International Atomic Energy Agency

INDC(CCP)-33/L

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

DETERMINATION OF REQUIRED ACCURACY OF NUCLEAR DATA

L.N. Usachev and Yu.G. Bobkov

Translated by the IAEA

July 1973

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

INDC(CCP)-33/L

DETERMINATION OF REQUIRED ACCURACY OF NUCLEAR DATA

L.N. Usachev and Yu.G. Bobkov

Translated by the IAEA

July 1973

This document consists of two papers. The first " Mathematical Theory of Experiments and Generalized Perturbation Theory - An Effective Approach to Reactor Physics Investigations " is from Nuclear Constants, Vol. 10. The second, " Determining the Necessary Accuracy of Nuclear Data With Allowance for Integral Experiments " is a paper presented at the Neutron Physics Conference Kiev, June 1973.

CHAPTER I. NUCLEAR DATA

MATHEMATICAL THEORY OF EXPERIMENTS AND GENERALIZED PERTURBATION THEORY - AN EFFECTIVE APPROACH TO REACTOR PHYSICS INVESTIGATIONS

L.N. Usachev, Yu.G Bobkov

Part 1

Sequential planning of integral experiments and an effective method of fitting constants with allowance for correlation of the errors of a set of microscopic measurements

1. Introduction

Generalized perturbation theory gives a linear relation which can be used to express the relative variation of any reactor parameter through relative variations of nuclear data and concentration of matter [1]. The existence of this linear relation or, as it is called, the linear response function of a reactor parameter to perturbation of the micro-constants enables us to use some effective methods which have now been developed in the mathematical theory of experiments for solving a number of problems of theoretical and experimental reactor physics. From the point of view of the mathematical theory of experiments the measurement of any reactor characteristic may be considered to be an indirect measurement of the nuclear constants. In this type of treatment one can use a set of microscopic and integral measurements for predicting the parameters of a reactor design and the dispersion of these parameters. In this paper we have overcome the main mathematical difficulty of this treatment, which is the need to invert a matrix, whose order of magnitude is equal to the number of nuclear parameters and may, according to existing sources, amount to 400. In this way, an algorithm can be performed on a small computer. The information content of any experiment, defined on the basis of its contribution to improving the accuracy of predictions of significant quantities, can and must be checked before the experiment is actually performed using the algorithm presented in this paper. In this way the efficiency of expensive experiments on critical

assemblies can be greatly increased. The usual estimates based on various specific applications of the experiment planning theory indicate an increase in experimental efficiency by a factor of 3-5. This estimate is confirmed in this paper by the results of an analysis of the information content of a number of integral experiments.

A. Existing methods of fitting group parameters on the basis of a set of integral and differential measurements

An excellent survey of work on the use of a set of microscopic and integral experiments for fitting group constants and for predicting reactor characteristics with computable accuracy is provided by Campbell and Rowlands in Ref. [5]. Therefore in this section we shall not consider the theory of the problem but shall follow the work of Rowlands and MacDougall [2] for introducing fundamental concepts. However, the method of allowing for error correlations in nuclear data will be taken from our own work on planning an optimum set of differential measurements and evaluations [8]. The allowance for error correlations is based on splitting up the relative error into components which differ in their correlation characteristics. According to the simple model adopted there are three such components. The first component is completely correlated. The statistical error is associated with this component. The second error component, caused by the systematic measuring error, for example, of the energy/cross-section dependence, is regarded as completely correlated in a certain energy interval, designated the correlation interval. This error component may be regarded as the error in the normalizing of the curve.

The third error component derives from the application in the measurements of a standard, the error in the value of which is transposed to the quantity in question and comprises its third component. Obviously this error component will be identical for different quantities measured with respect to the same standard.

The sensitivity of reactor parameters to variations in components of the first type is determined by the quantities $Z_\ell = S_{\alpha ij}$, where $S_{\alpha ij}$ are the coefficients of the perturbation theory relation.

$$\delta C/C = \sum_{\alpha i j} S_{\alpha i j} \left(\delta\sigma/\sigma\right)_{\alpha i j} \qquad (1)$$

α = the index of the isotope

i = the index of the process

j = the index of the energy group.

