PROBLEMS OF COMPILING NUCLEAR DATA

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Being a document containing a proposal for the activitites of a Nuclear Data Unit within the IAEA

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ABSTRACT

The magnitude of the task of compiling and presenting to users the data available within the field of interest of the International Nuclear Data Scientific Working Group is considered, both from the point of view of world-wide needs and of what part of this work the International Atomic Energy Agency could reasonably undertake. A proposal is also made in more precise terms for the initial stages of operation of the IAEA Nuclear Data Unit.

SUMMARY OF PROPOSED FUNCTIONS FOR IAEA UNIT

The following short term aims (v.p.18 below) are included:

maintain routine activities on behalf of INDSWG and support this group with technical assessments as necessary

perform the first task of studying 2200 m/sec cross sections and providing a survey paper for the 1964 Geneva conference.

as well as several items which represent interim action on the long term aims. The long term aims are (v.p.10):

receive and transmit, regularly or on request, results of measurements of nuclear data, and store them in suitable form, maintain files of measurer's or other comments on features, resolution, accuracy, reliability, etc. for all "raw" data held in archives

cooperate with the BNL data-file, or if operating on the larger scale, keep such a file and provide excerpts on request; publish data or representative samples at regular intervals

provide facilities for analysis and coordination of data for the use of visiting staff, and perform such work regularly with its own staff

aim, in cooperation with other active centres and laboratories, at producing complete sets of "evaluated data" in a format suitable for users (probably generally on magnetic tape) for important reactor materials, revise these periodically and distribute the resulting information

undertake critical reviews of data as appropriate.

N.B. The second of the long-term aims is clearly subject to discussion with Brookhaven or any other centres working in the same field.

1. The magnitude of the problem - needs to be met

1.1 The situation in Nuclear Data today

It is no new thought that the rate of production of information in the various fields of science has recently been growing so rapidly that the problem of keeping up with the literature is becoming overwhelming. In the narrower field of "Nuclear Data" this is no less true, rather, there are some special characteristics in this field which make the present time a particularly critical one. "Nuclear Data" is here used in the sense defined by the IAEA's International Nuclear Data Scientific Working Group, in which neutron cross sections predominate, for the reason that they are "of basic importance in nuclear energy programmes."

In addition to neutron cross sections for scattering, radiative capture, fission, etc. the field of "Nuclear Data" includes angular and energy distributions of scattered neutrons, both for thermal inelastic (the so-called "moderator scattering law") and true inelastic scattering and (n,2n) and similar processes. For the inelastic scattering or capture processes, the spectra of emitted photons, and their angular distribution, may also be of interest, while for fissile nuclei the quantities ν, η $(=\nu\sigma_f/\sigma_a)$ and α $(=\sigma_a/\sigma_f - 1)$ as well as fission fragment yields and energy must also be included.

Especially for cross sections for neutrons of energy between 10 eV and 10 keV the years around 1963/65 appear to be years of phenomenal growth in the amount and detail of data becoming available, while above 10 keV it is rather that more sophisticated techniques are at this time beginning to be used more widely, so that greater detail is in future to be expected to become available. The increase in data-production rate for the lower energy region is primarily due to the recent development and the currently increasing use of electron linear accelerators as high-intensity sources of very short pulses of neutrons, and the simultaneous development of electronic (time-analyser) techniques. Time-analysers currently in use frequently have 2048 or 4096 time channels, compared with the earlier 100, 256 or 1024 channel models, and the channel widths have been decreased to 10 nanosec in some cases, rather than the 1 or $\frac{1}{2}$ μsec formerly achieved. Two- or three-dimensional analysis systems with an effective number of channels of up to 2^{20} or 2^{24} (about 1-4 million) are also in use.

As a result of this increase in the rate of production of data, established compilation centres such as the Sigma Center at Brookhaven are changing to computer techniques for data-handling, instead of, e.g., plotting graphs by hand, and still the revisions of BNL-325 are appearing less frequently than formerly. In future publications of this type are likely to contain a sample of the available wares, and a catalogue of what is available in archives, rather than a complete representation of

available data. Another problem is that scientific journals - which have never liked printing extensive tables of results - will now seldom print graphs on a large enough scale, or in large enough numbers, to present the results of measurements adequately. Some journals are now even refusing altogether to publish papers of this type, unless some fundamental point of nuclear structure is involved or proved by the results, even though there is a need, for applied physics projects, for the data obtained.

