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A GENERAL MONTE CARLO NEUTRONICS CODE

by

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ABSTRACT

A general geometry Monte Carlo code suitable for neutron penetration problems is described. A detailed description of the preparation of a problem and a complete listing of the code are included.

I. INTRODUCTION

The code MCS is a general Monte Carlo neutron shielding calculation for time-independent geometry, written in the FLOCO coding system (described in LAMS-2339) for the IBM 7090 calculator. It is capable of treating an arbitrary three-dimensional configuration of first- and second-degree surfaces, as discussed in Chapter II.

The information describing the scattering and reaction of neutrons on various nuclei may be included in the calculation in as much detail as is warranted by the experimental data, and is described in Chapter III.

Chapter IV contains a brief description of the variance-reducing techniques utilized by the code. As one is frequently concerned with the penetration of neutrons through thick shields, such techniques may be necessary to obtain statistically significant results in a reasonable amount of computing time.

A summary of the treatment of a single neutron history will be found in Chapter V, with a brief description of each formula of the calculation and some flow charts. Detailed information on the preparation of a problem will be found in Chapter VI, while Chapter VII treats the mechanics of running a problem on the computer.

A problem of frequent interest is the determination of the spatial distribution of some nuclear reaction for a given neutron source in a given configuration of materials. Two methods of estimating the solution of such problems with the Monte Carlo code are described in Chapter VIII.

Appendix A defines the various parameters used by the code, and Appendix B describes the necessary data blocks. Appendix C describes the form in which the nuclear data is presented to the code. A list defining the order in which the various parameters and formula sets of the code must be loaded is in Appendix D, together with a complete listing of the code. Appendix E is similar in form to Appendix D but deals with the initiating code -- used in the preparation of a problem. Appendix F describes the reaction code MCR used with the Monte Carlo MCS; and Appendix G lists the changes in parameters, card loading, and code in the reaction variant to the Monte Carlo described in Chapter VIII.

The basic units utilized by the code are:

lengths in centimeters

times in shakes (1 shake = 10^{-8} sec.)

energies in Mev

The notation C(XX) = [contents of the core location designated XX by FLOCO] is used throughout.

II. TREATMENT OF THE GEOMETRY

The code is designed to handle an arbitrary three-dimensional configuration of first- and second-degree surfaces. The region of space under consideration is subdivided by these surfaces into a number of cells, in each of which the material properties -- isotopic composition and density -- and the neutron importance (see Chapter IV, below) are assumed to be constant. Allowance has been made for at most 432 surfaces and 2048 cells.

The surfaces of a problem are numbered consecutively $j = 1, 2, \ldots, J$, where $J(\leq 432)$ is the total number of surfaces in the problem. The surface type for each surface is specified by a parameter κ:

$\kappa = 1$: spherical surface centered at $(\bar{x},\bar{y},\bar{z})$ with radius d:

$$\sum_j(\vec{r}) = (x - \bar{x})^2 + (y - \bar{y})^2 + (z - \bar{z})^2 - d^2 = 0$$

$\kappa = 2$: plane surface:

$$\sum_j(\vec{r}) = Ax + By + Cz + D = 0$$

$\kappa = 3$: cylindrical surface with generators parallel to the y-axis, center at $(\bar{x},\bar{0},\bar{z})$, radius d:

$$\sum_j(\vec{r}) = (x - \bar{x})^2 + (z - \bar{z})^2 - d^2 = 0$$

$\kappa = 4$: cylindrical surface with generators parallel to the x-axis, center at $(\bar{0},\bar{y},\bar{z})$, radius d:

$$\sum_j(\vec{r}) = (y - \bar{y})^2 + (z - \bar{z})^2 - d^2 = 0$$

$\kappa = 5$: cylindrical surface with generators parallel to the z-axis, center at $(\bar{x},\bar{y},\bar{0})$, radius d:

$$\sum_j(\vec{r}) = (x - \bar{x})^2 + (y - \bar{y})^2 - d^2 = 0$$

$\kappa = 6$: reflecting plane (see below):

$$\sum_j(\vec{r}) = Ax + By + Cz + D = 0$$

$\kappa = 7$: special quadratic surface:

$$\sum_j(\vec{r}) = A(x - \bar{x})^2 + B(y - \bar{y})^2 + C(z - \bar{z})^2 + 2D(x - \bar{x}) + 2E(y - \bar{y}) + 2F(z - \bar{z}) + G = 0$$

$\kappa = 8$: general quadratic surface:

$$\sum_j(\vec{r}) = Ax^2 + By^2 + Cz^2 + Dxy + Eyz + Fzx + Gx + Hy + Jz + K = 0$$

In all the surface equations, $\vec{r} = (x,y,z)$ is a point on the surface being considered.

If the geometry of the problem possesses complete reflection symmetry in some plane, the specification of the problem may be simplified by defining that plane to be a reflecting plane ($\kappa = 6$, above). A neutron attempting to cross such a reflecting plane will find its trajectory specularly reflected in the plane.

The cells of a problem are numbered consecutively a = 1, 2, ..., A, where A($\leq$ 2048) is the total number of cells. A cell is defined by specifying its bounding surfaces and the sense of the cell with respect to each such surface.

The sense of a point $\vec{R}$ with respect to a surface j is defined to be the sign of $\sum_j(\vec{R})$, where $\sum_j(\vec{r}) = 0$ is the equation of the surface. The sense of a cell with respect to a bounding surface is defined to be the sense of all points in the cell with respect to that surface. For this definition to be unique it is necessary that cells and surfaces be so specified that every point in a cell have the same sense with respect to each surface bounding the cell.

This requirement of uniqueness frequently necessitates the specification of more cells and/or surfaces than considerations of the material configuration alone would require. For example, the configuration of materials illustrated in Figure 1a below does not lead to a unique sense for cell (1) with respect to its bounding surfaces (5) and (6). To obtain the necessary uniqueness, one may add a cell (3) (as in Figure 1b)

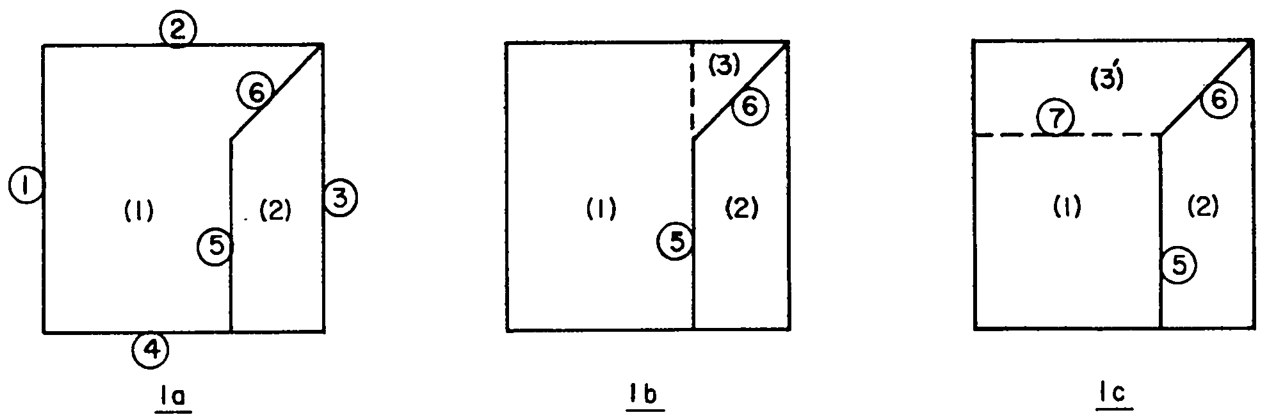


Fig. 1 - Cell (1) ambiguous with respect to surfaces (5) and (6). Surface numbers encircled (j); cell numbers in parentheses (a). Figures are plane figures.

or one may add both a cell (3') and a surface (7) (as in Figure 1c).

Some other examples of the ambiguities which can occur in the specification of a problem are illustrated in Figure 2. In Figure 2a, the ambiguity is due to every point in cell (2) having the same sense with respect to the surfaces bounding cell (3) as does every point in cell (3). Thus a neutron emerging from cell (1) cannot discriminate between cells (2) and (3). Figure 2b illustrates the analogous situation of the ambiguity with regard to the two sheets of a cone. Ambiguities of this class may be resolved by including in the specification of each such ambiguously defined cell an additional, non-bounding surface -- usually a plane -- such that the members of an ambiguously related pair will have opposite senses with respect to this added surface. Thus in Figure 2a, the addition of surface (5) to the specification of cells (2) and (3) removes the ambiguity in their definition. Similarly, the addition of surface (2) in Figure 2b uniquely separates the two sheets of surface (1) and so removes the ambiguity between cells (1) and (2). Such a non-bounding surface for a cell (a) is said to be an "<u>ambiguity surface</u>" for that cell.

An additional feature of the code which is often useful is the provision for tallying various quantities of interest whenever a neutron crosses a specified surface or whenever a collision occurs in a specified cell. Usage of this feature simplifies the accumulation of flux distributions, collision densities, and the like. The formula for accumulating the quantity of interest must be provided by the user and is to be given a formula number from the set F860 to F876, inclusive. The desired

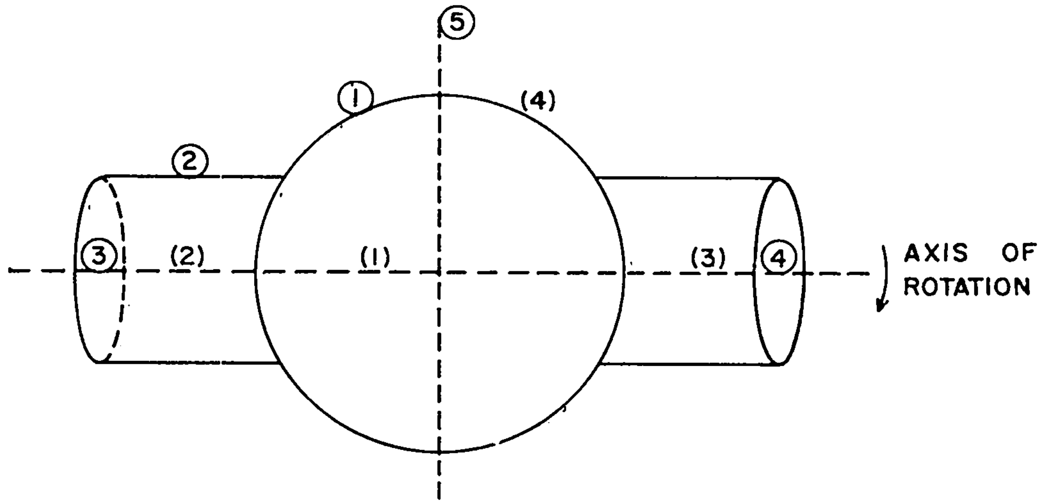


FIG. 2a

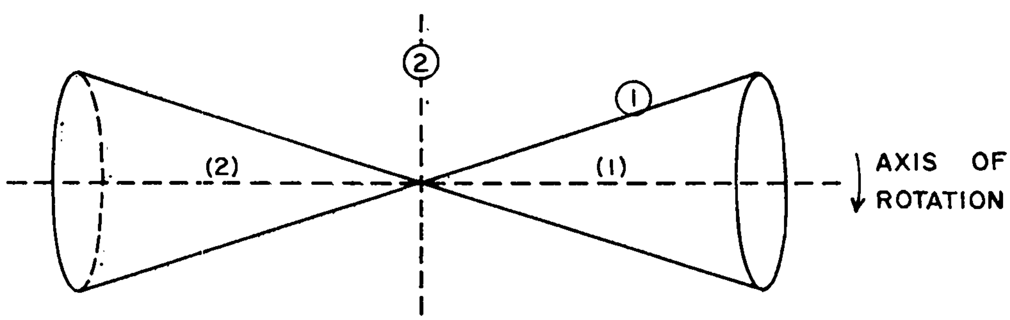


FIG. 2b

Fig. 2 - Figures are rotationally symmetric about the indicated axis of rotation.

result is usually a distribution of some quantity as a function of some variable: for example, the flux across a given surface as a function of energy, time, position, etc. Parameter blocks I00, J00, L00, M00, N00, T00, U00 have been reserved for the storage of the parameters defining the limiting values of the independent variables; and the accumulated quantity must be stored in one of the data blocks A0 through D4, the sizes of which are defined in parameter block P00 (see Appendix A). The use of the formula 827 (Chapter V, below) simplifies the accumulation of the desired data by storing it in a form which will then be automatically processed and listed with the rest of the problem results.

This feature of the code may be clarified by consideration of the following specific example. Suppose we wish to know the flux across a surface j as a function of energy. Let W(E) be the weight (see Chapter IV) of a neutron crossing surface j with energy E. Then the desired flux is the expected value of $\psi(E) = W(E)/|\mu_n|$, where μ_n is the cosine of the angle made by the neutron trajectory with the normal to surface j at the point of intersection (calculated by formula 915).

Define $\psi_n = \psi(E)$ when $E_{n-1} < E \leq E_n$, where the desired values of E_n are stored in parameter block L00 (n = 1, 2, ..., N). We choose to accumulate the ψ_n in data block $(B2)_n$ by means of a formula 865. In the specification of surface j (see pg. 53 below), we set R = 865 (FLOCO) = $1065_8 = 565_{10}$. The j^{th} word of the surface tally transfer block $(S7)_j$ will then contain a command (TSX, 4, L), where L is the address assigned by FLOCO to the first word of formula 865. The contents of P06 must be set equal to N by the user (see Appendix A).

An example of a suitable formula 865 is presented on the following page -- the FLOCO cards for which are loaded into the Monte Carlo code immediately following the basic formula set, as indicated in Appendix D. The expected value of the desired flux and the variance thereof will then automatically be calculated and listed by the general data process formula 830 (Chapter V, below).

In tracing the progress of a particle, the geometry is always considered from a "neutron's-eye" view. Given that, at a time t the neutron is at a point $\vec{r}$ in cell (a) moving with energy E in direction $\hat{\Omega}$ -- either as the result of some collision or of some source distribution -- the first surface the neutron will cross is determined by calculating the distance from $\vec{r}$ to the point of intersection of the neutron trajectory with every surface bounding cell (a). The smallest positive such distance, Δ_j, determines the desired surface (j). Comparison of this distance Δ_j with the path length to next collision of neutrons in cell (a) with velocity V then decides whether or not the neutron will reach this surface without first making a collision.

If it is determined that the neutron is to cross surface (j) its coordinates $(\vec{r},t)$ are advanced past the point of intersection

FLOCO

77	78	79	80	PROBLEM		
	M	C	S	PROGRAMMER	DATE	PAGE

	C	OPERATION P (2)	R (3)	(4)	S (5)	ADDRESS X (6)	R (7)	(8)	S (9)	REMARKS: Special tally of flux as function of energy
0	I	8					8	6	5	
1	10		S	X	D	4		7	7	Save entrance
2	19		L	X	D	2	A	4	3	c(2)=j
3	28		T	S	X	4	9	1	5	Compute μ_n
4	37		S	S	P					
5	46		S	T	Ø		1	0	0	$\lvert\mu_n\rvert$
6	55		C	L	A		A	1	6	W(E)
7	64		F	D	H		1	0	0	X 0
0	I		S	T	Q		1	0	1	$\psi(E)=W(E)/\lvert\mu_n\rvert$
1	10		L	X	A	1	4	0	1	c(1)=n=1
2	19		C	L	A		A	1	7	E
3	28		C	A	S	1	L	0	0	Compare E with E_n:
4	37	1			1	1	X	1	3	$E>E_n$: $(n+1)\rightarrow n$
5	46		N	Ø	P					$E=E_n$
6	55		L	D	Q		1	0	1	$E<E_n$: $C(Acc)=\psi_n$
7	64		C	L	A		B	2	*	X 1
0	I		T	S	X	4	8	2	7	Tally
1	10		L	X	D	4		7	7	Exit to $(\alpha+2)$
2	19		T	R	A	4			2	
3	28									
4	37									
5	46									
6	55									
7	64									X 2

Note: E_n must be greater than the maximum neutron energy possible in the problem.

$$\left[\vec{r} + (\Delta_j + \epsilon)\hat{\Omega}\right] \rightarrow \vec{r}$$

$$\left[t + (\Delta_j + \epsilon)/V\right] \rightarrow t$$

where ϵ is a small positive constant [C(CO4)] chosen to ensure that the neutron indeed crosses surface (j). It must then be decided into which cell (a') the neutron has passed. For this purpose all candidates for a' are collected and stored into a data block Y6, a candidate being a cell (a") possessing the surface (j) as a boundary and having a sense with respect to (j) opposite to that of cell (a). The neutron then considers each such candidate (a") in turn, comparing the computed senses of its position, $\vec{r}$, with respect to all the surfaces bounding cell (a") with the specified senses of that cell. When agreement of the senses is obtained for some (a"), that cell is accepted as the desired (a'). It is at this point that the ambiguities in Figure 2 above lead to errors.

The order in which the candidates (a") are examined clearly governs the efficiency of this process, because the neutron accepts the first cell found which satisfies the sense criteria. To expedite this procedure two possibilities are considered and are illustrated in Figure 3.

The most frequently encountered geometrical configuration is illustrated in Figure 3a, where there is a cell (a_2'') among the (a") which has at least one additional common surface (j_1) with cell (a)

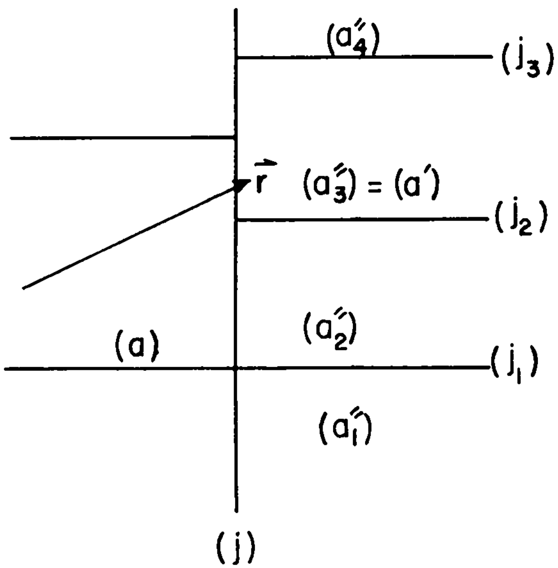


FIG. 3a

"SHORT ORDERING"

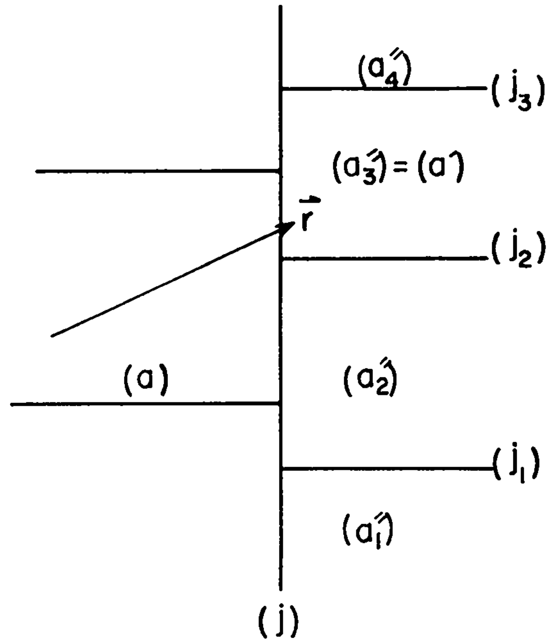


FIG. 3b

"LONG ORDERING"

Fig. 3

and with respect to which its sense is the same as that of cell (a). In this case cell (a_1'') -- having sense with respect to (j_1) opposite to (a) -- may immediately be discarded from further consideration, and the senses of $\vec{r}$ with respect to the bounding surfaces of cell (a_2'') are computed. In the example illustrated these computed senses are found to not agree with the specified senses of cell (a_2''), so cell (a_2'') is discarded. The remaining cells (a") -- other than (a_1'') and (a_2'') -- are then searched for a cell adjacent to (a_2''), that is, a cell possessing a common surface with (a_2'') across which the cell sense changes -- in the case illustrated, (a_3''). This procedure is called the "short ordering" and continues until a cell satisfying the sense criteria is found.

If there is no additional common surface (j_1) -- as illustrated in Figure 3b -- the first cell considered is that whose cell number, say (a_1''), has the largest numerical value, and the remaining cells are considered in adjacent order as in the "short ordering" case. In the event no adjacent cell is found the procedure is repeated, having first discarded from the (a") all cells previously rejected. This procedure is called the "long ordering" and is clearly less efficient.

Having determined a new cell (a') from one of the above procedures the next interaction is calculated and the whole process is repeated until it is determined that the neutron has made a collision.

III. NEUTRON SCATTERING AND REACTION DATA

The nuclear data required by the Monte Carlo calculation divides rather naturally into two classes: those data necessary to determine the point in space at which a neutron makes its next collision, and those data necessary to determine the outcome of that collision.

The determination of the point of next collision requires a knowledge of the macroscopic total neutron cross section in a material (m) at a given neutron energy E: $\overline{\sigma_m^{Tot}}(E)$ (in cm.$^{-1}$). In the geometrical subdivision of the system of interest into cells (as described in Chapter II), a cell is defined to be a spatial region of constant material properties -- isotopic composition and density. Thus a cell (a) will contain a material (m) at a density ρ_a (number of atoms $\times 10^{-24}$/cm.^{3}). Material (m) is determined by the specification of its isotopic composition: the numbers p_m^k proportional to the number of atoms of isotope (k) per unit volume of material (m). Thus, if $\sigma_k^{Tot}(E)$ is the total cross section in barns of isotope (k) for neutrons of energy E,

$$\overline{\sigma_m^{Tot}}(E) = \rho_a \left[\frac{\sum_{k=1}^{N_m} p_m^k \, \sigma_k^{Tot}(E)}{\sum_{k=1}^{N_m} p_m^k} \right] \text{cm.}^{-1}$$

summed over the N_m isotopes constituting material (m). The path length to the next collision is then picked from the distribution $\exp\left\{-\overline{\sigma_m^{Tot}}(E)\, S\right\}$, where S is a distance measured along the neutron trajectory.