The sensitivity to variations of components of the second type is determined by the values:

$$Z_\ell = \sum_{j=n}^{m} S_{\alpha i j} \qquad (1a)$$

where n and m are the numbers of the first and last groups of the correlation interval; finally, the sensitivity to variations of components of the third type is determined by the quantities:

$$Z_\ell = \sum_{\alpha} \sum_{i} \sum_{j} S_{\alpha i j} \qquad (1b)$$

Summation with respect to i and α is performed for three processes and isotopes respectively, in the measurement of which the given standard is employed.

The values of the error components listed above are statistically independent and the covariant matrix of such a set of measurements and evaluations will be diagonal. By definition in the mathematical theory of experiments this procedure is equivalent to constructing the orthogonal plan of a set of differential measurements and evaluations.

The problem of fitting the group constants is reduced to finding corrections for the cross-sections $f_x = (\delta\sigma/\sigma)_x$ minimizing the functional:

$$L = \sum_{x=1}^{N_1} f_x^2/g_x^2 + \sum_{I=1}^{N_0} \left(\frac{E_I - C_I'}{C_I}\right)^2 / e_I^2 \qquad (2)$$

where e_I and g_x are the accuracies of the integral and differential measurements respectively. N_1 is the number of independent components of the error in the differential measurements, N_0 = the number of integral

measurements. C_I is the theoretical value of the integral characteristic I, E_I is the experimentally measured value of this characteristic; $C_I' = C_I(1 + \Sigma Z_{Ix} f_x)$, Z being the sensitivity coefficients determined above. Here and subsequently we mean by sensitivity coefficients not simply the coefficients of relation (1) but the coefficients taking into account the correlation characteristics of the components. Finding the minimum (2) reduces to solving the system of linear equations

$$M \cdot f = Y \tag{3}$$

M is Fisher's information matrix, dependent on the perturbation theory coefficients and the measuring accuracy

$$M_{ij} = \sum Z_{Ii} Z_{Ij} / e_I^2 + \delta_{ij} / g_i^2 \tag{4}$$

δ_{ij} is the Kronecker symbol

$$Y_i = \sum_I \left[\frac{(E_I - C_I)}{C_I} \frac{1}{e_I^2} Z_{Ii}^T \right] \tag{5}$$

The solution of the system (3) is the vector

$$f = M^{-1} Y = D_{N_o} Y \tag{6}$$

The matrix D_{No} is called the covariant matrix of the set of N_o measurements. Displacement of the theoretical value R of the reactor parameter relative to its initial value, caused by using the results of the set of integral experiments, is written

$$\left(\frac{\Delta R}{R}\right)_{N_o} = Z^R \cdot f = Z^R D_{N_o} Y \tag{7}$$

Z^R are the sensitivity coefficients of the parameter.

The dispersion of the prediction of this parameter on the basis of the given set of measurements is determined by the value δ_{No}

$$\delta_{N_o}^2 = Z^R D_{N_o} Z^{R\,T} \tag{8}$$

Thus, when solving this problem, we run up against several difficulties: in the first place, it is necessary to convert the high order matrix M, since the number of constants, on which the integral parameter depends, is very high. In Ref. [5] it is as much as 200. We were only able to reach 53 in Ref. [6] because of the low computer capacity. Nor is it possible, on the basis of the above-mentioned considerations, to investigate what type of experiment should be performed to establish this reactor parameter more accurately. The shortcomings of the approach discussed above can be overcome by employing the concepts of sequential experiment planning.

B. Methods of sequential experiment planning as applied to reactor physics

Using these methods it is possible to carry out successive analysis of each new experiment from the point of view of its information content in relation to the preceding set. For this purpose it is necessary to express the covariant matrix of the set of $(N_o + 1)$ measurements by the covariant matrix of the N_o measurements. As we know from Ref. [7], this has been done by Box and Hunter.

