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Basic requirements of advanced neutron data storage and retrieval systems (CSISRS)* +

by

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A b s t r a c t

Advanced data storage and retrieval systems under development like CSISRS could be useful, if not become indispensable for a large variety of users within the nuclear community ranging from evaluators and reactor physicists to basic nuclear physicists, if these systems fulfil certain basic requirements. This paper tries to contribute some ideas and proposals to this question from the view point of an evaluator's experience and needs. A first requirement concerns a clear definition of what quantities to what extent and in what form should be compiled and supplied by such a system. A second requirement, in view of the unreliability of the nuclear data basis, particularly for fast reactor design, becomes of most urgent importance at present and in the future and concerns the physical documentation of the compiled data, i.e. the clear and comprehensive indication of the experimental conditions for which the respective compiled data are valid. A possible structure and details for such a physical documentation scheme are outlined on typical examples. A concerted effort of the data producers, compilers, and users is needed for the development of this documentation and its implementation, particularly for heavy fertile and fissionable nuclei and for standard reactions, in the CSISRS files and a proposal is made how this aim could be achieved in practice. Finally, some third generation computer requirements of CSISRS systems are outlined.

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Basic requirements of advanced neutron data storage and retrieval systems (CSISRS)

1. Historical basis

For the beginning let us recall briefly some pertinent historical facts. One of the basic tasks and responsibilities of the four neutron nuclear data centers in the world (the National Neutron Cross Section Center (NNCSC) at Brookhaven National Laboratory, the ENEA Neutron Data Compilation Centre (CCDN) at Saclay, the IAEA Nuclear Data Unit (NDU) in Vienna and the Nuclear Cross Sections Information Centre (NCSIC) at Obninsk) is to compile the experimental neutron nuclear data information from laboratory, university, and other research groups and institutions in their respective service areas and to make this information available to various kinds of users within the nuclear community. Among these data centers Brookhaven is by far the oldest one, whereas the other three centers are of more recent origin. The establishment of these centers was finally quite meaningful by the simple reason that the experimental physicists, i.e. the data producers, were liberated from the very laborious task of sending their data themselves to the various requestors; this means the centers were thought of to act as a sort of channel between the data producers and the data users. During the past years this reason became the more urgent, the more advanced experimental facilities like Van de Graaff machines, high resolution linear accelerators and cyclotrons were developed and, the larger the data output of these machines became. Among other reasons it was the large increase in the neutron data production in Western Europe in the beginning of the sixtieths, which for example led to the creation of the Saclay CCDN.

The primary incentive and necessity for the neutron data compilation activities came from the nuclear reactor development. Already in the years around 1960 the requirement of a more comprehensive neutron nuclear data basis than needed before for thermal reactors became apparent and important in particular with the beginning of the development of fast reactors. This

requirement determined the first boundary conditions of neutron data compilation. As reactor neutron energy distributions extend from 0 to 15 MeV, neutron cross sections and data had to be compiled over these about 10 decades of neutron energy. As the reactor neutrons do not omit any of the physically possible processes, all neutron reactions occurring in the mentioned energy range had to be considered. As comprehensively and up-to-date as possible the produced experimental neutron data information had to be gathered.

As a link between data producers and compilers on the one side and reactor physicists on the other side so-called evaluation groups developed, partly in the centres, mostly in national laboratories. They work mostly in close contact to national reactor programs, they are only partly staffed with experimentalists, but mostly with theorists. These groups undertook the task to elaborate the various experimental informations of varying quality and agreement into unique sets of so-called "best" data, to supplement lacking information by nuclear theory and systematics calculations and to develop libraries of these evaluated microscopic data as input for reactor physics calculations. As a consequence the evaluators within the reactor physics field, who, before the existence and/or sufficiently comprehensive operation of the centres had also to do the compilation of the data themselves, became the first and most important users of the data compiled in the data centres.

The amount of data flowing in from the nuclear experimentalists on the one side and requested for reactor physics purpose on the other side became rapidly so large, that computer handling of the data and computerisation of the link between data producers and users became indispensable. First, to help the most imminent need, i.e. to procure comprehensive and up-to-date information on the available neutron data sources a computer bibliography of neutron nuclear data references, CINDA, was developed. It is strongly aided and supported by a worldwide net of readers which scans continuously all available information sources like journals, proceedings, books, laboratory reports, preprints etc. The CINDA system finally succeeded in being worldwide accepted; it showed its real value by replacing more and more effectively the long private reference lists gathered previously in many tedious and multiplicating individual efforts of compilers and evaluators.

Now CINDA in this worldwide accepted form could ideally have served simultaneously as an index for a worldwide accepted neutron data storage and retrieval system. Unfortunately, the development of neutron data storage and retrieval was done separately and independently from CINDA. Furthermore, by various reasons, last but not least, by the difficulties introduced by differences in computers at different places not a unique system was developed in a worldwide cooperative effort, but different systems at different places which were not immediately compatible with each other, neither in concept, nor in computer organization or content. The most elaborate, probably also the most laborious system is the SCISRS system developed in Brookhaven. Independently the ECSIL system was developed at Livermore, which, however, took already partly account of deficiencies in the various experiences gained with the SCISRS system. In particular, it was written in FORTRAN-II for the IBM 7094 and was as such better compatible with other computers than the SCISRS system, which was written mostly in machine language for the same type of computer. At the Saclay CCDN, in a cooperative programming effort with the Centro di Calcolo at Bologna and with the CEN Saclay, use was already made of the third generation computers in adapting the ECSIL system to the IBM 360/30 and in going over from tape to direct access disk storage. Similarly at the Saclay CCDN SCISRS was transformed into the so-called NEUDADA system with two distinct new features: also direct access disk storage instead of tape storage, and partition of the data storage system into the three independent subsystems of index, data, and comment files. At the NDU of the IAEA also an independent development took place: here it was the so-called DASTAR system joint to a reference catalogue, called CINDU, written in a slightly modified CINDA format, both being handled on an IBM 1401 and an IBM 7040. Also at Obninsk much compilation work was certainly done in advance of the derivation of the famous ABBN 26-group cross section set, but probably still not so much with the help of computers.

Some of the deficiencies mentioned above which are mostly due to reasons of historical development are already on the way of getting remedied. From the fruitful cooperation of the four data centres in this direction we would like to mention in particular the efforts being made to create a joint index

for the data held in the four centres in close correlation to the CINDA index, furthermore the development of a common format of exchange of data between the centres.

These are rather short-term necessary interim steps on the much longer and harder, but even more necessary way to a unique worldwide data indexing, storage and retrieval system. Such a worldwide system has not necessarily to show one and the same unique computer realization in all of the centres, but as a minimum condition, should fulfil the requirement that different systems in use have the same principal and actual content and are unequivocally convertible into each other.

Actually starting from the experiences gained with the former systems, in particular with SCISRS-I, the Brookhaven NNCSC, with the active help of the other centres, has itself engaged on this way towards an improved and advanced SCISRS-II system, called CSISRS, which perhaps at a later time can be accepted in this or other forms and implemented by all data centres and also by interested laboratories. The fact that with CSISRS a new, still rather open development has been initiated, the concept of which has already found so much attention and discussion, gives the opportunity and makes it indispensable that the nuclear community, to which the system serves, in order to avoid wrong developments, on the basis of its present and foreseeable future requirements, consider thoroughly and systematically the fundamental principles of such an advanced neutron data storage and retrieval system with regard to content and computer organization. We shall discuss here mainly the present-day viewpoints of evaluators, although these will be seen to be closely related to the viewpoints and interests also of nuclear physicists, and we shall first have a brief look on the changed, more stringent boundary conditions and aspects, under which neutron nuclear data compilation has to be considered at present and in the near future.

2. Present and near-future boundary conditions of compilation

In the last years the rapid increase and improvement in computer capacity and performance led to a steady improvement and refinement of reactor theory methods. This improvement in theory went parallel and was partly also a response to the increasing refinements of the measurement techniques used in experimental reactor physics. As illustrative examples of the progress made we may mention on the theoretical side detailed Monte Carlo codes, two-

dimensional neutron transport codes and codes which allow the fine-mesh treatment of neutron slowing-down in several 100 groups, and correspondingly on the experimental side the capability of measuring detailed reactor neutron energy spectra by proportional counter or time-of-flight methods. At present a state is already reached, where the reliability of theoretical predictions of reactor, specifically fast reactor physical properties depends to the largest extent upon the reliability and comprehensiveness of the neutron nuclear data input and to a much lesser extent upon still existing deficiencies in the theoretical methods used.

