulting from the (γ,f) reactions have a very different energy dependence for U-235 and Pu-239 and therefore provide a means of discriminating between these two isotopes. The delayed neutrons (which have a total time integrated yield about two orders of magnitude less than the total prompt-neutron yield) are distinguished from the prompt-neutrons by their detection time. The prompt-neutrons are detected within a few hundred microsecs. after the irradiating pulse and since the next pulse occurs in a few millisecs., the delayed neutrons appear as a uniform distribution in the time interval after about 1 millisec. up to the next irradiating pulse. In addition, the ratio of prompt to delayed neutron yield is useful since it gives a measure of the relative isotopic composition in the SNM and is independent of the absolute magnitude of the flux.

Another useful signature is the time dependence of the delayed-neutron population. The shape of the decay curve is independent of external monitoring and therefore yields the isotopic ratios of the SNM.

Other [illegible] from the delayed-gamma ray spectra of fission products following photofission. For example, high energy gamma rays from short-lived (half-life = seconds) fission products such as Rb differ [illegible] for Pu-239 and U-235 fission. The detection of these high energy gamma-rays supplements the prompt and delayed neutron results, which is also very important due to the different penetrability of neutrons and gammas when SNM is present in hydrogenous materials, as occurs in the organic solvent wastes from reprocessing plants.

"At this stage it is not possible to specify the best active method (based on photoinduced reactions) to use since so much of the basic photonuclear physics data are incomplete for nuclear materials. Much more basic experimental work needs to be done" (...).

3. THE ROLE OF NUCLEAR DATA

I. In Sections 1 and 2 an attempt has been made to convey qualitative impressions of the complex hierarchy of problems encountered in developing and implementing an effective Safeguards system. In seeking to establish a certain separation amongst the host of problems involved in developing instruments and techniques for non-destructive measurements of SNM in the fuel cycle, a flow chart is shown in Fig. VII, which aims at separating those problems which are specifically concerned with nuclear data and those which arise outside of the field of nuclear data. From this it emerges that nuclear data is of basic relevance to the development of instrumentation, since firstly it provides the fundamental information as to whether or not sufficiently large quantitative discrimination exists between the different isotopic signatures of the U and Pu isotopes , and secondly it supplies knowledge of the accuracy and precision with which these isotopic signatures are known.

In view of the fact that nuclear materials Safeguards is a relatively new field of activity and in order to determine in greater depth whether

or not existing nuclear data, which has been acquired primarily for reactor research and development, are sufficient to meet the needs of Safeguards, the Nuclear Data Section (in collaboration with the Department of Safeguards and Inspection) dispatched a circular letter (see Appendix I) on 16 February 1970 to seventy scientists, at some forty-three Institutes in nineteen Member States, who are actively engaged in developing non-destructive or destructive materials assay techniques for Safeguards. The crucial aim of the letter was to ascertain from the individual experts "what improvements, if any, in existing nuclear data should be undertaken for Safeguards purposes?" and an analysis of the replies now follows.

II. Up to the time of preparing this report, replies and/or nuclear data request lists had been received from ten Member States and two International Organizations and the opinions of the individual experts, although having reflected in some cases rather opposite views, have in general been positive.

A. C. Weitkamp (Institut für Angewandte Kernphysik, Karlsruhe, Germany)

Weitkamp in his replies of 13 April and 8 May expressed the view that in the opinion of the Safeguards Project Group at Karlsruhe "The development of nuclear safeguards instrumentation has been suffering from an acute lack of elementary nuclear data. Not only is the accuracy of most methods now under development limited because of the scarcity or inaccuracy of the nuclear data available; (but in fact) the very feasibility of some promising new methods depends on a number of nuclear data presently unknown". He continues by stating that though this problem has been repeatedly discussed within the Karlsruhe Group, "no formal action has so far been taken for a coordination of the nuclear data needs of the different groups and sub-groups engaged in the development of nuclear safeguards instrumentation", and they "therefore appreciate very much the initiative taken by the IAEA to collect nuclear data requests from the different laboratories and eventually, perhaps, prepare and issue a request list similar to the compilation of requests for nuclear cross section measurements of the European and American Nuclear Data Committee".

In collaboration with five other experts (A. von Baeckman, Institut für Radiochemie; E.A. Fischer, Institut für Angewandte Reaktortechnik; F. Fröhner, Institut für Angewandte Kernphysik; V. Schneider, ALKEM GmbH and D. Stegemann, Institut für Kerntechnik (Hannover)) Weitkamp submitted a comprehensive list of nuclear data needed for the Safeguards activities pursued in the Federal Republic of Germany. This list (see Appendix II, List I), contains some sixty-seven data requests which, despite many similarities with requests for reactor R & D, contain certain differences due to the fact that nuclear materials Safeguards is a relatively new field of interest. Such "new" requests concern data on (γ,f) fission cross sections, photo-neutron spectra, fission product delayed γ-ray spectra, γ-ray spectra following neutron capture and specific decay heats (in watts/gram) for calorimetric Pu determinations. Eleven of the sixty-seven requests, initiated by E.A. Fischer and concerned with data required for burn-up calculations coincided with requests listed in the latest U.S.A. request list (FANDC(US)-133).

Weitkamp went on to point out that some of the requests submitted may be dropped in the near future, others added, priorities, energies and accuracies changed, whilst additional requests are still being evaluated (such as those on "fission product yields" for which detailed requests are in preparation). In addition, no information on the actual status of each request has a yet been submitted.

In conclusion, he states that "the preparation of a general request list for safeguards purposes is an important and useful project and all of my colleagues as well as myself would greatly appreciate any activity towards the making of such a list".

B. H. Kronberger (United Kingdom Atomic Energy Authority, Risley, U.K.)

Kronberger in his replies of 20 March and 4 May stated that the concensus of opinion in the UKAEA was that "there is no case for reviewing at this time the existing nuclear data, in the context of international safeguards. Until the physical methods for international safeguarding of materials are defined and the accuracy of any prediction which may be required can be properly assessed, taking into account data uncertainties,

it is clearly not possible to say whether or not existing nuclear data are adequate". He concluded by expressing the view that at the UKAEA it was expected that "the general data requirements for safeguards to be substantially the same as for the reactor programme as a whole; and indeed, safeguards which have to rely on especially high precision in selected items of differential nuclear data should, in our opinion, be viewed with reserve."

C. L.A. Kull and J.R. Beyster (Science Applications Inc., U.S.A.)

Kull focusses attention in his letter of 17 March primarily on the area of Safeguards applications based on photoinduced reactions, since it is in this field that he has had most experience. His list of data needs are given in Appendix II, List II, and additional information concerning the accuracies and priorities of each request are being awaited from the requestors. Kull went on to state that these data "would be very useful for a better understanding of present safeguards techniques and also aid in extrapolating experience obtained in specific applications to new and different problems". He continues by pointing out that though some experiments have been done in these areas, in many cases the data were acquired with equipment that since then has been considerably improved. In addition, some of the earlier measurements are "normalized in units which are not easily transferred to situations different from the ones they were measured in."

Kull then emphasizes that one of the basic and persistent problems is "that most existing data comes from bremsstrahlung measurements, where the bremsstrahlung spectrum shape and yield peculiar to the system used in the experiment are intrinsic to the published result", and therefore "a better knowledge of the behaviour of the bremsstrahlung spectrum, $Y(E_\gamma)$, and the photonuclear cross sections $\sigma(E_\gamma)$ would allow one to confidently calculate results pertinent to safeguards in a variety of situations".

In his concluding remarks, Kull expresses the hope "that the Committee (INDC) can help in directing efforts toward making some of these measurements".

D. J.H. Jennekens (Atomic Energy Control Board, Canada)

Jennekens in his reply of 8 April expressed the opinion of the Canadian Atomic Energy Control Board by stating that "the basic data obtained through normal nuclear and reactor physics research has been more than adequate for the safeguards development projects carried out up to the present time. The major deficiency seems to be in the practical application of existing data in the form of a reliable instrument or technique. For example, a simple, accurate, non-destructive technique for measuring plutonium content in spent fuel would be a valuable safeguards tool". Jennekens however goes on to observe that since the effort expended on Safeguards R & D has rapidly increased over the past few years, the consideration of this problem by the INDC "is most timely," and in addition, the Atomic Energy Control Board is "very interested in this phase of (the) Committee's work" and looks forward to "receiving the results of (the) June meeting".

In conclusion, Jennekens states that neither the Atomic Energy Control Board nor other interested Canadian bodies "have any specific suggestions for improvement in nuclear data at the present time", however, they shall inform the Committee should they "become aware of such a need in the future".

E. K. Oshima (Department of Nuclear Engineering, University of Tokyo, Japan)

Oshima submitted a list, Appendix II, List III, of nuclear data needs for both destructive and non-destructive testing for safeguards, which he has separated into five basic categories of nuclides;

A. Nuclides to be measured by γ- or β-activity;
e.g. Cs^{137}, Ru^{106}

B. Nuclides to be measured by mass spectrometry;
e.g. Nd-(148, 150, 146, 145, 143)

C. Nuclides relating to categories A and B, which tend to increase or decrease the production of the questioned nuclides.

D. Fissile nuclides

E. Nuclides important for neutron spectrum estimation;
e.g. (1) Co^{59}, Ni^{58}; (2) Co^{60}; Co^{58}

Amongst some of his demands for nuclear data, which in fact are rather vast, include the fission yield (chain yield and independent yield) of the nuclides in categories A, B and C from the nuclides in category D and the neutron capture cross sections of the nuclides in categories A, B and E-1. The other data needs concerning half-lives and decay schemes are given in Appendix II, List III. Oshima adds that all the data should be evaluated and that for both the fission yields and the capture cross sections the first demand is in thermal region, but that the data should finally be presented in the ENDF/B format.

In conclusion, Oshima states in his letter of 13 April that "on establishing the standard method for the Inspection other data not mentioned (in his list) would be asked: for example, the branching ratio and half life of delayed neutrons".

F. G.R. Keepin (Los Alamos Scientific Laboratory, U.S.A.)

Along with his letter of 15 April Keepin submitted a list, Appendix II, List IV, of nuclear data needed for Safeguards technical development which included some of the requests which he recently submitted to the latest U.S.A. request list, EANDC(US)-133. To this list, he added that measurements of (n, n'Y) gamma ray production cross sections for all relevant fission isotopes, U-233, U-235, U-238, Pu-239, Pu-240, Pu-241 and Pu-242 should be included. These measurements, he stated, should be performed with a Van de Graaff and a high resolution Ge(Li) detection system and should cover the energy range from 1 - 5 MeV and 14 MeV. He went on to claim that resolvable high energy (~1 MeV) gamma rays from neutron inelastic scattering might find application for isotopic assay of complex mixtures of fission isotopes.

In conclusion, Keepin observed that the Los Alamos Group would also like to see more Ge(Li) data on neutron capture gamma rays in the bombarding region from thermal to 1 MeV.

G. E. Nadjakov (Institute of Physics, Sofia, Bulgaria)

Nadjakov stated in his reply of 3 April that it was still too early for the Group at the Institute of Physics to explicitly enumerate their Safeguards

nuclear data needs. In his Progress Report to the INDC, INDC(BUL)-1/G (1970), Nadjakov, however, points out that the Group under V. Hristov are presently working in the field of neutron constants for Safeguards applications to heterogeneous media. Two methods are presently being investigated - the exponential and the removal cross section methods, and it is hoped that by the autumn it may be possible for the Group to provide more definitive statements with regard to their nuclear data needs.

H. H. Hick (Institut für Physik im Reaktorzentrum, Seibersdorf, Austria)

Hick focusses his reply of 9 March primarily on the problems of interpreting gamma-spectrometric measurements on spent fuel elements using Ge(Li) detectors. First of all, he points out that the nuclides of prime importance for gamma-spectrometry are: Cs-137, Ce-Pr-144, Ru-Rh-106, Ce-141, Zr-Nb-95, (Pa-233), Cs-134 (from Cs-133(n, γ)), Ba-La-140, Ag-110m, Eu-154 (from Eu-153 (n, γ)), Eu-155 (from Eu-154 (n, γ)) and Eu-156. For these nuclides, he stresses that the thermal, fast, accumulative and direct fission yields for fission of Th-232, U-233, U-235, U-238, Pu-239 and Pu-241 are important. In addition, the activation cross sections for these nuclides and all fissile nuclides and their neighbours are of particular interest in the epithermal region. However, since in a typical Safeguard situation there is rather imprecise information concerning the neutron specturm, it is "sufficient to represent activation cross sections as thermal cross section, total (infinite dilute) resonance integral and fission neutron cross section". The net result is that as no precise knowledge is assumed of the neutron spectrum their requirements on activation cross section accuracies are, in general, fulfilled. However, for the Eu-isotope activities a satisfactory interpretation cannot be achieved, at present, due to a lack of adequate cross section data.

In concluding, Hick emphasizes that after a rather thorough literature search, they have found that for the main γ-emitters a few important data, given in Appendix II, List V, are lacking.

I. P. Frederiksen (Atomic Energy Commission Research Establishment, Risö, Denmark)

Frederiksen points out in his letter of 1 April that in Denmark they have been studying the use of sealed safeguards instrumentation for

measurement of the integrated thermal power of a reactor containing highly enriched uranium. These measurements are aimed at verifying the "nuclear loss" in the material over the period of time between intermittent inspections and the instrumentation has operated satisfactorily for over one year, so much so that safeguards measurements of the integrated power in MWD (Megawatt-days) corresponds very closely with the operator's measurements.

They are now at the stage where the uncertainty factor for conversion of "nuclear loss" to integrated thermal power as measured in the cooling system has got to be evaluated. This necessitates more information on the uncertainty in the energy released in fission as well as the uncertainty in the energy deposition and energy transfer in various parts of the reactor.

In view of these factors, it appears that the fundamental data concerning energy released in fission and energy deposition in the reactor should be studied; however, Frederiksen concludes that at this stage it is difficult to state whether the uncertainties in the fission energy released and the energy deposition are more important than the uncertainties arising from other factors, and hence it is not clear "whether there is a need for special investigation by the International Nuclear Data Committee". In its reply, the Nuclear Data Section drew attention to the report by M.F. James (AEEW-M-863) on "Energy released in fission", in which an extensive discussion of energy production and deposition is given.

