A MONTE CARLO ANALYSIS OF NEUTRON THERMALIZATION IN GRAPHITE

by

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INTRODUCTION

The 250 Kev Cockroft - Walton electrostatic accelerator currently under construction at Virginia Polytechnic Institute is to be used as a pulsed neutron source. In one set of experiments, short bursts of neutrons will be produced in a block of graphite. Using this technique the time dependence of the neutron flux; the energy spectrum as a function of time; and various reactor parameters such as Fermi Age, slowing down time and diffusion length may be determined (26).

This thesis is a calculation of the results to be expected in such an experiment. Therefore this problem is essentially one of determining the spatial and energy distributions after a burst of fast neutrons has been created in a graphite block.

There are several ways in which this problem might be solved. It might be approached from any one of the variations of the transport theory, that is, the time dependent diffusion theory, the kernel method, the integral transport theory, or even the general transport theory due to Boltzmann (29). However, all of these theories involve complex equations which have been solved

only in special cases with simplifying approximations whose application to this problem is not valid.

The slowing of neutrons by elastic collisions with atomic nuclei is a three dimensional random walk (2) with variable step lengths and anisotropic angular distributions. This problem is very well suited to the Monte Carlo Method, since the probabilistic laws which determine the fate of each neutron at each collision are known. However, each neutron must be "tracked" from its birth until it has met some criterion, in this case, either escaping the pile or becoming thermalized. This process involves many identical computations. Since V.P.I. has an I.B.M. 650 computer, it seemed desirable to examine the feasibility of using this method.

Donsker and Kac (4) describe the Monte Carlo Method as follows:

> "The problems to which Monte Carlo techniques have been applied seem to be divided into two types. Typical of the first type is the problem of neutrons diffusing in material media in which the particles are subjected not only to certain deterministic influences but to random influences as well. In such a problem, the Monte Carlo approach consists in permitting a 'particle' to play a game of chance, the rules of the game being such that the actual deterministic and random features of the physical process are step by step

> exactly imitated by the game. By considering very large numbers of particles, one can answer such questions as the distribution of the particles at the end of a certain period of time, the number of particles to escape through a shield of specified thickness, etc. One important characteristic of the preceding approach is that the functional equation describing the diffusion process is by passed completely, the probability model used being derived from the process itself.
>
> A more sophisticated application of Monte Carlo methods is to the problem of finding a probability model or game whose solution is related to the solution of a partial differential equation ... ."

For further reading on the method and its application see references (11,15,20). Reference (20) has an 86 page bibliography on Monte Carlo and related problems.

THE MODEL

A simplified flow chart of the probability model appears in Figure 1. The remainder of this section will be devoted to an explanation of this model. For further details concerning the calculations, see Appendix I.

In the experiment to be performed, the neutrons will be produced by the reaction

$$D(d,n)He^3 .$$

The differential cross-sections used in this calculation are found in reference (8). The calculation assumes a deuteron bombarding energy of 200 Kev. As described in Appendix I, the reported cross-sections were transformed to the laboratory coordinate system.

Referring to Figure 1, a neutron must be "picked" according to the differential cross-section distribution, $f(\Theta)$, of the source reaction. Since this distribution is not a monotonic function of Θ (the angle between the incident deuteron direction and the emitted neutron direction), a table of the distribution versus Θ was made as follows:

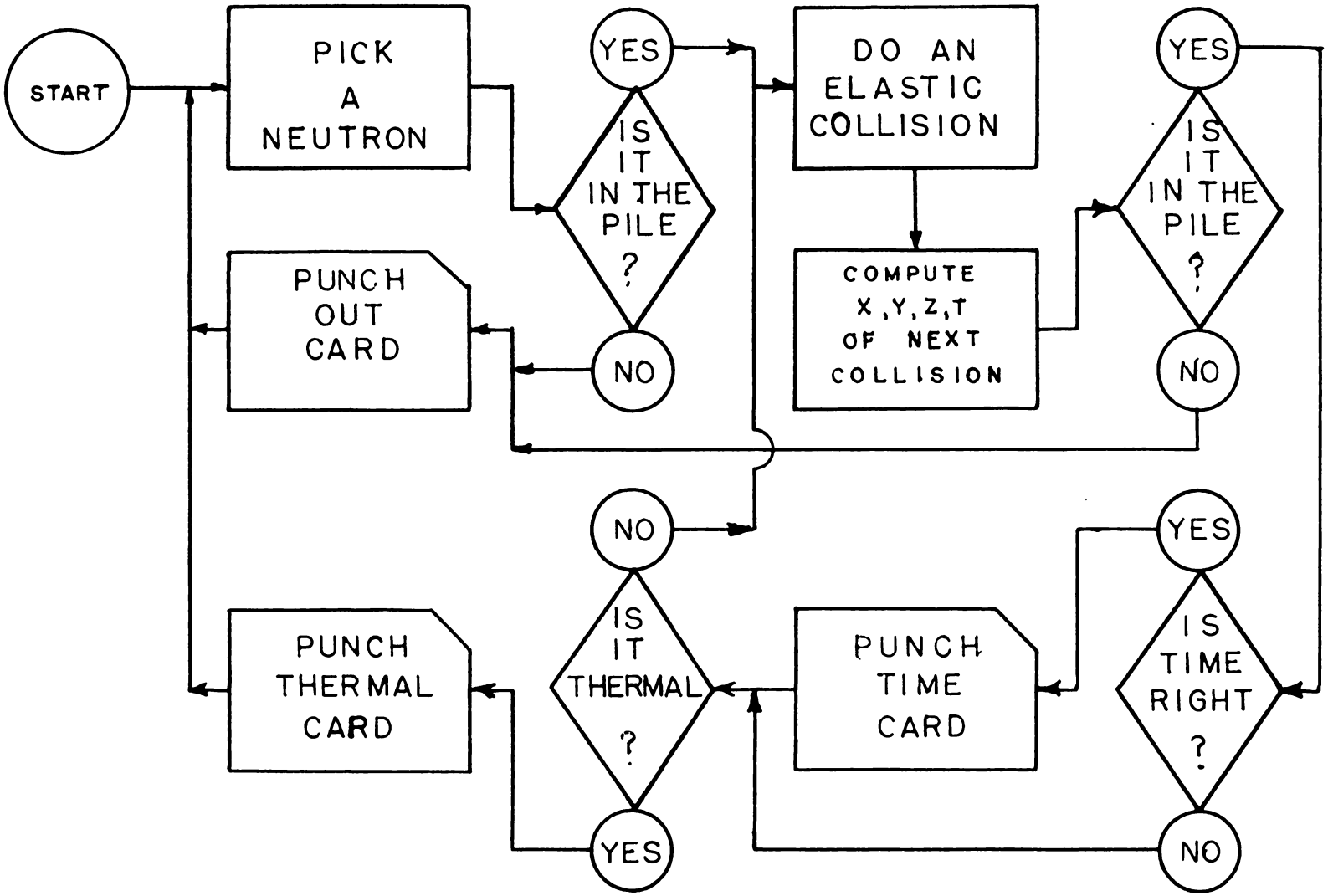

FIG. 1 - THE MONTE CARLO MODEL

Suppose $\theta_1 < \theta_2 < \theta_3 < \ldots < \theta_n$ and all $f(\theta_i)$ are positive. Then let

$$g(\theta_n) = f(\theta_1) + \ldots + f(\theta_n) \qquad (1)$$

and make a table of $g(\theta_i)$ versus θ_i . The function $g(\theta)$ is a monotonic increasing function of θ .

A random number, k, uniformly distributed on 0 to 1 was multiplied by $g(\theta_n)$. The angle θ was then chosen by the rule:

$$\theta = \theta_i \quad \text{when} \quad g(\theta_{i-1}) < kg(\theta_n) \leq g(\theta_i) \qquad (2)$$

Angles picked according to this procedure are distributed (except for the discreteness of the θ_i) with the distribution function, $f(\theta)$. For this problem, the θ_i's were taken at two degree intervals.

The method of generating random numbers was essentially that described in reference (21). The actual IBM 650 program used was Library Program 06.5.001.1 .

At all times during the life of one neutron in the pile, the position, velocity and elapsed time since creation of the neutron were recorded. The pile is

66 inches square and 100 inches tall. Cartesian coordinates were used with the origin at the center of the pile, the position of the neutron source (see Figure 2). The Z axis was taken to be along the deuteron beam while the Y axis was vertical. The angle between the Z axis and the velocity vector is θ , while that between the X axis and the projection of the velocity vector in the X-Y plane is ϕ .

Using a Polonium - Beryllium source, it was found that the flux was symmetric with respect to the origin (1). Because of this symmetry it was possible to solve the problem of the slowing down of neutrons using only the shaded quarter (Figure 2) of the pile. If a neutron escaped through either of the inner faces of the shaded quarter, it was replaced by its mirror image in that quarter.

The angle θ was picked as previously explained. The angle ϕ was picked by multiplying a random number, uniformly distributed on 0 to 1, by $\pi/2$.

The velocity of the neutron picked was uniquely determined once θ was specified.

The velocity dependent scattering cross-sections were taken into consideration by considering 71

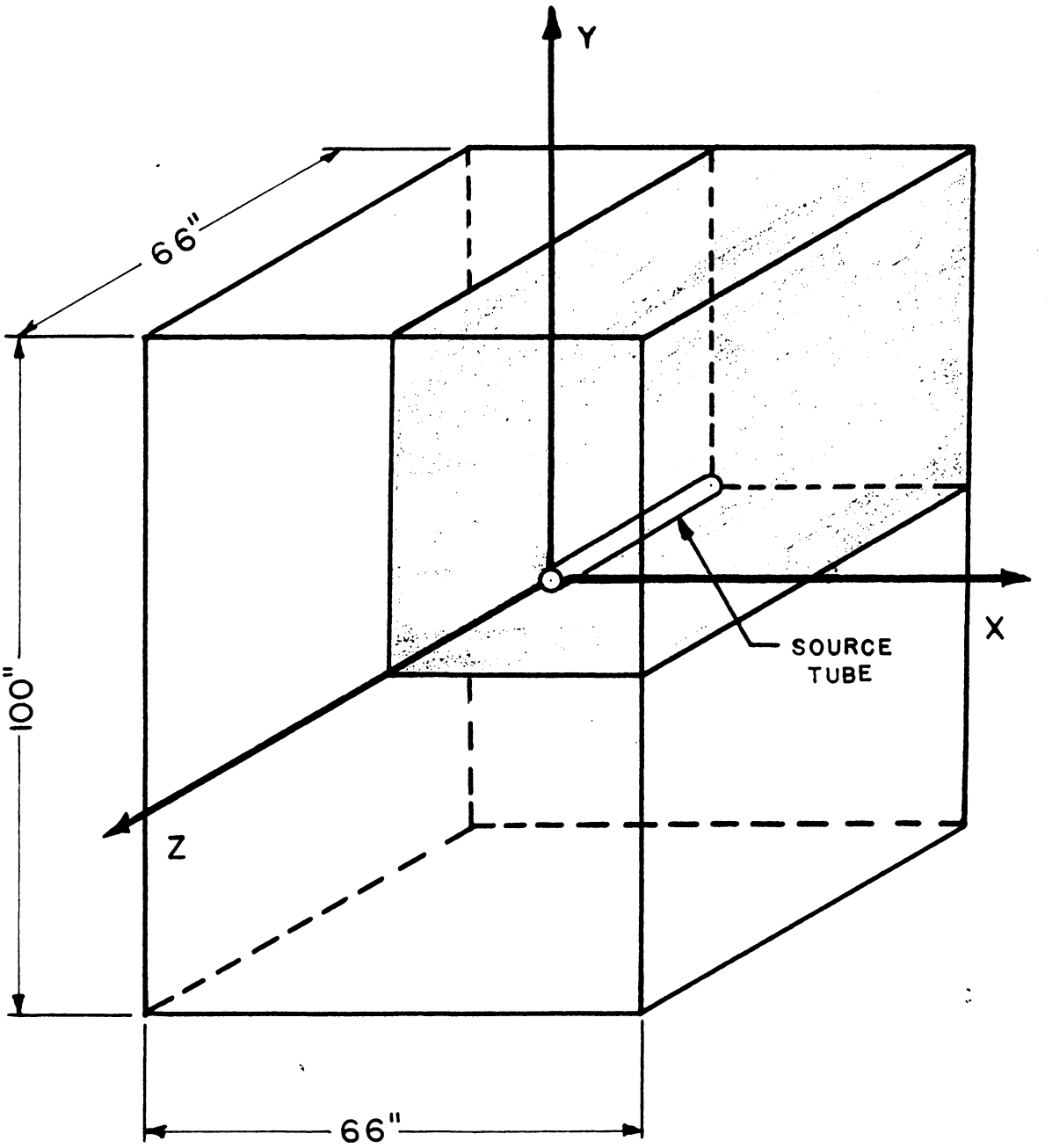

FIG. 2 - THE PILE

velocity groups. The cross-sections as found in references (12,13) were changed to mean free paths.

The distance to the first collision, d, was determined as the product of the velocity dependent mean free path, l(v), and the logarithm of a five-digit random number, j, uniformly distributed on 0 to 1. That is,

$$d = -l(v) \ln j \ . \qquad (3)$$

The time traveled from the source to the first collision was calculated as $t = d/v$. The position coordinates of the first collision were obtained by a spherical-to-cartesian transformation. As in Figure 1, these coordinates were checked to see that the neutron was in the pile. If it escaped through either of the inner faces of the shaded quarter, it was replaced by its mirror image in the shaded quarter. If it escaped through an outer face, an "out" card was punched.

An elastic collision was calculated in a coordinate system which was rotated so that the neutron traveled along the Z' axis. An isotropic scattering distribution was assumed for the center of mass system. This was transformed (see Appendix I) to an anisotropic

distribution for ϑ' in the laboratory system. The angle ϑ' uniquely determined the velocity after the collision. The angle ϕ was picked by multiplying a random number, uniformly distributed on 0 to 1 by 2π.

The distance, d, to the next collision was calculated as previously described. However, the x', y', and z' obtained from d had to be transformed to coordinates in the fixed system. This involved a rotation through two variable angles, ϑ and ϕ of the previous collision. The coordinates obtained from this rotation were added to the coordinates of the previous collision. The time was calculated as $t = d/v$ and added to the total elapsed time.

The coordinates were checked as explained before. If at the next collision the total elapsed time was first greater than 1, 2, 5, or 10 microseconds, a time card was punched. The speed was also checked. If it was below thermal (2.19×10^5 cm/sec), a thermal card was punched.

In order that the spatial and energy distribution as well as the transport flux could be determined, the following information was available after each scattering for each neutron:

1. neutron number
2. collision number
3. X, Y, Z position coordinates of next collision
4. speed
5. velocity direction, i.e. cos θ, cos ϕ, sin ϕ
6. total elapsed time when next collision occurs.

A card with this information was punched for each neutron considered under each of the following conditions:

a) The next collision would occur outside the graphite pile.

b) The next collision will be the first collision to occur after the neutron has been in the pile 1 microsecond.

c) Same as condition b for 2 microseconds.

d) Same as condition b for 5 microseconds.

e) Same as condition b for 10 microseconds.

f) The neutron energy became less than 0.025 ev during the last collision.

In the neutron energy range considered, 4 Mev to 0.025 ev, the absorption cross-section for carbon is very small compared to the scattering cross-section (12,13). Therefore, absorption was neglected.

The IBM 650 program for the problem was written in SOAP II. This system was used since it was felt that

it would give the best program optimization in the least amount of time especially for one inexperienced in programing. Four standard IBM 650 Library Programs were used:

Sine - Cosine	-	03.1.010
Log_{10} - Ln_e	-	03.1.013
Square Root	-	03.1.002
Random Numbers	-	06.5.001.1

A listing of the program deck appears in Appendix II.

Originally 10,000 neutron case histories were to be calculated. Since each case history required about four minutes of machine time, only 4,000 neutrons were tracked. Of these, 3,688 reached thermal, 102 escaped the pile, and the remaining 210 were lost due to an oversight in the program (see Appendix II for an explanation). This sample required 278.3 hours of 650 machine time.

RESULTS

From the data on the 1, 2, 5, and 10 microsecond cards the energy and spatial distributions as well as the flux can be determined as a function of time. The slowing down time and Fermi Age were obtained from the thermal cards.

Energy Distribution as a Function of Time

The energy distributions are given as velocity distributions at 1, 2, 5, and 10 microseconds in Tables 2, 3, 4, and 5 and plotted in Figures 3, 4, 5, and 6, respectively. For each of these histograms the number of neutrons, N, in the sample; the average velocity, $\bar{v}$; and the standard deviation, S, are given. The average time of one microsecond neutrons, for example, is greater than one microsecond since the time card was punched at a collision on which the total elapsed time was first greater than one microsecond. The smooth curve represents an approximate solution of the time dependent transport equation as derived by

Marshak (16) and was fitted to the experimental data. The equation of Marshak's curve is:

$$F(x) = A \exp(-b/x - x)\, x^2/(1-r^2) , \qquad (4)$$

where:

$x = vt/l_o$

l_o = mean free path

$r = (M-m)/(M+m)$

M = mass of scattering nucleus

m = mass of neutron

A = normalizing constant

b = a constant, to be discussed.

This equation was obtained assuming that the mean free path, l_o, was constant over the energy range. Thus in all calculations using this equation, l_o, is set equal to 2.7 centimeters, the thermal mean free path for carbon. For M = 12.01 and m = 1.01, F(x) becomes:

$$F(x) = A \exp(-b/x-x)\ x^{7.0} . \qquad (5)$$

Since $x = vt/l_o$ this function represents either the velocity distribution at a specified time or the time distribution at a specified velocity. This curve was

also fitted to the distribution of slowing down times (see next section).

For the one microsecond distribution $t = \bar{t} = 1.085$ microseconds. Then x becomes

$$x = 4.018v \ , \qquad (6)$$

where v is in units of 10^7 centimeters per second.

Marshak (17) said that the constant b should be determined by maximizing F(x) at $x = \bar{x}$. However, examination of his derivation shows that F(x) should be maximized at $x = x_p$, where x_p is the most probable value of x. Von Dardel (27) also comments on the determination of the constant b.

Normalizing F(v) at $v_p = 3.1 \times 10^7$ centimeters per second and for $\bar{t} = 1.085$ microseconds, the constants A and b were found to be 257.3 and 68.03, respectively. Thus for one microsecond the distribution function is

$$F(v) = 257.3 \exp(-16.93/v - 4.018v) \quad (4.018v)^7 \ . \qquad (7)$$

The following table gives the values of $\bar{t}$, v_p, $F(v_p)$, A, and b for the four velocity distributions given in Tables 2, 3, 4, 5 and plotted in Figures 3, 4, 5, 6, respectively.

Table 1

Normalization Constants for Velocity Distributions

Distribution (μ sec)	$\bar{t}$ (μ sec)	v_p (10^7 cm/sec)	$F(v_p)$	A	b
1	1.085	3.1	198	257.3	68.03
2	2.174	1.65	377	1,617	83.40
5	5.425	0.63	865	1,501	71.66
10	10.88	0.32	1582	3,891	76.11

Table 2

Velocity Distribution at One Microsecond

Velocity (10^7 cm/sec)	Number of Neutrons by Monte Carlo	Marshak Curve Normalized at *
1.0	1	
1.3	2	
1.4	5	
1.5	2	2.24
1.6	6	
1.7	8	
1.8	20	
1.9	34	
2.0	39	37.8
2.1	62	
2.2	92	
2.3	79	
2.4	95	
2.5	144	

Table 2 (con't.)