The information matrix of the set of N_o measurements $M(N_o)$ takes the form

$$M_{\alpha\beta} = \sum_{i=1}^{N_o} w_i Z_{i\alpha} \cdot Z_{i\beta} \qquad (8a)$$

w_i is the statistical weight of the i^{th} measurement
$w_i = 1/e_i^2$;
$Z_{i\alpha}$ are the sensitivity coefficients of this measurement.

Adding the new experiment with the statistical weight w and the sensitivity coefficients G:

$$M(N_o+1) = \sum_{i=1}^{N_o} w_i Z_i Z_i^T + w G G^T = \qquad (8b)$$

$$= M(N_o) + w G G^T$$

The covariant matrix $D(N_o + 1)$ is now written

$$D(N_o+1) = \left[M(N_o+1)\right]^{-1} = \left[D^{-1}(N_o) + w G G^T\right]^{-1} \qquad (9)$$

This formula, as shown in Ref. [7], page 6, may be converted to

$$\mathcal{D}(N_0+1) = \left(I - \frac{w\,\mathcal{D}(N_0)\,G\,G^T}{1 + w\,G\,\mathcal{D}(N_0)\,G^T} \right) \mathcal{D}(N_0) \qquad (10)$$

In addition

$$Y(N_0+1) = Y(N_0) + \left(\frac{E-C}{C}\right) w \cdot G^T \qquad (11)$$

The displacement vector of the group parameters takes the form

$$f(N_0+1) = \mathcal{D}(N_0+1)\, Y(N_0+1) \qquad (12)$$

2. A new method of fitting the group parameters, based on the combined use of the differential and integral experiments

Formula (10) is a recurrent relation for the covariant matrix. Our proposal is to commence the treatment with the whole set of differential measurements, the information matrix for which is diagonal, so that the covariant matrix can be simply obtained. Successive addition of one integral experiment, based on the use of formula (10), enables us to obtain the covariant matrix of any set of integral measurements together with the differential measurements by simple multiplication of the matrices. Thanks to the absence of the matrix inversion operation there is no limitation on the number of parameters. It is then easy to observe the information content of each experiment which is of course determined as its contribution to reducing the dispersion of the predicted reactor parameter.

It should be noted that, even with a set of purely differential measurements, if we do not divide the error into components with different correlation characteristics and do not proceed from coefficients S to Z, correlations between the different quantities arise, resulting from the methods of measurement and possible systematic errors, and this is bound to destroy the diagonality of the covariant matrix.

Thus, with no orthogonal plan for the microscopic measurements, it would be impossible to use the above method.

Moreover, since we can write the analytical expression for the dependence of the accuracy of the predicted reactor parameter on the accuracy of the new integral experiment, it is possible, even before a real formulation

of the experiment, to estimate its information content and formulate requirements with regard to measuring accuracy. The only data needed for this are the sensitivity coefficients.

3. Investigation of the information content of integral experiments

Formulae (10) and (11) can be used to obtain very useful relations for the displacement of the predicted reactor parameter by virtue of the $N_o + 1$ measurement:

$$\left(\frac{\Delta R}{R}\right)_{N_o+1} = Z^R D(N_o+1) Y(N_o+1) = \left(\frac{\Delta R}{R}\right)_{N_o} + \frac{w Z^R D(N_o) G^T}{1 + w G D(N_o) G^T}\left(\frac{E-C}{C}\right) - \frac{w Z^R D(N_o) G^T G D(N_o) Y(N_o)}{1 + w G D(N_o) G^T} \qquad (13)$$

