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TWO CODES FOR EVALUATION OF NUCLEAR ACCIDENT DOSIMETRY SYSTEM

Hungarian Academy of Sciences

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BUDAPEST

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TWO CODES FOR EVALUATION OF NUCLEAR ACCIDENT DOSIMETRY SYSTEM

P. Zaránd
Central Research Institute for Physics, Budapest Hungary
Reactor Research Department

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ABSTRACT

In this report the author describes two computer codes written for evaluating of nuclear accident dosimeters /NAD/ based on activation detectors. The codes compute and plot kerma, neutron dose due to H/n,gamma/ reaction, neutron dose due to recoils and neutron fluence along with other quantities useful in nuclear accident dosimetry.

РЕЗЮМЕ

В статье описываются две программы ЭВМ, которые предназначены для оценки ядерных аварийных дозиметров, собранных на активационных детекторах. С помощью программ вычисляются: керма, доза нейтронов /ядерная и протонная отдача вычислены отдельно от дозы, полученной по реакции H/n,γ/ /, а также сигнализация нейтронов гамма-детекторами. Программы записывают также производные по энергии нейтронного потока и керма.

KIVONAT

A riportban a szerző két FORTRAN nyelven irt programról számol be. Ezek alkalmasak aktivációs detektorokon alapuló baleseti doziméterek kiértékelésére. A programok a következő dozimetriai szempontból fontos mennyiségeket számolják: kerma, neutrondózis /a visszalökött magok és protonok ill. a H/n,gamma/ reakció külön-külön/ és a gamma-detektorok jelzése neutronokra. A neutron-fluens és a kerma energia szerinti differenciálhányadosát a program kirajzolja.

INTRODUCTION

The Nuclear Accident Dosimetry NAD system used routinely at the Central Research Institute for Physics was designed in 1964 by Deme and Békés [1] along the lines of the system of Braun and Nilsson [2]. Subsequent developments in nuclear accident dosimetry, the increased thermal power of the research reactor operated in the Institute, and the commencement of zero power experiments, however, have produced the need for a more elaborate dosimetric system and more sophisticated evaluation techniques.

NAD development in several countries including Hungary, is supported by the I.A.E.A. /Research Agreement No. 889/R1/CF/, and as a part of this work two programs, DZB1 and DZBB, have been written for dose computations on the basis of previously elaborated RFSP [3] and RF07 [4] codes respectively, which fit theoretical or supposed neutron spectra on to the measured activities of the NAD system. During this procedure code RFSP minimizes the quantity

$$\int_{E_{min}}^{E_{max}} \left(\frac{\Phi_o(E) - \Phi(E)}{\Phi_o(E)} \right)^2 . dE \qquad /1/$$

where $\Phi_o(E)$ is the input spectrum, $\Phi(E)$ is the fitted spectrum, and E_{max} and E_{min} are the energy values below and above of which $\Phi(E)$ is - or may be considered as zero. Code RF07 calculates the neutron spectrum by means of step by step iteration.

Both DZBB and DZB1 programs can read any spectrum from the neutron spectrum library called DPSC-LIBRARY [5]. This collection of measured and calculated spectra is made as a part of the I.A.E.A. Research contract No. 1115/RB. These programs compute the neutron kerma in three different forms discussed in the next part and the normalized neutron and kerma spectra, E*PHI(E) and E*K(E) versus logE are plotted through an off line plotter.

DOSE CALCULATIONS

The neutron dose /kerma/ calculations are used in biological experiments [6] and in evaluation of the NAD system [7]. For evaluation of biological experiments the approximate neutron fluence-to-kerma conversion factors /Lamberieux, [8]/ and their modified versions are used. A modification is necessary, when the neutrons with an energy less than 0.5 MeV are not negligible. For evaluation of NAD systems neutron kerma, surface-absorbed doses due to recoils and surface-absorbed doses due to H/n,gamma/ reaction conversion factors are those calculated by Auxier et al. [9].

As these programs are used for accident dosimetry, some additional modifications have been made to the codes to facilitate evaluation and intercomparison. The fractions of quantities mentioned above as well as those of neutron fluence are calculated in five energy ranges /thermal ÷ 0.01 Mev, 0.01 ÷ 0.75 MeV, 0.75 ÷ 1.5 MeV, 1.5 ÷ 2.5 MeV, and above 2.5 MeV/. The normalized neutron and kerma spectra are printed out together with apparent dose due to neutrons detected by LiF, BeO and Kodak Radiation Monitoring film. The neutron sensitivities of these gamma detectors were taken from the literature [10].