Having decided that a collision has occurred in material (m), the isotope (k) with which the neutron has collided may be determined by comparison of a random number uniformly distributed in $\left[0,1\right]$, with the quantities

$$P_k = \frac{\sum_{k'=1}^{k} p_m^{k'}\ \sigma_{k'}^{Tot}(E)}{\sum_{k'=1}^{N_m} p_m^{k'}\ \sigma_{k'}^{Tot}(E)}, \qquad (k = 1, 2, \ldots, N_m)$$

A neutron with energy E experiencing a collision with isotope (k) will be absorbed $\left[\text{reactions } (n,\gamma), (n,p), \text{etc.}\right]$ with probability $\sigma_k^{abs}(E) \Big/ \sigma_k^{Tot}(E)$, scattered elastically (that is, without energy loss in the neutron-nucleus center-of-mass system) with probability $\sigma_k^{el}(E) \Big/ \sigma_k^{Tot}(E)$, or scattered inelastically according to the various reaction probabilities for the isotope (k) at incident energy E. For each isotope a set of laboratory neutron velocities V_g^k are specified, at each of which the quantities $\sigma_{k,g}^{Tot}$, $\sigma_{k,g}^{abs}$, and $\sigma_{k,g}^{el}$ are tabulated. The cross sections at a given energy are then obtained by linear interpolation in the laboratory velocity if the neutron velocity V falls between two specified V_g^k's. If V is greater than the largest specified velocity $V_{g(max)}^k$, the cross section values $\sigma_{k,g(max)}$ are assumed to apply. If V is less than the smallest specified velocity $V^k_{g(min)}$, the elastic cross section $\sigma^{el}_k(E)$ is taken to be $\sigma^{el}_{k,g(min)}$, the absorption cross section $\sigma^{abs}_k(E)$ is extrapolated proportional to 1/V, and the total cross section $\sigma^{Tot}_k(E)$ may either be extrapolated like 1/V or taken equal to $\sigma^{Tot}_{k,g(min)}$.

Instead of discarding the neutron with probability $\sigma^{abs}_k(E) / \sigma^{Tot}_k(E)$, it is more efficient to multiply -- in every collision -- the neutron weight (see Chapter IV below) by the probability of the neutron not being absorbed $\left[1 - \sigma^{abs}_k(E) / \sigma^{Tot}_k(E)\right]$ and then require that this neutron always be scattered.

If it is decided that the neutron has scattered elastically from the isotope (k) the angle of scattering α (in either the laboratory or center-of-mass system) is picked by the rejection technique from the scattering distribution $S^{(k)}(\cos\alpha, E)$ for neutrons of energy E. For each isotope there is specified a set of energies $E^{el}_{k,g'}$ at which the data defining the scattering distribution $S^{(k)}_{g'}(\cos\alpha)$ are tabulated -- the value of $S^{(k)}(\cos\alpha, \dot{E})$ then being interpolated linearly in the energy. The scattering distribution at each energy $E^{el}_{k,g'}$ is defined either by a set of values of $\cos\alpha_n$ at which the $S^{(k)}_{g'}(\cos\alpha_n)$ are tabulated -- intermediate values being obtained by linear interpolation in $\cos\alpha$ -- or by the coefficients of a polynomial fit in $\cos\alpha$. The scattering distribution may be given in either the center-of-mass system or the laboratory system. If the mass number A_k of isotope (k) is greater than 25 the laboratory energy is assumed to be unchanged. If

$A_k \leq 25$ the new laboratory energy E' is calculated from the incident energy E and the angle of scattering α.

In the event that the neutron is inelastically scattered, the angle of scattering and the final neutron energy depend on the type of nuclear reaction. The reactions possible on a given isotope (k) over the energy range of interest (usually 0 to 15 Mev) are labeled $\nu = 1, 2, \ldots, N(\nu)$, and are identified according to reaction type by a tag T. For each isotope there is specified a set of laboratory energies $E_{k,g}^{inel}$ at which the data for each reaction ν are tabulated -- including the probability of the reaction at energy $E_{k,g}^{inel}$, the scattering distribution data for this reaction at this energy, and whatever additional information is necessary to determine the final neutron energy. The reaction ν is determined by comparing a random number uniformly distributed in $[0,1]$ with the probabilities of the various reactions on isotope (k) -- interpolated to the incident neutron energy. For this reaction the angle of scattering is then determined from the inelastic scattering distribution by a procedure identical to that used for elastic scattering.

The determination of the final neutron energy varies with the reaction type T:

<u>T = 0:</u> The final neutron energy E' is picked from an evaporation spectrum

$$P(E')\, dE' = \left(\frac{a^k}{E}\right) E' e^{-\sqrt{\frac{a^k}{E}}\, E'}\, dE' = xe^{-x}\, dx$$

where $x = \sqrt{\frac{a^k}{E}\, E'} = \left(\frac{b^k}{V}\right) E'$

1) $b^k = 13.89 \sqrt{a^k}$ may be a slowly varying function of E and is tabulated for each $E^{inel}_{k,g}$.

2) If the value of E' so chosen is greater than E, it is discarded and another value is picked.

3) If the angular distribution is given in the CM system, E' is the new CM energy and the new laboratory energy is calculated. In this case, $a^k_{CM} = \left(\frac{A + 1}{A}\right) a^k_{Lab}$. If the angular distribution is given in the laboratory system, E' is the new laboratory energy.

T = 1: Inelastic scattering with the excitation of a single nuclear level. Let the nuclear level excited have an energy Q (Mev) above the ground state (Q a CM quantity).

1) If the angular distribution is specified in the CM:

$E'_C = \left(\frac{A}{A + 1}\right)^2 \left[E - Q_L\right]$ is the final neutron energy in the CM and the final laboratory energy is calculated.

2) If the angular distribution is specified in the laboratory (for heavy elements)

$$E' = E - Q_L$$

In both cases, $Q_L = \left(\frac{A + 1}{A}\right) Q$ is tabulated for each value of $E^{inel}_{k,g}$.

<u>T = 2</u>: Tabulated distribution of final energies as a function of the initial energy -- in the same reference system as the scattering distribution. If $E^{inel}_{k,g-1} < E \leq E^{inel}_{k,g}$, then $P_{g,f}$ are the probabilities of the final energies $E_{g,f}$ for the incident energy E (f = 1, 2, ...). ($P_{g,1}$ must be zero.) Let ξ be a random number uniformly distributed in $[0,1]$ and suppose $P_{g,f-1} < \xi \leq P_{g,f}$. If no interpolation: $E' = E_{g,f}$ is the final energy. If interpolation:

$$E' = E_{g,f-1} + \left(\frac{\xi - P_{g,f-1}}{P_{g,f} - P_{g,f-1}}\right)(E_{g,f} - E_{g,f-1})$$

<u>T = 3</u>: Tabulated distribution of final energies as a function of the initial energy <u>and</u> the angle of scattering α -- in the same reference frame as the scattering distribution. A set of $\cos \alpha_j$ are specified such that if $\cos \alpha_{j-1} < \cos \alpha \leq \cos \alpha_j$ and $E^{inel}_{k,g-1} < E \leq E^{inel}_{k,g}$, then $P_{j,g,f}$ are the probabilities of the final energies $E_{j,g,f}$ with the same interpolation option as in reaction type T = 2.

<u>T = 4</u>: The final laboratory neutron energy is picked from the fission spectrum

$$P(E') \, dE' = 2 \times 0.775 \sqrt{\frac{0.775E'}{\pi}} \, e^{-0.775E'} \, dE'$$

1) The scattering distribution must be specified in the laboratory system.

2) For each $E^{inel}_{k,g}$ there is specified an average number of neutrons emitted per fission ν^k_g. $\nu^k(E)$ is obtained from these tabulated values by linear interpolation in the energy.

T = 5: The final CM neutron energy is picked from the "density of the final states" spectrum. The scattering distribution must be specified in the CM system. If Q is the CM energy threshold for the reaction, $Q_L = \left(\frac{A + 1}{A}\right) Q$, then M is the maximum possible final neutron energy in the CM system

$$M = \left(\frac{A}{A + 1}\right)^2 (E - Q_L)$$

This reaction allows two cases:

1) N' = 2: (useful for some (n,2n) reactions)

$$P_{(2)}(E'_C) \, dE'_C = \frac{2}{M} \sqrt{E'_C(M - E'_C)} \, dE'_C$$

where E'_C is the final CM neutron energy. The neutron weight is doubled and the final laboratory energy is computed.

2) N' = 3: (useful for some 3-body breakup reactions such as the $(n,n'3\alpha)$ reaction on C^{12})

$$P_{(3)}(E_C') \, dE_C'' \propto (E_C')^{1/2}(M - E_C')^2 \, dE_C'$$

The final laboratory energy is computed.

<u>T = 6</u>: (n,2n) reaction I: The first neutron emitted has the final laboratory energy $E_1' = \alpha(E - Q_L)$ -- this neutron is banked (see Chapter IV). The second emitted neutron has the final laboratory energy $E_2' = \beta(E - Q_L)$. The constants α, β, and $Q_L = \left(\frac{A + 1}{A}\right) Q$ are specified. The scattering distribution must be given in the laboratory system only.

<u>T = 7</u>: General (n,2n) reaction allowing each neutron to be picked from a different energy and angle distribution. The data are specified as for two different reactions with equal cumulative reaction probabilities, type T_1 (= 0, 1, 2, 3 as above) for the first neutron, T_2 for the second. The final laboratory energy and new direction cosines of the first neutron are chosen according to the prescription of reaction type T_1 and the neutron is banked (see Chapter IV below). The corresponding quantities for the second neutron are then chosen according to reaction type T_2. Both T_1 and T_2 must be less than four.

There is specified for each problem a <u>thermal</u> <u>energy</u>, E_{Th}, such that any neutron attempting to choose an energy

$E' < E_{Th}$ will have its energy reset to E_{Th}.

In general, the treatment of the nuclear reaction data has been designed to represent accurately the experimental data -- frequently at the expense of computing time.

The form in which the nuclear data is entered into a calculation will be found in Appendix C.

IV. SAMPLING TECHNIQUES

To improve the efficiency of the calculation several variance-reducing features have been included in the code. Central to all of them is the concept of the neutron weight.

Each neutron has associated with it a weight W, initially set to W_0 by the source routine F850. As the neutron moves through the system its weight will change for the various reasons to be considered below. Then, if the average weight of the neutrons crossing some surface j, say, is $\overline{W_j}$, this is interpreted as $\overline{W_j}$ neutrons crossing this surface for every W_0 neutrons born at the source.

All the variance-reducing techniques involve picking some quantity of interest -- the path length to the point of next collision, say -- from a probability distribution different from the actual physical distribution. The weight of the neutron must then be appropriately adjusted to correct for the error so introduced. Thus, if the quantity x is physically obtained from a normalized distribution p(x) and we instead choose it from a normalized distribution P(x), the weight of the neutron utilizing a value x_i must be modified by the ratio $p(x_i)/P(x_i)$ so that the result $\overline{f} = \sum_i f(x_i)\ p(x_i) = \sum_i \left\{f(x_i)[p(x_i)/P(x_i)]\right\} P(x_i)$ is unchanged, f representing some answer desired from the calculation.

On each collision the neutron has a probability $\left(\sigma^{abs}/\sigma^{Tot}\right)$ of being absorbed and a probability $p = \left(1 - \sigma^{abs}/\sigma^{Tot}\right)$ of being scattered. The code considers the neutron to be scattered always, $P = 1$, so the neutron's weight is multiplied by $p/P = \left(1 - \sigma^{abs}/\sigma^{Tot}\right)$.

To every cell of the system there are assigned three numbers -- $I_0^{(a)}$, $I_1^{(a)}$, $I_2^{(a)}$ (specified by the user) -- which reflect the importance which one assumes neutrons passing through the cell will have on the desired answer of the calculation. For example, very low energy neutrons in a strongly absorbing medium located far from the region of interest would probably have very small importance. The IMPORTANCE, $I^{(a)}(E)$, of a cell (a) for neutrons at energy E is defined to be $I^{(a)}(E) = I_0^{(a)} + I_1^{(a)}E + I_2^{(a)}E^2$.

Whenever a neutron crosses an interface from an old cell (a) into a new cell (a') the new importance $I' \equiv I^{(a')}(E)$ is compared with the old $I \equiv I^{(a)}(E)$. If (I'/I) is less than 1 the neutron is entering a region of less importance and so must play "Russian Roulette": the weight of the neutron is multiplied by (I/I') and the neutron is followed further with probability (I'/I) and killed with probability $(1 - I'/I)$. If (I'/I) is greater than 1 the neutron is entering a region of greater importance and so may be "split." Let n be the largest integer in (I'/I) and $y = \left[(I'/I) - n\right]$. The weight of the neutron is multiplied by (I/I'), $(n + 1)$ neutrons are banked with probability y, and n neutrons are banked with probability $(1 - y)$. If $I' = I$, the weight is unchanged and the neutron is followed further.

When a neutron is banked, its relevant parameters are relocated from working storage block A00 to a bank block Z7 and saved. Whenever the code is finished with a neutron, it picks the next neutron from the bank -- in the order inverse to that in which they were stored -- and follows it until finished, and continues this procedure until the bank is empty. Only then does the code return to the source routine F&50 to pick a new neutron.

In the calculation of the neutron transmission through thick shields of highly absorptive material it is frequently reasonable to expect that those neutrons contributing significantly to the result will be those having suffered relatively few collisions. In this case it may be more efficient to pick the neutron path length from a distribution with a smaller total cross section and appropriately adjust the weight -- so more neutrons get through, but each carries a smaller weight. To utilize this feature of the code the user specifies -- for each cell -- a quantity $q^{(a)}$ such that a total cross section $\overline{\sigma}' = 2^{-q^{(a)}}\overline{\sigma}$ is used in the determination of the neutron path length in the given cell. When a neutron passes through the cell -- with path length x -- its weight is multiplied by $\exp\left[-(\overline{\sigma} - \overline{\sigma}')x\right]$; when a neutron makes a collision in the cell -- with path length x to the collision -- its weight is multiplied by $(\overline{\sigma}/\overline{\sigma}')\exp\left[-(\overline{\sigma} - \overline{\sigma}')x\right]$.

V. DESCRIPTION OF THE CODE

The standard problem for which this code is designed to provide answers is the following: given a neutron source located in some complicated configuration of materials, what is the flux across some set of surfaces or what is the collision density in some set of cells? The Monte Carlo estimate of the solution consists of picking a sample of neutrons from the given source and following each neutron through a sequence of surface crossings and collisions until the neutron either escapes from the system or is no longer of interest for other reasons. The desired flux or collision density is accumulated for every neutron of the sample, and the sample size is increased until results of sufficient statistical significance are obtained.

A measure of the statistical significance of a given result $\bar{x} = N^{-1} \sum_{i=1}^{N} x_i$ is the variance $\sigma(\bar{x})$. Here N is the sample size, and x_i is the value of the quantity of interest, x, for the i^{th} neutron. For this calculation, the variance is defined as

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

and, according to the central limit theorem, provides an estimate of the error.

A neutron may be discarded for any one of several reasons:

1) If one is interested only in those neutrons contributing to the desired result within the <u>time</u> interval $(0,T_C)$, when the time coordinate, t, of a neutron becomes greater than T_C the neutron will be discarded.

2) If one is interested only in neutrons with <u>energy</u> greater than some value E_C, when the energy of a neutron becomes less than E_C the neutron will be discarded.

3) If one estimates the desired result to be $\bar{w}$, those neutrons with a weight much less than $\bar{w}$ may be assumed to contribute little to the result. Therefore, a <u>weight</u> cutoff $W_C(\ll \bar{w})$ is specified, and those neutrons with weight less than W_C are discarded.

4) If the IMPORTANCE of a cell is found to be zero, a neutron entering that cell will be discarded. A neutron entering a cell of smaller importance may be discarded by "Russian Roulette" (see Chapter IV).

Two versions of the FLOCODE (formula 800) exist, differing in the data they accumulate.

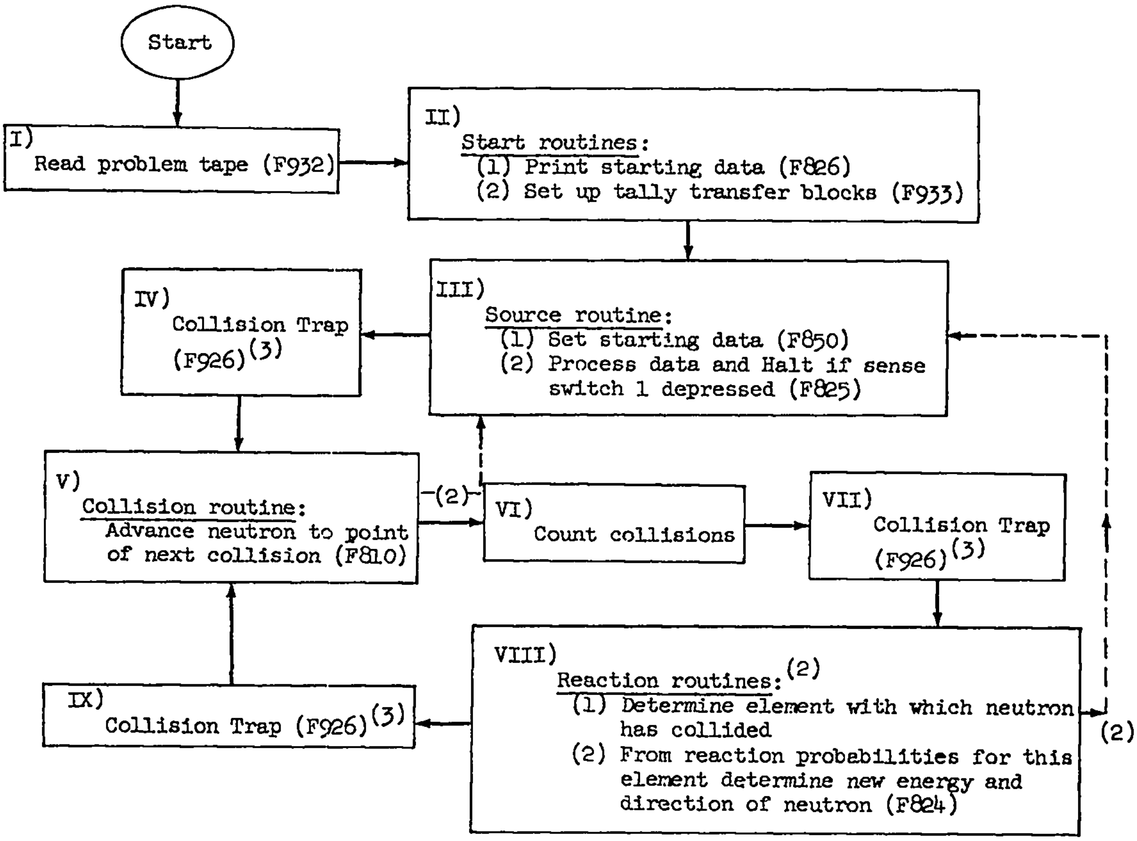
FC1: Accumulates only that data for which special tally routines have been written -- useful for computing fluxes or collision densities in a small number of cells. If this version of the code is utilized: $N(T) = C(D12) = 0$ and data block EO is omitted (see pg. 59).

FC2: For every collision, the neutron weight is accumulated as a function of cell (a) and energy E -- according to $E_{\bar{g}-1} < E \leq E_{\bar{g}}$, where $E_{\bar{g}} = C\left[(EO)_{\bar{g}}\right]$, $\bar{g} = 1, 2, \ldots, N(T) = C(D12) \neq 0$. Thus the use of FC2 provides the collision density in every cell and is useful for studying reaction densities.

The choice of these two versions is simply made by choosing the appropriate version of F800 and setting $N(T) = 0$ for FC1, $N(T) \neq 0$ for FC2. For FC2, the data block EO must be included.

A brief outline of the function of each formula of the code follows. A complete list of the code will be found in Appendix D.

F800: FLOCODE -- controls overall flow of calculation.[1]



Notes:

(1) Two versions of F800 exist, labeled FC1MC1 and FC2MC1. Code FC1MC1 is as diagrammed above; FC2MC1 includes a collision tally routine between blocks V and VI above -- to tally collisions as a function of cell and energy (F833).

(2) When neutron is finished -- due to escape, time or energy cutoff -- the control returns from blocks V or VIII to the source routine to pick another neutron.

(3) Collision traps operative only if sense switch 5 is depressed and sense switch 3 not depressed. (See description of sense switches, Chapter VIIB, and F926.)

F801: Controls the calculation of the path length to the nearest intersection of the neutron trajectory with the surfaces bounding cell a. (All distances less than 10^{-5} are rejected.)

Distance to intersection with j^{th} surface stored in $(Z2)_j$; if two positive intersections are obtained, the smaller is stored in $(Z2)_j$, the larger in $(Z3)_j$. (Uses F907, F910, F911, F912, F914. Entered from F810.)

F802: From among the cells a'_k (stored in $(Y6)_k$), to find a cell adjacent to a given cell -- if one exists -- and determine the common surface separating them. (Entered from "ordering" routines: F803, F805.)

F803: New cell a' found from among the a'_k by the "long-ordering" procedure: Starting with $k = K_T$, the cells a'_k are ordered according to their common surfaces (F802), and the sense of the neutron is compared with the specified cell senses until a cell a' is found. (Uses F802, F804, F913. Entered from F805, F806.)

F804: To compare the calculated sense of the neutron with respect to all the surfaces bounding cell a with the specified senses of cell a, including any "ambiguity" surface (see pg. 11).

F805: New cell a' found from among the a'_k by the "short-ordering" procedure: Starting with a flagged cell, the cells a_k' are ordered according to their common surfaces (F802), and the sense of the neutron is compared with the specified cell senses until a cell a' is found or until a second flagged cell is found. (Uses F802, F803, F804, F913. Entered from F806.)

F806: To determine new cell a', given that neutron has crossed surface j from cell a. (Entered from F810.)

I) Set cell numbers, a_k', of every cell on the opposite side of surface j from cell a into $(Y6)_k$. $(k = 1, \ldots, K_T)$

A) If $K_T = 1$: Set a_1' into a' and exit.

B) If $K_T \neq 1$: The sense of the neutron with respect to all surfaces for which the a_k''s have the same sense is set equal to the common sense.

