LA-4751

C.2

MCN: A Neutron Monte Carlo Code

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

LA-4751
SPECIAL DISTRIBUTION

ISSUED: January 1972

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

MCN: A Neutron Monte Carlo Code

by

E. D. Cashwell
J. R. Neergaard
W. M. Taylor
G. D. Turner

MCN: A NEUTRON MONTE CARLO CODE

by

E. D. Cashwell, J. R. Neergaard,
W. M. Taylor, and G. D. Turner

ABSTRACT

The general purpose Monte Carlo neutron code MCN is described in detail to help the user set up and run his own problems. The code treats general three-dimensional geometric configurations of materials, and can use point cross-section data in either the Livermore (LLL) or the Aldermaston (AWRE) format.

Optional standard variance reduction techniques are built into the code. Source information may be inserted in complete generality, although certain standard sources are included.

Neutron thermalization is treated by a free-gas model. In this treatment, light nuclei are assumed to have a Maxwellian velocity distribution with spatially dependent temperatures that may also vary with time.

Standard output includes currents and fluxes across arbitrary surfaces in the problem, average fluxes in designated cells, fluxes at each of a set of point detectors in space, and the number of particles captured in a cell as a function of energy and time.

A sample problem is described and set up, and the complete computer listing of a trial run is given.

I. Introduction

The general Monte Carlo neutron code MCN is written in FORTRAN IV. This program treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces, and some special fourth-degree surfaces.

The cross-sectional information necessary to treat the interactions of neutrons with matter may be included in the code in great detail. The code can deal with element cross sections from the nuclear data compilations of the Lawrence Livermore Laboratory (LLL), as well as those of Aldermaston (AWRE), at the users' discretion. The cross sections used in the program are usually read from the library presently maintained on the disk of the MANIAC at the Los Alamos Scientific Laboratory (LASL).

The code includes standard variance reduction techniques, which are optional and are described in this report. Also, the present code treats the thermalization of neutrons by the free-gas model. In this treatment, when considering elastic collisions between neutrons and light atoms, the latter are assumed to be in a Maxwell distribution with some thermal temperature that may be a function of time.

A number of useful quantities are included as standard output, such as currents and fluxes across arbitrary surfaces in the problem, average fluxes in designated cells, fluxes at each of a set of point detectors in space, and the number of captures in a cell as a function of energy and time.

A great deal of effort has gone into making this code as general and as versatile as possible, while at the same time keeping it simple to use. It is the latest of a series of general Monte Carlo neutron codes that began with a program written by Johnston.[1] The mechanics of setting up and running a problem are discussed below drawing heavily on an internal memorandum by Taylor;[2] a manual for another of our family of codes. In addition to these references, a general introduction to the type of calculation considered here is found in Ref. 3.

The units used in MCN are as follows.

1. Lengths in centimeters.
2. Times in shakes (10^{-8} sec).
3. Energies in MeV.
4. Atomic densities in units of 10^{24} atoms/cm^3.
5. Cross sections in barns (10^{-24} cm^2).

II. Geometry

The code will handle any number (limited only by the storage capabilities of the computer) of geometric cells bounded by first- and second-degree surfaces, as well as some fourth-degree surfaces. The subdivision of the physical system into cells is not necessarily governed by the different material regions occurring, but may take into consideration the problems of sampling as well as the restrictions necessary to specify a unique geometry. For the latter, suppose that $f(x,y,z) = 0$ is the equation of a surface in the problem. For an arbitrary space point (x_0,y_0,z_0), the sign of the quantity $f(x_0,y_0,z_0)$ is defined as the sense of the point (x_0,y_0,z_0) with respect to the surface $f(x,y,z) = 0$. It is clear that points in space are divided into two disjoint sets–those with positive sense with respect to the surface, and those with negative sense (we ignore the points on the surface, which have zero sense). Further, one must always write the equation $f(x,y,z) = 0$ in the same way if $f(x_0,y_0,z_0)$ is to be uniquely defined since $-f(x,y,z) = 0$ is also a perfectly acceptable way to represent the surface. If our equations are always written in the same manner, we require, in specifying the geometry of a problem, that all points in a cell must have the same sense with respect to a bounding surface, and this must be true for each bounding surface of the cell. Graphically, this means that all points are on the same "side" of a bounding surface, which rules out a cell such as depicted in Fig. 1 where c and d are reentrant surfaces. One way to remedy this situation, and there are clearly others, is to introduce surface f and make two cells out of one.

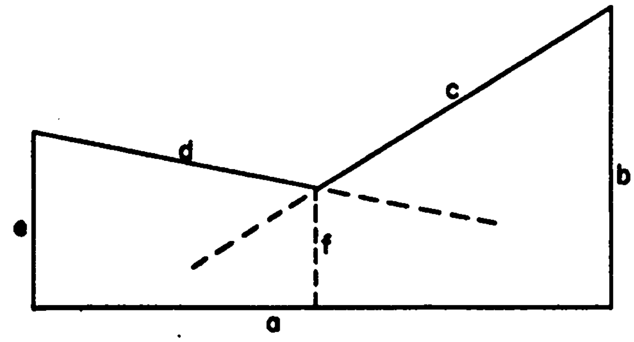

Fig. 1.

Further, it is essential that the description of the geometry of a cell be such as to eliminate any ambiguities as to which region of space is meant. That is, a particle entering a cell should be able to uniquely determine which cell it is in from the senses of the bounding surfaces. This eliminates a geometry such as shown in Fig. 2. Suppose the figure is rotationally symmetric about the y-axis. A particle entering cell (2) from the inner spherical region might think it was entering cell (1) because a test of the senses of its coordinates would satisfy the description of cell (1) as well as that of cell (2). In such cases, we introduce an "ambiguity surface" such as e, the plane $y = 0$. An ambiguity surface need not be a bounding surface of a cell, but of course it may be, and frequently is, the bounding surface of some cell other than the one in question. However, the surface must be listed among those in the problem. Referring to cells (1) and (2) in Fig. 2, we augment the description of each by listing its sense relative to surface e, as well as that of each of its regular bounding surfaces. A particle in cell (1) cannot have the same sense relative to e as does a particle in cell (2).

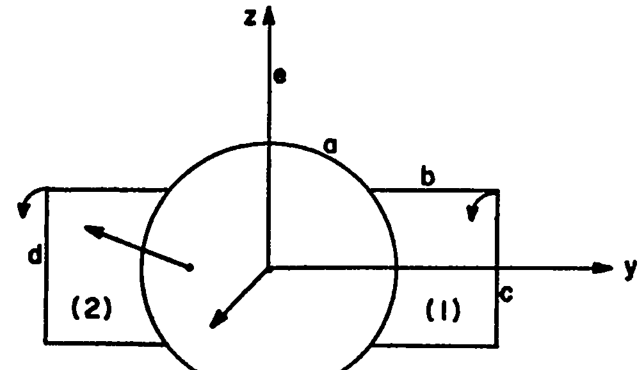

Fig. 2.

III. Cross Sections

Since in MCN we treat the various reactions precisely as they are described in the LLL and the UK compilations, we do not discuss the details of these reactions. The user may obtain listings of the cross sections, as well as a description of the various processes treated, in these cross section libraries. MCN uses the data directly from these compilations with no editing and with no changes apart from trivial modifications such as listing probabilities on our tape, instead of cross sections, to speed up the calculation. The cross sections are read into the problem in as much detail as is provided, and the program uses linear interpolation between the points given. This applies to the angular data, where we also interpolate between the angular distributions given at two distinct energies to obtain the scattering angle from an elastic or inelastic collision. If no angular data are provided for an inelastic collision, we assume the scattering is isotropic in the system of coordinates in which the energy is given. Similarly, when outcoming energy distributions from a reaction are given for a set of discrete incoming energies, we linearly interpolate between distributions to obtain the resulting energy of the neutron.

Our aim has been to use the data provided in this code with no introduction of significant alterations or processing of the data by us.

IV. Estimation of Errors

Let us assume that, in a Monte Carlo calculation, the independent sample values $x_1, x_2, \dots x_N$ are drawn from a population with a probability distribution that may be unknown. Consequently, even the mean E(x) and the variance $\sigma^2(x)$ may have to be approximated by their sample values. Certainly this is the case for most of the quantities of interest scored in the present code.

We define the sample mean

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad ,$$

and the sample variance of x

$$\bar{\sigma}^2(x) = \frac{1}{N-1}\left[\sum_{i=1}^{N}(x_i - \bar{x})^2\right]$$

$$= \frac{N}{N-1}\left[\frac{1}{N}\sum_{i=1}^{N} x_i^2 - \bar{x}^2\right] \quad ,$$

or

$$\bar{\sigma}^2(x) = \frac{N}{N-1}\left[\overline{x^2} - \bar{x}^2\right] \quad ,$$

where N represents the total sample drawn from the population. For example, in our neutron transport calculations, N represents the number of neutrons started from the source and x_i represents the total contribution to x from the i^{th} starting particle. This latter definition of x_i is important, for in using various methods of importance sampling and even in treating physical processes such as fission or (n − 2n) reactions leading to the creation of neutrons, the i^{th} particle and its offspring may contribute many times to a category or value x.

We are interested in estimating the error of the sample mean $\bar{x}$. It is well-known that if one draws a sample of size N from a population with true mean E(x) and variance σ^2, then with

$$\bar{x} = \frac{1}{N}\cdot\sum_{i=1}^{N} x_i \quad ,$$

$$E(\bar{x}) = E(x) \quad ,$$

$$\text{Variance }(\bar{x}) = \frac{\sigma^2}{N} \quad .$$

Consequently, we have for our estimate of the variance of the sample mean

$$\frac{\bar{\sigma}^2(x)}{N} = \frac{1}{N-1}\left[\overline{x^2} - \bar{x}^2\right] \quad .$$

Because N is usually sufficiently large that the error is negligible in replacing N − 1 by N, the code uses the following formula for the standard deviation of the sample mean.

$$\sqrt{\frac{\bar{\sigma}^2(x)}{N}} \equiv \bar{\sigma}(\bar{x}) = \sqrt{\frac{\overline{x^2} - \bar{x}^2}{N}} \quad ,$$

where $\bar{\sigma}(\bar{x})$ refers to the standard deviation of the sample mean, $\bar{x}$.

In applying this result to the sample values obtained by Monte Carlo, one uses the Central Limit Theorem from statistics, which may be stated in the form

$$\lim_{n\to\infty} \text{Prob}\left[E(x) + \alpha\frac{\sigma}{N^{1/2}} < \bar{x} < E(x) + \beta\frac{\sigma}{N^{1/2}}\right] = \frac{1}{\sqrt{2\pi}}\int_{\alpha}^{\beta} e^{-\frac{t^2}{2}}\, dt.$$

In terms of our sample variance, we restate this result in the following approximate form for large N.

$$\text{Prob } [\alpha\bar{\sigma}(\bar{x}) < \bar{x} - E(x) < \beta\bar{\sigma}(\bar{x})]$$

$$\simeq \frac{1}{\sqrt{2\pi}} \int_{\alpha}^{\beta} e^{-\frac{t^2}{2}} dt \quad .$$

In this form, results from Monte Carlo calculations are readily interpreted from tables of the normal distribution function.

In the present code, we give the errors in the form $\bar{\sigma}(\bar{x})/\bar{x}$, that is, we give the relative error corresponding to one standard deviation of the mean. This may be interpreted by using the Central Limit Theorem to mean that there is a 68.3% chance that the error is no larger than the value listed.

V. Sampling Techniques

Frequently, in Monte Carlo calculations, straight analogue sampling leads to prohibitively long running times to determine some quantity of interest with acceptable accuracy. Consequently, one tries to improve the efficiency of Monte Carlo sampling techniques. We call a class of schemes to alter or bias the probability density function, so as to sample more effectively the important particles, *importance sampling*. The basic idea may be demonstrated by considering the evaluation of the following simple one-dimensional integral.

$$F = \int_a^b f(x) \; p(x) \; dx \quad ,$$

where $p(x)$ is a probability density function, $\int_a^b p(x)dx = 1$. In straight analogue sampling, one would choose points $x_1, \ldots, x_N$ from the density function $p(x)$ and form the mean value $\bar{f}$.

$$\bar{f} = \frac{1}{N} \sum_{i=1}^{N} f(x) \quad .$$

This yields the Monte Carlo value for the integral. The variance of the random variable $f(x)$, σ^2, is given by

$$\sigma^2 = \int_a^b [f(x) - F]^2 \; p(x)dx = E(f^2) - F^2 \, .$$

Now suppose we sample from the density function $\tilde{p}(x)$ instead of from $p(x)$. For each point x_i selected from $\tilde{p}_{(x)}$, we give it the weight $w(x_i) = p(x_i)/\tilde{p}(x_i)$, and score the contribution of particle x_i as $w(x_i)f(x_i)$. The expected score is given by

$$\int_a^b w(x) f(x) \tilde{p}(x) dx$$

$$= \int_a^b f(x) p(x) dx \quad ,$$

so that the mean value is again F. However, the variance of the variable $w(x)f(x)$ is given by

$$\int_a^b [w(x) f(x) - F]^2 \; \tilde{p}(x) dx \quad ,$$

and is not usually the same as the variance in $f(x)$ when we sample from $p(x)$. Hence, it may be possible through judicious choice of $\tilde{p}(x)$ to decrease the variance in a calculation (while leaving the mean unchanged, of course). The decrease of variance is usually the primary reason for altering the probability density function, although one may do so in case the density $p(x)$ is difficult to sample.

In solving the Boltzmann transport equation, as we do with this program, it is possible to show that if the various density functions entering the equation are altered in just the right way, then the sampling procedure has zero variance. The solution of the adjoint transport equation must be known and it is not possible to achieve a zero variance scheme in a practical case, but it is useful in helping to find better sampling techniques.

A. Particle Splitting with Russian Roulette. Each cell in the problem is assigned an *importance*, a number which should be proportional to the average value that neutrons in the cell have for the quantity being scored. When a neutron of weight 1 passes from a cell of lower importance I to one of higher importance I′, the particle is split into identical particles of lower weight according to the following recipe. If I'/I is an integer n, the particle is split into n identical particles, each of weight $1/n = I/I'$. If I'/I is not an integer, let $n = [I'/I]$, where $[x]$ stands for the largest integer in x. Now the particle is split into $n + 1$ identical particles, each of weight $1/(n + 1)$. On the other hand, if a neutron passes from a region of higher importance I to one of lower importance I′, so that $I'/I < 1$, then the particle is killed with probability

$1 - I'/I$, and followed further with probability I'/I and weight I/I'.

This technique is perhaps the simplest and most reliable of all the variance reducing techniques used in general geometry codes. It can lead to substantial savings in machine time when used judiciously. Generally, in a deep penetration problem, one should arrange the splitting boundaries so as to keep the number of particles traveling in the desired direction more or less constant, that is, approximately equal to the number of particles started from the source.

B. Path Length Stretching. In a deep penetration problem such as frequently occurs in neutron shielding calculations, those particles that suffer relatively few collisions are apt to be the most important, although there are fewer of them. In such a case, it may be helpful to choose the distance to the next collision from a distribution in which the total cross section has been decreased, always correcting for the longer path lengths by altering the statistical weights of the particles involved.

On the other hand, it can also occur that one is interested in studying some collision process in a relatively thin material so that most of the particles traverse the region of interest with few, if any, collisions. In this case, it may prove advantageous to choose the distance to the next collision in such a region from an exponential distribution in which the total cross section has been increased.

To expedite treatment of the problems mentioned above, MCN provides for a function q(a) of each cell a to be defined as a positive or negative integer. The total macroscopic cross section in the cell a is then taken to be $\sigma' = 2^{-q(a)}\sigma$ insofar as neutron transport through that cell is concerned. If a neutron escapes from the cell and travels a distance x in so doing (the distance x determined by using the fictitious cross-section σ'), the neutron weight is multiplied by $e^{-(\sigma-\sigma')x}$. However, if a particle has a collision in the cell after traveling a distance x, the neutron weight is multiplied by $\sigma/\sigma' \, e^{-(\sigma-\sigma')x}$.

A word of caution: Although this technique can and has been used successfully to reduce variances in a variety of problems, unrestricted and excessive use of this device may do more harm than good. It is certainly neither as safe nor as foolproof to use as particle splitting with Russian roulette.