In the most challenging and heavily concerned field of fast reactors the last years saw more and more a transition from general trend investigations to detailed critical facilities and design studies. The dominant influence of the heaviest fissile and fertile materials on the fast reactor physical properties, and therefore the primary importance of an as detailed and accurate knowledge and understanding of the neutron physical properties of these nuclei, as one is not always accustomed to even in fundamental nuclear physics, became more and more apparent. As a consequence the accuracies requested particularly for fission and capture properties of the heaviest nuclei in the EANDC request lists for nuclear data measurements became higher and higher. Simultaneously in order to fulfil those requests new experimental methods for measurements of neutron cross sections and related data were developed and existing methods more and more refined. Furthermore, in order to meet the high accuracy target, not only the experimental statistics had to be improved, but also the analysis and correction of the experimental results for all possible systematic errors including those which formerly were considered of minor or negligeable importance had to be done much more reliably; I might only quote here the necessity for improved corrections for all possible backgrounds and target impurities.

Now we come to the decisive part of the discussion. Since the very beginning the evaluators were faced with the problem of systematic discrepancies between two or more data sets outside the respective statistical errors. Unfortunately it is not the normal, but the exceptional case that two or more different data sets agree with each other showing no systematic differences, but only differences in the statistical accuracy, so that they can simply be averaged in order to arrive at the needed unequivocal "best" values.

Then there are cases, and fortunately this happens not too rarely, where the sources of systematic deviations can rather easily be detected. Here we refer for example to the neglect of multiple scattering corrections in one inelastic experiment and its consideration in another, which may lead to rather big differences in the data. Another most common example is different normalization in different relative measurements, e.g. normalization to different values of the same standard or normalization to uncompatible values of different standards; this has been demonstrated to be one of the major sources for discrepancies between different capture cross section measurements.

Then there is the much larger and much more difficult group of systematic deviations between different data sets being due to different experimental conditions and methods used in different experiments, or, if the same principal method is used, to some changes in the experimental boundary conditions not taken into account in the data reduction. We might for example quote here the systematic differences observed between linear accelerator and lead pile capture cross section measurements. Among the various difficulties with discrepant data sets mentioned above this is the very bottle-neck of every evaluation; the basic task of evaluation could be defined as the reduction of the discrepancies between various experimental informations to the purely statistical differences.

Now, one could have expected that with the refinement and improvement of the experimental methods mentioned above in past and present days these discrepancies and their sources get more and more removed. Partially this expectation is going to be fulfilled, but unfortunately, with the most important fission and capture properties of heavy fertile and fissionable nuclei and also with standard cross sections and data about the opposite has come about. We might remind here only the capture cross section measurements on U^{238} in the so-called PETREL bomb shot which gave quite different average resonance parameters from all other resonance capture measurements, the large discrepancies in recent α measurements on Pu^{239}, which only very slowly are going to be removed, the discrepancies in the various measurements of the Cf^{252} spontaneous fission $\bar{\nu}$ standard, the systematic differences in the fission cross section measurements on U^{235} of White and Pönitz in the several 100 keV energy range. One could easily extend this list.

It is easy to conceive that those discrepancies as we just mentioned have the heaviest bearing particularly on the outcome and reliability of fast reactor physics calculations. Although, from more and more systematic comparisons between integral data measurements on critical facilities and calculations, the hope is increasing of getting more and more hints with regard to deficiencies and errors in the nuclear data basis underlying the calculations, at present the reliability of the knowledge of the nuclear data particularly for the heaviest nuclei can only be considered to be very unsatisfactory. At present, bearing in particular all the normalization correlations of the microscopic measurements in mind, it is impossible to meet in a throughout reliable and confident way the accuracy targets of fast reactor theoretical predictions, which, as indispensable conditions, are required by the technical reactor design and, which comprize e.g. the throughout reliable and confident prediction of k_{eff} of a fast reactor to an accuracy of 0.5% or better. This makes immediately clear that a $\pm 1\%$ uncertainty in the $\bar{\nu}_{Sp}(Cf^{252})$ standard or a $\pm 5\%$ uncertainty in σ_f of (U^{235}) over the most important keV range of neutron energies, which is the most optimistic accuracy estimate for these data on the basis of the presently available experimental information, are still not sufficient to meet the accuracy requirements of realistic reactor design.

Certainly often new precision measurements are necessary and most useful in order to resolve a persistent discrepancy. On the other side one has to remember how many expensive measurements on important cross sections have already been made, so that a really thorough evaluation or reevaluation of these measurements should first be tried before asking for a new experiment. This, however, requires from the evaluation physicist today and in the near future a much more detailed and precise knowledge and consideration of the experimental conditions, for which certain measured and published data are valid, and of the analysis methods used by the experimentalists themselves, than he was generally accustomed to before. He has to get much more familiar with experimental details as for example the sample geometry, homogeneity, isotopic composition, and impurities, the various corrections applied or not applied to the experimental raw data, with details of the analysis of the measurements by the experimentalist himself, and so on.

It is quite apparent that such more thorough critical comparisons and data assessments can only be done and can only be successful in close cooperation with experimental physicists and evaluators. It is to be emphasized that, in view of the very large difficulties involved in such very detailed data assessments, the difficulties and costs involved in the development of more and more sophisticated experimental methods and in the performance of more and more high precision measurements, the data requests from the reactor physics side have to be judged and assessed more critically in the light of really indispensable reactor design needs, than was generally the case before.

We would, however, also like to make it quite clear that the experimental physicists are requested to compare their own measured data with the measurements of their colleagues more thoroughly and systematically than was commonly the case before. The value of experimental results is finally determined by their usefulness for the nuclear community as a whole which requests such experiments for the simultaneous benefit of scientific, technical, and economical progress. Not only for the purpose of nuclear reactor development, but surely as much for the purpose of the progress of our understanding of fundamental nuclear properties the present situation of so many unsolved discrepancies in the basic experimental information is intolerable. Also it has often been demonstrated and is the evaluators' general experience that the best possible basic understanding of neutron nuclear interactions is required to give also a sound and confident nuclear data basis for nuclear reactor design.

If we consider the classical compilation task of the four centres within the framework of the last time evolution to these much more stringent boundary conditions, we see the centres immediately faced with the very necessary, but also very large and difficult task, not only to compile thoroughly and reliably measured data, a task, to which, by very obvious reasons, preponderant weight has been given in the past, but also, to compile from now on more and more thoroughly and in much more detail than before all pertinent physical information characterizing the experimental data and, to make this available, in addition to the data, to experimentalists and evaluators or to any other requestor or user within the nuclear community. This would from now on be a genuine and much appreciated contribution of the four data centres to and would certainly much help in and facilitate the accomplishment of successful data comparisons and evaluations.

It is clearly obvious that such a big task cannot be fulfilled by the centres alone, but only in a thorough concerted effort of neutron nuclear physicists, evaluators and members of the centres. Here it is helpful to consider the foreseeable time table of near-future nuclear data needs particularly from the nuclear reactors side. Clearly for the moment and for the next few years the nuclear data for the heaviest fertile and fissile materials and all standard cross sections and data will be of preponderant importance. This will surely be true at least as long as the various discrepancies and differences in these data have not really been reduced to a tolerable measure. The more this data basis gets settled and the more the detailed design and construction of fast prototype and power reactors advances, the more also the data of structural, cooling and shielding materials and of in reactor burnup produced transactinium isotopes will become important. In rather large coincidence with these needs on the reactor physics side the reviving theoretical and experimental interests in fission physics have to be considered. Probably also the questions of safeguards will play an increasingly important role in the future.

As a consequence of these considerations, the compilation by the four centres of cross sections and related nuclear data for the heavy fertile and fissionable nuclei and of all standard cross sections and data would have to be given first priority with an increasing emphasis and gradual shift to cross sections and nuclear data for the other materials and isotopes mentioned above. Fission physics and nuclear safeguards may increasingly involve additional cross section and data types not needed for reactor design purposes. As a further important consequence the physical documentation envisaged above would have to be developed and implemented in the imminent future. It is to be hoped that the above problems and ideas, in particular the problem of the physical documentation of the data, will be extensively discussed by the Panel.

In the following we will first rather briefly be concerned with some questions related to the quantities to be compiled by the centres. In a further section we deal more thoroughly with various details and proposals for possible practical procedures concerning the question of the physical documentation of the compiled data.

3. Some comments on the quantities to be compiled by the centres.

As the questions of the quantities to be compiled by the centres and of the development of appropriate and improved specification schemes for these quantities (particularly for CINDA) are dealt with in extenso in other papers submitted to this Panel, we may confine ourselves here to a few general comments and a few specific remarks.