2.6	160	
2.7	149	
2.8	173	
2.9	195	
3.0	169	
3.1	198	198.0 *
3.2	194	
3.3	172	
3.4	177	
3.5	168	173.0
3.6	132	
3.7	169	
3.8	141	
3.9	127	
4.0	141	108.8
4.1	116	
4.2	74	
4.3	80	
4.4	70	
4.5	68	
4.6	48	
4.7	43	
4.8	56	
4.9	34	
5.0	39	21.6
5.1	30	
5.2	27	
5.3	17	
5.4	20	
5.5	12	
5.6	16	
5.7	12	
5.8	12	
5.9	8	
6.0	8	2.98
6.1	4	
6.2	2	
6.3	4	
6.4	3	
6.5	1	
6.6	2	
6.7	2	
6.8	1	
6.9	1	
7.4	1	

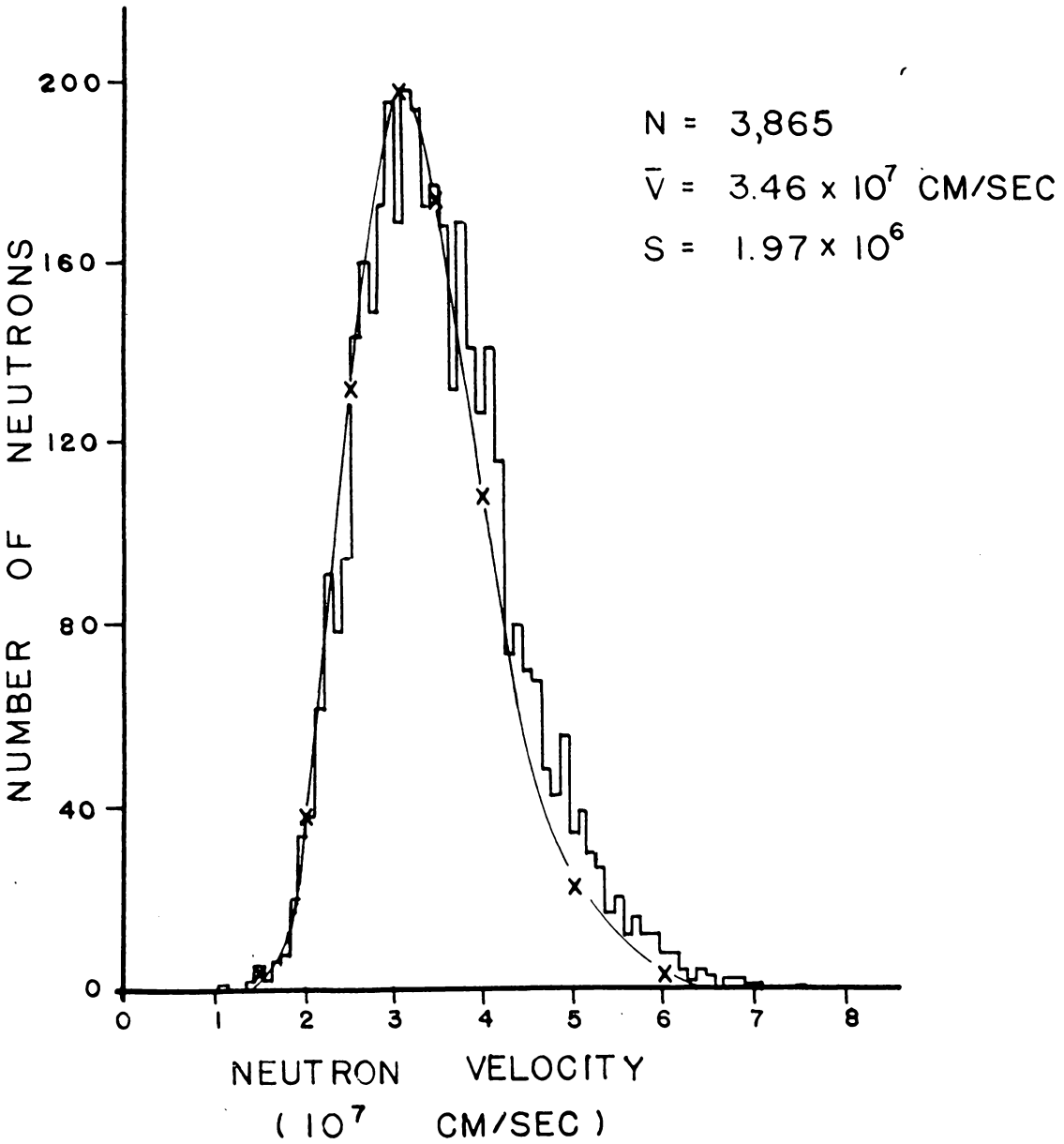

FIG. - 3

VELOCITY DISTRIBUTION AT ONE MICROSECOND

Table 3

Velocity Distribution at Two Microseconds		
Velocity (10^7 cm/sec)	Number of Neutrons by Monte Carlo	Marshak Curve Normalized at *
0.6	2	
0.7	13	
0.8	31	2.81
0.9	68	
1.0	107	19.9
1.1	174	
1.2	245	
1.3	293	180.5
1.4	334	
1.5	364	
1.6	377	
1.65		377.0 *
1.7	343	
1.8	258	348.0
1.9	287	
2.0	228	
2.1	203	
2.2	135	163.5
2.3	113	
2.4	65	
2.5	63	62.4
2.6	39	
2.7	30	
2.8	22	
2.9	14	
3.0	7	7.92
3.1	8	
3.2	4	
3.3	4	
3.4	3	
3.5	1	
3.6	3	
3.9	1	

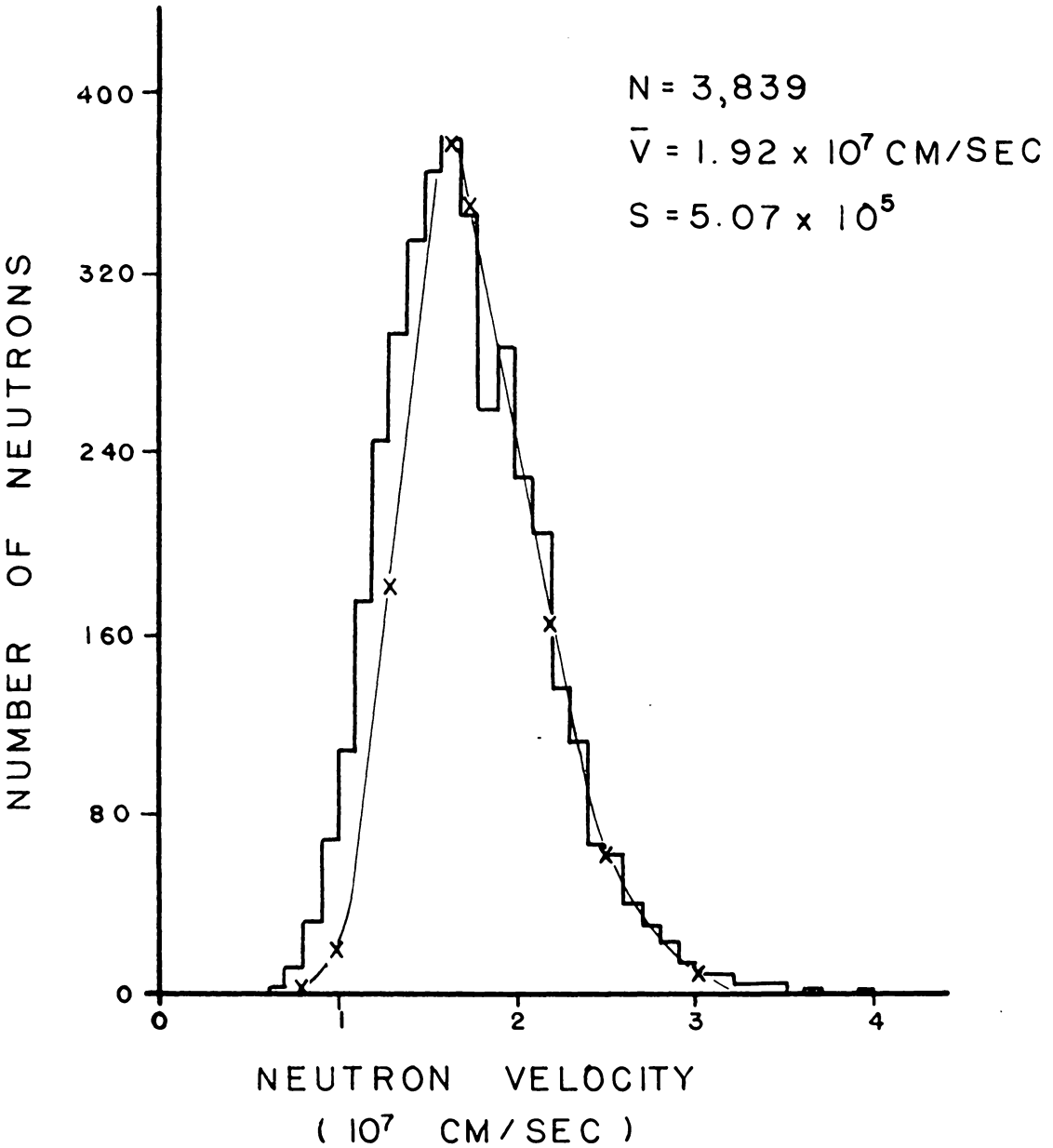

FIG. - 4

VELOCITY DISTRIBUTION AT TWO MICROSECONDS

Table 4

Velocity Distribution at Five Microseconds

Velocity (10^7 cm/sec)	Number of Neutrons by Monte Carlo	Marshak Curve Normalized at *
0.2	3	.008
0.3	109	
0.4	438	139
0.5	794	532
0.6	865	
0.63		865 *
0.7	705	
0.8	457	504
0.9	252	
1.0	116	105
1.1	45	
1.2	20	12.2
1.3	1	
1.4	1	

Table 5

Velocity Distribution at Ten Microseconds

Velocity (10^7 cm/sec)	Number of Neutrons by Monte Carlo	Marshak Curve Normalized at *
0.1	107	.007
0.2	1220	214
0.3	1582	
0.32		1582 *
0.4	700	970
0.5	140	
0.6	26	25.3
0.7	3	2.1

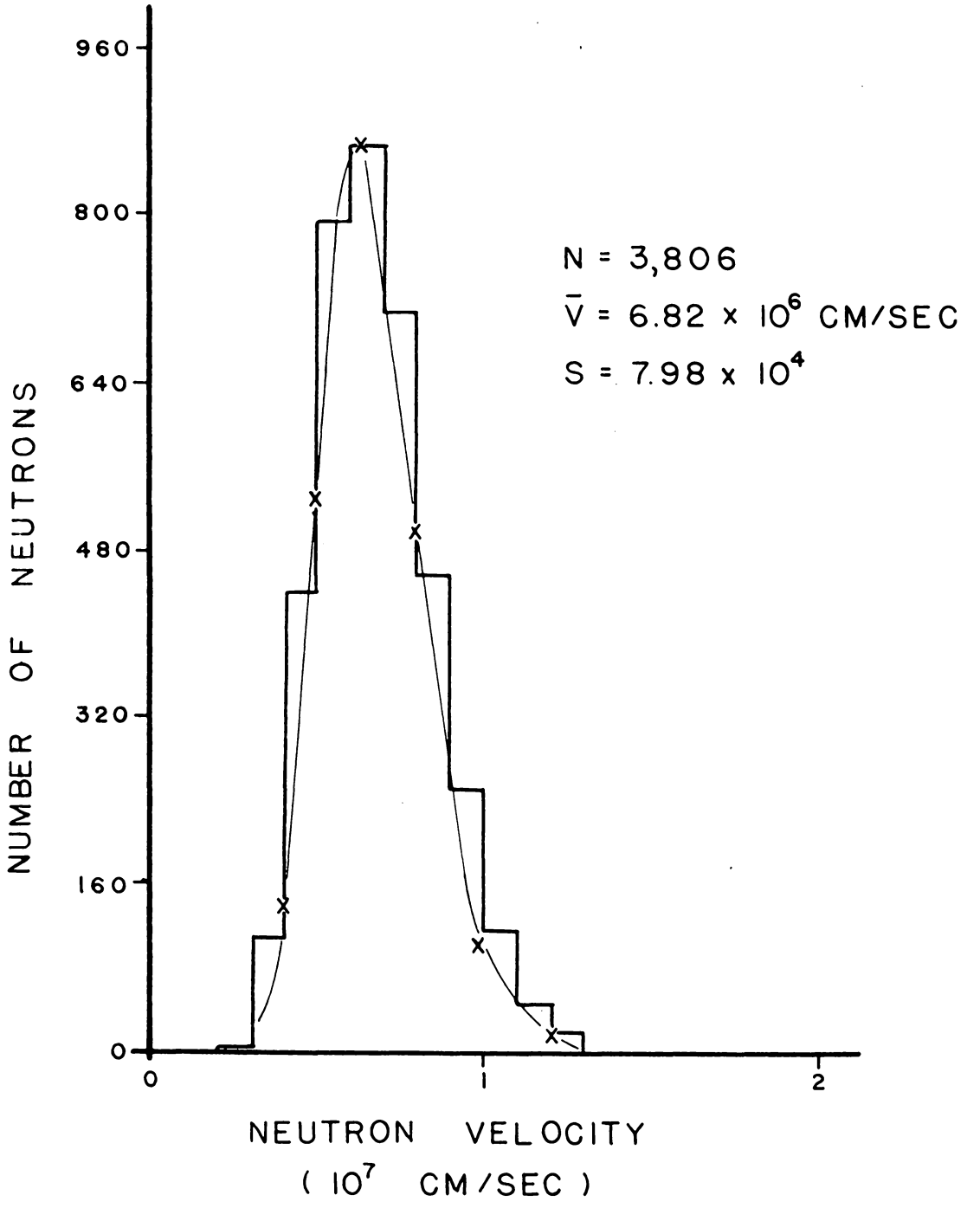

FIG. - 5

VELOCITY DISTRIBUTION AT FIVE MICROSECONDS

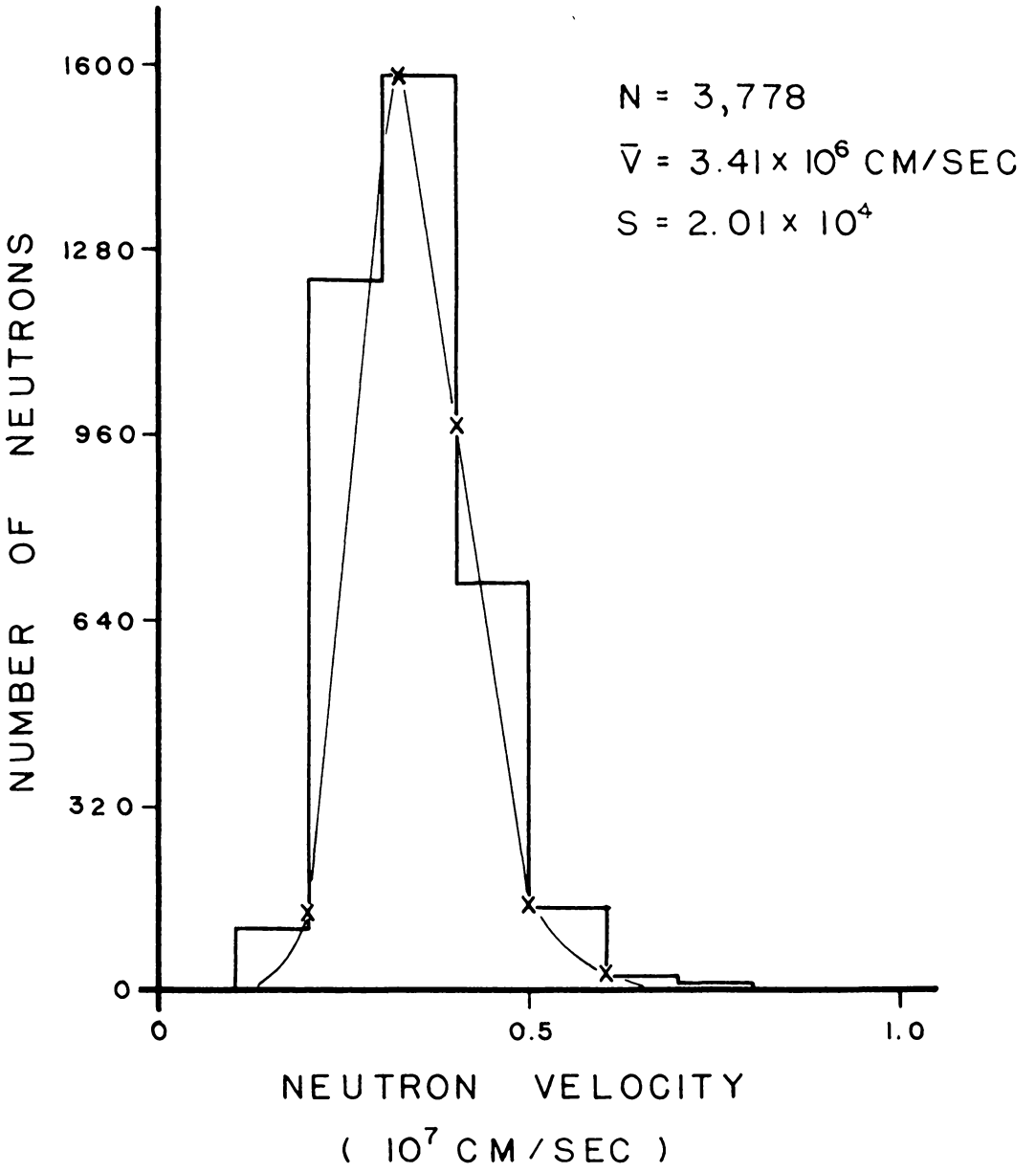

FIG. - 6

VELOCITY DISTRIBUTION AT TEN MICROSECONDS

Slowing Down Time and Fermi Age

As previously stated in equation (5),

$$F(x) = A \exp(-b/x - x) \quad x^{7.0} \tag{5}$$

represents the distribution of slowing down times for neutrons in graphite if the velocity is set equal to the thermal velocity. Taking $v_{thermal}$ as 2.19×10^5 centimeters per second and $l_o = 2.7$ centimeters gives

$$x = 0.081\ t \tag{8}$$

where t is in microseconds.

The curve was fitted to the experimental data by setting $F(t) = 52$ at $t = 165$ and $F'(t) = 0$ at $t = 168$ microseconds. The values of A and b determined were 372.5 and 90.16, respectively. The smooth curve in Figure 7 is given by

$$F(t) = 372.5 \quad \exp(-1113/t - 0.081t) \quad (0.081t)^{7.0} . \tag{9}$$

Figure 7 is a plot of the data given in Table 6.

Table 6

Distribution of Slowing Down Times

Slowing Down Time (μsec)	Number of Neutrons by Monte Carlo	Marshak Curve Normalized at *
80	4	0.06
90	7	
100	19	3.80
110	20	
120	32	17.1
130	43	
140	45	38.4
150	52	
160	39	
165		52.0 *
170	53	
180	41	
190	26	
200	16	38.3
210	21	
220	9	
230	10	
240	6	13.6
250	5	
260	8	
270	4	
290	3	
300	3	1.28
340	1	
350	1	

The Fermi Age, τ , is defined (18) as

$$\tau = \int_0^u \frac{du'\, l^2(u')}{3\xi(1-\overline{\cos\theta})} \qquad (10)$$

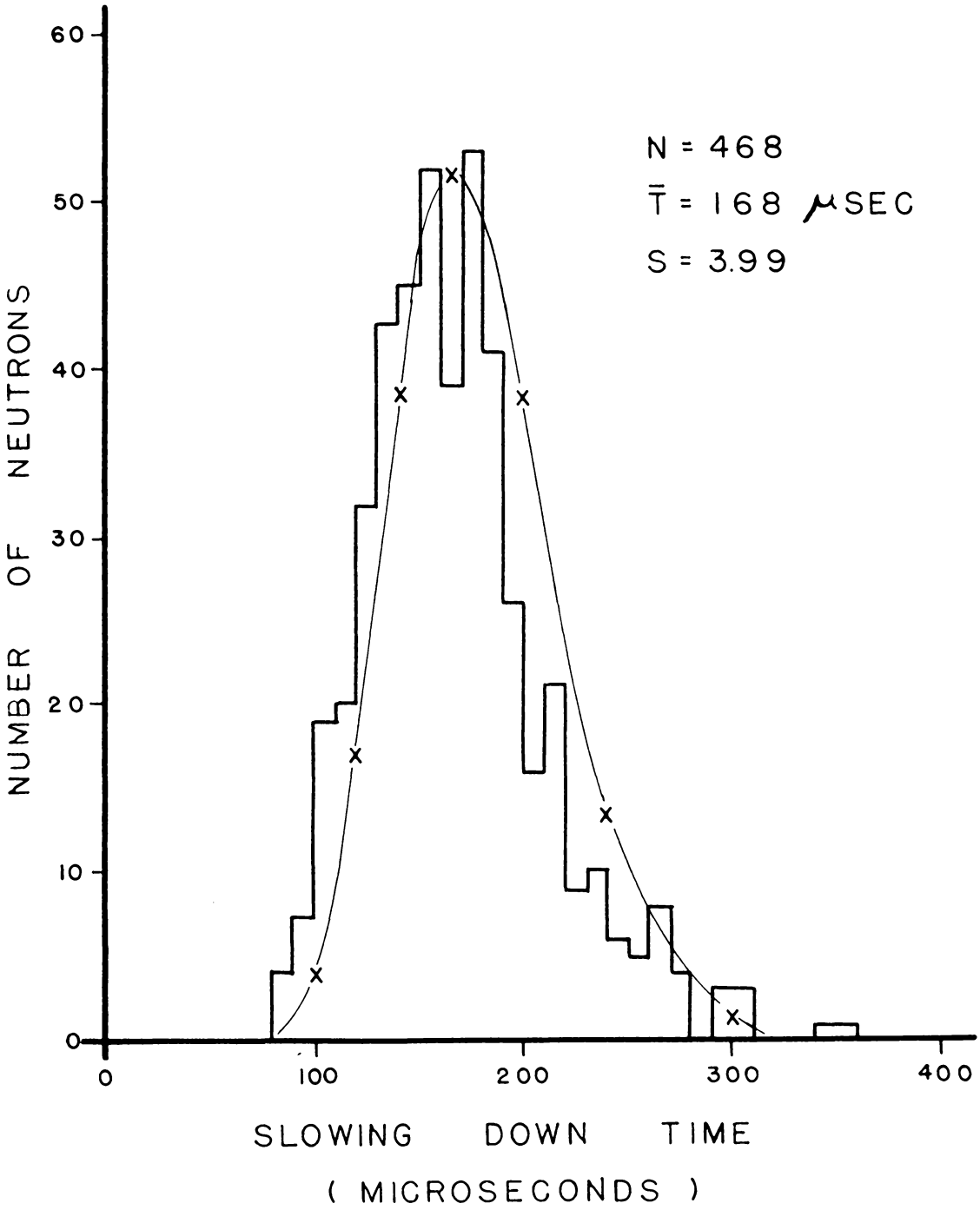

FIG. - 7

DISTRIBUTION OF SLOWING DOWN TIMES

where:

$u = \ln(E_o/E)$, the lethargy

$l(u)$ = energy dependent mean free path

$\xi = \frac{\int \Delta (\ln E)\, dn}{n}$, the average logarithmic energy change per collision

$\overline{\cos\theta} = 2/3M$, the average cosine of the scattering angle.

Age has the dimensions of area and represents the number of neutrons per unit volume per unit time which reach the age τ. The age is one-sixth of the mean square distance traveled by a neutron from its birth to age τ. The square root of the age to thermal is called the slowing down length. The age is related to the slowing down time by

$$\tau = \frac{}{D_o}\, t \,. \qquad (11)$$

where $\frac{}{D_o}$ is the average conventional diffusion coefficient, related to the diffusion coefficient for flux by

$$D_o = Dv \,. \qquad (12)$$

The distribution of distances to thermal squared is given in Table 7 and plotted in Figure 8. The age to thermal is one-sixth of the mean of this distribution. Therefore, the age to thermal is to 421.4 square centimeters, giving a slowing down length of 20.5 centimeters.

Throughout the Monte Carlo calculation the transport mean free path for carbon was used. However, the conventional scattering mean free path should have been used since the scattering was not assumed isotropic in the laboratory system. Thus the mean free paths used were 5.6% greater than they should have been.

Since the average distance traveled is proportional to the mean free path (3), then the slowing down length should be decreased by 5.6%. This correction gives a slowing down length of 19.4 centimeters. Murray (22) gives the age from 2 Mev to thermal as 364 square centimeters. When this is corrected to 3 Mev, using the values in reference (22), it becomes 383 square centimeters. This corresponds to a slowing down length of 19.5 centimeters.