II) For each k: If a_k' has a common surface j' with cell a -- other than those common to all the a_k', which were removed in IB) above -- the a_k' in $(Y6)_k$ is flagged or zeroed according to the sense of a_k' with respect to surface j' being the same or opposite to that of cell a. The number of such flagged cells is counted $\equiv N(1)$.

III) The new cell a' is determined from among the a_k' by finding that cell having the same sense with respect to its bounding surfaces as does the neutron.

A) If $N(1) > 0$: Try to obtain the new cell by the "short-ordering" procedure -- starting from a flagged cell a'_k -- and exit. (F805)

B) If N(1) = 0 or "short-ordering" procedure fails, the new cell is obtained by the "long-ordering" procedure and exit. (F803)

F807: To calculate the total cross section $\sigma_m^{Tot}(V)$ of material m for a neutron with velocity V.

I) For each isotope (k) in material (m), the total cross section at velocity V, $\sigma_k^{Tot}(V)$ is calculated and stored in $(Z5)_k$.

A) For V within the limits of the velocity table of element k (Block CO, Appendix C), the cross section is interpolated linearly in V between the tabulated values.

B) If $V > V_{max}$ (the maximum velocity tabulated for element k), $\sigma_k^{Tot}(V) = \sigma_k^{Tot}(V_{max})$.

C) If $V < V_{min}$ (the smallest velocity tabulated for element k), the code allows two possibilities depending on t_1 (t_1 = C(K03), Appendix C).

$$t_1 = 0: \quad \sigma_k^{Tot}(V) = \sigma_k^{Tot}(V_{min})$$

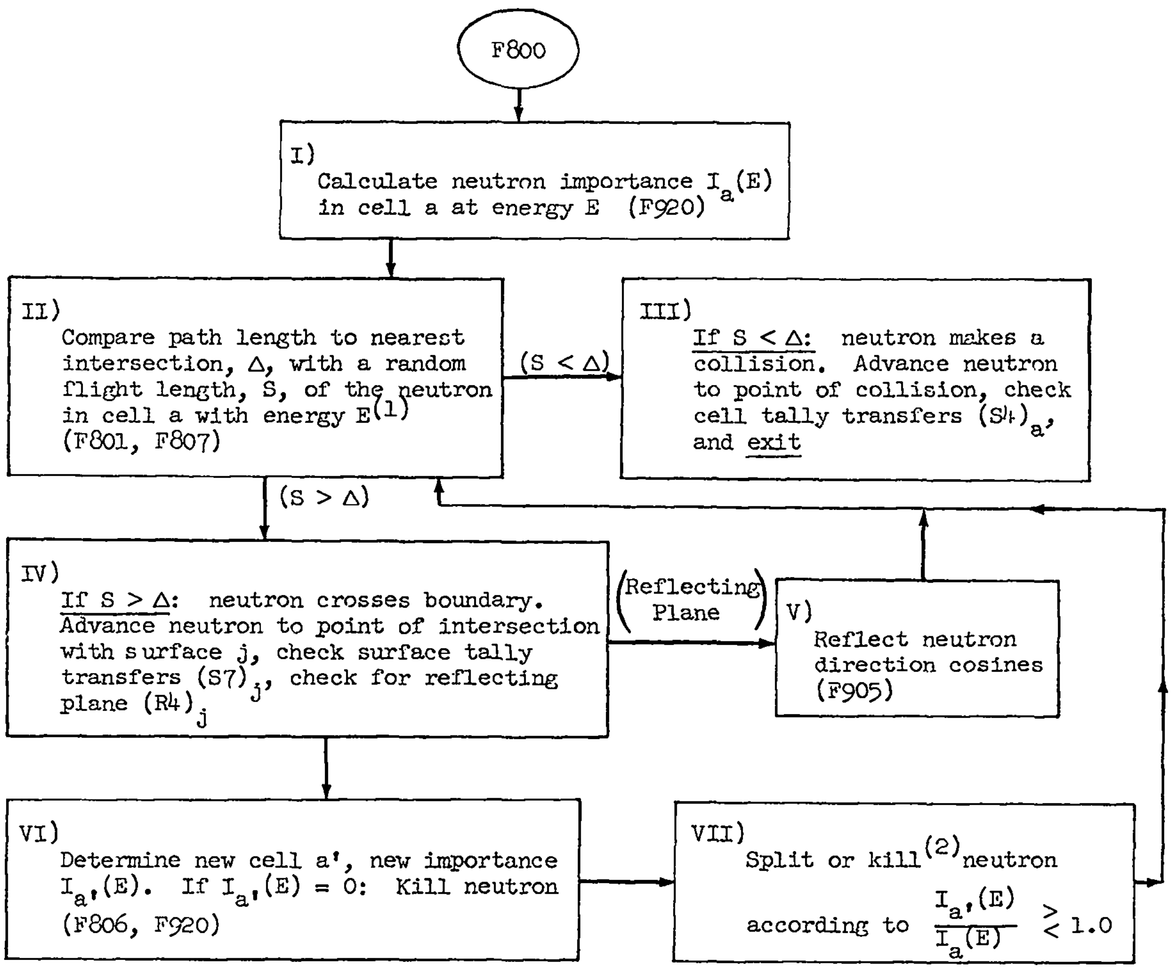
$$t_1 \neq 0: \quad \sigma_k^{Tot}(V) = \left(\frac{V_{min}}{V}\right) \sigma_k^{Tot}(V_{min})$$

II) Material cross section $\sigma_m^{Tot}(V)$ is mixture of element cross sections weighted by fractional atomic composition p_m^k:

$$\sigma_m^{Tot}(V) = \sum_{k \epsilon m} p_m^k \, \sigma_k^{Tot}(V)$$

the partial sums of which are stored in $(Z4)_k$.

F810: **To determine the point of next collision.**



Notes:

(1) If q of cell a ≠ 0 (Input $(Y6)_a$), S is increased by a factor 2^q and the neutron weight is appropriately modified. (See Chapter IV.)

(2) For description of split/kill criteria, see Chapter IV.

F811 - F821: Reaction routines. In every case, the new neutron directions are picked from a tabulated angular distribution (in center-of-mass or laboratory).

F811: Elastic scattering reaction: If element mass number $A \leq 25$, new laboratory energy is calculated for given angle of scattering; if $A > 25$, laboratory energy is unchanged.

F812: Inelastic reaction, $T = 0$: New neutron energy (in frame of reference of tabulated angular distribution) picked from evaporation spectrum

$$P(E') \, dE' = \left(\frac{a}{E}\right) E' \exp\left(- \sqrt{\frac{a}{E}} \, E'\right) dE'$$

where a is a constant of the material.

F813: Inelastic reaction, $T = 1$: Inelastic scattering with excitation of single level of target nucleus:

$$E_C' = E_C - Q$$

Q the nuclear level excited; E_C, E_C' initial and final center-of-mass energies.

If angular distribution given in laboratory (for heavy elements):

$$E' = E - Q_L , \qquad Q_L = \left(\frac{A + 1}{A}\right) Q$$

If angular distribution given in center-of-mass:

$$E'_C = \left(\frac{A}{A + 1}\right)^2 (E - Q_L)$$

and E' calculated from E'_C taking into account the angle of scattering.

F814: Inelastic reaction, T = 2: New neutron energy interpolated from a tabulated energy distribution -- table having incident laboratory energy as argument. New energy in laboratory or center-of-mass agreeing with the angular distribution data.

F815: Inelastic reaction, T = 3: New neutron energy interpolated from a tabulated energy distribution -- table having incident laboratory energy and angle of scattering (CM or laboratory) as argument. New energy in laboratory or CM agreeing with the angular distribution data.

F816: Inelastic reaction, T = 4: Fission. New neutron energy (laboratory only) picked from

$$P(E') \, dE' = 2 \times 0.775\sqrt{\frac{0.775E'}{\pi}} \; \exp(-0.775E') \, dE'$$

Angular distribution in laboratory only. ν tabulated as function of energy of incident neutron.

If $\nu \geq 3$: the new neutron weight $W' = \frac{1}{3} \nu W$ and two neutrons are banked.

$\nu < 3$: $W' = \frac{1}{2} \nu W$ and one neutron is banked.

F817: Inelastic reaction, T = 5: (n,2n) and 3-body breakup with energy spectrum governed by the density of final states available. Angular distribution in CM only.

I) (n,2n): $P(E'_C) \, dE'_C = \frac{2}{M}\sqrt{E'_C(M - E'_C)} \, dE'_C$

E'_C = new neutron energy in CM.

$M = \left(\frac{A}{A+1}\right)^2 \left[E - \left(\frac{A+1}{A}\right) Q\right]$ is maximum neutron energy possible, Q being the CM energy threshold.

Neutron weight is doubled.

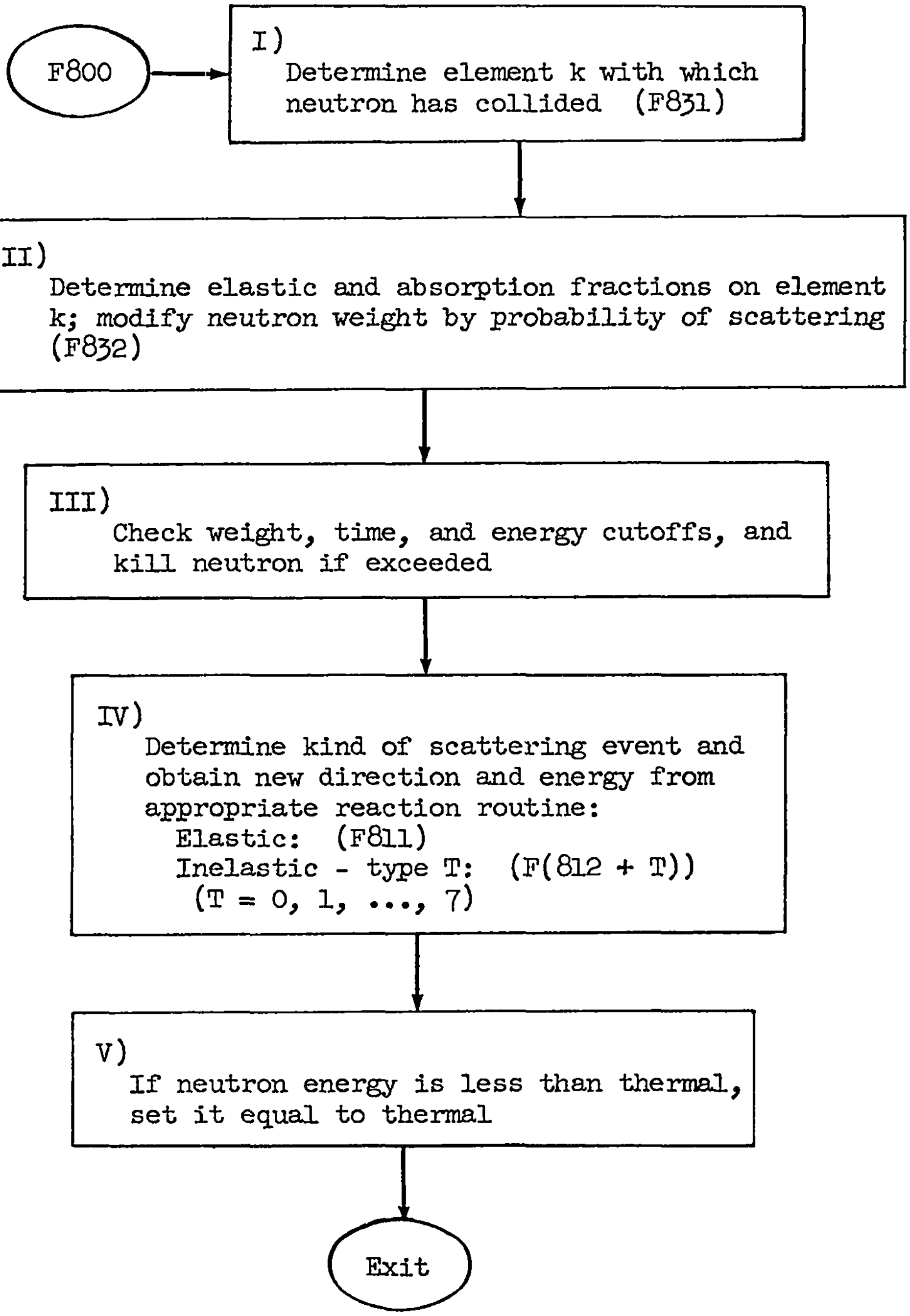
II) 3-body breakup: (good approximation for the reaction: $n + C^{12} \rightarrow n + 3\alpha$, See Rosen, Phys. Rev., 99, 1375 (1955))

$$P(E'_C) \, dE'_C \propto (E'_C)^{1/2}(M - E'_C)^2 \, dE'_C$$

F820: Inleastic reaction, $T = 6$: (n,2n) reaction. Angular distribution in laboratory only. First neutron has new laboratory energy $E_1' = \alpha(E - Q)$ and is banked. Second neutron has new laboratory energy $E_2' = \beta(E - Q)$, where α, β, and Q are given constants.

F821: Inelastic reaction, $T = 7$: (n,2n) reaction with different angular distribution and energy distribution for each neutron. Each neutron is picked independently from one of the above inelastic reactions ($T = 0, 1, 2, 3$) with its own angular distribution. The first neutron is banked.

F824: To determine new direction and energy of neutron from the reaction probabilities for the element with which neutron has collided.



F825: To start a new neutron.

I) If sense switch 1 depressed, processes data and halts.

II) If bank is not empty, picks neutron from bank and exits.

III) If bank is empty: counts particle and compares with data-process and print cycles. Picks new neutron from source routine (F850) and exits. (Uses F830, F850, F922, F926, F931. Enter from F800.)

F826: Starting print: Prints storage map (F976), tallied data (F925), IMPORTANCE coefficients, and source data.

F827: General tally routine: For use with special surface or cell tally routines (see pg. 11). To accumulate x_ν in block AO: enter on (TSX, 4, 827) with

C(Accumulator) = (AO*) (FLOCO control word for block AO)

C(MQ) = x_ν

C(Index register 1) = ν

F830: General data process routine. Calculates average values and statistical variance of every quantity stored in special tally accumulators (blocks AO through D6) having a non-zero size listed in block POO. If the collision density is accumulated (FLOCODE 2) its average and variance is computed. All such calculated quantities are printed off-line.

F831: To determine element k with which neutron has collided. A random fraction of the total material cross section is compared with the partial sums of the total cross section stored in block $(Z4)_k$ by F807 to obtain k.

F832: To determine elastic and absorption fractions for a neutron on element k with velocity V. Interpolated linearly in V within table, absorption cross section extrapolated like V^{-1} for neutron velocities below the lowest tabulated value.

F833: To tally collision density as a function of cell and energy. Entered from FLOCODE 2. Tally energies $E_{\overline{g}}$ in $(E0)_{\overline{g}}$, $\overline{g} = 1, 2, \ldots, N(T) = C(D12)$.

Neutron weight W accumulated in $(T6)_{\overline{g},a}$ for collision in cell a with energy E satisfying $E_{\overline{g}-1} < E \leq E_{\overline{g}}$. W^2 accumulated in $(U6)_{\overline{g},a}$.

F835: To proceed to next neutron. Transfers control to block diagram III of F800. (See pg. 34.)

F836: To tally collisions as a function of time and energy. Entered from cell tally transfers $(S4)_a$.

I) Tally times specified in block G00:

G01: Number of tallied times $\equiv N(\tau)$

G02: τ_1 } times in shakes (10^{-8} sec.)

G03: $\tau_2 > \tau_1$

etc.

II) Tally energies in block H00:

H01: Number of tallied energies $\equiv N(g)$

H02: E_1 } energies in Mev

H03: $E_2 > E_1$

etc.

III) Neutron weight W accumulated in $(D6)_{n,g}$ where n and g determined by E and t satisfying $E_{g-1} < E \leq E_g$, $\tau_{n-1} < t \leq \tau_n$.

IV) The size of block D6 = C(P20) = $\left[N(\tau) \times N(g)\right]$ must be specified on the P00 card.

F837: To turn on sense light 4 for cell flag tallies. Entered from cell tally transfers $(S4)_a$.

F840: To turn on sense light 4 for surface flag tallies. Entered from surface tally transfers $(S7)_j$.

F850: Source routine -- special routine to be supplied for each problem. To store the quantities in words A01 → A07, A17, and A50 (starting cell a in decrement) for a source neutron. Source data supplied by blocks S00, V00, W00.

F857: Data assign code. (See FLOCO Manual, LAMS-2339.)

F877: Error restart. Resets particle and collision count. If sense 4 depressed, reads last tape dump. Exit through (F933) to (F835).

Formulae F900 - F977 are subroutines used by the basic formula set F800 - F877.

F900: Punch dump.

F901: To convert the fixed-point number in the accumulator address to a floating-point number.

F902: Random number generator.

F903: Square root (LA S800).

F904: To pick the three direction cosines of a point on the unit sphere from a uniform distribution. $\hat{\Omega} \equiv (u,v,w)$: $u = C(B02)$, $v = C(B03)$, $w = C(B04)$.

F905: To reflect neutron direction cosines in a plane.

F906: Error code: Saves contents of index registers and MQ, prints error remark on-line, takes a memory print (F923) and tally print (F925), checks error count and continues to (F877).

F907: To calculate the intersection or sense of a neutron with respect to a special quadratic surface (type $\kappa = 7$, Chapter II).

F910: To control the calculation of the intersection of a neutron trajectory with a given surface. (Uses F907, F911, F912, F914.)

F911: To calculate the intersection of a neutron trajectory with a plane.

F912: To calculate the intersection of a neutron trajectory with a cylinder.

F913: To calculate the sense of a neutron with respect to a given surface. (Uses F907, F914.)

F914: To calculate the intersection or sense of a neutron with respect to a general quadratic surface (type $\kappa = 8$, Chapter II).

F915: To calculate the cosine of the angle made by a neutron trajectory with the normal to a surface. Enter with C(2) = j = surface number; exit with C(ACC) = μ_n.

F916: Natural logarithm (LA S820).

F917: Exponential (LA S816).

F920: To calculate the importance of a cell as a function of the neutron energy.

F921: To write a neutron into the bank (Z7) if bank is not full. If bank is full, sense light 1 turned on.

F922: To read a neutron from the bank (Z7) if bank is not empty.

F923: Memory print.

F924: Manual entry to error routine.

F925: Tally print.

F926: Trap print: Operative only if sense switch 5 is depressed. Saves contents of accumulator, MQ, and index registers A and B. If sense switch 3 is raised, takes a memory print only (F923); if sense 3 depressed, takes a tally print (F925) and a memory print (F923). Restore the contents of the accumulator, MQ, and index registers before exit.

F927: To convert center-of-mass energy and direction cosines to the corresponding laboratory quantities for a given element, angle of scattering, and energy loss in the center-of-mass system.

F930: To evaluate the scattering distribution $S_k(\cos\alpha, E)$ (see Chapter III) for a given element, angle of scattering α, and neutron energy E.

F931: To write accumulated data into the second file of the problem tape.

F932: To read the problem tape.

I) Reads basic problem data -- as set up by the Initiating code -- from the first file of the problem tape.

II) If sense switch 4 depressed: exit. (To restart problem from beginning.) If sense switch 4 raised: reads accumulated data from second file of problem tape. (To restart problem from last dump.)

F933: Start routine. To set up cell and surface tally transfers, and to store q's load in block (Y6) into block (R0) (see Appendix B).

F934: To read accumulated data from second file of the problem tape.

VI. PREPARATION OF A PROBLEM

To facilitate the preparation of a problem for the computer an Initiating code MCA (see Appendix E) has been written. It reads data cards prepared in a simplified format, stores the various quantities in the form and locations required by the Monte Carlo, performs some consistency checks to aid in the detection of errors in problem specification, writes the data blocks utilized by the Monte Carlo onto tape, and provides a listing of the data in a form useful for checking the specification of the problem.

The preparation of the data for the Initiating code is described in Section A below. The parameter cards and data blocks necessary to complete the specification of the problem are indicated in Sections B and C below, respectively. Finally, those routines which must be provided by the user for each particular problem -- for accumulating special tallies (see example on page 15) and for specifying the source -- are discussed in section D below.

A: THE INITIATING CODE DATA:

To prepare a problem for the computer the cells and their bounding surfaces must first be specified -- with attention to the possible ambiguities discussed in Chapter II. The cells are numbered consecutively

1 through A, and the surfaces 1 through J. The isotopes utilized in the problem are consecutively numbered 1 through K, and the materials are defined by their isotopic composition and are numbered m = 1, 2, ..., M.

THE SURFACE CARDS:

The surface specifications are entered into the Initiating code as data block A0.

Card label: col. 73-76: XXX A

77-80: PN = problem number

where XXX is the surface card count = 1, 2, ... For <u>each</u> surface (j) the data are entered in the following order:

1) j = surface number (j = 1, 2, ..., J).
2) R_j = formula number (in decimal) for special tallies of surface crossings of surface (j). (Flux tallies, time-energy distributions, etc. -- see Section D below.) If surface (j) is not to be so tallied, $R_j = 0$.
3) κ_j = surface type index (see pg. 7). <u>Note</u>: if any $\kappa_j = 7$ or 8, the contents of A15 (see Section B below) must be negative.
4) $N_a^{(j)}$ = the number of cells bounded by surface (j).
5) Surface coefficients (defined by the surface equations in Chapter II). For surface types:

$\kappa_j = 1, 3, 4, 5$	$\kappa_j = 2, 6$	$\kappa_j = 7$	$\kappa_j = 8$
$\bar{x}$	A	A	A
$\bar{y}$	B	B	B
$\bar{z}$	C	C	C
d^2	D	D	D
		E	E
		F	F
		G	G
		$\bar{x}$	H
		$\bar{y}$	J
		$\bar{z}$	K

6) The cell numbers of the cells bounded by surface (j):

$$\left.\begin{matrix} a_1^{(j)} \\ a_2^{(j)} \\ \vdots \end{matrix}\right\} N_a^{(j)} \text{ words.}$$

The data for each surface (j) are entered on FLOCO cards in the above listed order; the collection of such cards for all J surfaces constitute the SURFACE CARDS of Appendix E.

THE CELL CARDS:

The cell specifications are entered into the Initiating code as data block BO.