As far as the reactor physics needs are concerned which are valid for the largest class of centre users, the present SCISRS-I or ECSIL dictionaries appear to cover fairly well the needed quantities. In 1965, for example, the CCDN Saclay sent around a circular together with the SCISRS-I dictionary A for quantities to be compiled which received answers and comments from various European users of the CCDN. With the priority assignments, modifications, additions etc. made in these comments this list finally appeared to be fairly comprehensive and should in most practical cases allow an answer, whether certain data should be compiled or not. For doubtful cases we would like to repeat only very briefly some general guidelines for compilation.

Within the framework of reactor design needs the compilation should comprize all those measured microscopic quantities for neutron incident energies between 0 and 20 MeV for a given element or isotope, which are characteristic for neutron nucleus interactions, e.g. microscopic cross sections for all reactions occurring in the mentioned energy range, angular distributions for elastically and inelastically scattered neutrons, differential angular and energy dependent excitation data for outgoing neutrons, protons, α-particles etc. or outgoing combinations of these particles, energy distributions of inelastically scattered neutrons, numbers and energy spectra of prompt and delayed fission neutrons, derived quantities like $\alpha=\sigma_\gamma/\sigma_f$, $\eta=\bar{\nu}/1+\alpha$ etc., parametric data like resolved and statistical resonance parameters and quantities derived from resonance measurements by the experimentalists themselves like transmission or fission areas, peak cross sections and others (the resonance parameter list in dictionary A seems to be complete), to give the most important classes of data. Also needed is the compilation of nuclear level positions and quantum properties, what is the task e.g. of the Nuclear Data Group at Oak Ridge. Among the possible integral experimental data only standard "clean" integral data should be compiled. These "clean" integral data comprize in particular:

a. cross section (in particular absorption cross section) averages measured over thermal reactor neutron spectra,

b. infinite dilute resonance integrals for activation, absorption and fission,

c. cross section averages ($\bar{\sigma}_{np}$, $\bar{\sigma}_{n\alpha}$ etc.) over the fission neutron spe ctrum.

"Dirty" integral quantities like effective resonance integrals, spectral indices measured over neutron spectra in fast critical assemblies etc. would thus be definitely excluded. We feel, however, that it would be very useful to have also a separate pool of such "dirty" integral quantities. Whether the gathering of such a pool should also be a task of the centres, might be a worthwhile question for discussion.

In addition to experimental data for reactions induced by neutrons it would be worthwhile to compile cross section data on photoneutron and charged particle induced reactions with neutrons as outgoing particles like (p,n), (d,n) or (α,n) reactions particularly for light nuclei. Those reactions serve as neutron producing reactions e.g. in Van de Graaffs and cyclotrons; their knowledge is important for estimates of the initial neutron flux. Furthermore, being the inverse reactions to (n,γ), (n,p) etc. processes the detailed balance principle can be used to obtain independent estimates of $\sigma_{n\gamma}$, σ_{np} etc. from experimental data on $\sigma_{\gamma n}$, σ_{pn} etc. and to check the reliabi lity of $\sigma_{n\gamma}$, σ_{np} etc. curves evaluated from experimental data on $\sigma_{n\gamma}$, σ_{np} etc.

Ideally, the centres should have a complete pool of all pertinent data which is always up-to-date and comprizes all data information backwards. Realistically, depending upon the manpower available, one would have to think in terms of priorities. We touched already this question in section 2 of this report. Most important at present and for the near future would be that the centres keep full track with the currently produced information in their respective areas, and here particularly with the large data sets as generated e.g. by linear accelerators or cyclotrons on cross sections and other neutron nuclear data for the heavy fissionable and fertile isotopes. The backcoverage should preferably comprize the still important measurements particularly with larger data amounts and, those publications which contain the data only graphically

and not in tables. For the moment it might be still premature or not as urgent, but on a slightly longer time scale the compilation of gamma production data, of data for safeguards and of additional fission physics data should be given detailed consideration.

4. Physical documentation of compiled data sets.

We shall now turn to the, within the framework of this report, most important question of the physical documentation of compiled sets of experimental data. We sometimes presuppose some knowledge and use notions of the so-called "November 1967" and "March 1968 proposals" by Brookhaven concerning the development of a CSISRS system.

Here we have first to define and to outline in more detail what we understand by a "data set" or, to be more general, by a "basic information unit", as we would like to call it. This is related to the question of accession and status numbers within the concept of a CSISRS system. There is also the important question of the location of the physical characteristics of such basic information units. Anticipating our proposal to be outlined in more detail in section 5 to structure the experimental information in the computer in a bibliographic index file, the proper data file and a physical characteristics or comment file, there is the question which of these physical characteristics or comments should be located in the comment file itself or better in direct connection with the data in the data file. Then we have to try to attack the most important question which physical characteristics are actually needed for a sufficiently detailed description of the boundary conditions, under which a "data set" is valid, and in particular, how these characteristics can be structured according to the various types of data in a physically reasonable way. It is impossible, concerning the details of such characteristics, to cover as examples more than a few important neutron reactions. The following considerations should really be understood as a rough attempt to cut one possible way into this jungle of questions, which may form one of the bases of further discussions at and especially after the Panel. In particular a satisfactory approach to an answer to these questions is impossible without the active cooperation of the experimental physicists and we shall finally outline as one possibility a proposal, how such a cooperation between experimentalists, evaluators and centre members could be initiated in practice and made efficient in order to arrive at a computerizable physical documentation scheme.

4.1. Data set or basic information unit.

A "data set" or "basic information unit" will be defined as a number of data points measured for one given material (element, isotope, compound etc.), on one given data type, in a given range of primary and secondary arguments (energies, angles etc.), obtained under fixed experimental conditions. (In this strict sense, for example, a cross section measurement performed in one and the same experiment in several overlapping subregions of a given energy range with different energy resolutions would be several such "units", what might be too restrictive!.) This particular data set may be one of several different versions, among which preliminary, partly final - partly still under correction, final, partially or wholly corrected (e.g. renormalized) compared to original set etc. All these versions refer to the same experiment. This data set or "basic information unit" could get an accession number, the different versions of this set could be distinguished e.g. by status numbers. Each such basic information unit, therefore we chose this term, should in principle (with foreseeable practical exceptions) get its own physical documentation and comment.

The above definition of a basic information unit has the consequence that

a.) two and more data sets being obtained under exactly the same experimental conditions, that means being obtained in the same current experiment, being published in the same reference(s), but solely being for different nuclides (e.g. σ_γ for Cd, Rh, Nb and Mo),

b.) two or more different data sets for one and the same nuclide in the same argument range (not necessarily with exactly the same arguments) differing only by some important experimental parameter like normalization, sample thickness etc. (e.g. three $\sigma_\gamma(U^{238})$ data sets of Poenitz in the keV range with $Li^6(n,\alpha)$; $B^{10}(n,\alpha)$ and $Au^{197}(n,\gamma)$ as standards),

c.) two or more different data sets for one and the same nuclide in the same (or overlapping) argument range(s) pertaining to one and the same (overall) experiment, being published in one and the same reference(s), but containing different quantities (e.g. σ_T, σ_f, σ_γ and resonance parameter data sets of one experiment and reference in the resonance range for U^{235}; results of elastic scattering angular distribution measurements given pointwise in barn/steradian and as Legendre polynomial coefficients, i.e. two data sets with convertible content) get each a different accession number. (Still in

each individual case one has to distinguish between different data versions). This means that in all three cases one reference covering several materials (case a), several different experimental conditions (case b) or several quantities (case c), gets more then one accession number. The question is: should a (main) accession number be assigned to a reference or experiment and the various data sets contained in this reference be distinguished by suitably chosen subaccession numbers, or, should the "basic information unit" as defined above be assigned a (main) accession number and the interconnection between the data sets concerned be done in another way than by subaccession numbers. Closely connected is the question whether it is at all desirable or necessary to interconnect the data sets concerned. Both questions have to be answered in each of the three cases a, b and c.

Apparently, we prefer the latter way with the "basic information units" referred to by accession numbers and to indicate interconnections between data sets in the comment file. Only in those cases b and c we can see the necessity of interconnection between different data sets, where one part of given data sets is used (analysed etc.) by the experimentalist himself to generate another part of given data sets. To give some examples:

case b: transmissions measured for four different sample thicknesses (4 different data sets) are analysed in terms of resonance parameters Γ_n and Γ_γ (5th data set);

case c: σ_T, σ_f and σ_γ measurements for a fissionable nuclide (3 data sets) are analysed in terms of resonance parameters g Γ_n, Γ, Γ_f and Γ_γ (1 data set) and converted by the author to average cross sections or cross section integrals in certain energy groups (3 data sets).