Table 7

Distribution of Distances to Thermal Squared

Distance to Thermal Squared ($100\ cm^2$)	Number of Neutrons	Distance to Thermal Squared ($100\ cm^2$)	Number of Neutrons
0	98	72	13
2	174	74	11
4	225	76	4
6	238	78	6
8	207	80	7
10	217	82	8
12	197	84	11
14	189	86	8
16	175	88	6
18	165	90	4
20	130	92	6
22	144	94	1
24	135	96	4
26	100	98	4
28	112	100	6
30	110	102	3
32	102	104	1
34	90	106	3
36	89	108	3
38	66	110	2
40	64	112	2
42	63	114	3
44	65	116	2
46	45	118	4
48	37	120	0
50	44	122	1
52	41	124	1
54	40	126	1
56	33	128	1
58	26	130	1
60	26	132	1
62	29	134	1
64	16	136	1
66	32	138	1
68	12	140	1
70	12	142	2

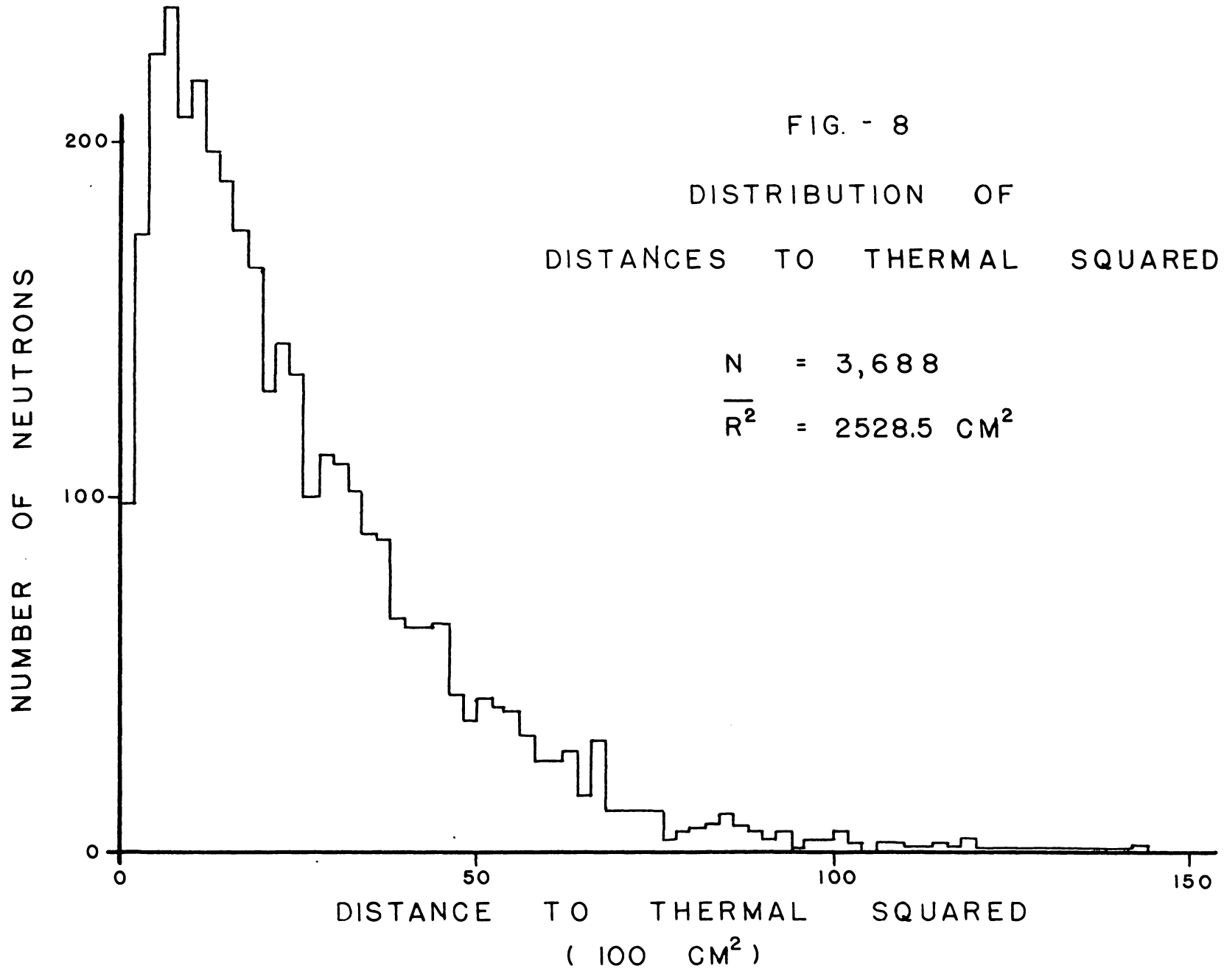

FIG. - 8

DISTRIBUTION OF

DISTANCES TO THERMAL SQUARED

$N = 3,688$

$\overline{R^2} = 2528.5\ CM^2$

Spatial Distribution and Neutron Flux as a Function of Time

For the purpose of presenting the spatial distribution and neutron flux data, the pile was divided into cells 10 centimeters on a side. These cells were denoted by three numbers, the ten's digit of each coordinate. For example a neutron with coordinates 17.62, 1.56, -45.57 would be put into cell 1,00,4-; while one at 40.50, 112.00, 5.83 would be put into cell 4, 11, 0.

Although the data on the time cards is sufficient to determine the transport flux only the diffusion flux is given. The diffusion flux is defined (23) as

$$\text{FLUX} = n\bar{v} \ , \qquad (13)$$

where the units are neutrons per square centimeter per second. Appendix III gives the spatial distribution and neutron flux in terms of cell number at 1, 2, 5, and 10 microseconds. Column 1 gives the cell number, Column 2 the number of neutrons in that cell, and Column 3 the flux, calculated as the sum of the velocities of the neutron in the cell.

The spatial distribution was not plotted. Tables 8 and 9 (taken from Appendix III) give the flux at one and ten microseconds along the Z axis. These are plotted in Figures 9 and 10, respectively.

The data in Appendix III for thermal neutrons cannot truly be considered a flux since the neutrons were thermalized at different times. However, the position at thermalization is given in terms of cell number.

Table 8

Flux at One Microsecond Along the Z Axis	
Cell Number	Neutron Flux (10^5 neut/cm^2-sec)
0,00,7-	0.45
0,00,6-	0.54
0,00,5-	0.36
0,00,4-	3.72
0,00,3-	10.66
0,00,2-	16.22
0,00,1-	19.31
0,00,0-	32.93
0,00,0	83.88
0,00,1	21.41
0,00,2	19.88
0,00,3	11.24
0,00,4	5.62
0,00,5	2.23
0,00,6	0.98
0,00,7	0.33
0,00,8	0.29

Table 9

Flux at Ten Microseconds Along the Z Axis	
Cell Number	Neutron Flux (10^4 neut/cm^2-sec)
0,00,7-	0.28
0,00,6-	0.00
0,00,5-	3.02
0,00,4-	3.14
0,00,3-	6.66
0,00,2-	14.84
0,00,1-	19.82
0,00,0-	16.08
0,00,0	15.59
0,00,1	17.41
0,00,2	11.37
0,00,3	10.91
0,00,4	4.06
0,00,5	1.17
0,00,6	1.25
0,00,7	1.10

Extrapolation to Long Times

According to von Dardel (28), the number of neutrons per cubic centimeter at r with age t, $n(r,t)$, satisfies the equation (neglecting absorption)

$$\frac{\partial n(r,t)}{\partial t} = \nabla^2 n(r,t) \qquad (14)$$

if t is very large.

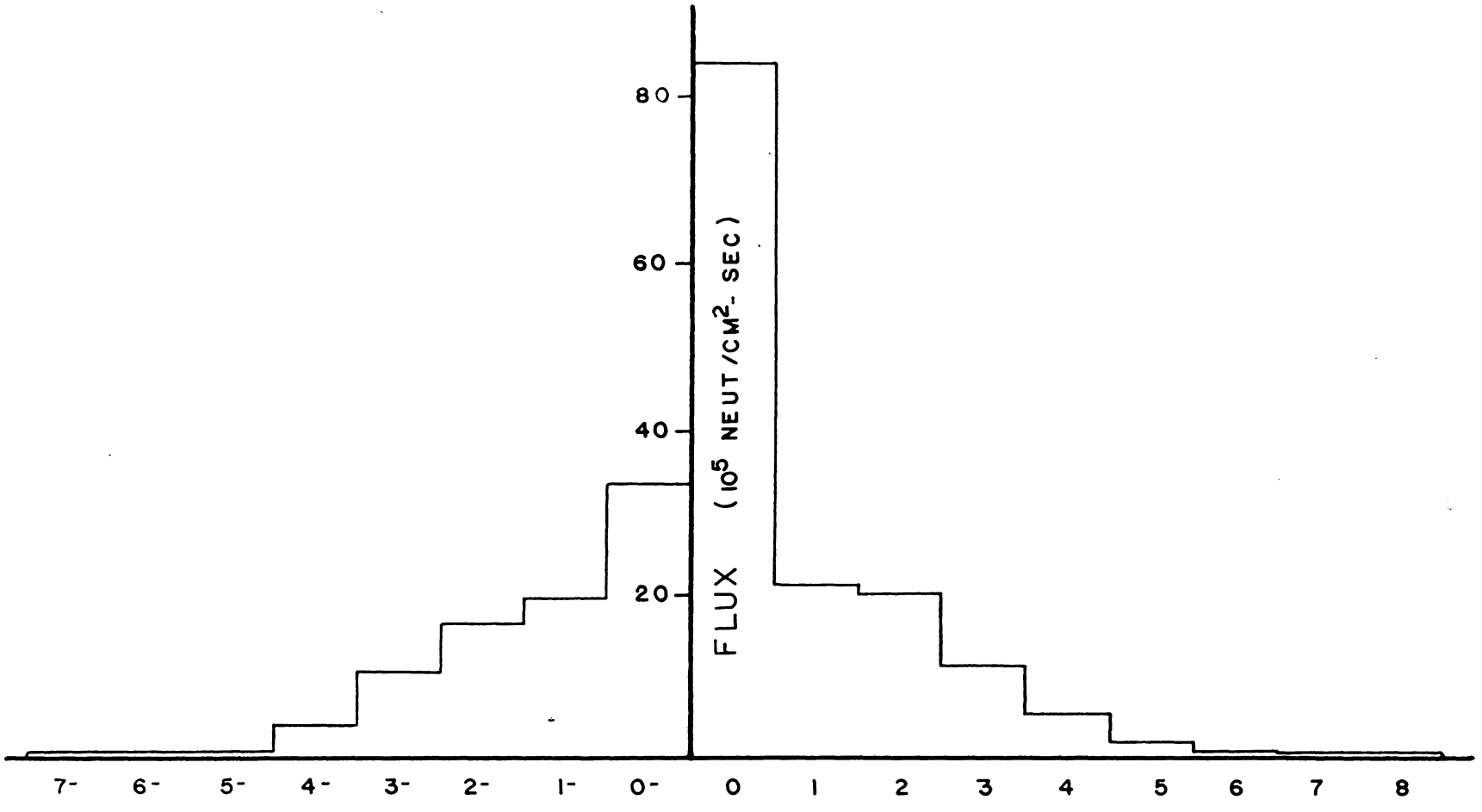

FIG. - 9

FLUX AT ONE MICROSECOND ALONG THE Z AXIS

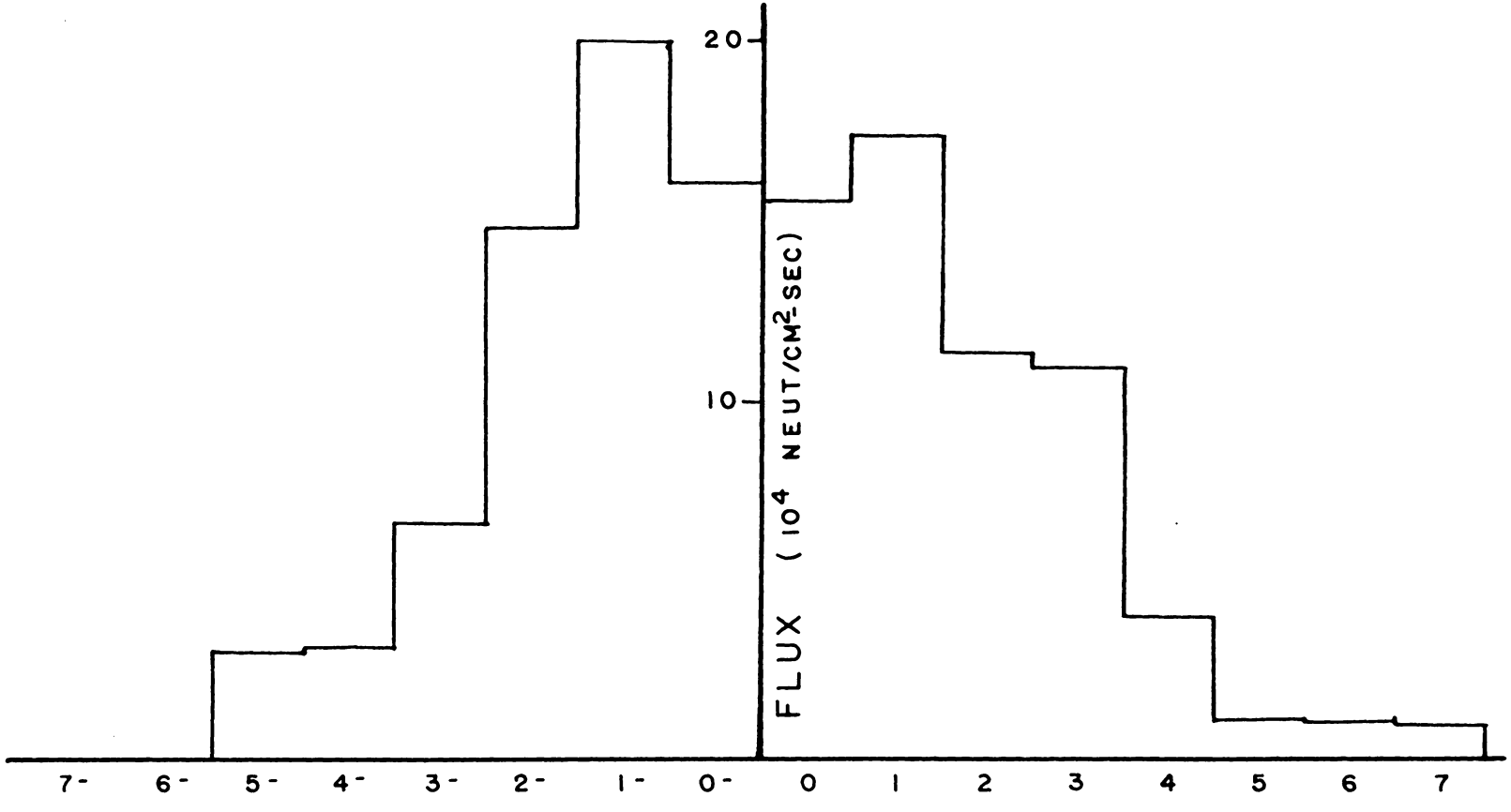

FIG. - 10

FLUX AT TEN MICROSECONDS ALONG THE Z AXIS

For a finite geometry, the solution of (14) can be written as the sum of a number of modes,

$$n(r,\tau) = \sum_{i=0}^{\infty} a_i R_i(r) \exp(-B_i^2 \tau) \qquad (15)$$

where $R_i(r)$ is an eigen-function which satisfies the finite geometry boundary conditions and the Helmholtz equation while B_i^2 is the geometrical buckling coefficient for the i^{th} mode.

Since τ is a linear function of time, defined by equation (11), $n(r,\tau)$ represents the neutron density as a function of time. Thus if the spatial distribution of neutrons is known at some time after the neutrons become thermal, it may be predicted at any later time. Since the neutrons are in equilibrium, the flux is proportional to the density.

The spatial distribution of thermal neutrons is given in Appendix III. If this is expanded in the eigen-functions $R_i(r)$, the geometrical bucklings for the various modes may be determined. The flux, then, at long times (compared to the slowing down time) may be predicted.

CONCLUSIONS

It is felt that the Monte Carlo method is feasible for the IBM 650. The problem was worked in a reasonable time and the results which could be checked seem to agree fairly well (when corrected for the mean free path) with values found in the literature. The constant b, determined by fitting Marshak's curve to the distribution of slowing down times, is not in disagreement with the value which may be interpolated between those he gives for M=9 and 15 (19). The results can be compared easily with experiments to be carried out using the Cockroft-Walton accelerator.

Since the 650 machine time is proportional to the number of collisions for which the neutron is tracked, the method would be very well suited for calculations with light moderators such as H_2O, D_2O, and Be. For hydrogenous materials the average number of collisions to thermal is about 18, whereas in carbon it is approximately 115. Further, other theoretical methods give poor results for the very light moderators. Thus, fairly accurate computations could be made for these materials in a comparatively short time.

ACKNOWLEDGMENTS

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APPENDIX I

Page

Conversion of the Source Distribution to the Laboratory System

Neutrons were assumed to be produced by the reaction

$$D(d,n)He^3 .$$

For a deuteron bombarding energy of 200 Kev, the angular distribution of emitted neutrons is (8)

$$d\sigma(\theta') = 1 + 0.95 \cos^2\theta' + 0.10 \cos^4\theta' \qquad (16)$$

where θ' is the angle in the center of mass system between the incident deuteron direction and the emitted neutron direction. The coefficients 0.95 and 0.10 were read from Figure 2 of reference (8).

The equations for the center of mass to laboratory transformation are (25)

$$\tan\theta = \frac{\sin\theta'}{\gamma + \cos\theta'} \qquad (17)$$

$$\gamma = \left[\frac{m_1 m_3}{m_2 m_4} \frac{E}{E + Q}\right]^{\frac{1}{2}} \qquad (18)$$

$$E = \frac{m_2}{m_1 m_2} E_o \qquad (19)$$

where:

Θ' was explained above

Θ is the laboratory angle corresponding to Θ'

Q is the Q value for the $D(d,n)He^3$ reaction

E_o is the deuteron bombarding energy

$m_1 = m_2$ = deuteron mass

m_3 = neutron mass

m_4 = He^3 nuclear mass.

Using the values for these constants found in Table 10,

$$\gamma = 9.965 \times 10^{-2} \tag{20}$$

$$\Theta = \arctan \left(\frac{\sin \Theta'}{.09965 + \cos \Theta'} \right) \tag{21}$$

The angle Θ', taken at two degree intervals was converted to Θ by equation (21), where Θ was picked to the nearest two degrees. The differential cross-section associated with Θ' (calculated by equation 16) was taken as that for the corresponding Θ .

Conversion of the Scattering Distribution to the Laboratory System

An elastic scattering was assumed isotropic in the center of mass system and was transformed to an anisotropic distribution in the laboratory system.

From reference (25)

$$\tan \Theta = \frac{\sin \Theta'}{\gamma + \cos \Theta'} \tag{22}$$

$$\gamma = m/M \tag{23}$$

where:

Θ' is the scattering angle in the c-m system

Θ is the scattering angle in the lab system

m = neutron mass

M = carbon nuclear mass.

Using the values in Table 10,

$$\gamma = 0.08405 \tag{24}$$

$$\Theta = \arctan \left(\frac{\sin \Theta'}{.08405 + \cos \Theta'}\right) \tag{25}$$

Again Θ' was taken at two degree intervals and Θ was calculated to the nearest two degrees by

equation (25). The values of θ so calculated were assigned equal differential scattering cross-sections.

Conversion of Cross Sections to Mean Free Paths

The cross-sections as found in references (12,13) were taken as constant in 71 energy intervals. According to Murray (24)

$$\lambda_s = \Sigma_s^{-1} \tag{26}$$

$$\Sigma_s = N\sigma_s = (\rho/A)\, N_o\, \sigma_s \tag{27}$$

where:

$_s$ refers to scattering

λ_s = mean free path

Σ_s = macroscopic cross-section

σ_s = microscopic cross-section

ρ = density of graphite

A = atomic mass of carbon, taken as 12.01 amu

N_o = Avogadro's Number.

An error was made in that the transport mean free path, λ_t, where

$$\lambda_t = \lambda_s / (1-\overline{\cos\theta}) , \tag{28}$$

was calculated and used rather than λ_s . Therefore, the mean free paths used were too large by 5.6%, since they were calculated as

$$\lambda_t = 13.198/\sigma_s \qquad (29)$$

where σ_s is in barns.

Calculation of Velocity from the Scattering Angle

The angle θ for either an emitted neutron, in the case of the source, or a scattered neutron, in the case of an elastic scattering, determined the velocity of the neutron.

In the case of a nuclear reaction (6)

$$Q = E_3(1+m_3/m_4) - E_1(1-m_1/m_4) - \frac{2\sqrt{m_1E_1m_3E_3}}{m_4}\cos\theta \qquad (30)$$

where all energies and angles are in the laboratory system. Using $E = \frac{1}{2}mv^2$, equation (30) was solved for v_3 as,

$$v_3 = \frac{m_1v_1}{m_3+m_4}\cos\theta + \sqrt{\left[\frac{m_1v_1}{m_3+m_4}\cos\theta\right]^2 + \frac{2m_4Q+m_1v_1^2(m_4-m_3)}{m_3(m_3+m_4)}} \qquad (31)$$

where Q is in ergs.

For the $D(d,n)He^3$ reaction,

v_3 is the velocity of the emitted neutron

v_1 is the velocity of the incident deuteron

Using the values in Table 10 and taking E_1 as 200 Kev, v_3 becomes

$$v_3 = \alpha + \sqrt{\alpha^2 + \beta} \tag{32}$$

where:

$$\alpha = 2.1907 \times 10^8 \cos \theta \tag{33}$$

$$\beta = 4.7804 \times 10^{18} \tag{34}$$

Thus when θ was picked, v_3 was calculated by equation (32).