USER'S MANUAL

This manual must be read in conjuction with the reports KFKI-70-39 RPT /code DZBB/ and KFKI-71-22 /code DZB1/, as it details only those modifications and additions to the codes necessary for their use.

PROGRAM NAME: DZBB and DZB1

The programs calculate the neutron spectrum from an input spectrum and foil measurements. The neutron spectrum is converted to a kerma spectrum and drawn on a plotter.

PROGRAM LANGUAGE	ICT 1900 FORTRAN	
	DZBB	DZB1
PERIPHERALS:	1 tape reader 1 line printer Magnetic tapes	1 tape reader 1 line printer Magnetic tapes
	2 scratch tapes RFSP-LIBRARY DPSC-LIBRARY /optional/ PLOTTER TAPE /optional/	scratch tape RFSP-LIBRARY DPSC-LIBRARY /optional PLOTTER TAPE /optional/
STORE USED	26700 words	27400 words

DESCRIPTIONS of the programs are presented in the reports mentioned above. Additional information necessary for using the programs is as follows:

The number of input E_i and PHI /E_i/ values for DZB1 must not exceed 40. No tape output is given with program DZBB.

Both programs are operated from paper tape, but the input data may be given on cards, in which case the tape reader has to be replaced with a card reader.

A typical time necessary for solving a problem is about 2 min for both programs without using the plotter. Use of the plotter subroutine necessitates about 2 min additional running time.

INPUT DATA

Kerma calculations are controlled in both codes by a record of the same type: the type of this record is 11 in code DZBB, IX in DZB1. In code DZB1 a record IX must be added after the last record type V, when record I has the value RUN or FROMTAPE /see below/. With code DZBB the last record type 10 must be always followed by a record 11.

Record IX /LY, LYL; 2I2/ written in the first four character
/Record 11 in DZBB/ positions of the record

LY = 0 No dose /kerma/ calculations are made.

LY = 1 Lamberieux dose is calculated.

LY = 2 Modified Lamberieux dose is calculated.

LY = 3 Both Lamberieux, and modified Lamberieux dose are calculated.

LY = 4 Kerma, neutron dose due to H/n,gamma/ reaction and neutron dose due to recoils are calculated

LY = 5 All calculations described for LY = 1, 2 and 4 are made

LYL = 1 Lamberieux dose spectrum and neutron spectrum are plotted as E * K/E/ and E * PHI/E/ versus log E.

LYL = 2 Modified Lamberieux dose spectrum is plotted as E * K/E/ and E * PHI/E/ versus log E.

LYL = Kerma spectrum and neutron spectrum are plotted as E * PHI/E/ and E * K/E/ versus log E.

Values of LYL must be in accordance with the actual values of LY /e.g. LYL = 3 is meaningless if LY = 1/.

Input spectra can be read from the DPSC-LIBRARY/neutron spectrum library/ as follows:

DZB1

The word FROMTAPE must be written in the first eight characters of record I, the other character positions being left empty. After this comes Record X, ISP /10A8/. The first eight character positions of the record carry the identifications characters of the spectrum needed from the library, the other positions are empty. This record is followed by records II, III and by record/s/ V, the last record is a record IX. In this operation mode IENER on record III is an arbitrary number in I3 format, as the true IENER is read from the library. On the DPSC-LIBRARY, however, IENER is always 48, so eight E and PHI/E/ values are omitted.

DZBB

Records 1, 2, 3, 4, 5, 6 and 7 are followed by a record 10. On this record the value NENBE /format I4/ is 0 /zero/. The next record /12/ has the same function as record X of DZB1 /format 10A8/. The last record is always a record 11.

An example of the input records for both programs is given in Fig. 2.

OUTPUT

The output is given on a line printer and on an off-line operated Computer Instrumentation Ltd Series 6000/601 Large Incremental Plotter. The spectra are plotted in the energy interval $10^{-6} \div 100$ MeV. The measure of the drawing is 32 x 20 cm.

The results of the spectrum fitting are printed in the manner described in reports KFKI-70-39 RPT and KFKI-71-22.

When the codes are operated from the DPSC-LIBRARY, all the information concerning the input spectrum which is contained in the library in block ITEXT/6/10A8// and the spectrum itself are printed out before the results, along with the identification number of the spectrum /Fig. 1/. Results of the kerma-calculating subroutines /Figs. 3a-b/ are printed out after the results of the last iteration as these calculations are performed only after the last iteration - reading of gamma detectors due to neutrons, followed by the results of Lamberieux and modified Lamberieux dose calculations and that of kerma, dose due to H/n,gamma/ reaction and dose due to recoils.