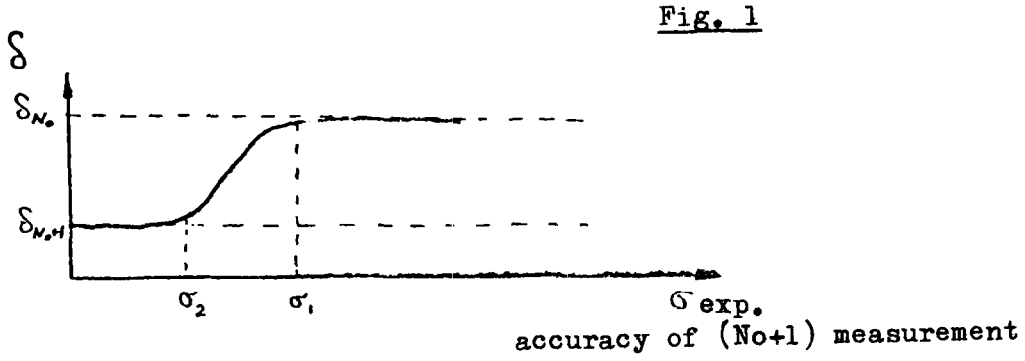
Here E and C are the measured and theoretical values of the $N_o + 1$ experiment. With this notation we can separate the part of the displacement which depends on $\left(\frac{E-C}{C}\right)$.

From formulae (10) and (8) we obtain the expression for the variation in dispersion of the predicted reactor parameter

$$\delta^2_{N_o+1} = \delta^2_{N_o} - \frac{w Z^R D(N_o) G^T G D(N_o) Z^{R^T}}{1 + w G D(N_o) G^T} \qquad (14)$$

Formula (14) shows that there is a simple analytical dependence of the prediction accuracy on the accuracy of the new integral experiment in the most general case. This dependence takes the form

Fig. 1



For specific calculations it is necessary to formulate clearly the purpose of a given experiment or set of experiments and to analyse how well they achieve this purpose. It may well be that the attainable accuracy of the experiment is to the right of the limit σ_1 so that no increase in accuracy is achieved or, conversely, it lies to the left of σ_2, so that further increase in the accuracy of the experiment is pointless. It is also necessary to investigate the information content of the given type of experiment, which we define as the increase in accuracy $\Delta = \delta_{No} - \delta_{No+1}$ at the limit of the infinitely small measuring errors in the given experiment. By the type of experiment we mean the measured quantity, the composition of the assembly etc. The information content of the experiment may prove insufficient to justify devoting considerable time and effort to the experiment.

To illustrate what has been set out above, we shall present the results of calculations of the information content of experiments on ZPR-III concerning the K_{eff} of BN-600 (Table 1). In the Table δ_1 is the accuracy of calculating K_{eff} of BN-600 from differential measurements alone (diagonal covariant matrix), δ_2 is the accuracy of calculating K_{eff} of BN-600 from the preceding set of differential measurements and the corresponding integral experiment performed with "infinite" (i.e. better than σ_2) accuracy. The quantity δ_2 characterizes the information content of the experiment.

The quantities σ_1 and σ_2 correspond to the symbols in the Figure. All the values are given as percentages.

Table 2 shows the results of calculations in the case where the experiments are analysed successively and are included in the covariant matrix with an accuracy of σ_{exp}.

From Table 2 it can be seen that the refinement of K_{eff} of BN-600 provided by five experiments for K_{eff} is almost the same as for the first two experiments and does not differ significantly from the refinement provided by one experiment for K_{eff} on ZPR-III-29, although all these experiments separately give considerable refinement (Table 1). A further increase in the accuracy of K_{eff} of BN-600 is difficult to achieve with K_{eff} experiments on the assemblies and one must resort to experiments of another type such as sample reactivity and lifetime.

The results of the calculations presented suffice to show that it is better to carry out experiments of different type on a large number of compositions and, having selected the most informative assembly, to study in detail the different reactor functionals, after first determining their information content with respect to the existing set of experiments and the optimum accuracy with which to measure that functional.