C. Statistical Estimation of Flux at a Point. Consider the problem of computing the neutron flux at a designated set of detector points in space. A standard way of treating this problem is to use statistical estimation at each collision point, that is, to compute the probability of the neutron scattering at just the correct angle to hit a unit area normal to the line joining the collision point and the detector point, and, moreover, to reach the detector with no further collisions.

Suppose we are following a neutron that has a collision and scatters at an angle θ about the line of flight of the neutron. If $\nu = \cos\theta$, let $p(\nu)d\nu$ be the probability of scattering between ν and $\nu + d\nu$. The probability of scattering so as to hit a unit area at a distance r from the collision point along the new direction is given by

$$p(\nu)\,d\nu \cdot \frac{\left(\frac{1}{r^2}\right)}{(2\pi d\nu)} = \frac{p(\nu)}{(2\pi r^2)} \quad .$$

For isotropic scattering in the laboratory system, $p(\nu) = 1/2$ so that the above expression reduces to $1/(4\pi r^2)$, as it should. The probability of the neutron reaching the detector with no further collisions is given by $e^{-\sigma r}$, where σ is the macroscopic total cross section at the new scattered energy of the particle.

To compute the probabilities above, one must use the information in the code to determine the scattering probabilities and the new particle energy for each of the scattering processes treated. For example, in the case of elastic scattering, the angular scattering probabilities are stored in the center-of-mass system of coordinates, whereas $\nu = \cos\theta$ is the angle of scattering in the laboratory system. However, we have the well-known relations

$$\nu = \frac{1 + A\mu}{\sqrt{1 + A^2 + 2A\mu}} \quad ,$$

where A is the ratio of the mass of the target atom to that of the neutron, and

$$E' = E\left(\frac{1+r}{2} + \frac{1-r}{2}\,\mu\right) \quad ,$$

where E is the incoming neutron energy, E′ is the energy of the scattered particle, and $r = (A-1)^2/(A+1)^2$. Making use of these formulas, we may compute $p(\nu) = p[\mu(\nu)]\, d\mu/d\nu$. Knowing ν from the position of a detector point, we may compute $\mu(\nu)$, hence determine $p(\nu)$ and the outcoming energy of the scattered neutron.

In treating the various inelastic processes, one must allow for scattering and energy distributions given in either the laboratory or the center-of-mass systems. In the first case, the evaluation of $p(\nu)$ is simple, but in the second case, one must use the appropriate formulas linking the incoming laboratory energy of the neutron, the outgoing laboratory energy, the outgoing energy in the center-of-mass system, the scattering angle in the center-of-mass system, and the scattering angle in the laboratory system. We shall not give these formulas, but they are readily derived from considerations of the collision process.

When the detector point is outside the scattering region, this method of calculating flux is in general quite reliable. However, when collisions can occur arbitrarily close to the detector, the variance of the flux can become infinite. Several methods have been devised to counteract this situation.[4,5] MCN contains only the simple device of computing an average contribution for collisions in a spherical neighborhood of the detector. To be more precise, if one assumes that the flux is isotropic and uniform in a spherical region surrounding the point, one can easily derive the expression

$$\frac{2p(\nu)\left(1 - e^{-\sigma r_o}\right)}{\frac{4}{3}\pi r_o^3 \cdot \sigma}$$

for the average contribution to the flux at the detector for particles colliding in the spherical region, where $p(\nu)$ and σ are defined as above, and r_o is the radius of the sphere about the point. Using this expression does not cure all difficulties arising in the computation of flux at a point, but it can help to prevent the rare collision, very close to the detector, from seriously perturbing the calculation. The choice of r_o may require some experimentation, because the sphere should be large enough to enclose a reasonable number of collisions, but not so large that the assumptions are violated. For a typical problem, r_o may be chosen as a fraction of a mean free path, but it is most important that one should obtain a good sample in the vicinity of the point detector. Otherwise, either the estimate of the flux will be too low or the occasional collision in the vicinity of the detector will carry too much weight, leading to large variances in the result.

A scheme which may often be used to advantage when the detector is embedded in the scattering medium has been suggested by Everett.[6] Suppose the point detector is enclosed by a finite set of spheres of decreasing radii, r_1 r_2, ... r_n (n is in general a small positive integer). It is simple to obtain the estimate of the flux outside of the sphere of radius r_1 (call it F_1), then the estimate outside of r_2 (F_2), and so on until we obtain the estimate of the flux outside of the sphere of radius r_n (F_n). Plotting F_i vs r_i leads to an extrapolated value for the flux at the point. Because no information is obtained from collision points inside r_n, it is important that r_n not be so large that extrapolation is risky, yet not be so small that a collision point close to the boundary of the n^{th} sphere can cause a large perturbation in the estimate. One can best gauge the size of the spheres to be used from analysis of the physical problem and experimentation. The latter is particularly helpful in the choice of r_n. Again, if the detector is not in a fairly accessible region, so that the occasional collison close by is very important, then biasing is called for to increase the number of particles in the vicinity of the detector. With poor sampling in the neighborhood of the point, no scheme is reliable.

Standard tallies. Definitions of some of the terms used to specify the output of MCN are given.

1. Currents Across Surfaces. By the current across a surface in a given direction we mean simply the number of particles crossing the surface in that direction as a function of time, energy, and angle with the normal to the surface. The code will yield the number crossing in each of the two directions of crossing for any subset of the boundary surfaces in the problem, and will tally the number of neutrons crossing in a common set of time, energy, and angle bins. The two directions of crossing are designated by (− to +) and (+ to −). The symbol (− to +) means that the particles cross the surface from a cell that has negative sense with respect to that surface into a cell that has positive sense with respect to that surface. The symbol (+ to −) is interpreted similarly, obviously referring to crossing in the opposite direction. In the problem printout, we use the more descriptive term "number of neutrons crossing" instead of "current" to avoid confusion.

2. Flux at a Surface. By flux we mean track length per unit volume per unit time. In printing out the flux across a boundary surface in the problem, we give the flux integrated over the entire surface, as well as over time and energy intervals. Hence, the average flux over the surface for the time and energy bins may be obtained by dividing by the surface area. In the sampling process, whenever a neutron of weight W crosses the surface in any direction, we compute μ, the cosine of the angle the line of flight of the particle makes with the normal to the surface, form the quantity $W/|\mu|$, and dump it into the appropriate time and energy bin for the flux.

3. Flux Tally in Cells. Frequently, in computing reactions, it is convenient to tally the average flux in a cell as a function of time and energy. Here we actually compute the total track length of the particles in the cell and divide by the volume of the cell. This method of computing average flux takes account of the geometric shape of the cell, and it can yield an accurate value of the flux in thin regions where few collisions take place.

4. Capture Tally in Cells. This is a straightforward collection of the number of particles captured in a designated set of cells of the problem. The information is classified into time and energy bins.

5. Flux Tally at Points. We described this calculation in Sec. V. C. The flux is computed as a function of time and energy at a prescribed set of points in space.

In any of the tallies described above, beside each quantity printed there appears the estimated error in that quantity. As described in our discussion of errors in Monte Carlo calculations, we print the relative error obtained by dividing $\bar{\sigma}(\bar{x})$ by $\bar{x}$. $\bar{x}$ refers to the mean quantity tallied, and $\bar{\sigma}(\bar{x})$ refers to the sample standard deviation in $\bar{x}$.

It is implicit in the definition of $\bar{x}$, but we emphasize the fact that all tallied quantities described above are normed by the number of particles starting from the source. That is, all answers are given "per starting neutron."

VI. Execution of Monte Carlo Neutron Programs

A. Initiation. The initiating program MCNI is employed in the first stage of the Monte Carlo solution. This program reads the problem deck, which is a description of the physical system and desired tallies, processes this information, and produces a data file needed by the running program MCN.

The problem deck consists of cards grouped as follows:

Problem ID card

Cell cards

Blank card

Surface cards

Blank card

Data cards

Blank card

The format of these cards is defined below.

The data file written by MCNI has the following structure:

Fixed data, such as geometry and tally controls (record #1)

Cross sections required by this problem (record #2)

Tally record (initial) (record #3)

If the option to store certain cross sections in Extended Core Storage (ECS) on the CDC-6600 or in the Large Core Memory (LCM) on the CDC-7600 is taken, an additional record of this data is written following the (fast core) cross-section record.

During its processing cycle, MCNI also prints out the card images of the problem deck, error messages if any, and other information pertinent to the problem initiation.

B. Running. The second stage, and succeeding stages if necessary, comprise the actual Monte Carlo calculation. This is executed by MCN, the running program. Input to MCN consists of the data file produced by the initiating program MCNI and a single data card, the run card. The run card contains the following problem parameters.

Problem time cut-off in shakes

Weight cut-off

Job time in minutes

NDP, printout cycle (tally printout occurs every NDP histories)

NDM, tally record write cycle

Tally record number (specifying tally record to begin this run with)

NPP, terminal history number (calculation stops after NPP histories)

The format of this card is defined by the FORTRAN statement FORMAT(3E10,4I10).

After reading the run card, MCN reads the fixed data and cross-section data from the data file. The specified tally record is then found and the calculation proceeds. (When the calculation is just beginning, only the initial tally record written by MCNI exists.) Shortly before the job time is to expire, MCN writes the latest tally record at the end of the data file. The Monte Carlo calculation is continued by stages, if desired, by executing MCN and reading the last tally record in the data file at each stage. As the calculation continues, the data file expands to accommodate the latest tally records.

C. File Manipulation. MCNI finds the needed cross sections by reading from a file called CODETP. The data file produced by MCNI is written to a file called RUNTP, which in turn is read by MCN. In practice, CODETP is a fixed magnetic tape consisting of three files; (1) MCN and its subroutines, (2) MCNI and its subroutine, and (3) neutron cross sections for all nuclides of interest. RUNTP is a scratch magnetic tape of two files; (1) a copy of the first file on the CODETP, namely, MCN and its subroutines, and (2) the data file.

The procedure used when initiating a calculation begins with mounting the CODETP and a scratch tape as RUNTP. The first file of the CODETP is copied over to the RUNTP. The second file of the CODETP, MCNI and subroutine, is then loaded and executed. At this point, the cross-section file is in position to be read. After writing the data file to RUNTP, MCNI rewinds RUNTP. Once the running stage is begun, the first file of RUNTP, a copy of MCN and subroutines, is loaded and executed. The data file is then in position to be read by MCN. To continue a calculation, only RUNTP is needed. The usual practice in a job initiating a calculation is to proceed into the running stage immediately after MCNI has finished, without first checking the initiation printout for errors. A brief run here by MCN costs little and often reveals errors, especially because the orderly completion of the initiation does not guarantee that the problem deck is correct.

Appendix A provides listings of "initiate and run" and "continue run" control card decks used within the operating systems for LASL'S CDC-6600 and CDC-7600 computers.

D. Card Format. Cell cards, surface cards, and data cards all conform to the same format. Columns 1-5 are reserved for the name (or number) associated with the card, if any. The name (or number) field can appear anywhere in columns 1-5. Blanks in these columns indicate a continuation of the data from the last named card. Columns 6-72 are for data entry associated with the name. With some exceptions on cell cards, separation between data entries is by one or more blank columns. In general, data entries may be integers or real numbers, inasmuch as the program makes the appropriate conversion. All items are read from the data field with a FORTRAN E20 format.

Two features of the FLOCO II loader have been incorporated into the code to facilitate card preparation.

1. nR: Repeat the last entry before this statement n times.

2. kI: Insert k linear interpolates between the entries immediately preceding and following this state.

These features apply to both integer and floating point quantities and may be used wherever applicable.

E. Problem ID Card. Any ID card may be used for problem identification; columns 1-80 are read. This card must be included even if it is a blank.

F. Cell Cards. The number of the cell is in columns 1-5. Columns 6-72 will contain, in the following order,

1. The cell material number,

2. The cell material atomic density, and

3. A complete list consisting of the number of a surface bounding the cell followed by the numbers of those cells on the other side of the surface which could be entered by a neutron leaving the given cell; a second surface, if it exists, followed by the cells on the other side into which a particle may escape, etc., running through all bounding surfaces of the cell.

The numbers of the surfaces bounding a cell are signed quantities, the sign being determined by the sense any point within the cell has with respect to the surface. If the sense is positive, the sign should be omitted. The list consisting of the surface number followed by the number of the cells on the other side is a list in the sense that each entry except the last must be followed immediately be a comma. The absence of the comma indicates that another bounding surface follows with its attendant cells on the other side. Blanks may be used optionally to further separate list entries. Ambiguity surfaces are treated as bounding surfaces having no cells on the other side. In this case, omit the comma following the number.

If a cell is a void, this may be indicated by entering a cell material number of 0 and omitting the density entry.

G. Surface Cards. The number of the surface appears in columns 1-5. MCN provides that any surface appearing in the problem may be a reflecting surface. To designate a reflecting surface, the space on the surface card immediately preceding the surface number should contain an asterisk. A neutron hitting such a surface finds itself specularly reflected and the calculation continues. Columns 6-72 contain, in the following order,

1. An alphabetic mnemonic indicating the surface type, and

2. The surface coefficients in proper order.

We list here the surface types, their mnemonics, and the order of entry of the surface coefficients.

Mnemonic	Type (Equation)	Coefficients in Order of Entry
P	$Ax + By + Cz - D = 0$	A, B, C, D
PX	$x - D = 0$	D
PY	$y - D = 0$	D
PZ	$z - D = 0$	D
SØ	$x^2 + y^2 + z^2 - R = 0$	R
S	$(x-\bar{x})^2 + (y-\bar{y})^2 + (z-\bar{z})^2 - R^2 = 0$	$\bar{x}, \bar{y}, \bar{z}, R$
SX	$(x-\bar{x})^2 + y^2 + z^2 - R^2 = 0$	$\bar{x}, R$

Mnemonic	Type (Equation)	Coefficients in Order of Entry
SY	$x^2 + (y-\bar{y})^2 + z^2 - R^2 = 0$	$\bar{y}$, R
SZ	$x^2 + y^2 + (z-\bar{z})^2 - R^2 = 0$	$\bar{z}$, R
C/X	$(y-\bar{y})^2 + (z-\bar{z})^2 - R^2 = 0$	$\bar{y}$, $\bar{z}$, R
C/Y	$(x-\bar{x})^2 + (z-\bar{z})^2 - R^2 = 0$	$\bar{x}$, $\bar{z}$, R
C/Z	$(x-\bar{x})^2 + (y-\bar{y})^2 - R^2 = 0$	$\bar{x}$, $\bar{y}$, R
CX	$y^2 + z^2 - R^2 = 0$	R
CY	$x^2 + z^2 - R^2 = 0$	R
CZ	$x^2 + y^2 - R^2 = 0$	R
K/X	$-t^2(x-\bar{x})^2 + (y-\bar{y})^2 + (z-\bar{z})^2 = 0$	$\bar{x}$, $\bar{y}$, $\bar{z}$, t^2
K/Y	$(x-\bar{x})^2 - t^2(y-\bar{y})^2 + (z-\bar{z})^2 = 0$	$\bar{x}$, $\bar{y}$, $\bar{z}$, t^2
K/Z	$(x-\bar{x})^2 + (y-\bar{y})^2 - t^2 (z-\bar{z})^2 = 0$	$\bar{x}$, $\bar{y}$, $\bar{z}$, t^2
KX	$-t^2(x-\bar{x})^2 + y^2 + z^2 = 0$	$\bar{x}$, t^2
KY	$x^2 - t^2(y-\bar{y})^2 + z^2 = 0$	$\bar{y}$, t^2
KZ	$x^2 + y^2 - t^2(z-\bar{z})^2 = 0$	$\bar{z}$, t^2
SQ	$A(x-\bar{x})^2 + B(y-\bar{y})^2 + C(z-\bar{z})^2$	A, B, C, D, E,
	$+ 2D(x-\bar{x}) + 2E(y-\bar{y})$	F, G, $\bar{x}$, $\bar{y}$, $\bar{z}$
	$+ 2F(z-\bar{z}) + G = 0$	
GQ	$Ax^2 + By^2 + Cz^2 + Dxy + Eyz$	A, B, C, D, E, F, G
	$+ Fzx + Gx + Hy + Jz + K = 0$	H, J, K
QD	$(y-\bar{y})^2/b^2 + (z-\bar{z})^2/c^2 = 1$*	$\bar{y}$, $\bar{z}$, b, c

*In this case, the equation shown is that of the ellipse in the yz-plane which generates the fourth-degree surface actually used in the code by the process of revolving the ellipse about the y-axis. The resulting elliptic torus has the equation

$$(x^2 + z^2 + \rho y^2 - 2\rho\bar{y}y + B_o)^2 = A_o(x^2+z^2) \quad ,$$

where $\rho = c^2/b^2$

$$B_o = \bar{z}^2 - c^2 + \rho\bar{y}^2$$

$$A_o = 4\bar{z}^2 \quad .$$

Because the torus is completely defined by the ellipse, we specify only the simpler equation in setting up the geometry.