COMMENT

The test case chosen for publication is the third burst of the HPRR at Oak Ridge during the I.A.E.A. intercomparison studies of May 1971. The input spectrum calculated is a fission spectrum penetrating through 12 cm lucite, and the neutron dose results are in good agreement with those of other participants.

ACKNOWLEDGEMENT

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APPENDIX A

The "Lamberieux dose" is an approximation of the first collision dose which in the energy range considered is practically equal to the kerma.

It is a linear approximation /y = m. E + b/. The values of m and b are given in Table I. The unit of y is rad $\cdot$ $cm^2 \cdot 10^{-9}$.

As this approximation is not satisfactory when the dose due to neutrons with an energy less than 0.5 MeV is important /e.g. heavy water moderated reactors/, it is modified here on the basis of the neutron fluence-to-kerma conversion curve published in ORNL-4168. These modified values are also given in Table I. The modified approximation is not linear in the energy range 4.10^{-8} MeV ÷ 10^{-5} MeV.
Here

$$y = \frac{2 * 10^{-2}}{(E/4 * 10^{-8})^{1/2}}$$

and E is given in MeV.

Table I. Constants needed to the calculation of approximate neutron fluence-to-kerma conversion factors

Energy range /MeV/	Lamberieux approx.		mod. Lamberieux approx.	
	m	b	m	b
$10^{-5} - 10^{-4}$	3.	0	0	1.2×10^{-3}
$10^{-2} - 2 \times 10^{-4}$	3.	0	0	1.6×10^{-3}
$2 \times 10^{-4} - 10^{-2}$	3.	0	10.	0
$10^{-2} - 2 \times 10^{-1}$	3.	0	5.2	4.8×10^{-2}
0.2 - 0.8	3.	0	2.16	0.667
0.8 - 4.0	0.56	1.93	0.56	1.93
4.0 - 8.0	0.3	3.	0.3	3.
above 8.0	0	5.4	0	5.4

Fig. 4 is the flow-chart of the kerma /and neutron dose due to recoils and H/n,gamma/ reactions/ calculations. The neutron spectrum is approximated with a step function. To avoid under or overestimation the neutron fluence differential in energy φ_E is considered in the energy range $\sqrt{E^{(i)} \cdot E^{(i-1)}} \div \sqrt{E^{(i)} \cdot E^{(i+1)}}$ equal to $\varphi_E^{(i)}$.

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FIGURE CAPTIONS

Fig. 1 Input spectrum, a part of the output of the codes DZB1 and DZBB when the input spectrum is read from the DPSC-LIBRARY.

Fig. 2 Input records of codes DZB1 /a/ and DZBB /b/ operated from the neutron spectrum library.

Fig. 3a Output records of the kerma calculating subroutines. Lamberieux and modified Lamberieux first collision dose spectra normalized to unit lethargy interval and f.c. dose fractions.

Fig. 3b Output records of the kerma calculating subroutines. Kerma spectrum normalized to unit lethargy interval. Absorbed dose, kerma and neutron fluence fractions.

Fig. 4 Flow-chart of the kerma calculations.