For an elastic scattering, Evans (7) gives an equation in terms of the ratio of the velocity after scattering, v_1, to the velocity before scattering, v, as

$$(v_1/v)^2 - 2(v_1/v)\,[M_1/(M_1+M_2)] \cos \theta - (M_2-M_1)/(M_1+M_2) = 0 \tag{35}$$

In terms of the neutron mass, m, and the carbon mass, M, letting

$$M_o = mM/(m+M)\ , \tag{36}$$

equation (35) can be written as

$$v_1/v = (M_o/M)\cos\theta + \sqrt{(M_o/M)^2\cos^2\theta + (M_o/m) - (M_o/M)}. \quad (37)$$

Using the values in Table 10, equation (37) becomes

$$v_1/v = \gamma + \sqrt{\gamma^2 + \delta^2}, \quad (38)$$

where:

$$\gamma = 7.7538 \times 10^{-2}\cos\theta \quad (39)$$

$$\delta^2 = 8.44924 \times 10^{-1} \quad (40)$$

If the term γ^2 of equation (38) is neglected, the maximum error in v_1/v is 0.33%. This was done and v_1/v was calculated as

$$v_1/v = \gamma + \delta. \quad (41)$$

Thus when θ was picked, v_1 was obtained by multiplying equation (41) by v, the velocity before the collision.

Coordinate Rotation Through the Angles $-\theta$ and $-\phi$

Each elastic scattering was calculated in a coordinate system which was rotated with respect to the fixed coordinate system in the pile. In Figure 11, the x, y, z axes are parallel to the corresponding fixed axes of the pile, while the origin is at the position of the i^{th} collision.

The vector $\bar{R}$ is the direction traveled to the $(i + 1)^{th}$ collision. The $(i + 1)^{th}$ collision is carried out in the x', y', z' system and the coordinates locating $\bar{R}'$ must then be transformed to the x, y, z system. Therefore, the primed system must be rotated through two variable angles, $-\theta$ and $-\phi$ where these angles are for the i^{th} collision.

If x', y', z' are the position coordinates of $\bar{R}'$ in the primed system, then x, y, z will be the position coordinates of $\bar{R}'$ in the unprimed system were x, y, and z are given by:

$$x = \cos\phi\,(x'\cos\theta + z'\sin\theta) - y'\sin\phi \qquad (42)$$

$$y = \sin\phi\,(x'\cos\theta + z'\sin\theta) + y'\cos\phi \qquad (43)$$

$$z = -x'\sin\theta + z'\cos\theta \qquad (44)$$

Table 10

List of the Constants Used

Symbol	Name	Value	Reference
m_1, m_2	Deuteron Mass	2.01473 amu	(9)
m_3, m	Neutron Mass	1.00898 amu	(10)
Q	D(d,n)He^3 Q Value	3.268 Mev	(14)
m_4	He^3 Mass	3.01697 amu	(by calc.)
M	Carbon Nuclear Mass	12.0038 amu	(9)
ρ	Density of Graphite	1.60 gm/cm^3	(22)
N_o	Avogadro's Number	6.025 x 10^{24}/g mole	(5)

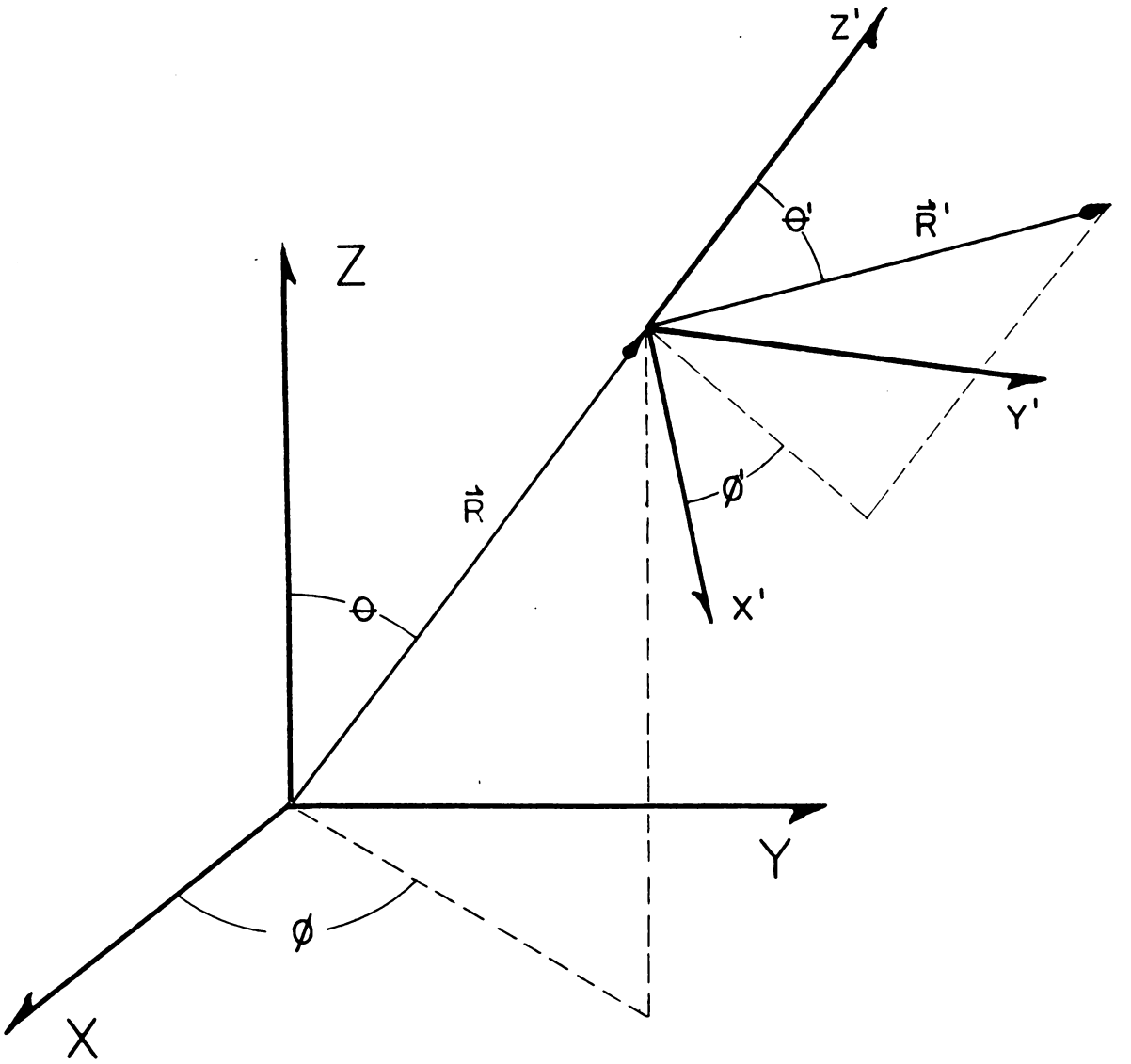

FIG. - 11

COORDINATE ROTATION

APPENDIX II

The 650 program deck is listed in Tables 11 and 12. Table 11 is the actual program, while Table 12 gives the table look-ups for the program. In Table 12, column 1 is the drum location and column 2 (10 digits) is the table entry.

There are two changes which should be made in the program in order that neutrons will not be lost due to a machine stop. In the elastic scattering section of the program, cos ϕ and sin ϕ are calculated after the transformation from x', y', z' to x, y, z. If either cos ϕ or sin ϕ is equal to 1, the machine will stop on a divide overflow. This will not happen if the dividend is shifted right before the division rather than after it.

The data on the output cards is located in the card as follows:

Column Number	Decimal Point	Data
1-5	nnnnn.	Neutron Number
6		Punch Code: 0- time card 8- thermal card 9- out card
7-10	cccc.	Collision Number
11-15	xx.xxx	X Coordinate of next collision
16-20	zz.zzz	Z Coordinate of next collision
25-30	yyy.yyy	Y Coordinate of next collision
31-40	vvvvvvvvvv.	Neutron Speed
41-50	c.cccccccc	Cos θ
51-60	c.cccccccc	Cos ϕ
61-70	c.cccccccc	Sin ϕ
71-80	ttt.ttttttt	Total Elapsed Time

Table 11 - Monte Carlo Program

		BOP							
		REL	0000						
		REQ	703SN	0000	ENTRY				
		REQ	703CS	0049	ENTRY				
		REQ	703XX	0003	EXIT				
2	0049	STD	0003	0006	COS	0049	24	0003	0006
2	0006	AUP	0009	0013		0006	10	0009	0013
2	0013	BMI	0025	0017		0013	46	0025	0017
2	0017	SUP	0020	0025		0017	11	0020	0025
2	0000	STD	0003	0025	SIN	0000	24	0003	0025
2	0025	BMI	0028	0029		0025	46	0028	0029
2	0028	AUP	0032	0037		0028	10	0032	0037
2	0029	SUP	0032	0037	THETA 2	0029	11	0032	0037
2	0037	STU	0042	0045	TO 42	0037	21	0042	0045
2	0045	BMI	0048	0099		0045	46	0048	0099
2	0048	AUP	0002	0007		0048	10	0002	0007
2	0099	SUP	0002	0007	THETA 3	0099	11	0002	0007
2	0007	STU	0012	0015	TO 12	0007	21	0012	0015
2	0015	BMI	0018	0019		0015	46	0018	0019
2	0018	AUP	0022	0027		0018	10	0022	0027
2	0019	SUP	0022	0027	THETA 4	0019	11	0022	0027
2	0027	STU	0082	0035	TO 82	0027	21	0082	0035
2	0035	RSM	F8003	0043		0035	68	8003	0043
2	0043	ALO	0046	0001		0043	15	0046	0001
2	0001	SLT	F0001	0057	THETA 5	0001	35	0001	0057
2	0057	STL	0011	0014	TO 11	0057	20	0011	0014
2	0014	RAU	F8001	0021		0014	60	8001	0021
2	0021	MPY	F8001	0005	SQ OF THET	0021	19	8001	0005
2	0005	STU	0056	0059	5 TO 56	0005	21	0056	0059
2	0059	RAU	0012	0069		0059	60	0012	0069
2	0069	BMI	0072	0073		0069	46	0072	0073
2	0072	RAU	0082	0087		0072	60	0082	0087
2	0087	BMI	0092	0050		0087	46	0092	0050
2	0073	RAU	0082	0038	PLUS SIN S	0073	60	0082	0038

```
2  0038  BMI  0050  0092  MIN COS SE  0038  46  0050  0092
2  0092  RSU  0095  0051  SIN SERIES  0092  61  0095  0051
2  0051  MPY  0056  0030  F11         0051  19  0056  0030
2  0030  AUP  0091  0096              0030  10  0091  0096
2  0096  RSU  F8003 0053              0096  61  8003  0053
2  0053  MPY  0056  0041  F9          0053  19  0056  0041
2  0041  AUP  0089  0094              0041  10  0089  0094
2  0094  RSU  F8003 0052              0094  61  8003  0052
2  0052  MPY  0056  0044  F7          0052  19  0056  0044
2  0044  AUP  0085  0090              0044  10  0085  0090
2  0090  RSU  F8003 0098              0090  61  8003  0098
2  0098  MPY  0056  0054  F5          0098  19  0056  0054
2  0054  AUP  0034  0040              0054  10  0034  0040
2  0040  RSU  F8003 0047              0040  61  8003  0047
2  0047  MPY  0056  0055  F3          0047  19  0056  0055
2  0055  AUP  0093  0097              0055  10  0093  0097
2  0097  RAU  F8003 0008              0097  60  8003  0008
2  0008  MPY  0011  0031  F1          0008  19  0011  0031
2  0031  STU  0036  0039  SIN AND CO  0031  21  0036  0039
2  0039  RAL  0042  0004              0039  65  0042  0004
2  0004  BMI  0070  0071              0004  46  0070  0071
2  0070  RAL  0036  0003  EXIT        0070  65  0036  0003
2  0071  RSL  0036  0003  EXIT        0071  66  0036  0003
2  0050  RSU  0056  0064  COS SERIES  0050  61  0056  0064
2  0064  STD  0079  0033              0064  24  0079  0033
2  0033  MPY  0086  0058  F12         0033  19  0086  0058
2  0058  AUP  0063  0068              0058  10  0063  0068
2  0068  RSU  F8003 0026              0068  61  8003  0026
2  0026  MPY  0079  0074  F10         0026  19  0079  0074
2  0074  AUP  0062  0067              0074  10  0062  0067
2  0067  RSU  F8003 0076              0067  61  8003  0076
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2  0080  AUP   0060  0065                    0080  10  0060  0065
2  0065  RSU   F8003 0023                    0065  61  8003  0023
2  0023  MPY   0079  0083  F2                0023  19  0079  0083
2  0083  AUP   0093  0031  F0                0083  10  0093  0031
2  0009  15    F7079 F6327 PI HALVES          0009  15  7079  6327
2  0020  62    F8318 F5307 TWO PI             0020  62  8318  5307
2  0032  31    F4159 F2654 PI                 0032  31  4159  2654
2  0002  15    F7079 F6327 PI HALVES          0002  15  7079  6327
2  0022  07    F8539 F8163 PI FOURTHS         0022  07  8539  8163
2  0046  07    F8539 F8163 PI FOURTHS         0046  07  8539  8163
2  0095  00    F0000 F0025 REC 11 FAC         0095  00  0000  0025
2  0091  00    F0000 F2756 REC 9 FACT         0091  00  0000  2756
2  0089  00    F0019 F8413 REC 7 FACT         0089  00  0019  8413
2  0085  00    F0833 F3333 REC 5 FACT         0085  00  0833  3333
2  0034  01    F6666 F6667 REC 3 FACT         0034  01  6666  6667
2  0093  10    F0000 F0000                    0093  10  0000  0000
2  0086  00    F0000 F0002 REC 12 FAC         0086  00  0000  0002
2  0063  00    F0000 F0276 REC 10 FAC         0063  00  0000  0276
2  0062  00    F0002 F4802 REC 8 FACT         0062  00  0002  4802
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      REQ   702XX 0018
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2  0021  STL   0027  0006                     0121  20  0127  0106
2  0006  RAL   0009  0013                     0106  65  0109  0113
2  0013  AUP   F8001 0022                     0113  10  8001  0122
2  0022  MPY   0027  0015                     0122  19  0127  0115
```

2	0015	RAL	F8003	0024			0115	65	8003	0124
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2	0023	SRT	F0001	0029			0123	30	0001	0129
2	0029	SLO	F8002	0037			0129	16	8002	0137
2	0037	MPY	F8001	0024			0137	19	8001	0124
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2	0009	50	F0000	F0000			0109	50	0000	0000
2	0019	00	F0000	F0050			0119	00	0000	0050
		REL	0150							
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2	0000	STD	0003	0006		3RN	0150	24	0153	0156
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2	0030	11	F6226	F1467		3RN	0180	11	6226	1467
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2	0016	76	F7299	F2089		3RN	0166	76	7299	2089
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		REQ	710LG	0024	ENTRY					
		REQ	710LN	0014	ENTRY					
		REQ	710XX	0027	EXIT					
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2	0080	LDD	0031	0085			0280	69	0231	0285

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2	0021	LDD	0032	0085		0221	69	0232	0285
2	0091	BMI	0099	0095	ARG IN UA	0291	46	0299	0295
2	0095	NZE	0098	0099	DEC PT CEN	0295	45	0298	0299
2	0099	HLT	F9999	F9999		0299	01	9999	9999
2	0098	SCT	F0000	0023		0298	36	0000	0223
2	0023	STL	0077	0081	77 HAS SHI	0223	20	0277	0281
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2	0030	ALO	0033	0038		0230	15	0233	0238
2	0038	SRD	F0001	0045		0238	31	0001	0245
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2	0017	SLO	F8001	0025		0217	16	8001	0225
2	0025	SLT	0009	0046		0225	35	0209	0246
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2	0037	SRD	F0000	0015		0237	31	0000	0215
2	0031	10	F0000	F0000		0231	10	0000	0000
2	0032	23	F0258	F5093	LN 10	0232	23	0258	5093
2	0015	STL	0022	0028		0215	20	0222	0228
2	0028	RAU	F8001	0035		0228	60	8001	0235
2	0035	MPY	0040	0036		0235	19	0240	0236
2	0036	AUP	0043	0001		0236	10	0243	0201
2	0001	RAU	F8003	0016		0201	60	8003	0216
2	0016	MPY	0022	0000		0216	19	0222	0200
2	0000	AUP	0003	0010		0200	10	0203	0210
2	0010	RAU	F8003	0018		0210	60	8003	0218
2	0018	MPY	0022	0004		0218	19	0222	0204
2	0004	AUP	0007	0011		0204	10	0207	0211
2	0011	RAU	F8003	0019		0211	60	8003	0219