1.2 The reasons for compiling Nuclear Data.

If the scientific journals are already refusing papers in this field, one is forced to ask the next question: who wants these data, and why? What, in fact, is the aim of, and who uses, compilations of Nuclear Data?

Consider as an example the BNL-325 compilation. This useful compilation serves many purposes, including casual users who need merely a few thermal cross sections (e.g. to calculate isotope production rates) or a general picture of resonance phenomena. Others may need one simple curve, such as $\sigma(E)$ for hydrogen, while nuclear structure specialists or astrophysicists have other interests, such as level spacings and other resonance parameters. It is generally the reactor designer's needs which are most detailed, and these concern isotopes contained or produced in the fuel, moderators, structural and shielding materials as well as fission products, burnable poisons, etc.

The determining factor in compilation is that everybody's needs should be satisfied, and in this case the reactor design needs are the ones which are most extensive and largely decide what is needed. As reactor calculations become more sophisticated - and more accurate - what will be increasingly needed is access to an evaluated set of data based on all available measurements, and on theory where no measurements exist. For this purpose detail rejected by journals may be very important. Thus a physicist measuring resonances may himself only analyse the "clean" cases, and publish parameters for enough resonances to make a point concerning nuclear theory, but the reactor designer needs the data from accidentally close pairs of resonances - or from resonances difficult to interpret theoretically - as much as from the "clean" cases. Even if no points of nuclear structure theory are involved, the results of measurement are still valuable.

There is another question. Should all data which has been measured be evaluated and compiled to a degree of detail limited only by measurement resolution, or can a required accuracy or degree of detail needed by the users be specified? If so, should one not try to specify what the users three or five years from now will need? There are also many reactor designers whose systems do not approach the limits of present knowledge and these may not wish to use a complete evaluated set of nuclear data such as has been envisaged here. They can work from

"integral" data and may prefer to use compilations like the Reactor Handbook ANL-5800. However, the workers who compile compilations specially aimed at reactor designers would have a much easier task if complete evaluated sets of "best values" for all data existed. It is not intended that any Nuclear Data compilation group would enter the Reactor Physics field to the extent necessary to produce a compilation like ANL-5800, which includes recipes for heterogeneous reactors (even to parameters for various cluster configurations or uranium rods, e.g.) and other data of this type. But in the last resort, except for self-consistency checks on matters of purely calculational method, all reactor calculations have ultimately to be compared with actual systems - experience or experiments - and imprecise data can therefore lead to wrong conclusions. The use, direct or indirect through Reactor Handbooks, of the best available values of data is therefore very important.

It is of course useless to refine data if no adequate calculational procedures exist to use the data, but we cannot merely take present methods as defining what data will be needed in future. The world compilation effort, although not negligible, is however much smaller than either the world effort in measuring data or in designing reactors and using the data. Centres for evaluation work, therefore, will not be "ivory towers", but equally we should not expect to leave unstudied every element (such as Ge or Ho) for the data on which we do not foresee any immediate reactor need; apart from nuclear structure interest, the effort involved in extending work to extra isotopes is very much smaller than developing and testing the data-handling and data-evaluation methods in the first place. And there are other interests, e.g. astrophysics, too.

Finally, concerning the required degree of sophistication of the data, cases vary. For a simple well moderated (e.g. natural-uranium D_2O) reactor system, unless extreme burn-up or other special conditions are contemplated, rather simple data may suffice. The opposite is true for power breeder reactors or intermediate-energy reactors generally. But the exact calculation of fuel temperature coefficients may in any case require many detailed resonance parameters to be known; in at least one case of a reactor calculation of which we are aware, an imaginary set of resonances has been postulated for this purpose, based on knowledge of strength-functions, etc., by random statistical methods in the overlapping region where measurement is impossible. In other cases group-average values (for anything from, say, 6 to 20-30 groups) may suffice, but these should be based on a well-evaluated $\sigma(E)$ set of values if they are reliably to represent nature. It is less clear exactly how accurately any particular datum (e.g. a resonance parameter) needs to be known and how soon a set of data should be discarded if small changes occur. On the one hand frequent changes render comparison of different reactor calculations difficult; on the other, significantly wrong data may lead to erroneous conclusions in interpreting observations on reactor systems. As reactor codes improve in reliability it may at once become easier to say what errors are significant but more difficult to provide data to the accuracy and with the detail which are in fact needed.