Card label: col. 73-76: XXX B

77-80: PN = problem number

where XXX is the cell card count = 1, 2, •••. For each cell (a) the data are entered in the following order:

1) a = cell number (a = 1, 2, •••, A).

2) m = material number of the material in cell (a) (m = 1, 2, •••, M).

3) t = importance zone number of cell (a).

Set t = a.

4) $\pm\overline{j_a}$ = surface number of "ambiguity surface" of cell (a) (see pg. 11).

If $\overline{j_a} = 0$: cell (a) is unambiguous.

If $\overline{j_a} \neq 0$: cell (a) is ambiguous with respect to its bounding surfaces and has (±) sense with respect to surface $\overline{j_a}$.

5) R_a = formula number (in decimal) for special tallies of collisions in cell (a) (collision densities, time-energy distributions, etc. -- see Section D below). If cell (a) is not to be tallied, $R_a = 0$.

6) x_a

7) y_a

8) z_a

(6–8) The coordinates of a point in cell (a) -- for computing the senses of cell (a) with respect to its bounding surfaces.

9) ρ_a = density of material (m) in cell (a) (atoms/cm.$^3 \times 10^{-24}$).

The data for each cell (a) are entered on FLOCO cards in the above listed order; the collection of such cards for all A cells constitute the CELL CARDS of Appendix E.

THE ELEMENT CARDS:

The nuclear data cards (described in Appendix C) for each isotope used in the problem are read by the Initiating code -- each isotope being preceded by an identification card J00:

J01: k = number assigned (for the given problem) to the isotope (k = 1, 2, ···, K).

J02:	A = mass number	Must agree with the corresponding quantities on the K00 card (see Appendix C) immediately following the J00 card.
J03:	Z = atomic number	
J04:	ID = identification	

The collection of all the isotope cards of the given problem constitute the ELEMENT CARDS of Appendix E.

THE MATERIAL CARDS:

The material specifications are entered into the Initiating code.

Card label: col. 73-76: XXX C

77-80: PN = problem number

where XXX is the material card count = 1, 2, ···. For each material (m) the data are entered in the following order:

1) Parameter card F00:

F01: m = material number

F02: N_m = number of isotopes in material (m)

2) Data block F0:

$C\left[(F0)_n\right] = k_n$, the number (k) assigned to the n^{th} isotope in material m ($n = 1, 2, \cdots, N_m$).

3) Data block $[(Fl)_n] = p_m^{k_n}$, the atomic fraction of isotope numbered k_n in material m (i.e. for H_2O, p = 0.677 for H, p = 0.333 for O).

4) TRANSITION CARD: labeled TR CRC MCA (see §II-11 of Appendix C).

The collection of all the material cards of the problem constitute the MATERIAL CARDS of Appendix E.

B: PARAMETER CARDS:

The sizes of variable length data blocks, the print and dump cycles, and the data utilized by the source and special tally routines are entered as FLOCO parameters.

1) Parameter block A00: must be specified as follows:

A01	18Z	
A02	$\nu_T(A + 1)$	$\left[\nu_T \equiv \text{(Integer part of } J/36) + 1\right.$
A03	$4(\nu_T + 1)$	(J = number of surfaces)]
A04	M = number of materials	
A05	K = number of isotopes	
A06	5Z	
A07	T = number of importance zones (set T = A)	
A10	1Z	
A11	PN = problem number	
A12	6Z	
A13	1	
A14	A = number of cells	
A15	$\pm\nu_T$	[(-) indicates the problem contains special

	surfaces of the types κ = 7, 8]
16	4Z
A17	J = number of surfaces
A20	1Z
21	E_{Th} = thermal energy (see pg. 26)
22	T_C = time cutoff (see pg. 32)
A23	3Z

2) Parameter block DOO: parameters controlling the running of the Monte Carlo -- see Appendix A.

3) Parameter block POO: sizes of data blocks used in the accumulation of special tallies -- see Appendix A.

4) Parameter blocks GOO, HOO: define limits of time and energy histograms accumulated by time-energy tally -- see F836 (pg. 46) and Appendix A. If no time-energy distributions are to be obtained, a card of zeros must be entered for both GOO and HOO.

5) Parameter blocks SOO, VOO, WOO: source definition. Generally SOO contains data specifying the source spatial distribution, starting cell, and initial weight; VOO and WOO specify the source energy distribution -- see Section D(2) below and Appendix A.

6) Parameter blocks IOO, JOO, LOO, MOO, NOO, TOO, VOO: blocks reserved for the special tally routines coded by the user -- see pg. 11 and Section D(1) below.

C: DATA CARDS:

The following data blocks must be prepared for loading with the Monte Carlo code MCS:

1) Data block EO: Tally energies $E_{\bar{g}}$ for accumulating fluxes or collision densities as a function of energy.

$$C\left[(EO)_{\bar{g}}\right] = E_{\bar{g}}\ ,\ \bar{g} = 1, 2, \cdots, N(T)$$

$$\left[N(T) = C(D12)\right]$$

Data for energy E accumulated under energy index g if $E_{\bar{g}-1} < E \leq E_{\bar{g}}$.

2) Data block IO:

$$C\left[(IO)_a\right] = I_0^{(a)}$$

3) Data block I1:

$$C\left[(I1)_a\right] = I_1^{(a)}$$

4) Data block I2:

$$C\left[(I2)_a\right] = I_2^{(a)}$$

(Data blocks IO, I1, I2:) Specifies Importance function of cell a. (a = 1, 2, ···, A) (see pg. 29)

5) Data block Y6:

$$C\left[(Y6)_a\right] = q^{(a)}\ ,\qquad (a = 1, 2, \cdots, A)$$

For biasing toward longer mean free paths (see pg. 30)

D: SPECIAL TALLY AND SOURCE ROUTINES (provided by the user):

1) The special tally routines for accumulating surface crossings or neutron collisions must be written and assigned formula numbers F860 to F876 -- as described on pg. 11. Any routine

entered from a surface crossing must exit to $(\alpha + 2)$, i.e. the exit command must be (TRA, 4, 2); those entered from a collision in a cell must exit to $(\alpha + 1)$. If it is desired to accumulate the collisions in some cells or set of cells as a function of the time and neutron energy one may utilize formula 836 (see pg. 46) and enter $R_a = 542_{10}$ in the appropriate cell cards (see pg. 55). (Note: $542_{10} = 1036_8$ = FLOCO 836.)

2) The source routine must be written and assigned the formula number F850. Its function is to choose -- for each neutron of the sample -- the starting values of position (x_0, y_0, z_0), time (t_0), direction (u_0, v_0, w_0), energy (E_0), weight (W_0), and the cell number (a_0) of the cell containing the starting position. The chosen values of the above quantities must be stored into parameter block A00:

$x_0 \rightarrow$ A01

$y_0 \rightarrow$ A02

$z_0 \rightarrow$ A03

$t_0 \rightarrow$ A04

$a_0 \rightarrow$ Decrement of A50

$u_0 \rightarrow$ A05 and A10

$v_0 \rightarrow$ A06

$w_0 \rightarrow$ A07

$E_0 \rightarrow$ A17

$W_0 \rightarrow$ A16

The parameter blocks S00, V00, and W00 are reserved for data specifying the distribution of the listed quantities.

The example on the following page provides a point source of neutrons at $\vec{r}_0 = (1, 1, 1)$, $t_0 = 30.0$, in cell $a_0 = 10$ with initial weight $W_0 = 23.7$. The neutron direction is chosen from an isotropic distribution (F904) and the starting energy spectrum is chosen from the tabulated distribution:

$P_1 = 0$ $\quad E_1 = 0.001$ Mev

$P_2 = 0.20$ $\quad E_2 = 0.1$

$P_3 = 0.50$ $\quad E_3 = 1.0$

$P_4 = 0.83$ $\quad E_4 = 3.0$

$P_5 = 1.0$ $\quad E_5 = 7.0$

where P_n is the probability that the neutrons have initial energy $E_0 \leq E_n$.

FLOCO

77	78	79	80	PROBLEM		
	M	C	S	PROGRAMMER	DATE	PAGE

	C	OPERATION P	R	S		ADDRESS X	R	S		REMARKS Isotropic point source, tabulated energy distribution
	1	2	3	4	5	6	7	8	9	
0	I	8					8	5	0	
1	(10)		S	X	D	4	X	4	3	Save entrance
2	(19)		L	X	A	4	4	0	4	(4)=4
3	(28)		C	L	A	4	S	0	0	
4	(37)		S	T	Φ	4	A	0	0	Set $(\vec{r}_0, t_0)$
5	(46)	2			1	4	X	0	3	
6	(55)		C	L	A		S	0	5	
7	(64)		A	L	S			2	2	X 0 S 1
0	I		S	T	Φ		A	5	0	Set a_0
1	(10)		T	S	X	4	9	0	4	$\hat{\Omega}$ uniform
2	(19)		L	X	A	4	4	0	3	(4)=3
3	(28)		C	L	A	4	B	0	1	
4	(37)		S	T	Φ	4	A	0	4	$\hat{\Omega} \rightarrow \hat{\Omega}_0$
5	(46)	2			1	4	X	1	3	
6	(55)		S	T	Φ		A	1	0	u
7	(64)		T	S	X	4	9	0	2	X 1 S 1 Pick ξ
0	I		L	X	A	4	4	0	1	(4)=n=1
1	(10)		C	A	S	4	V	0	1	Compare ξ with P_n:
2	(19)	1			1	4	X	2	1	$\xi < P_n$
3	(28)		N	Φ	P					$\xi = P_n$
4	(37)		F	S	B	4	V	0	0	$\xi < P_n$
5	(46)		S	T	Φ		A	1	7	$(\xi - P_{n-1})$
6	(55)		C	L	A	4	V	0	1	Interpolate for
7	(64)		F	S	B	4	V	0	0	X 2 S 1 E:
0	I		S	T	Φ			4	0	$(P_n - P_{n-1})$
1	(10)		C	L	A	4	W	0	1	
2	(19)		F	S	B	4	W	0	0	
3	(28)		F	D	H			4	0	
4	(37)		F	M	P		A	1	7	
5	(46)		F	A	D	4	W	0	0	
6	(55)		S	T	Φ		A	1	7	E
7	(64)		C	L	A		S	0	6	X 3 S 1

	C	OPERATION P	R	S		ADDRESS X	R	S		REMARKS
	1	2	3	4	5	6	7	8	9	
0	I		S	T	Φ		A	1	6	Set W_0
1	(10)		L	X	D	4	X	4	3	Exit
2	(19)		T	R	A	4			1	
3	(28)		H	T	R					
4	(37)									
5	(46)									
6	(55)									
7	(64)									X 4 S 1
0	9	*					S	0	0	
1	(10)	1	.	0						x_0
2	(19)	1	.	0						y_0
3	(28)	1	.	0						z_0
4	(37)		3	0	.	0				t_0
5	(46)							1	0	a_0
6	(55)	2	3	.	7					W_0
7	(64)									X 0 S 0
0	9	*					V	0	0	
1	(10)								0	
2	(19)	.	2	0						
3	(28)	.	5	0						
4	(37)	.	8	3						
5	(46)	1	.	0						
6	(55)									
7	(64)									X 0 V 0
0	9	*					W	0	0	
1	(10)	.	0	0	1					
2	(19)	.	1							
3	(28)	1	.	0						
4	(37)	3	.	0						
5	(46)	7	.	0						
6	(55)									
7	(64)									X 0 W 0

VII. RUNNING THE PROBLEM

With the data specifying the problem entered on FLOCO cards, as described in Chapter VI, the problem tape -- containing the data in the form necessary for use by the Monte Carlo code -- is prepared by the Initiating code MCA (or code MCB, see pg. 69 below). This code performs some consistency checks on the data -- seeking errors in the problem specification -- and provides data listings in a form useful for determining specification errors. The operation of the Initiating code is described in Section A below.

The problem tape having been prepared by the Initiating code, the Monte Carlo is ready to run -- as described in Section B.

A: THE INITIATING CODE MCA:

1) The code and data cards are loaded into the card reader in the order specified in Appendix E -- including the parameter cards A00. The systems tape (containing the FLOCO code) is on tape unit A01 (logical tape 1) and a blank tape -- hereafter designated as the problem tape -- is placed on tape unit A06 (logical tape 7). The tape to be written in BCD for later printing off-line is on unit A03 (logical tape 9).

2) Normally all sense switches (SS) are raised.

   SS6: if depressed, all printing is done on-line.

   SS3: operative only in the event that an error has been detected (see A-7 below): at an error stop, depressing sense switch 3 and pressing the "Start" button on the console causes the printing of the input data -- up to and including the quantity detected to be in error -- and calculation again stops.

   SS5: causes the calculator to stop on an error stop after the data for each isotope is read -- with an "Error type" (-k) printed, k being the isotope number. The nuclear data input blocks (see Appendix C) will be printed upon depressing sense switch 3 and pressing "Start." Pressing the "Start" at the conclusion of the data print causes the Initiating code to proceed to the next element. The use of sense switch 5 sometimes facilitates the detection of errors in the isotope data.

3) The Initiating code is read from cards into the computer and the problem identification (F932) is printed on-line and off-line. The surface cards are read and checked for errors, then the cell cards are read and checked.

   A description of the specification of the geometry is written off-line (tape A03), an example of which appears on the following page. The sets of data referring to different cells are separated by spaces. For each cell, the data on the first line are:

1	0	a	t	m	ρ

a = cell number.

t = importance index = a.

m = material number of material in cell a.

ρ = density of material in cell a.

On succeeding lines are listed information concerning the surfaces bounding cell a:

1	$\pm j$	± 0	a_1	j_{12}	a_2

$\pm j$: a has sense ($\pm$) with respect to bounding surface j.

± 0: (+): at most two cells on the other side of surface j from cell a.

(-): more than two cells on the other side of surface j from cell a.

If only one cell a_2 on the other side of j from a, $a_1 = 0$, $j_{12} = 0$. If two cells a_1, a_2 on the other side of j from a, j_{12} is the surface separating them and a_2 is (+), a_1 is (-), with respect to surface j_{12}. If no such separating surface exists, $j_{12} = 0$. If more than two cells on the other side of j from a, a_1 and a_2 are the two such cells nearest to a -- nearest meaning the smallest distance computed, using the

	CELL BOUNDARIES-	-A-	-T-	-M-	-RHO-
1	0.000000+00	1	1	1	9.999979-11
1	-1	0	0	0	2
1	0	2	2	1	1.000000+00
1	1	0	0	0	1
1	-2	-0	3	5	54
1	-3	0	5	4	4
1	0	3	3	1	9.999979-11
1	2	0	0	0	2
1	-3	0	5	4	4
1	-5	0	54	7	55
1	0	4	4	1	9.999979-11
1	3	0	2	2	3
1	4	0	0	0	5
1	-5	0	54	7	55
1	-6	0	6	12	7
1	0	5	5	2	1.109998-01
1	3	0	2	2	3
1	-4	0	0	0	4
1	-6	0	6	12	7
1	0	6	6	2	1.109998-01
1	6	0	5	4	4
1	-7	-0	15	10	12
1	-12	-0	7	7	9
1	0	7	7	1	9.999979-11
1	-5	0	54	7	55
1	6	0	5	4	4
1	-7	-0	12	12	9
1	12	-0	13	10	12
1	0	8	8	1	9.999979-11
1	-5	0	54	7	55
1	7	-0	6	12	7
1	13	-0	10	10	9
1	-16	0	0	0	64
1	0	9	9	1	9.999979-11
1	7	-0	6	12	7
1	10	-0	13	12	10
1	12	-0	13	10	12
1	-13	0	0	0	8
1	0	10	10	3	3.609991-02
1	-10	0	12	12	9
1	12	-0	13	0	14

cell coordinates (x_a, y_a, z_a) (see pg. 55). If the so determined a_1 and a_2 have a separating surface j_{12}, a_2 is (+), a_1 is (-), with respect to j_{12}.

4) The element cards are read and checked, one isotope at a time, with the heading for each isotope written off-line (parameter blocks J00, K00 -- see Appendix C). The material cards are read and checked, one material at a time, and the specification of each material is written off-line.

5) The data blocks utilized by the Monte Carlo code are written onto the problem tape, and the binary parameter card Q00 is punched -- specifying the size of the element data blocks (see Appendix A). This binary card must be placed immediately following the parameter card labeled "XOQO MC1" in the MCS deck to properly assign space for the element data read from tape. The contents of the Q00 card are printed on-line and off-line.

6) The MCS data blocks are written off-line in the following order: (see Appendix B for description of individual data blocks)

   a) R0, R3, R4, R5, R6, R7, S0, S1.

   b) S2, S3, S4, S5, S6, S7, T0, T1.

   c) T2, T3, T4, $\underbrace{x_a, y_a, z_a}$

      cell coordinates of cell (a).

   d) Parameter block A00.

   e) Data blocks M0, M1, M2, M3, M4.

Following the data listing, the remark "Initiation completed -- save tape A06" is written on-line and off-line and the calculator comes to a Program Stop.

7) Upon detection of an error in the problem specification, the calculator prints on-line an error remark, followed by

Error-type index	C(1)	C(2)	Decimal Location of detection of error

The same quantities are listed off-line, followed by parameter blocks

A00 (see Appendix A)

B00 (working storage used by code MCA)

J00 (see pg. 56)

K00, F00 } (see Appendix C)

Working storage: octal core locations 155_8 - 60_8. The calculator then comes to a Program Stop. Depressing sense switch 3 and pressing the "Start" button on the console causes the printing of the input data -- up to and including the quantity detected to be in error -- and the calculator again stops.

When the error is corrected, the initiation should be restarted from the beginning.

A list of the error stops and the corresponding error-type index will be found at the end of Appendix E.

8) The Initiating Code MCB: Once a problem has been initiated completely, a re-initiation, which changes geometry specifications only, may be more quickly effected by using the Initiating code MCB, which omits the reading of the element and material cards and reads instead the element data blocks already assembled on the problem tape. The card loading order for this code is indicated in Appendix E.

B: THE MONTE CARLO CODE MCS:

1) The code and data cards are loaded into the card reader in the order specified in Appendix D -- including the parameter cards A00 utilized in the Initiating code and the Q00 card punched by the Initiating code. The systems tape (containing the FLOCO code) is on tape unit A01 (logical tape 1) and the Monte Carlo Problem tape (prepared by the Initiating code) is placed on tape unit A06 (logical tape 7). The tape to be written in BCD for later printing off-line is on tape unit A03 (logical tape 9).

2) Normally all sense switches (SS) are raised.

SS1: The data are processed, dumped onto the problem tape, and the calculator comes to a Program Stop. Pressing the "Start" button on the console continues the calculation.

SS2: Not used by the code. Available to the user for use in the special tally routines or in the source routine.

SS3: Debug trap control -- if SS3 and SS5 are depressed, any debug traps placed in the code will be operative, the FLOCODE collision traps will not be operative (see pg. 74 below).

SS4: If depressed at the start of the calculation, any data previously accumulated on the problem tape are ignored, and the calculation starts from the beginning. If SS4 is depressed during the running of the code, upon detection of an error, the code will restart from the last tape dump (see pg. 72 below).

SS5: Debug trap control -- if SS5 is depressed, all debug traps are operative. The FLOCODE collision traps are printed only if SS5 is depressed and SS3 is raised.

SS6: Print control -- FLOCO print program prints on-line if SS6 depressed, off-line if SS6 raised.

3) The Monte Carlo code is read into the computer from cards. The problem specification data are read from the first file of the problem tape (Appendix D-V). If SS4 is not depressed, the data previously accumulated are read from the second file of the problem tape. A storage map (F976) is printed on-line followed by the problem identification remark and a count of the number of neutrons previously processed. The following

starting dump is written on the tape for off-line printing (see Appendices A and B for description):

a) Parameter blocks A00, D00.

b) Data blocks E0, T6, U6, A0 through D7.

c) Importance data blocks I0, I1, I2, Y6.

d) Source parameter blocks S00, V00, W00.

The first neutron is then picked from the source routine and the calculation proceeds.

Whenever the number of neutrons picked from the source equals an integral number of print cycles [C(D04)], a remark containing the neutron count is printed on-line and the accumulated data is dumped on the problem tape. The value of the print cycle should be chosen so that a dump occurs approximately every ten minutes of calculating time.

Whenever the neutron count equals an integral number of data process cycles, the data accumulated are processed to obtain the expectation values and variances and are then printed in the following order: (see Appendices A, B)

a) Parameter blocks A00, D00.

b) Data blocks E0, T6, U6, A0 through D7.

(If the FLOCODE 2 variant is used, the collision density in every cell has been accumulated as a function of energy (data block E0) -- the number of entries in each accumulated quantity is then listed following data block D7.)

4) Upon detection of an error, a remark describing the type of error is printed on-line followed by two lines of numbers:

i) Problem number, Particle count, Collision count

C(A36) C(A37) C(A40)

ii) Location of entry to the Error code, contents of the MQ and index registers 1 and 2, and the location of the last TSX instruction prior to entry to the error code (to assist in checking the flow of control).

The same quantities are printed off-line, followed by a memory print (see Section 6 below) and a tally print (described in Section 3 above).

If the number of errors detected is less than or equal to the number allowed [C(D10)], the calculation continues: if SS4 is raised, a new neutron is picked from the source; if SS4 is depressed, the last data dumped on the problem tape is read and then a new neutron is picked from the source -- i.e. problem restarted from the last dump but with a different initial random number.

If the number of errors detected is greater than the number allowed [C(D10)], the remark "ERROR STOP -- RELOAD PROBLEM TO CONTINUE" is written on-line and the calculator comes to a Program Stop. A manual entry to the Error code (for use in case calculator stops or is observed to be "looping") may be accomplished by entering 1124_8 into the console keys and pressing the "Start" button twice. The error routine is followed as described above, and the calculation proceeds.

5) The code has a built-in debug print routine (F926) which may be utilized in checking special routines added to the code. If all the following conditions are satisfied, an off-line listing will be written:

i) SS5 depressed.

ii) The particle count [C(A37)] ≥ particle count trap control [C(D05)].

iii) The collision count [C(A40)] ≥ collision count trap control [C(D06)].

iv) The random number count [C(A41)] ≥ the random number count control [C(D07)].

