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LA-4751 SPECIAL DISTRIBUTION ISSUED: January 1972



# MCN: A Neutron Monte Carlo Code





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#### 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.<sup>1</sup> The mechanics of setting up and running a problem are discussed below drawing heavily on an internal memorandum by Taylor;<sup>2</sup> 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  $(10^{-8} \text{ sec})$ .
- 3. Energies in MeV.
- 4. Atomic densities in units of 10<sup>24</sup> atoms/cm<sup>3</sup>.
- 5. Cross sections in barns  $(10^{24} \text{ cm}^2)$ .

## 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.



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  $x_1, x_2, ..., x_N$  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

$$\bar{\mathbf{x}} = \frac{1}{N} \sum_{i=1}^{N} \mathbf{x}_{i}$$

and the sample variance of x

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

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

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<sup>th</sup> 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<sup>th</sup> 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  $\overline{x}$ . It is well-known that if one draws a sample of size N from a population with true mean E(x) and variance  $\sigma^2$ , then with

$$\overline{\mathbf{x}} = \frac{1}{N} \cdot \sum_{i=1}^{N} \mathbf{x}_{i} ,$$

$$E(\overline{\mathbf{x}}) = E(\mathbf{x}) ,$$
Variance  $(\overline{\mathbf{x}}) = \frac{\sigma^{2}}{N} .$ 

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

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

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.

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

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

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

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

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

Prob 
$$\left[\alpha \overline{\sigma}(\overline{x}) < \overline{x} - E(x) < \beta \overline{\sigma}(\overline{x})\right]$$
  

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

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  $\overline{\sigma(x)}/\overline{x}$ , 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.

$$F = \int_{a}^{b} f(x) p(x) dx$$

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

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$$\overline{f} = \frac{1}{N} \sum_{i=1}^{N} f(x)$$

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This yields the Monte Carlo value for the integral. The variance of the random variable f(x),  $\sigma^2$ , 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

$$\int_{a}^{b} w(x) f(x) \widetilde{p}(x) dx$$
$$= \int_{a}^{b} f(x) p(x) dx$$

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

$$\int_{a}^{b} [w(x)f(x) - F]^{2} \widetilde{p}(x) dx ,$$

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  $\sigma' = \mathcal{I}^{q(a)}\sigma$  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  $\sigma'$ ), 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  $\theta$  about the line of flight

of the neutron. If  $\nu = \cos \theta$ , let  $p(\nu)d\nu$  be the probability of scattering between  $\nu$  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

$$\mathbf{p}(\mathbf{v})d\mathbf{v} \cdot \frac{\left(\frac{1}{\mathbf{r}^2}\right)}{(2\pi d\mathbf{v})} = \frac{\mathbf{p}(\mathbf{v})}{(2\pi \mathbf{r}^2)}$$

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  $\sigma$  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

$$v = \frac{1 + A\mu}{\sqrt{1 + A^2 + 2A\mu}}$$

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

,

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

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  $\nu$  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.<sup>4,5</sup> 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

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

for the average contribution to the flux at the detector for particles colliding in the spherical region, where p(v)and  $\sigma$  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 ro 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<sub>o</sub> 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.<sup>6</sup> Suppose the point detector is enclosed by a finite set of spheres of decreasing radii, r<sub>1</sub> r<sub>2</sub>, ... r<sub>n</sub> (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<sub>n</sub>). Plotting F<sub>i</sub> vs r<sub>i</sub> 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 nth 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<sub>n</sub>. 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  $\mu$ , 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  $\overline{\sigma}(\overline{x})$  by  $\overline{x}$ .  $\overline{x}$  refers to the mean quantity tallied, and  $\overline{\sigma}(\overline{x})$  refers to the sample standard deviation in  $\overline{x}$ .

It is implicit in the definition of  $\overline{x}$ , 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,

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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.

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

Mnemonic	Type (Equation)	Coefficients in Order of Entry
SY	$x^{2} + (y-\overline{y})^{2} + z^{2} - R^{2} = 0$	ÿ, R
SZ	$x^{2} + y^{2} + (z-\overline{z})^{2} - R^{2} = 0$	<b>z</b> , R
c/x	$(y-\bar{y})^2 + (z-\bar{z})^2 - R^2 = 0$	<b>y</b> , <b>z</b> , R
C/Y	$(x-\bar{x})^2 + (z-\bar{z})^2 - R^2 = 0$	<b>x</b> , <b>z</b> , R
C/Z	$(x-\bar{x})^2 + (y-\bar{y})^2 - R^2 = 0$	<b>x</b> , <b>y</b> , R
СХ	$y^2 + z^2 - R^2 = 0$	R
CY	$x^2 + z^2 - R^2 = 0$	R
CZ	$x^2 + y^2 - R^2 = 0$	R
к/х	$-t^{2}(x-\bar{x})^{2} + (y-\bar{y})^{2} + (z-\bar{z})^{2} = 0$	$\overline{x}$ , $\overline{y}$ , $\overline{z}$ , t <sup>2</sup>
к/ч	$(x-\bar{x})^2 - t^2(y-\bar{y})^2 + (z-\bar{z})^2 = 0$	$\overline{x}$ , $\overline{y}$ , $\overline{z}$ , $t^2$
K/Z	$(x-\bar{x})^{2} + (y-\bar{y})^{2} - t^{2} (z-\bar{z})^{2} = 0$	$\overline{x}$ , $\overline{y}$ , $\overline{z}$ , t <sup>2</sup>
KX	$-t^{2}(x-\bar{x})^{2} + y^{2} + z^{2} = 0$	$\bar{\mathbf{x}}$ , t <sup>2</sup>
КY	$x^2 - t^2(y-\bar{y})^2 + z^2 = 0$	$\bar{y}$ , t <sup>2</sup>
KZ	$x^{2} + y^{2} - t^{2}(z-\overline{z})^{2} = 0$	$\overline{z}$ , t <sup>2</sup>
SQ	$A(x-\bar{x})^2 + B(y-\bar{y})^2 + C(z-\bar{z})^2$	A, B, C, D, E,
	$+ 2D(x-\overline{x}) + 2E(y-\overline{y})$	F, G, x, y, z
	$+ 2F(z-\overline{z}) + G = 0$	
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	$(y-\bar{y})^2/b^2 + (z-\bar{z})^2/c^2 = 1^*$	y, 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

$$(x^{2} + z^{2} + \rho y^{2} - 2\rho \overline{y}y + B_{o})^{2} = A_{o}(x^{2} + z^{2}) ,$$
  
where  $\rho = c^{2}/b^{2}$   
 $B_{o} = \overline{z}^{2} - c^{2} + \rho \overline{y}^{2}$   
 $A_{o} = 4\overline{z}^{2} .$ 

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 IO, Y6, Y7, R1, ..., Rn. These cards continue the specification of

quantities by cell. The entries on the IO, 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 IO card must be that value assigned to the cell occupying the  $n^{th}$  position among the cell card entries.

The usage is as follows.

- IO: 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  $t_1, t_2, ..., t_n$  at which the cell thermal energies are given.
- R1: Cell thermal energies at the  $1^{st}$  time  $t_1$ .
- •
- .
- Rn: Cell thermal energies at the  $n^{th}$  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 DO 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  $t_1, ..., t_n$ . The first time,  $t_1$ , is written as the first entry on the RO 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 t2 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, UO, VO, and WO. 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  $1 \le n \le 8$ .
- 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.
- WO: A table of energies of source particles.

V0 and W0 together give the distribution function of the energy spectrum. A random number,  $\xi$ , 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 WO 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 VO card are the cumulative probabilities that a source neutron has an energy less than or equal to the corresponding entry on the WO card. In this case, the first entry on the VO 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 VO 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 VO 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 UO 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 UO card, then the entries on the VO 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 VO 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  $30^\circ$ , 30 to  $60^\circ$ , and 60 to  $90^\circ$  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 RO 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	Run card
	6789 card
JØB card CØMMENT. CØMPILE SØURCE, INITIATE, AND RUN PRØBLEM	When one of the standard sources is used, the fol- lowing deck suffices to "initiate and run."
ASSIGN MT, CØDETP(PLB, tape no., SHB)	B JØB Card
ASSIGN MT, RUNTP(NLB,,SHB)	CØMMENT. INITIATE AND RUN PRØBLEM
RUN(SX,B=RUNTP) CØMPILE SØURCE	ASSIGN MT,CØDETP(PLB,tape no.,SHB)
CØPYBF(CØDETP,RUNTP)	ASSIGN MT,RUNTP(NLB,,SHB)
C <b>ØPYBF(CØ</b> DETP,MCNI)	CØPYBF(CØDETP,RUNTP)
MCNI.	CØPYBF(CØDETP,MCNI)
RELTAPE(CØDETP)	MCNI.
CØPYBF(RUNTP,MCN)	RELTAPE(CØDETP)
MCN.	CØPYBF(RUNTP,MCN)
789 card	MCN.
Source subroutine deck (including COMMON)	789 card
789 card	Problem deck
Problem deck	789 card
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 RUNcontrol card and the source subroutine deck with its FMterminator.

"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.

#### 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 VO and WO 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

 $\mathsf{SRC}(4) = 0$ , 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 VO and WO cards.

SRC(1) = 0.

SRC(2) = 0.

SRC(3) = 0.

SRC(4) defined as in S1.

S6: A weighted, isotropic point source.

Requires UO, VO, and WO 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 SUB-ROUTINE 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,  $DEL = -2(X \cdot U + Y \cdot V + Z \cdot W).$ 

- The program name of the cell containing the IA source neutron, or, in the case of a surface source, the cell which will be entered by the neutron.
- The program name of the surface in question when JA 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).
- Neutron's weight (generally 1.0). WT
- 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(1), 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  $\xi$  (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.

I ADLL CH	TA	BL	E	C-I	
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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

Group	Energy (MeV)	Fractions in Group	times: 0-100 (shakes)
1	0.0001	0	angles: 1.0-0.8, 0.8-0.6, 0.6-0.4, 0.4-0.2, 0.2-0
2	0.001	0.01	(values are for the cosine of the angle
3	0.01	0.03	with the normal to the surface).
4	0.1	0.06	
5	0.5	0.20	C. Flux Across Surfaces. Tally the flux across sur-
6	1.0	0.30	face 17 for
7	5.0	0.20	energies: 0-0.01, 0.01-1.0, 1.0-5.0,
8	10.0	0.15	5.0-14.0 (MeV)
9	14.0	0.05	· · /
•			times: 0.20 20.40 40.60 60.80 80.100

(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.

-	(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).
Flux Ac	ross Surfaces. Tally the flux across sur-
energies	:0-0.01, 0.01-1.0, 1.0-5.0,

- (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)

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

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).

.

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## **TABLE C-II**

## **CELL QUANTITIES**

		I nermais (MeV)						
Cell	Importance	t ≤ 20 shakes	t = 40 shakes	t ≤ 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	Ó				
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 <sup>3</sup> )
Al	0.0603
Normal Li	0.0463
Be	0.123
СН	0.00926
CH <sub>2</sub>	0.1173
Fe	0.0847

DO

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 =  $10^{-4}$ . Card

# TABLE C-IV

# SAMPLE RUN

		SUBHOUTINE SOURCE
000001		COPHUN MAA . HAJ . HAS . HAF . HAT . HAFH . HALC . LC3 . IF . EBR . IXFM . LXS . LXSEC. EC
		A F + N = R + SHC [H] + SHE (24) + SWH (24) + SEG (24) + CDE TX (10+3) + R0 (10) + FRO (10) + F
		C 444 - 12 4 - 14 - 15 - 15 - 15 - 15 - 15 - 15 -
		D LCP+1D(8)+LUF(4)+RHD(90)+F10(90)+UA(90)+LCA(91)+HL1(90)+HL2(90)+
		E TH (90+5) + TTH (5) + VOL (90) + LJA (450) + LCAJ (450) + LAJ (720) + KST (80) + LSC (8
		F 11.5CF(240).LCP(720).LFU(6).FHE(100).LHE(100).LPR(6).IJP(60).IFP(
		G 601+P(100)+A(20)+LEC(20)+LEP(20)+LLCH(20)+LCHS(20)+KRN+NRN+TWS+TE
000001		= 31873181818111189121861181861181861181861181750000
		LUMMANYUS JUULUSIL VULUTMI LUVICSAUCSAUSAUSAUSAUSAUSAUSAUSAUSAUSAUSAUSAUSAUS
		2 15F
000001		CUMHUN/G2/IET(12).NET(12).DET(12).LET(12).CRT(12).THD(2).AHD(2).
		1 1TP(20) •TP(20) •D10(128) •EF\$(33)
000001		COMHUN/G3/1519+F241+F248+F243
000001		COMMON/DACOM/NIB+IDETX+CSDX+CS+DDETX+DXFAC+AMFP2+PHLSAV(13)+
		I LV2/LV3/LV4/LV5/LV5/LV7/PSC/DMULA/AW/VOLD/VOLD/WOLD/
	~	E VIG DIALIAN ADDALACE ANTICIDISINGE CARE
	č	UNIFORMLY DISTRIBUTED IN VOLUME IN SPECIFIED SPHERICAL CELL.
	Ċ	STARTING DIRECTION ISOTROPIC, BUT BIASED IN POSITIVE V-DIRECTION.
	č	ENERGY UISTNIHUTION.
	С	ST CARD REQUIRED IN PROBLEM DECK.
	ç	SHC(1)=CELL NUMBER.
	č	SHC(2) =RAILUS OF CELL IN CH.
	ž	DISTIVE V.
	č	
000001	•	DIMENSION ESHC(9) PESRC(9)
000001		DATA £5RC/.0001001.01.015.1.0.5.0.10.0.14.0/
000041		DATA PESHC/0++01++04++10++30++60++80++45+1+0/
	ç	DISTANCE FROM ORIGIN SAMPLED FROM THE INTERVAL (0.SRC(2))
	¢	DISTRIBUTED ACCORDING TO THE DISTANCE GURED.
000001	~	REDRUIZJY (FRN (KAN) / YW, 333333333 Samula (Nita Ome of Don Donate There The Unit Atdale).
000010		a TP (1) #FRNS(KRN)
000012		TP (2) =FHNS (KHN)
000014		TP (3) = TP (1) + +2 + TP (2) + +2
000017		IF (TP (3) .GT.1.) GO TO 10
	ç	TP(3) DISTRIBUTED UNIFORMLY ON THE INTERVAL (0.1). TP(4) IS
	G	THE LISINE OF THE FULAR ANGLE OF THE STARTING POINT.
000024		TP(5)=R*SORT((1,+TP(4)**2)/TP(3))
000033		X=N#1P(4)
460000		Y=1P(1)+1P(5)
000035		2=TP(2)=TP(5)
000037	_	IF (FMN (KHN) . GT . SHC (3)) GO TO 30
000045	С	SELV POSITIVE SRC(3) OF THE TIME.
000045		- V-ANJ(V) - WT80-5/566(3)
000050		15 [A=SHC(1)
000051		JA=1
00005Z		THEEU
000053		DEL=0
000054		Raf HN (KRN)
000057		00 20 1=2.9
000060		IF(R.LT.PESRC(1)) GO TO 25
000003		
		1 (PESRC(1)=PESRC(1=1))
000073		HETUHN
	C	SET V NEGATIVE 1-SRC(3) OF THE TIME.
000074		30 V=AUS(V)
000076		TITU•5/(1•5KC(3))
000101		
		2