00000002
HPPR
D= 12CM LUCITE
CALCULATED BY VERTES
26-05-72
**

E	PHI(E)	E	PHI(E)	E	PHI(E)	E	PHI(E)
8.91170E 00	4.46110E-03	7.07820E 00	1.23269E-02	5.62260E 00	2.22899E-02	4.46630E 00	3.47487E-02
3.54780E 00	5.03930E-02	2.81820E 00	7.22115E-02	2.23850E 00	1.01153E-01	1.78160E 00	1.25887E-01
1.41250E 00	1.37742E-01	1.12200E 00	1.52558E-01	8.91170E-01	1.69238E-01	7.07820E-01	1.90032E-01
5.62260E-01	2.09565E-01	4.46630E-01	2.15208E-01	3.54780E-01	2.22311E-01	2.81820E-01	2.40073E-01
2.23850E-01	2.89020E-01	1.78160E-01	3.50046E-01	1.41250E-01	4.19744E-01	1.12200E-01	4.79969E-01
8.91170E-02	5.55818E-01	7.07820E-02	6.49935E-01	5.62260E-02	7.59674E-01	4.46630E-02	8.97827E-01
3.54780E-02	1.07175E 00	2.81820E-02	1.29524E 00	2.23850E-02	1.57783E 00	1.78160E-02	1.93016E 00
1.41250E-02	2.36918E 00	1.12200E-02	2.90350E 00	6.81910E-03	4.58388E 00	3.16190E-03	9.59717E 00
1.46630E-03	2.06634E 01	6.81910E-04	4.45658E 01	3.16190E-04	9.61290E 01	1.46630E-04	2.11715E 02
6.81910E-05	4.58960E 02	3.16190E-05	9.98867E 02	1.46630E-05	2.20969E 03	6.01910E-06	4.81023E 03
3.16190E-06	1.04808E 04	1.46630E-06	2.31451E 04	7.07150E-07	4.81144E 04	3.53560E-07	9.62608E 04
2.17010E-07	0.00000E-01	8.83106E-04	8.81098E-04	8.76374E-04	8.68633E-04	8.57547E-04	8.42761E-04

Fig. 1

a./

```
FROMTAPE
00000002
 TEST CASE IAEA INTERCOMP. MAY 71 ORNL III B. AREA SP.LIBR
  1  1  2 0 05000E 00    5 2
S3(NP)P32         8 43000E 08  5 00000E-02
 1 1
ENDEND
```

b./

```
22 2 1
 1
S32(NP)P32        8.43000E 08
 TEST CASE IAEA INTERCOMPARISON, OAK RIDGE MAY 1971
   III BURST AREA DET. SPECTRUM FROM LIBR. NO. 00000002
   10   0.10000E 00 0.1
 1.00000E-08 1.70000E 01    20
 0.0          0.0           0.0            0.45
     0
 00000002
 4 3
 33
```

Fig. 2

READING OF GAMMA DETECTORS DUE TO NEUTRONS(E.GT.0.4EV) IN R

LIF 2.05702 BEO 3.41036 FILM 0.00000

NEUTRON DOSE SPECTRUM (RAD/LET.INT.)

LAMBERIEAUX DOSE

E	K(E)	E	K(E)	E	K(E)	E	K(E)
3.53560E-07	0.00000E-01	1.46630E-06	4.26867E-06	6.81910E-06	1.85278E-05	3.16190E-05	8.28598E-05
1.46630E-04	3.77935E-04	6.81910E-04	1.00160E-03	1.46630E-03	2.81694E-03	3.16190E-03	6.08123E-03
6.81910E-03	1.14344E-02	1.12200E-02	1.87915E-02	1.41250E-02	2.74444E-02	1.78160E-02	3.54683E-02
2.23850E-02	4.59032E-02	2.81820E-02	5.96686E-02	3.54780E-02	7.82485E-02	4.46630E-02	1.03885E-01
5.62260E-02	1.39304E-01	7.07820E-02	1.88890E-01	8.91170E-02	2.56047E-01	1.12200E-01	3.50467E-01
1.41250E-01	4.86263E-01	1.78160E-01	6.43239E-01	2.23850E-01	8.40834E-01	2.81820E-01	1.10596E 00
3.54780E-01	1.62310E 00	4.46630E-01	2.49011E 00	5.62260E-01	3.84287E 00	7.07820E-01	5.52287E 00
8.91170E-01	7.08338E 00	1.12200E 00	8.46660E 00	1.41250E 00	1.02464E 01	1.78160E 00	1.26713E 01
2.23850E 00	1.39506E 01	2.81820E 00	1.38036E 01	3.54780E 00	1.35395E 01	4.46630E 00	1.30229E 01
5.62260E 00	1.13570E 01	7.07820E 00	8.64392E 00	8.91170E 00	4.15092E 00		

NEUTRON DOSE SPECTRUM (RAD/LET.INT.)