J. P.J. Kreyger (Koninklije Nederlandsche Hoogevens en Staalfabrieken, Netherlands)

Kreyger's reply of 25 March is concerned with non-destructive uranium determination in spent MTR type fuel elements using the low energy γ-ray absorption technique. The technique is based on the differential absorption of γ-rays passing through the "test sample" and is due to the fact that the mass absorption coefficients for each material making up the "test sample" are different for a given energy. He points out that the successful determination of U content using this technique depends quite critically on a knowledge of the mass absorption coefficients of the fissile, fertile and cladding materials. He goes on to state that mass absorption coefficient values spread by about 5 % as indicated in the literature and a more precise knowledge is desirable.

With regard to Y-spectrometry, he states that at Petten it is felt that the present quality and versatility of available detectors and analyzing equipment are adequate for this type of work. In concluding, he however stresses that a major difficulty arises when the fissile material masses as determined by the Y-ray absorption method are compared with a mass spectroscopic isotope analysis of the same material. The problem being "that the mass spectroscopic method is very sensitive to minor contaminations with foreign materials which can enhance the theoretical error of the mass spectroscopic method determination by a factor of 20."

K. H. Condé (Research Institute of the Swedish National Defence, Sweden)

Condé submitted in his letter of 15 April a request (see Appendix II, List VI) from E. Hellstrand for new measurements of the resonance parameters for the 1.056 eV resonance in Pu-240.

He points out that a method for the non-destructive analysis of Pu-239 and Pu-240 content in plutonium-bearing fuel elements was developed in Sweden a few years ago, and was based on the transmission of epithermal neutrons through a fuel pin using a fast chopper. The dips in the low energy part of the spectrum caused by the Pu-239 and Pu-240 resonances were analyzed using the published values of the resonance parameters and with the isotopic concentrations N-239 and N-240 treated as unknowns. By means of this method it was found that the Pu-240 content was overestimated when compared to the results of masspectrometric analysis. One of the possible explanations of this is that the resonance parameters of the 1.056 eV resonance of Pu-240 are incorrect.

L. S. Untermyer II (National Nuclear Corporation, U.S.A.)

Untermyer in his letter of 6 March states that the role of the National Nuclear Corporation has been primarily that of a supplier of active (neutron) interrogation systems which are principally used by fuel fabricators and electric utilities. Concerning their specific data needs, he points out that for the designing of their systems the existing data available is more than adequate to meet their present needs, since in general such data as they require do not have to be of greater accuracy than that vailable in such sources as BNL-325 and Perlman.

Looking beyond their narrow scope of activity, Untermyer however stresses that it would appear that photo-fission and delayed neutron interrogation techniques should benefit considerably from more nuclear data, as well as there being a need to organize the data on radiations from the principal isotopes of thorium, uranium and the transuranics, since in particular it has been brought to his attention that there are significant interferences in some cases between Pu-239 gammas near 375 KeV and gammas growing in from americium daughters.

M. M. Bresesti (EURATOM, Ispra, Italy)

Bresesti states in his reply of 16 April that though his group is presently engaged in the applications of gamma-spectroscopy to Safeguards, he is not in a position to present any recommendations for nuclear data for Safeguards development.

N. H. Moeken (Eurochemic, Mol, Belgium)

Moeken's response was framed in somewhat general terms in his letter of 3 March. He points out two areas of Safeguards activities in which nuclear data are of importance:

1. Non-destructive assay techniques
2. Calculations following analytical measurements.

With each of these two areas of activity, he emphasizes three different techniques, Appendix II, List VII, for which nuclear data are essential, but he does not go on to state the accuracy, priority, etc. associated with each of these data needs.

4. SUMMARY AND CONCLUSIONS

Even at this very early stage of ascertaining the role of nuclear data in the development of Safeguards instrumentation and techniques, the Agency has already received over 150 explicit nuclear data requests which the requestors consider important for Safeguards instrumentation development. This list is still far from complete, since on the one hand a response to our enquiries is still being awaited from at least five major Institutes in three Member States which are engaged in the development of Safeguards

instrumentation and secondly, for several of the existing requests detailed points, such as the accuracies, priorities and status of the requests, have yet to be established.

An examination of the lists presented in Appendix II and the replies of the individual experts in Section 3, reveals that the existing requests cover an exceedingly wide scope of nuclear data, only some areas of which are closely related to or identical with requests for reactor R & D. It may therefore be advantageous to categorize the Safeguards data requests into the following groups:

A). Neutron data directly related to reactor R & D

E.g. Basic neutron cross section data, $\sigma_{n,f}$, $\sigma_{n,\gamma}$, $\alpha = \sigma_{n,\gamma}/\sigma_{n,f}$, delayed neutron yields, fission product yields and resonance parameters.

B). Neutron data indirectly related to reactor R & D

E.g. Neutron capture gamma ray spectra, fission product delayed gamma ray spectra and high-energy gamma rays from neutron inelastic scattering.

C). Photoirduced reaction data

E.g. Basic photon cross section data as $\sigma_{\gamma,f}$, $\sigma_{\gamma,n}$, prompt and delayed neutron and gamma ray yields following photon irradiation.

D). Decay Schemes and Half-Lives

E.g. Decay alpha, beta and gamma energies and intensities; decay schemes and half-lives of heavy nuclides.

E). Macroscopic Quantities

E.g. Specific decay heats for Pu isotopes and Am-241, and mass absorption coefficients.

Due to this vast scope, the Committee may wish to consider the advisability of establishing, either in the near or more distant future, a nuclear data request list for Safeguards purposes which embraces requests in all the five categories (A-E) listed above, since at present, the limited scope of the existing Data Request Lists (e.g. RENDA)(26) provides a means

of "advertising" only those Safeguards nuclear data requests which fall into categories A and B. In considering the desirability of creating, either separately or as an Appendix to the existing Data Request List, a Safeguards nuclear data request list whose scope embraces categories A-E above, certain points concerning the priorities and status of individual requests ought to be emphasized.

The priorities (I, II and III) presently assigned to nuclear data requests for reactor R & D are attributed to the requests according to well defined and established criteria. For example, the European American Committee for Reactor Physics assigns its highest priority (I) for reactor measurements as follows: "The highest priority should be given to requests for nuclear data for reactors to be built in the near future if:

α). These data are still necessary to predict the differential reactor properties after all information from integral experiments and operating reactors has been used; or

β). Information on an important reactor parameter is in principle attainable through mathematical calculation from nuclear data only; or

γ). These data are needed for materials required in reactor physics measurements"(26).

In contrast to this situation, the priorities to be assigned to Safeguards nuclear data requests are more complex due to the absence of well defined and established criteria; this may be readily seen by focussing attention on the fuel cycle as a whole. In Section 2, a brief review was presented of many different Active and Passive Non-destructive measuring techniques, which it is envisaged would be used at different points in the fuel cycle. Clearly, the development of these different techniques and instruments to not all have the same priority, since it is expected that some of these non-destructive methods would be used at different strategic measurement points in the fuel cycle which in turn, do not have the same relative importance when viewed from a Safeguards standpoint. As pointed out earlier, the question of assessing the relative importance of different strategic measurement points in the fuel cycle is a complex systems analytic problem, which is yet to be settled. The relative importance of strategic points is not only dependent on the fuel cycle in question (e.g. the low

enriched U-235 oxide cycle, the highly enriched U-235 alloy fuel cycle or the mixed PuO_2-UO_2 fuel cycle), but also on the amount of SNM passing through the strategic point, the strategic value of the SNM at the point and the accuracy and precision with which measurements can be executed at that point. It therefore emerges that the priorities associated with nuclear data requested for the development of Safeguards instruments and techniques, which are intended for use at a specific strategic point in the fuel cycle, should in some way reflect the importance of that strategic point.

The second point which it is important to briefly mention, concerns the status of requests. Because of the very wide scope of the existing nuclear data requests for Safeguards, the close cooperation of the individual requestors appears necessary if an up-to-date, and therefore useful, status is to be associated with each request.

In conclusion, it should be re-emphasized that this report, which is of a preliminary and exploratory nature, has aimed not at reviewing the development of Safeguards instrumentation, but at providing the Committee with a framework within which discussions and recommendations may be formulated.

Acknowledgements

The Nuclear Data Section wishes to express its gratitude to the staff of the Division of Development in the Department of Safeguards and Inspection for their valuable suggestions and comments, during the preparation of this preliminary report.

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Fig. 1

PROBABILITY OF DETECTING ONE-HALF THE DIVERTED AMOUNT, $\frac{1}{2}$ D,
FOR VARIOUS σ_{MUF} s; k=2 (95% confidence level)

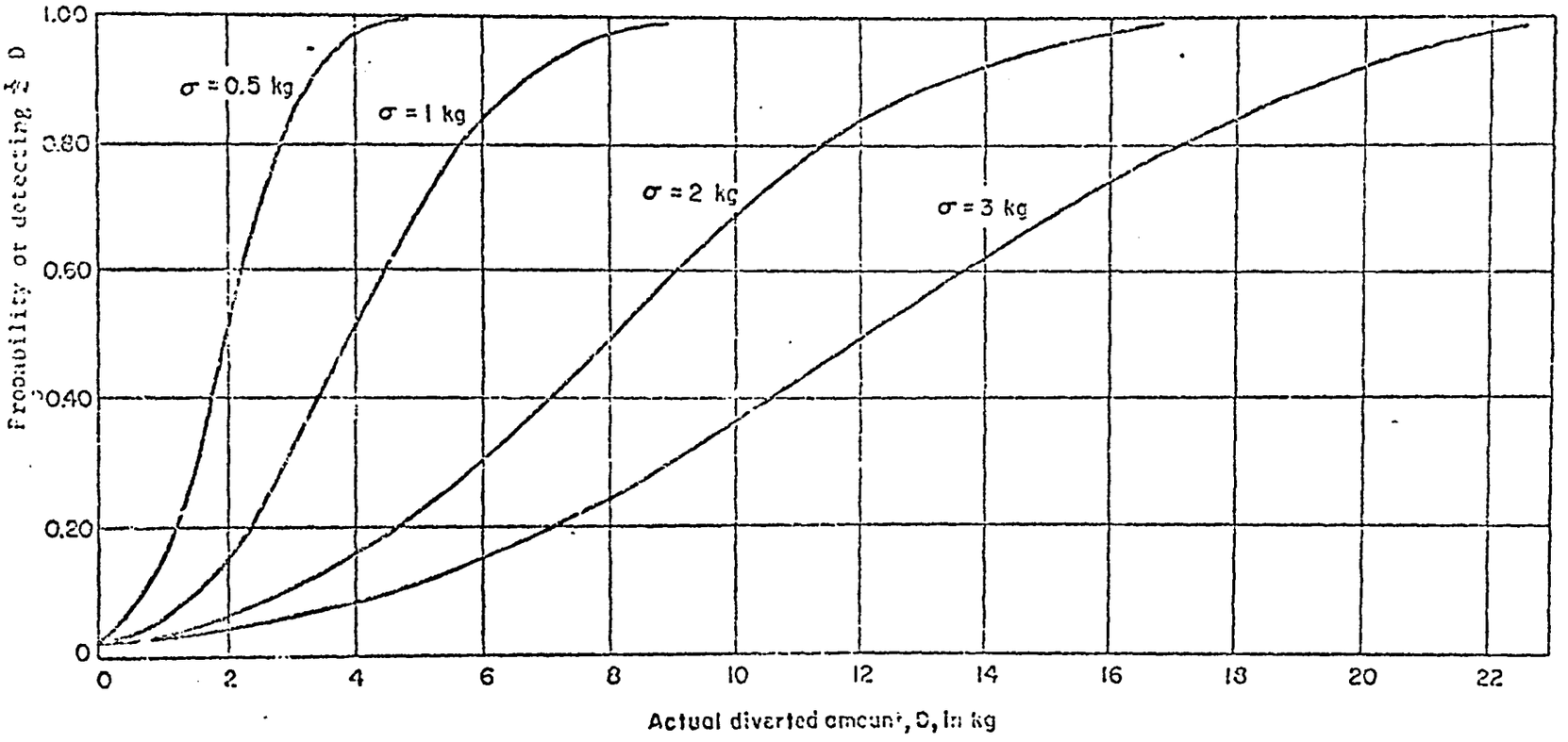
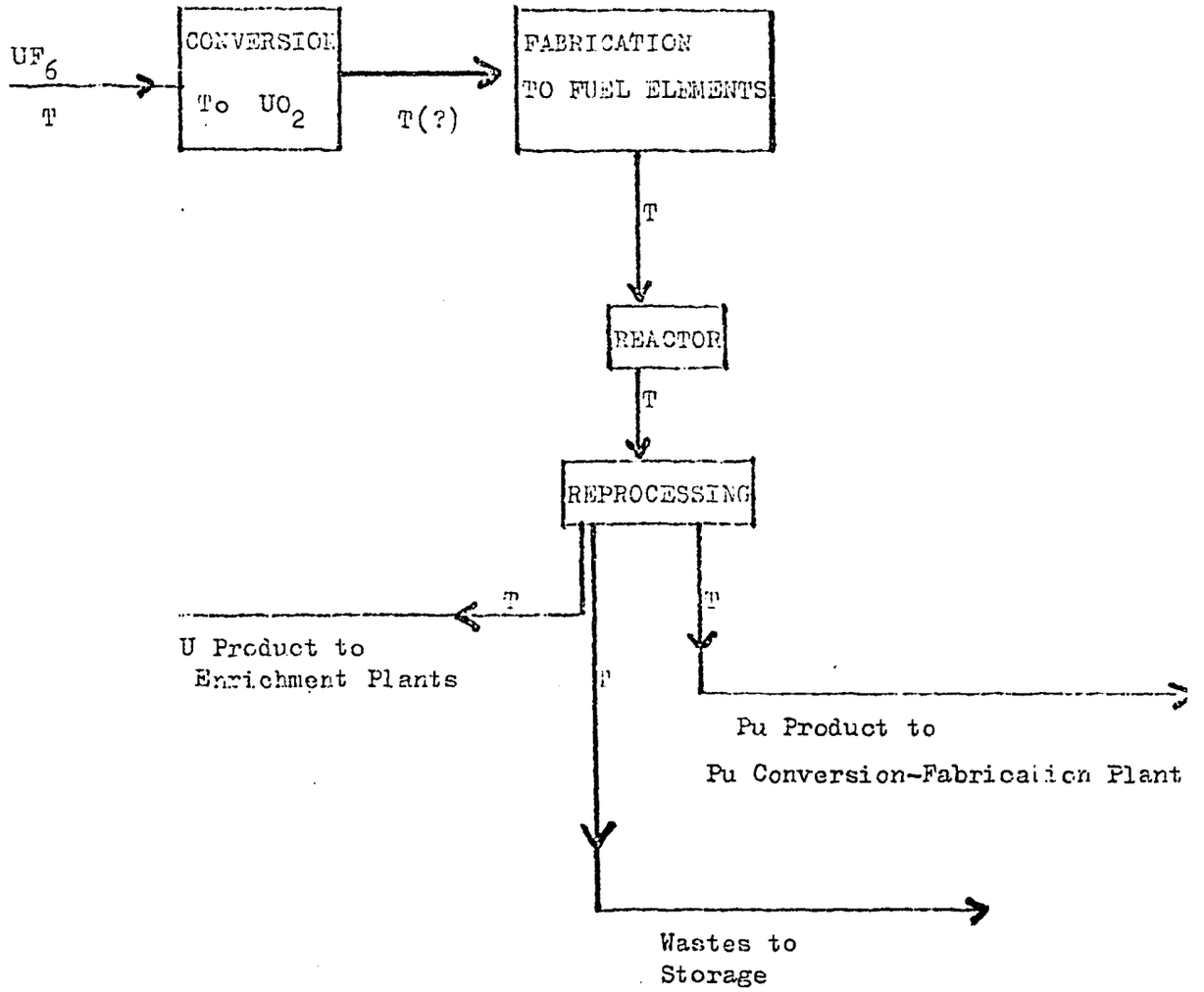