Table 1

No. of assembly	Type of exp.	δ_1	δ_2	σ_1	σ_2
25	K_{eff}	2,42	2,30	5.	0,5
23	K_{eff}	2,42	I,6	5.	0,5
2A	K_{eff}	2,42	I,6	5.	0,5
35	K_{eff}	2,42	I,2	5.	0,5
30	K_{eff}	2,42	I,2	5.	0,5
29	K_{eff}	2,42	I,0	5.	0,5
29	ℓ	2,42	2,3I	8.	0,7
II	ℓ	2,42	2,38	8.	0,7
II	Δk_8	2,42	I,8	20.	2
29	Δk_8	2,42	I,8	20.	2
25	Δk_8	2,42	I,8	20.	2
25	Δk_5	2,42	2,4		
29	Δk_5	2,42	2,38	20.	2
II	Δk_5	2,42	2,39	20.	2
29	$\overline{\sigma 8}/\overline{\sigma 9}$	2,42	2,4	6.	0,6
29	$\overline{\sigma 5}/\overline{\sigma 9}$	2,42	2,I	8.	0,7

Table 2

	No. of Assembly	Type of experiment	δ_1	δ_2	$\sigma_{экс}$
I	25	K_{eff}	2,42	2,3	0,5
2	29	K_{eff}	2,3	0,93	0,5
3	23	K_{eff}	I,06	I,055	0,5
4	2A	K_{eff}	I,055	I,043	0,5
5	35	K_{eff}	I,049	0,94	0,5
6	25	Δk_8	0,988	0,979	5
7	29	Δk_8	0,983	0,929	5
8	II	Δk_8	0,948	0,929	5
9	29	Δk_5	0,942	0,90	5
I0	25	Δk_5	0,940	0,68	5
II	29	ℓ	0,92	0,82	7
I2	25	ℓ	0,9I	0,66	7
I3	29	$\overline{\sigma 8}/\sigma 9$	0,88	0,56	2
I4	II	Δk_5	0,65	0,62	5
I5	29	$\overline{\sigma 5}/\overline{\sigma 9}$	0,63	0,62	0,5

δ_1 is the accuracy of calculating K_{eff} of BN-600 on the basis of the whole preceding set of experiments, δ_2 is the accuracy of calculating K_{eff} on the basis of the preceding set plus the given experiment with infinitely small measuring error; the experiments are added to the covariant matrix, it being assumed that they were performed with an accuracy of σ_{exp}.

REFERENCES

[1] USACHEV, L.N., Atomn. Energ. 15 (1963) 472.

[2] USACHEV, L.N., ZARITSKY, S.M., Bjul. inf. Centr jad. Dannym, issue No. 2, Moscow, Atomizdat (1965) 242.
ZARITSKY, S.M., Bjul. inf. Centr jad. Dannym, issue No. 6, Atomizdat (1969) 289.

** [2] ROWLANDS, J., MacDOUGALL, J., The physics of the design and manufacture of fast reactors, BNES, London (1969).

[3] BARRE, J.Y., RAVIER, J., in Fast Reactor Physics (Proc. Symp. Karlsruhe, 1967) IAEA, Vienna (1968) 205.

[4] GANDINI et al., Comparison of the experimental and theoretical characteristics of fast critical assemblies, ANL 7320 (1966).

[5] CAMPBELL, G.C., ROWLANDS, J.L., "The Relationship of Microscopic and Integral Data", Nuclear Data for Reactors (Proc. Conf. Helsinki, 1970) 2 IAEA, Vienna (1970) 391.

[6] USACHEV, L.N., BOBKOV, Yu.G., O sovokupnom ispol'zovanii resul'tatov integral'nyh i differencial'nyh izmerenij v probleme jadernyh dannyh dlja reaktorov (Combined use of the results of integral and differential measurements in nuclear data for reactors). Paper presented at Conference on Neutron Physics for Reactors, Kiev (1971).

[7] NALIMOV, V.V. (Editor), Novye idei planirovanija eksperimentov (New concepts of experiment planning) Moscow, izdat. Nauka (1970).

[8] USACHEV, L.N., BOBKOV, Yu.G., Planirovanie optimal'noi sovokupnosti mikroscopičeskih izmerenij i ocenok, obecpečivajuščee zadannuju točnost' rasčeta reaktora (Planning the optimum set of microscopic measurements and evaluations to give the required accuracy in reactor calculations), Paper presented at Panel on Neutron Nuclear Data Evaluation, Vienna 30 August-3 September 1971, summarized in IAEA Technical Reports Series 146 and reproduced in full in unpublished document IAEA-153 available from the Nuclear Data Section of the Agency.