MOD. LAMBERIEAUX DOSE

E	K(E)	E	K(E)	E	K(E)	E	K(E)
3.53560E-07	0.00000E-01	1.46630E-06	3.20551E-03	6.81910E-06	1.38731E-03	3.16190E-05	1.04823E-03
1.46630E-04	1.37465E-03	6.81910E-04	3.33865E-03	1.46630E-03	9.38979E-03	3.16190E-03	2.02708E-02
6.81910E-03	3.81148E-02	1.12200E-02	5.93691E-02	1.41250E-02	7.86636E-02	1.78160E-02	9.33315E-02
2.23850E-02	1.12376E-01	2.81820E-02	1.37302E-01	3.54780E-02	1.70920E-01	4.46630E-02	2.17283E-01
5.62260E-02	2.81102E-01	7.07820E-02	3.70107E-01	8.91170E-02	4.89785E-01	1.12200E-01	6.57454E-01
1.41250E-01	8.97938E-01	1.78160E-01	1.17272E 00	2.23850E-01	1.44012E 00	2.81820E-01	1.66837E 00
3.54780E-01	2.18529E 00	4.46630E-01	3.03184E 00	5.62260E-01	4.28569E 00	7.07820E-01	5.71039E 00
8.91170E-01	7.08338E 00	1.12200E 00	8.46660E 00	1.41250E 00	1.02464E 01	1.78160E 00	1.26713E 01
2.23850E 00	1.39506E 01	2.81820E 00	1.38036E 01	3.54780E 00	1.35395E 01	4.46630E 00	1.30229E 01
5.62260E 00	1.13570E 01	7.07820E 00	8.64392E 00	8.91170E 00	4.15092E 00		

DOSE FRACTIONS IN RAD

	LAMB.	MOD. LAMB.
UNDER .01 MEV	0.00000	0.06135
0.01-1.00 MEV	5.76190	6.94862
1.00-3.00 MEV	13.61318	13.61318
ABOVE 3.0 MEV	11.67694	11.67694
NEUTRON DOSE	31.05203	32.30010

Fig. 3a

KERMA SPECTRUM (RAD/UNIT LET. INT.),

E	K(E)	E	K(E)	E	K(E)	E	K(E)
3.53560E-07	0.00000E-01	1.46630E-06	2.12785E-03	6.81910E-06	1.11794E-03	3.16190E-05	6.46365E-04
1.46630E-04	1.48993E-03	6.81910E-04	3.00887E-03	1.46630E-03	7.97819E-03	3.16190E-03	2.15245E-02
6.81910E-03	3.64539E-02	1.12200E-02	4.81215E-02	1.41250E-02	7.34026E-02	1.78160E-02	1.18333E-01
2.23850E-02	1.49424E-01	2.81820E-02	1.84933E-01	3.54780E-02	2.34318E-01	4.46630E-02	2.95358E-01
5.62260E-02	3.70104E-01	7.07820E-02	4.78230E-01	8.91170E-02	6.05550E-01	1.12200E-01	7.61643E-01
1.41250E-01	9.78679E-01	1.78160E-01	1.17946E 00	2.23850E-01	1.39845E 00	2.81820E-01	1.66372E 00
3.54780E-01	2.20083E 00	4.46630E-01	3.03290E 00	5.62260E-01	4.17059E 00	7.07820E-01	5.30407E 00
8.91170E-01	6.60328E 00	1.12200E 00	7.84123E 00	1.41250E 00	1.03555E 01	1.78160E 00	1.25720E 01
2.23850E 00	1.37378E 01	2.81820E 00	1.39393E 01	3.54780E 00	1.46034E 01	4.46630E 00	1.25990E 01
5.62260E 00	1.12137E 01	7.07820E 00	8.45926E 00	8.91170E 00	2.35096E 00		

	NEUTRON DOSE (RAD) SURFACE ABSORBED DOSE H(N,GAMMA)	RECOILS	KERMA (RAD)	NEUTRON FLUENCE
UNDER .01 MEV	1.85338	0.24537	0.06780	5.12624E 09
0.01-0.75 MEV	1.00903	4.60551	5.03175	3.46496E 09
0.75-1.50 MEV	0.35416	6.10518	5.41673	1.37790E 09
1.50-2.50 MEV	0.47360	12.74629	10.16775	1.88807E 09
ABOVE 2.5 MEV	0.22556	13.04830	10.92083	3.34253E 09
SUM	3.91573	36.75065	31.60485	1.51997E 10