Fig. II

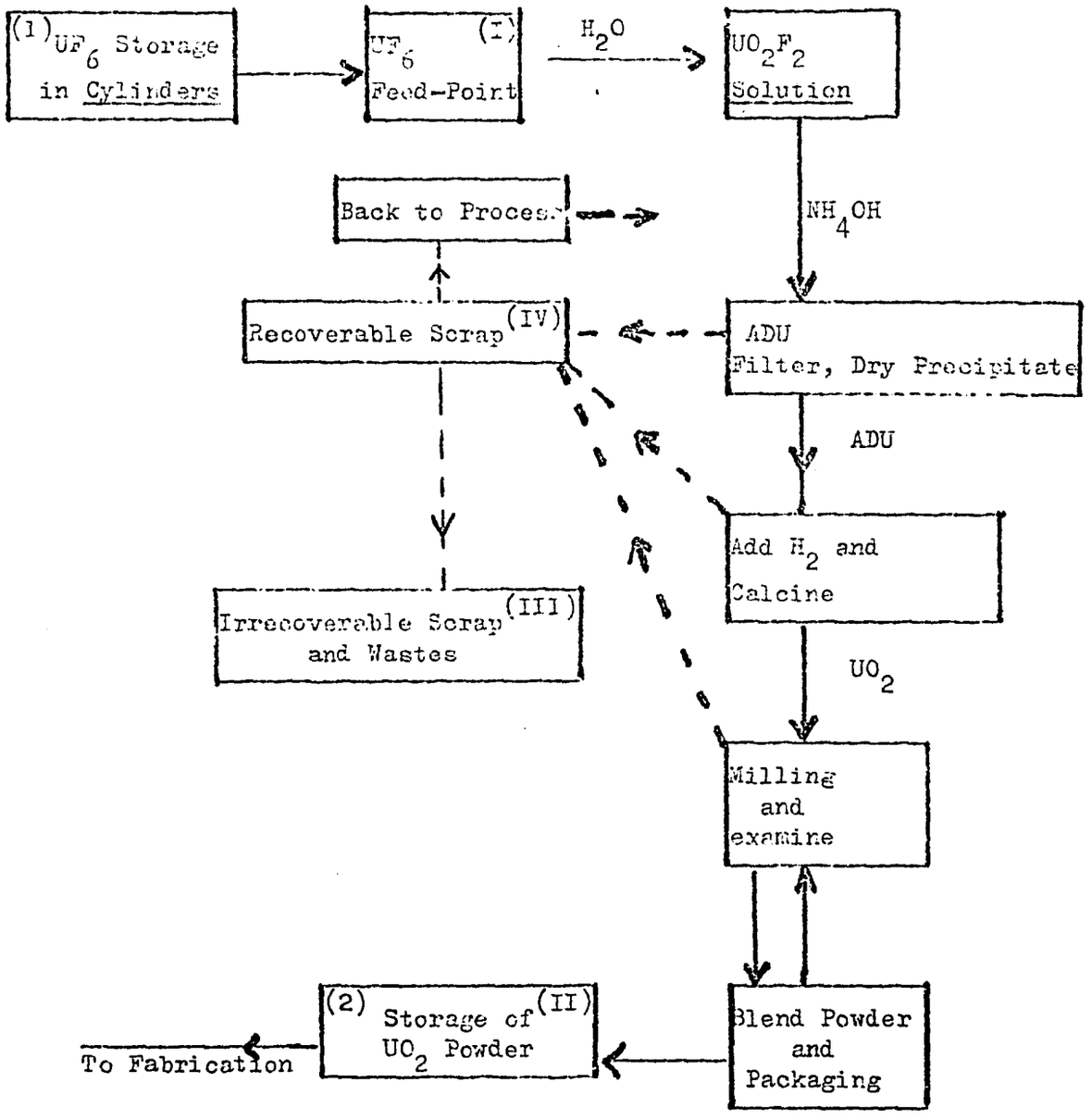
Post Enrichment Fuel Cycle - Low Enriched U-235



T refers to those points in the fuel cycle where TRANSPORT of SNM occurs. Though the problems of Transport Safeguards are great it is not discussed here, since the Containment and Surveillance procedures during Transport would appear to be the principal Safeguards tools.

Fig. III,(7)

Conversion



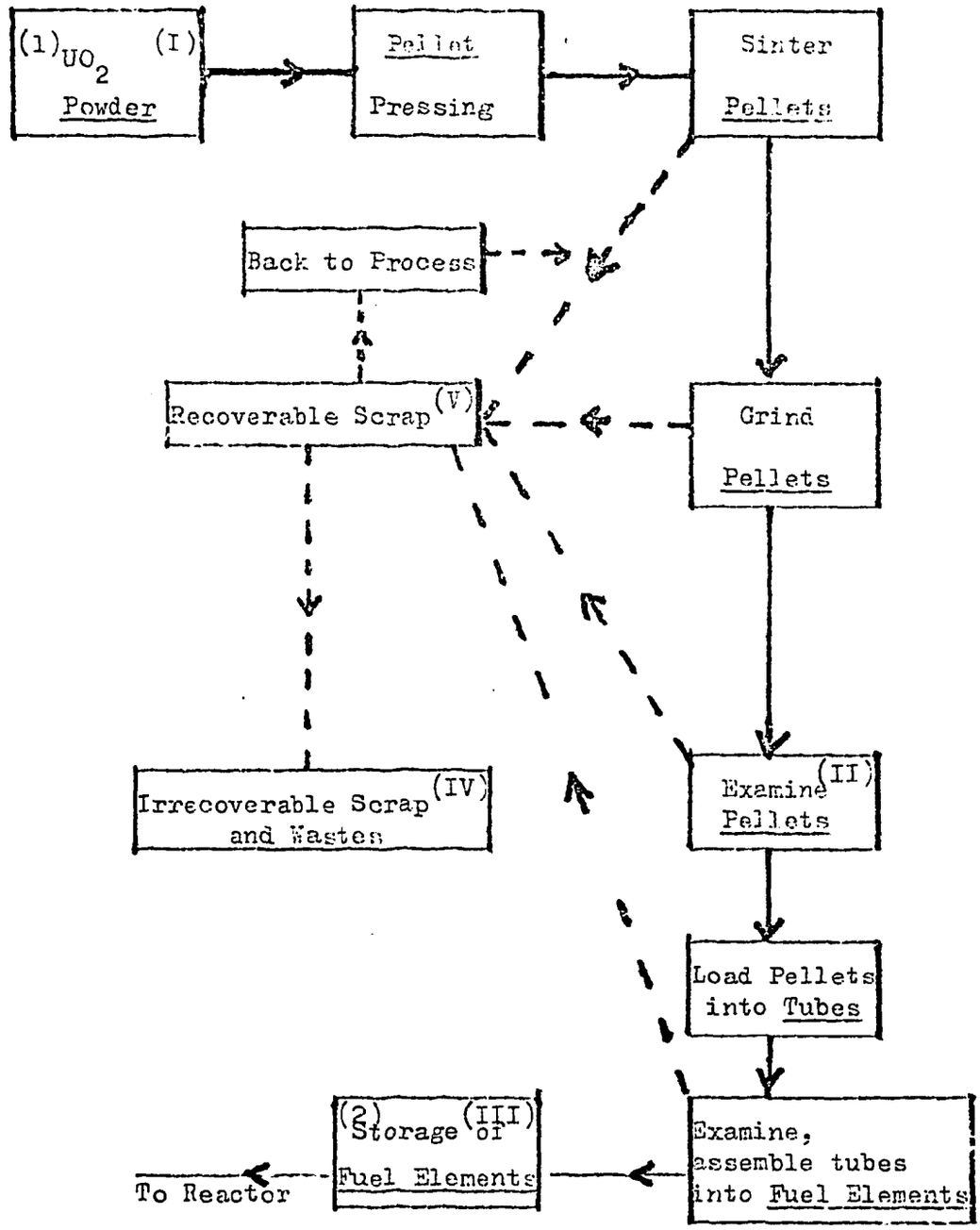
(1),(2), indicate the points at which one may expect Containment and/or Surveillance procedures to dominate.

(I),(II), etc. indicate the minimum number of points at which measurements should be made, so as to establish the flow of SNM.

(7) "A Detailed Analysis of the Safeguards Capabilities of Material Balance Accounting Systems in the Low Enriched UO_2 Conversion and Fabrication Sectors of the Commercial Fuel Cycle", by L.F. Wirfs, pp. 115-162, WASH-1140, Oct. 1969.

Fig. IV,(7)

Fabrication



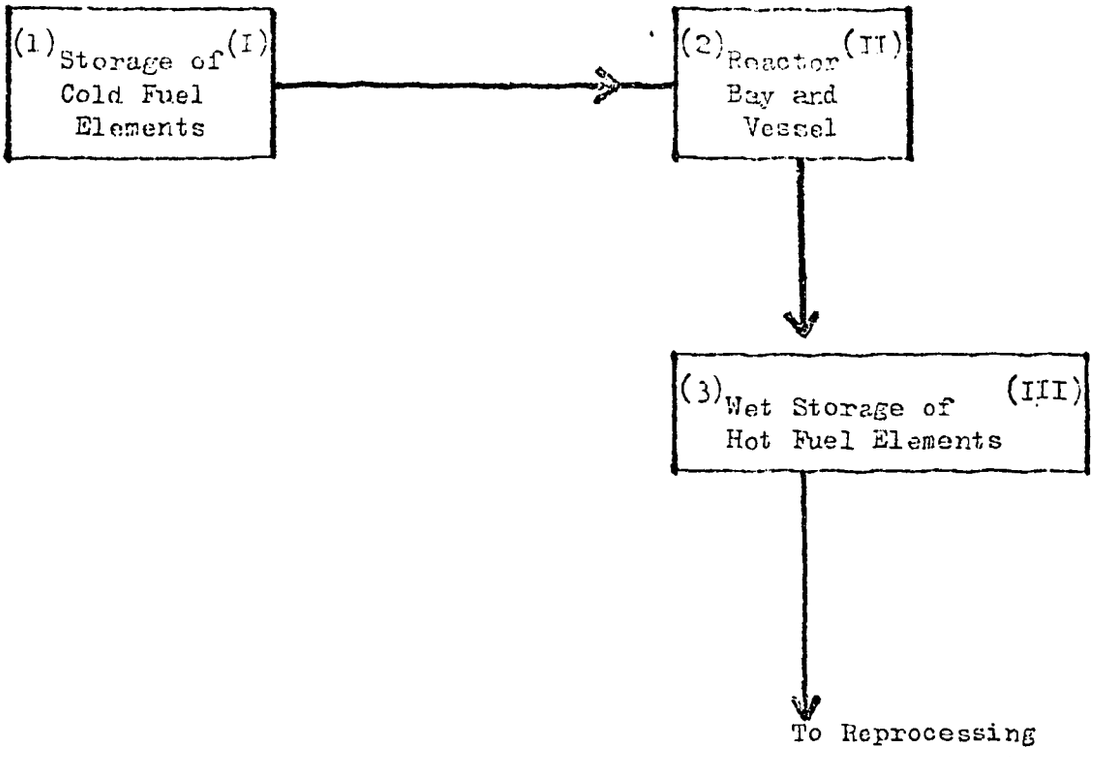
(1),(2), etc. indicate the points at which one may expect Containment and/or Surveillance procedures to dominate.

(I),(II), etc. indicate the minimum number of points at which measurements should be made, so as to establish the flow of SNM.

(7) "A Detailed Analysis of the Safeguards Capabilities of Material Balance Accounting Systems in the Low Enriched UO_2 Conversion and Fabrication Sectors of the Commercial Fuel Cycle", by L.F. Wirfs, pp.115-162, WASH-1140, Oct. 1969.