2. The Process of Compilation

In a number of reports, including the author's INDSWG-5, the compilation process for Nuclear Data has been considered as a series of logical stages, from "Indexing" - purely bibliographic - to "Preparation" of a suitable input for a particular type of (e.g. a certain multi-group) reactor calculation code. The latter will be excluded from consideration here, since this phase of the work is generally specific to the needs of some particular country's programme or some particular laboratory's methods, and thus not a suitable activity for a general service organization like the IAEA. At some later date reactor codes may be standardized, and some general service "preparation" activity become possible, but until this happens the most that could be envisaged would be that a worker on the payroll of some particular organization might be allowed access to the IAEA files and facilities to undertake the particular "preparation" work his country or organization required for its own work.

The remaining stages are Indexing, Compilation of "Raw Data", and Evaluation. Some authors use the term "Compilation" only for the processes which precede the "evaluation" stage; in the present report the word compilation is used to cover the whole process. By contrast, "evaluation" is taken to include re-normalization or coordination of results of different experimental "runs", and not confined to the process which finally produces a complete "evaluated" set of data.

2.1 Indexing

The process of preparing bibliographic indices to publications, reports and private communications within the Nuclear Data Field as we have defined it is not trivial, but it is already under way in the form known as "CINDA" in White Plains, N.Y., and also a new project at Electricité de France near Paris. In addition, the Brookhaven Sigma Center magnetic tape file, being developed as a raw data compilation procedure, also has retrieval features, but it is not specifically an "index". There is no present intention within the IAEA to perform any indexing work in Nuclear Data in the wider sense represented, e.g., by the U.S. (National Academy of Sciences) work of Dr. K. Way, except insofar as the Agency's Scientific and Technical Information Division's plans for a general information retrieval system will cover this field.

In view of these existing activities, it would appear that the rôle of the Agency in indexing might be limited to ensuring that references to all relevant material are exchanged between all eastern countries and those of the western area. But if some other country wished to set up an additional CINDA centre, in addition to those in the U.S. and France, the services of the IAEA might be involved to help start such a centre and to ensure a bi-directional flow of information thereafter.

2.2 Compilation of "raw" experimental data

In contrast to indexing, the collection of experimental data is an operation of rapidly-increasing magnitude. The effort required is not only that to receive and store the data. In order that access to the data at a later time for purposes of comparison with other measurements of the same or related quantities will be fruitful, it is also desirable to place on file any available information about the limitations of the method of measurement, and of any special features or deficiencies. It is in practice difficult to distinguish exactly the process from "evaluation"; for example, it is not clear whether the new BNL files will contain all the measurements which have been made of a quantity, or only those which are more recent or adjudged more reliable, or to what extent measured values will have been re-normalized to improve consistency.

For a first estimate of volume of data to be dealt with, the resonance region is worth considering in detail. Most of the data in the future will come from the large accelerators, six or eight of which will soon be working on Nuclear Data. These are mainly electron linacs but also include cyclotrons at Columbia University and the Moscow Theoretical & Experimental Physics Institute. In discussion, Dr. Joly has estimated the possible annual output of "numbers" from one flight path at such a machine as about 300,000 - 400,000. This figure is a little imprecise - it was obtained from considering total cross section measurements where the transmissions of several (perhaps 3 to 5) different sample thicknesses were measured. A "number" is then the result for one thickness and any one time channel; although other runs may overlap the same energy region, all the "numbers" obtained would be counted. Therefore, supposing that the average laboratory only devotes one flight path to Nuclear Data measurements, the world production rate of "numbers" would be of the order of two to three million annually; a rate which should be attained within at most a year or two from now; it will probably be higher if multi-dimensional analyser results are to be included in the compilation.

It is probable that the volume of "raw" data for faster neutrons is relatively much smaller, but it will probably require an evaluation effort comparable to that for the resonance region data. The total generation rate for nuclear data is therefore roughly estimated at three to four million "numbers" per year.