The off-line listing consists of a one-line remark "DEBUG PRINT" followed by the location of the entrance to the debug routine and contents of the accumulator and MQ registers. If SS3 is raised, a memory print follows (see Section 6 below); if SS3 is depressed, a memory print and a tally print (described in Section 3 above) follow.

The debug print routine preserves the contents of the accumulator, the MQ, and of index registers 1 and 2. It is entered on a command (TSX, 4, 926).

In addition to any debug traps the user may have included, the code contains a set of collision traps useful for following the flow of control as the calculation proceeds. These are located at the beginning and the end of the source routine, at the end of the section of code which determines the point at which a neutron makes its next collision, and at the end of the section of code which determines the outcome of the collision. These traps are operative whenever the conditions i)-iv) above are satisfied <u>and</u> if SS3 is raised.

6) The memory print routine (F923) writes off-line, the following: (see Appendices A, B)

Parameter blocks A00, B00.

Working storage: octal locations 130_8-100_8.

Data blocks Y6, Z2, Z3, Z4, Z5.

VIII. THE MONTE CARLO REACTION CODE MCH

The calculation of the spatial distribution of a specified nuclear reaction for a given neutron source and a given configuration of materials is a problem to which the Monte Carlo code may frequently be applied. The results of the FLOCODE 2 version of code MCS will yield the desired information, as they provide an estimate of the number of collisions per source neutron in each cell as a function of energy. Multiplying the so obtained collision densities by the energy-dependent probability per collision of the specified reaction then gives the result sought. A short code, MCR, which performs the above multiplication and lists the reactions per cell is described in Appendix F.

To obtain very detailed information in this manner requires the specification of many small cells, and the resulting small number of collisions per cell decreases the statistical significance of the results. Such fine-grained surface specification may, however, result in the neutron making many surface crossings per collision -- indicating that a calculation of the flux across the surfaces of interest would probably be of greater statistical significance than the collision density calculation.

To provide such a calculation of the neutron flux across specified surfaces as a function of energy and position on the surface and to perform the multiplication of these fluxes by the specified reaction cross sections, a variant of the general Monte Carlo has been developed -- the code MCH. This code differs from the code MCS primarily in a slightly simplified problem specification, in the data processing procedure, and in the results listed. This chapter will be concerned only with those features of code MCH differing from MCS. The method of specifying the surfaces and reactions to be tallied is described in Section A below, the changes in the Monte Carlo code are discussed in Section B, and the modified initiating code MCI in Section C. Details in the changes in card loading order and code listings will be found in Appendix G.

A: SPECIFICATION OF REACTIONS AND TALLIED SURFACES:

Specified exactly as for code MCS, with only the following differences:

1) Parameter block D00:

D01 - D12: See Appendix A.

D13: N(J) = Number of flux tally surfaces -- see data block E1 below.

D14: ±N(P) = Number of position coordinates specified per tallied surface -- see data block E2 below.

2) Parameter block <u>R00</u>: Specifies the isotopes and reactions to be studied.

R01: N_R = Number of reactions to be studied.

R02: k_1 = Isotope number } First reaction.
R03: $T(k_1)$ = Reaction number }

R04: k_2 = Isotope number } Second reaction.
R05: $T(k_2)$ = Reaction number }

etc.

where ($k_i = 1, 2, \cdots, K; i = 1, 2, \cdots, N_R$) and for a given isotope, the reaction numbers are defined as follows:

Reaction number T = 1: Total collisions on isotope k.
T = 2: Elastic collisions on isotope k.
T = 3: Absorptions on isotope k.
T = 4: Inelastic reactions ($\nu = 1$) on isotope k.
T = 5: Inelastic reactions ($\nu = 2$) on isotope k.

⋮ ⋮

$T = \left[3 + N(\nu)\right]$: Inelastic reactions, $\left[\nu = N(\nu)\right]$, on isotope k.

The reaction flux is listed for every specified reaction and surface as a function of surface number and position on the surface.

3) Data block E1: Surface numbers of flux tally surfaces (j).

$$C\left[(E1)_{\bar{j}} = \pm j(\bar{j})\right], \qquad \left[\bar{j} = 1, 2, \cdots, N(J)\right]$$

(+j): The flux across surface (j) will be accumulated under an index $\bar{j}$ for every neutron crossing surface (j).

(-j): The flux across surface (j) will be accumulated under an index $\bar{j}$ for a neutron crossing surface (j) if and only if sense light 4 is on.

Sense light 4 is turned on by F837 ($=543_{10}$) or F840 ($=544_{10}$) and is turned off by the new neutron routine, F825. The sense light status of a banked neutron is retained in the sign of the energy.

This option of tagging neutrons with sense light 4 is useful for studying the contribution to the desired flux of those neutrons which previously in their history have experienced some event of interest. For example, a calculation of the total flux on some surface (j) and, for the same surface, a calculation of the flux of those neutrons previously scattered in some reflector allows the separation of the flux on (j) into direct and reflected components. In this case, for every cell in the reflector, one would specify the special tally routine $R_a = 543_{10}$ (see pg. 55)

to turn on light 4 whenever a neutron makes a collision in the reflector. Surface (j) would then be specified twice in data block E1 -- once with positive and once with negative sign.

4) Data block E2: Coordinate values specifying the distribution of the accumulated flux data as a function of position on a given surface $\left[j(\bar{j})\right]$ -- y- or z-coordinates only.

z-coordinates if N(P) = C(D14) > 0.

y-coordinates if N(P) = C(D14) < 0.

The flux data are accumulated under surface index $\bar{j}$ for neutrons crossing surface $j(\bar{j})$, under energy index $\bar{g}$ for neutrons with energy E satisfying $E_{\bar{g}-1} < E \leq E_{\bar{g}}$, and position index n for neutrons satisfying the coordinate condition

$$\left.\begin{array}{ll} N(P) > 0: & z_{n-1,\bar{j}} < z \leq z_{n,\bar{j}} \\ N(P) < 0: & y_{n-1,\bar{j}} < y \leq y_{n,\bar{j}} \end{array}\right\} \left[n = 1,\ 2,\ \cdots,\ |N(P)|\right]$$

$$C\left[(E2)_{n,\bar{j}}\right] = \begin{cases} z_{n,\bar{j}}\ , & N(P) > 0 \\ y_{n,\bar{j}}\ , & N(P) < 0 \end{cases}$$

In general, the coordinate values will be different for different surfaces, but the number of such coordinate values specified and the choice of y- or z-coordinate must be the same for all surfaces tallied in a given problem.

B: DESCRIPTION OF THE MCH CALCULATION:

The code MCH is basically the same code as the general Monte Carlo MCS, with only those changes necessary to accomplish its special functions.

1) Parameter block A00 need not be specified -- it is set up from the parameter block L00 by the Initiating code MCI (see Section C below) and written into the first record of the problem tape. The data assign formula (F857) then reads this record into core before assigning space to the problem data blocks.

2) The Start routine (F933) stores the command (TRA, 0, 834) into the surface tally transfer data block, S7, for every Flux Tally surface listed in data block E1. The flux tally routine (F834) accumulates the flux for every neutron crossing such a Flux Tally surface as a function of energy, position, and surface.

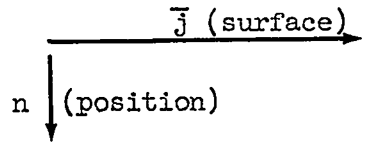
3) In addition to the processing carried out in code MCS, the data process routine calculates and lists off-line the average flux $\bar{\psi}_{\bar{g},n,\bar{j}}$ and the mean-squared flux $\overline{\psi^2_{\bar{g},n,\bar{j}}}$ as a function of energy and position for every Flux Tally surface. The format of the off-line listing is as follows:

   a) Problem identification remark.

   b) Parameter blocks A00, D00.

   c) Flux Tally surface numbers: data block E1.

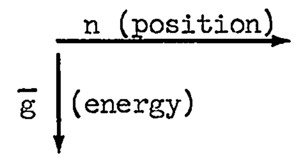
   d) Tally surface position coordinates: data blocks E2, E3:



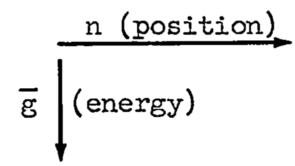
e) Tally energies: data block E0.

f) Average flux: $\overline{\psi}_{g,n,\bar{j}}$

$\bar{j} = 1$:



$\bar{j} = 2$:



etc.

g) Mean squared flux: $\overline{\psi^2_{g,n,\bar{j}}}$ (same format as for average flux).

h) Processed special tallies: data blocks A0 through D6 (as in code MCS).

The energy-summed flux and the computed variance therein is then written off-line as a function of position and surface in the same format as that of the position coordinates (3d above).

4) For each isotope specified on parameter card R00 the total cross section and the cross section for each specified reaction are averaged over the tally energy intervals (assuming constant flux

within such an interval) -- yielding $\overline{\sigma_{k,\bar{g}}^{Tot}}$ and $\overline{\sigma_{k,\bar{g}}^{React}}$. An estimate of the REACTION FLUX is then calculated from the average fluxes of Section 3f above according to

$$\overline{\psi_{n,\bar{j}}^{React}} = \sum_{\bar{g}=1}^{N(T)} \overline{\sigma_{k,\bar{g}}^{React}} \; \bar{\psi}_{\bar{g},n,\bar{j}} \, .$$

The results are written off-line for each specified reaction in the following format.

a) (See 3a above.)

b) Identification of isotope (k), reaction T(k), and the neutron count.

c, d) (See 3c, 3d above.)

e) Tally energies: $\overline{\sigma_{k,\bar{g}}^{Tot}}$: $\overline{\sigma_{k,\bar{g}}^{React}}$:

$= C\left[(EO)_{\bar{g}}\right]$ $\quad = C\left[(PO)_{\bar{g}}\right]$ $\quad = C\left[(P1)_{\bar{g}}\right]$

$\bar{g}$ ↓ (energy)

f) Reaction flux: $\overline{\psi_{n,\bar{j}}^{React}}$

$\bar{j}$ (surface) →

n ↓ (position)

g) Percentage variance in reaction flux: (same format as for reaction flux).

C: THE INITIATING CODE MCI:

The Initiating code MCI differs from the code MCA primarily in the omission of the element cards. The element data blocks S6, TO, T3, MO, M2, M3, M4 are taken to be the same as those of some problem previously initiated by code MCA, the Q00 binary card of which is utilized in the MCI loading deck. The problem tape of this previously initiated problem is designated the "control tape" and is mounted on tape unit A05 (logical tape 2). The element data blocks are then read from this tape instead of being assembled from the element cards as in code MCA.

A slight simplification in the preparation of a problem is obtained by the replacement of the specification of parameter block A00 by that of the simpler parameter block L00:

L01: PN = Problem number.

L02: J = Number of surfaces.

L03: A = Number of cells.

L04: M = Number of materials.

L05: E_{Th} = Thermal energy (Mev).

L06: T_C = Time cutoff (shakes).

The quantities in block A00 which vary with the problem specification are obtained from the contents of L00 and stored in their proper locations by the Initiating code MCI. The number of elements, K, is, however, loaded into MCI as a constant -- it must agree with the number of elements specified on the "control tape."

The printing off-line of data blocks M0 through M4 at the conclusion of a problem initiation is suppressed unless SS4 is depressed.

APPENDIX A: PARAMETER BLOCKS OF CODE MCS

1) Parameter block A00: Contains the working data -- defining the current state of a neutron being followed -- and problem specification data. Must be prepared by the user in the form described on pg. 57. This is the only parameter block used by both the Initiating and the Monte Carlo codes.

A01	x	Neutron space coordinates: $\vec{r} = (x,y,z)$(cm)
A02	y	
A03	z	
A04	t	Neutron time coordinate (shakes)
A05	u	Neutron direction unit vector $\hat{\Omega} = (u,v,w)$
A06	v	
A07	w	
A10	u	
A11	u^2	
A12	v^2	
A13	w^2	
A14	$\sigma_k^{abs}(E)$:	Absorption cross section of isotope k for neutrons with laboratory energy E (barns)

A15	$\sigma_m^{Tot}(E)$: Total cross section of material m for neutrons with laboratory energy E (barns)
A16	W: Neutron weight
A17	E: Neutron energy (Mev)
A20	$I^{(a)}(E)$: Importance of cell (a) for neutrons of laboratory energy E
A21	Number of collisions made by this neutron
A22	V: Neutron velocity (cm/shake)
A23	$\nu_T(A + 1)$: (See A47 below)
A24	$4(\nu_T + 1)$: (See A47 below)
A25	M: Number of materials in problem
A26	K: Number of elements in problem
A27	W_C: Weight cutoff
A30	$(\bar{j};\ \nu_{\bar{j}})$ } Next to nearest positive intersection is with surface $\bar{j}$ at a distance $\Delta_{\bar{j}}$ cm along the neutron trajectory
A31	$\Delta_{\bar{j}}$
A32	j: Surface number of nearest positive intersection printed here (stored in decrement of A43)
A33	Print count: increased by one for each source neutron picked and compared with C(D04); zeroed when print cycle completed
A34	T: Number of importance zones (=A) (See A46 below)
A35	N_P^C: Number of neutrons picked since last data process cycle (compared with C(D01) as A33 above)
A36	PN: Problem number
A37	N_P: Total number of neutrons started
A40	N_C: Total number of collisions followed
A41	$N(\xi)$: Total number of random numbers generated

A42 Decrement: (Current number of particles in the bank) × 21

Address: [(Maximum possible number of particles in the bank) × 21 - 1]

A43 Decrement: j (See A32 above)

Address: ν of the above j (See A47 below)

A44 ξ: The most recently generated random number

A45 N_R: Number of reflecting surfaces (must be ≥ 1)

A46 A: Number of cells in problem

A47 $\pm\nu_T$: For a given j: $\nu(\bar{j}) = \left[\left(\text{Integer part of } \frac{j}{36}\right) + 1\right]$
$\nu_T = \nu(J)$

(+): no special surfaces, type $\kappa = 7, 8$

(-): special surfaces $\kappa = 7, 8$

A50 a: Cell number of cell containing the neutron printed here. When code running:

Decrement: a

Address: k = isotope number of nucleus with which neutron last collided

A51 Δ_j: Distance to nearest positive intersection -- in cm along the neutron trajectory

A52 $j' = 2^J$, where J = j mod 36 (J = smallest residue)

A53 k: Isotope number from A50 printed here

A54 J: Number of surfaces in problem

A55 Number of particles killed by weight cutoff

A56 E_{Th}: Thermal energy (See pg. 26)

A57 T_C: Time cutoff

A60 Number of particles killed by energy cutoff

A61	Number of particles killed by time cutoff
A62	Tally flag word -- for tallying according to flag conditions by special tally routines

2) Parameter block <u>B00</u>: Contains data generated and used internally by code.

B01	$(K_2; t_1; K_1)$: Data locations for isotope total and inelastic scattering data (See description of data blocks M0, M3 below)
B02	u' — Random direction cosines generated by formula 904
B03	v' — Random direction cosines generated by formula 904
B04	w' — Random direction cosines generated by formula 904
B05	$\Delta_E = (E - E_{g-1})/(E_g - E_{g-1})$: Energy interpolator
B06	$(\pm L_2; t; L_1)_{g-1}$ — Data locators for elastic scattering angular distributions
B07	$(\pm L_2; t; L_1)_g$ — Data locators for elastic scattering angular distributions
B10	$\cos\alpha$: Angle of scattering
B11	$[N(E); A]$: $N(E)$ = Number of inelastic energies specified for isotope k. A = Mass number of isotope k
B12	$(L_4^{(\nu-1)}; t; L_3^{(\nu-1)})_{g-1}$ — Data locators for inelastic scattering energy and angle distributions (See data blocks M3, M4 below)
B13	$(L_4^{(\nu-1)}; t; L_3^{(\nu-1)})_g$ — Data locators for inelastic scattering energy and angle distributions (See data blocks M3, M4 below)

3) Parameter block <u>C00</u>: Fixed and floating decimal constants.

C01	(201 000 000 000) Octal: (loaded in K01)
C02	128
C03	-2.00
C04	$\epsilon = 10^{-5}$

C05	16, 515, 072 (Mask last 6 bits of decrement)
C06	588 (FLOCO 914)
C07	36
C10	10
C11	27
C12	32, 759 (Octal 77767)
C13	511 (Octal 777)
C14	32, 768 (1 in tag)
C15	(777 777 777 777) Octal: (loaded in K02)
C16	131, 072 (4 in tag)
C17	0.10: Minimum importance value allowed
C20	255 (Octal 377 masks 8 low bits)
C21	(300 000 000 000) Octal: (loaded in K03) Mask prefix
C22	18
C23	21: Bank size per neutron
C24	13.89125 ($V/\sqrt{E}$)
C25	25.0 (Largest mass number for CM data)
C26	16
C27	302
C30	581 (FLOCO 905)
C31	512 (FLOCO 800)
C32	65, 536 (2 in tag)
C33	Random number generator (load in K04)
C34	Starting random number (loaded in K05)

C35 | 2.86

4) Parameter block D00: Contains the data controlling the running of the problem. Must be prepared by user.

D01	Data process cycle (See pg. 71)
D02	W_C: Weight cutoff (See pg. 32)
D03	Bank size: If N_B is to be the maximum number of neutrons allowed in the bank (see Chapter IV) the bank size is $[21N_B - 1]$
D04	Print cycle (See pg. 71)
D05	Particle count } Trap controls (see Chapter VII, B5)
D06	Collision count } Trap controls (see Chapter VII, B5)
D07	Random number count } Trap controls (see Chapter VII, B5)
	[Every time the bank is filled, the contents of D07 are increased by one]
D10	Error count: Maximum number of errors to be allowed before taking calculation off the machine
D11	E_C: Energy cutoff
D12	N(T): Number of tally energies in data block
	E0: for special tallies and collision density tally.
	If using FLOCODE 1: N(T) must be zero
	If using FLOCODE 2: $N(T) \neq 0$

5) Parameter block E00: Fission spectrum -- a table of 64 equally probable final energies (see pg. 24).

6) Parameter block F00: Evaporation spectrum -- a table of 64

equally probable values of x from the distribution $P(x)\,dx = xe^{-x}\,dx$. Then the final neutron energy $E' = \frac{V}{b}x$. (See pg. 22).

7) Parameter block <u>G00</u>: Time tally limits for time-energy tally of collisions in a set of cells -- see formula 836. Neutron weights accumulated under index i if time t satisfies $\tau_{i-1} < t \leq \tau_i$: $(i = 1, 2, \cdots, N(\tau))$. <u>Must be prepared by the user.</u>

G01	$N(\tau)$: Number of tallied times
G02	τ_1
G03	$\tau_2 > \tau_1$
⋮	⋮
G[1 + N(τ)]	$\tau_{N(\tau)}$

8) Parameter block <u>H00</u>: Energy tally limits for time-energy tally of collisions in a set of cells -- see formula 836. Neutron weights accumulated under an index ℓ if the energy E satisfies $E_{\ell-1} < E \leq E_\ell$: $(\ell = 1, 2, \cdots, N(g))$. <u>Must be prepared by the user.</u>

H01	$N(g)$: Number of tallied energies
H02	E_1
H03	$E_2 > E_1$
⋮	⋮
H[1 + N(g)]	$E_{N(g)}$

9) Parameter blocks I00, J00: Reserved for use by special tally routines (see pg. 11).

10) Parameter block K00: Binary constants.

K01	201 000 000 000 (C01)	Octal representation
K02	777 777 777 777 (C15)	Octal representation
K03	300 000 000 000 (C21)	Octal representation
K04	Random number generator (C33)	
K05	Starting random number (C34)	

11) Parameter blocks L00, M00, N00: Reserved for use by special tally routines: (see pg. 11).

12) Parameter block P00: Specifies sizes of data blocks A0 through D7 -- used for accumulating special tallies (see pg. 11). If the data is accumulated under an index n, (n = 1, 2, ···, N), the size of the data block into which it is accumulated will be N. Must be prepared by the user.

P01	Size A0
P02	" A2
P03	" A4
P04	" A6
P05	" B0
P06	" B2
P07	" B4
P10	" B6

P11	Size C0
P12	" C2
P13	" C4
P14	" C6
P15	" D0
P16	" D2
P17	" D4
P20	" D6 = {[C(G01)] × [C(H01)]}. Time-energy tallies accumulated in data block D6

13) Parameter block <u>Q00</u>: Specifies sizes of data blocks whose length is determined by the Initiating code -- a binary card punched by the Initiating code which must be placed immediately following the card labeled Q00 in the Monte Carlo code (see Appendix D)

Q01	Size T2
Q02	" M0
Q03	" M1
Q04	" M2
Q05	" M3
Q06	" M4

14) Parameter block <u>S00</u>: Reserved for specification of the source routine (F850) -- see Section VI-D2. <u>Must be prepared by user.</u>

15) Parameter blocks <u>T00</u>, <u>U00</u>: Reserved for use by special tally routines: (See pg. 11).

16) Parameter blocks <u>V00</u>, <u>W00</u>: Reserved for specification of the source routine -- see Section VI-D2. <u>Must be prepared by the user.</u>

APPENDIX B: DATA BLOCKS OF CODE MCS

[Size of data block x indicated by S(x)]

1) Data blocks A0, A2, A4, A6, B0, B2, B4, B6, C0, C2, C4, C6, D0, D2, D4: Reserved for data accumulated by special tally routines (see pg. 11). Sizes specified by parameter block P00.

2) Data block D6: Time-energy distribution of collisions $W_{i\ell}$,

where Energy E: $E_{\ell-1} < E \leq E_\ell$, $\quad E_\ell = C[(H01)_\ell]$

Time t: $\tau_{i-1} < t \leq \tau_i$, $\quad \tau_i = C[(G01)_i]$

$$C[(D6)_{i\ell}] = W_{i\ell}, \qquad [i = 1, \cdots, N(\tau), \ \ell = 1, \cdots, N(g)]$$

(See Section VI-D1 and formula 836 in Chapter V.)

$$S(D6) = C(P20) = N(\tau) \times N(g): \quad N(\tau) = C(G01), \quad N(g) = C(H01)$$

3) Data block E0: Tally energies $E_{\bar{g}}$ at which cell collision densities are accumulated (see pg. 33)

$$C[(E0)_{\bar{g}}] = E_{\bar{g}}, \qquad [(\bar{g} = 1, 2, \cdots, N(T))]$$

$S(E0) = C(D12) = N(T)$

Must be specified by user of FLOCODE 2 calculation.