Fig. V

Reactor

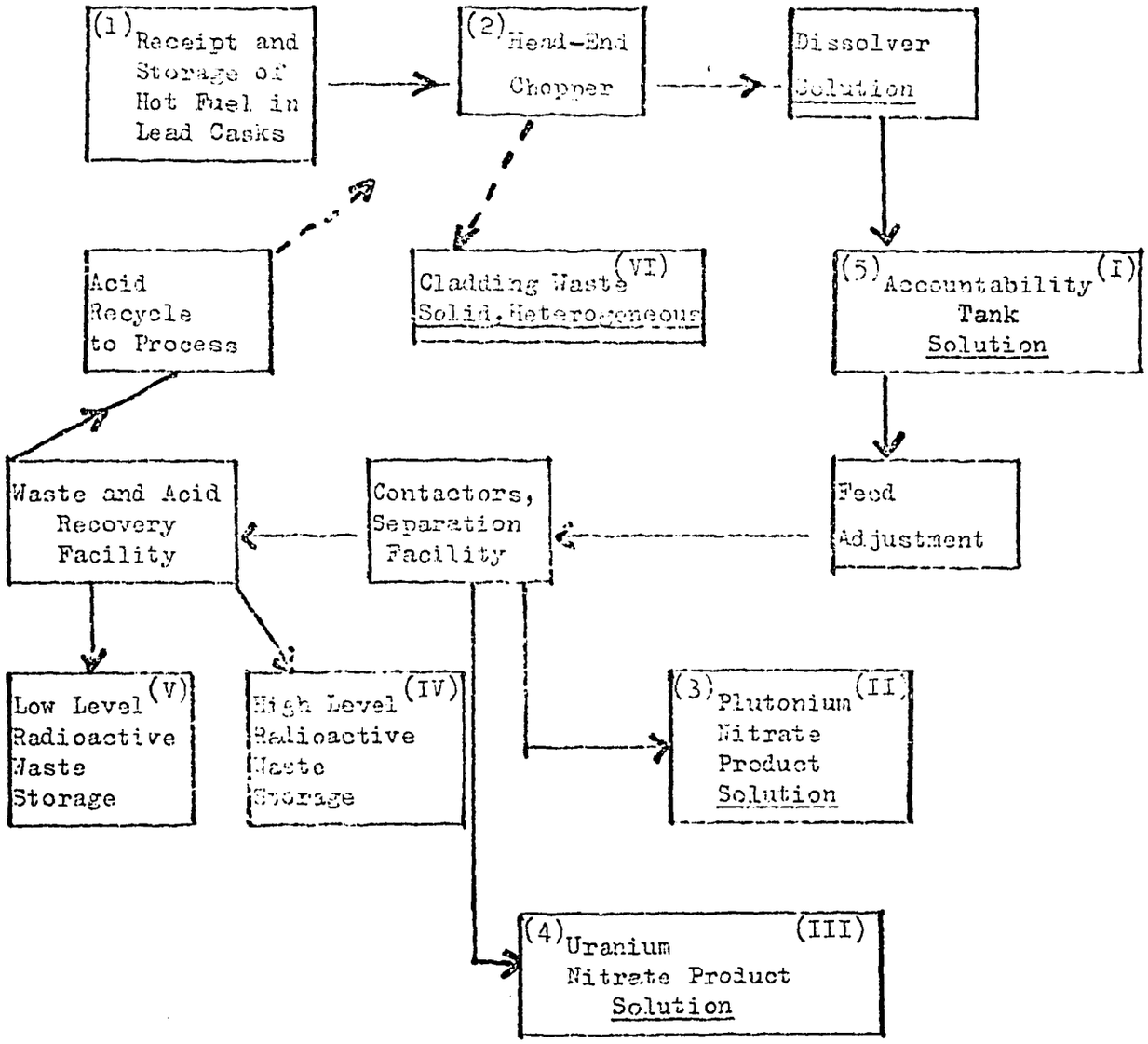


(1),(2), etc. indicate the points at which one may expect Containment and/or Surveillance procedures to dominate.

(I),(II), etc. indicate the minimum number of points at which measurements should be made, so as to establish the flow of SNM.

Fig. VI.(15)

Reprocessing



(1),(2), etc. indicate the points at which one may expect Containment and/or Surveillance procedures to dominate.

(I),(II), etc. indicate the minimum number of points at which measurements should be made, so as to establish the flow of SNM.

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(16) "Capability of a Typical Material Balance Accounting System for a Chemical Processing Plant", by R.A. Schneider and D.P. Granquist, pp. 75-114, WASH-1140, Oct. 1969.

Fig. VII

Development of Techniques and Instrumentation for Nondestructive Measuring of SNM in the Fuel Cycle

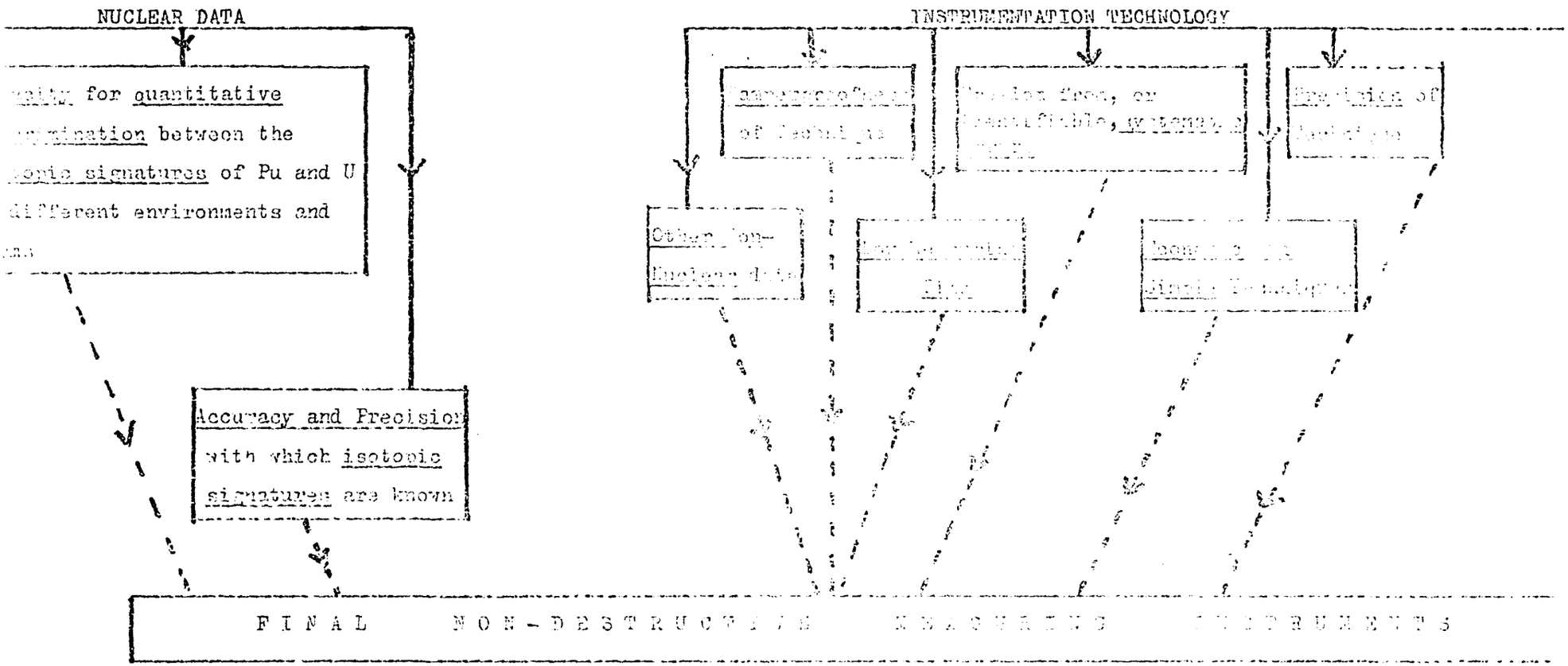

Table I.(9),(19)

CRITERIA FOR MEASURING METHODS OF FISSILE MATERIAL CONTENT IN UNIRRADIATED FUEL PINS AND SUBASSEMBLIES

Criteria	Remarks
1. Tamperproofness	Against all conceivable measures, which can simulate the presence or the absence of one of the fissionable elements (inhomogeneity, addition or removal of absorbers, reflectors, and foreign neutron and heat source)
2. Free from systematic errors	Any bias in the measurement should be identifiable and correctable
3. Capacity of discrimination	The method should be capable of discriminating between uranium and plutonium
4. Low measuring time	Depends on the throughput and the number of measuring units used in a plant. For 1 ton heavy metal/day capacity fabrication plant and one measuring unit, the measuring time should not exceed 2-3 minutes/pin
5. Total Measurement Uncertainty (Systematic & random)	For the same throughput as in (4) the overall measuring uncertainty for Pu should be less than $\pm$ 0.4 % and that for U-235 $\pm$ 1.6 % (1-σvalue)*
6. Simple, reliable, easy to automatise and adaptable to continuous operation	
7. Economic	

*These measurement uncertainties have been chosen so that, with the fabrication plant throughput expected in the Federal Republic of Germany in the early 1970's, the integrated uncertainties in throughputs reach a value of 10 effective kgs. of Pu over one year.

APPENDIX - I

Text and distribution of the Circular Letter of 16 February 1970 on Nuclear Data for Safeguards Technical Development. An aesterisk (*) indicates those experts (Institutes) from whom a reply had been received by 20 May 1970.

INTERNATIONAL ATOMIC ENERGY AGENCY
AGENCE INTERNATIONALE DE L'ENERGIE ATOMIQUE
МЕЖДУНАРОДНОЕ АГЕНТСТВО ПО АТОМНОЙ ЭНЕРГИИ
ORGANISMO INTERNACIONAL DE ENERGIA ATOMICA
KARNTNER RING 11, A-1010 VIENNA, AUSTRIA

TELEPHONE: 52 45 11
52 45 23
TELEX: 01-2645
CABLE: INATOM VIENNA

IN REPLY PLEASE REFER TO:
PRIÈRE DE RAPPELER LA RÉFÉRENCE:

16 February 1970

Nuclear Data for Safeguards Technical Development

At the last meeting of the International Nuclear Data Committee (INDC), which acts as an advisory body to the Director General of the International Atomic Energy Agency (IAEA) on all matters pertaining to nuclear data, one of the agenda items which was briefly discussed was the role of basic nuclear data in the technical development of international safeguards. The general feeling expressed by the Committee was that it would be particularly helpful if by the time of its next meeting (to be held in Vienna, 22-26 June 1970), it could be supplied with more specific definitions and priorities of the actual nuclear data needs for safeguards development, with particular reference being made to the merits of the existing neutron data request lists which have, to-date, been primarily oriented towards the data needs for reactor research and development.

Such a list of needs could serve to stimulate further experimental effort, on an international scale through the IAEA, towards performing those high priority measurements on nuclear materials for which existing data are either inconsistent, incomplete or unknown. In addition, it could also serve the purpose of initiating reviews and evaluations for those classes of data regarded as being of prime importance. Purely for the purposes of illustration, such relevant areas may include such diverse fields as photonuclear reaction data, fission neutron data, capture gamma-ray data and gamma and alpha particle spectrometry; of course, this is clearly not a comprehensive list.

In this context, we would find it particularly helpful if you could provide us with your comments on, as well as a list of, such present and near-future data needs, as viewed from the standpoint of someone

actively engaged in developing destructive or non-destructive materials assay techniques for safeguards. Framed in more direct language, in your opinion what improvements, if any, in existing nuclear data should be undertaken for safeguards purposes?

The views on and lists of specific data needs which are transmitted to the Agency in response to this enquiry, will be submitted to the June meeting of the INDC, following which the Committee may arrive at specific recommendations, if this is warranted, which could then lead to actions along the lines referred to earlier. We would be grateful if you could send us your reply by 15 April 1970, so as to allow both the Agency and the members of the INDC sufficient time to assess the situation in preparation for the June meeting of the Committee.

Looking forward to your reply,

Yours sincerely,

J.J. Schmidt
Scientific Secretary
International Nuclear
Data Committee

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W. Michaelis (Kernforschungszentrum Karlsruhe)
C. Weitkamp* (Kernforschungszentrum Karlsruhe)

INDIA

A.S. Divatia (Bhabha Atomic Research Centre)
P.N. Krishnamoorthy (Bhabha Atomic Research Centre)
H.I. Sethna (Bhabha Atomic Research Centre)

ITALY

G. Birkhoff	(EURATOM, Ispra)
A.M. Bresesti*	(EURATOM, Ispra)
N. Coppo	(EURATOM, Ispra)
C. Foggi	(EURATOM, Ispra)
E. Inzsiti	

JAPAN

R. Imai	(Japan Atomic Power Co.)
S. Mitsui	(Univ. of Tokyo)
K. Oshima*	(Univ. of Tokyo)

NETHERLANDS

J.J. Barendregt	
P.J. Kreyger*	(EURATOM, Petten)

NORWAY

H. Ager-Hanssen	(Institutt for Atomergie, Halden)
M. Bonnevie-Svendsen	(Institutt for Atomergie, Kjeller)

SWEDEN

H. Condé*	(Research Inst. of National Defense)
R.S. Forsyth	(AB Atomenergi, Studsvik)
A. Larsson	(AB Atomenergie, Stockholm)

SWITZERLAND

W. Hälg	
Th. Huerlimann	(Institut f. Reaktorforschung)
W. Zünti	(Institut f. Reaktorforschung)

USSR

A.I. Abramov	(Inst. of Physics and Power Engineering, Obninsk)
B.S. Dzhelepov	(JINR, Dubna)
A.M. Demidov	(Kurchatov Institute, Moscow)
L.V. Groshev	(Kurchatov Institute, Moscow)
A.K. Krasin	(Inst. of Nuclear Energy, Minsk)
I.D. Morokhov	(State Committee on the Utilization of Atomic Energy, Moscow)
C.S. Skvortzov	(Kurchatov Institute, Moscow)
G.N. Smirenkin	(Inst. of Physics and Power Engineering, Obninsk)
V.I. Spitsyn	(Inst. of Physical Chemistry, Moscow)

UK

D.B. Janisch	(UKAEA, Risley)
H. Kronberger*	(UKAEA, Risley)
F. Morgan	(UKAEA, Aldermaston)

USA

J.R. Beyster*	(Science Applications Inc.)
R. Bramblett	(Gulf General Atomic)
D. Crowson	(Office of Safeguards and Nuclear Materials Management)
R. Ewing	(Battelle Memorial Inst.)
R.L. Heath	(Idaho Nuclear Corp.)
W.A. Higinbotham	(BNL)
G.R. Keepin*	(LASL)
G.A. Kolstad - Info. Copy	(USAEC, Washington)
H. Kouts	(BNL)
W.J. McGonnagle	(Assoc. Midwest Universities)
N.C. Rasmussen	(MIT)
S. Untermyer II*	(National Nuclear Corp.)