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2       0019    MPY     0022    0026                    0219    19  0222    0226
2       0026    AUP     0029    0034                    0226    10  0229    0234
2       0034    RAU     F8003   0041                    0234    60  8003    0241
2       0041    MPY     0044    0005                    0241    19  0244    0205
2       0005    AUP     0008    0013                    0205    10  0208    0213
2       0013    SRT     F0001   0020                    0213    30  0001    0220
2       0020    ALO     F8001   0078                    0220    15  8001    0278
2       0029     86     F8591   F7180                   0229    86  8591    7180
2       0007     28     F9335   F5240                   0207    28  9335    5240
2       0003     17     F7522   F0710                   0203    17  7522    0710
2       0043     09     F4376   F4760                   0243    09  4376    4760
2       0040     19     F1337   F7140                   0240    19  1337    7140
2       0012     31     F6227   F7660                   0212    31  6227    7660
2       0033     31     F6227   F7660                   0233    31  6227    7660
2       0008     50     F0000   F0000                   0208    50  0000    0000
2       0078    STU     0082    0086                    0278    21  0282    0286
2       0086    RSU     0077    0083                    0286    61  0277    0283
2       0083    AUP     0087    0092                    0283    10  0287    0292
2       0087     00     F0000   F0004                   0287    00  0000    0004
2       0092    SRT     F0001   0079                    0292    30  0001    0279
2       0079    RAU     F8002   0042                    0279    60  8002    0242
2       0042    AUP     0082    0089                    0242    10  0282    0289
2       0089    MPY     0088    0027    ANS IN UA       0289    19  0288    0227
1
                BLR     0000    0299
                BLR     1400    1799
                REG     P1677   1686
        ESCAT   RAL     P0001                           0300    65  1677    0331
                ALO     EIN             STEP COLL       0331    15  0334    0339
                STL     P0001           NUMBER ONE      0339    20  1677    0330
                RAL     INSTL                           0330    65  0333    0337
                LDD     P0004           LOOK UP         0337    69  1680    0383
                TLU      1600    8002   LAMDA           0383    84  1600    8002
        INSTL   RAU     0000    NEXT6                   0333    60  0000    0305
        NEXT6   SLT     0007                            0305    35  0007    0321
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                SRT     0001                                    0321    30  0001  0327
                SUP     TWO                                     0327    11  0380  0335
              - STU     LAMDA   NEXTZ       STORELAMDA          0335  - 21  0340  0343
NEXTZ           LDD     INSTM   0150        TO RN SUB           0343    69  0346  0150
INSTM           RAL     8001                                    0346    65  8001  0303
                SRD     0005                                    0303    31  0005  0317
                RAU     8002                                    0317    60  8002  0325
                NZU     NOZER   NEXTZ                           0325    44  0329  0343
NOZER           LDD     INSTN   0214        TO LN SUB           0329    69  0332  0214
INSTN           RAU     8003                GET DIST            0332    60  8003  0389
                MPY     LAMDA               NEXT COLL           0389    19  0340  0310
              - STU     DIST                                    0310  - 21  0314  0367
                LDD     INSTO   0150        TO RN SUB           0367    69  0320  0150
INSTO           RAU     8001                                    0320    60  8001  0377
                MPY     1792                                    0377    19  1792  0312
                STU     ARGU                                    0312    21  0316  0319
                RAL     INSTP                                   0319    65  0322  0427
                LDD     ARGU                                    0427    69  0316  0369
                TLU     1700    8002        LOOK UP             0369    84  1700  8002
INSTP           RAU     0000    NEXT8       THETA PRIM          0322    60  0000  0355
NEXT8           SLT     0005                                    0355    35  0005  0417
              - STU     THETP                                   0417  - 21  0372  0375
                LDD     INSTQ   0049        TO COS SUB          0375    69  0328  0049
INSTQ           STL     COSTP                                   0328    20  0433  0336
                RAU     THETP                                   0336    60  0372  0477
                LDD     INSTR   0000        TO SIN SUB          0477    69  0430  0000
INSTR           STL     SINTP                                   0430    20  0385  0338
                RAU     GAMMA               CALCULATE           0338    60  0341  0345
                MPY     COSTP               NEW VEL             0345    19  0433  0304
                SLT     0002                                    0304    35  0002  0311
                AUP     DELTA                                   0311    10  0364  0419
                RAU     8003                                    0419    60  8003  0527
                MPY     P0004                                   0527    19  1680  0350
              - STU     P0004               STORE VEL           0350  - 21  1680  0483
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              RAU   8003                                   0483     60  8003  0391
              SCT   0000                    CALCULATE      0391     36  0000  0313
              SLT   0004                    TIME NEUT      0313     35  0004  0323
              STL   COUNT                   TRAVELED       0323     20  0577  0480
              ALO   INSTS                   SINCE LAST     0480     15  0533  0387
              STL   NEXT9    NEXTA          COLLISION      0387     20  0441  0344
     INSTS    SRT   0003     NEXTB                         0533     30  0003  0439
     NEXTA    RAU   DIST     NEXT9                         0344     60  0314  0441
     NEXTB    DVR   P0004                                  0439     64  1680  0390
              STL   TIME                    STORE TIME     0390     20  0395  0348
              RAL   COUNT                                  0348     65  0577  0381
              ALO   SHIFT                                  0381     15  0384  0489
              STL   LEFT                    ADD TIME       0489     20  0393  0396
              RAL   TIME     LEFT           TO TOTAL       0396     65  0395  0393
     SHIFT    SLT   0000     ADD            ELAPSED        0384     35  0000  0307
     ADD      ALO   P0008                   TIME           0307     15  1684  0539
            - STL   P0008                                  0539   - 20  1684  0437
              LDD   INSTT    0150           TO RN SUB      0437     69  0440  0150
     INSTT    RAU   8001                                   0440     60  8001  0347
              MPY   0020                    MPY BY         0347     19  0020  0490
            - STU   PHIP                    TWO PI         0490   - 21  0394  0397
              RAU   8001                                   0397     60  8001  0405
              LDD   INSTU    0049           TO COS SUB     0405     69  0308  0049
     INSTU    STL   COSPP                                  0308     20  0363  0366
              RAU   PHIP                                   0366     60  0394  0349
              LDD   INSTV    0000           TO SIN SUB     0349     69  0302  0000
     INSTV    STL   SINPP                                  0302     20  0357  0360
              RAU   DIST                    CALCULATE      0360     60  0314  0469
              MPY   SINTP                   AND STORE      0469     19  0385  0306
              SLT   0001                    X  PRIME       0306     35  0001  0413
              STU   DISTS                                  0413     21  0318  0371
              RAU   8001                                   0371     60  8001  0379
              MPY   COSPP                                  0379     19  0363  0434
              SLT   0001                                   0434     35  0001  0491
            - STU   X1                                     0491   - 21  0446  0399
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  RAU  DISTS    CALCULATE    0399    60 0318 0373
  MPY  SINPP    AND STORE    0373    19 0357 0378
  SLT   0001    Y  PRIME     0378    35 0001 0435
- STU  Y1                    0435  - 21 0540 0443
  RAU  DIST                  0443    60 0314 0519
  MPY  COSTP    CALCULATE    0519    19 0433 0354
  SLT   0001    AND STORE    0354    35 0001 0361
- STU  Z1       Z  PRIME     0361  - 21 0416 0569
  RAU  X1       TRANSFORM    0569    60 0446 0301
  MPY   1681    XYZ PRIME    0301    19 1681 0352
  SLT   0001    TO XYZ BY    0352    35 0001 0309
  STU  M        ROTATION     0309    21 0414 0467
  RAU  Z1       THROUGH      0467    60 0416 0421
  MPY   1685    ANGLES       0421    19 1685 0356
  SLT   0001    THETA AND    0356    35 0001 0463
  AUP  M        PHI          0463    10 0414 0619
  STU  N                     0619    21 0324 0627
  RAU   8001                 0627    60 8001 0485
  MPY   1682                 0485    19 1682 0402
  SLT   0001                 0402    35 0001 0359
  STU  O                     0359    21 0464 0517
  RAU  N                     0517    60 0324 0429
  MPY   1683                 0429    19 1683 0404
  SLT   0001                 0404    35 0001 0411
  STU  Q                     0411    21 0466 0669
  RAU  Y1                    0669    60 0540 0445
  MPY   1683                 0445    19 1683 0454
  SLT   0001                 0454    35 0001 0461
  STU  S                     0461    21 0516 0719
  RAU  O                     0719    60 0464 0769
  SUP  S                     0769    11 0516 0471
- STU  X        STORE  X     0471  - 21 0326 0479
  RAU  Y1                    0479    60 0540 0495
  MPY   1682                 0495    19 1682 0452
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          SLT   0001                        0452    35  0001  0409
          AUP   Q                           0409    10  0466  0521
        - STU   Y          STORE  Y         0521  - 21  0376  0529
          RAU   X1                          0529    60  0446  0351
          MPY    1685                       0351    19  1685  0406
          SLT    0001                       0406    35  0001  0513
          STU   R                           0513    21  0368  0571
          RAU   Z1                          0571    60  0416  0621
          MPY    1681                       0621    19  1681  0502
          SLT    0001                       0502    35  0001  0459
          SUP   R                           0459    11  0368  0423
        - STU   Z          STORE  Z         0423  - 21  0428  0431
          RAU    8001                       0431    60  8001  0589
          DVR   DIST       CALCULATE        0589    64  0314  0374
          SRT    0001      NEW COS          0374    30  0001  0481
        - STL   P0005      THETA            0481  - 20  1681  0484
          RAU    8002                       0484    60  8002  0493
          MPY    8001                       0493    19  8001  0566
          SLT    0001      CALCULATE        0566    35  0001  0473
          RSL    8003      NEW SINE         0473    66  8003  0531
          ALO   PLUS       THETA FROM       0531    15  0534  0639
          SLT    0001      COS THETA        0639    35  0001  0545
          LDD   B     0110 TO SR SUB        0545    69  0398  0110
  B       SRT    0001                       0398    30  0001  0455
        - STL   P0009                       0455  - 20  1685  0388
          RAM   X                           0388    67  0326  0581
          SML   Y                           0581    18  0376  0631
          BMI   C      A                    0631    46  0584  0535
  C       RAM   Y      G                    0584    67  0376  0681
  G       RAU    8002      CALCULATE        0681    60  8002  0689
          SCT    0000      NEW SINE         0689    36  0000  0511
          SLT    0004      AND COSINE       0511    35  0004  0671
          LDD   E          OF PHI           0671    69  0424  0677
          SDA   E                           0677    22  0424  0727
          LDD   F                           0727    69  0530  0583
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                SDA     F       I                               0583    22  0530    0633
          A     RAM     X       G                               0535    67  0326    0681
          E     SLT     0000    H                               0424    35  0000    0447
          F     SLT     0000    L                               0530    35  0000    0353
          I     RAU     X       E                               0633    60  0326    0424
          H     SRT     0001                                    0447    30  0001    0403
                LDD     8003                                    0403    69  8003    0410
                STD     J                                       0410    24  0563    0616
                MPY     8001                                    0616    19  8001    0590
                STU     XTWO                                    0590    21  0444    0497
                RAU     Y       F                               0497    60  0376    0530
          L     SRT     0001                                    0353    30  0001    0509
                LDD     8003                                    0509    69  8003    0666
                STD     K                                       0666    24  0819    0422
                MPY     8001                                    0422    19  8001    0496
                AUP     XTWO                                    0496    10  0444    0449
                RAL     8003                                    0449    65  8003    0407
                LDD     INSTW   0110    TO SR SUB               0407    69  0460    0110
          INSTW STL     SRXY    NEXTW                           0460    20  0315    0418
          NEXTW RAU     8001                                    0418    60  8001    0425
                NZU     NZER    ZEER                            0425    44  0579    0580
          NZER  NOP             NEXTC                           0579    00  0629    0683
          ZEER  LDD     ZERO                                    0580    69  0733    0386
                STD     P0007                                   0386    24  1683    0436
                LDD     PLUS                                    0436    69  0534    0487
                STD     P0006   NEXTU                           0487    24  1682    0585
          NEXTC RAU     J                                       0683    60  0563    0567
                DVR     SRXY                                    0567    64  0315    0426
                SRT     0001            STORE COS               0426    30  0001    0783
              - STL     P0006           OF PHI                  0783  - 20  1682    0635
                RAU     K                                       0635    60  0819    0523
                DVR     SRXY                                    0523    64  0315    0476
                SRT     0001            STORE SINE              0476    30  0001    0833
              - STL     P0007   NEXTU   OF PHI                  0833    20  1683    0585
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                NEXTU   RAL     X                                       0585    65  0326    0731
                        SRT      0003           CHECK   X               0731    30  0003    0739
                        STL     X                                       0739    20  0326    0679
                        RAL     P0002          SEPARATE X              0679    65  1678    0883
                        SLT      0005          AND   Z                 0883    35  0005    0595
                        STL     ZEE                                     0595    20  0499    1930
                        BMI     NEG30   POS30                           1930    46  1934    1932
                NEG30   LDD     MINUS                                   1934    69  0889    1912
                        STD     MPLY    NEXT                            1912    24  1901    0552
                POS30   LDD     PLUS                                    1932    69  0534    1944
                        STD     MPLY    NEXT                            1944    24  1901    0552
                NEXT    RAM      8003                                   0552    67  8003    0559
                        ALO     X               ADD  X FROM             0559    15  0326    0781
                        BMI     NEG5    POS5    LAST COLL               0781    46  0634    0685
                NEG5    RAM      8002   POS5    TO TOTAL X              0634    67  8002    0685
                POS5    SLO     MAGX                                    0685    16  0438    0543
                        BMI     NEG6    POS1                            0543    46  0546    0547
                NEG6    ALO     MAGX                                    0546    15  0438    0593
                        RAU      8002                                   0593    60  8002    0401
                        AML     ZEE             PACK  X Z               0401    17  0499    0453
                        SLT      0005           AND STORE               0453    35  0005    1915
                        MPY     MPLY                                    1915    19  1901    1925
                        SLT      0001                                   1925    35  0001    0365
                        STU     P0002                                   0365    21  1678    0831
                        RAL     Y               CHECK  Y                0831    65  0376    0881
                        SRT      0003                                   0881    30  0003    0789
                        ALO     P0003           ADD  Y FROM             0789    15  1679    0933
                        BMI     NEG7    POS7    LAST COLL               0933    46  0536    0537
                NEG7    RAM      8002   POS7    TO TOTAL Y              0536    67  8002    0537
                POS7    SLO     MAGY                                    0537    16  0640    0645
                        BMI     NEG8    POS1                            0645    46  0448    0547
                NEG8    ALO     MAGY                                    0448    15  0640    0695
                        STL     P0003                                   0695    20  1679    0382
                        RAL     Z               CHECK  Z                0382    65  0428    0983
                        SRT      0003                                   0983    30  0003    0541
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                  STL   Z                         SEPARATE X      0541  20  0428  0931
                  RAL   P0002                     AND  Z          0931  65  1678  1033
                  SLT    0005                                     1033  35  0005  0745
                  STL   P0000                                     0745  20  1676  0981
                  RAM    8003                                     0981  67  8003  0839
                  SLT    0005                                     0839  35  0005  0451
                  STL   X                                         0451  20  0326  0729
                  RAL   P0000                     ADD Z FROM      0729  65  1676  1083
                  SRT    0005                     LAST COLL       1083  30  0005  0795
                  ALO   Z                         TO TOTAL Z      0795  15  0428  1133
                  BMI   NEG9     POS9                             1133  46  0586  0587
         NEG9     LDD   MINUS                                     0586  69  0889  0342
                  STD   NEXTD    NEXTE                            0342  24  0845  0498
         POS9     LDD   PLUS                                      0587  69  0534  0637
                  STD   NEXTD    NEXTE                            0637  24  0845  0498
         NEXTE    RAM    8002                                     0498  67  8002  0457
                  SLO   MAGZ                                      0457  16  0510  0415
                  BMI   NEG10    POS1                             0415  46  0468  0547
         NEG10    ALO   MAGZ                                      0468  15  0510  0465
                  ALO   X                         PACK  X Z       0465  15  0326  1031
                  RAU    8002                     AND STORE       1031  60  8002  0939
                  MPY   NEXTD                                     0939  19  0845  0716
                  SLT    0001                                     0716  35  0001  0573
                - STU   P0002.   NEXTX                            0573 -21  1678  1081
         NEXTX    RAU   P0004                     CHECK VEL       1081  60  1680  0643
                  AUP    1600                                     0643  10  1600  0505
                  BMI   NEGA     POSA                             0505  46  0358  0609
         NEGA     RAU   P0001                                     0358  60  1677  0735
                  AUP   VCODE                                     0735  10  0486  1906
                  STU   P0001                     PUNCH IF        1906  21  1677  0777
                  PCH   P0001    START            VEL BELOW       0777  71  1677  1131
         VCODE    00     0008     0000            THERMAL         0486  00  0008  0000
         POSA     NOP            NEXTY                            0609  00  0659  0613
         NEXTY    RAL   P0008                                     0613  65  1684  0989
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                SLO   UNO                 CHECK TIME   0989   16   0392   0597
                BMI   NEG11   POS11       FOR 1 MU     0597   46   0400   0501
NEG11           NOP           ESCAT       SEC PUNCH    0400   00   0450   0300
POS11           RAU   BOX1                             0501   60   0504   0709
                SUP   EIN                              0709   11   0334   1039
                BMI   NEG12   POS12                     1039   46   0442   0693
NEG12           AUP   DOS                              0442   10   0895   0549
                STU   BOX1                             0549   21   0504   0507
                PCH   P0001   ESCAT                     0507   71   1677   0300
POS12           RAL   P0008                            0693   65   1684   1089
                SLO   TWOO                CHECK TIME   1089   16   1929   0785
                BMI   NEG13   POS13       FOR 2 MU     0785   46   0488   1139
NEG13           NOP           ESCAT       SEC PUNCH    0488   00   0538   0300
POS13           RAU   BOX2                             1139   60   0492   0647
                SUP   EIN                              0647   11   0334   1189
                BMI   NEG14   POS14                     1189   46   0542   0743
NEG14           AUP   DOS                              0542   10   0895   0599
                STU   BOX2                             0599   21   0492   0945
                PCH   P0001   ESCAT                     0945   71   1677   0300
POS14           RAL   P0008                            0743   65   1684   1239
                SLO   FIVE                CHECK TIME   1239   16   0592   0697
                BMI   NEG15   POS15       FOR 5 MU     0697   46   0500   0551
NEG15           NOP           ESCAT       SEC PUNCH    0500   00   0550   0300
POS15           RAU   BOX5                             0551   60   0554   0759
                SUP   EIN                              0759   11   0334   1289
                BMI   NEG16   POS16                     1289   46   0642   0793
NEG16           AUP   DOS                              0642   10   0895   0649
                STU   BOX5                             0649   21   0554   0557
                PCH   P0001   ESCAT                     0557   71   1677   0300
POS16           RAL   P0008                            0793   65   1684   1339
                SLO   TEN                 CHECK TIME   1339   16   1933   1389
                BMI   NEG17   POS17       FOR 10 MU    1389   46   0692   0843
NEG17           NOP           ESCAT       SEC PUNCH    0692   00   0742   0300
POS17           RAU   BOX10                            0843   60   1949   1905
                SUP   EIN                              1905   11   0334   1945
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                BMI     NEG18   ESCAT                           1945    46  1950    0300
NEG18           AUP     DOS                                     1950    10  0895    1910
                STU     BOX10                                   1910    21  1949    1920
                PCH     P0001   ESCAT                           1920    71  1677    0300
        ZERO    00      0000    0000                            0733    00  0000    0000
        ONE     00      0010    0000                            0600    00  0010    0000
        ALPHA   02      1907    0000                            0650    02  1907    0000
        BETA    04      7804    0000                            0700    04  7804    0000
        TWO     02      0000    0000                            0380    02  0000    0000
        MAGX    00      0008    3820                            0438    00  0008    3820
        MAGY    00      0012    7000                            0640    00  0012    7000
        MAGZ    00      0008    3820                            0510    00  0008    3820
        OUT     00      0009    0000                            0750    00  0009    0000
        PLUS    10      0000    0000                            0534    10  0000    0000
        MINUS   - 10    0000    0000                            0889  - 10  0000    0000
        EIN     00      0000    0001                            0334    00  0000    0001
        GAMMA   00      7753    8000                            0341    00  7753    8000
        DELTA   91      9197    5000                            0364    91  9197    5000
        UNO     00      1000    0000                            0392    00  1000    0000
        DOS     00      0000    0002                            0895    00  0000    0002
        FIVE    00      5000    0000                            0592    00  5000    0000
        TWOO    00      2000    0000                            1929    00  2000    0000
        TEN     01      0000    0000                            1933    01  0000    0000
        START   RAL     P0001           ZERO COLL               1131    65  1677    1181
                SRT     0005            NUMBER                  1181    30  0005    0893
                SLT     0005                                    0893    35  0005    0555
                ALO     ONE             STEP NEUT               0555    15  0600    0605
                STL     P0001           NUMBER                  0605    20  1677    0630
                LDD     ZERO                                    0630    69  0733    0636
                STD     P0002           ZERO  XYZ               0636    24  1678    1231
                STD     BOX10           TIME AND                1231    24  1949    1904
                STD     P0003           TIME COUNT              1904    24  1679    0432
                STD     P0008           BOXES                   0432    24  1684    0687
                STD     BOX1                                    0687    24  0504    0607
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                STD   BOX2                                  0607   24  0492  0995
                STD   BOX5                                  0995   24  0554  0657
                LDD   INSTA   0150      TO RN SUB           0657   69  0560  0150
INSTA           RAU    8001                                 0560   60  8001  0617
                MPY   1491                                  0617   19  1491  0362
                STU   ARGU                                  0362   21  0316  0869
                RAL   ZERO                                  0869   65  0733  0737
                LDD   ARGU                                  0737   69  0316  0919
                TLU    1400             LOOK UP             0919   84  1400  0655
                ALO   INSTB   8002      FOR THETA           0655   15  0408  8002
INSTB           RAU    0100   NEXT1                         0408   60  0100  0705
NEXT1           STU   THETA                                 0705   21  0610  0663
                LDD   INSTC   0049      TO COS SUB          0663   69  0766  0049
INSTC   -       STL   P0005                                 0766 - 20  1681  0684
                RAU   THETA                                 0684   60  0610  0515
                LDD   INSTD   0000      TO SIN SUB          0515   69  0518  0000
INSTD   -       STL   P0009                                 0518 - 20  1685  0588
                RAU   P0005             CALCULATE           0588   60  1681  0835
                MPY   ALPHA             NEUT VEL            0835   19  0650  0370
                SLT    0001                                 0370   35  0001  0877
                STU   ALPH1                                 0877   21  0482  0885
                RAU    8001                                 0885   60  8001  0943
                MPY   ALPH1                                 0943   19  0482  0602
                RAL    8003                                 0602   65  8003  0809
                ALO   BETA                                  0809   15  0700  0755
                LDD   INSTE   0110      TO SR SUB           0755   69  0458  0110
INSTE           ALO   ALPH1                                 0458   15  0482  0787
        -       STL   P0004             STORE VEL           0787 - 20  1680  1183
                RAL   INSTF                                 1183   65  0686  0591
                LDD   P0004                                 0591   69  1680  1233
                TLU    1600   8002      LOOK UP             1233   84  1600  8002
INSTF           RAU    0000   NEXT2     LAMDA               0686   60  0000  0805
NEXT2           SRT    0003                                 0805   30  0003  0713
                RAL    8002                                 0713   65  8002  0721
                SRT    0001                                 0721   30  0001  0927
```

```
                 SLO   TWO                                   0927     16  0380  0935
               - STL   LAMDA   NEXT3     STORELAMDA          0935   - 20  0340  0993
        NEXT3    LDD   INSTG   0150      TO RN SUB           0993     69  0596  0150
        INSTG    RAL    8001                                 0596     65  8001  0503
                 SRD    0005                                 0503     31  0005  0667
                 RAU    8002                                 0667     60  8002  0475
                 NZU   NZERO   NEXT3                         0475     44  0779  0993
        NZERO    LDD   INSTH   0214      TO LN SUB           0779     69  0532  0214
        INSTH    RAU    8003                                 0532     60  8003  1939
                 MPY   LAMDA                                 1939     19  0340  0660
               - STU   DIST              STORE DIST          0660   - 21  0314  0717
                 LDD   INSTI   0150      TO RN SUB           0717     69  0420  0150
        INSTI    RAU    8001                                 0420     60  8001  0977
                 MPY    0009             MPY BY              0977     19  0009  0680
                 RAU    8003             PI HALVES           0680     60  8003  0837
                 STU   PHI                                   0837     21  0792  1045
                 LDD   INSTJ   0049      TO COS SUB          1045     69  0548  0049
        INSTJ  - STL   P0006                                 0548   - 20  1682  0985
                 RAU   PHI                                   0985     60  0792  0747
                 LDD   INSTK   0000      TO SIN SUB          0747     69  0800  0000
        INSTK  - STL   P0007                                 0800   - 20  1683  0736
                 RAU   DIST              CALCULATE           0736     60  0314  0969
                 SRT    0003             AND STORE           0969     30  0003  0525
                 DVR   P0004             TIME                0525     64  1680  0690
               - STL   P0008                                 0690   - 20  1684  0887
                 RAU   DIST                                  0887     60  0314  1019
                 MPY   P0009             CALCULATE           1019     19  1685  0456
                 SLT    0001             X  CHECK            0456     35  0001  0763
                 RAU    8003             AND STORE           0763     60  8003  0771
                 STD   DISTS                                 0771     24  0318  0821
                 MPY   P0006                                 0821     19  1682  0652
                 SLT    0001                                 0652     35  0001  0859
                 RAL    8003                                 0859     65  8003  0767
```

```
                 SRD   0003                             0767   31  0003  1027
                 SLO   MAGX                             1027   16  0438  1043
                 BMI   NEG1    POS1                     1043   46  0646  0547
      POS1       RAL   OUT                              0547   65  0750  0553
                 ALO   P0001                            0553   15  1677  1281
                 STL   P0001                            1281   20  1677  0582
                 PCH   P0001   START                    0582   71  1677  1131
      NEG1       ALO   MAGX                             0646   15  0438  1093
                 SLT   0005                             1093   35  0005  0855
                 STL   P0002                            0855   20  1678  1331
                 RAU   DISTS           CALCULATE        1331   60  0318  0623
                 MPY   P0007           Y  CHECK         0623   19  1683  0604
                 SLT   0001            AND STORE        0604   35  0001  0561
                 RAL   8003                             0561   65  8003  1069
                 SRD   0003                             1069   31  0003  0829
                 SLO   MAGY                             0829   16  0640  1095
                 BMI   NEG2    POS1                     1095   46  0598  0547
      NEG2       ALO   MAGY                             0598   15  0640  1145
               - STL   P0003                            1145 - 20  1679  0632
                 RAU   DIST            CALCULATE        0632   60  0314  1119
                 MPY   P0005           Z  CHECK         1119   19  1681  0702
                 SLT   0001            AND STORE        0702   35  0001  0909
                 BMI   NEG3    POS3                     0909   46  0412  0813
      NEG3       LDD   MINUS                            0412   69  0889  0842
                 STD   NEXT5   NEXT4                    0842   24  1195  0648
      POS3       LDD   PLUS                             0813   69  0534  0937
                 STD   NEXT5   NEXT4                    0937   24  1195  0648
      NEXT4      RAM   8003                             0648   67  8003  0905
                 SRD   0003                             0905   31  0003  0565
                 SLO   MAGZ                             0565   16  0510  0615
                 BMI   NEG4    POS1                     0615   46  0568  0547
      NEG4       ALO   MAGZ            PACK  XZ         0568   15  0510  0665
                 ALO   P0002                            0665   15  1678  1283
                 RAU   8002                             1283   60  8002  0641
                 MPY   NEXT5                            0641   19  1195  0816
```