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CORE MAP	*******	FWA	- 71/09/03++++	TIME- 12.36.5	LENGTH	. NORMAL	LOAD		*********	********		******
	CODE	000100	147370	117714	027455							
	LOADER	143566	147771		-							
	TABLES	143565	141555									
				MANER			1.64				•	
	BBOGBAM	ANDRESS		COMMON	ADDRESS		BLOCK	ADDRESS				
F 166	FRUUMAN	AUDRESS										
CODETP												
	INU760L	011400		INCOM	000100 -							
	SNIP	107440		INCOM	000100							
212119	ACCOUR	110374									•	
	AUFEER	+10240										
	ECSRW	110322										
	ENDFIL	110352										
	IFENDE	110366										
	INPUTB	110406										
	INPUTC	110563										
•	INPUIS	110737										
	OUTPTC	111025										
	OUTPTS	111207			•							
	REWINM	111100										
	SYSTEM	111333										
	INAIEX	112370										
	RBAREX	115451							•			
	854020	112500										
	C4020 GETRA	113260		•								
	TOUTT	113334										
	KODER	114701										
	KRAKER	116106										
	MEMORY	117147										
	SKIPR	117327										
	ALNLOG	117400										
	EXP	117467										
	LASRT	117606										
	UNSATISFI	EU	REFE	RENCED			AT					
	EXTERNALS		BY				LOCATION	•				
			*==•		*******	******				842428	4 <b>4</b> 2 <b>4</b> 244	

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START OF CONSTANTS 000103 START OF TEMPORAHIES 000107 START OF INDIRECTS 000131 UNUSED COMPILER SPACE 104100

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SUBPRC 000161	I RD	M LENGTH									
FUNCT	ION	ASSIGNMENT	s								
STATE	ENT	ASSIGNMEN	(s								
10	-	000011	15	-	000051	25	-	000065	30	٠	000075
BLOCK	NA	ES AND LENS	THS								
		027455	G1	-	000041	62	•	000411	63	•	000004
DXCOM	•	000054						••••			
VARIA	BLE	ASSIGNMENT	5								
A Č		010543CU1	AHD	-	600076C03	CUETX		000137C01	CRT	•	000060C03
DEL	•	000026002	DET	-	000030C03	010	•	000150003	EFS	-	000350C03
ERG		20222000	ESRC	٠	000135	ETĤ		001335001	ETM	•	010717C01
F	•	0107+1C01	F10	•	000432001	FME	٠	007071C01	FRO		000207001
1	-	000160	IA	•	000027002	10	٠	000262001	1ET -	•	000000003
IFP	•	010303001	1 JP	•	010207001	ITP	٠	000100003	JA	٠	202060000
KRN	•	010707001	KST	-	n05522C01	LAJ	•	102202400	LCA	•	000716C01
LCAJ	•	003300CU1	LCR	•	006343001	LCMS	•	010063001	LDF	-	000272001
LEC	•	010567001	LET	•	0000+4C03	LFD	•	007063001	LFP	•	010613001
LJA	-	002376001	LLCM	•	010637001	LME	٠	010035001	LPR	•	010201001
LSC	•	002045001	ML1	•	001051001	HLS	٠	001203001	NET	•	000014003
NTM	-	010725C01	P	•	010377C01	PBLSAV	٠	000010005	PESRC	•	000146
QA	•	000564001	R	•	000157	RHO	٠	000100001	RO	•	000175001
SCF	•	005763C01	SEG	•	000107001	SPB	•	000027001	SRC	. •	000017001
SWM	•	000057001	THD	•	000074003	THE	•	000024C02	TP		000124003
TTH	•	002237001	v	-	000020002	AOF	٠	002244001			000023C02
WTH	•	010733C01	x	•	000014C02	¥	•	000015002	Z	-	00001ecoz
EXTER	AL	ASSIGNMENT	5		•						
FRN			HBAREX			FRNS			SORT		
START	0F	CONSTANTS									
00010	3									•	•

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SAMPLE PROBLEM

45. 00926 -1*2

43. 0603 1.1 -2.4.5.3

44. 123 2.2 -4.4 -3.6

45. 1173 2.2 -4.3 15.5 -3.6

46. 1173 2.2 -15.4 -3.15

41. 0463 3.4.43 -5.7 -7.8

43. 0603 5.6 15.16 -0.2; -7.9

41. 0463 -5.4 7.6 -4.10

43. 0603 5.6 17. -6.23 -8.11

41. 0463 -5.11 M.H -9.12

43. 0603 5.6 17. -6.23 -8.11

41. 0463 -5.11 M.H -9.12

43. 0603 5.6 17. -6.25 -11.32

43. 0603 5.6 16.10 -6.25 -11.32

43. 0603 5.5 16.17 -5.16

43. 0003 5.16.17 -5.16

43. 0003 5.16.18 -6.21 -15.7

45. 00926 -5.18 17.19 -16.15

43. 0003 -5.19 16.18 -6.21 -15.7

45. 00926 -5.18 17.32 -16.20

45. 1173 6.16 18.32 -4.20 -16.16

43. 0003 -5.19 18.32 -4.20 -16.16

43. 0003 -5.19 18.32 -4.20 -16.16

43. 0003 -5.19 18.32 -4.20 -16.16

43. 0003 -5.19 18.32 -4.20 -16.16

43. 0003 -5.19 18.32 -12.20 -8.20

46. 1173 6.11 4.23 -12.30 -9.25

46. 1173 6.13 9.24 -12.30 -9.25

46. 1173 6.14 9.24 -12.30 -9.25

46. 1173 6.14 9.28 -12.30 -9.25

47. 12.21 16.26 -13.31 -15.28

47. 0047 12.21 16.26 -13.31 -15.28

47. 0047 12.22 15.27 -13.31 -7.29

47. 0047 12.22 15.27 -13.31 -7.29

47. 0047 12.22 15.27 -13.31 -11.32

47. 0047 12.22 15.27 -13.31 -11.32

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47. 0047 12.22 15.27 -13.31 -11.32

47. 0047 12.24 2.90.30 1.32 -14.32 -11.32

47. 0047 12.24 2.90.30 1.32 -13.31 -11.32

47. 0047 12.24 2.90.30 1.30 2.91.33 -11.32

47. 0047 12.24 2.90.30 1.30 2.91.33 -11.32

47. 0047 12.24 2.90.30 1.30 2.91.432 -11.32

47. 0047 12.24 2.90.30 1.30 2.91.33 -11.32

47. 0047 12.24 2.92.5 0.30 -13.31 -11.32

47. 0047 12.24 2.90.30 1.30 2.91.432 -11.32

47. 0047 12.24 2.90.30 1.30 2.91.432 -11.32

47. 013.26.27.262.93.01 11.012 -11.422 -11.32

47. 0047 12.24 2.90.30 1.30 2.91.432 -11.32

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                                            S0 3.0

S0 5.0

S0 10.0

KY 0.3333333333

CY 10.

CY 11.

PY 15.

PY 20.

PY 25.

PY 30.

PY 31.

CY 14.

CY 15.

CY 15.

CY 26.

PY 0

PY -12.

PY -18.

PY -18.
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                                                1.E-3 0 14.0
   00
                                            1.E-3 0 14.0

1. 1. 2. 2. 1. 4. 4. 8. 8. 16. 8. 32. 16. 32. 1. 6R 4. 4. 8. 8.

1. 1. 2. 2. 1. 4. 4. 8. 8. 16. 8. 32. 16. 32. 1. 6R 4. 4. 8. 8.

1. 2. 2. 4. 1. 0

1. 3.0 .75

20. 40. 60.

10.E-6 0 10.L-6 1R 0 8R 10.E-6 0 10.E-6 0 0 1.E-6 5R 0 6R

10.E-6 0 0 50.L-6 1R 0 8R 50.E-6 0 50.E-6 0 0 10.E-6 5R 0 6R

.1E-3 0 0 .1L-J 1R 0 8R .1E-3 0 .1E-3 0 0 10.E-6 5R 0 6R
     10
     $7
H0
     H1
A2
H3
                                                10 11 14
•D1 1• 5• 14•
     F1
E1
T1
C1
                                                •0. •• •• •5 0
•8 •6 •• •5 0
                                              17
•01 1• 5• 14•
20• 40• 60• 80• 100•
     F22744
F22744
F55766661
F66761
                                              3

1 .5 1.0 5.0 14.0

10. 20. 40. 100.

345.52
                                       10.20.40.100.

245.52

10.25.0

.01 1.0 5.0 14.0

20.40.100.

4.51 1.0 14.0

10.20.40.100.

215.4244 2214 .0756

2035 1.

2035 1.

2036 1.

11 .5 3006 .5

11 2. 3006 1.
     H42
H43
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H44 H45 K66

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		35	CELLS		
PROGR NAME	PROBL NAME	MATERIAL	DENSITY	IMPORTANCE	XSEC MULT
1	1	45	9.2600E-03	1.0000E+00	1+0000E+00
ż	Ż	43	6-0300F-02	1.0000E+00	1.0000E+00
3	3	44	1.23001-01	2.000VE+00	1.0000E+00
Ă.	ě.	46	1.1730E=01	2.000VE+00	1.0000E+00
5	5	40	1.17308-01	1.000UE+00	1.0000E.00
6	6	41	4.63005-02	4.0000E+00	1.0000E+00
Ť	7	43	6+0300E=02	A.0000E+00	1.0000E+00
8	8	41	4.6300E-02	8.0000E+00	1.00001-00
ā	9	43	6.0300E-02	8.0000E+00	1.0000E+00
10	10	41	4.0300E-02	1.6000E+01	1.0000E+00
īi	11	43	6-03002-02	8.0000E+00	1+0000E+00
īž	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	3.20002+01	1.0000E+00
15	15	45	9.260DE=D3	1.000UF.+00	1+00002+00
16	16	43	6+0300E=02	1 .0000E+00	1+0000E+60
17	17	45	9.26002-03	1.0000E+00	1.0000E+00
18	18	43	6.0300L-02	1.00008+00	1+0000E+00
19	19	43	6.0300E+02	1.00002+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+C0
24	24	46	1.1730E-01	8+0000E+00	1+0000E+00
25	25	46	1.1730E-01	8.0000E+00	1.0000E+60
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
54	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	ō	0.	1.0000E+00	1+0000E+00
32	32	ò	0.	ů.	1.0000E+00

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TALLY PARAMETERS	THERMAL LI	MIT = 1.0000E-03		
FORHULA 1 NEUTRONS CROSSING SURFACE Subface 10 11 14	TIME(RO) Cell	2.0000E+01 R1	+.0000E+01 R2	6.0000E+01 R3
ENERGY 1.0000E-02 1.0000E.00 5.0000E.00 1.4000E.01 TIME 1.0000E.02	1 2	1.0000E-05	5.0000E-05	1+0000E-04
COSINE 8.0000E-01 6.0000E-01 4.0000E-01 2.0000E-01 0.	3	D.	0.	0.
FORMULA 2 FLUX INTEGRATED OVER SURFACE	5	1.00000-05	5.0000E-05	1.0000E-04
SURFACE 17 ENGRGY 1.00005+02 1.00005+00 5.00005+00 1.40005+01	6	0. 0.	0. 0.	0.
TIME 2.0000E+01 4.0000E+01 6.0000E+01 8.0000E+01 1.0000E+02		0.	0.	0.
FORMULA 4 PATH LENGTH/VOLUME	10	0. S.	0.	0+ 0+
CELL 3 ENERGY 1-00005-01 1-00005-00 5-00005-00 1-00005-01	11	0.	0.	0.
TIME 1.0000E+01 2.0000E+01 4.0000E+01 1.0000E+02	ij	0.	0.	0.
VOLUME Z.4552E+02	15	1.0000E-05	5.0000E-03	1.0000E-04
FORMULA 5 FLUX AT DETECTOR	16	0.	0.	0•
DETECTOR X Y 4 NEIGHBORHOOD	17	1+00008-05	5.0000E-05	1.0000E-04
ENERGY 1.0000E-UZ 1.0000E+00 5.0000E+00 1.4000E+01	19	0.	0.	0.
TIME 2.0000E+01 4.0000E+01 1.0000E+02	20	1.000000-06	1+0000L=05 1+0000E=05	1.0000E-05
FORMULA 6 CAPTURES	22	1.0000E-06	1.0000E-05	1.0000E-05
TIME 1.0000E+01 2.0000E+01 4.0000E+01 1.0000E+02	24	1.0000E-06	1.0000E+05	1.0000E-05
ENERGY }.0000E-03 1.0000E-01 1.0000E+00 1.4000E+01	25	1+0009E+06 0+	1.0000E-05	1.0000E-05
	27	0.	0.	0.
·	28 29	0. 0.	0. Ba	0.
	30	0.	0	0.
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SOURCE=7 SRC(1 1+0000E	) \$4C(2 +00 3.00008	2) (+00	SRC(3) 7.5000E-01						
MATENIAL NO.	COMPUNENT NUCL	IDE .FRACT	[ 0N						
41 42 43	2215, .92440 2035,1.00000 2035,1.00000	2214, .	37560					•	
45	11, 50000	3006 3006	50000 33333	•					
ASEC STO	RAGE								
NUCLIDE	FAST CORE	ECS							
11	493								
2008	1193 26MB						•		
2036	4684								
2214	2148								
2215	2036								
3006	1813	_							
TOTAL	10005	Q		•					
**********		********	•••••••	ITIATION C	OMPLETED	 		********	

CORE HAP		DATE	- 71/09/03++++	TINE- 12.36.5	5	NORMAL	LOAD ****		 *********	 
		FWA	LWA	BUNK COM	LENGIN					
	COUE LOADER TABLES	000100 143566 143565	146511 147771 137644	117035	027455					
	PROGRAM	ADDRESS		COMMON	ADURESS		BLOCK	ADDRESS		
RUNTP	. –									
	SOURCE	000632		G1 G2 G3 DxCON	000100 000141 000552					
	NU76EL	001013	•	01 02 03	000100 000141 000552		XSEC	0008090		
	DBPNT	105770		61 62 63	000140 000141 000552					
	FRN	106526								
	FHNS	106536	•							
	IRN	106547		61 62 63 DxCom	000100 000141 000552 000556					
	EX	106571								
SYSLIB										
	ACGOER	106613								
	BRUESET	106654								
	AUSSED	104776								
	CLUCKE	107057								
	ECSHW	107162								
	ENDEIL	107212								
	INPUTC	107226								
	IOCHEK	107402								
	LETGTH	107426								
	OUTPTC	107446			•					
	SSWTCH	107604								
	SYSTEM	107672								
	XIT	110727								
	ALNLUG	111046								
	EXP	111135								
	INALEA	111210								
	NHALEA	111241								
	Schi	111251								
	ANURT	111427	-							
	854020	111475								
	C4020	117255								
	ENTR	112351								
	GETHA	117405								
	IGUTIL	112441								
	KODER	113732								
	KHAKEN	115137								
	LAPHI	116200								
	OUTPTS	116466								
	PACKAGE	116557						•		
	REMARK	116644						•		
	RETN	116670								
	SKIPR	116720								
	BOI	116771								
		1.0	DFFF	RENCED			AT			
	UNDALISP	16 <b>-</b> 4	REFE BV				LOCATIO	N		
	EALENNAL	*							 	
	SPCOX		NU76	εL	002032					