H. Data cards. All data cards are distinguished by the alphabetic first character of the name. Data cards break down into the following six categories. If a data card contains all zeros, it may be omitted.

1. Cell Specification Cards. The names associated with the cell specification cards are I0, Y6, Y7, R1, ... ,Rn. These cards continue the specification of quantities by cell. The entries on the I0, Y6, and R1, ... ,Rn cards must correspond to the order in which the cell cards are placed in the deck. There are no ordering restrictions on either cell or surface cards; thus, the n^{th} entry on an I0 card must be that value assigned to the cell occupying the n^{th} position among the cell card entries.

The usage is as follows.

I0: Cell importance.

Y6: q(a), where $2^{-q(a)}\ \sigma^{tot}$ is the fictitious cross section used in cell a to compute distance to the next collision.

R0: A sequence of times $t_1, t_2, \ldots, t_n$ at which the cell thermal energies are given.

R1: Cell thermal energies at the 1st time t_1.

•

•

•

Rn: Cell thermal energies at the nth time, t_n.

Importances are cell constants independent of the energy of the neutron, thus necessitating only one entry per cell.

The cell thermal treatment requires an appropriate thermal "cut in" energy for the problem (see D0 card). All neutrons above this energy are treated as scattered from stationary nuclei. At neutron energies below this cut-in, and for scattering nuclei not belonging to one of a select group of light atoms, the elastic scattering event is treated as scattering from a stationary nucleus isotropically in the laboratory system with no energy loss. The select group of light nuclei, which always includes hydrogen and deuterium if present in the problem, are considered to be in thermal motion, having a Maxwellian distribution of velocities determined by the cell thermal energy. Scattering on these nuclei now includes the effect of the thermal motion. This treatment of thermalization of neutrons is often described as using the free-gas model.

The cell thermal energies can further be specified as a function of time. The thermal energies as a function of cell (each cell has its own thermal energy) are given at a discrete set of times $t_1, \ldots, t_n$. The first time, t_1, is written as the first entry on the R0 card; the second time, t_2, becomes the second entry on the R0 card, etc., through the n values of the time. The thermal energies at time t_1 are listed, cell by cell, on the R1 card; the corresponding cell thermal energies at time t_2 are listed on the R2 card, etc. A linear interpolation is used to determine the cell thermal energies at times between two entries. Time values occurring before t_1, or after t_n, use the thermal energies at the nearest time entry. Because thermal energy entries are required only for those cells whose material composition includes one of the select group of light elements treated by the free-gas model, all other cell entries can be set to zero.

Note. Here we use kT to denote the thermal energy of a cell rather than the more correct 3/2 kT. Of course, our units of energy are MeV.

2. Source Cards. The names associated with the source cards are Sn, U0, V0, and W0. All or some of these cards may be used with a particular source. (More details about the source subroutines are given in Appendix B.) The usage is as follows.

Sn: The particular source used may be specified by n. One may build up a library of sources each of which is denoted by a subscript, n; at present $1 \leqslant n \leqslant 8$.

U0: Source track fractions (described below).

V0: Cumulative probabilities that the energy of a source particle is less than the corresponding energy entry in W0.

W0: A table of energies of source particles.

V0 and W0 together give the distribution function of the energy spectrum. A random number, ξ, on the range (0,1) yields a unique starting energy by linear interpolation from this energy distribution function. The source may be arbitrary in MCN provided that it gives a complete description of the starting neutron's initial parameters. Usually this amounts to a specification of the position, direction, time, energy, weight, the number of the cell started from, and/or the number of the surface started on. Any or all of these quantities may be completely determinate or sampled from some distribution. The entries on the Sn card are generally associated with the weight, cell name, and/or surface name.

The first entry on the W0 card should be the minimum neutron energy from the source, followed by the energy entries in order of increasing magnitude through the maximum allowable energy. As mentioned above, the entries on the V0 card are the cumulative probabilities that a source neutron has an energy less than or equal to the corresponding entry on the W0 card. In this case, the first entry on the V0 card must always be 0 and the last entry must be 1. However, if the source probability distribution is derived from data giving the number of neutrons started in each energy group, this data can be entered directly onto the V0 card. The first entry is again 0, followed by the input for each energy group up through the highest energy group. The code will process these entries to form the corresponding probability distribution. The code distinguishes between the two modes of entry on the V0 card by examining the last entry. If this is 1, it assumes that a cumulative probability distribution was read in; otherwise, it processes the data to form the distribution.

The entries on the U0 card are used to bias the energy distribution of the source. We call these entries track fractions. Track fraction is the fraction of neutron histories (regardless of the weights attached to these histories), or "tracks" started in a given energy interval. For example, we may start more tracks at high energies in a shielding problem, correcting the distribution by altering the weights assigned to these tracks. In this way we should always start the correct amount of weight in each energy interval. The first entry on the U0 card must be a 0. This is followed by an entry proportional to the number of tracks to be started in the lowest energy group, the entries continuing in the same way, one for each energy group, through the highest group defined for the source. But when one is biasing the source by using a U0 card, then the entries on the V0 card must also be proportional to the number of particles from the actual source in the corresponding energy groups. (**Note**: A cumulative probability distribution on the V0 card is not used when the U0 card is used.) The code normalizes the entries on the U0 and V0 cards, divides the fraction of actual source particles in an energy bin by the fraction of tracks started (the "fictitious source") in that bin to obtain the weight assigned to particles in that energy group, puts the appropriate weights so obtained in the proper locations in the U0 block, and finally stores a cumulative probability distribution for the fictitious source (the distribution of tracks) in the V0 block in the correct storage locations.

In a similar way, it is sometimes helpful to bias the directions of the emerging source particles. For example, one might send more particles or tracks in a given direction than would normally emit from the source in that direction. Again, the directional distribution is corrected by altering the weights of the emerging particles so as to always send the correct amount of weight in any given direction. Sizable reductions in variance may result from energy and directional biasing of the source.

The Sn card may be used for entering source data not listed on the U0, V0, and W0 cards, such as dimensions related to the source, or quantities related to directional biasing, or any other parameter values such as starting weight, cell, energy, position, and direction of the source particles. (Appendix B gives some standard sources included in the code, as well as the general source routine.)

3. L-Card. The L card is an optional card that gives the names of problem nuclides whose cross sections are to be stored in ECS (or LCM). Total cross sections and corresponding energies for all nuclides in the problem reside in fast core. The rest of the cross-section information can be stored in ECS and brought into fast core when needed. A judicious selection of nuclides of lesser importance in a problem for ECS cross-section storage can save considerable fast core storage. This procedure costs very little in execution time because the transfer rate between ECS and fast core is so high. A table giving cross-section storage allocation between fast core and ECS is printed by MCNI at the end of initiation.

4. Function Cards. The function cards refer to the various tallying functions that the code can perform. The names associated with these cards are Fn, En, Tn, Cn, and P4. The usage is as follows.

Current tally: n = 1. The code tallies currents across any designated subset of the bounding surfaces in the problem in each of the two directions of crossing. Beside each printed number appears the relative error in that quantity.

Requires F1, E1, T1, and C1 cards.

F1: Tally surface numbers. The entries are the numbers of the surfaces across which currents are to be tallied. There are no ordering requirements on the surface number entries.

E1: Tally energies. The upper bounds of the energy bins must be entered in the order of increasing magnitude.

T1: Tally times. The upper bounds of the time bins must be entered in the order of increasing magnitude.

C1: Tally cosines. The angular limits are defined with respect to the normal to the surface at the neutron point of entry. The card entries are given as lower bounds of the cosine bins where the order of entry starts with the angle nearest the normal and continues around to the tangent plane. Thus, to tally currents within the angular limits 0 to 30°, 30 to 60°, and 60 to 90° with respect to the normal, the entries on the C1 card would be 0.8660, 0.5, 0.

Flux tally across surfaces: n=2. The code tallies fluxes across any designated subset of the bounding surfaces in the problem as a function of time and energy, and in addition lists the corresponding errors in the fluxes.

Requires F2, E2, and T2 cards.

F2: Tally surface numbers. The entries are the numbers of the surfaces across which fluxes are to be tallied. There are no ordering requirements on surface number entries.

E2: Tally energies. The energies must be entered in the order of increasing magnitude exactly as in E1 above.

T2: Tally times. The times must be entered in the order of increasing magnitude exactly as in T1 above.

Flux tally in cells: n=4. The track length per unit volume, or average flux, is tallied in any specified subset of cells in the problem as a function of time and energy. The corresponding errors are given.

Requires F4, E4, T4, and P4 cards.

F4: Cell tally numbers. The entries are the list of cells in which the flux is to be tallied. There are no ordering requirements on the cell number entries.

E4: Tally energies. The upper bounds of the energy bins must be entered in the order of increasing magnitude.

T4: Tally times. The upper bounds of the time bins must be entered in the order of increasing magnitude.

P4: Cell volumes. The volumes of the cells listed on the F4 card are entered in the same order.

Flux tally at points: n=5. The code tallies the flux at a designated set of points in space as a function of energy and time and prints these quantities along with their statistical errors.

Requires F5, E5, and T5 cards.

F5: Tally coordinates for each point detector. The entries are sets of ordered quadruples (x, y, z, R_0), one quadruple for each detector point, where (x, y, z) designates the location of the point in space, and R_0 is the radius of a fictitious sphere with center at (x, y, z) (see the description of flux tallies at points in Sec. V, Sampling Techniques). For each collision occurring inside this fictitious sphere, an average contribution is tallied at the detector point.

E5: Tally energies. The upper bounds of the energy bins must be entered in the order of increasing magnitude.

T5: Tally times. The upper bounds of the time bins must be entered in the order of increasing magnitude.

Capture tally in cells: n=6. The code tallies the number of neutrons captured in a designated subset of cells in the problem as a function of energy and time, and prints these quantities along with their statistical errors.

Requires F6, E6, and T6 cards.

F6: Cell tally numbers. The entries are the unordered list of cells in which the number of neutrons captured is to be found as a function of energy and time.

E6: Tally energies. The energies must be entered in the order of increasing magnitude just as in the above cases.

T6: Tally times. The times must be entered in the order of increasing magnitude just as in the above tallies.

The capture tally is easily modified to record some other quantity, such as fission or one of the other reactions, as a function of energy and time.

5. D0 Card. The D0 card has three entries ordered as follows.

1. Thermal Energy Cut-In. All neutrons having an energy less than this value are given the thermal treatment by using the free-gas model (see R0 and Rn cards). The thermal cut-in is usually assigned a value that is a factor of 10 greater than the maximum thermal energy in any cell of the problem. If thermal energies are not used, this entry is set to 0.

2. Energy Cut-Off. This is the lowest energy value of interest in the problem. If thermal energies are used (Rn cards), this entry should be zero.

3. Maximum Energy of the Problem. This entry should be at least as large as the energy of any particle in the problem.

If thermal energies are not used in the problem, the code will read in cross sections to cover only the energy range defined by 2 and 3 above; that is between E_{min} and E_{max} for the problem. The program for eliminating cross sections not pertinent to the problem is called SNIP. If thermal energies are used in the problem, SNIP is inoperative.

6. Material Cards. The names associated with material cards are Mn; n will be the number associated with a material and should appear on the appropriate cell cards, that is, on a cell card whenever that cell contains that material. The cross-section tape contains the cross sections of a list of elements or nuclides which themselves are identified by a number, both on the tape and in making up the composition of a material.

The entries on the material card should consist of the identifying number of a constituent element followed by the atomic fraction of that element, the number of a second constituent element followed by its atomic fraction, etc., running through all the elements needed to define the material.

Where problems are run using a list of standard materials, the appropriate material information is left in the code with each material then having a fixed identifying number. These material numbers are entered on the appropriate cell cards of the problem.

Example: To help the reader use the present Monte Carlo program, we work out in detail a sample problem in Appendix C. The descriptive material above will be more easily assimilated if the prescribed steps are followed in setting up the problem. Further, a complete print of the problem output is displayed.

REFERENCES

1. R. Johnston, "A General Monte Carlo Neutronics Code," Los Alamos Scientific Laboratory report LAMS-2856 (1963).

2. W. M. Taylor, internal memorandum (December, 1968).

3. E. D. Cashwell and C. J. Everett, *A Practical Manual on the Monte Carlo Method for Random Walk Problems*, (Pergamon Press, Inc., New York, 1959); also, published as Los Alamos Scientific Laboratory report LA-2120 (1957).

4. M. H. Kalos, "On the Estimation of Flux at a Point by Monte Carlo," Nucl. Sci. Engr. 16 111 (1963).

5. H. A. Steinberg and M. H. Kalos, "Bounded Estimators for Flux at a Point in Monte Carlo," Nucl. Sci. Engr. 44, 406 (1971).

6. C. J. Everett, private communication (1970).

APPENDIX A

CONTROL CARD DECKS

a. "Compile source, initiate, and run" deck for LASL's CDC-6600

JØB card
CØMMENT. CØMPILE SØURCE, INITIATE, AND RUN PRØBLEM

ASSIGN MT, CØDETP(PLB, tape no., SHB)

ASSIGN MT, RUNTP(NLB,,SHB)

RUN(SX,B=RUNTP) CØMPILE SØURCE

CØPYBF(CØDETP,RUNTP)

CØPYBF(CØDETP,MCNI)

MCNI.

RELTAPE(CØDETP)

CØPYBF(RUNTP,MCN)

MCN.

789 card

Source subroutine deck (including COMMON)

789 card

Problem deck

789 card

Run card

6789 card

When one of the standard sources is used, the following deck suffices to "initiate and run."

B JØB Card

CØMMENT. INITIATE AND RUN PRØBLEM

ASSIGN MT,CØDETP(PLB,tape no.,SHB)

ASSIGN MT,RUNTP(NLB,,SHB)

CØPYBF(CØDETP,RUNTP)

CØPYBF(CØDETP,MCNI)

MCNI.

RELTAPE(CØDETP)

CØPYBF(RUNTP,MCN)

MCN.

789 card

Problem deck

789 card

Run card

6789 card

"Continue run" deck for LASL's CDC-6600

CØMMENT. CØNTINUE RUN

ASSIGN MT,RUNTP(NLB,tape no.,SHB)

CØPYBF(RUNTP,MCN)

MCN.

789 card

Run card

6789 card

b. "Compile source, initiate, and run" deck for LASL's CDC-7600.

$. COMPILE SOURCE, INITIATE, AND RUN PROBLEM

$CREATE(FS=CØDETP,CL=U,PREMT=CRØS tape no.)

$RUN(C=SX,B=RUNTP) CØMPILE SØURCE

$CØPYF(I=CØDETP,Ø=RUNTP)

$SETQ(KEY=KKTP)

$SETQ.

$LDGØ(I=CØDETP) INITIATE

$IF(FALSE=RUN)

$DMPX.

$STØP.

$LABEL(RUN)

$SETQ(KEY=KKTP)

$SETQ.

$LDGØ(I=RUNTP) RUN

$IF(FALSE=TAPE)

$DMPX.

$LABEL(TAPE)

$AFSREL(RF=RUNTP,ADISP=TAPE)

$FM.

Source subroutine deck (including COMMON)

$FM.

Problem deck

Run card

$EJ.

As in the case of the corresponding CDC-6600 deck, the above deck can be converted to "initiate and run" with *a standard source* by simply removing the $RUN control card and the source subroutine deck with its $FM terminator.

"Continue run" deck for LASL's CDC-7600

$. CØNTINUE RUN.

$CREATE(FS=RUNTP,CL=U,PREMT=CROS tape no.)

$SETQ(KEY=KKTP)

$SETQ.

$LDGØ(I=RUNTP)

$IF(FALSE=TAPE)

$DMPX.