```
SLT     0001                                    0816     35   0001   0673
- STU   P0002   ESCAT                           0673   -  21   1678   0300
```

Table 12 - Monte Carlo Table Look-ups

1400	00	0020	5000
1401	00	0040	9860
1402	00	0061	4301
1403	00	0081	8046
1404	00	0102	0822
1405	00	0122	2364
1406	00	0142	2412
1407	00	0162	0716
1408	00	0181	7037
1409	00	0201	1147
1410	00	0220	2831
1411	00	0239	1890
1412	00	0257	8139
1413	00	0276	1408
1414	00	0294	1548
1415	00	0311	8423
1416	00	0329	1917
1417	00	0346	1935
1418	00	0362	8397
1419	00	0379	1244
1420	00	0395	0436
1421	00	0410	5951
1422	00	0425	7787
1423	00	0440	5958
1424	00	0455	0497
1425	00	0469	1456
1426	00	0482	8902
1427	00	0496	2917
1428	00	0509	3601
1429	00	0522	1067
1430	00	0534	5442
1431	00	0546	6866
1432	00	0558	5491
1433	00	0570	1481
1434	00	0581	5010
1435	00	0592	6260
1436	00	0603	5423
1437	00	0614	2699
1438	00	0624	8293
1439	00	0635	2418
1440	00	0645	5292
1441	00	0655	7136
1442	00	0665	8175
1443	00	0675	8638
1444	00	0685	8754
1445	00	0695	8754
1446	00	0705	8870

1447	00	0715	9333
1450	00	0726	0372
1451	00	0736	2216
1452	00	0746	5090
1453	00	0756	9215
1454	00	0767	4809
1455	00	0778	2084
1456	00	0789	1247
1457	00	0800	2497
1458	00	0811	6025
1459	00	0823	2015
1460	00	0835	0640
1461	00	0847	2064
1462	00	0859	6439
1463	00	0872	3905
1464	00	0885	4589
1465	00	0898	8604
1466	00	0912	6049
1467	00	0926	7008
1468	00	0941	1547
1469	00	0955	9718
1470	00	0971	1554
1471	00	0986	7069
1472	00	1002	6261
1473	00	1018	9108
1474	00	1035	5570
1475	00	1052	5588
1476	00	1069	9083
1477	00	1087	5958
1478	00	1105	6097
1479	00	1123	9367
1480	00	1142	5615
1481	00	1161	4674
1482	00	1180	6359
1483	00	1200	0468
1484	00	1219	6788
1485	00	1239	5092
1486	00	1259	5139
1487	00	1279	6680
1488	00	1299	9456
1489	00	1320	3201
1490	00	1340	7642
1491	00	1361	2502
1500	00	0000	0000
1501	00	3490	0000
1502	00	6980	0000
1503	01	0470	0000

1504	01	3960	0000
1505	01	7450	0000
1506	01	7450	0000
1507	02	0940	0000
1508	02	4440	0000
1509	02	7930	0000
1510	03	1420	0000
1511	03	4910	0000
1512	03	8400	0000
1513	04	1890	0000
1514	04	5380	0000
1515	04	8870	0000
1516	05	2360	0000
1517	05	5850	0000
1518	05	5850	0000
1519	05	9340	0000
1520	06	6320	0000
1521	06	6320	0000
1522	06	9810	0000
1523	07	3300	0000
1524	07	6790	0000
1525	08	0290	0000
1526	08	3780	0000
1527	08	7270	0000
1528	09	0760	0000
1529	09	4250	0000
1530	09	7740	0000
1531	10	1230	0000
1532	10	4720	0000
1533	10	4720	0000
1534	10	8210	0000
1535	11	1700	0000
1536	11	5190	0000
1537	11	8680	0000
1538	12	2170	0000
1539	12	5660	0000
1540	12	9150	0000
1541	13	2650	0000
1542	13	6140	0000
1543	13	9630	0000
1544	14	3120	0000
1545	14	6610	0000
1546	15	0100	0000
1547	15	3590	0000
1550	15	7080	0000
1551	16	0570	0000
1552	16	4060	0000

1553	16	7550	0000
1554	17	1040	0000
1555	17	4530	0000
1556	17	8020	0000
1557	18	1510	0000
1558	18	5010	0000
1559	18	8500	0000
1560	19	1990	0000
1561	19	5480	0000
1562	19	8970	0000
1563	20	2460	0000
1564	20	9440	0000
1565	21	2930	0000
1566	21	6420	0000
1567	21	9910	0000
1568	22	3400	0000
1569	22	6890	0000
1570	23	0380	0000
1571	23	3870	0000
1572	23	7370	0000
1573	24	0860	0000
1574	24	4350	0000
1575	24	7840	0000
1576	25	1330	0000
1577	25	4820	0000
1578	26	1800	0000
1579	26	5290	0000
1580	26	8780	0000
1581	27	2270	0000
1582	27	5760	0000
1583	27	9250	0000
1584	28	2740	0000
1585	28	6230	0000
1586	28	9720	0000
1587	29	3220	0000
1588	30	0200	0000
1589	30	3690	0000
1590	30	7180	0000
1591	31	0670	0000
1600	- 00	0021	9069
1601	- 00	0029	3087
1602	- 00	0033	9075
1603	- 00	0036	6064
1604	- 00	0043	7081
1605	- 00	0097	8075
1606	- 00	0138	3077
1607	- 01	3832	0082

1608	- 02	1870	3087
1609	- 03	0929	3091
1610	- 03	7880	5093
1611	- 04	3740	6096
1612	- 04	8903	5099
1613	- 05	3571	1101
1614	- 05	7863	4106
1615	- 06	1858	6111
1616	- 06	5610	9116
1617	- 06	9160	0122
1618	- 07	2535	6130
1619	- 07	5761	0138
1620	- 07	9458	8145
1621	- 08	1479	8148
1622	- 08	3566	3154
1623	- 08	5602	1158
1624	- 08	7808	7163
1625	- 09	0067	5168
1626	- 09	2270	9174
1627	- 09	4625	4179
1628	- 09	7021	4185
1629	- 09	9552	0190
1630	- 10	2019	8198
1631	- 10	4612	4205
1632	- 10	7231	5212
1633	- 10	9962	2219
1634	- 11	2881	3226
1635	- 11	5644	1236
1636	- 11	8504	0243
1637	- 12	1532	8252
1638	- 12	4641	6263
1639	- 12	7749	6273
1640	- 13	1003	0283
1641	- 13	4320	0296
1642	- 13	7696	2308
1643	- 14	1194	8322
1644	- 14	4807	2334
1645	- 14	8331	7350
1646	- 15	2152	0364
1647	- 15	5878	7381
1650	- 16	0117	0400
1651	- 16	4245	9417
1652	- 16	8273	5435
1653	- 17	2207	0453
1654	- 17	6595	2477
1655	- 18	1405	0498
1656	- 18	6090	5521

1657	- 19	0661	0546
1658	- 19	5614	0600
1659	- 20	0444	7400
1660	- 20	5627	5620
1661	- 21	0682	7630
1662	- 21	6062	7651
1663	- 22	1312	0625
1664	- 22	6861	7586
1665	- 23	2690	3460
1666	- 23	8376	4263
1667	- 24	4713	1948
1668	- 25	0889	8444
1669	- 25	7290	1374
1670	- 26	3897	7397
1671	- 27	0344	0428
1672	- 27	7330	7506
1700	01	0000	0000
1701	02	0000	0349
1702	03	0000	0698
1703	04	0000	1047
1704	05	0000	1396
1705	06	0000	1745
1706	07	0000	2094
1707	08	0000	2094
1708	09	0000	2444
1709	10	0000	2793
1710	11	0000	3142
1711	12	0000	3491
1712	13	0000	3840
1713	14	0000	4189
1714	15	0000	4538
1715	16	0000	4887
1716	17	0000	5236
1717	18	0000	5585
1718	19	0000	5934
1719	20	0000	6283
1720	21	0000	6632
1721	22	0000	6632
1722	23	0000	6981
1723	24	0000	7330
1724	25	0000	7679
1725	26	0000	8029
1726	27	0000	8378
1727	28	0000	8727
1728	29	0000	9076
1729	30	0000	9425
1730	31	0000	9774

1731	32	0001	0123
1732	33	0001	0472
1733	34	0001	0821
1734	35	0001	1170
1735	36	0001	1519
1736	37	0001	1868
1737	38	0001	2217
1738	39	0001	2566
1739	40	0001	2915
1740	41	0001	3265
1741	42	0001	3614
1742	43	0001	3963
1743	44	0001	4312
1744	45	0001	4661
1745	46	0001	5010
1746	47	0001	5359
1747	48	0001	5533
1750	49	0001	5883
1751	50	0001	6406
1752	51	0001	6755
1753	52	0001	7104
1754	53	0001	7453
1755	54	0001	7802
1756	55	0001	8151
1757	56	0001	8501
1758	57	0001	8850
1759	58	0001	9199
1760	59	0001	9548
1761	60	0001	9897
1762	61	0002	0246
1763	62	0002	0595
1764	63	0002	0944
1765	64	0002	1293
1766	65	0002	1642
1767	66	0002	1991
1768	67	0002	2340
1769	68	0002	2689
1770	69	0002	3038
1771	70	0002	3387
1772	71	0002	3737
1773	72	0002	4086
1774	73	0002	4435
1775	74	0002	4784
1776	75	0002	5482
1777	76	0002	5831
1778	77	0002	6180
1779	78	0002	6529

1780	79	0002	6878
1781	80	0002	7227
1782	81	0002	7576
1783	82	0002	7925
1784	83	0002	8274
1785	84	0002	8623
1786	85	0002	8972
1787	86	0002	9671
1788	87	0003	0020
1789	88	0003	0369
1790	89	0003	0718
1791	90	0003	1067
1792	91	0003	1416

APPENDIX III

The Spatial distribution and Flux are given at 1, 2, 5, and 10 microseconds in Tables 13, 14, 15, and 16, respectively. Table 17 gives the same data for thermal neutrons. In each table the first column is the cell number, composed of three numbers (the ten's digit of each coordinate); the second column is the number of neutrons in that cell; and the third column is the flux calculated as the sum of the velocities of the neutrons in that cell.

Table 13

FLUX AT

ONE MICRO SECOND

CELL NUMBER X Y Z	NUMBER OF NEUTRONS	FLUX TIMES TEN TO THE THIRD
0 00 0	90	8387745468
0 00 1	66	2140810490
0 00 2	59	1988106090
0 00 3	33	1124300173
0 00 4	16	562059390
0 00 5	5	223211947
0 00 6	2	97734029
0 00 7	1	33428008
0 00 8	1	29472527
0 01 0	66	2331855311
0 01 1	60	1941298137
0 01 2	40	1378072616
0 01 3	16	532242586
0 01 4	9	331075497
0 01 5	8	305562210
0 01 6	2	76279032
0 02 0	28	990620824
0 02 1	31	1052464864
0 02 2	29	1014257985
0 02 3	9	302606896
0 02 4	7	226940880
0 02 5	4	135340080
0 02 7	1	57693724
0 03 0	17	609008309
0 03 1	26	865834060
0 03 2	8	300198377
0 03 3	9	328791919
0 03 4	3	115556271
0 03 5	1	27544758
0 03 6	2	67966603
0 04 0	8	306069836
0 04 1	6	221476249
0 04 2	3	93796134
0 04 3	4	133745313
0 04 4	2	77603473
0 04 8	1	39304702
0 05 0	6	216986107

0	05	1	156753345
0	05	2	50220587
0	05	3	60512776
0	05	4	42166223
0	05	5	48062232
0	06	0	25888798
0	06	1	27377023
0	06	3	47435661
0	06	4	30179504
0	07	1	73519107
0	07	3	31224482
0	07	6	37147166
0	08	2	114994836
0	08	6	45299261
1	00	0	2206271210
1	00	1	2216618438
1	00	2	1029886549
1	00	3	651600727
1	00	4	212645924
1	00	5	72435014
1	00	6	29035580
1	01	0	1764261111
1	01	1	1537570684
1	01	2	448419223
1	01	3	475860371
1	01	4	629893641
1	01	5	60504903
1	01	6	64880010
1	02	0	964285511
1	02	1	1161684940
1	02	2	650613087
1	02	3	223722196
1	02	4	272371280
1	02	5	35668839
1	02	6	48086311
1	03	0	706564169
1	03	1	508053309
1	03	2	386585086
1	03	3	254866811
1	03	4	146004143
1	03	5	66818401
1	04	0	330113198
1	04	1	352558426
1	04	2	91996945
1	04	3	35251953
1	04	5	69498011
1	04	7	30758418

1	05	0	2	58773766
1	05	1	3	109184222
1	05	2	3	88733597
1	05	4	1	44770163
1	06	0	1	57859658
1	06	1	3	85526801
1	06	2	1	34315532
1	07	0	1	41153464
1	07	2	1	61856952
1	07	5	1	34328607
1	08	4	1	59209802
2	00	0	42	1477696021
2	00	1	34	1151352295
2	00	2	23	768787085
2	00	3	18	649634227
2	00	4	4	151967598
2	00	5	2	89730952
2	00	6	4	138002396
2	01	0	32	1132784438
2	01	1	29	1023662498
2	01	2	14	404336714
2	01	3	8	292765921
2	01	4	9	297923568
2	01	5	2	87216807
2	01	6	1	60833942
2	01	7	1	38531216
2	02	0	28	1042353376
2	02	1	12	420024730
2	02	2	14	484055521
2	02	3	11	438683999
2	02	4	5	200824334
2	02	5	2	65215044
2	02	6	3	102622003
2	03	0	7	296448239
2	03	1	10	369880602
2	03	2	7	225912617
2	03	3	3	96840939
2	03	4	4	141263186
2	03	5	2	88604613
2	03	6	1	23345651
2	03	7	2	77845884
2	04	0	4	113883194
2	04	1	5	172399107
2	04	2	7	274795709
2	04	3	2	61302315
2	04	6	1	40196725
2	05	0	5	179036210

2 05 1	2	44830480
2 05 2	1	31351757
2 05 3	3	134174222
2 05 5	3	112683704
2 06 0	1	31143653
2 06 1	2	72036430
2 07 1	1	48648579
2 07 3	1	55279514
3 00 0	17	566502368
3 00 1	13	520060826
3 00 2	13	467306438
3 00 3	9	297578857
3 00 4	4	113831909
3 00 5	2	60029088
3 00 6	3	101368659
3 01 0	19	634254261
3 01 1	15	542390909
3 01 2	8	273633600
3 01 3	6	208066197
3 01 4	1	43831263
3 02 0	10	375552018
3 02 1	14	479389574
3 02 2	6	239757465
3 02 3	2	69252834
3 02 4	1	28396984
3 02 6	1	45485056
3 03 0	10	310114053
3 03 1	7	272584788
3 03 2	5	116652823
3 03 3	4	183117226
3 03 4	2	87678501
3 03 5	1	64619542
3 03 6	1	33411249
3 03 7	1	29502816
3 04 0	3	105435742
3 04 2	2	62242660
3 04 4	1	32879632
3 05 1	1	43241827
3 06 0	1	33478119
3 06 4	1	52376749
4 00 0	9	321839444
4 00 1	6	214908916
4 00 2	7	260007731
4 00 3	9	357910252
4 00 4	2	62935580
4 00 5	1	33359185
4 01 0	12	419906675

4 01 1	6	213459386
4 01 2	4	157458680
4 01 3	6	186722154
4 01 4	1	32563558
4 01 6	1	40445801
4 02 0	3	68808694
4 02 1	6	206654496
4 02 2	4	145990715
4 02 3	5	186122996
4 02 4	1	56002018
4 02 6	2	98586790
4 03 0	2	76429759
4 03 1	1	29243097
4 03 3	5	212495074
4 03 4	1	26851711
4 03 5	3	106225232
4 04 0	2	88713967
4 04 1	1	22626773
4 04 3	3	111805747
4 05 1	3	141374112
4 05 2	2	83579212
4 05 3	1	32443881
4 06 3	1	29321512
4 06 4	1	40761977
4 07 2	1	40674236
4 09 0	1	41067270
5 00 0	3	135653996
5 00 1	3	101914694
5 00 2	2	85690173
5 00 4	2	74535880
5 00 5	2	67973729
5 01 0	2	73986120
5 01 1	3	93360702
5 01 3	1	31574142
5 01 4	2	74400376
5 01 8	1	51299875
5 02 0	3	113495438
5 02 1	1	44902103
5 02 2	1	20964632
5 02 4	1	26663592
5 02 8	1	34148647
5 03 1	1	21138092
5 03 3	1	50388092
5 03 4	1	47078852
5 04 1	1	33966276
5 04 2	1	40071931
5 04 3	1	47740535

5 05 0	2	88620840
6 00 0	3	110374259
6 00 1	1	29009194
6 00 2	1	48519863
6 00 4	1	20872623
6 01 0	1	26438288
6 01 5	1	48597841
6 02 0	2	66250115
6 02 1	1	49274800
6 02 3	1	35294826
6 02 5	1	22062426
6 02 6	1	38289083
6 03 0	1	43263946
6 03 1	1	35741058
6 03 8	1	23577683
6 04 2	1	46962137
6 05 1	1	31029050
6 07 3	1	46938220
7 00 1	2	77461769
7 02 4	1	37285030
7 03 0	1	27630466
7 03 1	1	55560096
8 00 2	1	40682230

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0 00 3-	29	1066052340
0 00 4-	10	371832550
0 00 5-	1	36118662
0 00 6-	2	54417200
0 00 7-	1	44653765
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0 01 2-	42	1494994591
0 01 3-	32	1084014396
0 01 4-	9	304320204
0 01 5-	3	77566701
0 01 6-	1	32519121
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0 02 0-	44	1458573696
0 02 1-	22	743803478
0 02 2-	24	832226284
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0 02 5-	3	97036496

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0 03 2-	11	401855426
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0 03 5-	1	41231674
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0 04 4-	2	71121105
0 04 5-	3	119475314
0 05 0-	3	93457668
0 05 1-	2	83342652
0 05 2-	2	70155581
0 05 3-	3	87800426
0 05 4-	1	43281038
0 05 5-	1	25030947
0 06 0-	1	28382120
0 06 1-	1	25099719
0 06 3-	1	50092891
0 07 2-	1	31992429
0 08 0-	1	32587886
0 08 1-	1	38652630
1 00 0-	61	2023119846
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1 00 2-	36	1187537043
1 00 3-	21	763473244
1 00 4-	10	334201768
1 00 5-	3	100568265
1 00 6-	3	77324691
1 00 7-	1	47400113
1 01 0-	42	1345156078
1 01 1-	41	1295147489
1 01 2-	32	1070779817
1 01 3-	14	456086478
1 01 4-	8	324895702
1 01 5-	1	37454026
1 01 7-	1	27654282
1 02 0-	33	967274289
1 02 1-	32	1151452658
1 02 2-	26	970358966
1 02 3-	11	394829009
1 02 4-	1	29253766
1 02 5-	1	39177745

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1	04	1-	3	129459661
1	04	2-	6	222033042
1	04	3-	3	111216346
1	04	5-	1	40033418
1	05	0-	2	76119794
1	05	1-	2	61003752
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1	05	4-	1	45484047
1	05	5-	1	31324710
1	05	6-	1	28756185
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1	06	1-	1	32829879
1	06	2-	1	38184920
1	06	3-	1	38006095
1	07	0-	1	32027077
1	07	2-	1	42722064
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2	00	1-	40	1286245668
2	00	2-	26	871297536
2	00	3-	16	596507487
2	00	4-	6	204822781
2	00	5-	4	153655586
2	00	6-	1	60119290
2	01	0-	38	1309770475
2	01	1-	19	658262441
2	01	2-	23	753752173
2	01	3-	11	420561753
2	01	4-	4	118082886
2	01	7-	2	76218599
2	02	0-	24	895062753
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2	02	2-	9	319232187
2	02	3-	6	237417097
2	02	4-	4	133585635
2	02	5-	1	26420505
2	02	6-	1	28756611
2	03	0-	11	403818047

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2 03 2-	4	132002744
2 03 3-	5	191670822
2 03 4-	1	19732726
2 03 5-	1	39330930
2 03 6-	1	33852459
2 04 0-	3	114378240
2 04 1-	4	138713725
2 04 2-	2	79197489
2 04 5-	1	31581068
2 05 0-	5	175001240
2 05 1-	6	231732651
2 05 2-	1	37041657
2 06 0-	2	92945203
2 07 0-	1	34933679
2 07 1-	1	32223493
2 07 2-	1	29540036
2 08 0-	1	61613312
2 08 2-	1	57089226
3 00 0-	22	769996928
3 00 1-	21	771223825
3 00 2-	15	550103341
3 00 3-	5	192957562
3 00 4-	2	81352372
3 00 5-	2	55746212
3 00 6-	2	68271207
3 01 0-	16	600824949
3 01 1-	13	408796276
3 01 2-	7	228069181
3 01 3-	8	288031985
3 01 4-	3	138039168
3 01 5-	2	85736372
3 02 0-	13	498439178
3 02 1-	7	225122329
3 02 2-	6	183176129
3 02 3-	3	102699631
3 02 4-	2	66784231
3 02 5-	1	36063416
3 02 7-	1	38482211
3 03 0-	3	78854312
3 03 1-	4	134726599
3 03 2-	7	260894705
3 04 0-	4	125869444