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SAMPLE PHOLEM       V       <	50	URCE ND.	TINE CUTOFF 1.0000E+02	WEIGHT C 1.0000E-	utoff 04	RU) 2 :	N TIME 0000E+09	PRINT CYCLE 23000	DUMP C1 25081	CLE	DUMP NO Q	cutoff ( P	YCLE
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $				SAMPLE PHON	LEM								
1 2.2877.600 3.7276.01 3.7276.01 1 1 4.0396.01 3.4206.01 3.4206.01 0 4.06677.01 0 3.2221.0 2 -1.4294.610 2.2246.00 -1.3017.00 1 1 2.2997.00 1 1 4.2495.00 -2.00177.01 0 4.66677.01 0 4.66977.01 2 -1.5776.00 8.7298.00 -1.72711.00 1 1 4.4495.00 -1.4208.00 -2.2397.01 0 2 0.0005.00 0 3.2606.00 -3.260	NP:	5 X	۲	Z	IA	JA	U	v		THE	NT	DEL	ERA
2 -3.4434 c1 2 -22404 c0 1 -3002 c0 1 1 1 1-2002 c0 4.2014 c0 4.20	1	5.28755+00	3+7276E-D1	-1.9H99E-01	1	1	4+6154E-01	4.1858E-01	3+4264E-01	0.	6.65672-01	0.	4-1427E-01
1 -1.53901-00 M.72001-01 -1771[F-00 1 1 9-9662F-01 -42.086-03 5.222[F-22 0, 8.6667F-01 0, 3.6697E-00 1 2.5566F-01 2-5567F-00 1 -7756F-00 1 1 -224556-01 -42.086E-03 -6.071E-01 0, 2.5000F-00 0, 3.2640E-0 5.2566F-01 2-4331E-00 -45937E-01 1 1 -24455F-01 -4.0301E-01 -6.071E-01 0, 2.5000F-00 0, 3.2640E-0 7.4620E-01 2-4331E-00 -45937E-01 1 1 -51340F-01 2-401E-01 -7611F-01 0, 4.6667F-01 0, 4.6667	S	-3.4934E-01	2+224HE+DD	-1+30U3E+00	1	1	1+29918-01	8.5080E-01	5-0917E-01	é.	6.6667E-01	0.	3.92212-03
<pre>4 -3.5 (0,t-0, 1.5.302 -01 -1.2246*00 1 1 -2.4455f-01 -7.64034E-01 -4.6354F-02 0. 2.0000500 0. 3.26460-0 5 -2.0005(00 -1.216,100 -1.0005*00 1. 1 -7.4551F-01 -6.034E-01 -6.0571F-01 0. 2.0005*00 0. 4.6457F-01 0. 3.0005*0 7 -2.4569(F-02 -4.6929*00 -2.2332F-01 1 -7.4551F-01 -6.041E-01 -6.05671F-01 0. 4.6457F-01 0. 4.6457F-01 7 -2.4569(F-02 -4.6929*00 -1.1571F-01 -7.6451F-01 -2.4559F-01 -7.6593F-01 -7.6593F-01 -7.6593F-01 -7.6593F-01 -7.6593F-01 -7.6593F-01 0. 2.00005*00 0. 4.64587F-01 9 -7.4525(F-01 -7.2579,F-01 -7.6451F-01 -1.5535F-01 -7.6593F-01 -7.6593F-01 0. 2.00005*00 0. 4.6583F-01 9 -7.4525(F-01 -7.6531F-01 -1.4607F-00 1 1 -6.535F-01 -7.6593F-01 0. 2.00005*00 0. 4.6637F-01 1 -4.6457F-01 -7.6531F-01 -4.6267F-01 -1.6653F-01 -7.6593F-01 0. 4.6667F-01 0. 4.6667F-01 0. 4.6667F-01 0. 4.6667F-01 0. 4.6607F-01 0. 4.66</pre>	3	-1.5394E+00	8.72HOF-01	-1+7711E+00	1	1	9.98638~01	4+28368-03	5-2221F-02	Ô.	6.6667E-01	0.	4.6492E-01
3       2.0090200       1.3114-00       1.00987-00       1.1284067-01       4.23927-01       0.       2.0000200       0.       8.60057-01         7       2.4001200       2.4101100       3.001200       1.142517-01       2.3307-01       0.23507-01       0.       8.60077-01       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.       8.60077-01       0.0005700       0.0005	2	-5-5/8/1-01	-5+5362F-01	-1+2246E+00	1	1.4	-2+4954F-01	-9•6408E-01	-9.1046E-D2	0.	2+0000E+00	0,	3.26402-01
7	3	2+08992+00	=1+3313E+00	1+1058F+00	1	1 .	-2+8440E-01	-4-0318E-01	-8.6971E-01	0.	2.00002+00	0.	S.S656E=01
n - 2/19940000       n 1/1097-001       3/20140001       2/2014001       7/4014000       0       4/404000       0       4/404000       0       6/404000       6/404000       6/404000       6/404000       6/4040000       6/4040000       6/40400000       6/40400000       6/40400000       6/404000000       6/404000000       6/40400000000       6/4040000000000       6/4040000000000000000000000000000000000	2		2**************	4+45336-01	1	_ <u>}</u> '	-]+4351E-01	8+9441E-D1	4.2359E-01	0.	6+6667E=01	0+	3.6066E-02
0       -7.27221-01       -4.34147-01       1       1       -9.4347-01       -6.55487-01       -7.2722-01       0.       2.0002000       0.       2.2002000       0.       2.2002000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       2.20020000       0.       0.0002000       0.       0.0002000       0.       0.0002000       0.       0.0002000       0.       0.0002000       0.       0.0002000       0.       0.0002000       0.       0.0002000       0.       0.00020000       0.       0.00020000       0.       0.00020000       0.       0.200200000000       0.       0.2002000000000       0.       0.2002000000000       0.       0.2002000000000       0.       0.200200000000000000000000000000000000	i i	-2.1090102	-2107202-00	3+22046-01	1	- 2	4+3334F+01	4.2601E-01	7+9418F-01	G •	6.6667E-01	0.	4.448BE-01
10 - 5,900E-01 - 1,702F-03 - 1,704F-00 1 1 30,500E-01 - 2,500E-01 0, 2000E-00 0, 400E-00		-2-33552-00	7.77646.01	-2.00102-01		1	-2+13946-01	2+04136-01	-8-16185-01	0.	6+6667E=01	0.	5-0756E-01
11       1.44447620       4.5316700       1       1.46497601       7.05306701       0.       5.0667761       0.       5.0007700       0.       5.0777777777777777777777777777777777777	10	-5.69005-01	#1.7042F+na	-1+300+++00				-0.45450E-01	-7-02932-01	g.	2.00006.00	0.	6.2863E-01
12       1.871[1-0]       -2.4555 e0       4.800[7-0]       1       1.0301[-0]       4.5307[-0]       0.6007[-0]       6.6007[-0]       0.6007[-0]       1.0301[-0]       1.14507[-0]       0.6007[-0]       1.3507[-0]       0.6007[-0]       1.3507[-0]       0.6007[-0]       1.3507[-0]       0.6007[-0]       1.3507[-0]       0.6007[-0]       0.6007[-0]       1.3507[-0]       0.6007[-0]       0.6	ii	1.44495+00	-8.5310F-01	1.00475400	÷.		9+0330F-01	-0103306-02	-2.34002-01	<b>Q</b> •	2+0000E+00	0.	0+005AF+00
13 5.9369 - 01 - 3.96 / F 00 1.000 F 00 1 1 - 1-230 - 1 1 - 1-230 - 1 1 - 1-230 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	iz	3.8711E-01	-2.4355F+00	4-54615-01	- 1		-1.92775-01	1.035002-01	1+1+202+41	0.	8+668/2=01	9+	4+3666L-01
14 9.937bE-02 1.8207E-00 -2.2337E-00 1 1 2.67727-01 5.8107E-01 -0.7856E-07 0 0 6007F-01 0 5.8270F0 16 2.1634E-03 2.130EF-00 -1.6027F00 1 1 3.7672F00 1 -4.5836E-01 -1.5857F00 0 6007F-01 0 5.8570F0 17 -1.4256E-00 -1.6027F00 -1.6027F00 1 1 3.72720F01 -1.45836E-01 -1.5857F00 0 6.6607F-01 0 8.6585E-00 18 -1.3566E-00 -1.6797E-01 -1.6797E00 1 1 -9.7366F0-01 -1.9368E-01 -1.2202F01 0 6.6607F-01 0 8.6457E-01 19 -1.3506E-00 -1.6797E-00 -1.6797E-00 1 1 -9.7366F00 -1.2202F01 0 6.6607F-01 0 8.6457E-01 19 -1.3506E-00 -1.6797E-01 -1.6797E-00 1 1 -9.7366F00 -1.2202F-01 0 6.6607F-01 0 8.6597E-01 20 -6.8013F-01 2.5107E-00 4.9107E-01 1 5.7777F-01 3.3221E-01 -5.7902F-01 0 6.6607F-01 0 8.6597E-01 21 -62607E-00 -6.6607F-01 0 1.5777F-01 3.3221E-00 -7.77862-01 0 6.6607F-01 0 8.6597E-01 22 -1.2650E-00 1.0997/E-00 2.6244E-00 1 1 5.6577F-01 9.0136E-01 2.7406E-01 0 6.6607F-01 0 8.6597E-01 22 -1.2650E-00 1.0997/E-00 2.6244E-00 1 1 5.6537F-01 9.0136E-01 2.7406E-01 0 6.6607F-01 0 8.6597E-01 22 -1.2650E-00 1.0997/E-00 2.6244E-00 1 1 5.6537F-01 9.0136E-01 2.7406E-01 0 6.6607F-01 0 8.6507F-01 0 8.6597E-01 23 -3.6221E-01 0.0297C-01 2.327821-02 0 1 1 5.68076E-01 9.0136E-02 0 2.0000F-00 0 2.5156E-0 24 -7.0297E-01 1-8(77E-01 -1.6212E-02 1 1 5.68076E-01 -7.1818E-02 0 2.0000F-00 0 2.5156E-0 25 -7.9092E-01 5.7677E-02 -2.23902F00 1 1 1.23236E-01 -2.0738E-01 -0 2.0000F-00 0 4.5152E-0 26 -7.9092E-01 5.7677E-02 -2.23907E-00 1 0 9.3338E-01 -2.0738E-01 -0 4.6667F-01 0 2.3374E-0 27 -0.6667F-01 0 -0.3314FE-0 27 -0.6607F-01 0 -1.332EF00 -2.0738E-01 -2.0738E-01 -0 4.6667F-01 0 2.334E-0 27 -0.000F-00 0 -2.3554E-00 -1 3.732E-00 -2.0738E-01 -2.0738E-01 -2.000F-00 0 .3352E-0 27 -0.000F-00 0 -3.352E-00 -2.0354E-01 0 -0.6667F-01 0 -0.6667F-01 0 -3.6667F-01 0 -3.755E-00 -3.6667F-01 0 -3.6667F-01 0 -3.6667F-01 0 -3.6667F-01 0 -3.6667F-01 0 -3.6667F-01 0 -3.755E-00 -3.6667F-01 0 -4.6667F-01 0 -4.6667F-	13	5-93848-01	=1+39+1E+0u	1.0609F+00	:		-1-74385-01	D-0067E-01		<b>0</b>	0.000(0-01		4+64VIC-VL
15 -0-7135E-01 -5.4574-01 -29242-00 1 1 7.46276-01 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	14	9.9378E-02	1 . A267E+00	-2+2313E+00	- i	1	3+47125-01	5.61.01E=01	-3+0+2/C-UL		8+000/C-UL	<b>V</b> •	3+25491-02
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	15	-9.7135E-01	-5-89741-01	1.29245.00	i	i	7+08216+01	6.95965-01	-1.1H68F-01	<b>.</b>	A.44475-01	0.	843770L*UU 8.8330FA00
17 -1.4245E-01 6.0H90E-01 -3.4690E-01 1 1 3.32920F-01 7.6192E-01 -3.7692E-01 0. 2.6000E+00 0. 2.0795E-01 19 1.307UE+00 -1.647UE+01 -1.3191E+00 1 1 -2.130H-01 -1.930E+0-1 0. 2.000E+00 0. 2.0795E-01 20 -6.80JIF-01 2.51UF+00 4.4910Z+01 1 1 7.2790F+01 3.922E+01 0. 4.6667E+01 0. 3.093E+0 21 1.6269E+00 4.6487F-01 4.2019E+01 1 1 7.2790F+01 3.092E+01 0. 4.6667E+01 0. 4.607E+01 22 -1.2760E+00 1.0797E+00 2.010HE+01 1 1 -3.3336F+01 9.013E+01 7.7219F+01 0. 4.6667E+01 0. 4.607E+01 23 2.233UE+01 4.6207E+01 -2.6248F+00 1 1 1.6337E+01 9.013E+01 7.7219F+01 0. 4.6667E+01 0. 4.607F+01 0. 4.6248E+0 24 3.6621E+01 4.0029E+01 2.7268E+00 1 1 1.6323UE+01 -7.834E+02 0. 2.0000E+00 0. 2.1564E+0 24 3.6621E+01 4.0029E+01 2.32733E+02 1 1 3.6407E+01 3.6328UE+01 -7.8348E+02 0. 2.0000E+00 0. 2.1564E+0 25 4.7827E+01 -1.6177E+02 -2.2390E+00 1 1 1.43346+01 4.6374E+01 0. 4.6667E+01 0. 2.0000E+00 0. 2.1564E+0 27 2.0808E+00 -1.4627E+00 3.137346+01 1 1.27266E+02 4.3811E+01 0. 4.6667E+01 0. 2.03748E+0 27 2.0808E+00 -1.4627E+00 3.03748E+00 1 1 4.73335F+01 -2.6735E+01 0. 2.0000E+00 0. 3.0321E+0 26 -5.6077E+01 2.0213F+01 1.191E+00 1 1 3.3062E+01 3.60374E+01 0. 4.6667E+01 0. 2.03748E+0 27 2.0808E+00 -1.4027E+00 1.1932E+00 1 1 4.3335F+01 -2.6735E+01 0. 4.6667E+01 0. 2.03748E+0 29 1.9451E+00 +1.0521F+00 1 1.191E+00 1 1 3.3062E+01 3.60374E+01 3.6056E+01 0. 6.6667E+01 0. 3.0321E+0 30 -1.6907E+00 -7.6907E+00 1.1919E+00 1 1 3.3062E+01 3.60376E+01 3.66667E+01 0. 6.6667E+01 0. 3.0321E+0 31 -1.4903E+00 1.7291E+00 1 1 4.643500 1 1 7.6332E+01 -2.6735E+01 3.66667E+01 0. 5.6667E+01 0. 5.6567E+01 0. 5.6567E+01 0. 5.6507E+01 0. 5.6507E+01 0. 5.6507E+01 0. 5.6667E+01 0. 5.6657E+01 0. 5.6657E+01 0. 5.6657E+01 0. 5.6667E+01 0. 5.	16	2-16346-03	2+1346E+00	-1.6022E+00	ī	ī.	-8+7678E-01	-4-58365-01	-1.45475-01	å.	2.00005000	0.	B-1071F-01
18 -1.3566E.00 -rt.8778E.01 -1.3518E.00 1 1 -2.1386F.01 -1.2736E.01 0. 2.00078.00 0. 2.00078.00 20 -0.8013F.01 2.5107E.00 4.0107E.01 1 7.27496F.01 3.022E.01 0. 4.6667F.01 0. 3.031E.0 21 1.6254E.00 6.4895F.01 4.2019E.01 1 7.27496F.01 3.06314E.01 7.21978.01 0. 4.6667F.01 0. 4.5057E.0 22 -1.2850E.00 1.0997E.00 2.0141F.01 1 1-3.336F.01 9.013E.01 2.7406E.01 0. 4.6667F.01 0. 4.2448E.0 23 -2.330E.01 6.6727E.01 -2.92454E.00 1 1 1.8737F.00 9.013E.01 2.7406E.01 0. 4.6667F.01 0. 4.2448E.0 24 3.6421E.01 0.0297E.00 2.0141F.01 1 1-3.336F.01 9.013E.01 2.7406E.01 0. 4.6667F.01 0. 4.2448E.0 24 3.6421E.01 0.0297E.01 2.3273E.02 1 1 5.4606F.01 9.013E.01 2.7406E.01 0. 4.6667F.01 0. 4.2448E.0 24 3.6421E.01 0.0297E.01 2.3273E.02 1 1 5.4606F.01 9.732E.02 0. 7408E.01 0. 4.6667F.01 0. 4.1248E.0 25 7.9092E.01 5.767ME.02 -2.2509E.00 1 1 1.036F.01 8.637AE.01 -4.6478E.01 0. 4.6667F.01 0. 2.1564E.0 26 7.9092E.01 5.767ME.02 -2.2509E.00 1 1 1.771141F.01 1.7266E.02 6.3811F.01 0. 4.6667F.01 0. 2.3704E.0 27 2.0800E.00 -1.06278F.00 1 1 4.7312E.00 1 1 4.7335F.01 1.7266E.02 6.3811F.01 0. 4.6667F.01 0. 1.3147E.0 28 -5.4077E.01 2.0157.00 -1.9964F.00 1 1 4.7335F.01 1.7266E.02 6.3811F.01 0. 4.6667F.01 0. 1.3147E.0 29 1.9497E.00 0.7237F.01 1.1191E.00 1 6.5375E.01 -2.0735F.01 0. 4.6667F.01 0. 3.3521E.0 20 1.9497E.00 0.7629F.00 1 1.0197E.01 1 2.7274E.01 -2.7278E.01 -2.035E.01 0. 4.6667F.01 0. 3.3521E.0 29 1.9497E.00 0.7237F.01 1.1191E.00 1 1 4.6955F.01 -3.9425F.01 -3.9464F.02 0 4.6667E.01 0. 3.5755E.0 30 -1.9997E.00 0.7629F.00 0 0.12947F.00 1 1 -3.94537F.02 4.2535E.01 -3.9464F.02 0 4.6667E.01 0. 3.5755E.0 31 -1.6901E.00 7.667E.00 0 1 1.7450F.00 1 1 -74505F.00 -3.9426F.01 0. 4.6667E.01 0. 4.6667E.01 0. 3.6755E.0 32 -2.9601E.00 7.667E.01 0 1 1.4191E.00 1 1 7.4590F.01 3.4664F.02 0. 4.6667E.01 0. 4.6667E.01 0. 4.7555E.0 33 -2.7661E.00 7.6494E.00 1 1 1.4755700 1 1 4.69557.01 -3.9426F.01 0. 4.6667E.01 0. 4.6667E.01 0. 4.7555E.0 34 -2.9600E.00 7.667E.00 0 1 1.4191E.00 1 1 7.459577.02 4.255577.01 0. 4.6667E.01 0. 4.6667E.01 0. 4.6667E.01 0. 4.66	17	-1.8245E-01	6.0690E-01	-3.9690E-01	ī	ī	3+2920E-01	7.4821E-01	-5.76038-01	0.	6.6667E-01	6.	A.A 350E+00
1 1.307U <sup>2</sup> 400 -#1.649U <sup>2</sup> -1.3519 <sup>2</sup> 00 1 1 72790 <sup>2</sup> -01 3.3221 <sup>2</sup> -01 0. 6.667 <sup>2</sup> -01 0. 6.667 <sup>2</sup> -01 0. 6.667 <sup>2</sup> -01 0. 4.500 <sup>2</sup> -01 0. 4.	18	-1.3566E+00	-H.8) N2E-01	~1+6791E+00	1	1 .	-9.7366F-01	-1.9368E-01	-1-20298-01	Q.	2+000002+00	ò.	2.07956-01
20 - 6.8013r01 2:51075'00 4.91075'01 1 7.27907'01 3.32215'01 -5.09025'01 0. 4.66677-01 0. 4.50355'00 22 -1.28505'00 1:09975'00 2:01815'01 1 1.2336'0'01 9:0135'01 2:72097'01 0. 4.66677'01 0. 4.26955'0 23 2:2335'01 6:575'7'01 2:528'01 1 1.3836'0'01 9:0135'01 2:72097'01 0. 4.66677'01 0. 4.26955'0 24 3.64215'01 4:00295'0'1 2:32735'02 1 1 3:4036'0'01 -7.1815'02 0. 2:00005'00 0. 2:15645'0 25 4.70275'01 1:61775'01 0:1252'0'2 1 1 3:4133'0'0'1 0:1252'0'2 -9.7745'01 0. 2:00005'00 0. 2:15645'0 26 4.70925'0'1 2:575775'0'2 -2:25905'00 1 1 1:4336'0'1 4:63765'01 -7.1815'0'2 0: 2:00005'0'0 0. 2:0565'0' 27 2:06965'00 -1.06205'0'0'0 1 1 -7.715'0'1 -7.2665'0'2 0:6115'0'1 0. 4:66677'01 0. 2:0736'5'0' 28 -5.60775'01 2:0255'0'0'0 1 1 -7.715'0'1 -7.2665'0'2 0:6115'0'1 0. 4:66677'01 0. 1:3367'0' 29 1:9645'F'00' -1.49205'0'0 1 1 9:4335'0'1 -2.72765'01 -2.0795'0'1 0. 2:00005'0'0 0. 3:3621'0' 29 1:9645'F'00' -1.9055'F'00' 1 1 9:4335''0'1 -2.72765'01 -2.0795'0'1 0. 4:66677'01 0. 1:3367''0' 29 1:9645'F'00' -1.1652''0'0' -1.49205''0'1 1 0:64870''0'1 7:3335''0'1 -2.0355''0'1 0. 4:66677''0'1 0. 3:3621''0' 30 -1.99975''0'0 0 4:1286''0'1 1 0:4870''0'1 7:3335''0'1 -2.0355''0'1 0. 4:66677''0'1 0. 3:3621''0' 31 -1.69975''0'0 0 4:1286''0'1 1 0:4870''0'1 7:3335''0'1 -2.0355''0'1 0. 4:66677''0'1 0. 3:3621''0' 32 -1.8605''0'0 7:4655''0'1 1 1:915''0'0'1 1 -3365''0'1 0:346''0'1 0. 4:66677''0'1 0. 3:6677''0'1 0. 3:3708''0' 32 -1.8605''0'0 7:4655''0'1 1 1:9785''0'0' 2:47355''0'1 1 2:4645''0'1 0. 4:66677''0'1 0. 3:3708''0' 33 -2.8605''0'0 7:4655''0'1 1 1:4755''0'1 0:47355''0'1 0:4005''0'1 0. 4:66677''0'1 0. 3:3708''0' 34 -28045''0'0 7:4655''0'1 1 1:4785''0'1 1 1:4756''0'1 4:47355''0'1 0. 4:66677''0'1 0. 3:37095''0' 35 -1.0855''0'0 7:4655''0'1 1 1:476''0'1 1 7:3505''0'1 3:4625''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66677''0'1 0. 4:66	19	1-307uE+00	-8.6HudE-01	-1+3519E+00	1	1 .	-2+1381F-01	7.76948-01	5-92228-01	Q.	6+6667E-01	<b>0</b> .	3-9514E+00
$ \begin{bmatrix} 21 & 1.62601 \cdot 00 & 6.648957 \cdot 01 & 6.20191 \cdot 01 & 1 & 3.65767 - 01 & 3.66367 \cdot 01 & 7.21937 \cdot 01 & 0. & 6.66671 - 01 & 0. & 4.2081 \cdot 00 \\ 23 & 2.23301 - 01 & 6.67671 - 01 & 2.62401 \cdot 01 & 1 & 1.65377 - 01 & 9.73222 - 02 & -9.77462 - 01 & 0. & 6.66671 - 01 & 0. & 4.2081 \cdot 00 \\ 24 & 3.6521 - 01 & 9.0026 - 01 & 2.32832 \cdot 02 & 1 & 1 & 5.6767 - 01 & -9.52332 \cdot 01 & -7.810267 - 02 & 0. & 2.00001 \cdot 00 & 0. & 2.1561 \cdot 00 \\ 25 & 4.70271 - 01 & -1.62172 - 02 & -0.37461 - 01 & -0.62261 - 01 & -0.40676 - 01 & 0. & 2.00001 \cdot 00 & 0. & 2.1561 \cdot 00 \\ 25 & 4.70271 - 01 & -1.62172 \cdot 02 & -0.3701 \cdot 01 & 1 & -3.3367 - 01 & -6.62261 - 0. & -2.00001 \cdot 00 & 0. & 4.10211 \cdot 00 \\ 26 & 7.60921 - 01 & -1.65721 \cdot 00 & -1.8721 \cdot 00 & 1 & 1 & -3.3367 - 01 & -2.67321 - 01 & 0. & 6.66671 \cdot 01 & 0. & 0.37481 - 0 \\ 26 & -5.67771 - 01 & 2.031021 \cdot 01 & 1 & -7.71411 - 01 & 1.72661 - 02 & -6.80111 - 01 & -6.66671 \cdot 01 & 0. & 0.37481 - 0 \\ 26 & -5.67771 - 01 & 2.031021 \cdot 01 & 1 & -9.3357 - 01 & -2.7274 - 01 & -2.07321 - 01 & 0. & 6.66671 \cdot 01 & 0. & 0.37481 - 0 \\ 26 & -1.69971 - 00 & -1.0521 + 00 & -1.099511 \cdot 00 & 1 & 3.3021 - 01 & -2.07321 - 01 & 0. & 6.66671 - 01 & 0. & 0.37481 - 0 \\ 30 & -1.99971 - 00 & -1.0521 + 00 & 1 & 1 & 9.3357 - 01 & -2.7274 - 01 & -2.07321 - 01 & 0. & 6.66671 - 01 & 0. & 3.3621 + 0 \\ 31 & -1.69971 - 00 & -0.2137 - 01 & 1 & -1.1911 \cdot 00 & 1 & 3.30621 - 01 & 8.677301 - 01 & 3.4646720 & 0. & 8.66671 - 01 & 0. & 3.7525 - 0 \\ 32 & -1.69071 - 00 & -7.669847 - 01 & 1 & -7.651267 - 01 & 6.77301 - 01 & 3.4646720 & 0. & 8.66671 - 01 & 0. & 3.67525 - 0 \\ 32 & -1.69071 - 00 & -7.669847 - 01 & 1 & -7.651267 - 01 & 6.75301 - 01 & 0. & 6.66671 - 01 & 0. & 3.67525 - 0 \\ 33 & -2.76012 - 00 & -7.69847 - 01 & 2.97571 - 01 & 2.95571 - 01 & -9.66671 - 01 & 0. & 6.66671 - 01 & 0. & 3.67525 - 0 \\ 34 & -2.69071 - 01 & -2.69871 - 01 & 1 & -2.65721 - 01 & -2.65871 - 01 & -2.608671 & 0. & 6.66671 - 01 & 0. & 3.67525 - 0 \\ 35 & -7.69351 - 01 & -7.69326 - 01 & 1 & -7.65351 - 01 & -7.65351 - 01 & -2.608671 - 01 & 0. & 6.66671 - 01 & -2.088647 -$	20	-0.8013E-01	2+51u7E+ua	4+9102E-01	1	1	7+2790F+01	3.32216-01	-5.99828-01	ů.	6+6667E-01	ā.	5+4592E+01