2.3 Evaluation of Nuclear Data

We have already remarked that it is difficult to separate the stages of compiling raw data from its evaluation. Thus, for the total cross section work discussed by Dr. Joly the numbers for the (3 to 5) different sample thicknesses are almost immediately combined to give one number, the cross section for that particular energy. With an allowance for overlapping energy ranges in successive runs, and similar factors, which are also likely to exist for other types of measurement, we see that the annual output of "numbers" expected is reduced by this first stage of evaluation from nearly four million to, say, about 750,000 "effective numbers".

There is also another factor operative; Dr. Joly's figures for a Saclay-type machine were of possible measurements, and in fact, the actual attained output of data "numbers" is currently only about 200,000 per year for his installation. This is because measurements tend to be stopped when the available manpower for interpretation of the results has enough data to keep it fully occupied. The accelerator team may then do something else, such as test or try to improve the machine or its instrumentation. On this basis a better estimate of the world output may be not more than perhaps 500,000 "effective numbers" annually. On the other hand, some newer machines will be more powerful than the Saclay machine - there may be more pressure to make extra measurements since they will be made more quickly on newer machines - and also some of the interpretative work may be done at data evaluation centres. So perhaps 800,000 "effective numbers" annually may remain a good figure to discuss.

The result of a completed "evaluation" operation should be a set of values ("best values" to use an older term) of the quantities concerned as a function of neutron energy, generally for the whole range from a few milli-eV to, say, 15 MeV. Theory or "educated guesses" may sometimes have to be invoked to fill gaps in the available measurements. Resonance parameters are convenient as reducing the number of data points to be quoted in the region where they give a good enough fit to the actual data. For the fissile isotopes σ_f, σ_T and $\bar{\nu}$ or α measurements have also to be combined into a best set. At higher energies, instead of problems of resonance interference, etc., one has to deal with other complications such as (n, 2n) and inelastic scattering phenomena.

It is difficult to estimate the man-power required - or even that already involved - in such work. Much of it is now done part-time by users of the results for reactor calculations, but established compilation groups at ANL, BNL, Livermore, AWRE, Karlsruhe and a number of other places already represent an effort which must approach, if not exceed, the equivalent of 30 to 40 full-time physicists. In many cases, especially in Europe for the higher-energy neutron data, it seems desirable for certain established groups to continue as they are, with only some co-ordination of their efforts or programmes. (In other fields a compilation centre in Vienna could make a valuable contribution of its own to the world evaluation effort.) Probably the best choice of a technical field where additional evaluation effort in Europe would improve the geographical balance of work and provide facilities of general advantage would be in the resonance region.* Such a centre could have the needs of users more closely in mind than groups at the sites where the measurements are made, and could also probably stimulate some of the experimental groups to undertake needed measurements in addition to their established programme, when this was limited by the locally-available interpretative effort. Suitable arrangements would of course be needed, and visits to the measuring sites by the data-centre staff who would analyse the results would of course be essential. It is not clear how much additional data could be obtained as a result of such cooperation, but for certain types of data for which a particular need existed this plan should have a considerable merit.

* See Appendix I for examples of activities proposed

This section therefore concludes with a rather more detailed study of the quantity of data available and the work to be done in the resonance region. The annual world output of perhaps 400,000 data points ("effective numbers") within this limited technical field may represent about 8,000 resonances to be analysed. This figure is obtained by assuming that, on the average, about 10-15 points lie within each resonance while some 30-50 points fall between resonances. Of course, cases vary widely, but it is estimated that shape or area analysis may be needed for, say, 5,000 - 6,000 resonances a year in the years around 1965/67. Multidimensional work (e.g. studies of gamma spectra resulting from neutron capture) is probably additional to this figure. It is interesting to note that there are about 300 isotopes which are stable and of reasonable abundance, or long-lived but of importance in reactors, in the isotope charts; if we assume that the average medium or heavy nucleus has 150-200 resonances in the energy region below that where overlapping is a serious problem, there must be some 50,000 resonances to be analysed, or an eight-to-ten-year "supply" at the rate quoted. In fact, it is not to be expected that all the isotopes will be exhaustively measured; another factor is that attainable experimental resolutions are now so high that further re-measurement with improved resolution may not generally be worth while. Therefore the existing trend towards more detailed studies, with multi-dimensional analyser systems, and away from total cross section measurements, is likely to become a predominant trend by about 1970.