3 04 1-	4	149863252
3 04 2-	2	81588900
3 04 5-	1	29657856
3 05 1-	1	52360834

3 05 3-	2	75117484
3 05 5-	1	48412220
3 07 0-	1	44347571
4 00 0-	11	428244326
4 00 1-	10	389288316
4 00 2-	9	330339409
4 00 3-	4	152836574
4 00 4-	2	67339187
4 00 5-	1	43262383
4 01 0-	7	233726821
4 01 1-	7	269408424
4 01 2-	2	79703077
4 01 3-	4	144481236
4 01 4-	3	108521116
4 01 5-	1	43642713
4 02 0-	5	188747623
4 02 1-	7	227329422
4 02 2-	5	193769213
4 02 3-	2	49069435
4 02 4-	1	32805657
4 02 6-	1	31628311
4 03 0-	3	103161897
4 03 1-	4	157638743
4 03 2-	3	118110863
4 03 4-	1	31594898
4 03 5-	1	37800626
4 04 0-	1	33502314
4 04 3-	1	30568188
4 05 5-	1	37330980
4 06 1-	1	36112609
4 09 0-	1	35957607
5 00 0-	2	61073167
5 00 1-	4	154137735
5 00 2-	5	205559597
5 00 3-	7	282210273
5 00 4-	1	31288874
5 01 1-	2	80366200
5 01 2-	1	23139408
5 01 3-	1	24280853
5 01 5-	1	27308590
5 02 0-	3	120534363
5 02 1-	4	136147171
5 02 2-	2	76412671
5 02 3-	1	37837131
5 03 0-	4	132766149
5 03 4-	1	32157664
5 03 5-	2	68598953

5 04 2-	1	31336653
5 05 1-	1	34176040
5 05 2-	1	34219185
5 06 1-	1	25300054
5 06 3-	2	85412910
5 07 1-	1	50914379
5 09 5-	1	32863093
6 00 1-	2	73285429
6 00 2-	2	77825913
6 00 4-	2	54366736
6 00 6-	1	55725896
6 01 0-	3	123402632
6 01 3-	1	29979154
6 03 2-	1	26468779
6 03 4-	1	41871728
6 04 1-	1	48152018
6 06 1-	1	22847613
7 01 4-	1	33352722
7 03 0-	2	48987018
8 04 0-	1	23085718

Table 14

FLUX AT

TWO MICRO SECONDS

CELL NUMBER X Y Z	NUMBER OF NEUTRONS	FLUX TIMES TEN TO THE THIRD
0 00 0	87	1431582681
0 00 1	59	957896394
0 00 2	45	775706530
0 00 3	28	478728734
0 00 4	16	263502193
0 00 5	6	105739959
0 00 6	2	33823697
0 01 0	62	1043058876
0 01 1	48	808921894
0 01 2	33	551679363
0 01 3	19	332155731
0 01 4	9	157204842
0 01 5	5	99974901
0 01 6	2	39434586
0 02 0	46	767120667
0 02 1	32	570209247
0 02 2	21	375898063
0 02 3	10	194815590
0 02 4	4	62723844
0 02 5	8	124702036
0 03 0	23	412371395
0 03 1	18	310136163
0 03 2	18	318209175
0 03 3	14	227496794
0 03 4	2	28350283
0 03 5	3	54367375
0 03 6	2	37378387
0 04 0	10	200549980
0 04 1	7	137456322
0 04 2	7	119125797
0 04 3	3	45569696
0 04 5	1	14032837
0 05 0	3	43608075
0 05 2	1	16531997
0 05 3	1	15101733
0 05 4	2	37789408
0 05 8	1	22736970

0 06 0	1	20502005
0 06 1	2	27921316
0 06 2	1	17995564
0 06 4	2	32074728
0 07 0	1	17965604
0 07 1	1	23935573
0 07 2	2	42181748
0 07 4	1	15636782
0 07 7	1	26358799
0 08 2	1	19374106
1 00 0	55	880006874
1 00 1	36	583976704
1 00 2	30	521708604
1 00 3	21	381161751
1 00 4	11	187132916
1 00 5	4	100863335
1 00 6	4	71873232
1 00 7	1	22302715
1 01 0	52	820421637
1 01 1	43	696495868
1 01 2	26	406486943
1 01 3	15	270065752
1 01 4	14	236925870
1 01 5	3	71083842
1 01 6	3	63283325
1 01 7	1	10759608
1 02 0	31	506619215
1 02 1	27	465072028
1 02 2	24	379481050
1 02 3	9	158857876
1 02 4	8	134991266
1 02 5	2	30235930
1 02 6	2	29115581
1 02 7	2	40114418
1 03 0	16	276128108
1 03 1	17	334634673
1 03 2	7	125045698
1 03 3	11	212659028
1 03 4	2	30547880
1 03 5	1	16157366
1 03 6	1	19646414
1 04 0	12	176201322
1 04 1	6	107402767
1 04 2	2	32121812
1 04 4	1	13257737
1 04 5	1	14479395
1 04 6	1	20768597

1	05	1	5	93700910
1	05	2	4	71844187
1	05	3	1	16282833
1	05	5	2	33312110
1	06	1	2	39364100
1	07	0	1	23650514
1	07	1	3	55599499
1	07	2	1	21005557
1	07	5	2	37547788
1	08	3	1	21622023
1	08	6	1	21812672
2	00	0	39	629090514
2	00	1	35	574343975
2	00	2	15	259099059
2	00	3	10	176062611
2	00	4	5	90178921
2	00	6	2	26082429
2	01	0	38	626072975
2	01	1	33	604821568
2	01	2	19	352531257
2	01	3	14	251563221
2	01	4	6	110853645
2	01	5	1	23324264
2	01	6	2	34296190
2	01	7	2	33199268
2	02	0	28	459457187
2	02	1	20	348551121
2	02	2	10	181837503
2	02	3	9	167971026
2	02	4	4	70543657
2	02	5	3	70010982
2	02	6	1	13533789
2	02	7	1	15956221
2	03	0	14	224904036
2	03	1	9	189391579
2	03	2	4	63497880
2	03	3	8	146427332
2	03	4	5	93632921
2	03	7	2	29166667
2	04	0	5	103815607
2	04	1	5	86037325
2	04	2	5	82052836
2	04	3	3	48290372
2	04	4	1	15094976
2	05	0	2	30346379
2	05	1	1	21649441
2	05	2	1	12671291

2 05 3	2	30971454
2 05 4	1	16510344
2 05 5	1	12526496
2 06 1	1	23859067
2 06 3	1	21942153
2 06 6	1	19630488
2 07 0	1	20760053
2 07 1	1	18595168
2 08 3	1	25764285
3 00 0	27	447635305
3 00 1	16	269522577
3 00 2	14	204851473
3 00 3	5	87802331
3 00 4	3	41148223
3 00 5	2	33461257
3 00 6	5	115981832
3 01 0	14	258008382
3 01 1	10	192569826
3 01 2	13	231572299
3 01 3	7	111024587
3 01 4	2	32503878
3 01 5	3	34553642
3 02 0	13	207086046
3 02 1	10	170093288
3 02 2	6	112172252
3 02 3	3	66484718
3 02 4	4	81101900
3 03 0	7	123442355
3 03 1	8	147074005
3 03 2	5	66048267
3 03 3	5	78856610
3 03 4	2	31234620
3 03 5	2	41806400
3 03 6	1	19484998
3 03 8	1	21538677
3 04 0	1	19550615
3 04 1	7	135046776
3 04 2	4	64335701
3 04 3	1	14920028
3 04 7	1	25259310
3 05 0	2	33650699
3 05 2	2	38855321
3 05 3	1	17705586
3 06 1	1	14243081
4 00 0	9	147327045
4 00 1	7	111342450
4 00 2	6	108363436

4 00 3	4	54596282
4 00 4	5	91750338
4 00 5	1	16728913
4 00 6	1	16312665
4 01 0	14	237266772
4 01 1	3	40656574
4 01 2	5	96676599
4 01 3	5	92199735
4 01 4	1	24357698
4 01 5	1	16815638
4 02 0	9	168027043
4 02 1	6	111667245
4 02 2	5	93005099
4 02 3	1	18360852
4 02 5	1	19461377
4 02 7	1	20215867
4 02 8	1	17632222
4 03 0	5	85436452
4 03 1	1	19567735
4 03 3	4	68691666
4 03 4	2	41221456
4 03 5	1	18424249
4 03 6	1	19184722
4 04 0	1	17269875
4 04 1	1	9215870
4 04 3	3	48455981
4 04 4	2	44965036
4 04 7	1	20384864
4 05 0	1	21650617
4 05 2	2	50855528
4 05 3	1	17256332
4 05 4	1	21468791
4 05 7	1	11998758
4 06 2	1	12658503
4 06 3	1	15294633
4 07 1	1	22943681
4 10 0	1	23751952
5 00 0	2	32722978
5 00 1	5	93821585
5 00 2	2	32328248
5 00 3	2	41569979
5 00 4	3	59525333
5 00 5	2	27217468
5 01 0	2	32909465
5 01 1	3	41145405
5 01 2	2	39972559
5 01 3	1	13912464

5 01 6	1	23408011
5 02 0	1	13512454
5 02 1	2	44557144
5 02 2	2	27956077
5 02 3	2	37446412
5 02 4	1	14086556
5 03 0	4	80086015
5 03 1	3	56515139
5 03 2	1	24157206
5 03 4	1	12322562
5 04 0	2	33824886
5 04 1	1	14629019
5 04 2	1	20220644
5 05 0	1	18651260
5 07 3	1	23293923
6 00 1	2	28552025
6 00 2	1	9681319
6 00 4	1	11760156
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6 01 1	2	34889001
6 01 2	2	46261982
6 01 4	1	21040470
6 02 0	1	19087835
6 02 1	2	35928964
6 02 3	2	37874681
6 02 6	2	23569035
6 03 1	1	22945674
6 03 2	1	18309321
6 03 3	1	20788890
6 04 0	1	16397683
6 04 1	2	37545589
6 04 5	1	34460769
7 01 1	1	21486527
7 02 1	2	33575279
8 00 2	1	19663313
8 04 0	1	12551247

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0 00 5-	3	48276236
0 00 7-	2	44412520
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0 01 4-	13	218718870
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0 01 7-	1	13567270
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0 06 5-	2	33730188
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1 00 5-	1	16676064
1 00 6-	3	53773676
1 00 7-	1	13722105
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1 03 5-	2	36876117
1 03 6-	1	33523042
1 03 7-	1	14710237
1 04 0-	7	134172330
1 04 1-	6	95865156
1 04 2-	6	119805939
1 04 3-	3	52652233
1 04 4-	1	16181159
1 04 6-	1	16325655
1 04 7-	1	21794871
1 05 0-	6	96041546
1 05 2-	3	55881083
1 05 3-	1	15341874
1 05 5-	1	17329502
1 06 0-	4	72335964
1 06 1-	2	27491351
1 06 2-	1	22582098
1 06 3-	1	18243925
1 07 2-	1	31380532
1 08 1-	1	20998762
1 09 0-	1	16185734
2 00 0-	34	595798240
2 00 1-	39	650779468
2 00 2-	21	347664672
2 00 3-	9	169717093
2 00 4-	5	88359124
2 00 5-	2	30381984
2 00 6-	1	21763577
2 00 7-	1	25821110
2 01 0-	26	406732133
2 01 1-	27	485944860
2 01 2-	13	207557752

2 01 3-	12	220410911
2 01 4-	4	68717196
2 01 5-	1	18806303
2 01 6-	2	39711123
2 02 0-	23	380421568
2 02 1-	14	278771706
2 02 2-	15	257002572
2 02 3-	10	172078799
2 02 4-	4	80779041
2 02 5-	1	16112706
2 02 7-	1	15329750
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2 03 1-	12	212206496
2 03 2-	9	167358340
2 03 3-	2	28097598
2 03 6-	1	18131322
2 04 0-	7	117190566
2 04 1-	5	74601897
2 04 2-	4	59250189
2 04 3-	1	13088796
2 04 4-	3	54178971
2 05 0-	2	23976356
2 05 1-	3	58444188
2 05 3-	3	55404740
2 05 5-	1	10765253
2 05 6-	1	16298707
2 06 1-	2	39144574
2 07 0-	1	20599241
2 08 0-	1	23889859
2 08 3-	1	18990548
3 00 0-	19	331609517
3 00 1-	20	330953574
3 00 2-	14	229500764
3 00 3-	9	183854950
3 00 4-	7	111661407
3 00 5-	1	26989450
3 00 6-	2	36105535
3 00 7-	1	27973034
3 01 0-	14	242317715
3 01 1-	21	367209237
3 01 2-	14	244950427
3 01 3-	5	82399496
3 01 4-	3	48383082
3 01 5-	1	18648205
3 02 0-	8	160610962
3 02 1-	5	91320273
3 02 2-	7	112268773

3 02 3-	6	115196844
3 02 4-	1	13516719
3 02 5-	3	33048354
3 02 7-	1	17769869
3 03 0-	9	135243385
3 03 1-	6	127109452
3 03 2-	4	78580403
3 03 3-	1	18513786
3 03 4-	1	17884188
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3 04 0-	6	91595576
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3 04 2-	2	41134473
3 05 0-	1	17015992
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3 05 4-	1	17340096
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3 06 2-	1	20671641
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3 09 0-	1	13262429
4 00 0-	10	168421404
4 00 1-	7	137228744
4 00 2-	6	114597543
4 00 3-	4	61377349
4 00 4-	5	108654556
4 01 0-	7	129486532
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4 01 2-	9	168129065
4 01 3-	6	86932218
4 01 4-	1	17100994
4 01 5-	1	23263797
4 01 6-	1	21650554
4 02 0-	3	54175284
4 02 1-	3	48057250
4 02 2-	6	96593521
4 02 3-	3	55504005
4 02 6-	1	16555420
4 03 0-	5	72879604
4 03 1-	3	52933441
4 03 2-	2	42675636
4 03 3-	1	27561332
4 03 4-	1	22337094
4 03 5-	1	21593539
4 04 0-	3	55107965
4 04 3-	1	18872342

4 05 1-	3	59272771
4 07 1-	1	21187805
5 00 0-	3	66375222
5 00 1-	5	86286336
5 00 2-	3	59204459
5 00 3-	3	35077508
5 00 4-	2	35025742
5 00 5-	1	19602450
5 00 6-	1	18116554
5 00 7-	1	23869835
5 01 0-	2	33037631
5 01 1-	4	77159326
5 01 2-	3	54031066
5 01 3-	2	38878237
5 02 1-	3	50717421
5 02 2-	1	12223718
5 02 3-	1	15995445
5 02 5-	2	32252218
5 03 0-	1	20923304
5 03 1-	1	22443652
5 03 2-	2	37321262
5 03 4-	2	27537201
5 04 1-	1	20075614
5 05 1-	1	16220271
5 05 2-	2	32477925
5 05 3-	1	20731558
5 06 2-	1	16793820
5 07 0-	1	12019470
6 00 1-	2	35752185
6 00 2-	2	35948668
6 00 3-	1	15879186
6 00 5-	1	12129054
6 01 0-	2	23432930
6 01 2-	3	52890507
6 02 0-	1	18204400
6 02 1-	1	20166378
6 02 2-	1	20532350
6 03 0-	1	14194801
6 09 6-	1	21897070
7 00 2-	1	17570858
7 01 4-	1	17629372
7 02 0-	1	15281595
7 03 0-	1	9390068
7 03 2-	1	10001585
7 05 1-	1	17056519

Table 15

FLUX AT

FIVE MICRO SECONDS

CELL NUMBER X Y Z	NUMBER OF NEUTRONS	FLUX TIMES TEN TO THE THIRD
0 00 0	56	359059808
0 00 1	64	423655043
0 00 2	45	313002040
0 00 3	27	165284832
0 00 4	15	100300491
0 00 5	8	47997939
0 00 6	3	22445422
0 00 7	4	32160461
0 01 0	46	297793230
0 01 1	29	186353273
0 01 2	42	279397929
0 01 3	14	82995520
0 01 4	10	64082855
0 01 5	2	15686189
0 01 6	7	46934115
0 01 7	1	7248267
0 02 0	31	201285147
0 02 1	33	215977950
0 02 2	20	134506583
0 02 3	17	123823209
0 02 4	6	45639041
0 02 5	3	22164430
0 02 6	2	15108995
0 03 0	27	200471338
0 03 1	17	112757355
0 03 2	14	102674675
0 03 3	11	86394378
0 03 4	4	32522136
0 03 5	4	34734842
0 03 6	2	14310898
0 04 0	12	70124718
0 04 1	12	83942664
0 04 2	6	33683284
0 04 3	7	52998352
0 04 4	2	13537599
0 04 5	1	7496964
0 05 0	7	49786286

0	05	1	4	27867169
0	05	2	3	25434783
0	05	4	1	8419552
0	05	5	1	4609206
0	05	6	1	7227258
0	06	0	1	9494873
0	06	1	1	7745160
0	07	0	1	9782095
0	07	1	2	13723954
0	07	3	1	4591398
0	07	5	1	5996190
0	07	6	1	7490937
0	08	2	2	14869873
0	09	3	1	8729022
1	00	0	62	410470108
1	00	1	39	259664393
1	00	2	29	198212049
1	00	3	13	97611668
1	00	4	5	26172524
1	00	5	3	26876558
1	00	6	3	20945248
1	00	7	2	13957804
1	01	0	44	283817063
1	01	1	40	258407475
1	01	2	23	157561206
1	01	3	18	115575253
1	01	4	12	104445112
1	01	5	2	16746686
1	01	6	2	16158125
1	02	0	34	240839389
1	02	1	27	179375573
1	02	2	18	124195944
1	02	3	11	74477537
1	02	4	5	30128364
1	02	5	2	11973952
1	02	6	1	5868936
1	02	7	2	14407389
1	03	0	16	109536330
1	03	1	11	80024679
1	03	2	6	36792609
1	03	3	10	62870847
1	03	4	6	39035978
1	03	5	4	29136967
1	03	6	1	7895851
1	03	7	1	5077280
1	04	0	6	45470797
1	04	1	11	66313952

1 04 2	6	48782694
1 04 3	5	33532642
1 04 4	2	16223962
1 04 6	1	6361063
1 05 0	3	18730949
1 05 1	8	59674699
1 05 2	2	15281969
1 05 5	1	7177000
1 05 6	1	5932359
1 06 0	1	4852723
1 06 1	2	13522931
1 06 2	1	4484914
1 06 3	1	6979119
1 07 0	1	9324875
1 07 1	1	5513834
1 07 2	2	13090735
1 07 3	2	16969391
1 07 5	1	5659364
1 09 6	1	9620511
2 00 0	42	264074710
2 00 1	35	230924473
2 00 2	19	118988573
2 00 3	17	122396596
2 00 4	5	34450683
2 00 5	4	26097380
2 00 6	3	22440181
2 00 7	1	6836363
2 01 0	36	215965031
2 01 1	31	207423594
2 01 2	12	80494888
2 01 3	11	77662050
2 01 4	4	25690971
2 01 5	1	9030579
2 01 6	1	5344651
2 02 0	18	124991142
2 02 1	23	157842110
2 02 2	14	90693167
2 02 3	8	54644522
2 02 4	5	38644432
2 02 5	3	20504814
2 02 6	1	8542385
2 03 0	13	92311706
2 03 1	13	93011954
2 03 2	9	58972968
2 03 3	4	23599778
2 03 4	5	40690946
2 03 5	1	6385509

2 03 7	1	4498003
2 04 0	5	33914546
2 04 1	3	23562014
2 04 2	7	48946192
2 04 3	2	11482662
2 04 4	2	16678799
2 04 5	1	7687623
2 05 0	3	19472324
2 05 1	5	35834224
2 05 2	1	10531891
2 05 5	1	4732656
2 05 6	1	5440107
2 06 2	1	6674745
2 06 3	1	7023989
2 06 4	1	7927926
2 06 7	1	8585993
2 07 2	1	9434082
2 07 5	1	5208405
2 08 0	1	8908123
2 08 2	1	9895581
2 08 3	1	7328196
3 00 0	18	121444140
3 00 1	18	137528100
3 00 2	10	65785117
3 00 3	5	33340757
3 00 4	5	30821388
3 00 5	6	44749532
3 00 6	2	15942790
3 01 0	19	118217511
3 01 1	15	100771769
3 01 2	8	51259435
3 01 3	6	47372557
3 01 4	6	40741879
3 01 5	2	12575972
3 02 0	15	108963792
3 02 1	5	31746298
3 02 2	13	90143573
3 02 3	4	29964637
3 02 4	5	34069635
3 02 5	2	16895491
3 02 6	1	7089861
3 02 7	2	10660033
3 03 0	8	51822488
3 03 1	7	49016410
3 03 2	6	53541571
3 03 3	4	28674953
3 03 4	2	18826342

3 03 5	2	13850777
3 03 6	2	15774094
3 03 7	1	7959421
3 04 0	3	17033330
3 04 1	1	5953148
3 04 3	4	23656283
3 04 4	1	6333632
3 04 5	1	8067257
3 05 0	1	4695349
3 05 1	2	12908280
3 05 3	2	12840778
3 05 4	4	36692047
3 05 7	1	6817011
3 06 1	2	14273861
3 06 3	1	6213000
3 06 4	1	6959941
4 00 0	7	48651811
4 00 1	9	60342797
4 00 2	10	70002496
4 00 3	5	38481611
4 00 4	4	31662434
4 00 5	4	29636212
4 00 6	1	10633490
4 01 0	12	79113924
4 01 1	10	69041626
4 01 2	2	9801155
4 01 3	3	20768970
4 01 4	1	8530298
4 01 5	1	5884508
4 01 7	1	7529796
4 02 0	3	20836476
4 02 1	5	38081193
4 02 2	2	18906818
4 02 3	3	19799242
4 02 4	1	5002381
4 02 5	3	24224494
4 03 0	5	32768036
4 03 1	3	25245307
4 03 2	2	17655474
4 03 3	4	24786985
4 03 4	1	8639708
4 03 6	1	11246635
4 04 0	2	9917584
4 04 1	2	12639700
4 04 2	3	25036201
4 04 3	1	5099763
4 04 6	2	12664254

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4 05 2	1	7698089
4 05 3	1	4826832
4 05 6	1	10389561
4 06 3	2	15546945
4 06 5	1	8643885
4 07 1	1	10365095
5 00 0	5	31696698
5 00 1	7	46856447
5 00 2	2	11430222
5 00 3	3	25053037
5 00 5	2	17064108
5 01 0	5	39117775
5 01 1	2	11656025
5 01 2	1	7884147
5 01 3	1	4843663
5 02 0	3	20887674