22       1.09972.00       2.01M1E-01       1       1.33365-01       9.0135E-01       2.7506E-01       0.       4.6667E-01       0.       4.26467E-01       0.       4.26467E-01       0.       4.26467E-01       0.       4.26467E-01       0.       4.2667E-01       0.       4.2667E-01       0.       4.2667E-01       0.       2.1566E-0         24       3.6421E-01       H:0292E-01       1       3.4737F-01       -7.5184E-02       0.       2.0000E+00       0.       2.1566E-0         25       4.7092E-01       1.577ME-02       -2.2590E+00       1       1.3036F-01       8.6378E-01       -4.6478E-01       0.       6.6667E-01       0.       4.3748E-0         26       7.0992E+00       3.0768E+01       1       -7.7141F-01       1.7266E+02       6.3611F-01       0.       6.6667E-01       0.       1.33276E+00       3.3748E+00       1.3332F+01       -2.07332E+01       2.0000F+00       0.       3.3221E+00       3.33221E+01       2.07335E+01       0.       6.6667E+01       0.       3.3221E+00       3.332721+01       3.3325E+01       3.3321E+01       3.33221E+01       3.3325E+01       3.3350E+01       3.3350E+01       3.3350E+01       3.3350E+01       3.3350E+01       3.3350E+01       3.3350E+01       3.3350E+01	21	1+62641+00	6.4885E-01	4.2014E-01	3	1	5+8578F-01	3.68342-01	7+21938-01	Ó.	6+6667E-01	0.	4.506#E-01
1       1		-1.54246.00	1.09972.00	2.01H1E=01	1	1.	-3-35365-01	9.0135E-01	2+7406E-01	0.	6.6667E-01	0.	4.24982+00
2:5       4:787E=01       -1.607E=01       -1.313E=02       0.       2:0000E+00       0.       2:1564E=02         2:6       4:787E=01       -1.607E=01       1:8:137=01       -6:0226=01       5:160E=01       0.       2:0000E+00       0.       4:021E+00         2:6       7:0002E=01       5:767E=02       -2:2590E+00       1       1:1:3036E=01       0.       6:667E=01       0.       4:076E=01       0.       3:078E=01       0.       4:0667E=01       0.       3:078E=01       0.       4:0667E=01       0.       3:078E=01       4:0752E=01       4:0667E=01       0.       3:076E=01       0.       4:0667E=01       0.       3:0752E=00       3:076E=01       0.       4:0667E=01       0.       3:0752E=00       3:076E=01       0.       4:0667E=01       0.       3:0752E=00       3:076E=01       0.       4:0667E=01       0.       3:079E=01	23	2.23300-01	0.02012-01	-2.6244£.00	1	1	1+8537E-01	9.7322E-02	-9.7784E-01	0.	6.6667E-01	0.	8.4044E+00
26       7.0092E-01       5.767/KE-02       2.2390E-00       1       1.3036F-01       8.637/KE-01	25	A.7827E-01	#1.#177E#41	2032035-02	1	1	5+8800F=01	10-31542+0-	-7-1814E-02	0.	2 • 0000E • 00	0.	2+1564E+01
2:       1: <td< td=""><td>26</td><td>7.90925-01</td><td>6.747NE-47</td><td>-1.56146-08</td><td></td><td></td><td>8-41331-01</td><td>-0+05505-01</td><td>5+18058-01</td><td>0.</td><td>5 • 0000E • 00</td><td>Q.</td><td>4+1021E+00</td></td<>	26	7.90925-01	6.747NE-47	-1.56146-08			8-41331-01	-0+05505-01	5+18058-01	0.	5 • 0000E • 00	Q.	4+1021E+00
24       -5.007F-01       2.0010F-00       1.9303F-01       -7.7260E-02       6.361F-01       0.       6.6667F-01       0.       3.3021E-00         24       -1.407F-01       -1.052F-00       -1.9944F-00       1       6.4330F-01       -2.7274E-01       -2.0356E-01       0.       6.6667F-01       0.       3.3021E-00         20       -1.9947E-00       -0.02356F-01       -1.9426E-01       0.       6.6667F-01       0.       7.2630E-00         31       -1.4903E+00       -7.6206F-00       1.33062F-01       2.42506E-01       0.       6.6667E-01       0.       3.4752E-0       3.46047E-01       0.       6.6667E-01       0.       3.4752E-0       3.4752E-01       3.46047E-01       0.       6.6667E-01       0.       3.4752E-0       3.4752E-01       3.4752E	27	2.08905400	#1.04705+00	2.07486-01		1.	1+30305-01	8+6374E-01	-4.86/8E-01	0.	6.6667E-01	0.	2+3748E-01
20       1.0451F.00       1.052F.00	28	-5.4077E-01	2.03708.000	-1-8420E400	í.	1.	0.20367-01	1-12001-02	0+36117=01	0.	6+6667E+01	0.	1+3147E+01
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	29	1.94518+00	-1-10521-00	-1.995KF+00	1	•	5+48705-01	7.77776-01	-2+0/936-01	0.	2 . DOODF 00	g.	3+3651E+00
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	30	-1.99978+00	6+02138-01	1.11916400	•	;	3+30625 #41	8.67165-01	-2.03346-01			44	2+110+L+01
32       1.28681E*00       2.30456*00       1.2280*01       1       1.39453*0.0       4.2536*01       0.407*01       0.       6.6667*01       0.       3.4552*01         33       -2:5761E*00       4.0807*01       1.1404*00       1       1.74507*01       1.4695*01       -6.5057*01       0.       6.6667*01       0.       3.752*01         34       2:0403E*00       2:2754*01       1.448*200       1       1.572*01       1.4695*01       -6.5057*01       0.       6.6667*01       0.       3.7909*0         35       2:043E*00       7:651*6*01       9.135*2*01       -7.185*01       0.       6.6667*01       0.       3.7909*0         36       9.655*1*01       -2:245*4*00       7:13*2*0*00       1       2:347*0*1       7.7185*01       0.       6.6667*0*01       0.       3.6667*0*01       0.       7.677*0*0         37       1.453*4*00       7:95*1*0*0       1       3.143*0*0       -2.245*7*0*0       4.723*5*0*0       0.       4.6667*0*0       0.       1.4626**0*0         36       3.305*0*0       1.302*0*0       1       3.143*0*0       -5.670*0*0*0*0*0*0       0.       1.4626**0*0       0.       4.6667**0*0       0.       4.6667**0*0       0.       4.6667**0*0 <t< td=""><td>31</td><td>-1.A903E+00</td><td>1.76292.00</td><td>-7.68965-01</td><td>;</td><td>;.</td><td>7.61765-01</td><td>6.47305-01</td><td>3.8.446-02</td><td></td><td>0.000/C-01</td><td>0.</td><td>7.24301.00</td></t<>	31	-1.A903E+00	1.76292.00	-7.68965-01	;	;.	7.61765-01	6.47305-01	3.8.446-02		0.000/C-01	0.	7.24301.00
33       -2:586[1:00       -0:069(2:01       1:100(2:00) <td< td=""><td>32</td><td>1.288882+00</td><td>2+30458+00</td><td>8-12286-01</td><td>;</td><td>. i .</td><td>3-9-515-02</td><td>4.25 36Fen1</td><td>9.04075-01</td><td>0.</td><td>#1000/C-01</td><td></td><td>8:33005401</td></td<>	32	1.288882+00	2+30458+00	8-12286-01	;	. i .	3-9-515-02	4.25 36Fen1	9.04075-01	0.	#1000/C-01		8:33005401
36       2.94032*00       2.28542*01       1       1       5.2729*01       3.0102*00       7.53612*01       0.       5.66672*01       0.       3.787972*0         35       2.10852*00       7.6516*01       9.10512*01       1       2.37474*01       7.7356*01       0.       5.66672*01       0.       3.66672*01       0.       2.08944*0         36       9.05572*01       -2.24741*00       9.10742*04*02       9.05512*01       #1.756*01       0.       6.66672*01       0.       9.75772*00         37       1.45342*00       -1.07537*00       1       1.311432*01       -8.24572*01       4.72322*01       0.       2.00002*00       0.       1.42662*0         36       *3.0507*01       J*6334*00       1       1.56701*01       7.95467*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       0.       4.66672*01       <	33	-2+58612+00	-4-08695-01	1-14042-00	î	i	7+4509E-01	1.46958-01	-6.5057F-01	0.	6.6567Fent	0.	3141322400
35       2:1085C*00       7:581+C*01       9:107E*01       1       2:3747E*01       7:7185E*01       -3:0786*01       0:       6:6672*01       0:       2:0894E*0         36       9:6557C=01       -2:2444:00       7:17165E*01       -3:0786*01       0:       4:66672*01       0:       4:66672*01       0:       9:77772*0         37       1:4534E*00       7:1952E*01       3:1143E*01       8:2457*01       4:7732E*01       0:       2:0000E*00       0:       1:42662*01         36       -3:3059E*01       3:0320E*01       1       3:1143E*01       -7:3990E*01       4:6667E*01       0:       4:6648E*00       0:       4:6492E*00       1:       -5:2150E*01       3:2557E*01       3:2057E*01       0:       4:6667E*01       0:       4:6482E*00       0:       1:       -4:692E*01       3:2552E*01       3:2552E*01       3:2552E*01       0:       0:       4:6667E*01       0:       3:3322E*01       0:       4:667E*01       0:       4:645E*00       0:       3:3322E*01       0:       5:6679E*01       0:       0:3322E	34	2.9403E+0U	2+28542-01	2.8432E-01	ĩ	i	5.2729E-01	3-92105-01	7.53816-01	0.	A.66675-01	0.	3.87495-03
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	35	2+1085E+00	7+681+E-01	9.1u31E-0]	1	ĩ	2.34745-01	7.7185E-01	-5.9088E-01	<b>5</b> .	6.66678-01	6.	2.08445+00
37       1.45345*00       71.95516*01       71.32965*00       1       311432*01       -0.24575*01       4.72325*01       0.       2*00005*00       0.       1*42665*0         36       73.0595*01       2*45255*01       0.       1*50325*00       1       -5*67015*01       7*9306*01       2*10595*01       0.       4*66675*01       0.       4*51355*0         39       *4.98365*01       1.55526*01       1       1*3:5526*01       9.39545*01       0.       4*66675*01       0.       4*64855*0         40       1.63395*00       1.55595*01       1       1*3:5526*01       7:55485*01       0.       4*66675*01       0.       4*64855*0         40       1.63395*00       1.55595*01       1       1*5:2159*01       7:55485*01       0.       4*66675*01       0.       4*6485*0         41       2*43295*01       1*7:5155*01       3*2557*01       0.2565*01       0.       4*66675*01       0.       1*68545*0         42       2*1642*00       1*2550*01       1       1*7:7972*01       2*0586*01       0.       4*66675*01       0.       3*97535*0         43       9*1025*01       1*36965*00       1       1*7:7972*01       7:6355*01       0.       4*66675*01       0.	36	-9.8557E-01	-2.24941.00	-2+1474E-01	1	Ì	7-42946-02	9+0561E-01	-4+1756E-01	0.	6+66678-01	0.	0.7677F+00
36       -3.30501-01       3.4801[-01       1.3503E*00       1       1       -5.4701[-01       7.9930[E=01       -2.1959E*01       0.       4.6667E*01       0.       3.3221E*01       7.5448E*01       1.4719E*01       0.       6.6667E*01       0.       3.3221E*01       7.5448E*01       0.       6.6667E*01       0.       4.6685E*02       0.       1.8322E*01       7.5448E*01       0.       6.6667E*01       0.       4.6685E*02       0.       1.8322E*02       1.2515E*01       1.4692E*01       3.2557E*01       6.2667E*01       0.       1.8636E*00       1.8332E*02       1.8636E*01       0.       6.6667E*01       0.       1.8636E*02       1.2515E*01       1.46936E*00       1.1       1.46936E*01       3.2557E*01       0.       2.0000E*00       0.       1.8636E*00       1.8336E*02       1.9797E*01       3.2752E*01       1.1       1.87972E*01       3.2655E*01       0.       3.6667E*01       0.       3.752E*01       4.6667E*01       0.       3.752E*02       4.6667E*01       0.       3.752E*02 <td>37</td> <td>1.45348.00</td> <td>-1.95516-01</td> <td>-1-3294E+00</td> <td>1</td> <td>1</td> <td>3+1143E-01</td> <td>-8.2457E-01</td> <td>4.7232E-01</td> <td>0.</td> <td>2+0000E+00</td> <td>0.</td> <td>1.42662+00</td>	37	1.45348.00	-1.95516-01	-1-3294E+00	1	1	3+1143E-01	-8.2457E-01	4.7232E-01	0.	2+0000E+00	0.	1.42662+00
39 44.9830E-01 -5.4525E-01 3.0220E-01 1 1 -3.55287-01 9.1949E-01 1.67197-01 0. 6.6667E-01 0. 4.6485E-0 40 1.6339E-00 1.54597E-01 -1.4439E+00 1 1 -3.51587E-01 7.5548E-01 -3.9849F-01 0. 6.6667E-01 0. 3.32224-0 41 2.4329E-01 -1.7115E-00 2.4440E+00 1 1 -4.6928E-01 3.2537E-01 0.2058E-01 0. 6.6667E-01 0. 1.8854E-0 42 2.1842E+00 1.225UE+00 -3.8593E-01 1 1 -7.7972F-01 -2.0058E-01 -5.4313E-01 0. 2.0000E+00 0. 2.4112E-0 43 -9.1702E-01 1.330E+00 -3.8593E-01 1 1 -7.1542E+02 6.0788E-02 -9.9544E-01 0. 6.6667E-01 0. 9.3307E+0 44 -2.1979E+00 -5.4575E-01 -2.7525E-01 1 1 -7.1542E+02 6.0788E+02 -9.9544E-01 0. 6.6667E-01 0. 9.3307E+0 45 9.6033E+02 -1.330E+00 -1.713E+00 1 1 5.9268E+01 8.1199E-02 -6.552E-02 0. 6.6667E-01 0. 8.4603E+00 46 -1.4230E+00 -1.3614E+00 1.1713E+00 1 1 5.9268E+01 0.8794E+01 0. 6.6667E+01 0. 6.3534E+00 47 7.1920E+01 1.3139E+00 2.2804E+00 1 1 1.6077E+01 -9.3548E+01 0. 2.0000E+00 0. 6.16457E+01 0. 6.15344E+00 47 7.990E+01 1.5414E+00 1. 1 1.0077E+01 -9.3548E+01 0. 4.6667E+01 0. 6.10457E+01 0. 6.16454E+00 47 7.990E+01 1.5414E+00 1 1 1.9077E+01 -9.3548E+01 0. 4.6667E+01 0. 6.16457E+01 0. 6.15344E+00 47 7.990E+01 1.54240E+00 1 1 1.9278E+02 0. 4.23676E+01 0. 4.6667E+01 0. 6.16454E+00 47 7.990E+01 1.54240E+00 1. 1 1.9278E+02 0. 4.23548E+01 0. 4.6667E+01 0. 6.16457E+01 0. 6.16454E+00 47 7.990E+01 1.54240E+00 1 1 1.9278E+00 1 4.23954E+01 0. 4.6667E+01 0. 6.16457E+01 0. 6.16454E+00 48 9.93912E+01 1.54240E+00 1 1 1.9278E+00 1. 1 1.0077E+01 -9.3548E+01 0. 4.6667E+01 0. 6.16454E+00 49 9.93912E+01 1.54240E+00 1 1 1.2778E+00 1. 1 1.0077E+01 -9.3548E+01 0. 4.6667E+01 0. 7.8534E+00 40 9.93912E+01 1.54240E+00 1 1 1.2778E+00 1. 1 1.0077E+01 -9.3548E+01 0. 4.6667E+00 0. 7.8534E+00 40 9.93912E+01 1.54240E+00 1 1 1.2778E+00 1. 1.2778E+00 0. 4.2774E+00 0. 4.6667E+00 0. 7.8534E+00 40 9.93912E+01 1.54240E+00 1 1 1.2778E+00 0. 4.23548E+01 0. 4.24578E+00 0. 7.8534E+00 40 9.83912E+01 0.5462912+01 0. 7.878E+00 40 9.83912E+01 0.5462902	36	-3-3059E-01	8+6801E=01	1+3503E+00	1	1.	-5+6701F-01	7.9390E-01	-2-1959E-01	Q.	4+6667E-01	0.	A.5)85E-01
40 1.03301.00 1.54591.01 -1.94398.00 1 1 -5:21501.01 7.55488.01 -3.98491.01 0. 6.46671.01 0. 3.33221.00 41 2.03291.01 -1.71051.00 2.04600.00 1 1 -4.69280.01 3.25570.01 0.2006.01 0. 6.66671.01 0. 1.08540.00 42 2.15622.00 1.22501.00 -3.65931.01 1 1 -7.9727.01 -2.00580.01 -5.93131.01 0. 2.00000.00 0. 2.4122.00 43 -9.1022.01 1.33301.00 1 1.560391.01 7.56310.01 -3.3655.01 0. 6.66671.01 0. 2.40122.00 44 -2.19791.00 -5.45750.01 -2.75250.01 1 1 -7.35427.02 6.07880.02 0. 95440.01 0. 6.66670.01 0. 3.77527.0 45 9.60431.02 -1.33000.01 -2.75250.01 1 1 -7.45427.02 6.07880.02 0. 95440.00 0. 4.66677.01 0. 9.377527.0 45 9.60431.02 -1.33000.01 -7.7135.01 1 1 -5480680.01 8.11492.01 -6.55520.02 0. 4.66677.01 0. 8.40030.00 46 -1.92300.00 -1.36100.01 1.1130.00 1 1 5.40080.01 8.11492.01 -6.55520.02 0. 4.66670.01 0. 8.40030.00 47 7.99000.01 1.31390.00 2.20000.01 1 1.27760.01 9.35480.01 0. 2.00000.00 0. 4.10400.00 47 7.99000.01 1.31390.00 2.20000.01 1 1.27760.01 9.35480.01 3.38710.01 0. 4.646470.01 0. 8.10400.00 47 7.99000.01 1.31390.00 2.20000.01 1 1.27760.01 9.75480.01 0. 4.64670.00 0. 4.104000.00 48 9.40930.00 0. 4.104000000000000000000000000000	24	-4-90302-01	*5+4525E=01	3.0550E-01	1	1 -	3-5528F-01	9.19548-01	1-67198-01	Q.,	6+6667E=Q1	ũ.,	4+64#5E-Q4
*1       2×32***********************************	<b>1</b> 0	1.63346.00	1+5454E-01	-1-44395+00	1	1.	S.2150E-01	7+54+8E-01	-3.98495-01	0.	6-6667E-01	0.	3+33228+02
43 -9.7102E-01 1.3302E*00 -3.6593E*01 1 1 -7.7972F*01 -2.0058E*01 -5.913E*01 0. 2.0000E*00 0. 2.4112E*0. 43 -9.7102E*01 1.3302E*00 -3.6575E*01 -2.7525E*01 1 1 -7.5542E*02 6.0788E*02 -9.9544E*01 0. 6.6667E*01 0. 3.9753E*0 44 -2.1979E*00 -3.4575E*01 -2.7525E*01 1 1 -7.5542E*02 6.0788E*02 -9.9544E*01 0. 6.6667E*01 0. 9.3307E*0 45 9.6043E*02 -1.3306*00 -3.7713E*00 1 1 -5.4068E*01 8.1149E*01 -6.552E*02 0. 6.66647E*01 0. 8.4603E*0 46 -1.4230E*00 -1.3614E*00 1.1713E*00 1 1 5.42068E*01 8.0199E*01 4.1869E*01 0. 6.66647E*01 0. 6.3534E*0 47 7.1900E*01 1.3139E*00 2.2804E*00 1 1 1:0077E*01 -9.3548E*01 3.3871E*01 0. 6.46647E*01 0. 6.1044E*0 47 7.49019E*01 1.54291E*01 0.2804E*00 1 1 1:0077E*01 4.2306*01 0. 3.871E*01 0. 6.46467E*01 0. 6.1044E*0	71	2+43242-01	-1+/1056-00	2+0++0E+00	1	1-	4+6928E-01	3+2557E=01	8.2084E-01	0.	6-6667E-01	Ŭ.	1.8854E-01
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45 9.6032 02 -1.3906F*00 -3.7713E*00 1 1 -54394E*02 6.0789E*02 -67.9544E*01 0.		-2.1979F+00	-5.45755 whi	1-31046-00		1	2-20344-01	1+2031E=01	-3+3645E-01	<b>q</b> .	6.6667E-01	Q •	3+97538-01
46 -1.423DE+00 -1.3610E+00 1.113E+00 1 1.57864001 0.87926E+01 0.869E+01 0. 0.46667E+01 0. 0.43534E+0 47 7.990E+01 1.3139E+00 2.2006E+00 1 1.10077E+01 -9.3548E+01 3.3871E+01 0. 2.0000E+00 0. 0.1046E+0 48 0.7819E+01 5.4291E+01 1.2948E+00 1 1.2786E+01 0.3548E+01 0.4704E+01 0. 0.44467E+01 0.8794E+00 0. 0.1046E+00	45	9.60836-02	=1+3906F+00	-2-13232-01	;		50-13PCL-1	010100E-02	-y, Y344E-01	G.	4.6667E-01	0.	9.3307E-01
47 7.1900E-01 1.3139E+00 2.2804E+00 1 1 1:0077E-01 9.3548E-01 3.3871E-01 0. 2.000E+00 0. 4.1648E-0 48 8.9819E-01 5.6291E-01 1.2948E+00 1 1 1:2766E-01 4.2396E-01 0. 4.6467F-01 0. 4.1648E-0	46	-1.9230E+00	#1+3618E+un	1.17136.00	î	- † 1	\$-0384E-^\	0011972401 A-87015-41	-1043332E=0Z		0+6667E=01	0.	#+4003E+00
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49 5+4211E-01 -1+4588E-01 4+3039E-01 1 1 -9+5503E-01 2+0018E-01 2+1876E-01 0+ 4+247E-01 0+	49	5+4211E-01	-1+4588E-01	4-3039E-01	ī	- i -	9-55035-01	2.00185-01	2.1874F-01	<b>0</b> .	4.4447E-A1	<b>NI</b>	##1/#95.400
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SOURCE ND. 7	TIME CUTOFF 1+0000E+02	WEIGHT CUTOFF 1+0000E=04	RUN TIME 2+000000+00	PRINT CYCLI 25000	E DUMP C 2500	Ycle 0	DUMP NO.	CUTOFF CYCLE
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NUMBER OF NEUTRONS STANTED 2793	TOTAL NUMBER OF COLLISIONS 128717	Random Numbers Genemated 1307597	TOTAL WEIGHT STAH 1E11 2+8247E+03	TOTAL ENERGY STARTED T+2182E+03	COLLISIONS PEH NEUTHON STANTED +.6086E+01	TRACKS PEH NEUTRON STARTED 4+4726E+00	NEUTRONS PROCESSED PER MINUTE 1.5691E+93	
TOTAL TRACKS Started 12492	LOSS TO Energy Cutoff 0	LOSS TO TIME Cutoff 4710	LOSS TO WEIGHT CUTOFF 22	LOSS TO Escape 1396	LDSS TO SPLITTING 6264	TOTAL THACKS LOST 12492	·	
WEIGHT Started Per Neutron 1+0099E+00	LOSS TO Energy Cutoff 0+	LOSS 70 TIME CUTOFF 7.3707E~01	LOSS 70 WEIGHT Cutoff 3-1045E+07	LOSS TO ESCAPC 2+J2J7E-DJ	LOSS TO CAPTURE 3+6311E=02	VEIGHT Lost Per Neutron 1-0058E+00	•	
ENERGY Started Per Neuthon 2.5844E+00	LOSS TO Fnergy Cutoff 0+	LOSS 10 Time Cutoff 8+02108-05	LOSS TO WEIGHT CUTOFF 4.6648E=11	LD35 To ESCAPE 7.42635-01	LOSS TO CAPTURE 7.00525-02			