APPENDIX-II

In this Appendix the preliminary request lists for nuclear data measurements important for the technical development of Safeguards are presented. The sequence and meaning of the entries in the lists follow the general format of the EANDC Request list "RENDA"(26), and are as follows, unless otherwise stated:

1. Request Number (Req.No.) which references only those requests which coincide, in all aspects, with a request in the latest U.S.A. request list, EANDC(US)-133 (November 1969), by the same or different requestors.
2. Target
3. Reaction Type (Quantity and Variable)
4. Priority of the request
5. Energy range of the incident particles - unless otherwise stated, neutrons are always assumed as the incident particle.
6. Accuracy required
7. Name of requesting laboratory with the organization in parenthesis
8. Name of the requestor - directly under the requestor's name the relevant Comments and Status of the request are given, if necessary, and if available at present.
9. Year of initiation of the request

Due to the limitations of time in the preparation of this report, requests are listed separately on the basis of the Institute and Member State from which they have originated, and not on the basis of a target-isotope-reaction type (ZAQ) hierarchy. However, it is planned that by the time of the INDC Meeting (22-26 June 1970) copies of the merged requests sorted on the ZAQ basis would be available.

List I

Preliminary list of nuclear data measurements important for Safeguards technical development

Submitted by Dr. C. Weitkamp, Institut für Angewandte Kernphysik, Karlsruhe, Germany

Names and Addresses of Requestors:

1. Dr. A. von Baeckmann, Institut für Radiochemie, Gesellschaft für Kernforschung mbH, 75 Karlsruhe, Postfach 3640, Germany

2. Dr. W.A. Fischer, Institut für Angewandte Reaktortechnik (IAR), Gesellschaft für Kernforschung mbH (GfK), 75 Karlsruhe, Postfach 3640, Germany

3. Dr. F. Fröhner, Institut für Angewandte Kernphysik (IAK), Gesellschaft für Kernforschung mbH (GfK), 75 Karlsruhe, Postfach 3640, Germany

4. Dr. V. Schneider, ALKEM-Alpha-Chemie und-Metallurgie GmbH, 7501 Leopoldshafen, Germany

5. Prof. Dr. D. Stegemann, Lehrstuhl und Institut für Kerntechnik (IKT), Technische Universität Hannover (TUH), 3 Hannover, Germany

6. Dr. C. Weitkamp, Institut für Angewandte Kernphysik (IAK), Gesellschaft für Kernforschung mbH (GfK), 75 Karlsruhe, Postfach 3640, Germany

List I

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	U-235	σ(n,f)		I	5 Kev - 15 Mev	1 %	IKT(TUH)	Stegemann Status:	70
	U-235	ALPHA	$\sigma_{n,\gamma}/\sigma_{n,f}$	I	5 Kev - 15 Mev	5 %	IKT(TUH)	Stegemann Status:	70
	U-235	Nu-Bar	Prompt	I	5 Kev - 15 Mev	2 %	IKT(TUH)	Stegemann Average number of prompt neutrons per neutron fission required. Status:	70
	U-235	Delayed -N-Y	$P(E_{n'})$	I	5 Kev - 15 Mev	3 %	IKT(TUH)	Stegemann Delayed neutron fraction, β_i, required. Status:	70
	U-235	(n,Y)	$P(E_\gamma)$	I	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Capture gamma-ray spectra required. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	U-235	Delayed-F-Y					IKT(TUH)	Stegemann Yield of specific fission products required; detailed requests in preparation. Status:	70
	U-235	Delayed-Y-Y	$P(E_\gamma)$	I	5 Kev - 15 Mev	2 %	IKT(TUH)	Stegemann Delayed fission Y-ray spectra required. Status:	70
	U-235	Delayed-Y-Y	$P(E_\gamma, T1/2)$	I	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Delayed fission Y-ray spectra as a function of delay time required. Particularly interesting for intervals < 1 sec. Accuracy refers to Y-ray intensities. Errors of - 50% to + 100% for T1/2 acceptable. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	U-235	$\sigma(\gamma,f)$		I	E_γ=5-8 Mev	3 %	IKT(TUH)	Stegemann Status:	70
	U-235	(γ,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0 ~ 100 eV requirel. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70
	U-238	$\sigma(n,f)$		II	5 Kev - 15 Mev	3 %	IKT(TUH)	Stegemann Status:	70
	U-238	$\sigma(n,\gamma)$		II	5 Kev - 15 Mev	5 %	IKT(TUH)	Stegemann Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	U-238	Nu-Bar	Prompt	II	5 Kev - 15 Mev	2 %	IKT(TUH)	Stegemann Average number of prompt neutrons per neutron fission required. Status:	70
	U-238	Delayed-N-Y	$P(E_{n'})$	II	5 Kev - 15 Mev	3 %	IKT(TUH)	Stegemann Delayed neutron fraction, β_i, required. Status:	70
	U-238	(n,Y)	$P(E_\gamma)$	I	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Capture gamma-ray spectra required. Status:	70
	U-238	Delayed-Y-Y	$P(E_\gamma)$	II	5 Kev - 15 Mev	3 %	IKT(TUH)	Stegemann Delayed fission Y-ray spectra required. Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	U-238	$\sigma(\gamma,f)$		II	E_γ=5-8 Mev	5 %	IKT(TUH)	Stegemann Status:	70
	U-238	(γ,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0 ~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70
362	93-Np-237	$\sigma(n,f)$		II	1 Kev - 5 Mev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: Paya at Saclay has σ_{nT}, σ_{nf}, resonance parameters to 2 Kev.	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
364	93-Np-237	σ(n,Y)		I	0.001 eV - 1 Kev	3-10 %	IAR(GfK)	Fischer For burn-up calculations. Accuracy of 3% from Thermal - 10 eV. Accuracy 5 % Y-n. Accuracy 10% Y-Y from Thermal - 1 Kev. Status: Paya at Saclay has σ_{nT}, σ_{nf}, resonance parameters to 2 Kev.	70
364	93-Np-237	σ(n,Y)		II	1 Kev - 5 Mev		IAR(GfK)	Fischer For burn-up calculations. Status: Paya at Saclay has σ_{nT}, σ_{nf} and resonance parameters to 2 Kev.	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	93-Np-237	(γ,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0 ~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70
366	94-Pu-238	σ(n,f)		I	1 - 10 Mev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: WASH-1124, Silbert (LASL) has fission data.	70
370	94-Pu-238	σ(n,γ)		I	Thermal - 1 Kev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: WASH-1124, Silbert (LASL) has capture-fission data. Nucl.Sci.Eng.,30,p.365, Young, resonance parameters to 290 eV.	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requester, Comments, Status	Year
370	94-Pu-238	σ(n,Y)		II	1 Kev - 10 Mev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: WASH-1124, Silbert (LASL) has capture-fission data.	70
371	94-Pu-238	σ(n,Y)		II	Thermal - 2 Mev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: WASH-1124, Silbert (LASL) has capture-fission data.	70
	94-Pu-238	(n,Y)	$P(E_\gamma)$	II	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Capture gamma-ray spectra required. Status:	70
	94-Pu-238	Decay Heat (See Comments)		I	_____	0.1%	ALKEM(ALKEM)	Schneider Specific decay heat, in e.g. Watts/gram for calorimetric Pu determinations. Consistent data for Pu-238 particularly urgent. Percentage of heat carried off by longe-range particles(x-rays,Y-rays) would be useful. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requester, Comments, Status	Year
	94-Pu-238	Delayed-Y-Y	$P(E_\gamma,T1/2)$	III	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Delayed fission Y-ray spectra as a function of delay time required. Particularly interesting for intervals < 1 sec. Accuracy refers to Y-ray intensities. Errors of - 50% to + 100% for T1/2 acceptable. Status:	70
	94-Pu-238	(Y,n) Spectra (See Comments)	I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requester, Comments, Status	Year
	Pu-239	σ(n,f)		I	5 Kev - 15 Mev	1 %	IKT(TUH)	Stegemann Status:	70
	Pu-239	ALPHA	$\sigma_{n,\gamma}/\sigma_{n,f}$	II	5 Kev - 15 Mev	5 %	IKT(TUH)	Stegemann Status:	70
	Pu-239	Nu-Bar	Prompt	I	5 Kev - 15 Mev	2 %	IKT(TUH)	Stegemann Average number of prompt neutrons per neutron fission required. Status:	70
	Pu-239	Delayed-N-Y	$P(E_{n'})$	I	5 Kev - 15 Mev	3 %	IKT(TUH)	Stegemann Delayed neutron fraction, β_i, required. Status:	70
	Pu-239	(n,Y)	$P(E_\gamma)$	I	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Capture gamma-ray spectra required. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	Pu-239	Decay Heat (See Comments)		II	_____	0.1%	ALKEM(ALKEM)	Schneider Specific decay heat, in e.g. Watts/gram required for calorimetric Pu determinations. Percentage of heat carried off by longe-range particles(x-rays,Y-rays) would be useful. Status:	70
	Pu-239	Delayed-F-Y					IKT(TUH)	Stegemann Yield of specific fission products required; detailed requests in preparation. Status:	70
	Pu-239	Delayed-Y-Y	$P(E_\gamma)$	I	5 Kev - 15 Mev	2 %	IKT(TUH)	Stegemann Delayed fission Y-ray spectra required. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	Pu-239	Delayed-γ-Y	$P(E_\gamma,T1/2)$	I	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Delayed fission γ-ray spectra as a function of delay time required. Particularly interesting for intervals < 1 sec. Accuracy refers to γ-ray intensities. Errors of - 50% to + 100% for T1/2 acceptable. Status:	70
	Pu-239	$\sigma(\gamma,f)$		I	E_γ=5-8 Mev	3 %	IKT(TUH)	Stegemann Status:	70
	Pu-239	(γ,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Trönner Photo-neutron spectra with resolved resonances and neutron energies between 0~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	Pu-240	(n,Y)	$P(E_\gamma)$	I	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Capture gamma-ray spectra required. Status:	70
	Pu-240	Decay Heat (See Comments)		II	_____	0.1%	ALKEM(ALKEM)	Schneider Specific decay heat, in e.g. Watts/gram required for calorimetric Pu determinations. Percentage of heat carried off by longe-range particles(x-rays,Y-rays) would be useful. Status:	70
	Pu-240	(Y,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	Pu-241	σ(n,f)		II	5 Kev - 15 Mev	1 %	IKT(TUH)	Stegemann Status:	70
	Pu-241	σ(n,f)		I	30 Kev - 10 Mev	5-10%	IAR(GfK)	Fischer For burn-up calculations. Status:	70
398	94-Pu-241	σ(n,f)		I	Thermal - 30 Kev	3-10%	IAR(GfK)	Fischer For burn-up calculations. Accuracy to 3% from thermal to 10 eV, and to 10% from 10 eV to 30 Kev. Ratio to U-235 or Pu-239 would be useful. Status: WASH-1136, p. 70, Smith is evaluating for ENDF/B file. See also AERE-M-2157, James evaluates to 20 Kev.	70
	94-Pu-241 ALPHA	$\sigma_{n,\gamma}/\sigma_{n,f}$		II	5 Kev - 15 Mev	5 %	IKT(TUH)	Stegemann Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
402	94-Pu-241	σ(n,Y)		I	Thermal - 30 Kev	3 %	IAR(GfK)	Fischer For burn-up calculations. Accuracy to 3% in Eta. Cross-section or alpha needed. Status: WASH-1136, p. 70, Smith is evaluating for ENDF/B file.	70
403	94-Pu-241	ALPHA	$\sigma_{n,\gamma}/\sigma_{n,f}$	II	1 Kev - 2 Mev	20 %	IAR(GfK)	Fischer Capture cross-section would be equally useful. For burn-up calculations. Status: None	70
	94-Pu-241	Nu-Bar	Prompt	II	5 Kev - 15 Mev	2 %	IKT(TUH)	Stegemann Average number of prompt neutrons per neutron fission required. Status:	70
	94-Pu-241	Delayed-N-Y	$P(E_{n'})$	II	5 Kev - 15 Mev	3 %	IKT(TUH)	Stegemann Delayed neutron fraction, β_i, required. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-241	(n,Y)	$P(E_\gamma)$	I	Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Capture gamma-ray spectra required. Status:	70
	94-Pu-241	Decay Heat (See Comments)		II	_____	0.3%	ALKEM(ALKEM)	Schneider Specific decay heat, in e.g. Watts/gram required for calorimetric Pu determinations. Percentage of heat carried off by longe-range particles(x-rays,Y-rays) would be useful. Status:	70
	94-Pu-241	Delayed-Y-Y	$P(E_\gamma)$	II	5 Kev - 15 Mev	3 %	IKT(TUH)	Stegemann Delayed fission Y-ray spectra required. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-241	Delayed-γ-γ	$P(E_\gamma, T1/2)$		Thermal; 2-25 Kev	10 %	IAK(GfK)	Weitkamp Delayed fission γ-ray spectra as a function of delay time required. Particularly interesting for intervals ∠1 sec. Accuracy refers to γ-ray intensities. Errors of - 50% to + 100% for T1/2 acceptable. Status:	70
	94-Pu-241	$\sigma(\gamma,f)$		II	E_γ=5-8 Mev	3 %	IRT(TUH)	Stegemann Status:	70
	94-Pu-241	(γ,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-242	(n,Y)	$P(E_\gamma)$	III	Thermal; 2-25 Kev	50 %	IAK(GfK)	Weitkamp Capture gamma-ray spectra required. Status:	70
	94-Pu-242	Decay Heat (See Comments)		III	_____	1 %	ALKEM(ALKEM)	Schneider Specific decay heat, in e.g. Watts/gram required for calorimetric Pu determinations. Percentage of heat carried off by longe-range particles (x-rays,Y-rays) would be useful. Status:	70
	94-Pu-242	Delayed-Y-Y	$P(E_\gamma,T^1/2)$	III	Thermal; 2-25 Kev	50 %	IAK(GfK)	Weitkamp Delayed fission Y-ray spectra as a function of delay time required. Particularly interesting for intervals $\angle$ 1 sec. Accuracy refers to Y-ray intensities. Errors of - 50% to + 100% for $T^1/2$ acceptable. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-242	(γ,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70
	95-Am-241	σ(n,f)		II	100 Kev - 10 Mev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: Nuclear Physics, A 96, p. 605, Seeger, 20 eV to 1 Mev.	70
418	95-Am-241	σ(n,f)		II	20 - 200 Kev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: Nuclear Physics, A 96, p. 605, Seeger, 20 eV to 1 Mev.	70
	95-Am-241	σ(n,γ)		II	100 Kev - 10 Mev	20~30%	IAR(GfK)	Fischer For burn-up calculations. Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Yea
419	95-Am-241	σ(n,Y)		I	Thermal - 1 Kev	10 %	IAR(GfK)	Fischer For burn-up calculations. Status: None.	7(
420	95-Am-241	σ(n,Y)		I	100 eV - 300 Kev	50 %	IAR(GfK)	Fischer For burn-up calculations. Status: None.	7(
	95-Am-241	Decay Heat (See Comments)		I	_____	0.1 %	ALKEM(ALKEM)	Schneider Specific decay heat in e.g. Watts/gram for calorimetric Pu determinations. Consistent data for Am-241 particularly urgent. Percentage of heat carried off by long-range particles (x-rays,Y-rays) would be useful. Status:	7(

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	95-Am-241	(γ,n)Spectra (See Comments)		I	E_γ=5-8 Mev	10 %	IAK(GfK)	Fröhner Photo-neutron spectra with resolved resonances and neutron energies between 0~100 eV required. Accuracies refer to shape, absolute values with 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev Status:	70

Von Baeckmann pointed out that as far as the analytical chemical aspects of Safeguards measurements were concerned, he had no particular interest in new determinations of nuclear data. However, since the data are available in any case, they were interested in the first place, in fission yields of inert gases during fission of heavy nuclei under the most varied conditions, and secondly, in the decay data (half-life, decay schemes, alpha, beta and gamma energies, etc.) of the heavy nucleii. He concluded that he would appreciate receiving such data of the types specified above as are not already known from the literature.