Each of these interconnected data sets should in principle get its own physical comments. Under each comment all interconnected data sets concerned could be briefly indicated by data types and the accession numbers of the corresponding data sets (case c), by data types, pertinent experimental conditions and the accession numbers of the corresponding data sets (case b). In some cases b and all cases a an interconnection between different data sets of the same reference is not necessary, but might be desirable by the one or other reason. In this case the same procedure can be adopted as before, in case a data types, materials and the accession numbers of the corresponding data sets would have to be indicated.

In addition to this it might be useful to foresee as another status number a "yes" or "no" answer to the following questions:

a. One data set only in this particular reference?

b. If answer to question a. is "no", then: are these several data sets necessarily (in the sense outlined above) interconnected or not?

In the cases b and c above each data set necessarily gets its own comment. Only in case a one could conceive having one and the same comment stored only once and connected with all relevant data sets by accession numbers. It might, however, sometimes be necessary to introduce different comments also in case a inspite of exactly the same experimental method, because of differences in sample geometry and composition, different β- and γ-decay schemes etc. for different materials.

Concerning the physical basis of accession numbers the foregoing discussions might be a guide-line, along which one could study the matter more thoroughly. Hopefully, the most important among the simplest cases have been picked out; hopefully, the largest and most important part of conceivable more complicated cases shows differences in more than one of the above mentioned three main items (material, quantity, experimental condition), have thus necessarily different accession numbers and are not interconnected. If there is still interconnection, this could be treated in the comments as above. As far as we went here with the matter of accession, no subaccession numbers at all would be needed and it appears, that one could get along quite nicely with accession numbers, status numbers and physical comments.

4.2. Physical documentation of data sets.

In this section we want to outline in some detail what qualitative and quantitative physical informations characteristic for a given data set in a given experiment or briefly what comments should be compiled. Naturally, the comments should and cannot replace a publication; the most important purpose of the comments would be to contain in one place in a condensed manner all those physical statements and charateristics including "unpublishable"remarks and opinions of the author himself which are necessary to be known in the evaluation process for the purpose of correct judgement, comparisons, selection, renormalization etc. of the data sets considered.

We try to outline a certain scheme of characteristics and to fill in this scheme with various typical examples of those informations which, from evaluation experience, we found useful or even indispensable. Works like the various available evaluation reports, detailed experimental descriptions and reviews, Marion-Fowler, BNL-325 and BNL-400, the reaction cross section compilations of Neuert and Pollehn (EUR-122e) and of Liskien and Paulsen (EUR-119e), the comments in CINDA etc. were of first great help in finding those examples.

We would like to make a distinction between indispensable comment items which may include quantitative as well as qualitative statements and those additional useful informations which might be entered under an item "further comments" or "miscellaneous". We propose the following scheme of (unfortunately sometimes still overlapping) main characteristics items:

1. Experimental facility
2. Experimental method
3. Type of neutron source
4. Sample
5. Detector
6. Standard
7. Data analysis method
8. Corrections applied
9. Comments on argument (energy, angle) resolution, error or uncertainty
10. Comments on quantity error or uncertainty

Then we shall look for various subitems and/or examples for main and subitems for the following selected data types:

I. Resolved resonance parameters
II. Total cross sections
III. Capture cross sections at thermal neutron energies
IV. Capture cross sections at fast neutron energies
V. Inelastic level excitation cross sections
VI. Cross sections for the (n,p) process
VII. Elastic scattering angular distributions

In order to find as many characteristic subitems and examples as possible it might be the simplest way, as we try it here, to compile them first for various possible data types, to combine them later under the common main items and to structure them more thoroughly than has been tried here. It might also well be that some of the subitems indicated below should rather be stored under "further comments" or "miscellaneous".

I. Resolved resonance parameters

I.1. Experimental facility

Linear accelerator
Van de Graaff
Cyclotron
Synchrocyclotron
Slow chopper
Fast chopper
Mechanical monochromator
Crystal spectrometer
} working with reactor (which?) neutrons
Pulsed fast reactor
Slowing down time spectrometer
Betatron

I.2. Experimental method (see also IV.2. for σ_γ)

Transmission measurement
Flat detection
Selfdetection
} with continuous spectrum time-of-flight method or "monoenergetic" neutrons
Detection of fission fragments
Detection of fission neutrons

I.3. Type of neutron source (see also I.1.)

"Monoenergetic" neutrons from charged particle neutron production reactions with light nuclei
D(p,n)
D(d,n)
T(p,n)
T(d,n)
Li^7(p,n)
etc.

Continuous spectrum neutron sources

- reactor sources
  - H_2O, D_2O, graphite thermal reactors
  - fast pulsed reactor
- high energy accelerator sources
  - linear electron (proton) accelerator with/ without boosters
  - cyclotron
- nuclear explosions

I.4. Sample

Sample dimensions, at least sample thickness

Sample isotopic composition including impurities, at least enrichment in measured isotope and content of other isotopes, and qualitative statement regarding impurity admixtures (the latter under "further comments")

Sample chemical compound

Sample temperature

Sample canning material

Sample canning material dimensions, at least cladding thickness

Number of sample thicknesses investigated (in transmission measurements)

Half lives used for sample constituents (fissionable and fertile nuclei)

I.5. Detector

Li-glass detector	transmission
BF_3 proportional counter	transmission
Recoil proportional counter	transmission
Recoil chamber	transmission
Boron slab counter	transmission
Moxon-Rae detector and improved versions	σ_γ
Large (B-,Cd-,Gd-loaded) liquid scintillators	σ_γ
NaI (Tl) crystal	σ_γ
Ge (Li) detector	(capture γ-ray spectra)
Pair spectrometer	(capture γ-ray spectra)
Ionization chamber	σ_f
Gas scintillation counter	σ_f
Liquid scintillator for fission neutron detection	σ_f
Solid state counter telescopes	σ_f

I.6. Standard

σ_n (H) (E)

σ_α (B^{10}) (E) $\sim$ 1/v

σ_α (Li^6) (E)

σ_γ (Au) (0.0253 eV)

σ_f (0.0253 eV) of measured isotope

Cross section integral of other authors (reference? accession number?) between given energy limits, over given resonance(s) of the measured isotope (e.g. fission)

σ values of measured isotope due to other author in a given energy range (e.g. fission)

Γ_f/Γ_a of another author for given resonance(s) of the measured isotope

η (0.0253 eV)
$\bar{\nu}$ (0.0253 eV) } of measured isotope

I.7. Data analysis method

General comments

The quantities (data sets) should be indicated (together with the accession numbers) which were measured and used in order to derive the resonance parameters contained in the commented data set.

When in addition to own measurements measurements and/or informations are taken over from other authors (reference? accession number?), this should comprehensively and in detail be documented under "further comments".

Analysis methods

Area analysis

Area analysis with wing corrections

Partial area analysis

Shape analysis

Shape fit to resonance wings

(which resonances are shape and/or area analysed under "further comments")

Minimum transmission analysis

Γ_γ values used (under "further comments")

taken over from other author(s) (reference? accession number?) for which resonances

analysed by author himself for which resonances

Source of Γ_n and/or J values taken over from other authors' transmission measurements (reference? accession number?) for derivation of Γ_γ from author's own σ_γ measurements.

$\Gamma_\gamma = \langle\Gamma_\gamma\rangle$ assumed for all or part (which one?) of the resonances estimated by author himself (by which arguments?) or taken over from other authors (reference?)

Negative energy resonance (under "further comments")

Negative resonance accounted for in order to get fit to measured low energy resp. thermal cross sections

One or more negative resonances considered

How were position(s) and parameter(s) of this (these) negative resonance(s) fixed

"further comments" like these:

Resonance peaks (which?) identified by comparison with better resolved data of other authors (reference? accession number?)

2g Γ_n (for which resonances?) of author's own σ_T measurement divided between adjoining resonances on basis of better resolved σ_T measurement of other author(s) (reference? accession number?)

Analysis theories

(In case of simultaneous consideration of several resonances: how many resonances were considered at left and right? Furthermore: value of scattering length assumed resp. obtained in analysis?)

Single level analysis

- Single level formula for one isolated resonance
- Sums of single level terms for several resonances

Multilevel analysis

- S-matrix analysis (mostly light nuclei)
- Bethe approximation (medium weight nuclei)
- R-matrix analysis
  - Exact one channel-multilevel formula (medium weight nuclei)
  - Multi-channel approximations due to Vogt, Reich and Moore, Adler and Adler (for fissionable nuclei)

In relevant cases under "further comments": number of fission and capture channels assumed resp. obtained?)