TIME	0.	1.0	000E+US						
COSINE	1+0	0002+00 11.00	300E-01						
		•	SUHFACE	10			SURFACE	11	
ENENG	•	- 10 + H	EL. ERROR	+ TO - 1	EL. ERROR	- TO + RE	L. ERROR	• TQ =	REL. ERROR
1.00002-	-02	0+04r20E=04	.18409	3.275332-05	.71436	1.72269E-03	+42585	0.	0.0000
5 0000E	- 00	1.200478-03	,12061	7.63787E-05	.302+0	2.62339E-03	.30918	0.	0.0000
1-60006	-00	4.441775-04	.19068	1.38381E-05	.70686	3.02173E-03	.33410	0.	9.00003
		49307116-04	.23534	0,081042-00	*AAA45	2.99431F-03	.31288	0.	8.0000
E ME HE	~	- 10	SURFACE	14					
1 00005		- 10 + H	C. EHRUR	+ 10 - 1	EL. ERRON				
1.00000		1.54040F-05	.19691	0.	0.00000				
5.00000		5	.10040	0.	0.00000				
1.4000F	• 0 1	A. 14/326-02	10920	<b>.</b>	0.00000				
		403400EF-0E	110030	v.	0.00000				
COSINE	8.00	006-01 6.00	005-01						
			SURFACE	10			SUDEACE		
ENERGY	Y	- 10 + 84	1 . CPHOP	• TO - 1	CL . CD000	- 70 - 0-	JUNFALL		
1.00001-	-07	3.805341-04	.22042	2.677245405		1 334635-03	L+ ERRUR	• 10 •	HEL. EHRON
1.0000E	+00	7.00349F-04	12079	7.909855-05	30169	1.067345-03	- 36 384		0.00000
5.0000E4	+00	2.51 JUBE-04	19941	2.083335-05	.7.444	5-926605-04	42764		0.00000
1.4000E4	+01	9.4/49HF-05	. 57+ 19	0.	0.0000	3.760485-04			0.00000
			SUPEACE	14	0.00000	31104005-04	102131	<b>V</b> •	0.00000
ENERGI	Y	- IQ + HE	TA FRHOH	· · · · ·	51. 50000				
1.0000F-	-07	3.302485 03	40541	n. 10 - 1					
1.00005.	• 0 0	1.7-0425-02	.14830	0.	0.00000				
5.0000E.	00	1.15148F-02	20286	0.	0.00000				
1.40U0E+	1	9.806225-03	.22065	0.	6 66466				
	••				0.00000				
COSINE	6.00	002-01 4.00	00E-01						
			SURFACE	10			SUDTACE		
ENERGY	r	- 10 + HF	L. FRHOR	• 10 - 4			JUNFALL	** . TO	
1.0000E-	02	2.577738-04	.22068	3.05795F=05	.70348	A. 02655F+0A	. 30464	. · · · · · · · · · · · · · · · · · · ·	RELO ERRUR
1.0000£+	00	3.749505.04	16514	8.54080F=05	28883	8-166185-04	. 33863	0.	0.00000
5.ngug£+	00	1.06195E-04	.22525	2.10906E-05	.57751	1.962598-04	23606	0.	0.00000
1.AUUOF+	01	4.24+396-05	.40801	6.56115E-06	.99982	4-244155-05		<u>.</u>	0.00000
			SURFACE	14		***************************************			0100000
ENEHGY	1	- IO + HE	L. ERHON	- + TO - H	EL. ERHOR				
1.0000E-	-02	1.833702-03	.55791	0.	0.00000				
1.00008.*	90	6.203172-03	.26830	0.	0.00000				
5.00u0E+	00	1+01069E-03	.37789	0.	0.00000				
1.4U00E+	01	3.435486-03	.46744	0.	0.00000				
COZINE	4.00	00E-01 2.00	00E-01						
-		<b>*</b> •	SURFACE	10 _			SURFACE	11	
ENENGT		- 10 + RE	L. ERROR	• TO - R	EL. ERHOR	- TO + REI	. ERROR	• To =	REL. ERROR
1.000000	02	9.30725E +05	.40174	2.17466E-05	.57715	9.64017E-05	•41393	0.	0.00800
E const.	00	5+14+04E-04	.23749	4.16984E=05	++1116	1.52330E-04	+28282	0.	0.00000
3.00000	00	3.301455-05	.44/28	1.94136E-05	.57751	4.26305E-05	<b>.</b> 4082 <b>8</b>	0.	0.00000
1.40000.4	01	0+100105-00	* AAANS	0.	0.00000	6.70070E-06	•9998Z	0.	0.00080
ENL JOY	,	~ to	SURFACE	14					
1 BURGE			L. ERHOR	• 10 - R	EL. ERNOR				
1.00000	02	7.150105-04	• <b>99982</b>	<b>0</b> .	0.00000				
5-000000		A. 730705-04	.999482	0.	0.00000				
1.400024	00	4+137385°U4	./058/	0.	0.00000				
1040000	•1	••	0.00000	••	0.00000				
COSINE	2.00	00F=01 0.							
		••••		•-					
ENLUGY	,	- 10 - 86	SURFACE	10	F. 59000	- 10	SURFACE	11 . 70 -	
1.00005-		A.788315-06		# 07677E-05	57076	- 10 + HE	Le ERRUR		RELS ERROR
1.000000		A. /43105-05	272177	3.030/72-05	67020	1.472/72-04	+03074		0.0000
S-0000E*		1.996025-43	*JEE11 \$7836	J 36919112903	100100	3.408175-05	++0013	v.	V+U0000
1.40005-		14104652-03	.3/020	1.33711E-06		5+04011F=03	60000	<b>V</b> •	0.00000
		••	SUBEACE	14	******	<b>U</b> •	410004	V.	0.00000
ENF RGY	1	- IO + HF	L. FRROR	• TO • 4	FI . FRHOR				
1.00005-	02	0.	0.00000	0.	0.00000				
1.00005.	00	A.	0.00000	0.	0.00000				
5.00005.	00	0.	0.00000	0.	0.00000				
1.4000F+	01	0.	0.00000	<b>.</b>	0.00000				
	-	-		**					