List II

Submitted by Dr. L.A. Kull, Science Applications Incorporated (SAP), California, U.S.A.

Names and Addresses of Requestors

Dr. L.A. Kull and Dr. J.R. Beyster, Science Applications Incorporated, P.O. Box 2351, 1250 Prospect Street, La Jolla, Cal. 92037, U.S.A.

Further details, such as accuracy and priority, are being awaited from the requestors.

List II

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	92-U-233	σ	(γ,n)		E_γ=4-20 Mev		SAP (SAP)	Kull Total photoneutron cross sections required. Development of non-destructive assay techniques. Status:	70
	92-U-233	σ	(γ,f)		E_γ=4-20 Mev		SAP (SAP)	Kull Total photofission cross sections required. Development of non-destructive assay techniques Status:	70
	92-U-235	σ	(γ,n)		E_γ=4-20 Mev		SAP (SAP)	Kull Total photoneutron cross sections required. Development of non-destructive assay techniques Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	92-U-235	$\sigma(\gamma,f)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photofission cross sections required. Development of non-destructive assay techniques. Status:	70
	92-U-233	Delayed-N-Y			E_γ=4-15 Mev		SAP (SAP)	Kull Average number of delayed neutrons per photofission required. Development of non-destructive assay techniques. Status:	70
	92-U-233	Nu-Bar	Prompt		E_γ=4-15 Mev		SAP (SAP)	Kull Average number of prompt neutrons per photofission required. Development of non-destructive assay techniques. Status:	70
	92-U-235	Delayed-N-Y			E_γ=4-15 Mev		SAP (SAP)	Kull Average number of delayed neutrons per photofission required. Development of non-destructive assay techniques. Status:	70

Req. No.	Target	Reaction Type: Quantity	Reaction Type: Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	92-U-235	Nu-Bar	Prompt		E_γ=4-15 Mev		SAP (SAP)	Kull Average number of prompt neutrons per photofission required. Development of non-destructive assay techniques. Status:	70
	92-U-238	$\sigma(\gamma,n)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photoneutron cross sections required. Development of non-destructive assay techniques. Status:	70
	92-U-238	$\sigma(\gamma,f)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photofission cross sections required. Development of non-destructive assay techniques. Status:	70
	90-Th-232	$\sigma(\gamma,n)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photoneutron cross sections required. Development of non-destructive assay techniques. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	90-Th-232	$\sigma(\gamma,f)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photofission cross sections required. Development of non-destructive assay techniques. Status:	70
	94-Pu-239	$\sigma(\gamma,n)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photoneutron cross sections required. Development of non-destructive assay techniques. Status:	70
	94-Pu-239	$\sigma(\gamma,f)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photofission cross sections required. Development of non-destructive assay techniques. Status:	70
	94-Pu-240	$\sigma(\gamma,n)$			E_γ=4-20 Mev		SAP (SAP)	Kull Total photoneutron cross sections required. Development of non-destructive assay techniques. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	94-Pu-240	σ(γ,f)			E_γ=4-20 Mev		SAP (SAP)	Kull Total photofission cross sections required. Development of non-destructive assay techniques Status:	70
	94-Pu-241	σ(γ,n)			E_γ=4-20 Mev		SAP (SAP)	Kull Total photoneutron cross sections required. Development of non-destructive assay techniques Status:	70
	94-Pu-241	σ(γ,f)			E_γ=4-20 Mev		SAP (SAP)	Kull Total photofission cross sections required. Development of non-destructive assay techniques Status:	70
	90-Th-232	Delayed-N-Y			E_γ=4-15 Mev		SAP (SAP)	Kull Average number of delayed neutrons per photofission required. Development of non-destructive assay techniques Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	90-Th-232	Nu-Bar	Prompt		E_γ=4-15 Mev		SAP (SAP)	Kull Average number of prompt neutrons per photofission required. Development of non-destructive assay techniques. Status:	70
	94-Pu-239	Delayed-N-Y			E_γ=4-15 Mev		SAP (SAP)	Kull Average number of delayed neutrons per photofission required. Development of non-destructive assay techniques. Status:	70
	94-Pu-239	Nu-Bar	Prompt		E_γ=4-15 Mev		SAP (SAP)	Kull Average number of prompt neutrons per photofission required. Development of non-destructive assay techniques Status:	70
	94-Pu-240	Delayed-N-Y			E_γ=4-15 Mev		SAP (SAP)	Kull Average number of delayed neutrons per photofission required. Development of non-destructive assay techniques Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	94-Pu-240	Nu-Bar	Prompt		E_γ=4-15 Mev		SAP (SAP)	Kull Average number of prompt neutrons per photofission required. Development of non-destructive assay techniques Status:	70
	94-Pu-241	Delayed-N-Y			E_γ=4-15 Mev		SAP (SAP)	Kull Average number of delayed neutrons per photofission required. Development of non-destructive assay techniques. Status:	70
	94-Pu-241	Nu-Bar	Prompt		E_γ=4-15 Mev		SAP (SAP)	Kull Average number of prompt neutrons per photofission required. Development of non-destructive assay techniques Status:	70
	90-Th-232	Delayed-Y-Y	$P(E_\gamma,T1/2)$		E_γ=		SAP (SAP)	Kull Detailed measurements of the time behaviour of the energy spectrum of delayed gamma rays from micro-seconds to hours after brems-strahlung irradiation. Development of non-destructive assay techniques Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	92-U-233	Delayed-γ-γ	$P(E_\gamma, T^1/2)$		E_γ=		SAP (SAP)	Kull Detailed measurements of the time behaviour of the energy spectrum of delayed gamma rays from microseconds to hours after bremsstrahlung irradiation. Development of non-destructive assay techniques. Status:	70
	92-U-235	Delayed-γ-γ	$P(E_\gamma, T^1/2)$		E_γ=		SAP (SAP)	Kull Detailed measurements of the time behaviour of the energy spectrum of delayed gamma rays from microseconds to hours after bremsstrahlung irradiation. Development of non-destructive assay techniques. Status:	70
	92-U-238	Delayed-γ-γ	$P(E_\gamma, T^1/2)$		E_γ=		SAP (SAP)	Kull Detailed measurements of the time behaviour of the energy spectrum of delayed gamma rays from microseconds to hours after bremsstrahlung irradiation. Development of non-destructive assay techniques. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	94-Pu-239	Delayed-Y-Y	$P(E_\gamma,T^1/2)$		E_γ-		SAP (SAP)	Kull Detailed measurements of the time behaviour of the energy spectrum of delayed gamma rays from micro-seconds to hours after brems-strahlung irradiation. Development of non-destructive assay techniques. Status:	70
	94-Pu-240	Delayed-Y-Y	$P(E_\gamma,T^1/2)$		E_γ-		SAP (SAP)	Kull Detailed measurements of the time behaviour of the energy spectrum of delayed gamma rays from micro-seconds to hours after brems-strahlung irradiation. Development of non-destructive assay techniques. Status:	70
	94-Pu-241	Delayed-Y-Y	$P(E_\gamma,T^1/2)$		E_γ-		SAP (SAP)	Kull Detailed measurements of the time behaviour of the energy spectrum of delayed gamma rays from micro-seconds to hours after brems-strahlung irradiation. Development of non-destructive assay techniques. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization Requestor, Comments, Status	
	74-W	Bremsstrahlung (see Comments)				SAP (SAP)	Kull Detailed measurements of the absolute yields and spectrum shapes of bremsstrahlung radiation from thick converters, as a function of end-point energy. Status:	7
	79-Au-197	Bremsstrahlung (see Comments)				SAP (SAP)	Kull Detailed measurements of the absolute yields and spectrum shapes of bremsstrahlung radiation from thick converters, as a function of end-point energy. Status:	7
	73-Ta-181	Bremsstrahlung (see Comments)				SAP (SAP)	Kull Detailed measurements of the absolute yields and spectrum shapes of bremsstrahlung radiation from thick converters, as a function of end-point energy. Status:	

List III

Submitted by Prof. K. Oshima, Department of Nuclear Engineering (DNE), University of Tokyo (UTK), Japan.

Name and Address of Requestor

Prof. K. Oshima, Department of Nuclear Engineering, University of Tokyo, Bunkyo-ku, Tokyo, Japan.

Further details concerning the status and, in such cases as necessary, the accuracies of specific requests are required.

List III

Oshima first lists, in five basic categories, those nuclides of importance to both destructive and non-destructive testing for Safeguards, according to the following priority order:

I - Most Important; II - Important; III - Desirable

A. Nuclides to be measured by γ- or β-activity

I). Cs-137, Ce-144
II). Ru-106
III). Zr-95, Sr-90, Sr-89, (Ba-140 eventually)

B. Nuclides to be measured by mass spectrometry

I). Nd: A = 148,150,146,145,143, (144 and 142 for spike).
Mo: A = 100,98,97, (96,94 and 92 for spike)

II). Ag: A = 109 as mass spectrometry standard (107 for spike).
Pd: A = 110,108,105, (104 and 102 for spike).
Cd: A = 116,114,112,111, (110,108 and 106 for spike).

III). Tc - 99 (long-lived nuclide, can be analyzed chemically).

C. Nuclides related to those in categories A and B

I). Those chain nuclides which increase the production of the nuclides in question; e.g.,

$$\text{Xe-136 (n,}\gamma\text{) Xe-137} \xrightarrow{\beta^-} \text{Cs-137}$$

II). Those chain nuclides which decrease the production of the nuclides in question; e.g.,

$$\text{Xe-137 (n,}\gamma\text{) Xe-138} \xrightarrow{\beta^-} \text{Cs-138}$$

D. Fissile Nuclides

I). U : A = 235,238
Pu: A = 239,240

II). U : A = 233,234,236
Pu: A = 241,242

E. Nuclides of importance for neutron spectrum estimation

E-1. II). Co-59, Ni-58, Fe-54, Fe-58

E-2. II). Co-60, Co-58, Co-57, Mn-54, Fe-59

Amongst the demands for nuclear data are:

1. Decay Schemes and Half-Lives

1-1. Nuclide-Priority — Demands

I. Cs-137, Ce-144
II. Ru-106, Co-60, Co-58, Co-57, Mn-54, Fe-59
III. Zr-95, Sr-90, Sr-89, Ba-140

Demands: Complete decay schemes, including main and high energy γ-abundance.

1-2. Nuclide-Priority

I. Nd: A = 148,150,146,145,143,144,142
I. Mo: A = 100,98,97,96,94,92
II. Ag: A = 109,107
II. Pd: A = 110,108,105,104,102
II. Cd: A = 116,113,112,111,110,108,106
III. Tc - 99

1. Decay modes and branching ratios.
2. Half-lives.

1-3. Nuclide-Priority

I. U-235, U-238, Pu-239, Pu-240
II. U-233, U-234, U-236, Pu-241, Pu-242

1. Complete decay schemes including α- and γ-abundances
2. Half-lives.

1-4. Nuclide-Priority

I. Cs-137, Ce-144
II. Ru-106
III. Zr-95, Sr-90, Sr-89, Ba-140

Half-lives.

2. Neutron capture cross sections

2-1. Nuclide-Priority — Demands

I. Cs-137, Ce-144
I. Nd: A = 148,150,146,145,143,144,142
I. Mo: A = 100,98,97,96,94,92
II. Ru-106, Co-59, Ni-58, Fe-54, Fe-58
II. Ag: A = 109,107
II. Pd: A = 110,108,105,104,102
II. Cd: A = 116,113,112,111,110,108,106
III. Tc-99, Zr-95, Sr-90, Sr-89, Ba-140

Neutron capture cross sections, first for thermal neutrons, and later on for the whole reactor energy range.

3. Fission yields (chain yield and independent yield)

First for thermal neutrons, and later on for the whole reactor energy range.

Fissile Nuclides - Priority	Yields of Specific Fission Products - Priorities
I. U-235, U-238, Pu-239, Pu-240	I. Cs-137, Ce-144
	I. Nd: A = 148,150,146,145,143,144,142
II. U-233, U-234, U-236	I. Mo: A = 100,98,97,96,94,92
II. Pu-241, Pu-242	I. Nuclides in Oshima's category C, which tend to increase production of nuclides in question.
	II. Ru-106
	II. Ag: A = 109,107
	II. Pd: A = 110,108,105,104,102
	II. Cd: A = 116,113,112,111,110,108,106
	II. Nuclides in Oshima's category C, which tend to decrease production of nuclides in question.
	III. Tc-99, Zr-95, Sr-90, Sr-89, Ba-140

Oshima concludes by stating that all the data should be evaluated, and that for the capture cross sections and fission yields the first demand is for thermal neutron data and that the data should be presented in the format of the ENDF/B file. He also notes that some of these data are, at present, on the ENDF/B file. Also in other evaluated data files evaluated data on capture cross sections of several fission products may be found, covering an energy region from below thermal to about 10 Mev. Such data, at present, exist for (27):

Sr-89, Sr-90, Mo-92, Mo-94, Mo-96, Mo-97, Mo-98, Mo-100, Tc-99, Pd-102, Pd-104, Pd-105, Pd-108, Pd-110, Ag-107, Ag-109, Cd-106, Cd-110, Cd-111, Cd-112, Cd-113, Cd-116, Cs-137, Ba-140, Nd-142, Nd-143, Nd-144, Nd-145, Nd-146, Nd-148, and Nd-150.