** Translator's Note. There are two [2]s in the original.

Neutron Physics Conference, Kiev, June 1973

DETERMINING THE NECESSARY ACCURACY OF NUCLEAR DATA WITH ALLOWANCE FOR INTEGRAL EXPERIMENTS

L.N. Usachev, Yu.G. Bobkov
Institute of Physics and Power Engineering

The problem formulated in the title of this paper will be considered as applied to the dispersion of theoretical predictions of the conversion ratio (CR) and the effective multiplication factor (K_{eff}) for a simplified model of a large plutonium reactor, described by the authors and V.N. Manokhin in Ref. [1]. The reactor has the following parameters: a core volume of 5 m^3, a capacity of 1000 MW(e), a plutonium charge of 1630 kg, and a concentration of fuel (mixture of uranium and plutonium oxides), sodium and steel in the core of 40, 40 and 20% respectively. The plutonium concentration in the fuel is 11.3% and the isotope composition of the plutonium is ^{239}Pu 61%, ^{240}Pu 30%, ^{241}Pu 6% and ^{242}Pu 3%. Fission fragments account for 4% of the amount of plutonium and uranium.

The permissible dispersions of the predicted CR and K_{eff} due to errors in the nuclear data are considered to be 4 and 1, corresponding to permissible errors of 2% and 1%. Dispersions of 36 in the CR and 10.4 in the K_{eff}, i.e. errors of 6% and 3.8% respectively, correspond to the attained level of accuracy of nuclear data described in Ref. [1].

The first three columns as well as the seventh column of Table 1 reproduce in abbreviated form the data in Ref. [1] for the isotope and the quantity, the energy interval, the accuracy attained in the nuclear data and the contributions of the errors of different nuclear data to the dispersion of the CR.

The fourth column of the Table shows the required accuracy of the set of microscopic values which provides the required accuracy of the reactor parameters and the sixth and eighth columns show the corresponding contributions

to the dispersion of K_{eff} and CR, i.e. to unity and to four. The contributions of the errors of the different values to the dispersion of K_{eff} at the accuracy level achieved are shown in column 5.

The required accuracy of the different values, which is given in the fourth column, was obtained using an algorithm described in Ref. [2], in which the problem of determining these required accuracies is formulated as a problem of the mathematical theory of experiments which involves finding the optimum plan for the measurements and evaluations of microscopic nuclear data. The meaning of the errors in Table 1 follows from the simple and realistic model proposed in Ref. [2] for taking into account correlations between errors of different quantities. The error in $\bar{\nu}$ is the component of the error in the measurements relative to $\bar{\nu}$ of ^{252}Cf correlated over the whole energy range. The achieved and the required error of $\bar{\nu}$ of ^{252}Cf, which is 0.3%, is not included in the error values presented. The cross-section errors presented are the components of the error in measurement relative to a particular standard cross-section and are fully correlated in the given energy intervals. By the error in flux measurement we mean the error in the standard cross-section (above 100 keV for σ_f of uranium-235 and less than that for boron-10). Here again we are concerned only with the error component which is completely correlated over the given energy intervals.

It should also be noted that the required accuracy given in the fourth column differs from the required accuracy which provides a dispersion in the CR equal to 4 (see Ref. [1]), in the more stringent requirements for the fission cross-section of ^{239}Pu and for the accuracy of the standard cross-section (flux). The requirements of the fourth column provide dispersions in the CR and K_{eff} of 4 and 1.

As we can see by comparing the third and fourth columns, the accuracy requirements for the microscopic experiments are on average three times higher, which means that the experiments to be carried out will cost nine times as much as those performed hitherto, if the cost of an experiment is taken to be inversely proportional to the square of the error.

The question arises whether it would be possible to use integral experiments to reduce the accuracy requirement for microconstants and under what conditions.