4) Data blocks IO, I1, I2: Specification of Importance $I^{(a)}(E)$ of cell (a) for neutrons with energy E: $I^{(a)}(E) = I_0^{(a)} + I_1^{(a)}E + I_2^{(a)}E^2$. (See Chapter IV.)

$$C[(I0)_a] = I_0^{(a)} , \quad C[(I1)_a] = I_1^{(a)} , \quad C[(I2)_a] = I_2^{(a)}$$

$$S(I0) = S(I1) = S(I2) = C(A34) = T = A$$

Must be specified by user.

5) Data blocks MO through M4 contain the material and isotope data prepared from the nuclear data cards (Appendix C) and written onto the problem tape by the Initiating code MCA. The sizes of these data blocks are entered in parameter block Q00. The quantities listed below are described in Appendix C -- to which the below notation conforms.

a) Data block MO: Total, absorption, and elastic scattering data for each element k stored under data locator $(K_1)_k = C[(TO)_k]$ (address).

$$[N(V^k);\ t_1;\ A] = C\{MO.[0 - (K_1 + 1)]\}$$

$$V_g^k = C\{MO.[0 - (K_1 + 1 + g)]\}$$

$$\sigma_{k,g}^{Tot} = C\{MO.[0 - (K_1 + 1 + N(V^k) + g)]\}$$

$$\sigma_{k,g}^{abs} = C\{MO.[0 - (K_1 + 1 + 2N(V^k) + g)]\}$$

$$\sigma^{el}_{k,g} / \sigma^{scatt}_{k,g} = C\{MO.[0 - (K_1 + 1 + 3N(V^k) + g)]\}$$

$$(\sigma^{scatt} = \sigma^{Tot} - \sigma^{abs})$$

$$[N(E^{el}); A] = C\{MO.[0 - (K_1 + 1 + 4N(V^k) + 1)]\}$$

$$E^{el}_{k,g'} = C\{MO.[0 - (K_1 + 2 + 4N(V^k) + g')]\}$$

$[\pm P; L_2; t; L_1]_{g'}$: Elastic differential data locator. (See description in data block M2 below.)

$$= C\{MO.[0 - (K_1 + 2 + 4N(V^k)$$

$$+ N(E^{el}) + g')]\}$$

b) Data block M1: Material specification data stored under data locator $(M')_m = C[(S5)_m](\text{address})$. Quantities are defined in Chapter VI - under THE MATERIAL CARDS.

$$\left[p_m^{k_n}; k_n \right] = C\{M1.[0 - M' - (n - 1)]\}$$

(Isotope number stored in the 8 low-bits of the floating point number $p_m^{k_n}$)

c) Data block M2: Angular distribution data stored according to the differential data locators.

$[\pm P; L_2; t; L_1]$

(+): Scattering isotropic; L_1, L_2, P ignored (t not ignored).

(-): Scattering anisotropic.

$t = 0$: Angular distribution given in laboratory system.

$t = 1$: Angular distribution given in CM system.

$P = 0$: Tabulated angular distribution.

$$\mu_1 = C[M2.(0 - L_1)\ , \qquad S(\mu_1) = C[M2.(0 - L_2)]$$

$$\mu_2 = C[M2.(0 - L_1 - 1)]\ , \ S(\mu_2) = C[M2.(0 - L_2 - 1)]$$

etc.

$P = 1$: Polynomial fit of degree N to angular distribution

$$a_N = C[M2.(0 - L_1)]$$

$$a_{N-1} = C[M2.(0 - L_1 - 1)]$$

etc.

$$(N + 1) = C[M2.(0 - L_2)]$$

d) Data block M3: Inelastic data for each element k stored under data locator $(K_2)_k = C\ (TO)_k](\text{decrement})$.

$$[N(E^{inel}), A] = C\{M3.[0 - (K_2 + 1)]\}$$

$$E^{inel}_{k,g} = C\{M3.[0 - (K_2 + 1 + g)]\}$$

$$[L_4;\ L_3]_g = C\{M3.[0 - (K_2 + 1 + N(E^{inel}) + g)]\}$$

Energy distribution data locators (see data block M4 below).

$$[\pm P;\ L_2;\ t;\ L_1]_{g,\nu} = C\{M3.[0 - (K_2 + 1 + (\nu + 1)\ N(E^{inel}) + g)]\}$$

Inelastic differential data locator for $\nu^{\underline{th}}$ reaction (see data block M2). Omitted if $C[(TO)_k] < 0$: scattering isotropic.

e) Data block <u>M4</u>: Reaction data for each element k stored under data locators $[L_4;\ L_3]$(see data block M3) according to reaction type T.

$$\sum\nolimits^{(k)}_{\nu,g} = C\{M4.[0 - (L_{4,g} + \nu - 1)]\}$$

(See Appendix C, III (2): data block EO.) Reaction-type tag T stored 6 low-bits.

<u>T = 0</u>: $b^k_g = C\{M4.[0 - (L_{3,g} + \nu - 1)]\}$

<u>T = 1</u>: $(Q_L)_g = C\{M4.[0 - (L_{3,g} + \nu - 1)]\}$

<u>T = 2</u>: $[\Delta;\ \bar{t};\ L_5]_{g,\nu} = C\{M4.[0 - (L_{3,g} + \nu - 1)]\}$

$$P_{g,f} = C\{M4.[0 - (L_{5,g} + f - 1)]\}$$

$$E_{g,f} = C\{M4.[0 - (L_{5,g} + \Delta + f - 1)]\}$$

$\bar{t} = 0$: no interpolation in the $E_{g,f}$

$\bar{t} = 1$: interpolate in the $E_{g,f}$

<u>T = 3</u>: $[\Delta; \bar{t}; L_5]_{g,\nu} = C\{M4.[0 - (L_{3,g} + \nu - 1)]\}$

$\alpha_{j,g} = C\{M4.[0 - (L_{5,g} + j - 1)]\}$ with $L_{6,j,g}$ in the address bits.

$P_{j,g,f} = C\{M4.[0 - (L_{6,j,g} + f - 1)]\}$

$E_{j,g,f} = C\{M4.[0 - (L_{6,j,g} + \Delta + f - 1)]\}$

$\bar{t} = 0$: no interpolation in the $E_{j,g,f}$

$\bar{t} = 1$: interpolation in the $E_{j,g,f}$.

<u>T = 4</u>: $\nu_g = C\{M4.[0 - (L_{3,g} + \nu - 1)]\}$

<u>T = 5</u>: $(Q_L)_g = C\{M4.[0 - (L_{3,g} + \nu - 1)]\}$

<u>T = 6</u>: $Q = C\{M4.[0 - L_5]\}$

$\alpha = C\{M4.[0 - (L_5 + 1)]\}$

$\beta = C\{M4.[0 - (L_5 + 2)]\}$

<u>T = 7</u>: Data stored as for the two constituent reactions with equal cumulative probabilities $\sum_{\nu,g}^{(k)}$. The tag T = 7 is in the 6 low-bits of $\sum_{\nu,g}^{(k)}$ and the T-value for the individual neutrons is stored in

the next 6 bits.

6) Data block RO:

$C[(RO)_a] = (q_a; t_a; \overline{j_a})$ $\qquad$ $(a = 1, 2, \cdots, A)$

q_a = C(prefix): (See Chapter IV) - entered in data block Y6.

$\overline{j_a}$ = C(address): "Ambiguity surface."

t_a = C(decrement): Importance zone of cell (a).

S(RO) = A = C(A46)

Written on problem tape by Initiating code.

7) Data block R3:

$C[(R3)_a] = \rho_a$: density of material in cell a. Material number m_a in 8 low-bits.

S(R3) = A = C(A46)

Written on problem tape by Initiating code.

8) Data block R4: Reflecting surface transfers.

$C[(R4)_j]$ = (TRA, 0, 905) if surface (j) reflecting.

= (TRA, 4, 2) if surface (j) not reflecting.

= ν_j in last 6-bits of the decrement.

S(R4) = J = C(A54)

Written on problem tape by Initiating code, transfer locations set by F933.

9) Data block <u>R5</u>: Boundary tags.

$C[R5.(0 - \nu_T\ a - \nu)] = R^a_{T1}(\nu)$: 1 in j^{th} bit if surface (j) bounds cell (a)

$S(R5) = \nu_T(A + 1) = C(A23)$

Written on problem tape by Initiating code.

10) Data block <u>R6</u>: Sense tags.

$C[R6.(0 - \nu_T\ a - \nu)] = R^a_{T2}(\nu)$: 1 in j^{th} bit if cell (a) has positive sense with respect to surface (j)

$S(R6) = \nu_T(A + 1) = C(A23)$

Written on problem tape by Initiating code.

11) Data blocks <u>R7</u>, <u>S0</u>, <u>S1</u>, <u>S2</u>: Surface coefficients (see pg. 54)

$C[(R7)_j] = A_j$ or $\overline{x_j}$

$C[(S0)_j] = B_j$ or $\overline{y_j}$

$C[(S1)_j] = C_j$ or $\overline{z_j}$

$C[(S2)_j] = D_j$ or d^2

Sizes = J = C(A54)

Written on problem tape by Initiating code.

12) Data block S3: Surface type indicators.

If $C[S3.(0 - 4\nu - \mu)] = 1$ in $j^{\underline{th}}$ bit: $\kappa = \mu + 2$,

$(\mu = 0, 1, 2, 3)$

$S(S3) = 4(\nu_T + 1) = C(A24)$

Written on problem tape by Initiating code.

13) Data block S4: Cell special tally transfers.

$C[(S4)_a] = (TRA, 0, R_a)$ if cell (a) is to be tallied by formula R_a

$= (TRA, 4, 1)$ if cell (a) not tallied

$S(S4) = A = C(A46)$

Written on problem tape by Initiating code, transfer locations set by F933.

14) Data block S5: Material data locator.

$C[(S5)_m] = (N_m; M')$

N_m: Number of isotopes in material m.

M': Data locator of material m in data block M1.

$S(S5) = M = C(A25)$

Written on problem tape by Initiating code.

15) Data block S6:

$C[(S6)_k] = (A/A + 1)_k^2$, A_k = Mass number of $k^{\underline{th}}$ isotope

$S(S6) = K = C(A26)$

Written on problem tape by Initiating code.

16) Data block S7: Surface special tally transfers.

$C[(S7)_j]$ = (TRA, 0, R_j) if surface (j) is to be tallied by formula R_j.

= (TRA, 4, 2) if surface (j) not tallied.

S(S7) = J = C(A54)

Written on problem tape by Initiating code, transfer locations set by F933.

17) Data block T0: Isotope data locators.

$C[(T0)_k] = [(\pm); K_2; (t); K_1]_k$

K_1: Data locator of block M0.

K_2: Data locator of block M3.

(+): Some inelastic scattering is anisotropic (t ignored).

(-): All inelastic scattering is isotropic:

t = 0: in Laboratory system

t = 1: in CM system.

S(T0) = K = C(A26)

Written on problem tape by Initiating code.

18) Data blocks T1, T2: Data for special surfaces.

$C[(T1)_j] = [L_j; R_j]$ if surface (j) is a special surface (i.e. κ = 7, 8)

where $C[T2.(0 - L_j)]$ = first word of surface coefficients.

R_j: Formula number of routine calculating senses and intersections of surface (j).

$S(T1) = J = C(A54)$, $S(T2) = C(Q01)$

Written on problem tape by Initiating code.

19) Data block <u>T3</u>:

$C[(T3)_k] = (A + 1)_k$, A_k = Mass number of $k^{\underline{th}}$ isotope

$S(T3) = K = C(A26)$

Written on problem tape by Initiating code.

20) Data block <u>T4</u>:

$C[(T4)_j] = j' = 2^{[j(\mathrm{Mod}\ 36)]}$

$S(T4) = J = C(A54)$

Written on problem tape by Initiating code.

21) Data blocks <u>T6</u>, <u>T7</u>: Collision density $\psi_{\bar{g},a}$ as a function of cell (a) and energy E:

$E_{\bar{g}-1} < E \leq E_{\bar{g}}$, $[\bar{g} = 1, 2, \cdots, N(T) = C(D12)]$,

$E_{\bar{g}} = C[(E0)_{\bar{g}}]$

$C[(T6)_{\bar{g},a}] = \psi_{\bar{g},a}$

$S(T6) = N(T) = C(D12)$, $S(T7) = A = C(A46)$: a two-dimensional data block with zero length if $N(T) = 0$. Used only with FLOCODE 2.

22) Data blocks U6, U7: Variance in collision density as a function of cell (a) and energy E.

$E_{\bar{g}-1} < E \leq E_{\bar{g}}$, $[\bar{g} = 1, 2, \cdots, N(T) = C(D12)]$,

$[E_{\bar{g}} = C\ (E0)_{\bar{g}}]$

$C[(U6)_{\bar{g},a}] = \psi^2_{\bar{g},a}$

$S(U6) = N(T) = C(D12)$, $S(U7) = A = C(A46)$: a two-dimensional data block with zero length if $N(T) = 8$. Used only with FLOCODE 2 (see T6, T7 above).

23) Data block Y6: In starting the calculation:

$C[(Y6)_a] = q^{(a)}$, $(a = 1, 2, \cdots, A)$ for biasing toward longer mean free paths (see Chapter IV). Starting formula 933 relocates the $q^{(a)}$ into the prefix of data block $(R0)_a$; data block (Y6) is used by the geometry formulas for ordering the cell numbers according to their common surfaces.

$S(Y6) = A = C(A46)$

Must be specified by user.

24) Data blocks Z0, Z1: Accumulate computed senses

$C[(Z0)_\nu] = 1$ in $j^{\underline{th}}$ bit: sense of particle computed with respect to surface (j).

$C[(Z1)_\nu] = 1$ in $j^{\underline{th}}$ bit: sense of particle positive with respect to surface (j).

$S(Z0) = S(Z1) = \nu_T = C(A47)$

25) Data blocks Z2, Z3: Accumulate distance Δ_j along neutron trajectory to intersection with surface (j)

$C[(Z2)_j] = \Delta_j$

$C[(Z3)_j] =$ distance $\Delta_j^{(2)}$ to second positive intersection of neutron trajectory with surface (j) -- if two positive distances exist.

$S(Z2) = S(Z3) = J = C(A54)$

26) Data block Z4: Isotope collision probabilities of material m_a in cell (a) for neutrons of energy E.

$C[(Z4)_k] = P_k$, $(k = 1, 2, \cdots, N_m)$ (see pg. 20)

$S(Z4) = K = C(A26)$

27) Data block Z5: Total cross section of $k^{\underline{th}}$ isotope in material m_a in cell (a) for neutrons of energy E.

$C[(Z5)_k] = \sigma_k^{Tot}(E)$, $(k = 1, 2, \cdots, N_m)$

$S(Z4) = K = C(A26)$

28) Data block Z7: Bank (see Chapter IV)

S(Z7) = Bank size = C(D03)

APPENDIX C: NUCLEAR DATA CARDS

FOR EACH ELEMENT:

I - Card label: col. 73-76: XXCO

77-80: νYYA

XXCO is the usual FLOCO label: ex. 9^{th} card of block C5: XXCO = YOC5

ν is the reaction number

C(YY) = the atomic number Z

C(A) = ID for atomic number Z (specifies isotope -- see C(K11) below).

II - The nuclear data cards are loaded in the following order:

1) Parameter block K00:

K01: A = Mass number of element

K02: $N(V^k)$ = number of velocities at which the scattering data is tabulated.

K03: Tag t_1: $t_1 = 0$: $\sigma_k^{Tot}(V) = \sigma_{k,1}^{Tot}$ for $V \leq V_1^k$

$t_1 = 1$: $\sigma_k^{Tot}(V) = (V_1^k/V)\ \sigma_{k,1}^{Tot}$ for $V \leq V_1^k$

K04: $N(E^{el})$ = number of energies at which the angular distribution for elastic scattering is specified. If $N(E^{el}) = 0$ there is no elastic scattering on this element.

K05: $N(\nu)$ = number of inelastic reactions treated.

K06: $N(E^{inel})$ = number of energies at which the inelastic reaction data is specified. If $N(E^{inel}) = 0$ there is no inelastic scattering on this element.

K07: Tag t_2: $t_2 = 0$: some inelastic scattering on this element is anisotropic

$t_2 = +1$: all inelastic scattering (for all reactions ν) is isotropic in lab.

$t_2 = -1$: all inelastic scattering (for all ν) is isotropic in CM.

K10: Z = atomic number of the element.

K11: ID of element -- to distinguish between different cross section sets for same Z: different isotopes, different reaction fits to same isotope, etc.

2) Data block <u>C0</u>: Table of laboratory velocities V_g^k at which cross sections are tabulated.

$$C[(C0)_g] = V_g^k \text{ (in cm./shake)}, \qquad g = 1, 2, \cdots, N(V^k)$$

<u>Note</u>: $V_{g+1}^k \geq V_g^k$.

3) Data block <u>C1</u>: Table of total cross sections $\sigma_{k,g}^{Tot}$, evaluated at the neutron laboratory velocities V_g^k.

$$C[(C1)_g] = \sigma_{k,g}^{Tot} \text{ (in barns)}, \qquad g = 1, 2, \cdots, N(V^k)$$

4) Data block <u>C2</u>: Table of absorption cross sections $\sigma_{k,g}^{abs}$, evaluated at the neutron laboratory velocities V_g^k.

$$C[(C2)_g] = \sigma_{k,g}^{abs} \text{ (in barns)}, \qquad g = 1, 2, \cdots, N(V^k)$$

the inelastic reaction data are tabulated: reaction probabilities, angular distribution data, etc.

$$C[(D0)_g] = E^{inel}_{k,g} , \qquad g = 1, 2, \cdots, N(E^{inel})$$

10) Data block D1: Table of reaction tags, T_ν, specifying the reaction type, T, for each reaction ν.

$$C[(D1)_\nu] = T_\nu , \qquad \nu = 1, 2, \cdots, N(\nu)$$

11) TRANSITION CARD to "card read control" of initiating code:

(I* 5, 4, 855), labeled TR CRC MCA.

III - The nuclear data reaction cards -- for each reaction ν of the $N(\nu)$ reactions on the given element -- are loaded in order of increasing values of ν, each reaction being followed by a TRANSITION CARD (II-11 above).

1) Parameter block R00:

R01: A = C(K01) .

R02: Z = C(K10) .

R03: ID = C(K11) .

R04: ν = reaction number of this reaction

$\nu = 1, 2, \cdots, N(\nu)$.

R05: T = reaction-type tag defining type of inelastic reaction (see pg.

For neutron of laboratory energy $E^{el}_{k,g'}$:

$\mu_1 = C[C6.(0 - L^{el}_{k,g'})]$, $S^{el}_{k,g'}(\mu_1) = C[C7.(0 - L^{el}_{k,g'})]$

$\mu_2 = C[C6.(0 - L^{el}_{k,g'} - 1)]$, $S^{el}_{k,g'}(\mu_2) = C[C7.(0 - L^{el}_{k,g'} - 1)]$

etc.

b) If $(-L^{el}_{k,g'})$, the scattering distribution is specified as a polynomial of degree N in the scattering cosine:

$$S^{(k)}_{g'}(\mu) = \sum_{n=0}^{N} a^{(k)}_{g',n}\,\mu^n , \qquad (N + 1) \text{ terms.}$$

For neutron of laboratory energy $E^{el}_{k,g'}$:

$a^{(k)}_{g',N} = C[C6.(0 - L^{el}_{k,g'})]$, $(N + 1) = C[C7.(0 - L^{el}_{k,g'})]$

$a^{(k)}_{g',N-1} = C[C6.(0 - L^{el}_{k,g'} - 1)]$

etc.

c) If $L^{el}_{k,g'} = 0$, the elastic scattering is isotropic in the frame of reference indicated by the sign of the energy.

Note: in all cases the $S^{el}_{k,g'}(\mu)$ is normalized such that its maximum value in the interval $(-1 \leq \mu \leq 1)$ is 1.0.

8) Data blocks C6, C7: Elastic scattering angular distribution data -- see description of block C5 above.

9) Data block D0: Table of laboratory energies $E^{inel}_{k,g}$ at which

the inelastic reaction data are tabulated: reaction probabilities, angular distribution data, etc.

$$C[(D0)_g] = E^{inel}_{k,g} , \qquad g = 1, 2, \cdots, N(E^{inel})$$

10) Data block D1: Table of reaction tags, T_ν, specifying the reaction type, T, for each reaction ν.

$$C[(D1)_\nu] = T_\nu , \qquad \nu = 1, 2, \cdots, N(\nu)$$

11) TRANSITION CARD to "card read control" of initiating code:

(I* 5, 4, 855), labeled TR CRC MCA.

III - The nuclear data reaction cards -- for each reaction ν of the $N(\nu)$ reactions on the given element -- are loaded in order of increasing values of ν, each reaction being followed by a TRANSITION CARD (II-11 above).

1) Parameter block R00:

R01: A = C(K01) .

R02: Z = C(K10) .

R03: ID = C(K11) .

R04: ν = reaction number of this reaction

$\nu = 1, 2, \cdots, N(\nu)$.

R05: T = reaction-type tag defining type of inelastic reaction (see pg.

R06:

R07:

R10:

R11:

} Data utilized by specific types of reactions.

2) Data block <u>E0</u>: Table of the cumulative probabilities, $\sum_{\nu,g}^{(k)}$, that the reaction number ν' be less than or equal to ν for neutrons with laboratory $E_{k,g}^{inel}$

$$C[(E0)_g] = \sum_{\nu,g}^{(k)} \quad (\leq 1.0) \ , \qquad g = 1, 2, \cdots, N(E^{inel})$$

3) Data block <u>E1</u>: Inelastic scattering angular distribution data locators $\pm L_{k,g}^{inel}$ for neutrons with laboratory energies $E_{k,g}^{inel}$.

$$C[(E1)_g] = \pm L_{k,g}^{inel} \ , \qquad g = 1, 2, \cdots, N(E^{inel})$$

Data specified exactly as for elastic scattering, with data block E2 replacing C6, E3 replacing C7.