$LABEL(TAPE)

$AFSREL(FS=RUNTP,ADISP=STAPE,POSMT=same tape no. as in $CREATE)

$FM.

Run card

$EJ.

APPENDIX B

SOURCE SUBROUTINES

I. Standard Sources

The general nature of the geometry of many Monte Carlo problems has some bearing upon conventions established for source routines. Although we make no attempt to be exhaustive, we include some frequently occurring sources. Suppose the source is at the center of, in, or on the surface of a spherical cell; in the sources below, this cell is assumed centered at (0,0,0), the origin of the coordinate system. Also, all point sources are assumed to be at (0,0,0). When we speak of a biased source below, we mean that the angular distribution is biased in the sense that more neutrons are started in the positive y direction than in the negative, always correcting for the bias by altering the weights of the starting particles. In general, we start more neutrons in the hemisphere symmetric about the +y direction than in the hemisphere symmetric about the −y direction, with the correct angular distribution in each hemisphere.

Occasionally it is desirable to bias the energy distribution of the source, to emphasize the effects of certain energy groups. This is effected by modifying the source probability distribution and the particle weighting by means of the track fractions. (See Source Cards, Sec. VI.H.2.) A source having this capability is referred to below as a weighted source.

To use the following sources without modification, the cell containing the source should be cell number 1 and, if the bounding surface of cell 1 is a sphere, it should be surface number 1. The entries on the Sn card will be designated in order of their entry as SRC(1), SRC(2), ... , SRC(N). If cell 1 is a spherical region, by setting SRC(4) = radius of sphere as in source S1 below, the code will not compute the distance to the boundary traveled by source particles. However, if SRC(4) = 0, the code will compute the distances to all boundary surfaces of cell 1, selecting that surface corresponding to the smallest positive distance as the surface crossed if the particle reaches the boundary before collision. For example, if cell 1 is not a spherical region, one should set SRC(4) = 0.

Source Routines.

S1: A biased point source.

Requires V0 and W0 cards.

SRC(1) = fraction of neutrons directed in +y direction.

SRC(2) = weight of a neutron directed in +y direction.

SRC(3) = weight of a neutron directed in −y direction.

SRC(4) = radius of cell 1, if cell 1 is a spherical region

SRC(4) = 0, otherwise.

S2: A weighted, biased point source.

Required U0 and V0, and W0 cards.

(Entries on Sn card same as in source S1.)

S3: A biased, cosine distribution relative to the outward normal of a sphere (surface 1).

Requires V0 and W0 cards.

(Entries on Sn card same as in source S1, except that SRC(4) = radius of surface 1. Particles are started in cell 2).

S4: A weighted, biased, cosine distribution relative to the outward normal of a sphere (surface 1).

Requires U0, V0, and W0 cards.

(Entries on Sn card same as in source S3).

S5: An isotropic point source.

Requires V0 and W0 cards.

SRC(1) = 0.

SRC(2) = 0.

SRC(3) = 0.

SRC(4) defined as in S1.

S6: A weighted, isotropic point source.

Requires U0, V0, and W0 cards.

(Entries on Sn card same as in S5.)

II. General Source Subroutine

When the source cannot be represented by one of the standard sources described above, it is necessary to write a FORTRAN subroutine headed by a SUBROUTINE SOURCE card and a COMMON deck provided by LASL Group TD-6. Neutron parameters discussed below must be assigned initial values within this subroutine. In conjunction with the source subroutine there is an S7 or S8 card in the problem deck.

III. Neutron Parameters

X x-coordinate of neutron's position.

Y y-coordinate of neutron's position.

Z z-coordinate of neutron's position.

U x-axis direction cosine of neutron's direction.

V y-axis direction cosine of neutron's direction.

W z-axis direction cosine of neutron's direction.

At the point of the call of source subroutine, MCN has already sampled and assigned U, V, and W from an isotropic distribution. Unless the source distribution is anisotropic, the parameters U, V, and W need not be assigned.

DEL A special quantity used by MCN in computing distances to surfaces bounding a cell to determine which surface is intersected by the neutron's flight path. If DEL is set to zero, distances to all surfaces are computed; this is generally the value used when the source neutron is *within* a cell. When the source is on surface JA, DEL must in general be set to −1.0 to avoid inadvertent selection by the program of surface JA as the nearest bounding surface. There are two exceptions to these rules. If the distance from the source point to bounding surface JA is constant, as for a point source at the center of a sphere, then DEL should be set equal to that distance, thus obviating this computation by MCN. The other exception occurs when the source is on a second-degree surface JA and the neutron flight path intersects JA at another point besides the source point. Then DEL must be set equal to the distance from the source point to the other intersection point. For example, if JA is a sphere and the source is on the surface directed inward, DEL = −2(X·U + Y·V + Z·W).

IA The program name of the cell containing the source neutron, or, in the case of a surface source, the cell which will be entered by the neutron.

JA The program name of the surface in question when DEL has been set to a nonzero value. When DEL is zero, JA should be set to 1.

TME Neutron's time in shakes (1 shake = 10^{-8} sec).

WT Neutron's weight (generally 1.0).

ERG Neutron's energy in MeV.

IV. S7 or S8 Card

An S7 or S8 card in the problem deck signals the code that subroutine SOURCE is to be called for source neutron parameters. The S8 card is used only in the following special situation. If a point detector calculation is being made, and neutrons are emitted from the source anisotropically, then MCN needs to know the probability density PSC of emitting directly towards the detector. The S8 card causes a call to a subroutine SRCDX that must be provided along with SOURCE and which must assign a value to PSC. The quantity PSC is used to calculate the contribution of the source neutron directly to a detector. If the S8 card is not used in a detector calculation, MCN assumes that the source emission is isotropic and sets PSC equal to 0.5.

Up to eight values may be punched on an S7 or S8 card. These values are stored in order in the array SRC(I), I = 1, 2, ... ,8, and are available to subroutine SOURCE via COMMON.

V. Random-Number Generators

Sampling from distributions for source energies, times, etc., may be accomplished as needed by the use of the random-number generators FRN(KRN) and FRNS(KRN), which are loaded as function subprograms into core with MCN. Each use of FRN(KRN) will give the next random number ξ ($0 < \xi < 1.0$, uniformly distributed) in the sequence. The use of FRNS(KRN) in a statement gives a random number on the range (−1.0,1.0) (in effect, FRNS(KRN) = 2.*FRN(KRN) − 1.). If more than one random number is required in a FORTRAN statement, a little finesse is called for because the compiler notices identical functions and then uses the function only once. For example, the expression

AMAX1(FRN(KRN), FRN(KRN)) will not do since it results in the same random number being used for both arguments of AMAX1. Some preliminary assignment statement such as RN = FRN(KRN) preceding AMAX1(RN,FRN(KRN)) is successful.

APPENDIX C

SAMPLE PROBLEM

In order to illustrate the steps in setting up a typical problem, as well as to portray some of the standard output features, consider the geometrical configuration of Fig. C-1. Figure C-2 shows how this problem might be zoned to prepare it for MCN.

We shall specify the various input and output functions and proceed to set up and make a sample run of the problem. (See Tables C-I through C-IV.) This problem is used merely to instruct and is not necessarily meant to represent a physical problem. In a practical problem, one might proceed differently and with more regard to the physics of the situation in zoning the problem, in specifying some of the input functions, and particularly in the choice of the output functions available to the user.

A. Source. The source, with energy distribution listed in Table C-I, is uniformly distributed in volume throughout cell 1 (Fig. C-2), and isotropic in direction. Because we are tallying mainly along the positive y direction, we decided to bias the directional distribution, sending three-fourths of the particles isotropically with positive v (v is the y-direction cosine) and one-fourth of the

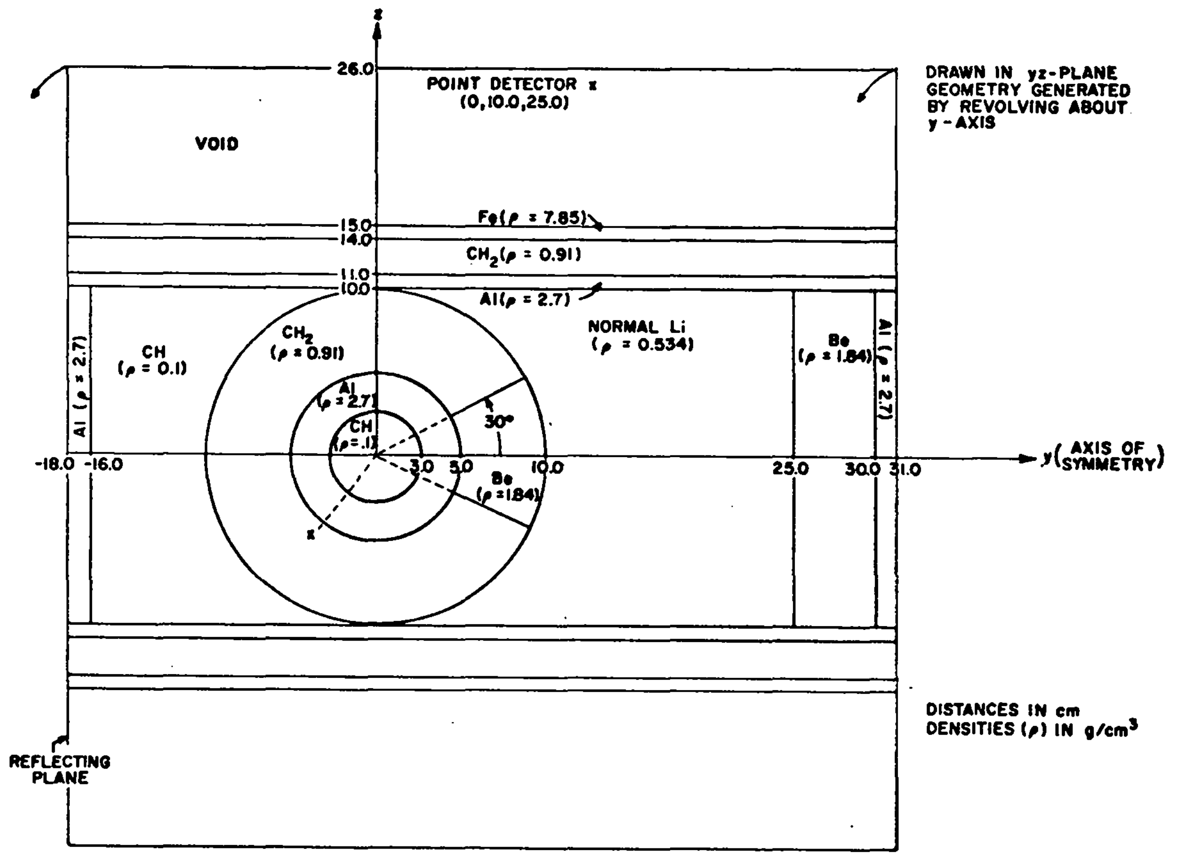

Fig. C-1.
Sample problem for the MCN code.

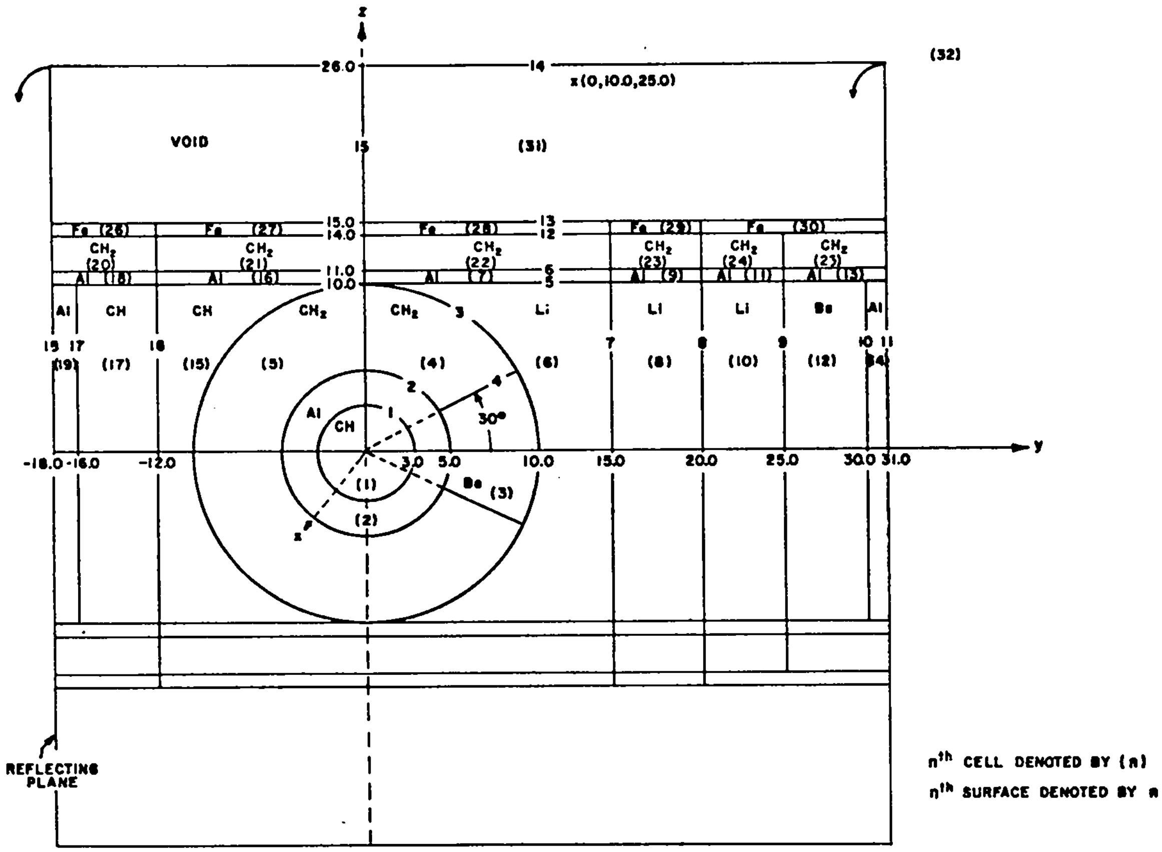

Fig. C-2.
Sample problem zoned for input to MCN.

TABLE C-I

SOURCE

Group	Energy (MeV)	Fractions in Group
1	0.0001	0
2	0.001	0.01
3	0.01	0.03
4	0.1	0.06
5	0.5	0.20
6	1.0	0.30
7	5.0	0.20
8	10.0	0.15
9	14.0	0.05

(The energy listed is the upper bound of the energy group.)

particles isotropically with negative v, correcting the weights of the source particles so that one-half of the weight has positive v and one-half has negative v.

If the problem has a time cutoff of 100 shakes, suppose we ask for the following information.

B. Currents. Tally currents across surfaces 10, 11, and 14 for

energies: 0-0.01, 0.01-1.0, 1.0-5.0, 5.0-14.0 (MeV)

times: 0-100 (shakes)

angles: 1.0-0.8, 0.8-0.6, 0.6-0.4, 0.4-0.2, 0.2-0 (values are for the cosine of the angle with the normal to the surface).

C. Flux Across Surfaces. Tally the flux across surface 17 for

energies: 0-0.01, 0.01-1.0, 1.0-5.0, 5.0-14.0 (MeV)

times: 0-20, 20-40, 40-60, 60-80, 80-100 (shakes).

D. Flux in a Cell. Tally the average flux in cell 3 for

energies: 0-0.1, 0.1-0.5, 0.5-1.0, 1.0-5.0, 5.0-14.0 (MeV)

times: 0-10, 10-20, 20-40, 40-100 (shakes).

E. **Flux at a Point.** Tally the flux at the point (0, 10, 25) for

energies: 0-0.01, 0.01-1.0, 1.0-5.0, 5.0-14.0 (MeV)

times: 0-20, 20-40, 40-100 (shakes).

F. **Capture in a Cell.** Tally the number of particles captured in cells 4 and 5 for

energies: 0-0.001, 0.001-0.1, 0.1-1.0, 1.0-14.0 (MeV)

times: 0-10, 10-20, 20-40, 40-100 (shakes).