With present techniques, and with the help of computers and automatic plotters, etc., it would still appear that a physicist can probably not analyse more than 70-80 resonances a year, so that some 100 resonance-analysers will be needed to cope with the world's measurements. Only when "fitting" methods for analysis become much more sophisticated, eliminating human intervention (and the plotting of graphs for this purpose) at several stages of the process of studying each group of resonances, is it likely that this figure will rise greatly. At the experimental sites there will probably be 40-50 such physicists continually studying resonances. For the compilation centres of the world to have a total of 15-20 physicists working on data for slow and intermediate neutron energy data would not be unreasonable; perhaps the most that we can expect for international and other world compilation centres for all neutron data is 25-35 physicists, the rest being workers in national laboratories who may spend part of their time on evaluation of data and the rest in preparing it for reactor computation, or in making such computations themselves. Of this latter type of physicist there must already be at least 100, and probably more, with perhaps an evaluation effort equivalent to 50 full-time workers.

3. The suggested long-term rôle of the IAEA in Nuclear Data compilations

We therefore here outline what would appear to be a desirable target, to be attained within a few years, for the work of a Nuclear Data unit within the IAEA. We here consider world needs rather than present budgetary or other limitations, or how long it would take to raise budget ceilings -

in a following section some interim practical steps are proposed. But the fundamental points in the longer-term planning should be:

(a) World needs, as outlined above, of data "consumers".

(b) World supply of data from measuring centres.

(c) Possible extra data measurements which could be stimulated by a data centre offering to interpret the results where a need for certain data could be demonstrated.

(d) The need to attract competent physicists to the work in adequate numbers; adequate facilities are of course pre-supposed.

(e) Competent physicists are essential if the data centre is to achieve scientific respectability and adequately to perform the liaison functions between east and west.

It is felt that such a data centre should keep archives of "raw" data with such critical notes as will facilitate later re-evaluations or comparison of new results with those already held in archive. It should also perform some current evaluation work. It is not felt that a data exchange of a librarianship type is adequately to meet the needs.

As a minimum viable size it would seem necessary to have a team of about six physicists in an IAEA data unit; if the proposed evaluation activities for resonance data are accepted, at least three workers in this field are needed, and two physicists for fast data is a reasonable minimum. There will also be routine archiving and data transmission functions, and technical direction of the work, as well as the IAEA's duties in maintaining the operations of the INDSWG; including the latter functions, a group of at least one senior officer and six supporting professional workers is proposed as a basic IAEA-paid staff. Attachments from national laboratories, or visiting specialists, should bring the total up to 9-10 physicists. If the 6-7 IAEA-payroll figure is in fact not attainable, the only sensible way of reducing staff would seem to be not to undertake any evaluation or critical functions for fast neutron data, in which case a staff of 4 physicists plus an administrative (or librarian-type) assistant with some technical knowledge might suffice. These numbers do not include clerical assistants, card punchers or computer coders.

This proposal is quite modest in terms of the world need, given above as 15-20 physicists in data centres for resonance data alone, and if Brookhaven does not maintain the predominant position it now has, it would be desirable for the IAEA's group to be at least double, and perhaps treble, the size proposed above, rising in the latter case to 20 physicists plus nationally attached staff, making 25-30 in all. Such a centre, efficiently organized, would be able to perform an excellent service on the world scale, although perhaps then it would feel the need to station a few of its workers in the American continent (say New York or Brookhaven), and perhaps two or three in other areas.

3.1 Technical functions of the IAEA data unit (long-term proposal)

A unit such as that proposed should, to summarize:

(a) Receive and transmit, regularly or on request, results of measurements of nuclear data, and store them in suitable form.

(b) Cooperate with the BNL data-file, or if operating on the larger scale, keep such a file and provide excerpts on request.

(c) Publish data or representative samples at regular intervals.

(d) Maintain files of measurer's or other comments on features, resolution, accuracy, reliability, etc., for all "raw" data held in archives.

(e) Provide facilities for analysis and coordination of data for the use of visiting staff, and perform such work regularly with its own staff.