Resonance isotopic assignment

From peak cross section value

Taken from other authors

obtained on basis of peak-to-valley cross section ratio considerations

Obtained by sum-coincidence method

Obtained by observing known (which?) decay activities

For weak resonances obtained from measured capture γ-ray spectra

Resonance parity resp. ℓ-value assignment

ℓ=0 ($\neq$0) concluded from presence (absence) of resonance-potential scattering interference dip below resonance

From comparison of observed and theoretical peak cross section and/or intensities of known radiative transitions (also J-values)

From phase shift analysis of measured angular distributions (also J-values, light and medium-weight nuclei)

From measurements of γ-ray spectra

From measurements of angular distributions of capture γ-rays

Resonance spin (J-value) assignment (mostly odd nuclei)

Relative J-value from measurement of ratio of asymmetric to symmetric fission (fissionable nuclei)

From peak cross sections (medium weight nuclei)

Combination of scattering and transmission measurements

From presence or absence of certain known γ-transitions

From two step γ-ray cascades

From requirement $\Gamma_n \leq \Gamma$

From change in transmission upon reversing neutron beam polarization in transmission measurements with polarized neutrons and polarized targets

(in the case of no spin assignment g values adopted in order to obtain stored Γ_n values from measured $g\Gamma_n$)

I.8. Corrections applied

Corrections for different (which?) types of background

Corrections for beam attenuation in sample

Corrections for geometrical resonance self shielding

Corrections for multiple scattering before capture (σ_γ measurements)

Corrections for multiple scattering (e.g. in angular distribution measurements)

Corrections for inscattering (transmission measurements)

Resonance half widths corrected for Doppler effect

Resonance half widths corrected for neutron energy resolution

Corrections for potential scattering

Corrections not applied and error sources which the author(s) considered negligeably small (which?) applies also under (II-VII)8)

I.9. Comments on energy resolution etc.

Exact assignment of resolution(s) or energy spread(s) in the total energy range considered (in parts of this range) to the commented data set as a whole (or in parts) in appropriate units allowing minimum number of statements; it would not suffice to give best resolution or upper limit of resolution

Definition or description of resolution function

Gaussian resolution function

Triangular resolution function

Rectangular resolution function

Lorentz-type resolution function

Definition of given resolution (s)

Total half width of one of the above mentioned distributions

I.10. Comments on quantity error etc.

At what energies are resonances not resolved?

Peak interpreted as one resonance consists probably of several resonances. Probably doublet, triplet or how many resonances?

Still not interpreted overlapping peaks consist probably of how many resonances?

Resonance(s) only seen in capture, not in transmission, at what energies?

Resonances for which isotopic assignment questionable or tentative on the basis of which arguments?

Resonances isotopically identified which probably belong to another isotope of the element investigated (to which?) or to an impurity (to which?)

Analysed peak probably due to statistics or to a multiple scattering effect

ℓ and/or J values of resonance(s) given in data set uncertain, preferred by author, tentative, etc. and author's reasons for choice

Probable ℓ and/or J values of resonance(s) not given in data set

Author's opinion of the results of part or all of his own previous work (reference? accession number?) in the given context or of the results of other authors (reference? accession number?) (other data partially or wholly improved, outdated, superseded, probably wrong etc., under "further comments")

Author's private "unpublishable" opinion on certain error sources, deficiencies etc. in his present work, which the centres should be allowed by the author to enter in their comment files and evaluators be permitted to use (difficulty with possible deterioration of author's reputation)

II. Total cross sections

II.1. Experimental facility (see I.1.)

II.2. Experimental method (see subitems in I.2. concerning σ_T)

II.3. Type of neutron source (see I.1. and I.3.)

II.4. Sample (see I.4.)

II.5. Detector (see I.5. for transmission)

II.6. Standard

Mostly absolute measurements

Occasionally relative e.g. to $\sigma_n(C)$

II.7. Data analysis method (see also I.7.)

Data analysed in terms of strength functions

Data fitted to some (energy) function

II.8. Corrections applied (see also I.8.)

Measurements (near thermal) corrected for Doppler effect

Data corrected for second neutron group in $Li^7(p,n)$ source reaction

Data corrected for inscattering

using observed angular distributions,

assuming isotropic angular distributions,

partly using observed angular distributions (energy limits?), partly assuming isotropic angular distributions (energy limits?)

II.9. Comments on energy resolution etc. (see I.9.)

Broad energy spread in different energy ranges (thermal, keV, fast, MeV) centered around some effective energy, extending between which energy limits, percentage of neutrons in various subgroups

II.10. Comments on quantity errors etc.

III. Capture cross sections at thermal neutron energies

III.1. Experimental facility (see I.1.)

III.2. Experimental method

Neutron life time in H_2O, D_2O, graphite, boron solution

Neutron diffusion length in H_2O, D_2O, polyethylene, paraffine, at which temperature(s)

Neutron density diminution in H_2O with distance from (e.g. Po-Be) neutron source, relative to that in boron solution

Activation

- Measurement of decay betas ($\tau_{1/2}$?)
- Measurement of internal conversion beta spectrum
- Measurement of capture γ-rays
  - counted γ-ray of definite energ(y,ies)
  - measured capture γ-ray spectrum with which bias
  - measured capture γ intensities
  - compared intensity of decay γ with intensit(y,ies) of γ line(s) of other isotopes
  - measured area under photopeak
  - measured isomer production (which isomer g, m_1, m_2,... with which $\tau_{1/2}$?)
- Detection of atomic inner shells x-radiation
- Absolute β-γ-coincidence counting

Absorption

H_2O, D_2O, graphite pile oscillator

Transmission (crystal spectrometer, mechanical monochromator, slow and fast chopper), e.g. below Bragg-cutoff (energy?)

Transmission from reactor thermal column relative to σ_T(B)

Measurement of reactivity coefficient relative to B

Mass spectrometric analysis before and after irradiation

Radiochemical separation

III.3. Type of neutron source

Reactor thermal column
Pulsed neutron sources with moderator
Sb-Be photoneutron source inside paraffin box or D_2O
Ra-Be, Po-Be neutron source with paraffin as moderator

III.4. Sample (see I.4.)

III.5. Detector

BF_3-detector
Boron loaded emulsion
Scintillation spectrometer
Pair Spectrometer
4π β-γ-coincidence counter
Solid state detector (anthracene, stilbene)
Nuclear emulsion
Gamma ionization chamber
4π gas proportional counter
End-window beta counter for decay betas
Magnetic lens spectrometer for conversion electrons

III.6. Standard

σ_α (B) $\sim$ 1/v
σ_α (B) (0.0253 eV)
indicate kind of standard boron used (Harwell, Fontenay, Geel, ANL/BNL) and its composition
σ_γ (H) (0.0253 eV)
σ_γ (D) (0.0253 eV)
σ_α (Li)(0.0253 eV)
σ_α (C) (0.0253 eV)
σ_γ (F) (0.0253 eV)
σ_γ (Na)(0.0253 eV)
σ_γ (Al)(0.0253 eV)
σ_γ (Mn)(0.0253 eV)
σ_γ (Co)(0.0253 eV)
σ_γ (Cu)(0.0253 eV)
σ_γ (I^{127})(0.0253 eV)
σ_γ (Au)(0.0253 eV)
σ_γ (Pb^{207})(0.0253 eV)

III.7. Data analysis method

In transmission: σ_T fitted by $\sigma_T = \sigma_a + \sigma_n = a/\sqrt{E} + b$

III.8. Corrections applied

Corrected for flux distortion produced by detectors?

Reactor spectrum value converted to 0.0253 eV value?

Corrected for epicadmium contributions, for resonance flux by taking Cd ratios?

Corrected for beta self-absorption

III.9. Comments on energy resolution etc.

Reactor spectrum

Thermalized spectrum

Subcadmium spectrum

0.0253 eV

III.10. Comments on quantity errors etc.

Measured quantities are here also:

σ_{act} (isotope of element x)/σ_{act} (other isotope of element x)
e.g. $\sigma_{act}(Br^{79})/\sigma_{act}(Br^{81})$

σ_m/σ_g, σ_{mi}/σ_g or the reciproces

σ (high spin)/(σ(high spin)+σ(low spin))

σ (high spin)/σ_{total}

very useful comments, particularly for the heaviest nuclei, to be found in BNL-325

IV. Capture cross sections at fast neutron energies

IV.1. Experimental facility (see I.1.)

IV.2. Experimental method

Activation, beta and γ counting (see before) ($\tau_{1/2}$?)

Sphere transmission

Slowing down time spectrometer

Associate activity method

IV.3. Type of neutron source (see also I.1. and I.3.)

Photoneutron sources (Sb-Be, Na-D_2O, Na-Be)

IV.4. Sample (see I.4.)

IV.5. Detector (see also I.5. for σ_γ and III.5.)