Let us consider the integral experiments on the BFS-23 assembly [3] and the ZPR-3-48 assembly [4] which contain plutonium in the core. The core volume, the plutonium charge and its concentration in the fuel are 0.8 m^3, ~70 kg and 13% respectively for BFS-23, and 0.37 m^3, 260 kg and 17% for ZPR. The types of experiment are indicated in Table 2 and in the remarks in Table 1. The methods of using integral experiments to reduce the dispersion of the predicted reactor parameters is developed by the authors in Ref. [5] in terms of the method of sequential experiment planning, described by Fedorov in Ref. [6].

Provided that all the experiments indicated in Table 2 are carried out on both assemblies with an accuracy of σ_1, the requirements for measurements of the microscopic constants are reduced to those given in column 9 of Table 1. If only the experiments on the cross-section ratios in the centre of the assembly are employed, the requirements are reduced to those given in column 10 of Table 1.

The reductions in the requirements are very significant but at the present time they cannot be considered of practical value, since the errors in the integral experiments, which - apart from the errors of the experiment itself - include the disparity between the theoretical model and the experiment, are better characterized at present by the σ_2 column of Table 2. This means that, for all practical purposes, the requirements for microscopic experiments are not reduced.

It is interesting to note the theoretically determined fact that the various integral experiments on the ratios of processes in the centre of the assembly actually affect only the contributions of the errors of the cross-sections which are included in the measured ratios. Thus, for example, if the integral measurement of $\alpha = \frac{\sigma_c^9}{\sigma_f^9}$ in the centre of the assembly is excluded, this merely has the effect of taking away the reduction in requirements for microscopic measurements of α which has practically no effect on the other values. It should also be noted that the integral experiments investigated do not reduce at all the accuracy requirement in respect of inelastic scattering by ^{238}U and reduce only to a small extent the accuracy requirement for capture by ^{238}U; moreover, the requirements for α of plutonium are not reduced either, since the

integral experiment for α with the required accuracy is obviously very problematical, and the K_{eff} experiment does not affect the requirements for α.

It should also be noted that the process for reducing accuracy requirements by integral experiments on the various error components obviously leads to a better plan than that described in Ref. [1], which is based on uniform reduction of requirements for all values and not just those which are most markedly affected by this integral experiment. An illustration of this is the significant reduction in accuracy requirements for the fission cross-section and the flux measurement to the values already attained by virtue of the integral measurement of K_{eff}, if the requirements are lowered in those components which are most greatly affected by the integral experiment. If the lowering of requirements is distributed all over components, as was done in Ref. [1], this effect will be less significant.

And, finally, it should be noted that it was possible to present the requirements and the reductions in requirements due to the integral experiments for both CR and K_{eff} with good accuracy in one table (Table 1). The requirements for fission cross-sections and flux measurements are determined by the K_{eff}, α is determined by the CR and the remaining values are determined by both of these in equal degree.

Table 1

Isotope Quantity	Energy interval MeV	Acc.y attained	Requ.d Acc.y	Contr.to disp. of Keff: Attained	Contr.to disp. of Keff: Required	Contr.to disp.of CR: Att.	Contr.to disp.of CR: Requ.	Accuracy requ. w/allowance f. integral experiments	Accuracy requ. w/allowance only f.cross-section ratio experiments	
I	2	3	4	5	6	7	8	9	IO	
Pu^{239} σ_F	0,8-0.I	6	I.5	0.85	0.09	0.0I	0.00	6	8 + 2.5	
	<0.I	5	I.5	0.90	0.I2	0.04	0.0I	6	8 + 2.5	
Pu^{239} σ_C	0.8-0.I	I5	5	0.03	0.0I	I.I5	0.I3	5(I5*)	5 (I5*)	
	<0.I	I0	3.6	0.08	0.0I	3.I7	0.42	3,6(I0*)	3,6 (I0*)	
Pu^{239} ν_F	I0,5-0.00	I.5	0.5	0.60	0.05	2.0	0.26	I,5	0.5	Keff of the assemblies considered is assumed to be measured with an accuracy of 0.5%
U^{238} σ_C	0.8-0.I	I0	3.0	0.83	0.04	I.42	0.I4	4.5	4.5	The ratio $\sigma_c 8/\sigma_f 9$ is assumed to be measured in the assemblies with an accuracy of 2%
	<0.I	I5	2.7	3.0I	0.07	I3.5	0.43	5	5	
U^{238} σ_F	I0.5-I.I	5	2	0.I6	0.02	0.54	0.09	5	5	
U^{238} ν_F	I0.5-I.I	3	I.0	0.I3	0.0I	0.43	0.08	3	I.0	

* Provided that there is integral measurement of $\sigma_c 9/\sigma_f 9$, otherwise the requirements are not lowered.