TABLE C-II

CELL QUANTITIES

		Thermals (MeV)		
Cell	Importance	$t \leq 20$ shakes	$t = 40$ shakes	$t \leq 60$ shakes
1	1.0	0.00001	0.00005	0.0001
2	1.0	0	0	0
3	2.0	0	0	0
4	2.0	0.00001	0.00005	0.0001
5	1.0	0.00001	0.00005	0.0001
6	4.0	0	0	0
7	4.0	0	0	0
8	8.0	0	0	0
9	8.0	0	0	0
10	16.0	0	0	0
11	8.0	0	0	0
12	32.0	0	0	0
13	16.0	0	0	0
14	32.0	0	0	0
15	1.0	0.00001	0.00005	0.0001
16	1.0	0	0	0
17	1.0	0.00001	0.00005	0.0001
18	1.0	0	0	0
19	1.0	0	0	0
20	1.0	0.000001	0.00001	0.00001
21	1.0	0.000001	0.00001	0.00001
22	4.0	0.000001	0.00001	0.00001
23	4.0	0.000001	0.00001	0.00001
24	8.0	0.000001	0.00001	0.00001
25	8.0	0.000001	0.00001	0.00001
26	1.0	0	0	0
27	1.0	0	0	0
28	2.0	0	0	0
29	2.0	0	0	0
30	4.0	0	0	0
31	1.0	0	0	0
32	0	0	0	0

TABLE C-III

MATERIAL DENSITIES

Material	Atomic Density (atoms/cm^3)
Al	0.0603
Normal Li	0.0463
Be	0.123
CH	0.00926
CH_2	0.1173
Fe	0.0847

DO Card

Thermal energy cut-in = 10^{-3} MeV.
Energy cut-off = 0 MeV.
Maximum energy of problem = 14.0 MeV.
Time cut-off = 100 shakes.
Weight cut-off = 10^{-4}.

TABLE C-IV

SAMPLE RUN

```
              SUBROUTINE SOURCE
000001        COMMON MXA,MAJ,MXS,MXF,MXT,MXFM,MXLC,LC3,IFO,EBR,IXFM,LXS,LXSEC,EC
             A F,NSR,SRC(8),SPB(24),SWM(24),SEG(24),CDETX(10,3),RO(10),FRO(10),I
             B 11,I12,J11,J12,K11,K12,II1,LL1,IL1,IKL1,I21,I22,J21,J22,II2,I41,I
             C 42,J41,J42,II4,I51,I52,II5,J51,J52,I61,I62,J61,J62,II6,NDETX,LCD,
             D LCP,ID(8),LDF(6),RHO(90),FIO(90),UA(90),LCA(91),ML1(90),ML2(90),E
             E TM(90,5),TTM(5),VOL(90),LJA(450),LCAJ(450),LAJ(720),KST(80),LSC(8
             F 1),SCF(240),LCP(720),LFD(6),FME(100),LME(100),LPR(6),IJP(60),IFP(
             G 60),P(100),A(20),LFC(20),LFP(20),LLCM(20),LCMS(20),KRN,NRN,TWS,TE
             H S,NPS,NTR,NCT,THO,ETM(6),NTM(6),WTM(6),F(7500)
000001        COMMON/G1/SIG,DLS,PL,QPL,PMF,LV1,CSJA,CSA,IAP,KE,NCP,KDB,
             1 X,Y,Z,U,V,W,ERG,WT,TME,VL,DEL,IA,JA,NP,USQ,VSQ,WSQ,I4F,I1F,I2F,
             2 I5F
000001        COMMON/G2/IET(12),NET(12),DET(12),LET(12),CRT(12),THD(2),AMD(2),
             1 ITP(20),TP(20),D10(128),EFS(33)
000001        COMMON/G3/IS19,F241,F248,F243
000001        COMMON/DXCOM/NIP,IDETX,CSDX,CS,DDETX,DXFAC,AMFP,AMFP2,PBLSAV(13),
             1 LV2,LV3,LV4,LV5,LV6,LV7,PSC,DMUDA,AW,UOLD,VOLD,WOLD,
             2 XNU,D,W1,AK,UCAP,VCAP,WV,CTH,STH,CEP,SEP
          C
          C  UNIFORMLY DISTRIBUTED IN VOLUME IN SPECIFIED SPHERICAL CELL.
          C  STARTING DIRECTION ISOTROPIC, BUT BIASED IN POSITIVE V-DIRECTION.
          C  ENERGY DISTRIBUTION.
          C     S7 CARD REQUIRED IN PROBLEM DECK.
          C     SRC(1)=CELL NUMBER.
          C     SRC(2)=RADIUS OF CELL IN CM.
          C     SRC(3)=FRACTION OF NEUTRONS WHOSE STARTING DIRECTION HAS
          C            POSITIVE V.
          C
000001        DIMENSION ESRC(9),PESRC(9)
000001        DATA ESRC/.0001,.001,.01,.1,.5,1.0,5.0,10.0,14.0/
000001        DATA PESRC/0.,.01,.04,.10,.30,.60,.80,.95,1.0/
          C     DISTANCE FROM ORIGIN SAMPLED FROM THE INTERVAL (0,SRC(2))
          C     DISTRIBUTED ACCORDING TO THE DISTANCE CUBED.
000001        R=SRC(2)*(FRN(KRN))**.3333333333
          C     SAMPLE UNIFORMLY FROM POINTS INSIDE THE UNIT CIRCLE.
000010     10 TP(1)=FRNS(KRN)
000012        TP(2)=FRNS(KRN)
000014        TP(3)=TP(1)**2+TP(2)**2
000017        IF(TP(3).GT.1.) GO TO 10
          C     TP(3) DISTRIBUTED UNIFORMLY ON THE INTERVAL (0,1).  TP(4) IS
          C     THE COSINE OF THE POLAR ANGLE OF THE STARTING POINT.
000023        TP(4)=2.*TP(3)-1.
000024        TP(5)=R*SQRT((1.-TP(4)**2)/TP(3))
000033        X=R*TP(4)
000034        Y=TP(1)*TP(5)
000035        Z=TP(2)*TP(5)
000037        IF(FRN(KRN).GT.SRC(3)) GO TO 30
          C     SET V POSITIVE SRC(3) OF THE TIME.
000045        V=ABS(V)
000046        WT=0.5/SRC(3)
000050     15 IA=SRC(1)
000051        JA=1
000052        TME=0
000053        DEL=0
000054        R=FRN(KRN)
000057        DO 20 I=2,9
000060        IF(R.LT.PESRC(I)) GO TO 25
000063     20 CONTINUE
000064     25 ERG=ESRC(I-1)+(ESRC(I)-ESRC(I-1))*(R-PESRC(I-1))/
             1 (PESRC(I)-PESRC(I-1))
000073        RETURN
          C     SET V NEGATIVE 1-SRC(3) OF THE TIME.
000074     30 V=-ABS(V)
000076        WT=0.5/(1.-SRC(3))
000101        GO TO 15
000101        END
```

```
SUBPROGRAM LENGTH
000161

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
10      -  000011     15      -  000051     25      -  000065     30      -  000075

BLOCK NAMES AND LENGTHS
        -  027455     01      -  000041     02      -  000411     03      -  000004
DXCOM   -  000054

VARIABLE ASSIGNMENTS
A       -  010543C01 AHD     -  000076C03 CDETX   -  000137C01 CRT     -  000060C03
DEL     -  000026C02 DET     -  000030C03 D10     -  000150C03 EFS     -  000350C03
ERG     -  000022C02 ESRC    -  000135    ETH     -  001335C01 ETM     -  010717C01
F       -  010741C01 FIO     -  000432C01 FME     -  007071C01 FRO     -  000207C01
I       -  000160    IA      -  000027C02 ID      -  000262C01 IET     -  000000C03
IFP     -  010303C01 IJP     -  010207C01 ITP     -  000100C03 JA      -  000030C02
KRN     -  010707C01 KST     -  005522C01 LAJ     -  004202C01 LCA     -  000716C01
LCAJ    -  003300C01 LCB     -  006343C01 LCMS    -  010063C01 LDF     -  000272C01
LEC     -  010567C01 LET     -  000044C03 LFD     -  007063C01 LFP     -  010613C01
LJA     -  002376C01 LLCM    -  010637C01 LME     -  010035C01 LPR     -  010201C01
LSC     -  005642C01 ML1     -  001051C01 ML2     -  001203C01 NET     -  000014C03
NTM     -  010725C01 P       -  010377C01 PBLSAV  -  000010C05 PESRC   -  000146
QA      -  000564C01 R       -  000157    RHO     -  000300C01 R0      -  000175C01
SCF     -  005763C01 SEG     -  000107C01 SPB     -  000027C01 SRC     -  000017C01
SWM     -  000057C01 THD     -  000074C03 TME     -  000024C02 TP      -  000124C03
TTH     -  002237C01 V       -  000020C02 VOL     -  002244C01 WT      -  000023C02
WTH     -  010733C01 X       -  000014C02 Y       -  000015C02 Z       -  000016C02

EXTERNAL ASSIGNMENTS
FRN                  HBAREX               FRNS                 SQRT

START OF CONSTANTS
000103

START OF TEMPORARIES
000107

START OF INDIRECTS
000131

UNUSED COMPILER SPACE
104100




CORE MAP ************** DATE-  71/09/03**** TIME-  12.36.51************ NORMAL LOAD ****************************************************
                    FWA       LWA                  BLNK COM  LENGTH
                    -------   -------              -------   -------
         CODE       000100    147370               117714    027455
         LOADER     143566    147771
         TABLES     143565    141555

                                                   NAMED                         LCM
FILE     PROGRAM    ADDRESS                        COMMON    ADDRESS             BLOCK     ADDRESS
-------  -------    -------                        -------   -------             -------   -------
CODETP
         INU760L    011400                         INCOM     000100
         SNIP       107440                         INCOM     000100
SYSLIB
         ACGOER     110226
         BUFFEO     110240
         ECSRW      110322
         ENDFIL     110352
         IFENDF     110366
         INPUTB     110406
         INPUTC     110563
         INPUTS     110737
         IOCHEK     111025
         OUTPTC     111051
         OUTPTS     111207
         REWINM     111300
         SYSTEM     111333
         IBAIEX     112370
         RBAREX     112421
         BS4020     112500
         C4020      113260
         GETBA      113354
         IOUTIL     113410
         KODER      114701
         KRAKER     116106
         MEMORY     117147
         SKIPR      117327
         ALNLOG     117400
         EXP        117467
         BOI        117542
         LABRT      117606

         UNSATISFIED                   REFERENCED                                AT
         EXTERNALS                     BY                                        LOCATION
         -------    -------            -------             -------   -------     -------   -------   -------   -------   -------
```

SAMPLE PROBLEM

```
 1   45 .00926   -1,2
 2   43 .0603   1,1 -2,4,5,3
 3   44 .123   2,2 -4,4 -3,6
 4   46 .1173   2,2 4,3 15,5 -3,6
 5   46 .1173   2,2 -15,4 -3,15
 6   41 .0463   3,4,3 -5,7 -7,8
 7   43 .0603   5,6 15,16 -6,22 -7,9
 8   41 .0463   -5,9 7,6 -8,10
 9   43 .0603   5,8 7,7 -6,23 -8,11
10   41 .0463   -5,11 8,8 -9,12
11   43 .0603   5,10 8,9 -6,24 -9,13
12   44 .123   -5,13 9,10 -10,14
13   43 .0603   5,12,14 9,11 -6,25 -11,32
14   43 .0603   -5,13 10,12 -11,32
15   45 .00926   3,5 16,17 -5,16
16   43 .0603   5,15 16,18 -6,21 -15,7
17   45 .00926   -5,18 17,19 -16,15
18   43 .0603   5,17,19 18,32 -6,20 -16,16
19   43 .0603   -5,18 18,32 -17,17
20   46 .1173   6,18 18,32 -12,26 -16,21
21   46 .1173   6,16 16,20 -12,27 -15,22
22   46 .1173   6,7 15,21 -12,28 -7,23
23   46 .1173   6,9 7,22 -12,29 -8,24
24   46 .1173   6,11 8,23 -12,30 -9,25
25   46 .1173   6,13 9,24 -12,30 -11,32
26   42 .0847  12,20 18,32 -13,31 -16,27
27   42 .0847  12,21 16,26 -13,31 -15,28
28   42 .0847  12,22 15,27 -13,31 -7,29
29   42 .0847  12,23 7,28 -13,31 -8,30
30   42 .0847  12,24,25 8,29 -13,31 -11,32
31   0    13,26,27,28,29,30 18,32 -14,32 -11,32
32   0    14,31 -18,19,18,20,26,31 11,14,13,25,30,31

 1   SO 3.0
 2   SO 5.0
 3   SO 10.0
 4   KY 0 .3333333333
 5   CY 10.
 6   CY 11.
 7   PY 15.
 8   PY 20.
 9   PY 25.
10   PY 30.
11   PY 31.
12   CY 14.
13   CY 15.
14   CY 26.
15   PY 0
16   PY -12.
17   PY -16.
*18  PY -18.

D0   1.E-3 0 14.0
I0   1. 1. 2. 2. 1. 4. 4. 8. 8. 16. 8. 32. 16. 32. 1. 6R 4. 4. 8. 8.
     1. 1. 2. 2. 4. 1. 0
S7   1 3.0 .75
H0   20. 40. 60.
H1   10.E-6 0 0 10.E-6 1R 0 8R 10.E-6 0 10.E-6 0 0 1.E-6 5R 0 6R
H2   50.E-6 0 0 50.E-6 1R 0 8R 50.E-6 0 50.E-6 0 0 10.E-6 5R 0 6R
H3   .1E-3 0 0 .1E-3 1R 0 8R .1E-3 0 .1E-3 0 0 10.E-6 5R 0 6R
F1   10 11 14
E1   .01 1. 5. 14.
T1   100.
C1   .8 .6 .4 .2 0
F2   17
E2   .01 1. 5. 14.
T2   20. 40. 60. 80. 100.
F4   3
E4   .1 .5 1.0 5.0 14.0
T4   10. 20. 40. 100.
P4   245.52
F5   0 10. 25. 0
E5   .01 1.0 5.0 14.0
T5   20. 40. 100.
F6   4 5
E6   .001 .1 1.0 14.0
T6   10. 20. 40. 100.
M41  2215 .9244  2214 .0756
M42  2036 1.
M43  2035 1.
M44  2008 1.
M45  11 .5  3006 .5
M46  11 2.  3006 1.
```

32 CELLS

PROGR NAME	PROBL NAME	MATERIAL	DENSITY	IMPORTANCE	XSEC MULT
1	1	45	9.2600E-03	1.0000E+00	1.0000E+00
2	2	43	6.0300E-02	1.0000E+00	1.0000E+00
3	3	44	1.2300E-01	2.0000E+00	1.0000E+00
4	4	46	1.1730E-01	2.0000E+00	1.0000E+00
5	5	46	1.1730E-01	1.0000E+00	1.0000E+00
6	6	41	4.6300E-02	4.0000E+00	1.0000E+00
7	7	43	6.0300E-02	4.0000E+00	1.0000E+00
8	8	41	4.6300E-02	8.0000E+00	1.0000E+00
9	9	43	6.0300E-02	8.0000E+00	1.0000E+00
10	10	41	4.6300E-02	1.6000E+01	1.0000E+00
11	11	43	6.0300E-02	8.0000E+00	1.0000E+00
12	12	44	1.2300E-01	3.2000E+01	1.0000E+00
13	13	43	6.0300E-02	1.6000E+01	1.0000E+00
14	14	43	6.0300E-02	3.2000E+01	1.0000E+00
15	15	45	9.2600E-03	1.0000E+00	1.0000E+00
16	16	43	6.0300E-02	1.0000E+00	1.0000E+00
17	17	45	9.2600E-03	1.0000E+00	1.0000E+00
18	18	43	6.0300E-02	1.0000E+00	1.0000E+00
19	19	43	6.0300E-02	1.0000E+00	1.0000E+00
20	20	46	1.1730E-01	1.0000E+00	1.0000E+00
21	21	46	1.1730E-01	1.0000E+00	1.0000E+00
22	22	46	1.1730E-01	4.0000E+00	1.0000E+00
23	23	46	1.1730E-01	4.0000E+00	1.0000E+00
24	24	46	1.1730E-01	8.0000E+00	1.0000E+00
25	25	46	1.1730E-01	8.0000E+00	1.0000E+00
26	26	42	8.4700E-02	1.0000E+00	1.0000E+00
27	27	42	8.4700E-02	1.0000E+00	1.0000E+00
28	28	42	8.4700E-02	2.0000E+00	1.0000E+00
29	29	42	8.4700E-02	2.0000E+00	1.0000E+00
30	30	42	8.4700E-02	4.0000E+00	1.0000E+00
31	31	0	0.	1.0000E+00	1.0000E+00
32	32	0	0.	0.	1.0000E+00