Concerning capture cross section evaluated data for the nuclides of interest in neutron spectrum estimation, data are available for:

Fe-54, Fe-58, Ni-58, and Co-59.

List IV

Submitted by Dr. G.R. Keepin, Los Alamos Scientific Laboratory (LASL), Office of Safeguards and Materials Management (OSMM), U.S.A.

Name and Address of Requestor

Dr. G.R. Keepin, Los Alamos Scientific Laboratory,
University of California, P.O. Box 1663, Los Alamos,
New Mexico 87544, U.S.A.

The Request Numbers refer to those requests which coincide, in all aspects, with a request in the latest U.S.A. request list, EANDC(US)-133 (November 1969) by Dr. G.R. Keepin.

List IV

Req. No.	Target	Reaction Type: Quantity	Reaction Type: Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
18	4-Be	$(n,p)Li^{9}$	$\beta^{-}\rightarrow Be^{9*}\longrightarrow n$	I	14-16 Mev	5 %	LASL(OSMM)	Keepin Accuracy should be 5% or a few tenths mb. Absolute delayed neutron yield required. Development of non-destructive assay techniques. Status: None which gives energy dependence.	69
41	8-O-17	$(n,p)N^{17}$	$\beta^{-}\rightarrow O^{17*}\longrightarrow n$	I	8.5 - 16 Mev	5 %	LASL(OSMM)	Keepin Accuracy should be 5% or a few tenths mb. Absolute delayed neutron yield required. Development of non-destructive assay techniques. Status: None which gives energy dependence.	69
308	92-U-233	Delayed-N-Y	$P(E_{n'})$	I	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin Need spectrum of neutrons in different groups characterized by different decay constants. Absolute number of delayed neutrons required. Isotopic signatures for non-destructive assay. Status: Older measurements not altogether consistent, Shorter-lived groups still not known. LASL and BNL are planning experiments.	69

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
311	92-U-233	Delayed-Y-Y	$P(E_\gamma)$	II	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin High-resolution absolute Y-ray yields required. Ultimately, assign discrete Y's to specific fission products. Isotopic signatures for non-destructive assay techniques. Half-life and energy distributions required for $E_\gamma < 2$ Mev. Status: None.	69
316	92-U-233	Delayed-F-Y		III	Thermal - 15 Mev	15 %	LASL(OSMM)	Keepin Absolute yields of fission isomers versus times (>10 msec) required. Isotopic signatures for non-destructive assay techniques. Status: None which gives the necessary energy dependence.	69
334	92-U-235	Delayed-N-Y	$P(E_{n'})$	I	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin Absolute numbers of delayed neutrons required. Isotopic signatures for non-destructive assay. Status: ANL, Cox and Whiting, 0.35 Mev, 0.6 Mev and 1.3 Mev, PAPS, 11, 236.	69

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
336	92-U-235	Delayed-Y-Y	$P(E_\gamma)$	I	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin High-resolution absolute Y-ray yields required. Ultimately, assign discrete Y's to specific fission products. Isotopic signatures for non-destructive assay techniques. Status: None.	69
342	92-U-235	Delayed-F-Y		II	Thermal - 15 Mev	15 %	LASL(OSMM)	Keepin Absolute yields of fission isomers versus times (> 10 nsec) required. Isotopic signatures for non-destructive assay techniques. Status: None which gives the necessary energy dependence.	69
353	92-U-238	Delayed-N-Y	$P(E_{n'})$	I	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin Absolute numbers of delayed neutrons required. High res. Time and Energy spectra also of interest. Isotopic signatures for non-destructive assay techniques. Need to confirm ANL results using smaller samples. Status: ANL Cox and Whiting, BAPS 11,536. 1.4 Mev, 1.5 Mev and 1.7 Mev.	69

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status
358	92-U-238	Delayed-γ-Y	$P(E_\gamma, T^1/2)$	I	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin High-resolution absolute γ-ray yields required. Time and energy spectra also of interest. Ultimately, assign discrete γ's to specific fission products. Isotopic signatures for non-destructive assay techniques. Status: None.
359	92-U-238	Delayed-F-Y		II	Thermal - 15 Mev	15 %	LASL(OSMM)	Keepin Absolute yields of fission isomers versus times (>10 nsec) required. Isotopic signatures for non-destructive assay techniques. Status: None which gives the necessary energy dependence.
379	94-Pu-239	Delayed-N-Y	$P(E_{n'})$	I	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin Absolute numbers of delayed neutrons required. High res. Time and Energy spectra also of interest. Isotopic signatures for non-destructive assay. Status: None.

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Cross.	Requestor, Comments, Status
382	94-Pu-239	Delayed-Y-Y	$P(E_\gamma, T_{1/2})$	I	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin High-resolution absolute Y-ray yields required. Time and energy spectra also of interest. Ultimately, assign discrete Y's to specific fission products. Isotopic signatures for non-destructive assay. Status: None.
388	94-Pu-239	Delayed-F-Y		II	Thermal - 15 Mev	15 %	LASL(OSMM)	Keepin Absolute yields of fission isomers versus times (>10 nsec) required. Isotopic signatures for non-destructive assay techniques. Status: None which gives the necessary energy dependence.
391	94-Pu-240	Delayed-N-Y	$P(E_{n'})$	II	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin Absolute numbers of delayed neutrons required. High res. time and Energy spectra also of interest. Isotopic signatures for non-destructive assay. Status: None.

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
396	94-Pu-240	Delayed-Y-Y	$P(E_\gamma, T1/2)$	II	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin High-resolution absolute Y-ray yields required. Time and energy spectra also of interest. Ultimately, assign discrete Y's to specific fission products. Isotopic signatures for non-destructive assay. Status: None.	6
397	94-Pu-240	Delayed-F-Y		III	Thermal - 15 Mev	15 %	LASL(OSMM)	Keepin Absolute yields of fission isomers versus times (>10 msec) required. Isotopic signatures for non-destructive assay techniques. Status: None which gives the necessary energy dependence.	69
405	94-Pu-241	Delayed-N-Y	$P(E_{n'})$	II	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin Absolute numbers of delayed neutrons required. High res. time and energy spectra also of interest. Isotopic signatures for non-destructive assay techniques. Status: None which meets the accuracy requirements.	6

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status, etc.
406	94-Pu-241	Delayed-γ-γ	$P(E_\gamma, T_{1/2})$	II	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin High-resolution absolute γ-ray yields required. Time and energy spectra also of interest. Ultimately, assign discrete γ's to specific fission products. Isotopic signatures for non-destructive assay techniques. Status: None which meets the accuracy requirements.
407	94-Pu-241	Delayed-F-γ		III	Thermal - 15 Mev	15 %	LASL(OSMM)	Keepin Absolute yields of fission isomers versus times (>10 nsec) required. Isotopic signatures for non-destructive assay techniques. Status: None which gives the necessary energy dependence.
411	94-Pu-242	Delayed-N-γ	$P(E_n,)$	II	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin Absolute number of delayed neutrons required. High res. time and energy spectra also of interest. Isotopic signatures for non-destructive assay techniques. Status: None which meets the accuracy requirements.

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organizat.	Requestor, Comments, Status
414	94-Pu-242	Delayed-Y-Y	$P(E_\gamma, T^1/2)$	II	Thermal - 15 Mev	5 %	LASL(OSMM)	Keepin High-resolution absolute Y-ray yields required. Time and energy spectra also of interest. Ultimately, assign discrete Y's to specific fission products. Isotopic signatures for non-destructive assay techniques. Status: None which meets the accuracy requirements.
416	94-Pu-242	Delayed-F-Y		III	Thermal - 15 Mev	15 %	LASL(OSMM)	Keepin Absolute yields of fission isomers versus times (>10 nsec) required. Isotopic signatures for non-destructive assay techniques. Status: None which gives the necessary energy dependence.

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Reference, Comments, Status
	92-U-233	(n,n'γ)	$P(E_\gamma)$		1-5 Mev, 14 Mev		LASL(OSMM)	Keepin Gamma ray production cross sections required. Resolvable, high energy γ-rays from n inelastic scattering. For isotopic assay of complex mixtures of fission isotopes. Measurements should be performed with Van de Graaff and high resolution Ge(Li) detection system. Status:
	92-U-235	(n,n'γ)	$P(E_\gamma)$		1-5 Mev, 14 Mev		LASL(OSMM)	Keepin Gamma ray production cross sections required. Resolvable, high energy γ-rays from n inelastic scattering. For isotopic assay of complex mixtures of fission isotopes. Measurements should be performed with Van de Graaff and high resolution Ge(Li) detection system. Status:

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	92-U-238	(n,n'γ)	$P(E_\gamma)$		1-5 Mev, 14 Mev		LASL(OSMM)	Keepin Gamma ray production cross sections required. Resolvable, high energy γ-rays from n inelastic scattering. For isotopic assay of complex mixtures of fission isotopes. Measurements should be performed with Van de Graaff and high resolution Ge(Li) detection system. Status:	70
	94-Pu-239	(n,n'γ)	$P(E_\gamma)$		1-5 Mev, 14 Mev		LASL(OSMM)	Keepin Gamma ray production cross sections required. Resolvable; high energy γ-rays from n inelastic scattering. For isotopic assay of complex mixtures of fission isotopes. Measurements should be performed with Van de Graaff and high resolution Ge(Li) detection system. Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-240	(n,n'Y)	$P(E_\gamma)$		1-5 Mev, 14 Mev		LASL(OSMM)	Keepin Gamma ray production cross sections required. Resolvable, high energy Y-rays from n inelastic scattering. For isotopic assay of complex mixtures of fission isotopes. Measurements should be performed with Van de Graaff and high resolution Ge(Li) detection system. Status:	70
	94-Pu-241	(n,n'Y)	$P(E_\gamma)$		1-5 Mev, 14 Mev		LASL(OSMM)	Keepin Gamma ray production cross sections required. Resolvable, high energy Y-rays from n inelastic scattering. For isotopic assay of complex mixtures of fission isotopes. Measurements should be performed with Van de Graaff and high resolution Ge(Li) detection system. Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-242	(n,n'Y)	$P(E_\gamma)$		1-5 Mev, 14 Mev		LASL(OSMM)	Keepin Gamma ray production cross sections required. Resolvable, high energy Y-rays from n inelastic scattering. For isotopic assay of complex mixtures of fission isotopes. Measurements should be performed with Van de Graaff and high resolution Ge(Li) detection system. Status:	70
	92-U-233	(n,Y)	$P(E_\gamma)$		Thermal - 1 Mev		LASL(OSMM)	Keepin High resolution Ge(Li) detection system. Resolvable capture gamma ray spectra required. For isotopic assay of complex mixtures of fission isotopes. Status:	70
	92-U-235	(n,Y)	$P(E_\gamma)$		Thermal - 1 Mev		LASL(OSMM)	Keepin High resolution Ge(Li) detection system. Resolvable capture gamma ray spectra required. For isotopic assay of complex mixtures of fission isotopes. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	92-U-238	(n,Y)	$P(E_\gamma)$		Thermal - 1 Mev		LASL(OSMM)	Keepin High resolution Ge(Li) detection system. Resolvable capture gamma ray spectra required. For isotopic assay of complex mixtures of fission isotopes. Status:	70
	94-Pu-239	(n,Y)	$P(E_\gamma)$		Thermal - 1 Mev		LASL(OSMM)	Keepin High resolution Ge(Li) detection system. Resolvable capture gamma ray spectra required. For isotopic assay of complex mixtures of fission isotopes. Status:	70
	94-Pu-240	(n,Y)	$P(E_\gamma)$		Thermal - 1 Mev		LASL(OSMM)	Keepin High resolution Ge(Li) detection system. Resolvable capture gamma ray spectra required. For isotopic assay of complex mixtures of fission isotopes. Status:	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-241	(n,γ)	$P(E_\gamma)$		Thermal - 1 Mev		LASL(OSMM)	Keepin High resolution Ge(Li) detection system. Resolvable capture gamma ray spectra required. For isotopic assay of complex mixtures of fission isotopes. Status:	70
	94-Pu-242	(n,γ)	$P(E_\gamma)$		Thermal - 1 Mev		LASL(OSMM)	Keepin High resolution Ge(Li) detection system. Resolvable capture gamma ray spectra required. For isotopic assay of complex mixtures of fission isotopes. Status:	70

List V

Submitted by Dr. H. Hick, Institut für Physik im Reaktorzentrum Seibersdorf, Austria

Name and Address of Requestor

Dipl. Ing. Dr. H. Hick, Institut für Physik im Reaktorzentrum Seibersdorf, Lenaugasse 10, A-1082 Vienna, Austria

List V

For the main γ-emitters, the following data are needed for evaluation of Ge(Li) detector measurements on burnt fuel elements.

	Nuclide	Quantity
1.	Ce-141	Accurate Intensity of 145.0 kev γ-line.
2.	Eu-152	Accurate Intensities of γ-lines.
3.	Eu-156	Accurate Intensities of γ-lines.
4.	(Pa-233)	Accurate Intensities of γ-lines.
5.	(Np-239)	Accurate Intensities of γ-lines.

List VI

Submitted by Dr. H. Condé, Research Institute of the Swedish National Defence, Stockholm, Sweden

Name and Address of Requestor

Dr. E. Hellstrand, Research Institute (RI) of the Swedish National Defence (SND), S-104 50, Stockholm 80, Sweden

List VI

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organization	Requestor, Comments, Status	Year
	Pu-239	RESON	PARAMS		1.056 eV		RI(SND)	Hellstrand Resonance parameters for 1.056 eV resonance in Pu-240 required. For non-destructive analysis of Pu-239 & Pu-240 content in Pu bearing fuel elements by transmission of epithermal neutrons. Status: Ramakrishna, et.al., Paper No. CN-26/48, at Helsinki Nuclear Data Conference (June 1970) reports and compares new measurements.	70

List VII

Submitted by Dr. H. Moeken, Eurochemic, Mol, Belgium

Name and Address of Requestor

Dr. H. Moeken, Eurochemic, Mol, Belgium

List VII

Moeken points out two areas of Safeguards activities for which nuclear data are important:

A. Non-destructive Assay Techniques

B. Calculations following Analytical Measurements

Within each of these two areas, he emphasizes three different techniques:

A-1. Calorimetric measurements on Pu containers -

Decay schemes and alpha energies of Pu isotopes needed.