(f) Aim, in cooperation with other active centres and laboratories, at producing complete sets of "evaluated data" in a format suitable for users (probably generally on magnetic tape) for important reactor materials, revise these periodically and distribute the resulting information.

(g) Undertake critical reviews of data as appropriate.

It is not intended (v. page 5, para 1, above) to undertake "preparation" of data for specific reactor codes or to deal with specifically reactor physics problems. The items (b) and (c) above, it must be admitted, are somewhat dependent on decisions yet to be taken with Brookhaven or concerning the activities of any other centres which may also work with Brookhaven in these matters.

3.2 Location of work - costs and preliminary budgetary estimates for the long-term proposals

Exact cost-estimates are rather difficult to make at present, since it is not clear either where the work will be done or what computers will be available. The most favourable case would arise if, at the time in question, an IBM 7090 or similar machine were available for this work in Vienna. It is in general cheapest to use a small fraction of the time of a large computer, but in Vienna we may have to pay some kind of a premium price to obtain the facilities we will need; the alternative is to locate some (or all) of the work away from Vienna. This would cost some money in travelling expenses but we might save on computing costs. A location such as, say, the Paris area (where large computers are available) also has the advantage of the possibility of the members of the group discussing technical problems with experimenters working with the various measuring and analysis techniques. Some of the details of the situation concerning computers in Vienna is given in para. 4 below. But at this time all that can be said is it would be desirable to have most - if not all - the nuclear data unit located at one site if it were away from Vienna. Plans may also be affected by any arrangements which may be made (see para 4.2 below) to cooperate with any other data centre which may be set up.

The budgetary figures which follow are only orders of magnitude, proposed for discussion. "Contingencies or travel" covers the extra costs mentioned in the previous paragraph, normal duty travel being included in staff overheads. We have four cases to consider, viz.

(a) Near-minimum size staff envisaged in para.3 above including some fast neutron specialists, assuming Brookhaven and similar centres continue.

(b) The same but pruned to exclude fast neutron field.

(c) As (a) above but with some margin over the minimum, e.g. enabling visiting specialists to be offered emoluments to come to Vienna to analyse their own work there and correlate it with older measurements available in the archives.

(d) An order of magnitude of what would be needed if centres like Brookhaven closed down and the IAEA had to fill the gap.

There is also a small allowance in the figure for computing time for the costs of a general computer service (card punching and normal programming), but an extra item is shown for the cost of programming staff particular to our own work. This item is quite uncertain since it will depend on where the work is done and how the computer is organized. In all cases, some small additional items (e.g. Fellowships to enable suitable persons to learn-while-working with the Data Unit) may be involved in addition to the items shown below. All figures are $ per annum.

Budget basis (see above)	a	b	c	d
Professional staff*	100,000	70,000	120,000	240,000
Programming staff (est.)*	12,000	10,000	13,000	25,000
General Service Staff*	25,000	18,000	28,000	48,000
Computing time, etc.	80,000	65,000	90,000	175,000
Contingencies or travel	12,000	10,000	14,000	25,000
Publishing and incidental	6,000	5,000	7,000	12,000
Totals $ per year	235,000	178,000	272,000	525,000

The present budget ("a man and a boy") is about $ 75,000, on this basis.

4. <u>A proposal for interim operations of the IAEA Nuclear Data Unit</u>

For 1964 a group of six or seven physicists working on Nuclear Data within the IAEA is not attainable, the budget provides $ 35,000 for computing time, etc., and two staff members will be available, with some expert assistance, e.g. for initial computer programming. Further staff may be hired during the year, but no specific posts yet exist. The aims at this stage are therefore, in addition to drawing up plans for the future:

* including overheads

(a) studying a first (rather modest) technical programme, i.e., the values of the 2200 m/sec cross sections of the fissile isotopes

(b) making arrangements for receiving and placing in archive significant samples of data and for their onward transmission

(c) preparing for the resonance analysis project already described.

First steps have therefore been taken to try to ensure that the basic hardware for such operations is available at the same time that the additional staff members are being recruited. Early in 1964, after the routine matters of the INDSWG meeting have been disposed of, serious compilation activities can begin. During February-May 1964 work will be concentrated on item (a) of the above list which will include a least-squares fit for η and ν as well as the cross-sections. Some work on the values of the resonance integrals for these isotopes will also be involved incidentally in interpreting some of the measured values. This work will lead to the somewhat broader survey of the situation in reactor data for which a paper from the IAEA has been proposed for the 1964 3rd International Conference on the Peaceful Uses of Atomic Energy. The task (b), to be begun more gradually, is the continuing one of keeping archives and maintaining the flow of information, and should also form a basis for the work under heading (c).