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NUMBER OF NEUTHONS CHOSSING SUPFACE

FLUX	INTEGRATE	D OVEH SURFAC	E
TIME	0.	2.0	0U0E+01
		SUNFACE	RELATIVE
E١	ERGY	17	ERROR
1.00	000E-02	1.67786E-02	.39955
1.00	00E+00	6.54114E-0Z	,19609
5.00	00E+00	1.57087E-02	.25210
1.40	00E+01	1.360028-02	.33819
TIME	2.00	00E+01 4.0	000E+01
		SURFACE	HELATIVE
E!	VERGY	17	ERROR
1.00	00E-02	6.40735E-03	.53957
1.00	00E+00	0.	0.00000
5.00	006+300	0.	0,00000
1.40	000E+01	0.	0.00000
TIME	A 00		0005+01
1196	4.00	SUNEARE	USI ATTUS
	ICHOY	JUNFALL	FDBAB
		3-445005-44	- 00083
1.00		20403996-04	0.00000
5.00		0.	0.00000
1.40	0002+00	0.	0.00000
	0002.002		
TIME	6.00	00E+01 8.0	000E+01
		SURFACE	HELATIVE
E1	NEHGY	47	ERHOR
1.0	000E-02	9.76102E-04	• 79258
1.0	000E+00	0.	0.00000
5.0	000E+00	0.	0.00000
1.4	000E+01	0.	0,00000
TIME	8.00	00E+01 1+0	20+3000
		SURFACE	RELATIVE
E	NERGY	17	ERROR
1+0	000E-02	1.090476-03	•9 <b>99</b> 82
1.0	000E+00	0.	0.00000
5.0	U00E+00	0.	0.00000
1.4	000E+01	0.	0.00000