"Grey" neutron detector

IV.6. Standard

σ_α (B^{10}) (E)
σ_α (Li^6) (E)
σ_γ (Au) (E)
σ_γ (Ta) (E)
σ_n (H) (E)
σ_a (U^{235})(E)
σ_f (U^{235})(E)
σ_γ (I^{127})(E)
σ_γ (In) (E)
σ_γ (Mn) (E)
σ_γ (400 keV) for the same element or isotope, but measured by other author(s) (reference? accession number?)
σ_γ (Ag) (30 keV)
σ_γ (I^{127}) (0.0253 eV; 25 keV; 65 keV; 200 keV; 2.5-3.1-4.0 MeV)
σ_γ (Au^{197}) (25 keV)
σ_γ (In^{115}) ($\tau_{1/2}$=54 m) (25 keV; 195 keV)
σ_γ (In) (30 keV)
σ_γ (0.0253 eV) of same isotope (e.g. slowing-down time spectrometer measurements)

Normalization to other author's data around certain energy, in certain energy range

Normalization chains: measurement relative to one standard (e.g. $I^{127}(n\gamma)$) which in turn is measured relative to another one (e.g. $U^{235}(nf)$)

σ_{α} (Al) (14 MeV)

σ_{2n} (Cu) (14 MeV)

IV.7. Data analysis method

Data analysed in terms of resolved resonance parameters (see I.7.)

Data analysed in terms of statistical resonance parameters (strength functions, average capture widths)

Data analysed in terms of direct capture

IV.8. Corrections applied

Corrected for multiple scattering before capture? (important particularly in measurements in large scattering resonances in medium-weight nuclei)

Corrected for γ-background?

Bias in γ-energies detected?

Corrected for geometrical resonance self shielding?

IV.9. Comments on energy resolution etc.

Energy resolution, energy spread (see I.9., II.9.)

Fission neutron spectrum

IV.10. Comments on quantity errors etc.

Cross section value given

tentative

upper limit

spectrum (e.g. fission spectrum) average

Probable (certain) reasons given by author(s) (or someone else) for discrepancies to his own earlier or to other authors' measurements (reference? accession number?)

V. Inelastic level excitation cross sections

V.1. Experimental facility (see I.1.)

V.2. Experimental method

Counted neutrons ($\Longrightarrow$ neutron inelastic excitation cross sections for individual levels or groups of levels)

Counted gammas ($\Longrightarrow$ inelastic excitation gamma emission cross sections for definite γ-lines)

} in ring or other geometry

Neutron-gamma coincidences

Sphere transmission measurement, e.g. between two detector biases

Inverse spherical geometry measurement

V.3. Type of neutron source (see also I.1. and I.3.)

V.4. Sample (see I.4.)

V.5. Detector

Nuclear emulsions

Cloud chamber

He^3 detector

pair spectrometer

Ge(Li)-detector

V.6. Standard

σ_n (H) (E)

σ_n (C) (E)

relative to $\sigma_{n'}(E_\gamma = 4.433$ MeV) von C^{12},

or to $\sigma_{n'}(E_\gamma = 0.845$ MeV) von Fe^{56} at certain energy and/or angle

$\sigma_{n'}(\Theta)$ measurement normalized at angle Θ_i (e.g. 95°) to measurement of other author(s) (reference? accession number?)

V.7. Data analysis method

Neutron level excitation obtained from measured gamma emission cross sections by means of measured (or assumed) level decay branching ratios

$\sigma_{n'} = 4\pi\ \sigma_{n'}(\Theta_i)$

$\sigma_{n'} = 4\pi\ \sigma_{n'}(\Theta_1 \to \Theta_2)$

neutron excitation cross section measured only at one angle (Θ_i, e.g. 90°) or in a restricted angular range (Θ_1-Θ_2, e.g. 45-125°); total σ obtained by assuming isotropic angular distribution, i.e. by multiplying the experimental result by 4π

Separation in direct and compound contributions (percentages?) as estimated by author

Data analysed in terms of Legendre polynomial coefficients

Data analysed in terms of coefficients of development in powers of cosΘ

V.8. Corrections applied

Corrected for multiple scattering?
how large multiple/single scattering ratio?

Above (n,2n) threshold: corrected for presence of (n,2n) neutrons?

Corrected for γ-attenuation?

Corrected for neutron self absorption?

V.9. Comments on energy resolution etc.

Cutoff energy

Broad angular spread

V.10. Comments on quantity errors etc.

Except for the normal $\sigma_{n,i}(E,E_i,(\Theta))$ and $\sigma_{n,\gamma}(E,E_\gamma,(\Theta))$ the following quantities are measured and used in evaluation:

σ for emission of neutrons from all inelastic processes

σ for neutron excitation for levels comprized between energies E_1 and E_2, total σ or differential σ at certain angle(s)

σ for neutron inelastic scattering with outgoing neutron energies comprized between E'_1 and E'_2

σ for inelastic excitation of two or more (not distinguished) levels

Resonance positions and widths (in light nuclei)

Ratio of excitation probability of two levels at certain energ(y,ies)

Branching ratios in the γ-decay of levels

Total σ for production of gammas of all energies

Ratio of gamma emission cross sections of two different isotopes (e.g. $\sigma_{n,\gamma}{}^{Fe54}$ (E_γ=1.4 MeV)/$\sigma_{n,\gamma}{}^{Fe56}$ (E_γ=0.85 MeV))

Ratio of inelastic excitation cross sections at two different angles (e.g. $\sigma_{n,i}(30^o)/\sigma_{n,i}(150^o)$)

Relative γ-ray intensities

Fission spectrum average of inelastic cross section, only neutrons counted which loose less energy than a certain fission threshold (e.g. 1.4 MeV in U^{238})

Gamma emission cross section at certain angle(s) for γ-energies comprized between $E_{\gamma 1}$ and $E_{\gamma 2}$

Inelastic scattering cross section with sphere transmission (see σ_X) or inverse spherical geometry with exclusion of certain levels or energies

Reliability of data corrections for detector efficiency

VI. Cross sections for the (n,p) process

VI.1. Experimental facility (see I.1.)

VI.2. Experimental method

Absolute measurement

Counted protons

Counted betas

- certain state(s) only
- total γ-ray activity
- counted decay betas and following gammas

Counted gammas

- certain γ-line(s) only
- total γ-ray activity
- definite γ-energies or area in photopeak

Measurement of positron annihilation radiation by coincidences

VI.3. Type of neutron source (see also I.1. and I.3.)

VI.4. Sample (see I.4.)

VI.5. Detector

Solid state detector

Counter telescope

Nuclear emulsions

Proportional counter

Cloud chamber

Scintillation counter

Plastic scintillator

NaI(Tℓ), KI(Tℓ), CsI crystal

VI. 6. Standard

σ_n (H) (E) σ_α (Li^6)(E) σ_α (Al^{27}) (E) σ_p (S^{32}) (E) σ_p (Fe^{54}) (E) σ_f (U^{235}) (E)	energy dependent standards
σ_α (Li^6) σ_p (O^{16}) σ_p (Al^{27}) σ_α (Al^{27}) σ_p (Si^{28}) σ_p (Fe^{56}) σ_{2n}(Cu^{63}; Cu^{65})	at energies between 14 and 15 MeV
$\bar{\sigma}_p$ (Al^{27}) $\bar{\sigma}_\alpha$ (Al^{27}) $\bar{\sigma}_p$ (P^{31}) $\bar{\sigma}_p$ (S^{32}) $\bar{\sigma}_p$ (Fe^{56})	fission spectrum averages for fission spectrum average measurements

VI.7. Data analysis method

σ_{np} obtained from σ_{pn} by reciprocity theorem (light nuclei)

$\sigma_p = 4\pi\ \sigma_p(\Theta_i)$, measurement performed only at angle Θ_i, total σ_p obtained by assuming $\sigma_p(\Theta)$ to be isotropic, i.e. by multiplying measured value by 4π

Separation in direct and compound contributions (percentages?) as estimated by author

Separation of (n,p) and (n,np) and/or (n,pn) processes by statistical theory with certain (which?) level density laws

σ_p measured for protons with energies above a certain energy E_p, below E_p σ_p contribution computed with statistical theory

VI. 8. Corrections applied

Corrected for (n,np) and/or (n,pn) and/or (n,d) contributions above thresholds

VI.9. Comments on energy resolution etc.

VI.10. Comments on quantity errors etc.

Measured σ_p value lower limit because

only protons counted above certain bias

excitation of restricted number of rest nucleus levels measured

Store under comments values for $\sigma_{n,np}$, $\sigma_{n,pn}$ and/or $\sigma_{n,d}$ given by author

Errors introduced by fact that

in proton registration method no discrimination possible between (n,pγ) and (n,pn) processes

Author's judgement of discrepancies between his own and other measurements (reference? accession number?)