By the middle of 1964 it is expected that adequate computer facilities will be available; the details of the position concerning computers is given in Appendix II.

It is proposed to attempt to obtain one or two additional assistant posts for the Nuclear Data Unit, and if possible to have both of them start work during the latter half of 1964. At this time first trials of methods of resonance analysis should have been made and serious work in this field can begin, with efforts directed simultaneously at using existing programmes and developing more flexible ones, including ones based on multi-level resonance theory. The budget request for computer time is being stepped up from this date, and automatic plotting facilities may then become an important requirement.

In 1965 a further increase in staff for the Nuclear Data Unit should become possible. The decision then to be made is whether to start a section within the Unit for critically considering and actively working on fast neutron data. If a budget of roughly the size of alternative (a) of para.3.2 above looks attainable in or by the end of 1966, the time to start looking for a fairly senior specialist on fast neutron data is in 1965, and if this course is possible (in the circumstances prevailing at that time) its adoption is recommended. The team, without the fast data specialist, should then number four and they would be handling the more routine matters (including the committee business of INDSWG) as well as the resonance region work. From late 1965 onwards a further enlargement from five to six or seven staff members should be expected, including at least one additional man primarily for fast neutron data, and there should then also be about three non-professional staff in the group including an (either full- or part-time) computer programming assistant.

4.1 Activities during the initial period

On the basis of a staff complement as outlined above and with perhaps some support in the form of attached staff, it is hoped to fulfill the following functions (the order in which the items are given is roughly chronological, and does not represent their relative importance):

(i) maintain routine activities on behalf of INDSWG and support this group with technical assessments as necessary

(ii) perform the first task of studying 2200 m/sec cross sections and providing a survey paper for the 1964 conference

(iii) maintain archive files of "raw" data and exchange data on a world-wide basis

(iv) perform resonance analysis and other data coordination functions as a contribution to "evaluation" activities

(v) keep in touch with other evaluation work and start to keep archives of evaluated constants, and distribute these on request

(vi) consider problems of publication and relations with other compilation centres.

In the above list, points (iii) and (vi) involve questions of some form of collaboration with Brookhaven. It is believed that the IBM 7040 computer can easily handle activities similar to those proposed by the BNL group for their new magnetic tape data file. By the time the Brookhaven group has built up a useful file of data on magnetic tapes, we should have access to high-density tape facilities and thus be able to take a full part in this work. We would then offer to assume the rôle of an European counterpart and corresponding subsidiary to the BNL Sigma Centre group, to receive and transmit for them data from and to all countries in Europe, and perhaps other areas.

4.2 Relations with other International Nuclear Data Centres

It now appears that another international centre in Europe for Nuclear Data distribution and compilation is also being proposed, under the aegis of ENEA. While additional effort in this field is welcome, it should be a matter for cooperation, and steps should be taken to avoid too much overlapping of function. We also believe that the next few months should enable the IAEA group to clarify any questions of technical feasibility, as well as to demonstrate an actual flow of information in operation. On this basis we would offer to provide close cooperation with the BNL magnetic tape data file system, and if desired to act as European counterpart. By the time their programmes are written and tested, and a useful amount of information has been filed using this system, we should be quite ready with the necessary technical facilities in Vienna.

There has also been a proposal to have, perhaps at Electricité de France, a centre for bibliographic indexing on the lines of CINDA as hitherto operated in the USA (White Plains, N.Y.). We welcome this proposal and do not propose to compete in this activity. If a centre in another geographical area should also wish to establish a CINDA file, and to exchange entries reciprocally, the IAEA would hope to be in a position to provide encouragement and assistance in the initiation of such a centre and to act as a channel thereafter, if desired, for reciprocal exchange of new references between the new site and the older ones.

5. Conclusion

This document is written for discussion within the INDSWG and must therefore be treated as entirely provisional.