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PATH LEN	@TH/VC	UME	
TIME	٥.		1.0000E+01
		CELL	RELATIVE
ENERG	۲	3	ERROR
30000E	-01	6.82189E	-04 .09909
5.0000E	-01	7+00233E	-09114
1.0000E	+00	3.423155	-04 ,10993
5.0000E	•00	3.53245E	-04 .11597
1.4000E	+01	2.167398	-04 .14486
TIME	1.00	00E+01	2+0000F+01
		CELL	RELATIVE
ENE.HG	۲	3	ERROR
1.0000E	-01	1.53JZ7E	-04 .15)91
5.0000E	-01	Ū•	0.00000
1.0000E	•00	0.	0.0000.0
5.0000E	+00	0.	0.00000
1.4000E	•01	0•	0.00000
TIME	5.00	00E+01	4.0000F+01
		CELL	HELATIVE
ENERG	Y	3	ERROR
1.0000E	-01	1.489716	-04 .15458
5.0000E	-01	0.	0.0000
1.0000E	+00	0.	0.00000
5.0000E	•00	0.	0.00000
1.4000E	•01	0 •	0.00000
TIME	4.00	00E+01	1.0000F+02
		CËLL	RELATIVE
ENERG	Y	3	ERROR
1.0000E	-01	4.01099E	-04 .11924
5.0000E	-01	0.	0.0000
1.0000E	+00	0.	0.0000
5.0000E	+00	0.	0.0000
1.4000E	+01	0 •	0.0000

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CAPTURES	5						FLUX A	I DETEC	TOR	
ENERLY	٥.	1.0	00003				TIME	٥.	2.0	000E+01
2		CLLI.	HELATIVE	CELL	RELATIVE				DETECTOR	HELATIVE
TIME		•	ERROR	5	ERRON		ENE	RGY	1	ERHOR
1.0000E	+01	7.74J62E-05	.04317	•.15080E-05	.06389		1.000	0E-02	5.21+228-07	.33477
2.0000E	+01	1.25505E-04	.03709	1.43805E-04	.05488		1.000	DE+00	1.140672-05	.09099
4.0000F	+01	2.50417E-04	.03549	2.87100E-04	.05172		5.000	DE+00	8.87375E-06	.07868
1.0000E	+02	6.10019E-04	.03401	7.21740E-04	+0+661		1.400	0£+01	1.01085E-00	·11768
ENENGY	1.0	000E-03 1.0	0000E-01				TIME	2.0	000E+01 +.4	000F+01
		CELL	RELATIVE	CELL	RELATIVE				DETECTON	RELATIVE
TIME		4	ERROR	5	ERHOR		ENE	NGY	1	ERROR
1.0000E	E+01	4.51243E-05	.03074	5.31591E"05	+0+237		1.000	0E-02	1.10J77E-06	.24219
2.0000E	E+01	2.57366E 06	.15294	2.26343E=05	.17365		1.000	0E+00	5.94024E*00	.84533
4.0000E	E+01	9.721535-08	.39414	5.054352-07	•36423	•	5.000	0E+00	0.	0.00000
1.0V00E	502	4.48714E-08	.65227	0.	0-00000		1+400	0E+01	0.	0,00000
ENERGY	1.0	0008-01 1.0	00005+00				TIME	4.0	000E+01 1.0	20+3000
		CËLL	RELATIVE	CELL	RELATIVE			•	DETECTOR	PELATIVE
TIME		4	ERHOR	5	ERHOR		ENE	RGY	1	ERROR
1.0000E	E+01	3.47684Er 05	.03068	4,43384E-05	.04616		1+000	0E-02	5.36296E-06	.14431
Z.0000E	E+01	0.	0.00000	0.	0.00000		1.000	0E+00	7.28014E-12	.67615
4.0000E	+01	0.	0.00000	0.	0.00000		5.000	0E+00	0.	0.00000
1.0000E	E+02	0.	0.00000	0.	0.00000	•	1.400	0E+01	0.	0.00000
ENERGY	1.0	000E+00 1.4	+000F+01							
		CELL	HELATIVE	CELL	RELATIVE					
TIME		4	ERROR	5	ERROR		•			
1.00005	• 01	1.73172E-04	.17808	2,538995-04	.38486					
2.00008	E+01	0.	0.00000	۹.	0.00000					
4.0U00E	E+01	0.	0.00000	0.	0.00000					
1.00005	E+02	0.	0.00000	0.	0.00000					
*******				**********	*********	***************		*****	*******	
TAPE DUP	4P NO+	2	NP3 = 2793							

THE	F QL	LOWING	15	•	CONA	UF	DAY	FIL	E	J	0 <b>F</b> 1	AH		UP	۲u	TIM	E	12.	35.	44
12.35.	<b>5</b> 1	SHATH	00	c	Rot	1.35	. 71	204	/01	1	-	н.	14							
			•		r	APE	5-1	600	06	•										
12.35.	53	SUMTR		•4	SFH	MUN	ITOF	OF	70	1/1	0/1	6 1	INIT	TAI	14	а.				
12.35.	53	SUMTR		•1		411E1	TUP	INHA.	21/	110	UAT	E	1 1866		71/(	14/0 : Tu	3		100	
12,35.	53	SUNTR		F	ILC 1	SET	INF	5	ò	IN F	NEU		JFFE	R I	ENC	STH	=00	0010	100.	:
12.35.	53	SUNTH		۰F	TLE	SET	ĴOŁ	NIN	(	)PE	NEL	+ BL	IFFE	RI	ENC	STH	=00	0032	100	
12.35.	53	SUMTR		•F	ILL.	SE I	JOH	IN		LO	SED	• BI	FFE	RL	-EN(	атн	=00	1032	100	•
12.35.	53			."	HEAD	5	214	RIT	11C E.S	.°р	osi	110	INS	03	ISK	RUS	i (	ISK	WRS	5
12.35.	53			U	00'10	026.	00	000	000	0	000	000	0000	0	000	0000	110	0000	000	00
12.35.	53	8000		:	A		-000	000	143	33.	029	ICE	=03							<b>.</b>
		-064		₽Ľ	=50 ·	TL=	343	(n) n( (q)		L.	-0,	U.A.I				0.00	126.1	HCN	JARI	P 4
12.35.	53	+CCP		۶.	C 1H	PILE	. so	NHC	Ε.	IN	111	ATE		NO	RUP	I PH	OBL	.ЕМ.		
12.35.	53	•CCP		₹C Su	REAT	E (F:	5=00		P•(	:L*	U . P	REE	11=2	XQ	382	; <u>]</u> )				
12.35.	54	SUNTR		•F	ILF	SET	RUN	ITP	Ϊ.	)PE	NED	•BL	FFE	H I	ENC	Тн	= 0 (	032	100.	
12.35.	54	SUNTR		• F	ILE :	SĒT	QUI		C	٣Ē	NED	, BL	FFE	RI	ENC	TH	=00	032	100	•
12.35.	54	SHUN		•f	TEL II	LFL	GTH	IS		ģ	436	76								
12.35.	54	+CCP		30	0445	(1=C	CTI	TPa	) a u D = H	1UN	70 (P)	250								
12.35.	55	SUHTR		٠Ē	ILE S	SET	COL	ETP	Q	PE	NEO	. HL	FFE	RL	.E^ @	ITH	=00	032	100.	
12.35.	55	<b>SHHTH</b>		R	010	UTS	TAN	TED												
12.30	56	5HMTH 91 05		н хх	00110	01 U 23		NTE		1M		т 3					'a			
12.30.	49	SUHTH		H	0[1]1	Ñ SI	ART	ED			01					106.1	•			
12.30.	49	SHATH		H	OLLI	1 100	NF.													
12.36.	50 50	•CCP		35	ET 70	KE Y	IKKT	(P)												
12.30	50	•CCP		31	Day.	1.0	DET	P		I	NIT	IAT	Έ							
12.36.	53	INU76D	L	۰Ε	NO							_								
12,30,	53	SUNTR		• F	ILE	SET	INA	GE		1 D	NED	• 80	FFE	RL	ENG.	ТЫ	=00	064	100	•
12.30.	53			۰F	TLE	SET	STA	TIS	110	5	360						-00	1004	100.	•
12.36.	53	•		•	RE 10	s ¯	. W	RIT	Ę\$	P	usi	110	)NS	01	(SK	RDS	i (	) I SK	AN:	5
12.30.	53			.0	0000	0000	00	000	000	13	000	000	001	00	0000	1000	0 0	000	0000	04
12.30.	54	*cCP		ŝŢ	FIFA	SE	RUN	1)		3.	0	100	-03						•	
15.30	54	•CCP		۶L	ABLL	HUN	1													
12,30,	54 51	●CCP ●CCP		35	ET4() ET4),	<Υ	IKK	Pì												
12.36.	54	•CCP		ŝĹ	ngol	1=+1	INTP	5		RU	NP	кон	LEN	1						
12.38.	2	NU76EL		٠Ę	NO		• · · · •													
12.30.4	•2	SUMTR		1	11.5	551	1144	GE	2	1 D	420 560	• BU	IFFE	R L סיו	.ENG	БТН 1.Тм		064	100.	•
12.38.	ž			۰F	ILZ :	SET	STA	TIS	TIČ	ŝ	360	• •••					-00	1004	100	•
12.30.	12			•	READ	5	i i	RIT	ES	P	051	110	NS	01	L SK	RDS	i C	ISK	WR!	5
12.30.4	12			.°	0000		00	000	000 771	3.	000 nfv	100	001	00	1010	000	1 0	0000	0000	94
12.38.	¥3	CCP		\$1	F (FA	SE	TAP	E												
12.38.	63	•CCP		SL.	ABEL	TAP	E)													
12.30-	4.J	SUNTR		3A 15	r Shei Ti J	SET	RUA	ALIP ITP	s AC r	115	r=T SEn	+RL	. I 1 <b>F F</b> F	R	.ENG	ITH	=04	032	100	
12.34.	Ē			۰F	ile :	SET	STA	TIS	TIČ	S								E		•
12.34.	£4			• .	READ	s		RIT	ES	P	oSI	TIC	NS	D	SK	ROS	i 0	ISK	WR:	5
12.38.	6.J			۰.	0000	00.32	2 00	000	003	3	000 054	000	003	00	0000	000	6 0	0000	000	10
12.36-4	• 3	*ccP		ŝc			-000	015	212	i <b>q</b> 1		100	03							
12,38.	¥4	FLUSHO	F	• D	AYFI	LE P	LUS	HED	۲O	D	ISK	-	Te	1	2.3	8.4	4			

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FILE	PROGRAM	M ADDRESS		NAMED Common	ADDRESS		LCM BLOCK	ADDRESS				
RUNTP	SOURCE NU76EL	01013		G1 G2 G3 DxCom G1 G2	000100 000141 000552 000556 000100 000141		XSEC	000000				
	DRPNT	105770		63 DxCom 61 62 63	000552 000556 000100 000141 000552							
	FRN	106526		UALUM .	000550							
	FRNS	106536						•				
	IRN	106547		61 62 63	000100 000141 000552							
	Ex	106571		DACON	000228							
SYSLIB												
	BACKSP	106625									•	
	BUFFEI	106654										
		106775										
	ECSHW	107162										
	ENDFIL	197212										
	IDCHEK	10/220								•		
	LENGTH	107426										
	OUTPTC SSWTCH	137446										
	SYSTEM	107672										
	XIT ALMOD	110727									-	
	EXP	111135										
	IRAIEX	111210										
	RBAREX	111272										
	SORT	111351										
	BS4020	111427										
	C4020	112255										
	GETHA	112351										
	TOUTIL	112441										
	KODER	113732										
	LARRI	115137										
	MEMORY	116306	•									
	OUTPTS	116466										
	REMARK	116644						-				
	RETN	116670										
	SKIPR Boi	116720										
			01 6 7 1									
	UNSATI	SFIEL	HEFEN	ENCED			LOCATI	ON				
								*******			******	
	SRCDX		NU768	ί <b>ι</b> ,	002032							
SOURCE N	0.	TIME CUTOFF	WEIGHT CUTOF	F RUN TIME	PRINT CY	CLE	DUMP CY	CLE	DUMP NO.	CUTOFF	CYCLE	
7		1.0000E+02	1.0000E-04	1.0000E+01	25000		25000		0		0	
		SAM	PLE PROBLEM									
SOURCE N	0.	TIME CUTOFE	WEIGHT CUTOF	F QUN TIME	PRINT CY		DUMP CY		OUMP NO.	CUTOFF	CYCLE	
7		1.0000E+02	1.0003E-04	1,0000E+01	25000		25000		2	60.011	0	
				TTWE 11.66	A MINITES							
				1100-11000								
NUMBE	H OF	TOTAL	RANDOM	TOTAL			STONS	TRACKS	NEUTRONS			
NEUTR	ONS	NUMBER OF	NUMBERS	WEIGHT	ENERGY	PERN	EUTRON	PER NEUTRO	N PROCESSE	0		
START	ED 32	COLLISIONS	GENERATED	STARTED	STARTED	START	FD	STARTED	PER MINU	ITE		
1				1100712404	4110030104	4.033	11111	4131712-00	1.330824	43		
TOTAL		1055 70		1000 10	1050	1055		T-T-1				
TRACK	s	ENERGY	TIME	WEIGHT	10	10		TRACKS				
START	EU	CUTOFF	CUTOFF	CUTOFF	ESCAPE	SPLIT	TING	LOST				
#25	10	G	OFAOF	140	9107	417	01	02570				
	-											
WE IGH	1 FD	L055 TO	L035 TO TIME	LOSS TO WETANT	L055 T0	LOSS		WEIGHT				
PER N	EUTRON	CUTOFF	CUTOFF	CUTOFF	ESCAPE	CAPTU	RE	PER NEUTRO	N			
1.003	3E+00	٥.	7.39592-01	3.8864E-07	2.3581E-01	3.698	6E-02	1.0124E+00				
_												
ENERG	Y	LOSS TO	LOSS TO	LOSS TO	LOSS	LOSS						
PER N	EUTRON	CUTOFF	CUTOFF	CUTOFF	ESCAPE	CAPTU	IRE					
2.610	0E+00	0+	7.8911E-05	5.2616E-11	7.2201E-01	6.125	2E-02					

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NUMBER OF NEUTRONS CROSSING SURFACE