Reliability of author's $\sigma_{n,np}$, $\sigma_{n,pn}$ and/or $\sigma_{n,d}$ estimates

(n,np) yield assumed isotropic

tentative value for $\sigma_{n,d}$

Quantities measured may also comprize:

proton spectra at various angles

fission spectrum averages

σ for groups of protons emitted by two or more excited rest nucleus states

VII. Elastic scattering angular distributions

VII.1. Experimental facility (see I.1.)

VII.2. Experimental method (see also V.2.)

Time-of-flight measurement

Ring geometry

Pulse heigth distribution of recoil nuclei

VII.3. Type of neutron source (see I.1. and I.3.)

VII.4. Sample (see I.4.)

Sample dimensions particularly needed in order to judge importance of multiple scattering in cases where measurements were not corrected for multiple scattering.

VII.5. Detector

Biased (liquid) scintillator

Recoil gas scintillator

(Diffusion) cloud chamber

Biased proportional counter

Counter telescope

BF_3 counters in moderator

Moderating tank detector

Nuclear emulsions

Recoil ionization chamber

Hornyak detector

VII.6. Standard

$\sigma_n(H)\ (E)$, $\sigma_n\ (H)\ (E,\Theta_i)$

$\sigma_n(Be)(E)$

$\sigma_n(C)\ (E)$

Normalized to total σ in same or other (reference? accession number?) experiment

Normalized to $\sigma_n(\Theta_i)$ of other author(s) (reference?) accession number?) at same energy

Normalized to theoretical $\sigma(\Theta)$ curve

VII.7. Data analysis method

Data analysed in terms of (variously defined) Legendre polynomial coefficients

Data analysed in terms of coefficients of development in powers of $\cos\Theta$

Phase shift analysis

VII.8. Corrections applied

Corrected for end and wall effects?

Corrected for beam attenuation?

Corrected for double, triple, multiple scattering?

Corrected for angular resolution?

Corrected for inelastic scattering contributions? (seeVII.10)

Corrected for second group of neutrons in $Li^7(p,n)Be^7$ source reaction?

Corrected for fission neutrons? (fissionable and fertile (above threshold) nuclei)

VII.9. Angular resolution etc.

Indicated $\Delta\Theta$ half or full width angular spread?

Broad angular resolution

VII.10. Quantity errors etc.

Only relative angular distribution measurements

Relative recoil spectrum

Absolute recoil spectrum

Absolute values measured at single energy

Measurements cover only restricted angular range, e.g. only small range of forward scattering angles or only one or a few selected angles

Ratio measurements like

$\sigma_n(\cos\Theta)/\sigma_n(-\cos\Theta)$

$\sigma_n(180^\circ)/\sigma_n(90^\circ)$

Measurement of total scattering angular distributions ($\sigma_n(\Theta)+\sigma_{n'}(\Theta)$)

Corrections for inelastic scattering:

bias energy for outgoing neutrons

some inelastic scattering contribution probable

at some energies (which?) inelastic scattering contributions

results include inelastic scattering to (which?) level(s)

percentage (or other quantitative) estimate by author of inelastic scattering contribution

Quantity errors

errors on individual points statistics only (and due to uncertainty in estimate of multiple scattering correction)

how much larger is estimated absolute than statistical error?

errors in energy dependence of detector efficiency in measurements covering larger energy range.

Because of their particular importance for evaluation we would like to deal a bit more with standards, quantity and argument errors in the next two subsections and their possible location within a CSISRS file.

4.3. Standards

It is well known that in spite of a worldwide effort the cross section values for those common standard reactions as e.g. $Li^6(n,\alpha)$, $B^{10}(n,\alpha)$ or $U^{235}(n,f)$ or the average number of Cf^{252} spontaneous fission neutrons are still not known to sufficient accuracy and that discrepancies between different measurements are often explainable by differing or wrong standard values assumed by the experimentalists. As a consequence the evaluator has often to reconsider and recalculate those standards. In order to be able to do this with the computer, the standards have to be stored at appropriate retrievable places under comments and in the data files. From the various reactions and possibilities appearing in the characteristics list of the last section one can abstract the following five general cases (which could be distinguished by key numbers):

a.) An energy dependent cross section measurement is normalized to a standard cross section expressed as an analytic function, e.g. $\sigma_{n\alpha}(B^{10})=c/v$.

b.) All measured energy dependent data points of an experiment are normalized to one single standard value like an individual cross section point (e.g. $\sigma_{n\gamma}$(Au) at 30 keV) or the area under a cross section curve (U^{235} fission area as measured by Shore and Sailor between 8 and 10 eV, Pu^{239} fission area under the 7.8 eV resonance as measured by Bollinger).

In both cases, a and b, it would suffice to store a full characterization of the standard together with the necessary numerical information (constants, cross section and area values) under comments in the field provided for the standard. Thus, in case a the standard nuclide, the type of reaction, its representation as analytic function and the values of the constant(s) occurring in this function, together with its (their) error(s) should be stored. In the first case b standard nuclide, type of reaction, energy and cross section values, together with their errors, in the second case b standard nuclide, type of reaction, lower and upper energy limits and the area value together with its errors, should be given, in all three cases in addition the key number. The individual items just mentioned should be retrievable by subscripted numbers.

c.) The measured energy dependent data of an experiment are pointwise normalized to the same standard reaction, but different standard cross section values at different energies.

In this case it suffices to enter under comment in the standard field the key number for case c and the reaction. In the field columns provided for standards in the data file at each energy of the measurement the standard cross section value should be stored, together with its error.

d.) The measured energy dependent data are data ratios, e.g. cross section ratios like $\sigma_{nf}(Pu^{239})/\sigma_{nf}(U^{235})$ and no standard is given.

These data may be treated as absolutely measured data with only the key number for cross section ratios entering the standard field in the comment.

It is certainly not claimed that this list is complete; the five cases mentioned are the extract of experiences gained during former evaluation work. In more complicated cases it might become necessary to store additional information under the comments.

In this context we would like to mention that the old SCISRS-I standard dictionary is deficient particularly in the respect that it does often not specify the standard reaction type. Furthermore, the restriction to one character would be unnecessary. We feel that, within the framework of the development of a physical characteristics scheme, the standard dictionary should be completely revised ty a cooperative effort of the centres, the evaluation and experimental physicists.

Finally, we have a comment on the status questions as specified in the "November 1967 proposal", page 10. The third status question reads: Normalization up to date? As long as no final unique reference values for standard data are established and worldwide accepted in the neutron data field, as long this question is senseless. We recommend that the experimental data be included in data files together with the standard values as chosen by the experimentalist himself. The centres should not be permitted to change the standard values used for normalization by the experimentalist and to renormalize experimental data. Renomalization should be up to the experimentalist himself, who wants to correct his data given to a centre, and to the users like evaluation physicists who during a certain evaluation, say of $\sigma_{n\gamma}(E)$ for U^{238}, want to reevaluate "best" values of the pertinent standard cross sections used and to renormalize the different measurements to these new "best" values.

This principle should be maintained for the data files which the users request and get from the centres. Naturally, this says nothing against users in the centres themselves, who want to renormalize data, for example, by a SCØRE-program for publications like BNL-325. To come back to the status question no. 3 this could read: Original normalization changed by author; but then it would coincide with status question no. 1 and could be completely dropped.

4.4. Errors in quantities, energies and angles

Concerning errors in quantities, energies and angles it would also be indispensable to get much more thorough and detailed comments from the experimentalists themselves than we intend to give here. The quantity errors are composed of statistical and systematic errors, statistical errors due e.g. to counting statistics, and systematic errors of various types, being for example due to sample impurities, sample thickness, counts below bias, background, extrapolation, normalization, calibration etc. Whereas the statistical errors are symmetric to the measured value, the systematic errors may be asymmetric being different on either side of the measured value. It was already said that in the comparison, weighting and evaluation of different measurements one has to consider both error types. In the data files therefore (at least) three columns should be foreseen, one for the statistical error and two for the negative and positive systematic errors. Only total systematic errors should be listed in the data files; partial systematic errors should be entered under com-

ment together with an explanation, how the total was obtained from the partial systematic errors. Two further columns should be foreseen for the negative and positive total errors, as calculated from the statistical and total systematic errors or as directly given by the experimentalists.

As is outlined in the "November 1967 proposal" on page 30 under c a given incident energy error might have different meanings depending on the neutron spectrum or resolution function used in the measurement of the individual data points. The neutron spectrum or resolution function may be "monochromatic", more or less broad, symmetric, asymmetric etc., the corresponding energy errors given be symmetric or asymmetric or indicating the width of the distribution according to some given definition. In addition, there might be systematic errors in the energy scale of a measurement. Actually, all this information is needed for evaluation. Therefore, the data files should foresee columns for negative and positive energy errors, possibly also for total distribution width to each measurement point. Under comments the shape (Gaussian, triangular, group- or pointwise etc.) of the distribution or resolution function and the meaning of the energy errors given with the data should be specified.