18 SURFACES

PROGR NAME	PROBL NAME	
1	1	
2	2	
3	3	
4	4	
5	5	
6	6	
7	7	
8	8	
9	9	
10	10	
11	11	
12	12	
13	13	
14	14	
15	15	
16	16	
17	17	
18	18	REFLECTING

TALLY PARAMETERS

```
FORMULA 1 -- NEUTRONS CROSSING SURFACE
SURFACE      10    11    14
ENERGY     1.0000E-02  1.0000E+00  5.0000E+00  1.4000E+01
TIME       1.0000E+02
COSINE     8.0000E-01  6.0000E-01  4.0000E-01  2.0000E-01  0.

FORMULA 2 -- FLUX INTEGRATED OVER SURFACE
SURFACE      17
ENERGY     1.0000E-02  1.0000E+00  5.0000E+00  1.4000E+01
TIME       2.0000E+01  4.0000E+01  6.0000E+01  8.0000E+01  1.0000E+02

FORMULA 4 -- PATH LENGTH/VOLUME
CELL          3
ENERGY     1.0000E-01  5.0000E-01  1.0000E+00  5.0000E+00  1.4000E+01
TIME       1.0000E+01  2.0000E+01  4.0000E+01  1.0000E+02
VOLUME     2.4552E+02

FORMULA 5 -- FLUX AT DETECTOR
       DETECTOR       X              Y              Z           NEIGHBORHOOD
           1      0.             1.0000E+01     2.5000E+01      0.
ENERGY     1.0000E-02  1.0000E+00  5.0000E+00  1.4000E+01
TIME       2.0000E+01  4.0000E+01  1.0000E+02

FORMULA 6 -- CAPTURES
CELL          4     5
TIME       1.0000E+01  2.0000E+01  4.0000E+01  1.0000E+02
ENERGY     1.0000E-03  1.0000E-01  1.0000E+00  1.4000E+01
```

THERMAL LIMIT = 1.0000E-03

TIME(R0)	2.0000E+01	4.0000E+01	6.0000E+01
CELL	R1	R2	R3
1	1.0000E-05	5.0000E-05	1.0000E-04
2	0.	0.	0.
3	0.	0.	0.
4	1.0000E-05	5.0000E-05	1.0000E-04
5	1.0000E-05	5.0000E-05	1.0000E-04
6	0.	0.	0.
7	0.	0.	0.
8	0.	0.	0.
9	0.	0.	0.
10	0.	0.	0.
11	0.	0.	0.
12	0.	0.	0.
13	0.	0.	0.
14	0.	0.	0.
15	1.0000E-05	5.0000E-05	1.0000E-04
16	0.	0.	0.
17	1.0000E-05	5.0000E-05	1.0000E-04
18	0.	0.	0.
19	0.	0.	0.
20	1.0000E-06	1.0000E-05	1.0000E-05
21	1.0000E-06	1.0000E-05	1.0000E-05
22	1.0000E-06	1.0000E-05	1.0000E-05
23	1.0000E-06	1.0000E-05	1.0000E-05
24	1.0000E-06	1.0000E-05	1.0000E-05
25	1.0000E-06	1.0000E-05	1.0000E-05
26	0.	0.	0.
27	0.	0.	0.
28	0.	0.	0.
29	0.	0.	0.
30	0.	0.	0.
31	0.	0.	0.
32	0.	0.	0.

SOURCE=7

SRC(1)	SRC(2)	SRC(3)
1.0000E+00	3.0000E+00	7.5000E-01

MATERIAL NO.	COMPONENT NUCLIDE,FRACTION	
41	2215, .92440	2214, .07560
42	2036,1.00000	
43	2035,1.00000	
44	2008,1.00000	
45	11, .50000	3006, .50000
46	11, .66667	3006, .33333

XSEC STORAGE

NUCLIDE	FAST CORE	ECS
11	493	
2008	1193	
2035	3588	
2036	4684	
2214	2198	
2215	2036	
3006	1813	
TOTAL	16005	0

INITIATION COMPLETED

```
CORE MAP ************** DATE-  71/09/03**** TIME-  12.36.55************ NORMAL LOAD ****************************************************
                    FWA      LWA                  BLNK COM  LENGTH
                  -------  -------                -------   -------
         CODE     000100   146511                 117035    027465
         LOADER   143566   147771
         TABLES   143565   137644

                                                  NAMED                         LCM
FILE     PROGRAM  ADDRESS                         COMMON    ADDRESS             BLOCK    ADDRESS
-------  -------  -------                         -------   -------             -------  -------
RUNTP
         SOURCE   000632                          G1        000100
                                                  G2        000141
                                                  G3        000552
                                                  DXCOM     000556
         NU76EL   001013                          G1        000100              XSEC     0000000
                                                  G2        000141
                                                  G3        000552
                                                  DXCOM     000556
         DBPNT    105770                          G1        000100
                                                  G2        000141
                                                  G3        000552
                                                  DXCOM     000556

         FRN      106526
         FRNS     106536
         IRN      106547                          G1        000100
                                                  G2        000141
                                                  G3        000552
                                                  DXCOM     000556
         EX       106571
SYSLIB
         ACGOER   106613
         BACKSP   106625
         BUFFEI   106654
         BUFFEO   106775
         CLOCKF   107057
         ECSRW    107162
         ENDFIL   107212
         INPUTC   107226
         IOCHEK   107402
         LENGTH   107426
         OUTPTC   107446
         SSWTCH   107604
         SYSTEM   107672
         XIT      110727
         ALNLOG   111046
         EXP      111135
         IRAIEX   111210
         RRAIEX   111241
         RRAREX   111272
         SQRT     111351
         ABORT    111427
         BS4020   111475
         C4020    112255
         ENTR     112351
         GETBA    112405
         IOUTIL   112441
         KODER    113732
         KRAKER   115137
         LABRT    116200
         MEMORY   116306
         OUTPTS   116466
         PACKAGE  116557
         REMARK   116644
         RETN     116670
         SKIPR    116720
         BOI      116771

         UNSATISFIED                   REFERENCED                    AT
         EXTERNALS                     BY                          LOCATION
         -------  -------              -------   -------   -------   -------   -------   -------   -------   -------
         SRCDX                         NU76EL    002032
```

SOURCE NO.	TIME CUTOFF	WEIGHT CUTOFF	RUN TIME	PRINT CYCLE	DUMP CYCLE	DUMP NO.	CUTOFF CYCLE
7	1.0000E+02	1.0000E-04	2.0000E+00	25000	25000	0	0

SAMPLE PROBLEM

NPS	X	Y	Z	IA	JA	U	V	W	TME	WT	DEL	ERG
1	2.2875E+00	3.7276E-01	-1.9899E-01	1	1	4.6154E-01	8.1828E-01	3.4264E-01	0.	6.6667E-01	0.	4.1427E-01
2	-3.4934E-01	2.2248E+00	-1.3003E+00	1	1	1.2991E-01	8.5080E-01	5.0917E-01	0.	6.6667E-01	0.	3.9221E-03
3	-1.5399E+00	8.7280E-01	-1.7711E+00	1	1	9.9863E-01	4.2836E-03	5.2221E-02	0.	6.6667E-01	0.	4.6492E-01
4	-5.5782E-01	-5.5362E-01	-1.2246E+00	1	1	-2.4954E-01	-9.6408E-01	-9.1046E-02	0.	2.0000E+00	0.	3.2640E-01
5	2.0899E+00	-1.3313E+00	1.1058E+00	1	1	-2.8640E-01	-4.0338E-01	-8.6971E-01	0.	2.0000E+00	0.	8.8686E-01
6	-4.8075E-01	2.4031E+00	4.9533E-01	1	1	-1.4351E-01	8.9441E-01	4.2359E-01	0.	6.6667E-01	0.	3.6066E-02
7	-2.8690E-02	-2.8978E+00	3.2509E-01	1	1	4.3334E-01	4.2601E-01	7.9418E-01	0.	6.6667E-01	0.	4.4488E-01
8	-2.3599E+00	8.1552E-01	-2.0618E-01	1	1	-5.1389E-01	2.6413E-01	-8.1618E-01	0.	6.6667E-01	0.	5.0756E-01
9	-7.8826E-01	7.2759E-01	-1.3609E+00	1	1	-4.3904E-01	-5.5958E-01	-7.0293E-01	0.	2.0000E+00	0.	6.2863E-01
10	-5.6906E-01	-1.7042E+00	1.0086E+00	1	1	9.6330E-01	-8.6596E-02	-2.5408E-01	0.	2.0000E+00	0.	8.6029E+00
11	1.4449E+00	-8.5310E-01	1.9067E+00	1	1	-6.9409E-01	7.0580E-01	1.1456E-01	0.	6.6667E-01	0.	4.3666E-01
12	3.8711E-01	-2.4355E+00	4.5961E-01	1	1	-1.9277E-01	1.0331E-01	-9.7577E-01	0.	6.6667E-01	0.	4.6801E-01
13	5.9389E-01	-1.3941E+00	1.0809E+00	1	1	-1.2638E-01	9.9067E-01	-5.0927E-02	0.	6.6667E-01	0.	3.2590E-02
14	9.9378E-02	1.8267E+00	-2.2313E+00	1	1	2.4712E-01	5.6161E-01	-7.8964E-01	0.	6.6667E-01	0.	8.5996E+00
15	-9.7135E-01	-5.6979E-01	1.2924E+00	1	1	7.0821E-01	6.9596E-01	-1.1868E-01	0.	6.6667E-01	0.	5.5220E+00
16	2.1634E-03	2.1396E+00	-1.6622E+00	1	1	-8.7678E-01	-4.5836E-01	-1.4547E-01	0.	2.0000E+00	0.	5.1071E-01
17	-1.8245E-01	6.0690E-01	-3.9690E-01	1	1	3.2920E-01	7.6821E-01	-5.7603E-01	0.	6.6667E-01	0.	4.4350E+00
18	-1.3566E+00	-8.8102E-01	-1.6791E+00	1	1	-9.7366E-01	-1.9368E-01	-1.2029E-01	0.	2.0000E+00	0.	2.0795E-01
19	1.3070E+00	-8.6808E-01	-1.3519E+00	1	1	-2.1381E-01	7.7699E-01	5.9222E-01	0.	6.6667E-01	0.	3.9514E+00
20	-6.8013E-01	2.5107E+00	4.9102E-01	1	1	7.2790E-01	3.3221E-01	-5.9982E-01	0.	6.6667E-01	0.	5.4592E-01
21	1.6269E+00	6.4885E-01	6.2019E-01	1	1	5.8578E-01	3.6834E-01	7.2193E-01	0.	6.6667E-01	0.	4.5068E-01
22	-1.2850E+00	1.0997E+00	2.0181E-01	1	1	-3.3536E-01	9.0135E-01	2.7406E-01	0.	6.6667E-01	0.	4.2498E+00
23	2.2330E-01	6.6267E-01	-2.6249E+00	1	1	1.8537E-01	9.7322E-02	-9.7784E-01	0.	6.6667E-01	0.	8.4094E+00
24	3.6421E-01	8.0029E-01	2.3283E-02	1	1	5.6006E-01	-8.2533E-01	-7.1814E-02	0.	2.0000E+00	0.	2.1564E-01
25	4.7827E-01	-1.8177E-01	-1.5212E-02	1	1	8.4133E-01	-6.6226E-01	5.1805E-01	0.	2.0000E+00	0.	4.1021E+00
26	7.9092E-01	5.7678E-02	-2.2540E+00	1	1	1.3036E-01	8.6374E-01	-4.8678E-01	0.	6.6667E-01	0.	2.3748E-01
27	2.0890E+00	-1.0629E+00	3.9748E-01	1	1	-7.7141E-01	1.7266E-02	6.3611E-01	0.	6.6667E-01	0.	1.3147E+01
28	-5.4077E-01	2.0310E+00	-1.8320E+00	1	1	9.3935E-01	-2.7274E-01	-2.0793E-01	0.	2.0000E+00	0.	3.3621E+00
29	1.9451E+00	-1.1052E+00	-1.9958E+00	1	1	6.4870E-01	7.3332E-01	-2.0354E-01	0.	6.6667E-01	0.	5.1164E-01
30	-1.9997E+00	6.0213E-01	1.1191E+00	1	1	3.3062E-01	8.5745E-01	-3.9429E-01	0.	6.6667E-01	0.	7.2450E+00
31	-1.8903E+00	1.7629E+00	-7.6896E-01	1	1	-7.6126E-01	6.4730E-01	3.8468E-02	0.	6.6667E-01	0.	6.3500E-01
32	1.2888E+00	2.3045E+00	8.1228E-01	1	1	-3.9453E-02	4.2536E-01	9.0407E-01	0.	6.6667E-01	0.	3.4752E+00
33	-2.5861E+00	-4.0869E-01	1.1404E+00	1	1	7.4509E-01	1.4695E-01	-6.5057E-01	0.	6.6667E-01	0.	3.7969E+00
34	2.9403E+00	2.2854E-01	2.8432E-01	1	1	5.2729E-01	3.9210E-01	7.5381E-01	0.	6.6667E-01	0.	3.8789E-01
35	2.1085E+00	7.6814E-01	9.1031E-01	1	1	2.3474E-01	7.7185E-01	-5.9088E-01	0.	6.6667E-01	0.	2.0894E+00
36	-9.8557E-01	-2.2494E+00	-2.1974E-01	1	1	7.4294E-02	9.0561E-01	-4.1756E-01	0.	6.6667E-01	0.	9.7677E+00
37	1.4534E+00	-1.9551E-01	-1.3294E+00	1	1	3.1143E-01	-8.2457E-01	4.7232E-01	0.	2.0000E+00	0.	1.4266E+00
38	-3.3059E-01	8.6801E-01	1.3503E+00	1	1	-5.6701E-01	7.9390E-01	-2.1959E-01	0.	6.6667E-01	0.	4.5185E-01
39	-4.9836E-01	-5.4525E-01	3.0220E-01	1	1	-3.5528E-01	9.1969E-01	1.6719E-01	0.	6.6667E-01	0.	4.6485E-04
40	1.6339E+00	1.5459E-01	-1.9439E+00	1	1	-5.2150E-01	7.5448E-01	-3.9849E-01	0.	6.6667E-01	0.	3.3322E-02
41	2.9329E-01	-1.7105E+00	2.0440E+00	1	1	-4.6928E-01	3.2557E-01	8.2084E-01	0.	6.6667E-01	0.	1.8854E-01
42	2.1842E+00	1.2250E+00	-3.8593E-01	1	1	-7.7972E-01	-2.0058E-01	-5.9313E-01	0.	2.0000E+00	0.	2.4112E-01
43	-9.7102E-01	1.3630E+00	1.5189E+00	1	1	5.6039E-01	7.5631E-01	-3.3645E-01	0.	6.6667E-01	0.	3.9753E-01
44	-2.1979E+00	-5.4575E-01	-2.7525E-01	1	1	-7.3542E-02	6.0788E-02	-9.9544E-01	0.	6.6667E-01	0.	9.3307E-01
45	9.6083E-02	-1.3906E+00	-3.7713E-01	1	1	-5.8068E-01	8.1149E-01	-6.5552E-02	0.	6.6667E-01	0.	8.4003E+00
46	-1.9230E+00	-1.3618E+00	1.1713E+00	1	1	5.9286E-01	6.8791E-01	4.1869E-01	0.	6.6667E-01	0.	6.3536E-01
47	7.1900E-01	1.3139E+00	2.2804E+00	1	1	1.0077E-01	-9.3548E-01	3.3871E-01	0.	2.0000E+00	0.	6.1664E-01
48	8.9819E-01	5.6291E-01	1.2948E+00	1	1	1.2784E-01	4.2396E-01	8.9704E-01	0.	6.6667E-01	0.	8.1788E+00
49	5.4211E-01	-1.4588E-01	4.3039E-01	1	1	-9.5503E-01	2.0018E-01	2.1874E-01	0.	6.6667E-01	0.	8.8901E+00
50	2.0962E+00	-1.7114E+00	2.3410E-01	1	1	6.0707E-01	-4.1430E-01	-6.7828E-01	0.	2.0000E+00	0.	2.7384E+00