- continued

Table 1 (continued)

I	2	3	4	5	6	7	8	9	I0	II
U 238	I0.5-6.5	80	9	0.27	0.02	0.7I	0.I0	9	9	
Sin	2.5-I.4	I5	3+4	I.03	0.04	I.98	0.I7	3 + 4	3 + 4	
	I.4-0.8	I0	3.0	0.46	0.03	3.42	0.22	3.0	3.0	
Flux	I0.5-0.8	6	I.5	I.49	0.05	I.6I	0.I5	6	2	
	0.8-0.I	3	I.5	0.I0	0.0I	0.03	0.02	3	2	
	0.I-0.8	4.0	2.5	0.0I	0.00	0.I3	0.04	4	2.5	
Steel	I0.5-0.8	50	I7	0.I3	0.02	0.39	0.07	I7	I5	
	0.8-0.I	80	I3	0.05	0.0I	0.I9	0.05	I3	I0	
	0.I-0.0	30	I0	0.04	0.0I	0.40	0.08	I0	I0	

* Provided that there is integral measurement of $\sigma_c 9/\sigma_f 9$, otherwise the requirements are not lowered.

Table 2

Required accuracies of integral experiments

Type of experiment	Δ	σ_1	σ_2
Keff	3 ÷ 4	0.5	5
σ_{F8}/σ_{F9}	20	6	25
σ_{c3}/σ_{F9}	6 ÷ 7	2	I0
σ_{F41}/σ_{F9}	9	3	I2
σ_{c9}/σ_{F9}	I0	3	I3

Δ The accuracy with which this experiment can be calculated on the basis of the existing accuracies of nuclear constants.

σ_1 Lower accuracy limit of the experiment. Performing the experiment with an accuracy better than σ_1 does not increase its information content.

σ_2 Upper accuracy limit of experiment. Performing the experiment with an accuracy less than σ_2 is pointless, because the experiment becomes quite uninformative.

REFERENCES

[1] USACHEV, L.N., MANOKHIN, V.N., BOBKOV, Yu.G., Točnost' jadernyh dannyh i ee vlijanie na razrabotku bystryh reaktorov (The accuracy of nuclear data and its influence on fast reactor development), Applications of Nuclear Data in Science and Technology (Proc. Symp. Paris, 1973) IAEA, Vienna, in press.

[2] USACHEV, L.N., BOBKOV, Yu.G., Planning of an Optimum Set of Experiments and Evaluations. INDC(CCP)-19/U, Vienna, 1972.

[3] VOROPAEV, A.I. et al., Analiz resul'tatov nekotoryh integral'nyh experimentov na sborkah BFS-22 i BFS-23 (Analysis of the results of some integral experiments on the BFS-22 and BFS-23 assemblies) (1973).

[4] BROMFIELD, A.M. et al. ZPR-III-Assembly 48: Studies of a Dilute Plutonium-Fuelled Assembly. Proc. Int. Conf. on Fast Critical Experiments and Their Analysis. ANL 7320 (1966).

[5] USACHEV, L.N., BOBKOV, Yu.G. Matematiceskaja teorija planirovani ja experimenta i obobščennaja teorija vozmuščenij - effektivnyj podhod k fizike reaktorov (Mathematical theory of experiment planning and generalized perturbation theory - an effective approach to reactor physics), Jadernye Konstanty, issue No. 10, Moscow, Atomizdat (1972).

[6] MALIMOV, V.V. (Editor) Novye idei planirovanija experimenta (New concepts of experiment planning) Moscow, Izdat. Nauka (1970).