5 02 1	2	10289494
5 02 2	3	23287446
5 02 3	4	23617059
5 03 0	4	29954?19
5 03 1	1	9240711
5 03 5	1	8872291
5 04 0	1	4401383
5 04 2	3	18789798
5 04 3	1	5985500
5 04 4	1	7106691
5 05 0	1	7573354
5 05 1	1	7369804
5 05 2	1	9952017
5 06 2	1	7960542
5 07 4	1	7184154
5 10 0	1	5574968
6 00 0	1	5706244
6 00 1	1	7991128
6 00 3	1	8313569
6 00 5	1	4097157
6 01 1	1	8365289
6 01 2	2	11541225
6 01 5	1	5241115
6 02 0	2	10719730
6 02 1	1	3915544
6 02 2	2	16437922
6 02 3	1	4651540
6 03 0	1	5756331
6 03 1	1	5954377
6 03 6	1	4386273

6 04 5	1	7544968
6 05 0	1	6855872
6 05 2	1	5758246
6 05 4	1	7007661
6 06 0	2	11517707
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7 01 1	1	8187902
7 01 6	1	7767018
7 02 0	2	15353720
7 02 1	1	5023573
7 03 2	1	7860971
7 04 2	1	11609872
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1	05 5-	1	5167445
1	05 6-	1	7694335
1	06 0-	3	22615828
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1	06 2-	2	15898735
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4 00 6-	1	7755558
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4 02 3-	2	10531652
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4 04 4-	1	9819543
4 05 0-	1	8488897
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4 06 4-	1	6756737
4 09 1-	1	5398446
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5 00 2-	3	19376050
5 00 3-	6	39545330
5 00 4-	3	18259719
5 00 5-	1	8206928
5 01 0-	3	20669323
5 01 1-	2	15581135
5 01 2-	4	26490749
5 01 3-	3	21698273
5 01 4-	1	12560953
5 01 5-	3	22284776
5 02 0-	2	16001548
5 02 1-	6	40991065

5	02 2-	2	14424321
5	02 3-	1	8534209
5	03 1-	6	44164715
5	03 4-	1	4229271
5	03 5-	1	7385356
5	03 7-	1	5773077
5	04 1-	1	7164261
5	04 3-	1	9220283
5	05 0-	1	6448941
5	05 1-	1	5797892
5	05 2-	1	9260032
5	05 3-	1	5727733
5	06 1-	1	9871083
6	00 0-	1	7625955
6	00 3-	1	6178743
6	00 7-	1	6637797
6	01 1-	4	30831545
6	01 2-	2	12551722
6	01 3-	2	17426694
6	01 6-	1	6408322
6	02 0-	1	8750499
6	02 1-	1	7344101
6	03 0-	1	7110684
6	03 1-	1	6484955
6	03 5-	1	5626177
6	04 0-	1	9738096
6	05 1-	1	9302695
6	05 4-	1	6751245
6	08 0-	1	4608136
6	10 7-	1	6667731
7	00 1-	1	8517593
7	00 2-	1	6897207
7	00 4-	1	5735160
7	01 3-	1	8533608
7	01 4-	1	5531600
7	03 1-	1	7857079
7	04 0-	2	10280777
8	02 0-	1	5088651

Table 16

FLUX AT

TEN MICRO SECONDS

CELL NUMBER X Y Z	NUMBER OF NEUTRONS	FLUX TIMES TEN TO THE THIRD
0 00 0	50	155900466
0 00 1	53	174114468
0 00 2	34	113682775
0 00 3	33	109115440
0 00 4	13	40627824
0 00 5	4	11650248
0 00 6	4	12513261
0 00 7	3	11012761
0 01 0	48	167126179
0 01 1	32	108839817
0 01 2	31	100938754
0 01 3	22	65311312
0 01 4	7	22707431
0 01 5	4	11818515
0 01 6	3	7367986
0 01 7	2	7927639
0 02 0	32	111229745
0 02 1	27	89887512
0 02 2	18	69405019
0 02 3	9	27228498
0 02 4	6	18764440
0 02 5	3	14170954
0 02 6	5	15008280
0 02 7	2	6950323
0 03 0	24	81336451
0 03 1	13	47152920
0 03 2	19	59927788
0 03 3	12	40887365
0 03 4	1	3949575
0 03 5	3	11166351
0 03 6	1	3659366
0 04 0	12	36291103
0 04 1	12	41877501
0 04 2	6	21634110
0 04 3	4	14673990
0 04 4	3	11045924
0 04 7	1	4647090

0 05 0	3	13828434
0 05 1	6	21973277
0 05 2	3	9769627
0 05 3	4	16679937
0 05 4	1	3766029
0 05 5	1	2776559
0 05 6	3	14215053
0 06 0	6	22424270
0 06 1	1	3979639
0 06 2	3	9687292
0 07 0	1	4288639
0 07 2	1	3908307
0 07 5	1	2489452
0 07 6	1	3237817
0 08 3	2	5671011
0 09 2	1	3746183
1 00 0	54	183339733
1 00 1	35	127680062
1 00 2	29	98311733
1 00 3	18	61191476
1 00 4	9	29276734
1 00 5	8	27872903
1 00 6	3	9939901
1 00 7	1	3534359
1 01 0	56	183180136
1 01 1	39	126749849
1 01 2	25	77463970
1 01 3	17	51969097
1 01 4	4	15357361
1 01 5	1	3918984
1 01 6	3	11675196
1 01 7	1	4089156
1 02 0	17	57546038
1 02 1	17	58816869
1 02 2	23	70977249
1 02 3	12	45981656
1 02 4	8	29169405
1 02 5	6	21191827
1 02 7	2	5667983
1 03 0	17	64848615
1 03 1	20	56428949
1 03 2	10	35469459
1 03 3	9	35243129
1 03 4	7	28482655
1 03 5	1	2743402
1 03 6	1	3398329
1 04 0	7	26566592

1 04 1	8	25522089
1 04 2	9	26641152
1 04 3	5	17669758
1 04 4	6	19274697
1 04 5	1	3905163
1 04 6	1	3283353
1 05 0	9	30488081
1 05 1	2	7253919
1 05 2	1	3771114
1 05 3	4	12576478
1 05 6	1	2123189
1 05 7	1	3725770
1 06 0	1	2823271
1 06 3	1	2178263
1 06 5	1	3036127
1 07 0	1	4847692
1 07 2	3	9156065
1 07 3	2	7166802
1 09 3	1	4805913
1 09 6	1	3907569
1 10 3	1	4538141
2 00 0	33	110104412
2 00 1	34	115584765
2 00 2	17	56915853
2 00 3	14	42235745
2 00 4	5	21512052
2 00 5	6	23490307
2 00 6	2	7936375
2 01 0	31	96589091
2 01 1	24	67829043
2 01 2	20	66154249
2 01 3	8	26941784
2 01 4	8	30926837
2 01 5	5	16928181
2 01 6	1	5593569
2 02 0	22	73698615
2 02 1	17	58159338
2 02 2	13	46753822
2 02 3	14	44727796
2 02 4	3	14968988
2 02 5	6	19495395
2 03 0	10	35847006
2 03 1	11	33129719
2 03 2	8	23606693
2 03 3	8	23581748
2 03 4	1	3599887
2 03 5	4	13682108

2 03 6	2	7850883
2 03 8	1	3537286
2 04 0	6	21130935
2 04 1	8	31337334
2 04 2	7	22682485
2 04 3	2	5971003
2 04 4	5	22776226
2 05 0	6	23312912
2 05 1	4	12379434
2 05 2	3	11946632
2 05 3	1	4257586
2 06 0	2	7528796
2 06 3	1	2453092
2 06 4	1	3984735
2 06 6	1	2773972
2 06 7	1	2415850
2 07 0	1	2949080
2 07 2	1	3087056
2 08 0	1	4058191
2 09 2	1	4380475
3 00 0	19	66846764
3 00 1	16	58725985
3 00 2	11	40741560
3 00 3	5	19227423
3 00 4	9	30222224
3 00 5	3	9166817
3 00 6	4	11468097
3 01 0	14	48483846
3 01 1	14	42655871
3 01 2	12	44412842
3 01 3	5	15008832
3 01 4	3	12580408
3 01 5	1	4092170
3 01 8	1	2725405
3 02 0	15	49032789
3 02 1	12	39538294
3 02 2	9	31969606
3 02 3	8	27234333
3 02 4	5	14034910
3 02 5	1	3668427
3 03 0	6	22458015
3 03 1	7	25338889
3 03 2	2	8717189
3 03 3	3	9625007
3 03 4	3	13490334
3 03 5	3	11323924
3 04 0	1	3373359

3 04 1	6	22401961
3 04 2	2	8594100
3 04 3	2	4699646
3 04 4	1	3755979
3 04 5	1	5144461
3 04 6	1	2402811
3 04 7	1	3326935
3 05 0	2	7581434
3 05 2	1	3347789
3 05 3	1	3807305
3 05 8	1	4000508
3 06 0	1	2434954
3 06 1	2	5455578
3 06 3	1	3158088
3 06 4	2	5565656
3 07 3	1	3207724
4 00 0	8	27275390
4 00 1	6	18329916
4 00 2	6	24293394
4 00 3	3	11009537
4 00 4	3	8854867
4 00 5	2	5963942
4 00 6	1	6420671
4 01 0	8	24942899
4 01 1	8	28144387
4 01 2	6	19381488
4 01 3	3	10304320
4 01 4	1	3297109
4 01 5	1	2816807
4 02 0	4	12605229
4 02 1	2	6126433
4 02 2	7	28133210
4 02 4	1	2022950
4 02 5	2	7127986
4 03 0	7	24548281
4 03 1	3	11146132
4 03 2	1	4074723
4 03 3	2	6096290
4 03 4	4	11330320
4 03 5	2	8573593
4 04 0	2	7592381
4 04 1	1	2624926
4 04 2	1	3483525
4 04 3	1	2122501
4 04 6	1	2474486
4 04 8	1	3746823
4 05 0	1	2591273

4	05	3	1 2785622
4	05	4	1 3758731
4	06	0	1 3843349
4	06	1	1 3859373
4	06	3	2 5799255
4	06	4	1 3752653
4	06	5	1 4379894
4	07	2	1 7409211
4	08	0	1 6038775
5	00	0	6 16342501
5	00	1	4 12333771
5	00	2	7 23024766
5	00	3	1 1651364
5	00	4	1 3767212
5	00	5	2 8985980
5	01	0	6 20669245
5	01	1	2 6866331
5	01	2	2 4943996
5	01	3	2 6002181
5	01	4	2 5619187
5	01	6	1 4082725
5	02	0	3 10161339
5	02	1	2 5751306
5	02	2	1 3163042
5	02	4	1 2656215
5	03	2	2 8011502
5	03	3	1 3183488
5	03	4	1 4239184
5	03	7	1 3169681
5	04	2	3 11504582
5	04	3	1 3060084
5	04	5	2 9692830
5	05	0	2 7198103
5	05	1	1 3547546
5	05	3	1 3647252
5	06	5	2 7698873
5	07	0	2 7487607
6	00	0	2 7418343
6	00	1	2 7951165
6	00	2	2 4939541
6	00	3	1 2875327
6	00	4	1 4228682
6	00	5	1 2432700
6	01	0	2 6733388
6	01	1	1 2542992
6	01	5	2 6433524
6	02	1	4 12194849

6 02 2	1	3601421
6 02 4	1	3291813
6 03 0	1	3251537
6 04 0	1	2931507
6 05 2	1	3872217
6 06 1	1	3561151
7 00 1	1	4169902
7 01 0	1	4384691
7 01 1	1	5784199
7 01 5	1	4139034
7 02 0	1	4173424
7 02 1	1	3164965
7 02 2	1	2687282
7 03 2	1	3683150
7 03 3	1	3822306
7 04 5	1	4589409
7 05 2	1	2344775
7 05 4	2	7358481
8 00 4	1	5374498
8 05 2	1	4656584

0 00 0-	46	160757389
0 00 1-	59	199193438
0 00 2-	48	148396598
0 00 3-	20	66613333
0 00 4-	8	31388239
0 00 5-	9	30161794
0 00 7-	1	2808047
0 01 0-	47	148110214
0 01 1-	33	114613970
0 01 2-	28	104838754
0 01 3-	17	56748822
0 01 4-	10	37331314
0 01 5-	5	13821170
0 01 6-	3	10267638
0 02 0-	30	102050061
0 02 1-	28	88975207
0 02 2-	19	65757592
0 02 3-	18	59640731
0 02 4-	7	21786984
0 02 5-	2	7226406
0 02 6-	1	2483071
0 03 0-	14	47448598
0 03 1-	23	82797269
0 03 2-	8	30264911
0 03 3-	11	40037427

0 03 4-	5	15896270
0 03 5-	2	8126269
0 03 6-	1	2831009
0 04 0-	9	29885343
0 04 1-	7	25933044
0 04 2-	11	32559231
0 04 3-	4	14070034
0 04 4-	6	25779567
0 05 0-	4	12132547
0 05 1-	2	5584284
0 05 2-	4	13839168
0 05 3-	3	10666718
0 05 5-	3	8873586
0 05 6-	1	3604507
0 06 0-	1	4975893
0 06 1-	1	2980333
0 06 2-	4	14886617
0 06 4-	1	3559768
0 06 5-	1	2509593
0 07 1-	2	7064609
0 07 4-	1	2968666
0 07 6-	1	3733041
0 08 1-	1	3720805
0 09 2-	1	4805983
1 00 0-	62	222755413
1 00 1-	34	118069749
1 00 2-	27	91455592
1 00 3-	17	61349052
1 00 4-	11	42402915
1 00 5-	6	17544396
1 00 7-	1	4139575
1 01 0-	47	153562196
1 01 1-	23	79515907
1 01 2-	36	116243813
1 01 3-	15	48801489
1 01 4-	11	32101548
1 01 5-	7	24426040
1 01 6-	4	15420770
1 01 7-	1	2796936
1 02 0-	31	104276186
1 02 1-	23	84574014
1 02 2-	19	61854429
1 02 3-	12	39109309
1 02 4-	11	36861807
1 02 5-	2	8046314
1 02 6-	1	4370763
1 03 0-	20	71134358

1 03 1-	12	41880047
1 03 2-	12	45955747
1 03 3-	8	26077981
1 03 4-	5	19777800
1 03 5-	1	3127251
1 03 6-	1	2267149
1 04 0-	8	27342349
1 04 1-	6	20094806
1 04 2-	4	16872586
1 04 3-	4	13763647
1 04 4-	3	10973380
1 04 6-	1	2928678
1 05 0-	5	18898453
1 05 1-	4	12411550
1 05 2-	4	15276307
1 05 3-	3	9859971
1 05 4-	1	3492637
1 05 6-	1	2741684
1 06 0-	2	5515431
1 06 1-	3	15132995
1 06 2-	1	3537663
1 07 1-	1	4269915
1 07 2-	1	3562039
1 07 3-	1	4191736
1 08 0-	1	3152339
2 00 0-	31	104882317
2 00 1-	26	94102079
2 00 2-	16	53047755
2 00 3-	12	38427687
2 00 4-	2	10189749
2 00 5-	3	9868548
2 00 6-	1	3280377
2 01 0-	31	111840376
2 01 1-	28	86534097
2 01 2-	20	62900974
2 01 3-	7	24234197
2 01 4-	5	15762873
2 01 5-	5	18054619
2 01 6-	2	7054397
2 01 7-	1	2716036
2 02 0-	23	71380097
2 02 1-	20	61638728
2 02 2-	11	40176552
2 02 3-	8	30685170
2 02 4-	3	9736085
2 02 5-	2	5978080
2 02 6-	2	8465854

2 02 7-	1	3308322
2 03 0-	12	43118004
2 03 1-	8	25807099
2 03 2-	11	36021731
2 03 3-	7	22298553
2 03 6-	1	2619003
2 04 0-	8	26655754
2 04 1-	5	17193220
2 04 2-	3	9706315
2 04 3-	6	20295289
2 04 4-	1	4212573
2 04 5-	1	6959591
2 05 0-	1	2767718
2 05 1-	5	18139688
2 05 2-	2	5971982
2 05 5-	1	3559978
2 05 6-	1	2886274
2 06 0-	1	3989897
2 06 1-	2	8585011
2 06 2-	1	3111843
2 09 4-	1	2035394
3 00 0-	18	53416230
3 00 1-	15	54084489
3 00 2-	5	17172693
3 00 3-	14	53276614
3 00 4-	6	24373331
3 00 5-	5	18914959
3 01 0-	12	40565844
3 01 1-	16	55753180
3 01 2-	9	32328885
3 01 3-	1	2105135
3 01 4-	2	7423457
3 01 5-	4	13922672
3 01 6-	2	6635140
3 01 7-	1	3311352
3 02 0-	9	31549918
3 02 1-	9	30331668
3 02 2-	9	30161131
3 02 3-	8	26434496
3 02 4-	3	13627896
3 02 5-	3	9164475
3 03 0-	7	23563203
3 03 1-	1	2799646
3 03 2-	5	17073026
3 03 5-	2	8836948
3 04 0-	6	18393748
3 04 1-	3	9382138

3 04 2-	3	9110811
3 04 3-	3	9190349
3 04 4-	1	1692119
3 04 6-	1	2257875
3 05 0-	1	2360045
3 05 1-	1	3455153
3 06 0-	3	10911655
3 06 2-	2	5598214
3 06 3-	2	7685848
3 07 0-	1	4002331
3 07 1-	2	5083763
3 07 3-	1	2967554
3 08 1-	1	6774825
3 11 0-	1	4727060
4 00 0-	8	30217370
4 00 1-	7	28169433
4 00 2-	14	42457348
4 00 3-	7	24678247
4 00 4-	3	9791107
4 00 6-	1	3137662
4 01 0-	3	11948341
4 01 1-	8	28238081
4 01 2-	7	23770588
4 01 3-	2	7629251
4 01 4-	3	14403239
4 01 5-	2	6026257
4 01 6-	1	2933970
4 01 7-	1	2799274
4 02 0-	2	6892141
4 02 1-	7	31779620
4 02 2-	2	6754197
4 02 3-	2	7858286
4 02 4-	3	10486427
4 02 5-	1	2597032
4 02 6-	1	2017213
4 03 0-	7	20635021
4 03 1-	5	16045253
4 03 2-	3	9809511
4 03 3-	2	7700056
4 03 4-	1	2716488
4 03 5-	2	9364544
4 04 0-	3	9881266
4 04 1-	1	2698552
4 04 2-	3	9318999
4 04 3-	1	4136491
4 05 1-	1	4062793
4 09 0-	1	3126224

5 00 0-	9	29103721
5 00 1-	6	18993736
5 00 2-	2	7263255
5 00 3-	3	11206583
5 00 4-	2	6111062
5 01 0-	7	23556466
5 01 1-	2	7725764
5 01 2-	9	29199214
5 01 3-	3	10125229
5 01 5-	4	14430645
5 02 0-	7	25299431
5 02 1-	4	15303697
5 02 2-	3	11984163
5 02 3-	1	5242830
5 03 0-	3	10933053
5 03 1-	2	7602934
5 03 2-	3	8084825
5 03 3-	3	11656835
5 03 4-	1	5532024
5 03 6-	1	3463902
5 03 8-	1	3635246
5 04 0-	2	7116877
5 04 1-	1	2377045
5 05 0-	1	4357394
5 05 2-	1	3546898
5 05 3-	2	7260719
5 05 4-	1	2812528
5 06 2-	1	1892744
6 00 0-	1	3474910
6 00 2-	2	6506686
6 00 3-	3	9199315
6 00 4-	1	4199715
6 01 0-	2	9960068
6 01 2-	1	4603751
6 01 3-	2	7753332
6 01 6-	1	5321654
6 02 0-	1	3705123
6 02 1-	2	6126741
6 02 2-	2	8898384
6 02 3-	3	12565537
6 02 6-	1	4420135
6 03 3-	1	2933330
6 04 5-	1	2593763
6 05 1-	1	3434536
6 07 1-	1	3002518
7 00 1-	2	6900530
7 00 2-	1	3674840

7 00 4-	1	6050090
7 01 1-	1	3366038
7 01 2-	1	4262247
7 02 0-	1	3714190
7 03 0-	1	4096701
7 04 1-	1	2929261
8 04 1-	1	2554678

Table 17

FLUX OF THERMAL NEUTRONS

CELL NUMBER X Y Z	NUMBER OF NEUTRONS	FLUX TIMES TEN TO THE THIRD
0 00 0	32	6514523
0 00 1	37	7584573
0 00 2	32	6479320
0 00 3	21	4337499
0 00 4	15	3144038
0 00 5	8	1637692
0 00 6	2	407420
0 01 0	34	6982963
0 01 1	41	8335871
0 01 2	28	5747991
0 01 3	23	4791761
0 01 4	10	2030416
0 01 5	7	1438149
0 01 6	4	807842
0 01 7	1	216607
0 02 0	21	4294041
0 02 1	20	4196409
0 02 2	12	2430134
0 02 3	16	3265941
0 02 4	10	2107222
0 02 5	4	855923
0 02 6	1	205225
0 02 7	1	207755
0 03 0	21	4345880
0 03 1	16	3295327
0 03 2	18	3707941
0 03 3	6	1273029
0 03 4	6	1265882
0 03 5	6	1200063
0 03 6	3	620468
0 04 0	10	2101039
0 04 1	7	1430966
0 04 2	6	1254166
0 04 3	4	809163
0 04 4	4	809744
0 04 5	2	411555
0 04 6	1	199251
0 05 0	6	1255863
0 05 1	6	1268807

0 05 2	8	1620033
0 05 3	5	1037579
0 05 4	6	1241590
0 05 5	3	597087
0 05 7	2	425411
0 06 0	2	418138
0 06 1	1	215705
0 06 2	1	196529
0 06 4	1	196071
0 06 6	1	212034
0 06 7	1	207416
0 07 0	2	421222
0 07 1	4	811776
0 07 2	1	209444
0 07 3	2	420502
0 07 4	1	203233
0 07 5	1	211357
0 08 1	1	201314
0 08 3	1	198325
0 09 1	1	216154
0 09 4	1	196929
0 09 5	1	218581
0 10 0	1	203739
1 00 0	32	6531494
1 00 1	29	6014466
1 00 2	23	4710716
1 00 3	15	3035892
1 00 4	9	1810687
1 00 5	2	410775
1 00 6	3	608952
1 00 7	1	213199
1 01 0	41	8545479
1 01 1	25	5131867
1 01 2	11	2253884
1 01 3	19	3859109
1 01 4	6	1227428
1 01 5	4	836196
1 01 6	4	807157
1 01 7	2	393889
1 02 0	24	4902181
1 02 1	23	4713910
1 02 2	19	3860335
1 02 3	12	2475946
1 02 4	9	1881298
1 02 5	6	1231673
1 03 0	18	3677012
1 03 1	19	3874397

1 03 2	13	2681694
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ABSTRACT

The 250 Kev Cockroft - Walton accelerator currently under construction at Virginia Polytechnic Institute is to be used as a pulsed neutron source. The time dependence of neutron flux, energy spectrum as a function of time, and various reactor parameters such as Fermi Age, slowing down time, and diffusion length in graphite will be measured using the pulsed source method.

This thesis is a Monte Carlo calculation of the results to be expected in such an experiment. The neutron flux and energy spectrum was calculated at 1, 2, 5, and 10 microseconds after a burst of fast neutrons. The neutrons were "tracked" to thermal and the Fermi Age and slowing down time were determined.