A-2. Radiometric measurements on Pu containers -

Decay schemes and γ-energies of Pu isotopes needed.

A-3. Gamma/neutron measurements on Pu and U products -

Spontaneous fission cross sections, (α,n) cross sections, prompt gamma/neutron yields and energies needed.

B-1. Alpha Spectrometry on Pu - Decay Schemes and alpha energies of Pu isotopes needed.

B-2. Gamma Spectrometry for burn-up determination -

Decay schemes and gamma energies of Cs-137 and Cs-134 needed.

B-3. Burn-up calculations - Fission yields for the different fission processes of some isotopes, such as Cs-137, Cs-134, and Nd-148 needed.

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International Atomic Energy Agency

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INDC(NDS)-21/G
Addendum 1

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

NUCLEAR DATA REQUESTS FOR SAFEGUARDS TECHNICAL DEVELOPMENT

Trevor A. Byer
Nuclear Data Section

Vienna, June 1970

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

DRAFT
INDC(NDS)-21/G
Addendum 1

NUCLEAR DATA REQUESTS FOR SAFEGUARDS TECHNICAL DEVELOPMENT

INTRODUCTION

Following completion of the Draft Report, INDC(NDS)-21/G, a reply to the Circular Letter of 16 February, dated 28 May 1970, and a list of nuclear data needs for Safeguards technical development was received by the Nuclear Data Section from Dr. R.L. Bramblett of Gulf General Atomic (U.S.A.). It is the purpose of this Addendum to summarize the views expressed in this letter and present the list of nuclear data needs submitted by Dr. Bramblett.

0. R.L. Bramblett (Gulf General Atomic, U.S.A.)

In his reply of 28 May Bramblett emphasized that the Safeguards development work at Gulf General Atomic, which is based mainly on photonuclear reactions, "does not benefit from the existing neutron request lists" (e.g. RENDA), but that "it does seem that a compilation of data for safeguards would be useful". He then went on to focus attention on an exceedingly important question which should be carefully considered when deciding "to generate a Safeguards Data Request List" - namely, "what Agencies will be motivated to fund measurements that are listed?" He points out that the existing neutron cross-section request lists "have limited value because the requestor has not identified a supportable requirement for the data and the requestor usually has no influence on the availability of funding to carry out measurements". Bramblett then concluded by expressing the view that "presumably, appearance of a data requirement on an IAEA sponsored request list would imply that IAEA would consider funding the work".

In addition to these remarks, Bramblett submitted a list of nuclear data needs, relevant to the Safeguards development work pursued at Gulf General Atomic, which are presented as List VIII.

List VIII

Submitted by Dr. R.L. Bramblett, Gulf General Atomic Inc. (GGA), U.S.A.

Name and Address of Requestor

Dr. R.L. Bramblett, Gulf General Atomic Inc., P.O. Box 608,
San Diego, Cal. 92112, U.S.A.

The incident energy, E_e, in these requests refers to the electron energy from a LINAC, i.e. the bremsstrahlung end-point energy. Furthermore the symbol, xY, in the Reaction Type (Quantity) code refers to incident bremsstrahlung as distinct from incident monoenergetic gammas.

List VIII

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	1-D-2	(xγ,n)			E_e -Threshold-10 Mev ΔE_e = 1%	20%	GGA(GGA)	Bramblett Total neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	4-Be-9	(xγ,n)			E_e -Threshold-10 Mev ΔE_e = 1%	20%	GGA(GGA)	Bramblett Total neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	6-C-13	(xγ,n)			E_e=Threshold-10 Mev ΔE_e = 1%	20%	GGA(GGA)	Bramblett Total neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	3-Li-6	(xγ,n)			E_e=Threshold-10 Mev ΔE_e = 1%	20%	GGA(GGA)	Bramblett Total neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	8-O-17	(xγ,n)			E_e = Threshold-10 Mev ΔE_e = 1%	20%	GGA(GGA)	Bramblett Total neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	92-U-233	(xγ,n)			E_e = Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Neutron yield (including fission) produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Yea
	92-U-233	Delayed-N-Y			E_e=Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Delayed neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	92-U-233	Delayed-Y-Y			E_e = 10 Mev ΔE_e = 5%	10%	GGA(GGA)	Bramblett Fission product delayed gamma-ray yield produced by brems-strahlung required. Yield may be relative to U-238 or may be absolute. Emergent gamma-ray energies, E= (0.5-5) Mev, with Δ E=3 Kev. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	92-U-234	(xγ,n)			E_e=Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Neutron yield (including fission) produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	92-U-234	Delayed-N-Y			E_e=Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Delayed neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	92-U-234	Delayed-γ-γ			E_e = 10 Mev ΔE_e = 5%	10%	GGA(GGA)	Bramblett Fission product delayed gamma-ray yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent gamma-ray energies, E= (0.5-5) Mev, with ΔE=3 Kev. Effect on non-destructive photonuclear assay. Status:	70
	92-U-236	(xγ,n)			E_e = Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Neutron yield (including fission) produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	92-U-236	Delayed-N-Y			E_e =Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Delayed neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	92-U-236	Delayed-Y-Y			E_e = 10 Mev ΔE_e = 5%	10%	GGA(GGA)	Bramblett Fission product delayed gamma-ray yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent gamma-ray energies, E= (0.5-5) Mev, with E=3 Kev. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-240	(xY,n)			E_e=Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Neutron yield (including fission) produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	94-Pu-240	Delayed-N-Y			E_e=Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Delayed neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-240	Delayed-Y-Y			E_e = 10 Mev ΔE_e = 5%	10%	GGA(GGA)	Bramblett Fission product delayed gamma-ray yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent gamma-ray energies, E= (0.5-5) Mev, with ΔE=3 Kev. Effect on non-destructive photonuclear assay. Status:	70
	94-Pu-241	(xY,n)			E_e=Threshold-10 Mev ΔE_e = 1%	10%	GGA(GGA)	Bramblett Neutron yield (including fission) produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-241	Delayed-N-Y			E_e=Threshold-10 Mev ΔE_e= 1%	10%	GGA(GGA)	Bramblett Delayed neutron yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent neutron energy-flat response. Effect on non-destructive photonuclear assay. Status:	70
	94-Pu-241	Delayed-Y-Y			E_e= 10 Mev ΔE_e= 5%	10%	GGA(GGA)	Bramblett Fission product delayed gamma-ray yield produced by bremsstrahlung required. Yield may be relative to U-238 or may be absolute. Emergent gamma-ray energies, E= (0.5-5) Mev, with Δ E=3 Kev. Effect on non-destructive photonuclear assay. Status:	70

INDC-338, Add.2

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INDC(NDS)-21/G

Addendum 2

International Atomic Energy Agency

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

NUCLEAR DATA REQUESTS FOR SAFEGUARDS TECHNICAL DEVELOPMENT

Compiled and Edited

by

Trevor A. Byer

Nuclear Data Section

Vienna, July 1970

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

DRAFT
INDC(NDS)-21/G
Addendum 2

NUCLEAR DATA REQUESTS FOR SAFEGUARDS TECHNICAL DEVELOPMENT

INTRODUCTION

Following completion of the Draft Reports, INDC(NDS)-21/G and Addendum 1, an official reply to the Circular Letter of 16 February, dated 29 June 1970, and a list of nuclear data needs for the scientific and technical development of Safeguards was received by the Director General of the IAEA from the Resident Representative of the USSR to the IAEA. In this Addendum, the concerted opinion of Soviet scientists on the matter of the need for and importance of nuclear data for Safeguards technical development, as summarized in the official communication of 29 June, is presented. In addition, the statement presented to the last INDC meeting (22 - 26 June 1970) by Dr. G.B. Jankov, Adviser to the INDC Member of the USSR, is briefly summarized.

P. Union of Soviet Socialist Republics.

In the statement presented at the last INDC meeting, Dr. Jankov began by saying that the USSR supported the initiative taken by the INDC with regard to establishing a nuclear data request list for the technical development of Safeguards. He went on to point out that much work was being carried out in the USSR on Safeguards and, in particular, work on the determination of the burn-up rate of fuel elements of the Novoronezhskoi nuclear power station had been performed pursuant to a research contract with the Agency (IAEA/RB/577). Dr. Jankov went on to state that this experimental investigation was based on the non-destructive measurement of the concentration of long-lived fission products in spent fuel elements using Ge(Li) detectors.

Concerning the need for and importance of nuclear data for Safeguards technical development, Soviet scientists expressed the view

that in order to ascertain non-destructively the amount of spent and unused fuel in fuel elements from the fission product content of the fuel, nuclear data of the accuracies specified in List IX, were required to ensure that an error of not more than 5 - 10 % would exist in the determination of the fuel content of the fuel elements.

List IX

Submitted through the Resident Representative of the USSR to the IAEA.

Requestor
USSR State Committee on the Utilization of Atomic Energy.

Further details concerning the Status, Priority and, in such cases as necessary, the energy range of incident neutrons are required, in addition to information on the type of specimens for the requests on neutron yields arising from (α, n) reactions for UO_2, PuO_2, UC and PuC.

List IX

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Ye.
	44-Ru-106	HALF-LIFE			---------	~1 %	USSR	Half-life of Ru-106 required to an accuracy of ~1 %. Status:	70
	44-Ru-106	$\sigma(n,\gamma)$			Thermal-1 MeV	~3 %	USSR	Capture σ for thermal neutrons and for the whole reactor energy range required. Status:	70
	45-Rh-106	Delayed-γ-Y				~1 %	USSR	Yield of γ-quanta from Rh-106 per beta-decay event required to an accuracy of ~1 %. Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Crganiz.	Requestor, Comments, Status	Year
	55-Cs-133	$\sigma(n,\gamma)$			Thermal - 1MeV	~3 %	USSR	Capture σ for thermal neutrons and for the whole reactor energy range required. Status:	70
	55-Cs-134	$\sigma(n,\gamma)$			Thermal - 1MeV	~3 %	USSR	Capture σ for thermal neutrons and for the whole reactor energy range required. Status:	70
	55-Cs-134	HALF-LIFE			----------	~1 %	USSR	Half-life of Cs-134 required to an accuracy of ~1 % Status:	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	55-Cs-134	Delayed-γ-Y				~1 %	USSR	Yield of γ-quanta from Cs-134 per beta-decay event required to an accuracy of ~1 %. Status	70
	55-Cs-137	$\sigma(n,\gamma)$			Thermal-1 MeV	~3 %	USSR	Capture σ for thermal neutrons and for the whole reactor energy range required. Status	70
	55-Cs-137	HALF-LIFE			----------	~1 %	USSR	Half-life of Cs-137 required to an accuracy of ~1 % Status	;C

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	55-Cs-137	Delayed-γ-Y				~1 %	USSR	Yield of γ-quanta from Cs-137 per beta-decay event required to an accuracy of ~1 % Status	70
	56-Ba-140	$\sigma(n,\gamma)$			Thermal-1 MeV	~3 %	USSR	Capture σ for thermal neutrons and for the whole reactor energy range required. Status	70
	56-Ba-140	HALF-LIFE			----------	~1 %	USSR	Half-life of Ba-140 required to an accuracy of ~1 % Status	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	57-La-140	Delayed-γ-Y				~1 %	USSR	Yield of γ-quanta from La-140 per beta-decay event required to an accuracy ~1 %. Status	70
	58-Ce-144	HALF-LIFE			----------	~1 %	USSR	Half-life of Ce-144 required to an accuracy of ~1 %. Status	70
	59-Pr-144	Delayed-γ-Y				~1 %	USSR	Yield of γ-quanta from Pr-144 per beta-decay event required to an accuracy ~1 %. Status	

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	90-Th-232	$\sigma(n,\gamma)$			Av.thermal and av.over fiss. n spectrum	~1 %	USSR	Averaged thermal and average over fission neutron spectrum of capture σ required. **Status**	70
	90-Th-232	$\sigma(n,f)$			Av.over fiss n spectrum	~5 %	USSR	Fission σ averaged over fission neutron spectrum required. **Status**	70
	92-U-235	$\sigma(n,f)$			Av.thermal and av.over fiss n spectrum	~1 %	USSR	Fission σ averaged thermal and average over fission neutron spectrum required. **Status**	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	92-U-235	FISS YIELD				≤ 1 %	USSR	Yields of the following isotopes per fission event required to an accuracy ≤ 1 %: Cs-137, Ce-144, Ru-106, Cs-133 and Ba-140. Status	70
	92-U-238	$\sigma(n,\gamma)$			Av. thermal and av. over fiss n spectrum	~1 %	USSR	Averaged thermal and average over fission neutron spectrum of capture σ required. Status	70
	92-U-238	$\sigma(n,f)$			Av. over fiss n spectrum	~5 %	USSR	Fission σ averaged over fission neutron spectrum required Status	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	94-Pu-239	σ(n,f)			Av.thermal and av.over fiss n spectrum	~1 %	USSR	Fission σ averaged thermal and average over fission neutron spectrum required. Status	70
	94-Pu-239	σ(n,γ)			Av.thermal and av.over fiss n spectrum	~1 %	USSR	Averaged thermal and average over fission neutron spectrum of capture σ required. Status	70
	94-Pu-239	FISS YIELD				$\leq$1 %	USSR	Yields of the following isotopes per fission event required to an accuracy $\leq$1 %: Cs-137, Ce-144, Ru-106, Cs-133 and Ba-140. Status	70

Req. No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	UO_2	N YIELD				10 %	USSR	The neutron yield from the (α,n) reaction for UO_2 required, in which α's arise from natural radioactivity of natural U. Status	70
	UC	N YIELD				10 %	USSR	The neutron yield from the (α,n) reaction for UC required, in which α's arise from natural radioactivity of natural U. Status	70
	PuO_2	N YIELD				5 %	USSR	The neutron yield from the (α,n) reaction for PuO_2 required, in which α's arise from natural radioactivity of Pu. Status	70

Req. No.	Target	Reaction Type: Quantity	Variable	Priority	Incident Energy	Accuracy	Lab/Organiz.	Requestor, Comments, Status	Year
	PuC	N YIELD				5 %	USSR	The neutron yield from the (α,n) reaction for PuC required, in which α's arise from natural radioactivity of Pu. Status	70
	Sb-Be	SPECTRUM (see Comments)			————	$\leq$ 10 %	USSR	The neutron energy spectrum for an Sb-Be photoneutron source required to an accuracy $\leq$ 10 %. Status	70