KERMA SP. IS PLOTTED

Fig. 3b

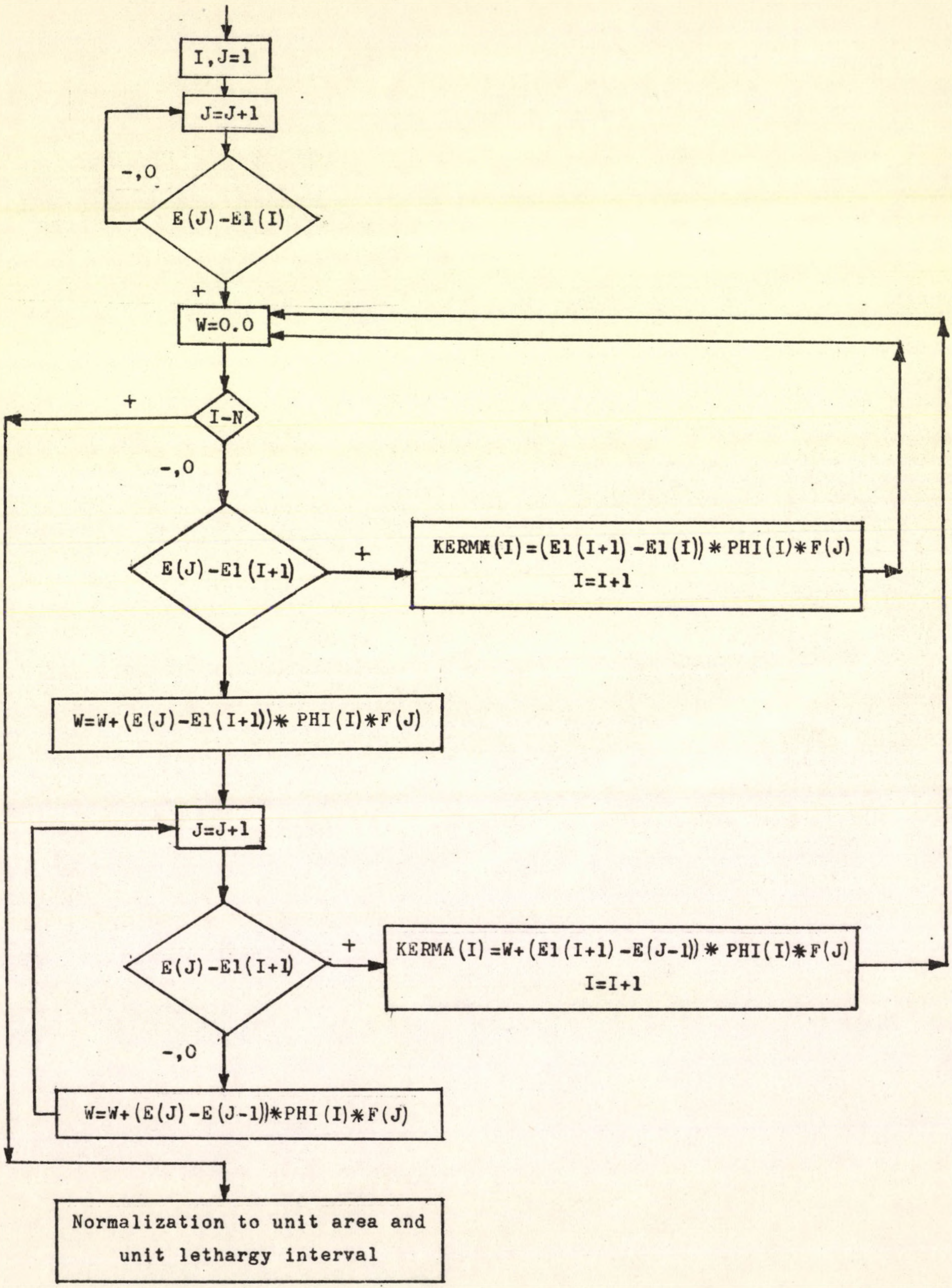
I,J=1
J=J+1
-,0
E(J)-E1(I)
+
W=0.0
+
I-N
-,0
E(J)-E1(I+1)
+
KERMA(I)=(E1(I+1)-E1(I))*PHI(I)*F(J)
I=I+1
W=W+(E(J)-E1(I+1))*PHI(I)*F(J)
J=J+1
E(J)-E1(I+1)
+
KERMA(I)=W+(E1(I+1)-E(J-1))*PHI(I)*F(J)
I=I+1
-,0
W=W+(E(J)-E(J-1))*PHI(I)*F(J)
Normalization to unit area and
unit lethargy interval

Fig. 4

61.583

Kiadja a Központi Fizikai Kutató Intézet
Felelős kiadó: Szabó Ferenc, a KFKI Reaktorkutatási Tudományos Tanácsának elnöke
Szakmai lektor: Kötél Gyula, Fischer Ádám
Nyelvi lektor: T. Wilkinson
Példányszám: 305 Törzsszám: 72-7411
Készült a KFKI sokszorositó üzemében, Budapest
1972. október hó.