SAMPLE PROBLEM

SOURCE NO.	TIME CUTOFF	WEIGHT CUTOFF	RUN TIME	PRINT CYCLE	DUMP CYCLE	DUMP NO.	CUTOFF CYCLE
7	1.0000E+02	1.0000E-04	2.0000E+00	25000	25000	1	0

TIME= 1.780 MINUTES

NUMBER OF NEUTRONS STARTED	TOTAL NUMBER OF COLLISIONS	RANDOM NUMBERS GENERATED	TOTAL WEIGHT STARTED	TOTAL ENERGY STARTED	COLLISIONS PER NEUTRON STARTED	TRACKS PER NEUTRON STARTED	NEUTRONS PROCESSED PER MINUTE
2793	128717	1307597	2.8207E+03	7.2182E+03	4.6086E+01	4.4726E+00	1.5691E+03

TOTAL TRACKS STARTED	LOSS TO ENERGY CUTOFF	LOSS TO TIME CUTOFF	LOSS TO WEIGHT CUTOFF	LOSS TO ESCAPE	LOSS TO SPLITTING	TOTAL TRACKS LOST
12492	0	4810	22	1396	6264	12492

WEIGHT STARTED PER NEUTRON	LOSS TO ENERGY CUTOFF	LOSS TO TIME CUTOFF	LOSS TO WEIGHT CUTOFF	LOSS TO ESCAPE	LOSS TO CAPTURE	WEIGHT LOST PER NEUTRON
1.0099E+00	0.	7.3707E-01	3.1035E-07	2.3237E-01	3.6311E-02	1.0058E+00

ENERGY STARTED PER NEUTRON	LOSS TO ENERGY CUTOFF	LOSS TO TIME CUTOFF	LOSS TO WEIGHT CUTOFF	LOSS TO ESCAPE	LOSS TO CAPTURE
2.5844E+00	0.	8.0210E-05	4.6648E-11	7.4265E-01	7.0052E-02

NUMBER OF NEUTRONS CROSSING SURFACE

TIME 0. 1.0000E+02

COSINE 1.0000E+00 8.0000E-01

ENERGY	SURFACE 10 - TO +	REL. ERROR	SURFACE 10 + TO -	REL. ERROR	SURFACE 11 - TO +	REL. ERROR	SURFACE 11 + TO -	REL. ERROR
1.0000E-02	6.69820E-04	.18409	3.27533E-05	.71438	1.72269E-03	.42585	0.	0.00000
1.0000E+00	1.25645E-03	.12061	7.63787E-05	.30240	2.62339E-03	.30918	0.	0.00000
5.0000E+00	6.54225E-04	.19068	1.38381E-05	.70686	3.02173E-03	.33410	0.	0.00000
1.4000E+01	4.98177E-04	.23834	6.68108E-06	.99982	2.99431E-03	.31288	0.	0.00000

ENERGY	SURFACE 14 - TO +	REL. ERROR	SURFACE 14 + TO -	REL. ERROR
1.0000E-02	1.24086E-02	.19691	0.	0.00000
1.0000E+00	4.94601E-02	.10040	0.	0.00000
5.0000E+00	5.45745E-02	.09721	0.	0.00000
1.4000E+01	4.34732E-02	.10830	0.	0.00000

COSINE 8.0000E-01 6.0000E-01

ENERGY	SURFACE 10 - TO +	REL. ERROR	SURFACE 10 + TO -	REL. ERROR	SURFACE 11 - TO +	REL. ERROR	SURFACE 11 + TO -	REL. ERROR
1.0000E-02	3.80538E-04	.22042	2.67729E-05	.84872	1.22452E-03	.52976	0.	0.00000
1.0000E+00	7.00349E-04	.12079	7.90985E-05	.30159	1.06734E-03	.25284	0.	0.00000
5.0000E+00	2.51368E-04	.19941	2.08333E-05	.73484	5.92660E-04	.42754	0.	0.00000
1.4000E+01	9.47498E-05	.57439	0.	0.00000	3.76968E-04	.65737	0.	0.00000

ENERGY	SURFACE 14 - TO +	REL. ERROR	SURFACE 14 + TO -	REL. ERROR
1.0000E-02	3.30248E-03	.40561	0.	0.00000
1.0000E+00	1.78842E-02	.16830	0.	0.00000
5.0000E+00	1.15148E-02	.20786	0.	0.00000
1.4000E+01	9.80627E-03	.22065	0.	0.00000

COSINE 6.0000E-01 4.0000E-01

ENERGY	SURFACE 10 - TO +	REL. ERROR	SURFACE 10 + TO -	REL. ERROR	SURFACE 11 - TO +	REL. ERROR	SURFACE 11 + TO -	REL. ERROR
1.0000E-02	2.57973E-04	.22068	3.05795E-05	.70348	4.02655E-04	.30466	0.	0.00000
1.0000E+00	3.74940E-04	.16514	8.54080E-05	.28883	8.16618E-04	.33862	0.	0.00000
5.0000E+00	1.86195E-04	.22525	2.10906E-05	.57751	1.96259E-04	.23606	0.	0.00000
1.4000E+01	4.29439E-05	.40801	6.56115E-06	.99982	4.24415E-05	.40799	0.	0.00000

ENERGY	SURFACE 14 - TO +	REL. ERROR	SURFACE 14 + TO -	REL. ERROR
1.0000E-02	1.83370E-03	.55791	0.	0.00000
1.0000E+00	6.20317E-03	.26837	0.	0.00000
5.0000E+00	1.61069E-03	.37789	0.	0.00000
1.4000E+01	3.03598E-03	.46744	0.	0.00000

COSINE 4.0000E-01 2.0000E-01

ENERGY	SURFACE 10 - TO +	REL. ERROR	SURFACE 10 + TO -	REL. ERROR	SURFACE 11 - TO +	REL. ERROR	SURFACE 11 + TO -	REL. ERROR
1.0000E-02	9.50925E-05	.40174	2.17466E-05	.57715	9.64017E-05	.41393	0.	0.00000
1.0000E+00	2.19409E-04	.23749	4.16984E-05	.41116	1.52330E-04	.28282	0.	0.00000
5.0000E+00	3.50142E-05	.44728	1.94136E-05	.57751	4.26305E-05	.40828	0.	0.00000
1.4000E+01	6.70070E-06	.99982	0.	0.00000	6.70070E-06	.99982	0.	0.00000

ENERGY	SURFACE 14 - TO +	REL. ERROR	SURFACE 14 + TO -	REL. ERROR
1.0000E-02	2.11043E-04	.99482	0.	0.00000
1.0000E+00	7.15018E-04	.99482	0.	0.00000
5.0000E+00	4.73438E-04	.70687	0.	0.00000
1.4000E+01	0.	0.00000	0.	0.00000

COSINE 2.0000E-01 0.

ENERGY	SURFACE 10 - TO +	REL. ERROR	SURFACE 10 + TO -	REL. ERROR	SURFACE 11 - TO +	REL. ERROR	SURFACE 11 + TO -	REL. ERROR
1.0000E-02	4.78831E-05	.49144	5.03677E-05	.67026	1.49279E-04	.63694	0.	0.00000
1.0000E+00	6.74310E-05	.32211	3.91817E-05	.63067	9.35919E-05	.40613	0.	0.00000
5.0000E+00	1.98602E-05	.57826	7.35917E-06	.99982	2.09817E-05	.57803	0.	0.00000
1.4000E+01	0.	0.00000	0.	0.00000	0.	0.00000	0.	0.00000

ENERGY	SURFACE 14 - TO +	REL. ERROR	SURFACE 14 + TO -	REL. ERROR
1.0000E-02	0.	0.00000	0.	0.00000
1.0000E+00	0.	0.00000	0.	0.00000
5.0000E+00	0.	0.00000	0.	0.00000
1.4000E+01	0.	0.00000	0.	0.00000

FLUX INTEGRATED OVER SURFACE

TIME 0. 2.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	1.67786E-02	.39955
1.0000E+00	6.54114E-02	.19609
5.0000E+00	1.57087E-02	.25210
1.4000E+01	1.36602E-02	.33819

TIME 2.0000E+01 4.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	6.40735E-03	.53957
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 4.0000E+01 6.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	2.40599E-04	.99992
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 6.0000E+01 8.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	9.76102E-04	.79258
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 8.0000E+01 1.0000E+02

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	1.09047E-03	.99982
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

PATH LENGTH/VOLUME

TIME 0. 1.0000E+01

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	6.82189E-04	.09909
5.0000E-01	7.00233E-04	.09114
1.0000E+00	3.82315E-04	.10993
5.0000E+00	3.53245E-04	.11597
1.4000E+01	2.16739E-04	.14486

TIME 1.0000E+01 2.0000E+01

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	1.53327E-04	.15191
5.0000E-01	0.	0.00000
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 2.0000E+01 4.0000E+01

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	1.48971E-04	.15458
5.0000E-01	0.	0.00000
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 4.0000E+01 1.0000E+02

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	4.01699E-04	.11924
5.0000E-01	0.	0.00000
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

CAPTURES

ENERGY 0. 1.0000E-03

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	7.74362E-05	.04317	9.15080E-05	.06389
2.0000E+01	1.25505E-04	.03909	1.43805E-04	.05488
4.0000E+01	2.50217E-04	.03549	2.87100E-04	.05172
1.0000E+02	6.10619E-04	.03401	7.21740E-04	.04661

ENERGY 1.0000E-03 1.0000E-01

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	4.51243E-05	.03074	5.31591E-05	.04237
2.0000E+01	2.57366E-06	.15294	2.26343E-06	.17365
4.0000E+01	9.72153E-08	.39414	5.05435E-07	.36423
1.0000E+02	4.48714E-08	.65227	0.	0.00000

ENERGY 1.0000E-01 1.0000E+00

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	3.97684E-05	.03068	4.43384E-05	.04616
2.0000E+01	0.	0.00000	0.	0.00000
4.0000E+01	0.	0.00000	0.	0.00000
1.0000E+02	0.	0.00000	0.	0.00000

ENERGY 1.0000E+00 1.4000E+01

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	1.73172E-04	.17808	2.53899E-04	.38486
2.0000E+01	0.	0.00000	0.	0.00000
4.0000E+01	0.	0.00000	0.	0.00000
1.0000E+02	0.	0.00000	0.	0.00000

FLUX AT DETECTOR

TIME 0. 2.0000E+01

ENERGY	DETECTOR 1	RELATIVE ERROR
1.0000E-02	5.21422E-07	.33477
1.0000E+00	1.14067E-05	.09099
5.0000E+00	8.87375E-06	.07868
1.4000E+01	7.01082E-06	.11768

TIME 2.0000E+01 4.0000E+01

ENERGY	DETECTOR 1	RELATIVE ERROR
1.0000E-02	1.16377E-06	.24219
1.0000E+00	5.94624E-08	.84533
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 4.0000E+01 1.0000E+02

ENERGY	DETECTOR 1	RELATIVE ERROR
1.0000E-02	5.36296E-06	.14431
1.0000E+00	7.28614E-12	.67615
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TAPE DUMP NO. 2 NPS = 2793

```
THE FOLLOWING IS A COPY OF DAYFILE   JOF1AH    UP TO TIME  12.38.44

12.35.53 SHMTR  00  CHOS 1.35 71/04/01  MACH. 14
                          TAPE SV760006
12.35.53 SUMTR      .USER MONITOR OF 70/10/16 INITIALIZED.
12.35.53 SUMTR      .JOB NAME=TURNHH21AH,DATE =      71/04/03
12.35.53 SUMTR      .FILE SET CCU      OPENED,BUFFER LENGTH =00001100.
12.35.53 SUMTR      .FILE SET INP      OPENED,BUFFER LENGTH =00010100.
12.35.53 SUMTR      .FILE SET JOBIN    OPENED,BUFFER LENGTH =00032100.
12.35.53 SUMTR      .FILE SET JOBIN    CLOSED,BUFFER LENGTH =00032100.
12.35.53            .FILE SET STATISTICS
12.35.53            . READS     WRITES  POSITIONS  DISK RDS  DISK WRS
12.35.53             000000263 000000000 000000000 000000001 000000000
12.35.53            .      LWA=0000001433,DEVICE=03
12.35.53 *CCP       $JOB'NAME=TURNHH21,CL=U,CAT=05,AC=V06,USF=MCNSAMP,
                    PL=50,TL=3M)
12.35.53 *CCP       $. COMPILE SOURCE, INITIATE, AND RUN PROBLEM.
12.35.53 *CCP       $CREATE(FS=CODETP,CL=U,PREMT=XX003023)
12.35.54 *CCP       $RUN,C=SX,R=RUNTP)      COMPILE SOURCE
12.35.54 SUMTR      .FILE SET RUNTP    OPENED,BUFFER LENGTH =00032100.
12.35.54 SUMTR      .FILE SET OUT      OPENED,BUFFER LENGTH =00032100.
12.35.54 SRUN       .FIELD LENGTH IS -  043676
12.35.54 SRUN       .RUN-RUN  CTIME 000.270 SEC.
12.35.54 *CCP       $COPYF(I=CODETP,O=RUNTP)
12.35.55 SUMTR      .FILE SET CODETP  OPENED,BUFFER LENGTH =00032100.
12.35.55 SHMTR       ROLLOUT STARTED
12.35.56 SHMTR       ROLLOUT DONE
12.36.23 *LOS       AX003A23  MOUNTED ON UNIT 3 FILE  CODETP
12.36.49 SBMTR       ROLLIN STARTED
12.36.49 SHMTR       ROLLIN DONE
12.36.50 *CCP       $SETQ(KEY=KKTP)
12.36.50 *CCP       $SETQ.
12.36.50 *CCP       $LDGO(I=CODETP)      INITIATE
12.36.53  INU76DL   .END
12.36.53 SUMTR      .FILE SET IMAGE    OPENED,BUFFER LENGTH =00064100.
12.36.53 SUMTR      .FILE SET IMAGE    CLOSED,BUFFER LENGTH =00064100.
12.36.53            .FILE SET STATISTICS
12.36.53            . READS     WRITES  POSITIONS  DISK RDS  DISK WRS
12.36.53             000000000 000000003 000000001 000000000 000000004
12.36.53            .      LWA=0000147715,DEVICE=03
12.36.54 *CCP       $IF(FALSE=RUN)
12.36.54 *CCP       $LABEL(RUN)
12.36.54 *CCP       $SETQ(KEY=KKTP)
12.36.54 *CCP       $SETQ.
12.36.54 *CCP       $LDGO(I=RUNTP)     RUN PROBLEM
12.38.42  NU76EL    .END
12.38.42 SUMTR      .FILE SET IMAGE    OPENED,BUFFER LENGTH =00064100.
12.38.42 SUMTR      .FILE SET IMAGE    CLOSED,BUFFER LENGTH =00064100.
12.38.42            .FILE SET STATISTICS
12.38.42            . READS     WRITES  POSITIONS  DISK RDS  DISK WRS
12.38.42             000000000 000000003 000000001 000000001 000000004
12.38.42            .      LWA=0000147715,DEVICE=03
12.38.43 *CCP       $IF(FALSE=TAPE)
12.38.43 *CCP       $LABEL(TAPE)
12.38.43 *CCP       $AFSHEL(FS=RUNTP,ADISP=TAPE)
12.38.43 SUMTR      .FILE SET RUNTP    CLOSED,BUFFER LENGTH =00032100.
12.38.43            .FILE SET STATISTICS
12.38.43            . READS     WRITES  POSITIONS  DISK RDS  DISK WRS
12.38.43             000000032 000000033 000000003 000000006 000000010
12.38.43            .      LWA=0000125156,DEVICE=03
12.38.43 *CCP       $COPYDF.
12.38.44  FLUSHDF   .DAYFILE FLUSHED TO DISK -  T=  12.38.44
```

```
CORE MAP ************** DATE-  71/10/01**** TIME-  16.23.50************ NORMAL LOAD ***********************************************************
                  FWA       LWA                    BLNK COM  LENGTH
                -------   -------                  -------   -------
         CODE     000100    146511                  117035    027455
         LOADER   143566    147771
         TABLES   143565    137644

                                                   NAMED                             LCM
FILE     PROGRAM  ADDRESS                          COMMON    ADDRESS                 BLOCK     ADDRESS
-------  -------  -------                          -------   -------                 -------   -------
RUNTP
         SOURCE   000632                           G1        000100
                                                   G2        000141
                                                   G3        000552
                                                   DXCOM     000556
         NU76EL   001013                           G1        000100                  XSEC      0000000
                                                   G2        000141
                                                   G3        000552
                                                   DXCOM     000556
         DRPNT    105770                           G1        000100
                                                   G2        000141
                                                   G3        000552
                                                   DXCOM     000556
         FRN      106526
         FRNS     106536
         IRN      106547                           G1        000100
                                                   G2        000141
                                                   G3        000552
                                                   DXCOM     000556
         EX       106571
SYSLIB
         ACGOER   106613
         BACKSP   106625
         BUFFEI   106654
         BUFFEO   106775
         CLOCKF   107057
         ECSRW    107162
         ENDFIL   107212
         INPUTC   107226
         IOCHEK   107402
         LENGTH   107426
         OUTPTC   107446
         SSWTCH   107604
         SYSTEM   107672
         XIT      110727
         ALNLOG   111046
         EXP      111135
         IRAIEX   111210
         RRAIEX   111241
         RRAREX   111272
         SQRT     111351
         ABORT    111427
         BS4020   111475
         C4020    112255
         ENTR     112351
         GETBA    112405
         IOUTIL   112441
         KODER    113732
         KRAKER   115137
         LABRT    116200
         MEMORY   116306
         OUTPTS   116466
         PACKAGE  116557
         REMARK   116644
         RETN     116670
         SKIPR    116720
         BOI      116771

         UNSATISFIED                   REFERENCED                                     AT
         EXTERNALS                     BY                                          LOCATION
         -------  -------              -------              -------   -------   -------   -------   -------   -------   -------
         SRCDX                         NU76EL               002032

SOURCE NO.    TIME CUTOFF    WEIGHT CUTOFF   RUN TIME     PRINT CYCLE     DUMP CYCLE       DUMP NO.    CUTOFF CYCLE
    7         1.0000E+02     1.0000E-04      1.0000E+01     25000           25000             0              0
                          SAMPLE PROBLEM

SOURCE NO.    TIME CUTOFF    WEIGHT CUTOFF   RUN TIME     PRINT CYCLE     DUMP CYCLE       DUMP NO.    CUTOFF CYCLE
    7         1.0000E+02     1.0000E-04      1.0000E+01     25000           25000             2              0
                                         TIME= 11.568 MINUTES

   NUMBER OF     TOTAL         RANDOM        TOTAL         TOTAL         COLLISIONS    TRACKS        NEUTRONS
   NEUTRONS      NUMBER OF     NUMBERS       WEIGHT        ENERGY        PER NEUTRON   PER NEUTRON   PROCESSED
   STARTED       COLLISIONS    GENERATED     STARTED       STARTED       STARTED       STARTED       PER MINUTE
     18032         835948        8454601     1.8091E+04    4.7063E+04    4.6359E+01    4.5791E+00    1.5588E+03

   TOTAL         LOSS TO       LOSS TO       LOSS TO       LOSS          LOSS          TOTAL
   TRACKS        ENERGY        TIME          WEIGHT        TO            TO            TRACKS
   STARTED       CUTOFF        CUTOFF        CUTOFF        ESCAPE        SPLITTING     LOST
     82570             0         30930           146          9707         41787         82570

   WEIGHT        LOSS TO       LOSS TO       LOSS TO       LOSS          LOSS          WEIGHT
   STARTED       ENERGY        TIME          WEIGHT        TO            TO            LOST
   PER NEUTRON   CUTOFF        CUTOFF        CUTOFF        ESCAPE        CAPTURE       PER NEUTRON
   1.0033E+00    0.            7.3959E-01    3.8864E-07    2.3581E-01    3.6986E-02    1.0124E+00

   ENERGY        LOSS TO       LOSS TO       LOSS TO       LOSS          LOSS
   STARTED       ENERGY        TIME          WEIGHT        TO            TO
   PER NEUTRON   CUTOFF        CUTOFF        CUTOFF        ESCAPE        CAPTURE
   2.6100E+00    0.            7.8911E-05    5.2616E-11    7.2201E-01    6.1252E-02
```