4) Data blocks <u>E2</u>, <u>E3</u>: Inelastic scattering angular distribution data -- same as data blocks C6, C7, respectively.

5) Data block <u>E4</u>: Table of inelastic scattering angular distribution flags, $t_{k,g}^{inel}$, for neutrons with laboratory energies $E_{k,g}^{inel}$.

$$C[(E4)_g] = t_{k,g}^{inel} \ , \qquad g = 1, 2, \cdots, N(E^{inel})$$

$$t_{k,g}^{inel} = \begin{cases} 0, & S_{k,g}^{inel} \text{ specified in laboratory system} \\ 1, & \text{" \quad " \quad " \quad CM \quad "} \end{cases} .$$

Data stored according to reaction type T:

T = 0:

6) Data block GO:

$$C[(GO)_g] = b_g^k$$

T = 1:

6) Data block GO:

$$C[(GO)_g] = (Q_L)_g$$

T = 2:

C(R06) = (±Δ):

Δ = number of final energies tabulated

(+) = no interpolation in the table of final energies

(-) = interpolation in the tabulated final energies.

6)' Data block GO: Table of inelastic reaction data locators, $\ell_{\nu,g}^{(k)}$, for laboratory energies $E_{k,g}^{inel}$. Data for final neutron energy distribution stored in blocks G1, G2 starting from $\ell_{\nu,g}^{(k)}$ word.

$$C[(GO)_g] = \ell_{\nu,g}^{(k)}, \qquad g = 1, 2, \cdots, N(E^{inel})$$

7) Data block G1: Table of cumulative probabilities $P_{g,f}$ of final neutron energies $E_{g,f}$ for neutrons incident with laboratory energy $E_{k,g}^{inel}$.

$C[G1.(0 - \ell_{\nu,g}^{(k)})] = P_{g,f=1}$ must be zero

$C[G1.(0 - \ell_{\nu,g}^{(k)} - 1)] = P_{g,f=2}$ $\quad (f = 1, 2, \cdots, \Delta)$

a) $P_{g,f} \equiv$ probability that the neutron has final energy $E' \leq E_{g,f}$, E' in same frame of reference as the angular distribution (re. block $(E4)_\nu$).

b) $P_{g,f=\Delta}$ must be ≥ 1.0.

8) Data block G2: Table of final neutron energies $E_{g,f}$ for neutrons incident with laboratory energy $E_{k,g}^{inel}$.

$C[G2.(0 - \ell_{\nu,g}^{(k)})] = E_{g,f=1}$

$C[G2.(0 - \ell_{\nu,g}^{(k)} - 1)] = E_{g,f=2}$ $\quad (f = 1, 2, \cdots, \Delta)$

etc.

$E_{g,f+1} \geq E_{g,f}$

T = 3:

C(R06) = (±Δ): same as reaction type T = 2 above.

C(R07) = J: the number of angles specified -- same for all incident energies $E_{k,g}^{inel}$.

6) Data block G0: Table of energy locators, $\ell_{\nu,g}^{(k)}$, for neutrons with incident energies $E_{k,g}^{inel}$. (See block G4 below.)

$C[(G0)_g] = \ell_{\nu,g}^{(k)}, \quad g = 1, 2, \cdots, N(E^{inel})$

7) Data block $\underline{G3}$: Table of cosines of scattering angles -- laboratory or CM agreeing with $(E4)_\nu$.

$$C[(G3)_j] = \cos\alpha_j\ , \qquad j = 1,\ 2,\ \cdots,\ J$$

$$(\cos\alpha_1 = -1.0\ , \qquad \cos\alpha_{j+1} > \cos\alpha_j\ , \qquad \cos\alpha_J = 1.0)$$

8) Data block $\underline{G4}$: Table of inelastic reaction data locators, $m^{(k)}_{\nu|j,g}$, for neutrons with incident laboratory energy $E^{inel}_{k,g}$ and scattering angle α_j. Data for final neutron energy distribution stored in blocks G5, G6, starting from $m^{(k)}_{\nu|j,g}$ word.

$$C\{G4.[0 - \ell^{(k)}_{\nu,g} - (j - 1)]\} = m^{(k)}_{\nu|j,g}$$

9) Data block $\underline{G5}$: Table of cumulative probabilities $P_{j,g,f}$ of final neutron energies $E_{j,g,f}$ for neutrons incident with laboratory energy $E^{inel}_{k,g}$ and scattered through an angle α_j.

$$C[G5.(0 - m^{(k)}_{\nu|j,g})] = P_{j,g,f=1} \text{ must be zero}$$

$$C[G5.(0 - m^{(k)}_{\nu|j,g} - 1)] = P_{j,g,f=2} \qquad (f = 1,\ 2,\ \cdots,\ \Delta)$$

a) $P_{j,g,f} \equiv$ probability that the neutron has final energy $E' \leq E_{j,g,f}$, E' in the same frame of reference as the angular distribution (re. block $(E4)_\nu$).

b) $P_{j,g,f=\Delta}$ must be ≥ 1.0.

10) Data block $\underline{G6}$: Table of final neutron energies $E_{j,g,f}$

for neutrons incident with laboratory energy $E_{k,g}^{inel}$ and scattered through an angle α_j.

$$C[G6.(0 - m_{\nu|j,g}^{(k)})] = E_{j,g,f=1}$$

$$C[G6.(0 - m_{\nu|j,g}^{(k)} - 1)] = E_{j,g,f=2} \qquad (f = 1, 2, \cdots, \Delta)$$

etc.

$$E_{j,g,f+1} \geq E_{j,g,f}$$

<u>T = 4</u>: (Fission)

6) Data block <u>GO</u>:

$$C[(GO)_g] = \nu_g^k$$

<u>T = 5</u>:

C(R06) = N'

6) Data block <u>GO</u>:

$$C[(GO)_g] = (Q_L)_g$$

<u>T = 6</u>: (n, 2n)

$C(R06) = Q_L$

$C(R07) = \alpha$

$C(R10) = \beta$

T = 7: (n, 2n)

C(R10) = T_1

C(R11) = T_2

where T_1, T_2 are the two reaction types comprising this reaction. The data for the two reactions must be entered as successive values of ν. C(E0) must be the same for both reactions.

APPENDIX D: MONTE CARLO CODE MCS

I - CARD LABEL CONVENTION

Col. 73-74: usual FLOCO labeling (X0-Z7)

75-76: XX for formula 8XX or 9XX

77: blank for formula 8XX

9 for formula 9XX

78-80: code label MC1.

II - CARD LOADING ORDER

(Number of cards in parentheses)

1 Advance NBA (card label 1 MC1)

2 A00 (3)

3 Q00 (2): X0Q0 + binary card punched by code MCA

4 D00 (2)

5 G00

6 H00

7 P00

8 S00

9 V00

10 W00

11 B00 (1)

12 COO (4)

13 EOO (5)

14 FOO (5)

15 KOO (2)

16 Advance NBA and record origins (cards labeled 2 MCl and 3 MCl)

17 Remark cards: R940-957, R963 (18)

18 Load instructions 857(card labeled 4 MCl)

19 F857 -- Data assign code (11)

20 Load instructions 903 (card labeled 5 MCl)

21 Subroutine LA S800 (2)

22 Load instructions 916 (card labeled 6 MCl)

23 Subroutine LA S820 (2)

24 Load instructions 917 (card labeled 7 MCl)

25 Subroutine LA S816 (4)

26 Load instructions 901 (card labeled 8 MCl)

27 F901 (1)

28 F900 (4)

29 F902 (2)

30 F921 (5)

31 F922 (5)

32 F923 (5)

33 F925 (7)

34 F926 (5)

35	F931 (4)
36	F932 (9)
37	F906 (7)
38	F924 (1)
39	F904 (7)
40	F905 (7)
41	F907 (9)
42	F911 (5)
43	F912 (6)
44	F910 (24)
45	F913 (14)
46	F914 (14)
47	F915 (24)
48	F920 (2)
49	F927 (5)
50	F930 (9)
51	F933 (12)
52	F934 (4)
53	F835 (1)
54	F801 (7)
55	F802 (10)
56	F804 (8)
57	F803 (5)
58	F805 (6)

59 F806 (20)

60 F807 (11)

61 F810 (23)

62 F811 (13)

63 F812 (8)

64 F813 (8)

65 F814 (11)

66 F815 (12)

67 F816 (11)

68 F817 (10)

69 F820 (9)

70 F821 (9)

71 F831 (5)

72 F832 (9)

73 F833 (5)

74 F824 (21)

75 F826 (4)

76 F827 (4)

77 F830 (15)

78 F836 (4)

79 F837 (1)

80 F825 (9)

81 SPECIAL TALLY ROUTINES: F860-876 (see pg. 11)

82 Load instructions 877 (card labeled 9 MC1)

83 F877 (3)

84 Load instructions 850 (card labeled 10 MC1)

85 SOURCE ROUTINE F850

86 Load instructions 800 (card labeled 11 MC1)

87 F800: FLOCODE (Version 1 or 2)

88 E0

89 I0

90 I1

91 I2

92 Y6

93 Transition card (labeled 12 MC1)

Quantities 27-80 usually replaced by a binary deck of 156 cards.

III - REMARKS CARDS FOR MONTE CARLO CODE MCS

940 Error stop -- Reload problem to continue

941 Error -- Square root of negative number

942 Error -- No intersection found

943 Error -- No cell found

944 Error -- K(T) = 1

945 Memory print -- (A00, B00, 127-100, Y6, Z2, Z3, Z4, Z5)

946 Debug print

947 Tally routine not specified

950 GMC 1 tally print

951

952 Problem finished -- Press start to continue. Save tape A06 if finished

953 Problem number -- Number neutrons -- Number collisions

954 Energy negative -- T = 1. Press start for no energy loss

955 Error -- Manual entry

956 Importance coefficients

957 Error -- Bank full

963 Source data -- (S00, V00, W00)

IV - FORMULA SET OF MONTE CARLO CODE MCS

FLOCODE 1

```
X00 8     800
X01  TSX4932
X02  TSX4826
X03  TSX4933
X04  TSX4825
X05  PSE 163
X06  TSX4926
X07  TSX4810

X10  TRA X04
X11  CLA A40
X12  ADD 401
X13  STO A40
X14  CLA A21
X15  ADD 401
X16  STO A21
X17  PSE 163

X20  TSX4926
X21  TSX4824
X22  TRA X04
X23  PSE 163
X24  TSX4926
X25  TRA X07
```

FLOCODE 2

```
X00 8     800
X01  TSX4932
X02  TSX4826
X03  TSX4933
X04  TSX4825
X05  PSE 163
X06  TSX4926
X07  TSX4810

X10  TRA X04
X11  TSX4833
X12  CLA A40
X13  ADD 401
X14  STO A40
X15  CLA A21
X16  ADD 401
X17  STO A21

X20  PSE 163
X21  TSX4926
X22  TSX4824
X23  TRA X04
X24  PSE 163
X25  TSX4926
X26  TRA X07
```

```
X00 8     801
X01  SXD4X64
X02  SXD1X65
X03  STZ A31
X04  STZ A51
X05  STZ 126
X06  LXA1401
X07  LXA4A47

X10  CLA A50
X11 6  14X14
X12  ADD A50
X13  TRA X11
X14  STD 127
X15  LXD4127
X16  SXD1X17
X17 1  14X20

X20  LXA2126
X21  CAL4R5
X22  TZE X30
X23  LBT
X24  TRA X26
X25  TSX4910
X26  ARS    1
X27 1  12X22

X30 1  11X31
X31 3A471X36
X32  CLA 126
X33  ADD C07
X34  STO 126
X35  TRA X15
X36  CLA A31
X37  TZE X56

X40  FSB A51
X41  STO A31
X42  CLA A51
X43  LXD2A43
X44  LDQ2T4
X45  STQ A52
X46  LXD4X64
X47  LXD1X65

X50  TNZ4   1
X51  CLA X55
X52  TSX4906
X53  HPR
X54  TSX4877
X55 0     942
X56  CLS C10
X57  STO A30

X60  TRA X42
X61  NOP
X62  NOP
X63  NOP
X64  HTR
X65  HTR
```

```
X00 8     802
X01  SXD4Y07
X02  SXD2Y10
X03  SXD1Y11
X04  CLA2Y6
X05  STO B05
X06  PAX4
X07  LXA1401

X10 1  14X11
X11  CLA4R5
X12  STO1175
X13  CAL4R6
X14  SLW1161
X15  COM
X16  SLW1145
X17 1  11X20

X20 7A471X10
X21  STZ2Y6
X22  LXD2124
X23  CLA2Y6
X24  TZE X36
X25  CLA2Y6
X26  PAX4
X27  LXA1401

X30 1  14X31
X31  CAL4R5
X32  ANA1175
X33  TNZ X45
X34 1  11X35
X35 7A471X30
X36 2  12X23
X37  LXD1Y11

X40  LXD2Y10
X41  LXD4Y07
X42  CLA B05
X43  STO2Y6
X44  TRA4   1
X45  SLW 102
X46  ANA1145
X47  ANA4R6

X50  TNZ X57
X51  CAL4R6
X52  COM
X53  ANA1161
X54  ANA 102
X55  TZE X34
X56  SSM
X57  SLW 103

X60  CLM
X61  STO 104
X62  PXD1
X63  ARS   22
X64  STA 104
X65  LDQ 103
X66  LXA4C11
X67  CLA 400
```

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X70   LGL   11
X71   TNZ  X73
X72  1C124X70
X73   LBT
X74   TRA  X76
X75   TRA  Y00
X76   ARS    1
X77 1   14X73

Y00 6   11Y02
Y01 1 444Y00
Y02   SXD4 104
Y03   CLA  104
Y04   LXD1Y11
Y05   LXD4Y07
Y06   TRA4   2
Y07   HTR

Y10   HTR
Y11   HTR

X00 8      803
X01   SXD4X40
X02   SXD2X41
X03   LXD2124
X04   CLA2Y6
X05   TNZ  X14
X06 2   12X04
X07   CLA  X13

X10   TSX4906
X11   HPR
X12   TSX4877
X13 0      943
X14   TSX4802
X15   TRA  X31
X16   TSX4913
X17   TQP  X22

X20   TPL  X23
X21   TRA  X14
X22   TPL  X14
X23   CLA  B05
X24   TSX4804
X25   TRA  X03
X26   CLA  B05
X27   LXD4X40

X30   TRA  X42
X31   TSX4804
X32   TRA  X35
X33   LXD4X40
X34 1   14X42
X35   STZ2Y6
X36   TRA  X03
X37 9   22X24

X40   HTR
X41   HTR
X42   NOP
X43   TRA4   2
```

```
X00 8      804
X01   CLA2Y6
X02   SXD4X72
X03   SXD2X73
X04   SXD1X74
X05   PAX1
X06   PDX4
X07   CAL4R0

X10   TRA  X67
X11   CLA  400
X12   STO  134
X13   LXA2134
X14   CLA  134
X15   ADD  C07
X16   STO  134
X17 1   11X20

X20   CAL1R5
X21   TZE  X47
X22   LBT
X23   TRA  X42
X24   SLW  135
X25   PXD2
X26   TSX4913
X27   CAL2T4

X30   ANA1R6
X31   TNZ  X34
X32   TQP  X35
X33   TRA  X41
X34   TQP  X41
X35   LXD4X72
X36   LXD2X73
X37   LXD1X74

X40   TRA4   1
X41   CAL  135
X42   ARS    1
X43 1   12X44
X44 7A542X21
X45   LXD4X72
X46 2   14X36
X47   LXA2134

X50 7A542X14
X51   TRA  X45
X52   CAL4R0
X53   ANA  441
X54   ALS   22
X55   SXD4126
X56   TSX4913
X57   LXD4126

X60   CAL  C32
X61   ANA4R0
X62   TQP  X65
X63   TZE  X11
X64   TRA  X35
X65   TZE  X35
X66   TRA  X11
X67   ANA  C14
```

```
X70   TNZ  X11
X71   TRA  X52
X72   HTR
X73   HTR
X74   HTR

X00 8      805
X01   SXD4X56
X02   SXD2X57
X03   NOP
X04   CLA  125
X05   PDX2
X06   CLA  123
X07   SUB  401

X10   STO  123
X11   TSX4802
X12   TRA  X31
X13   TSX4913
X14   TQP  X17
X15   TPL  X20
X16   TRA  X25
X17   TPL  X25

X20   CLA  B05
X21   TSX4804
X22   TRA  X40
X23   CLA  B05
X24   TRA  X51
X25   CAL2Y6
X26   ANA  C14
X27   TZE  X11

X30   TRA  X06
X31   TSX4804
X32   TRA  X37
X33   LXD4X56
X34   NOP
X35   NOP
X36   TRA4   2
X37   STZ2Y6

X40   CLA  123
X41   TZE  X47
X42   LXD2124
X43   CAL2Y6
X44   ANA  C14
X45   TNZ  X06
X46 2   12X43
X47   TSX4803

X50   TRA  X33
X51   LXD4X56
X52   NOP
X53   NOP
X54   TRA4   3
X55 9   22X21
X56   HTR
X57   HTR
```

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X00 8      806
X01   SXD4Z30
X02   SXD2Z31
X03   SXD1Z32
X04   STZ  123
X05   LXA4A47
X06   CAL  A50
X07   LDQ  C15

X10   STQ4Z0
X11   STQ4Z1
X12 6   14X15
X13   ADM  A50
X14   TRA  X10
X15   STD  117
X16   ARS   22
X17   ADM  A43

X20   STA  117
X21   PAX4
X22   CAL  A52
X23   ANA4R6
X24   TNZ  X27
X25   CLS  A43
X26   STO  A43
X27   NOP

X30   NOP
X31   NOP
X32   NOP
X33   LXA1401
X34   LXD4117
X35 1   14X36
X36   CAL4R5
X37   SLW1175

X40   CAL4R6
X41   SLW1161
X42   COM
X43   ANA4R5
X44   SLW1145
X45 1   11X46
X46 7A471X35
X47   LXA2401

X50   LXA1401
X51   LXA4A43
X52   PXD4
X53   SLW  101
X54   LDQ  A43
X55   CAL  A52
X56   ANA4R5
X57   TZE  X75

X60   ANA4R6
X61   TQP  X64
X62   TZE  X75
X63   TRA  X65
X64   TNZ  X75
X65   PXD1
X66   ORA  C16
X67   STO2Y6
```

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X70  PXD4
X71  SUB 101
X72  ARS  22
X73  STA2Y6
X74 1  12X75
X75 1A474X76
X76 1  11X77
X77 7A461X55

Y00 3  12Z27
Y01  CLA YC5
Y02  TSX49C6
Y03  HPR
Y04  TSX4877
Y05 0     944
Y06 7  12Z15
Y07  SXD2124

Y10  LXA1401
Y11  CLA2Y6
Y12  PAX4
Y13 1  14Y14
Y14  CAL4R6
Y15  ANS1Z1
Y16  CØM
Y17  ANA4R5

Y20  ANS1Z0
Y21 7A471Y13
Y22 2  12Y10
Y23  LXA1A47
Y24  LXD4117
Y25 1A474Y26
Y26  CAL1Z0
Y27  ØRA1Z1

Y30  SLW1Z0
Y31  CØM
Y32  ANS1175
Y33  ANS1161
Y34  ANS1145
Y35  ANA4R5
Y36  ØRS1Z0
Y37  ANA4R6

Y40  ØRS1Z1
Y41 2  14Y42
Y42 2  11Y26
Y43  LXD2124
Y44  LXA1401
Y45  MSE 143
Y46  NØP
Y47  CLA2Y6

Y50  PAX4
Y51 1  14Y52
Y52  CAL4R5
Y53  ANA1175
Y54  TZE Z03
Y55  SLW 100
Y56  ANA4R6
Y57  ANA1145

Y60  TNZ Z01
Y61  CAL4R6
Y62  CØM
Y63  ANA 1C0
Y64  ANA1161
Y65  TNZ ZC1
Y66  MSE 143
Y67  TRA Y71

Y70  TRA Z03
Y71  CLA C14
Y72  ØRS2Y6
Y73  CLA 123
Y74  ADD 401
Y75  STØ 123
Y76  PSE 143
Y77  SXD2125

Z00  TRA Z03
Z01  STZ2Y6
Z02  TRA Z05
Z03 1  11Z04
Z04 7A471Y51
Z05 2  12Y44
Z06  MSE 143
Z07  NØP

Z10  CLA 123
Z11  CAS 401
Z12  NØP
Z13  TSX48C5
Z14  TSX4803
Z15  CLA2Y6
Z16  STD A50
Z17  LXD4Z30

Z20  LXD2Z31
Z21  LXD1Z32
Z22  TRA4  1
Z23 8    2Y20
Z24 1   11Y21
Z25 8    2X53
Z26 1A474X54
Z27 2  12Y06

Z30  HTR
Z31  HTR
Z32  HTR

X00 8     807
X01  SXD4Y13
X02  SXD2Y14
X03  SXD1Y15
X04  STZ A15
X05  STZ 102
X06  PAX1
X07  CLA1S5

X10  PAX1
X11  ANA 442
X12  STØ 1C3
X13  CLA1M1
X14  STØ 104
X15  ANA C20
X16  PAX4
X17  CLA4T0

X20  PAX4
X21 1  14X22
X22  CLA4M0
X23  STØ 105
X24  STD X42
X25  STD X45
X26  STD X64
X27  PCX2

X30 1  14X31
X31  CLA A22
X32  CAS4M0
X33  TRA X50
X34  TRA X45
X35  CLA 105
X36  ANA 445
X37  TZE X45

X40  CLA4M0
X41  FCH A22
X42 1  04X43
X43  FMP4M0
X44  TRA X72
X45 1  04X46
X46  CLA4MC
X47  TRA X72

X50 6  12X45
X51 1  14X52
X52  CLA A22
X53  CAS4M0
X54  TRA X50
X55  TRA X45
X56  CLA4M0
X57  FSB4M0-

X60  STØ 105
X61  CLA A22
X62  FSB4M0-
X63  STØ 106
X64 1  04X65
X65  CLA4M0
X66  FSB4M0-
X67  FCH 105

X70  FMP 106
X71  FAD4M0-
X72  LRS  43
X73  FMP 104
X74  FAD A15
X75  STØ A15
X76  LXD4102
X77 1  14YC0

Y00  SXD4102
Y01  STØ4Z4
Y02  CLA 1C3
Y03  SUB 415
Y04  TZE Y06
Y05 1  11X12
Y06  LXD4Y13
Y07  LXD2Y14

Y10  LXD1Y15
Y11  LDQ A15
Y12  TRA4  1
Y13  HTR
Y14  HTR
Y15  HTR
Y16 8    2X72
Y17  STQ 105

Y20  TRA X73
Y21 8    2Y01
Y22  CLA 105
Y23  STØ4Z5
Y24  TRA YC2

X00 8     810
X01  SXD4Y77
X02  SXD2Z00
X03  SXD1Z01
X04  STZ 801
X05  LXA4A54
X06  STZ4Z2
X07  STZ4Z3

X10 2  14X06
X11  LXD1A50
X12  TSX4920
X13  STØ A20
X14  TSX4801
X15  TRA X21
X16  NØP
X17  NØP

X20  NØP
X21  FAD C04
X22  STØ 100
X23  CLA1R0
X24  ANA C21
X25  ARS   6
X26  STØ 101
X27  CLA1R3

X30  ANA C20
X31  TSX4807
X32  FMP1R3
X33  STØ 102
X34  SUB 101
X35  STØ 1C3
X36  TSX4902
X37  TSX4916
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X40   CLA 400
X41   CHS
X42   FCH 103
X43   STQ 104
X44   CLA 104
X45   CAS 100
X46   TRA X63
X47   TRA X36