APPENDIX I

Examples of special activities concerning the neutron resonance region

As mentioned in the body of the report, in some cases results might be analysed at the international data centre, the measurements concerned being made specially by one of the national laboratories on request from the centre (being additional to those measurements for which local analysis efforts exist). This would be particularly valuable if data were wanted for reactor purposes which did not have a great interest in connection with theories of nuclear structure and therefore might not otherwise be measured.

Also, analyses could be performed by way of supplement to those done by the original investigators, and subsequent thereto, in order to extract whatever additional information can be obtained, e.g., from close pairs of resonances, the nearly-overlapping region, or other special cases.

Although it is technically one of the most difficult problems, a principal aim of the centre should be to study and co-ordinate the measurements (e.g., of σ_f, σ_T and α or η/ν as a function of energy) for the principal fissile isotopes. The problem of adjusting such data for consistency may have to be dealt with before an understanding of resonance interference effects for these isotopes can be reached.

Multi-level formulae of various types should also be made the basis for semi-automatic analysis. This subject has some interesting possibilities; to take one example, which arises from the fact that multi-level fits appear not to be unique - a given set of experimental results might be reasonably well fitted by several different multi-level formulae. The nuclear data unit might then, for example, perform doppler-width-variation or other studies based on the different theoretical fits, and proceed - if necessary in collaboration with some interested reactor design group - to investigate whether any significant differences existed, from the users' point of view, between the results using different models to fit the data.

Summary of Computer Facilities expected to be available in Vienna.

In Service Centres in Vienna there are available a Zuse 23 and an IBM 1401 as well as, at present, an IBM 1620 (which however may shortly be discarded). However it is felt that the receipt, storage and reissue of data, probably at irregular intervals and in miscellaneous formats, is not a very suitable operation for contracting to a commerical Service Centre. In an earlier document the plans for installing an IBM 1620 computer at Seibersdorf in the Austrian Atomic Energy Studiengesellschaft laboratories were also mentioned, but these are now in abeyance. No decision has yet been taken about installing a computer on the IAEA premises but it is clear that any such computer would necessarily be a small unit of limited capabilities.

However, the Vienna Technische Hochschule Institute for Mathematics and Mathematical work (under Professor R. Inzinger) is expecting delivery of an IBM 7040 computer around 1st April 1964, and it is now clear that access by IAEA personnel to this installation can be arranged. The financial terms for such access have yet to be negotiated and some features of this installation still depend on confirmation of a contract for part-time use by the IBM Research Group in Vienna. However, it now appears almost certain that a 16384-word memory will be available and that five IBM type 7330 magnetic tape units will be attached to the machine. It also seems likely that provision of a 32768-word memory or magnetic tape units of a more advanced type could also be arranged if we required these, but in such a case a partnership-contract, including a guaranteed minimum time-rental clause, would have to be negotiated. Some other details are not yet settled, including whether time could be rented on a smaller machine for input and output operations or how or where an automatic graphical plotter could be installed. It is possible that the IBM Service Centre 1401 computer could have the necessary features added to enable it to perform these functions, but several alternatives also appear possible.

Such an IBM 7040 computer appears likely to be suitable for essentially all the resonance analysis work which we propose to undertake, and we plan to do everything except input operations and format changes (such as punched tape to card conversion) on the 7040. With suitable arrangements for graphical plotting, good facilities for semi-automatic resonance parameter fitting work would thus be provided. Since the Technische Hochschule is only five minutes walk from the IAEA headquarters, this arrangement appears very favourable. Whether or not a computer is installed on the IAEA premises thus appears to affect our plans only peripherally.

We therefore expect to be able to confirm, before the January INDSWG meeting, that arrangements as indicated above with Professor Inzinger are in fact possible. The computer should be available for use in April 1964, although the magnetic tape units may only arrive one or two months later. Other changes subsequently found to be necessary (e.g., larger memory size) could be added, with only the normal delays for delivery of IBM equipment from the date of the necessary special contract and minimum-time guarantee. The costs of any unused time incurred under such a guarantee could probably be justified because the only alternative would be to spend additional funds on locating the Nuclear Data unit away from Vienna. Subject, therefore, to any recommendations from the January meeting we expect to be able to arrange adequate facilities for this work with a minimum of difficulty.

Appendix II revised:
4th December 1963