TIME	0. 1	•0000E+02				
COSINE	1+00000+10	.0000E-01				
		SURFACE	10	SURPACE	11	
ENERGY	- TO +	REL. ERROR	+ TO - REL. ERROR	- TO + REL. ERHOR		HELS CRAUR
1.00005-0	02 0.236202-0	4 +06268	1.59834E=05 .31399	1.119282-03 .12528	0.	0.00000
1.00078+1	00 1 <b>.</b> 26138E-0	3 .04664	9.02739E-05 · .12810	2,621888-03 ,10414	8.	0.00000
5.00078+1	00 8.79751F-0	4 +06758	2.70424E-05 .26311	2.768562-03 .11858	0.	0.00000
1.4000E+	01 6.70223E-0	4 .1073A	2.12789E-06 .70733	· 2,50866E-03 .10445	0.	0.00000
		SURFACE	14			
ENERGY	- 10 +	PEL . ERROR	• TO - REL . ERROR			
1.00005-	1.4.2145-0	2 .06970	0 0 00400			
1.00005+	5.226876-0	2 .03784	0 0 00000			
E 0000E +		3 43764				
1 40005+1	0.0 3.34140E-0	2 .03/3/	0. 0.00000			
1.4000240	4.53444F=0	2 .04338	0.00000			
CORTNE		00005-01				
CUTINE	200005-11 0				••	
		SURFACE	10	SURPACE	11	
FNERUY	= în +	REL. ERROR	• 10 - REL. ERROR	• TO • REL. ENROR	+ 10 +	HELS ENRUR
1.0000E-	02 4.35537E-0	4 +07289	2.13228E-05 .26110	7,542428-04 .14432	0.	0.00000
1.0000E+	00 6.9x704E-0	4 +05396	1.01401E-04 .12896	1,60258E=03 .13628	•.	9.00000
5.0000E+	00 3.4n562F-0	4 .0770R	1.60002E-05 .27449	1.11526E-03 .16463	0.	0.00000
1.4000E+	01 1.19302F-0	4 .14160	0. 0.00000	7.55346E-04 .19146	0.	0.00008
	• • • • • • •	SURFACE	14			
ENERGY	- 10 +	RFL FRROR	+ TO - REL . ERROR			
1.00005-0	3.945625-0	3 .13966	0. 0.0000			
1 000000		3 07044				
5 0000E+			0. 0.00000			
3.00002+0	1.470082-0	2 10/322	0.00300			
1.40000.40	9,341316-0	3 +08990	0. 0.00000			
CO	< 0000F-03	00005-01				
CUSINE	Programment d	*0000E=01				
		SURFACE	10	SURFACE	11 _	
ENFRGY	- TO +	REL. FAROR	• TO - REL. EAROR	- TO + PEL, ERROR	+ TO =	WEL ENHOR
1,000nE-0	2 2.779452-0	<ul><li>.08755</li></ul>	1.48791E-05 .31907	4,473698-04 .15315	0.	0.00000
1.0000E+	00 4.5100¥F-0	4 .06605	9.671362-05 .13529	6,11854E-04 ,12390	0.	0.00000
5.00001-+1	10 1.40214E-0	4 10259	1.98193E-05 .23009	4.97057E-04 .19785	0.	0.00008
1.40005+0	1 4.54624F-0	5 .20223	A.18363E+06 .50010	1.347575-04 .40370	0.	0.00040
10-000		SUDFACE	14		••	
ENEDGY		DEL SOPOD	** * TO - PEL SEPOR			
1	1 168465-4	3 33361				
1.000000-0	1.145000-0	3 •••3321	u. 0.00000.			
1.000000+0	30 3.977716-0	3 15463	0.00000			
5.000nL+0	0 3.2.1382E-0	3 +15769	0. 0.00000			
1.40002+0	)] <b>2.2/9656</b> +0	.1 •20030	0.00000			
COSINE	4.00002-01 2	*U000F=01				
		SURFACE	10	SURFACE	11	
ENERGY	- 10 +	REL. ERROR	+ TO - REL. ERROR	- TO + REL. ERROR	+ TO =	REL. ERROR
1.0000E-0	1.176198-0	4 .11828	1.441012-05 .27626	1.75729E-04 .20051	0.	0.00000
1.00005+0	2.43680F=0	4 .08524	7.216245-05 .16084	2.782535-04 .20408	9.	0.00000
5.0000E+	6.935355-0	5 .14301	- 1.85559F=05 .24844	9.466785-05 .18700	0.	0.00080
		6 .43364	5.303135-06 .44794	A. 369555-05 .80270	0.	0.00004
1.40005.40	11 44691936-0	10 143300	24305135-00 444140	4030332-03 000613		*******
		SURFACE	19			
ENENGT	- 10 -	HEL. ENRUN	+ IU - HELL EMHUR			
1.0000E-0	JZ 3.26888E-0	5 .99997	0.00000			
1.0000E+0	00 1.313758-0	3 .24521	0. 0.00000			
5.0000E+	00 5.12017E-0	4 .36596	0. 0.00000			
1.4000E+0	01 2 <b>.</b> 13511E-0	4 .70715	0. 0.00000			
COSINE	2.0000E-01 0	•				
		SURFACE	10	SURFACE	11 _	
ENERGY	- TO +	REL FRROR	+ TO - REL ERROR	- TO + REL ERROR	+ TO -	RELL ERROR
1.00005-	02 4.33162Fer	15 .16856	2.373528-05 .32858	1.76038E-04 .63524	0.	0.00000
1.000054	AA 7.338A75-/	5 .13421	4-11331E-05 -23207	1.16432E-04 .33807	0.	0.00000
R AAAAF	AA 1.84740F-4	5 .28744	8.46748F=06 .36446	3.024628-05 .28445	0.	0.00000
3.000nc+			A A A A A A A A A A A A A A A A A A A	A.788685-05 .74540	<u>.</u>	0.00000
1.40000	01 0°A1(1)E(	10 447048	ue 0+00000	4910000£-03 818300	~ •	
		SURFACE	14			
ENERGY	<del>-</del> TO +	HEL. ERROR	• TO • REL. ERROR			
1.0000E-	02 0.	0.00000	0. 0.0000			
1.0000E+	00 0.	0.00000	0. 0.00000			
5.0000F+	00 1.083345-0	4 .99997	0.00000			
1.400054	01 0.	0.00000	0. 0.00000			
********	~. ~.	******				

FLUX INTEGRATED OVER SURFACE

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TIME	۸.		0005.01
	••	EUDEACE	00000001
ENED		3047862	FOROT
1 0000	5	8 202025-42	ENHOR
1 0000		0.37392E-03	.21229
E 00000		5.20228E-02	-08590
1 40000		2.044145-02	.10444
1.40001		1.401425-02	•11777
TINE	2.00	00E+01 4.0	000E+01
		SURFACE	RELATIVE
ENER	ŝΥ	17	ERROR
1,00008	5-02	1.00435E-02	.26045
1.00001	E+00	0.	0.00000
5.0000	E+00	0.	0.00000
1.4000	E+01	0.	0.00000
TIME	4+00	00E+01 6.0	000E+01
		SURFACE	RELATIVE
FNER	37	17	ERROR
1.0000	50-3	4.77182E-03	.18832
1,00008	E+00	0.	0.00000
5.00006	+00	0.	0.00000
1.40001	E+01	D.	0.00000
THE	6.00	006+01 8+0	0006+01
		SURFACE	RELATIVE
ENERG	3Y	17	ERROR
1.0000	-02	5.23446E-03	+43527
1.0000	E+00	0.	0.00000
5.0000	+00	0.	0.00000
1.40008	+01	0.	0.00000
TIME	8.00	00E+01 1.0	0002+02
		SURFACE	PELATIVE
ENER	37	17	ERROR
1.00008	-02	3-83569E-03	.20722
1.0000	+00	<b>0</b> .	0.00000
5.00006	+00	0.	0.00000
1,40006		0.	0.00000

PATH LE	NGTH/VC	)LUME	
TIME	٥.	1	0000E+01
		CELL	RELATIVE
ENER	GY	3	ERROR
1.0000	E-01	5.92883E-0	.03818
5,0000	E-01	6.71835E-0	+ +03544
1,0000	E+00	3.79171E-0	.04026
5,0000	E+00	4.12319E-0	s .04402
1,4000	E+01	2.20469E-0	.05611
TIME	1.00	00E+01 2	,0000E+01
		CELL	RELATIVE
ENER	0Y	3	ERROR
1.0000	E-01	1.55371E+0	05980
5.0000	E-01	0.	0.00000
1.0000	E+00	0.	0.00000
5,0000	E+01	0-	0.00000
1.4000	E+01	0.	0.00000
TIME	2.00	000±+01 4	.0000E+01
		CELL	RELATIVE
FNER	GY	3	ERROR
1.0000	E-01	1.52753E+0	06584
5.0000	E-01	0.	0.00000
1.0000	E+00	0.	0.00000
5.0000	E+00	0,	0.00000
1.4000	E+01	0.	0.00000
TIME	4.00	005.+01 1	0000E+02
		CELL	RELATIVE
ENER	GY	3	ERROR
1.0000	E-01	3.942248-0	.04663
5.0000	E+01	0.	0.00000
1.0000	E+00	0.	0.00000
5.0000	E+00	0.	0.00000
1.4000	£+01	0.	0.00000

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C.(	PT	UR	FS.

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CAPTURES					FL	UX AT DE	TECTOR	
. ENFRGY	0. 1.0	000E-03			T	MF	n. 2.0	000E+01
	CELL	RELATIVE	CELL	RELATIVE			DETECTOR	RELATIVE
TIME	4	ERROR	5	ERROR		ENERGY	1	FRROR
1.0000E+0	1 7.74926E-05	.01594	8,99111E+05	.02459	1	.0000E-0	2 5.42880F-07	.13333
2.0000F+0	1 1.24729F-04	.01534	1.414R0E-04	.02244	1	.0000E+0	0 1.194375-05	-04162
4,000nE+0	1 2.42261E-04	.01443	2.78034E-04	.02048		.0000E+0	0 1.109825-05	.04251
1.00000.00	2 5.984508-04	+01413	7.14885E-04	+01854	Ĩ	.4000E+0	1 7.89015E-06	.05347
ENERGY	1.0000E-03 1.0	0000E-01			TI	ME	2.0000E+01 4.0	000E+01
	CELL	RELATIVE	CELL	RELATIVE			DETECTOR	RELATIVE
TIME	4	ERROR	5	ERROR		ENERGY	1	EDDOD
1.0000£+0	1 4.62964E-05	+01185	5.10686E-05	.01735	1	.0000E-0	2 1.60610F-0A	-10494
2.0000E+0	1 2.050256-06	.05479	2.09608E-06	.07094	1	.0000E+0	0 4.773705-08	
4.000nE+0	1 2.879248-07	.14534	3.59986E-07	.15673	•	.0000E+0	0 6.	0.00000
1.0000€+0	2 3.33184E-08	•25337	3.53650E-08	.42423	1	+4000E+0	1 0.	0.00000
ENERGY	1.0003E-01 1.0	000E+00			TI	HE	4.0000E+01 1.0	0005+02
	CELL	PELATIVE	CELL	RELATIVE		•	DETECTOR	RELATIVE
TIME	4	ERROR	5	ERROR		ENERGY	1	FORAD
1.0000E+0	1 3.93536E-05	•01196	4.363578-05	. +01B47	1	-0000E-0	2 6.374495-04	. 04330
2.0000E+0	1 0.	0.00000	ο.	0,00000	ī	.0000E+0	0 1.977925-11	43834
4.0000E+0	1 9.	0.00000	o.	0.00000		.0000F+0	0 0.	0.00000
1.0000E+0	2 0.	0.00000	<b>6.</b>	0.00000	ĩ	.4000E+0	1 0.	0.00000
ENERGY	1.0000E+00 1.4	•000E+01						
	CELL	RELATIVE	CELL	RELATIVE				
TIME	4	FRADR	5	ERROR	•			
1.0000.00+0	1 2.155528-04	•06206	2.153226-04	.12435				
2.000nE+0	1 0.	0.00000	0.	0.00000				
4.0000E+0	1 0.	0.00000	0.	0.00000				
1.00noE+0	5 0+	0.00000	0.	0.00000				
********			**************	*******	***********************************	*******	******	
TAPE DUMP	NO. 3 1	SE081 = 290			•			

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THE FO	DLLOWING IS	A COPY OF	DAYFILE	JUFIFE	UP TO TIME	16.35.44
15.43.4	3 SAMTA 00	CHOS 1.3	6 71/09/2	7 MACH. 14		
		TAPE	SY760032	!		
15.43.4	A SUMTR	.USER MON	ITOH OF 1	/0/10/16 INIT	IALIZED.	
15,43,4/	SUMTR	.JOH NAME	=TUHNHH21	FE+DATE =	71/10/01	
15.43.4	4 +004	S JOH (NAHE	#TUHNRM2	+CL=U,CAT=05	+AC=V06+US	SF#MCNSAMP+
		PL=50.TL=	1043			
15.43.4	FLUSHOF	+DAYF1LF	FLUSHED	O DISK - T	15.43.4/	•
15.43.4	S REMARK	DAYF ILF	COPIED TO	FILESET	SYSTAT	
15.43.4	SUMTR	AFILE SET	CCD	OPENED BUFFE	R LENGTH	00001100.
17.43.4		APILE SET	INP	OPENEDOBUFFE	R LENGTH	00010100.
1749349	1 <b>1</b> 000114	of LE St.	JUNIN	CLOSEDIBUPPE	R LENGTH	00032100.
17.43.44		+FILE SET	SIAILST	005.710.0	DICK DOE	
15 43 44		• FE #()3	3 000000	D PUSITIUNS	DI2M MD2	D124 #42
15 43 4		01000002		00 0000000000		000000000
15.43.4		6 L.44				
15 43 44		BCDCATE /	C-DUNTO /	U LUPY UUIPU	11 10 TAPE	
16.41.4		SCETO/NEY				1030531
15.43.4	0 accp	BLE TO INC				
16.43.4	AUDA C	SL060/1-4	11.170			
15.43.4	SUNTR	FILE SET	DUNTD	OPENED BUEER	-	
15.43.4		POLLOUT	CTAUTED	OF CHEDINOFFE	- LENGIN -	
15 47.5	CONTO	8011001	JINNE			
16.44.36.7		*******				
14.21.4	-L01 05 • CUNTD		TANTED			600 HF1.
16.23.4	REMTR	BOLLIN	ONE			
16.21.5	SUMIR	FIFSET	OUT	OPENED. BUEFE	-	00032100.
16.30.3	SONTO	POLLOUT	STANTED	0.5000000000000		
16.30.3	SONTO	POLLOUT	DONE			
16.32.30	SAMTR	ROLLINS	TARTED			
16.32.3	T SAMTA	BOILTN	ONE			
16.35.42	NUTAFL	END	0.00			
16.35.4	SUNTR	FILE SET	INAGE	OPENED BUFFE	R LENGTH	1.0064100-
16.35.4	SUMTR	FILE SET	THAGE	CLOSED+BUEFF	D I ENGTH	00064100
16.35.4		FILE SET	STATIST	ICS		
16.35.42	5	READS	WRITES	POSTTIONS	DISK RDS	DISK WRS
16.35.4		00000000	0 000000	03 00000001	00000000	00000004
16.35.4	2	. LwA	=00001471	15.DEVICE=02		
16.35.4	3 +CCP	STE LEALSE	#TAPE)	••••••		
16.35.4	3 +CCP	SLAHEL ITA	PEI			
16.35.4	A PCCP	SAF SREL (F	S=RUNTP .	DISPESTAPE P	OSHT=XX003	1023)
16.35.4	SUNTR	.FILE SET	RUNTP	CLOSED . BUFFE	R LENGTH	.0032100.
16.35.4	3	FILE SET	STATIST	CS		
16.35.4	3	. READS	WRITES	POSITIONS	DISK RDS	DISK WRS
16,35.43	3	00000003	3 000000	02 00000002	000000007	200000000
16.35.43	3	• LwA	=00001437	A3+DEVICE=03		
16,35,44	+cCP	SCOPYDF.		•		
16,35.44	FLUSHOF	.DAYFILE	FLUSHED 1	0 DISK - T=	16.35.44	•

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ALT/11:244(200)