Angular errors can be easier treated than energy errors. They are symmetric to the axis detector target centre and are essentially given by the detector dimensions. Two columns for negative and positive angular errors in data files are needed only by the reason that symmetric errors in the angle do generally not correspond to symmetric errors in the cosine of the angle and vice versa.

4.5. Proposal for the development of a physical documentation scheme

We come now to the important point how to proceed practically in the development of a scheme of physical characteristics. Obviously the Panel can impossibly discuss all the details of such a scheme, it can only possibly advance some more precise ideas on its general structure and propose and recommend certain procedures for its further development. We see the following possible ways of procedure. Probably the technically best would be if experimental physicists, with the background of their most immediate experience, would draft such a scheme, if experts in the various fields of capture, fission, elastic scattering etc. reactions in the thermal, resonance, fast energy ranges could be obtained for this purpose. These drafts could be examined and

checked by other experimentalists and so be iterated to a final state, in which they could be put forward to and adopted and implemented by the centres. This procedure certainly would involve rather many people from the very beginning and still more cross correlations and would thus probably be rather time consuming. Also, it would be desirable to have the experience of compilers and evaluators also involved in this iteration process. Therefore, we would like to propose another procedure, which probably is a more realistic and efficient way. A small group of volunteering experimental,compilation and/or evaluation physicists could be formed respectively proposed at the Panel, with a clear, but coarser division of the tasks than in the first proposal above. This group first would work out a scheme and agree on it, then send it around to a large number of competent people concerned asking for comments, modifications etc., then redraft it and ask for further comments and so on. Probably by this procedure more rapid convergence would be guaranteed than by the first one. The lists of characteristics items in section 4.2 could serve as a start help in this latter procedure. It should, however, be clearly ascertained that the final scheme and corresponding lists have found the approval of competent experimental physicists.

The second, certainly still more laborious step, which requires much more work per reference than a CINDA entry, is the implementation of such a finally adopted scheme into the data files of the centres and the supplement of the data sets already existing in or to be entered into the files by the foreseen physical comments. Certainly in many cases a close contact between centres and the originators of the data will be needed in addition to the published information in order to make the physical documentation of the data sets concerned really useful. The priorities required above for the compilation of the data themselves are the more valid for the setting up of their physical documentation. Furthermore, it is very likely that in the course of the use of and increasing experience with such physical comments in actual evaluation work by experimental and evaluation physicists the initially adopted scheme will find alterations. Therefore, we would like to propose that the centres, hopefully with active cooperation of the experimental physicists concerned, begin with setting up those physical comments for the most important case of cross section data of the common heavy

fertile and fissionable materials and for standard data starting with recent data sets and going back to older ones. As in compilation and with increasing experience one could gradually go over also to other data. Concerning new data sent in to be entered into the files the authors themselves hopefully will get accustomed to send in all necessary physical characteristics in the framework of the approved scheme together with the data. Finally, we would like to mention that possible contributions for example of the centres to the physical comments might arise from optical or other comparisons of compiled data sets, which might lead to the detection of systematic deviations like differences in energy scales between different experiments.

5. Some computer requirements of CSISRS systems

In this last section we will touch only very briefly on some computer aspects and requirements of advanced neutron data storage and retrieval systems like CSISRS and make a few selected comments. First, CSISRS should have an archive file, from which upon request also retrievals could be made, which contains the experimental data in a free input format and in those units in which the data were sent in by the experimentalist. Actually, such an archive file appears to be foreseen in the present development stage of CSISRS, but as far as we know, no retrieval possibility is foreseen. One of the reasons for such a free format archive file is that the experimentalists should get the possibility to check and correct their own data input before it is finally entered into the system. This task is obviously much alleviated by using e.g. the same units as the originators of the data (e.g. resolution in nsec/m and not in ΔE(eV) attached to each E value). This procedure has been adopted by the NDU at the IAEA and has found the particular acknowledgement of the experimentalists. The concept of a free input format in such an archive file obviously includes that the experimentalists should be free to send in their data information in a format whatsoever. Another reason is that the principal possibility should exist to check at every time the content of an inverted file, e.g. a file with a fixed input format generated from the archive file, against the original data information contained in the archive file.

It is probably more reasonable and surely sparing computer time, if not the free input archive file, but a fixed input standard file generated from the archive file with data units corresponding to the bulk of the requests

is used as the working storage medium for retrievals and fulfilments of requests. One has only always to be sure that the contents of archive and standard file are identical. Also for those users who want to have the requested data in other units than in those of the standard file, the possibility should exist to generate from the standard file another subfile in those requested units. This is not a very large requirement, because the number of unit conversion possibilities in the neutron data field is actually not very large. We have tried to compile the most common ones in the following list:

a.) Energies or quantities with the dimensions of an energy (neutron incident and outgoing energies, charged particle and γ-ray energies, energy uncertainties, level distances, resonance half widths, nuclear levels, nuclear temperatures etc.) may be given in meV, eV, keV or MeV.

b.) Energy resolutions or uncertainties may be given in μsec/m, nsec/m, psec/m, in one of the above energy units, as last place(s) figure errors or in percent of the (incident or outgoing) energy.

c.) Angles, angular resolutions and uncertainties may be given in angular units, in steradians or as cosine in the laboratory or centre-of-mass system.

d.) Cross sections may be given in barns, mb or μb.

e.) Angular distributions may be given pointwise in barns/steradian or mb/steradian, or as Legendre polynomial coefficients in a few different representations of the coefficients or as coefficients of a development in powers of $\cos\theta$ in the laboratory or centre-of-mass system.

f.) Generally, errors may be given as absolute errors in the same or (seldom) different units as the quantity concerned or as relative errors, e.g. in percent or permille.

To our mind the most commonly requested units would be eV or MeV for energies and energy uncertainties, angular units or cosine θ in the centre-of-mass system for angles and angular uncertainties, barn for cross sections, barns/steradian or Legendre polynomial coefficients in the centre-of-mass system for angular distributions. So these units could be foreseen for the standard file.

A second requirement for the archive as well as for the standard file would be to have the bibliographic index to the data, the data themselves and the physical documentation in separate files connected by accession numbers; however, as has been outlined in section 4.3, a small part of the physical documentation like numerical values of standards would also be contained in the data file. Concerning the structure of the bibliographic index file the following requirements should be fulfilled:

a.) as index to the data file the bibliographic index or briefly BIB file should be as short as possible,

b.) it should be similar to the CINDA index, containing all of the items of a CINDA entry except for most of the comments, but with the addition of a few items to be specified below,

c.) it should contain all information, which is normally entered in a literature reference quoted in a publication.

Thus, a BIB file entry should contain as a minimum (not necessarily in this order)

Z (or element initials)
A
Quantity
Minimum
Maximum } incident energy
Title
Author(s)
Reference
Corporate author(s)
Date of entry
Status number
Accession number

As far as the data file represents only a pool of experimental and not e.g. of theoretical data, the "type" entry in the CINDA format can be omitted. Partly the role of the "type" entry can be taken over by the status numbers and/or by the comments. For further comments to some of the above items we refer to the CINDA introductions. The incident energy might also be a thermal spectrum, a fission spectrum, a broad energy spectrum centered about an "effective" energy or covering predominantly "eV" or "MeV" energies etc. All other information should be foreseen within the physical documentation.

For the physical characteristics in principle three locations are possible: in an own file, or connected with the references in the BIB file or connected with the data sets in the data file (before or behind a data set). An own comment file would be useful in itself, it would spare storage place in the two other files and it could be connected with the BIB file by the same accession number as the corresponding data set. Thus, it would appear most favourable (with the exceptions already mentioned above) to have the physical characteristics (as in NEUDADA) in an own file separated from the BIB and data files.

Thirdly, in view of the availability of third generation computers of e.g. the CDC and IBM 360 types in almost all more important laboratories as well as in the centres or in their organizations, it would be highly desirable, if from the beginning the CSISRS system is layed out for a modern storage medium like direct access disk storage and, if the needed storage, correct, change, delete, update and retrieval programs are written in a usual problem-oriented programming language like FØRTRAN-IV or PL/1. It would also be necessary and have to be contemplated to have an easy connection to Russian computers. It is probably also of more general interest, for storage economy reasons and for the purpose of compatibility with other types of computers that the 4-bit representation of the numeric information in the archive file be adopted.

Finally, I wish to thank Mr. Sanitz and Mr. Woll for helpful discussions and criticisms, particularly on this last section.