NUMBER OF NEUTRONS CROSSING SURFACE

TIME 0. 1.0000E+02

COSINE 1.0000E+00 8.0000E-01

	SURFACE 10				SURFACE 11			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	6.23620E-04	.06268	1.59834E-05	.31399	1.11928E-03	.12528	0.	0.00000
1.0000E+00	1.26138E-03	.04664	9.02739E-05	.12810	2.62188E-03	.10814	0.	0.00000
5.0000E+00	8.79751E-04	.06758	2.70424E-05	.26311	2.76856E-03	.11858	0.	0.00000
1.4000E+01	6.70223E-04	.10738	2.12789E-06	.70733	2.50866E-03	.10445	0.	0.00000

	SURFACE 14			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	1.47218E-02	.06970	0.	0.00000
1.0000E+00	5.22683E-02	.03784	0.	0.00000
5.0000E+00	5.34190E-02	.03757	0.	0.00000
1.4000E+01	4.23949E-02	.04338	0.	0.00000

COSINE 8.0000E-01 6.0000E-01

	SURFACE 10				SURFACE 11			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	4.35537E-04	.07289	2.13228E-05	.26110	7.54242E-04	.14632	0.	0.00000
1.0000E+00	6.98704E-04	.05396	1.01401E-04	.12896	1.60258E-03	.13628	0.	0.00000
5.0000E+00	3.40562E-04	.07708	1.60002E-05	.27449	1.11526E-03	.16463	0.	0.00000
1.4000E+01	1.19302E-04	.14160	0.	0.00000	7.55346E-04	.19146	0.	0.00000

	SURFACE 14			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	3.94562E-03	.13960	0.	0.00000
1.0000E+00	1.60816E-02	.07066	0.	0.00000
5.0000E+00	1.47008E-02	.07322	0.	0.00000
1.4000E+01	9.38131E-03	.08990	0.	0.00000

COSINE 6.0000E-01 4.0000E-01

	SURFACE 10				SURFACE 11			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	2.77945E-04	.08755	1.48791E-05	.31907	4.47369E-04	.15315	0.	0.00000
1.0000E+00	4.51004E-04	.06605	9.67136E-05	.13529	6.11854E-04	.12390	0.	0.00000
5.0000E+00	1.40216E-04	.10259	1.98193E-05	.23009	4.97057E-04	.19785	0.	0.00000
1.4000E+01	4.59624E-05	.20223	4.18363E-06	.50010	1.34757E-04	.40370	0.	0.00000

	SURFACE 14			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	1.15566E-03	.23351	0.	0.00000
1.0000E+00	3.95581E-03	.12923	0.	0.00000
5.0000E+00	3.21382E-03	.15769	0.	0.00000
1.4000E+01	2.27965E-03	.20650	0.	0.00000

COSINE 4.0000E-01 2.0000E-01

	SURFACE 10				SURFACE 11			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	1.17619E-04	.11828	1.44101E-05	.27626	1.75729E-04	.20051	0.	0.00000
1.0000E+00	2.49680E-04	.08524	7.21624E-05	.16084	2.78253E-04	.20408	0.	0.00000
5.0000E+00	6.93535E-05	.14301	1.85559E-05	.24844	9.46678E-05	.18700	0.	0.00000
1.4000E+01	9.80163E-06	.43360	5.30213E-06	.44796	4.36955E-05	.80279	0.	0.00000

	SURFACE 14			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	3.26888E-05	.99997	0.	0.00000
1.0000E+00	1.31375E-03	.24521	0.	0.00000
5.0000E+00	5.12017E-04	.36596	0.	0.00000
1.4000E+01	2.13511E-04	.70715	0.	0.00000

COSINE 2.0000E-01 0.

	SURFACE 10				SURFACE 11			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	4.33162E-05	.18856	2.37352E-05	.32858	1.76038E-04	.63524	0.	0.00000
1.0000E+00	7.33807E-05	.13421	4.11331E-05	.23207	1.16432E-04	.33807	0.	0.00000
5.0000E+00	1.86768E-05	.25740	8.46748E-06	.35446	3.02462E-05	.28445	0.	0.00000
1.4000E+01	8.97717E-06	.47046	0.	0.00000	4.78868E-05	.76560	0.	0.00000

	SURFACE 14			
ENERGY	- TO +	REL. ERROR	+ TO -	REL. ERROR
1.0000E-02	0.	0.00000	0.	0.00000
1.0000E+00	0.	0.00000	0.	0.00000
5.0000E+00	1.08334E-04	.99997	0.	0.00000
1.4000E+01	0.	0.00000	0.	0.00000

FLUX INTEGRATED OVER SURFACE

TIME 0. 2.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	8.39392E-03	.21229
1.0000E+00	5.26228E-02	.08590
5.0000E+00	2.69979E-02	.10444
1.4000E+01	1.46145E-02	.11777

TIME 2.0000E+01 4.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	1.00435E-02	.26045
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 4.0000E+01 6.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	4.77182E-03	.18832
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 6.0000E+01 8.0000E+01

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	5.23446E-03	.43527
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 8.0000E+01 1.0000E+02

ENERGY	SURFACE 17	RELATIVE ERROR
1.0000E-02	3.83569E-03	.20722
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

PATH LENGTH/VOLUME

TIME 0. 1.0000E+01

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	5.92883E-04	.03818
5.0000E-01	6.71835E-04	.03544
1.0000E+00	3.79171E-04	.04026
5.0000E+00	4.12319E-04	.04402
1.4000E+01	2.20469E-04	.05611

TIME 1.0000E+01 2.0000E+01

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	1.55371E-04	.05980
5.0000E-01	0.	0.00000
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 2.0000E+01 4.0000E+01

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	1.52753E-04	.06584
5.0000E-01	0.	0.00000
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 4.0000E+01 1.0000E+02

ENERGY	CELL 3	RELATIVE ERROR
1.0000E-01	3.94229E-04	.04663
5.0000E-01	0.	0.00000
1.0000E+00	0.	0.00000
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

CAPTURES

ENERGY 0. 1.0000E-03

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	7.78926E-05	.01594	8.99111E-05	.02459
2.0000E+01	1.24729E-04	.01534	1.41480E-04	.02244
4.0000E+01	2.42261E-04	.01443	2.78034E-04	.02048
1.0000E+02	5.98450E-04	.01413	7.14885E-04	.01854

ENERGY 1.0000E-03 1.0000E-01

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	4.62964E-05	.01185	5.10686E-05	.01735
2.0000E+01	2.05025E-06	.05479	2.09608E-06	.07094
4.0000E+01	2.87924E-07	.14534	3.59986E-07	.15673
1.0000E+02	3.33184E-08	.25337	3.53650E-08	.42423

ENERGY 1.0000E-01 1.0000E+00

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	3.93536E-05	.01196	4.36357E-05	.01847
2.0000E+01	0.	0.00000	0.	0.00000
4.0000E+01	0.	0.00000	0.	0.00000
1.0000E+02	0.	0.00000	0.	0.00000

ENERGY 1.0000E+00 1.4000E+01

TIME	CELL 4	RELATIVE ERROR	CELL 5	RELATIVE ERROR
1.0000E+01	2.15552E-04	.06206	2.15322E-04	.12435
2.0000E+01	0.	0.00000	0.	0.00000
4.0000E+01	0.	0.00000	0.	0.00000
1.0000E+02	0.	0.00000	0.	0.00000

FLUX AT DETECTOR

TIME 0. 2.0000E+01

ENERGY	DETECTOR 1	RELATIVE ERROR
1.0000E-02	5.42880E-07	.13333
1.0000E+00	1.19437E-05	.04162
5.0000E+00	1.10982E-05	.04251
1.4000E+01	7.89015E-06	.05347

TIME 2.0000E+01 4.0000E+01

ENERGY	DETECTOR 1	RELATIVE ERROR
1.0000E-02	1.60610E-06	.10494
1.0000E+00	4.77370E-08	.43866
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

TIME 4.0000E+01 1.0000E+02

ENERGY	DETECTOR 1	RELATIVE ERROR
1.0000E-02	6.37449E-06	.06239
1.0000E+00	1.92792E-11	.42870
5.0000E+00	0.	0.00000
1.4000E+01	0.	0.00000

****

TAPE DUMP NO. 3 NPS = 18032

```
THE FOLLOWING IS A COPY OF DAYFILE   JUF1FE    UP TO TIME  16.35.44

15.43.48 $RMTR  00  CHOS 1.36 71/09/27  MACH. 14
                         TAPE SY760032
15.43.48 $UMTR      .USER MONITOR OF 70/10/16 INITIALIZED.
15.43.48 $UMTR      .JOB NAME=TURNRM21FE,DATE =      71/10/01
15.43.48 *CCP       $JOB(NAME=TURNRM21,CL=U,CAT=05,AC=V06,USF=MCNSAMP,
                    PL=50,TL=10M)
15.43.48  FLUSHDF   .DAYFILE FLUSHED TO DISK -  T=  15.43.48
15.43.48  REMARK    .DAYFILE COPIED TO FILESET    SYSTAT
15.43.48 $UMTR      .FILE SET CCD      OPENED,BUFFER LENGTH =00001100.
15.43.48 $UMTR      .FILE SET INP      OPENED,BUFFER LENGTH =00010100.
15.43.48 $UMTR      .FILE SET JOHIN    CLOSED,BUFFER LENGTH =00032100.
15.43.48            .FILE SET STATISTICS
15.43.48            . READS     WRITES  POSITIONS  DISK RDS  DISK WRS
15.43.48             000000023 000000000 000000002 000000001 000000000
15.43.48            .      LWA=0000000102,DEVICE=02
15.43.48 *CCP       $. CONTINUE RUN AND COPY OUTPUT TO TAPE.
15.43.48 *CCP       $CREATF(FS=RUNTP,CL=U,SCT=2000,PREMT=XX003023)
15.43.49 *CCP       $SETQ(KEY=KKTP)
15.43.49 *CCP       $SETQ.
15.43.49 *CCP       $LOGO(I=RUNTP)
15.43.49 $UMTR      .FILE SET RUNTP    OPENED,BUFFER LENGTH =00032100.
15.43.49 $RMTR       ROLLOUT STARTED
15.43.50 $RMTR       ROLLOUT DONE
15.48.20 *LOS  05   XX003023 IS ON UNIT 1  FILE RUNTP        800 BPI.
16.23.48 $RMTR       ROLLIN STARTED
16.23.48 $RMTR       ROLLIN DONE
16.23.50 $UMTR      .FILE SET OUT      OPENED,BUFFER LENGTH =00032100.
16.30.32 $RMTR       ROLLOUT STARTED
16.30.33 $RMTR       ROLLOUT DONE
16.32.36 $RMTR       ROLLIN STARTED
16.32.37 $RMTR       ROLLIN DONE
16.35.42  NU76EL    .END
16.35.42 $UMTR      .FILE SET IMAGE    OPENED,BUFFER LENGTH =00064100.
16.35.42 $UMTR      .FILE SET IMAGE    CLOSED,BUFFER LENGTH =00064100.
16.35.42            .FILE SET STATISTICS
16.35.42            . READS     WRITES  POSITIONS  DISK RDS  DISK WRS
16.35.42             000000000 000000003 000000001 000000000 000000004
16.35.42            .      LWA=0000147115,DEVICE=02
16.35.43 *CCP       $IF(FALSE=TAPE)
16.35.43 *CCP       $LABEL(TAPE)
16.35.43 *CCP       $AFSREL(FS=RUNTP,ADISP=STAPE,POSMT=XX003023)
16.35.43 $UMTR      .FILE SET RUNTP    CLOSED,BUFFER LENGTH =00032100.
16.35.43            .FILE SET STATISTICS
16.35.43            . READS     WRITES  POSITIONS  DISK RDS  DISK WRS
16.35.43             000000033 000000002 000000002 000000007 000000002
16.35.43            .      LWA=0000143743,DEVICE=03
16.35.44 *CCP       $COPYDF.
16.35.44  FLUSHDF   .DAYFILE FLUSHED TO DISK -  T=  16.35.44
```