X50   FAD C04
X51   CAS 100
X52   TRA X36
X53   TRA X36
X54   LDQ 104
X55   TSX4Y35
X56   TSX4Y76
X57   LXD4Y77

X60   LXD2Z00
X61   LXD1Z01
X62   TRA4  2
X63   FSB C04
X64   CAS 100
X65   TRA X70
X66   TRA X36
X67   TRA X36

X70   LDQ 100
X71   TSX4Y35
X72   TSX4X73
X73   TRA2S7
X74   TSX4X75
X75   TRA2R4
X76   TRA Y00
X77   TRA X14

Y00   TSX4806
Y01   LXD1A50
Y02   TSX4920
Y03   STO 105
Y04   TZE Y31
Y05   TSX4902
Y06   STO 110
Y07   CLA 105

Y10   FCH A20
Y11   STQ 106
Y12   CLA 106
Y13   CAS 421
Y14   TRA Z12
Y15   TRA X14
Y16   CLA A16
Y17   FDH 106

Y20   STQ A16
Y21   CLA 110
Y22   CAS 106
Y23   TRA Y31
Y24   TRA Y31
Y25   TRA X14
Y26   NOP
Y27   NOP

Y30   NOP
Y31   LXD4Y77
Y32   LXD2Z00
Y33   LXD1Z01
Y34   TRA4  1
Y35   STQ 120
Y36   SXD4Y75
Y37   CLA 101

Y40   TZE Y54
Y41   CLA 103
Y42   FSB 102
Y43   LRS  43
Y44   FMP 120
Y45   TSX4917
Y46   CLA 400
Y47   NOP

Y50   NOP
Y51   LRS  43
Y52   FMP A16
Y53   STO A16
Y54   LXA4403
Y55   LDQ 120
Y56   FMP4A04
Y57   FAD4A00

Y60   STO4A00
Y61 2  14Y55
Y62   CLA 120
Y63   FDH A22
Y64   STQ 122
Y65   CLA A04
Y66   FAD 122
Y67   STO A04

Y70   CLA B01
Y71   FAD 120
Y72   STO B01
Y73   LXD4Y75
Y74   TRA4  1
Y75   HTR
Y76   TRA1S4
Y77   HTR

Z00   HTR
Z01   HTR
Z02 8   2X55
Z03   CLA 101
Z04   TZE X56
Z05   CLA 102
Z06   FDH 103
Z07   FMP A16

Z10   STO A16
Z11   TRA X56
Z12   MSE 141
Z13   TRA Z21
Z14   PSE 141
Z15   CLA D07
Z16   ADD 401
Z17   STO D07

Z20   TRA Y25
Z21   LXD4A42
Z22   LXA2401
Z23   LDQ 421
Z24   STQ 111
Z25   STO 112
Z26   FSB 421
Z27   STO 106

Z30   CAS 110
Z31   10234Z47
Z32   NOP
Z33   CLA A16
Z34   FCH 112
Z35   STQ A16
Z36 7  12Y25
Z37   TSX4921

Z40   TRA Z42
Z41 2  12Z36
Z42   CLA Z46
Z43   TSX4906
Z44   HPR
Z45   TSX4877
Z46 0     957
Z47   70034Z56

Z50   CLA 111
Z51   STO 112
Z52   CLA D07
Z53   ACD 401
Z54   STO D07
Z55   TRA Z33
Z56   CLA 111
Z57   FAD 421

Z60   STO 111
Z61   CLA 106
Z62 1  12Z26
Z63 8   2Y11
Z64   CLA 105
Z65   STO A20
Z66   TRA Y12

X00 8     811
X01   SXD4X73
X02   SXD2X74
X03   LXA2B01
X04 1  12X05
X05   CLA2M0
X06   ANA 442
X07   ALS   2

X10   STD X11
X11 1  02X12
X12 1  12X13
X13   CLA2M0
X14   STD X44
X15   STD Y05
X16   ANA 441
X17   TSX4901

X20   STO 110
X21   LXD4X44
X22 1  12X23
X23   CLA2M0
X24   CAS A17
X25   TRA Y04
X26   TRA Y04
X27 6  14Y04

X30 1  12X31
X31   CLA A17
X32   CAS2M0
X33   TRA X27
X34   TRA Y04
X35   CLA2M0
X36   FSB2M0-
X37   STO B05

X40   CLA A17
X41   FSB2M0-
X42   FDH B05
X43   STQ B05
X44 1  02X45
X45   CLA2M0
X46   STO B07
X47   CLA2M0-

X50   STO B06
X51   TSX4902
X52   STO 111
X53   TSX4904
X54   CLA B10
X55   TSX4930
X56   CAS 111
X57   TRA X62

X60   TRA X62
X61   TRA X51
X62   LXA2A50
X63   CLA B06
X64   ANA C14
X65   TZE X75
X66   LDQ 110
X67   TSX4927

X70   LXD4X73
X71   LXD2X74
X72   TRA4  1
X73   HTR
X74   HTR
X75   LXA4403
X76   CLA4B01
X77   STO4A04

Y00 2  14X76
Y01   NOP
Y02   CLA C25
Y03   TRA Y11
Y04   STZ B05
Y05 1  02Y06
Y06   CLA2M0
Y07   STZ B07
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Y10   TRA X50
Y11   CAS 110
Y12   TRA Y17
Y13   TRA Y17
Y14   CLA A17
Y15   LDQ A22
Y16   TRA X70
Y17   LDQ 110

Y20   FMP 110
Y21   STO 100
Y22   LDQ B10
Y23   FMP B10
Y24   FAD 100
Y25   FSB 421
Y26   TSX4903
Y27   CLA 400

Y30   FAD B10
Y31   FDH2T3
Y32   STQ 100
Y33   FMP A22
Y34   STO 102
Y35   LDQ 100
Y36   FMP 100
Y37   LRS  43

Y40   FMP A17
Y41   LDQ 102
Y42   TRA X70


X00 8     812
X01   SXD4X54
X02   SXD2X55
X03   LXA2B12
X04   CLA2M4
X05   STO 112
X06   TSX4902
X07   STO 113

X10   TSX4904
X11   CLA B10
X12   TSX4930
X13   CAS 113
X14   TRA X17
X15   TRA X17
X16   TRA X06
X17   TSX4902

X20   CLA 400
X21   LDQ A44
X22   LLS   5
X23   PAX4
X24   CLA4F01
X25   FDH 112
X26   FMP A22
X27   STO 114
```

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X30   CLA B06
X31   ANA C14
X32   TZE X56
X33   LXA2A50
X34   CLA 114
X35   FDH A17
X36   STQ 115
X37   CLA 115

X40   TSX4903
X41   TRA X72
X42   LRS  43
X43   FMP2T3
X44   LRS  43
X45   TSX4927
X46   CAS A17
X47   TRA X17

X50   NOP
X51   LXD4X54
X52   LXD2X55
X53   TRA4  1
X54   HTR
X55   HTR
X56   LXA4403
X57   CLA4B01

X60   STO4A04
X61 2  14X57
X62   CLA 114
X63   TSX4903
X64   TRA X72
X65   LRS  43
X66   FMP C24
X67   LRS  43

X70   CLA 114
X71   TRA X51
X72   CLA X76
X73   TSX4906
X74   HPR
X75   TSX4877
X76 0     941


X00 8     813
X01   SXD4X43
X02   SXD2X44
X03   LXA4B12
X04   CLA4M4
X05   STO 112
X06   TSX4902
X07   STO 113

X10   TSX4904
X11   CLA B10
X12   TSX4930
X13   CAS 113
X14   TRA X17
X15   TRA X17
X16   TRA X06
X17   CLA B06
```

```
X20   ANA C14
X21   TZE X45
X22   LXA2A50
X23   CLA A17
X24   FSB 112
X25   LRS  43
X26   FMP2S6
X27   FDH A17

X30   STQ 115
X31   CLA 115
X32   TSX4903
X33   TRA X64
X34   LRS  43
X35   FMP2T3
X36   LRS  43
X37   TSX4927

X40   LXD4X43
X41   LXD2X44
X42   TRA4  2
X43   HTR
X44   HTR
X45   CLA A17
X46   FSB 112
X47   STO 115

X50   TSX4903
X51   TRA X64
X52   LRS  43
X53   FMP C24
X54   STO 114
X55   LXA4403
X56   CLA4B01
X57   STO4A04

X60 2  14X56
X61   CLA 115
X62   LDQ 114
X63   TRA X40
X64   CLA X70
X65   TSX4906
X66   HPR
X67   TSX4877

X70 0     941


X00 8     814
X01   SXD4X70
X02   SXD2X71
X03   LXA4B12
X04   CLA4M4
X05   STO 112
X06   STD X40
X07   STD X77
```

```
X10   TSX4902
X11   STO 113
X12   TSX4904
X13   CLA B10
X14   TSX4930
X15   CAS 113
X16   TRA X21
X17   TRA X21

X20   TRA X10
X21   TSX4902
X22   STO 114
X23   CLA 112
X24   ANA C14
X25   TZE X72
X26   LXA4112
X27   CLA 114

X30   CAS4M4
X31 1  14X30
X32   NOP
X33   FSB4M4-
X34   STO 114
X35   CLA4M4
X36   FSB4M4-
X37   STO 115

X40 1  04X41
X41   CLA4M4
X42   FSB4M4-
X43   FDH 113
X44   FMP 114
X45   FAD4M4-
X46   STO 114
X47   CLA B06

X50   ANA C14
X51   TZE Y02
X52   LXA2A50
X53   CLA 114
X54   FDH A17
X55   STQ 115
X56   CLA 115
X57   TSX4903

X60   TRA Y17
X61   LRS  43
X62   FMP2T3
X63   LRS  43
X64   TSX4927
X65   LXD4X70
X66   LXD2X71
X67   TRA4  3

X70   HTR
X71   HTR
X72   LXA4112
X73   CLA 114
X74   CAS4M4
X75 1  14X74
X76   NOP
X77 1  04Y00
```

```
Y00   CLA4M4
Y01   TRA X46
Y02   CLA 114
Y03   TSX4903
Y04   TRA Y17
Y05   LRS  43
Y06   FMP C24
Y07   STØ 115

Y10   LXA4403
Y11   CLA4B01
Y12   STØ4A04
Y13 2   14Y11
Y14   CLA 114
Y15   LDQ 115
Y16   TRA X65
Y17   CLA Y23

Y20   TSX4906
Y21   HPR
Y22   TSX4877
Y23 C       941

X00 E       815
X01   SXD4X76
X02   SXD2X77
X03   LXA4B12
X04   CLA4M4
X05   STØ 112
X06   STD X46
X07   STD Y04

X10   TSX4902
X11   STØ 113
X12   TSX4904
X13   CLA B10
X14   TSX4930
X15   CAS 113
X16   TRA X21
X17   TRA X21

X20   TRA X10
X21   TSX4902
X22   STØ 114
X23   LXA4112
X24   CLA B10
X25   CAS4M4
X26 1   14X25
X27   NØP

X30   CLA4M4
X31   PAX4
X32   CLA 112
X33   ANA C14
X34   TZE Y00
X35   CLA 114
X36   CAS4M4
X37 1   14X36

X40   NØP
X41   FSB4M4-
X42   STØ 114
X43   CLA4M4
X44   FSB4M4-
X45   STØ 113
X46 1   04X47
X47   CLA4M4

X50   FSB4M4-
X51   FDH 113
X52   FMP 114
X53   FAD4M4-
X54   STØ 114
X55   CLA B06
X56   ANA C14
X57   TZE Y07

X60   LXA2A50
X61   CLA 114
X62   FDH A17
X63   STQ 115
X64   CLA 115
X65   TSX4903
X66   TRA Y24
X67   LRS  43

X70   FMP2T3
X71   LRS  43
X72   TSX4927
X73   LXD4X76
X74   LXD2X77
X75   TRA4  4
X76   HTR
X77   HTR

Y00   CLA 114
Y01   CAS4M4
Y02 1   14Y01
Y03   NØP
Y04 1   04Y05
Y05   CLA4M4
Y06   TRA X54
Y07   CLA 114

Y10   TSX4903
Y11   TRA Y24
Y12   LRS  43
Y13   FMP C24
Y14   STØ 115
Y15   LXA4403
Y16   CLA4B01
Y17   STØ4A04

Y20 2   14Y16
Y21   CLA 114
Y22   LDQ 115
Y23   TRA X73
Y24   CLA Y30
Y25   TSX4906
Y26   HPR
Y27   TSX4877

Y30 C       941

X00 E       816
X01   SXD4Y14
X02   SXD2Y15
X03   LXA4B12
X04   LXA2B13
X05   CLA B05
X06   TZE Y16
X07   CLA2M4

X10   FSB4M4
X11   LRS  43
X12   FMP B05
X13   FAD4M4
X14   STØ 120
X15   LXA24C2
X16   CAS 423
X17   NØP

X20 1   12Y20
X21   FDH 422
X22   FMP A16
X23   STØ A16
X24   TSX4902
X25   STØ 114
X26   TSX4904
X27   CLA B10

X30   TSX4930
X31   CAS 114
X32   TRA X35
X33   TRA X35
X34   TRA X24
X35   TSX4902
X36   STØ 114
X37   CLA 400

X40   LDQ A44
X41   LLS   5
X42   PAX4
X43   CLA4E02
X44   FSB4E01
X45   LRS  43
X46   FMP 114
X47   FAD4E01

X50   STØ 115
X51   TSX4903
X52   TRA Y22
X53   LRS  43
X54   FMP C24
X55   STØ 116
X56   LXA4403
X57   CLA4B01

X60   STØ4A04
X61 2   14X57
X62 7   12Y07
X63   CLA 115
X64   STØ A17
X65   CLA 116
X66   STØ A22
X67   CLA A05

X70   STØ A10
X71   LXA4403
X72   LDQ4A04
X73   FMP4A04
X74   STØ4A10
X75 2   14X72
X76   TSX4921
X77   TRA Y01

Y00 2   12X24
Y01 7   22Y04
Y02   LDQ 423
Y03   TRA Y05
Y04   LDQ 422
Y05   FMP A16
Y06   STØ A16
Y07   CLA 115

Y10   LDQ 116
Y11   LXD4Y14
Y12   LXD2Y15
Y13   TRA4  5
Y14   HTR
Y15   HTR
Y16   CLA4M4
Y17   TRA X14

Y20   FDH 423
Y21   TRA X22
Y22   CLA Y26
Y23   TSX4906
Y24   HPR
Y25   TSX4877
Y26 C       941

X00 E       817
X01   SXD4Y15
X02   SXD2Y16
X03   LXA4B12
X04   CLA A17
X05   FSB4M4
X06   LXA2A50
X07   LRS  43

X10   FMP2S6
X11   STØ 112
X12   CAL4M4
X13   ANA 403
X14   TSX4901
X15   STØ 115
X16   SUB 422
X17   TNZ X23

X20   LDQ 115
X21   FMP A16
X22   STØ A16
X23   TSX4902
X24   STØ 113
X25   TSX4904
X26   CLA B10
X27   TSX4930
```

```
X30   CAS 113
X31   TRA X34
X32   TRA X34
X33   TRA X23
X34   TSX4902
X35   STO 113
X36   TSX4902
X37   STO 114

X40   CLA 422
X41   CAS 115
X42   TRA Y00
X43   TRA Y00
X44   CLA 421
X45   FSB 113
X46   STO 116
X47   CLA 113

X50   TSX4903
X51   TRA Y10
X52   FDH C35
X53   FMP 116
X54   LRS  43
X55   FMP 116
X56   CAS 114
X57   TRA X62

X60   TRA X62
X61   TRA X34
X62   LDQ 113
X63   FMP 112
X64   FDH A17
X65   STO 116
X66   CLA 116
X67   TSX4903

X70   TRA Y10
X71   LRS  43
X72   FMP2T3
X73   LRS  43
X74   TSX4927
X75   LXD4Y15
X76   LXD2Y16
X77   TRA4  6

Y00   CLA 421
Y01   FSB 113
Y02   LRS  43
Y03   FMP 113
Y04   TSX4903
Y05   TRA Y10
Y06   ACD 411
Y07   TRA X56

Y10   CLA Y14
Y11   TSX4906
Y12   HPR
Y13   TSX4877
Y14 0     941
Y15   HTR
Y16   HTR

X00 8     820
X01   SXD4X63
X02   SXD2X64
X03   SXD1X65
X04   LXA4B12
X05   CLA4M4
X06   PAX2
X07 1   12X10

X10   LXA1402
X11   CLA A17
X12   FSB2M4-
X13   STO 115
X14   TSX4902
X15   STO 113
X16   TSX4904
X17   CLA B10

X20   TSX4930
X21   CAS 113
X22   TRA X25
X23   TRA X25
X24   TRA X14
X25   LDQ 115
X26   FMP2M4
X27   STO A17

X30   TSX4903
X31   TRA X66
X32   LRS  43
X33   FMP C24
X34   STO A22
X35   LXA4403
X36   CLA4B01
X37   STO4A04

X40 2   14X36
X41 7   11X55
X42   TSX4921
X43   TRA X46
X44 2   11X45
X45 1   12X14
X46   CAL A16
X47   ACL 411

X50   SLW A16
X51   CLA A44
X52   ARS   5
X53   LBT
X54   TRA X44
X55   CLA A17
X56   LDQ A22
X57   LXD4X63

X60   LXD2X64
X61   LXD1X65
X62   TRA4  7
X63   HTR
X64   HTR
X65   HTR
X66   CLA X72
X67   TSX4906

X70   HPR
X71   TSX4877
X72 0     941
X73 8    2X41
X74   CLA A05
X75   STO A10
X76   LXA4403
X77   LDQ4A04

Y00   FMP4A04
Y01   STO4A10
Y02 2   14X77
Y03   TRA X42

X00 8     821
X01   SXD4X63
X02   LXD4B12
X03   CLA4M4
X04   ARS   6
X05   ANA 446
X06   PAX4
X07 7   34X15

X10   CLA X14
X11   TSX4906
X12   HPR
X13   TSX4877
X14 0     947
X15   TRA4X21
X16   TSX4815
X17   TSX4814

X20   TSX4813
X21   TSX4812
X22   STO  77
X23   CLA A17
X24   STO 126
X25   CLA A22
X26   STO 127
X27   CLA  77

X30   STO A17
X31   STQ A22
X32   TSX4921
X33   TRA X64
X34   CAL B12
X35   ACL 425
X36   SLW B12
X37   CAL B13

X40   ACL 425
X41   SLW B13
X42   CLA 126
X43   STO A17
X44   CLA 127
X45   STO A22
X46   LXD4B12
X47   CLA4M4

X50   ARS   6
X51   ANA 446
X52   PAX4
X53 3   34X10
X54   TRA4X60
X55   TSX4815
X56   TSX4814
X57   TSX4813

X60   TSX4812
X61   LXD4X63
X62   TRA4 10
X63   HTR
X64   CAL A16
X65   ACL 411
X66   SLW A16
X67   CLA A44

X70   ARS   5
X71   LBT
X72   TRA X34
X73   CLA A17
X74   LDQ A22
X75   TRA X61
X76 8    2X31
X77   CLA A05

Y00   STO A10
Y01   LXA4403
Y02   LDQ4A04
Y03   FMP4A04
Y04   STO4A10
Y05 2   14Y02
Y06   TRA X32

X00 8     824
X01   SXD4X65
X02   LXD4A50
X03   CLA4R3
X04   ANA C20
X05   TSX4831
X06   STA A50
X07   PAX4

X10   CLA4TC
X11   STO B01
X12   TSX4832
X13   STO 125
X14   FMP A16
X15   STO A16
X16   CAS A27
X17   TRA Z27

X20   TRA Z27
X21   CLA A55
X22   ACD 401
X23   STO A55
X24   LXD4X65
X25   TRA4  1
X26   CLA A04
X27   CAS A57
```

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X30   TRA Z44
X31   TRA Z44
X32   TSX4902
X33   CAS 125
X34   TRA X67
X35   NOP
X36   TSX4811
X37   CAS A56

X40   TRA X52
X41   NOP
X42   CLA A56
X43   STO A17
X44   TSX4903
X45   CLA 400
X46   LRS  43
X47   FMP C24

X50   STO A22
X51   TRA X54
X52   STO A17
X53   STO A22
X54   CLA A05
X55   STO A10
X56   LXA4403
X57   LDQ4A04

X60   FMP4A04
X61   STO4A10
X62 2   14X57
X63   LXD4X65
X64   TRA4   2
X65   HTR
X66   HTR
X67   SXD2X66

X70   LXD2B01
X71 1   12X72
X72   CLA2M3
X73   STO B11
X74   PDX4
X75 1   12X76
X76   CLA2M3
X77   CAS A17

Y00   TRA Y51
Y01   TRA Y51
Y02 6   14Y51
Y03 1   12Y04
Y04   CLA A17
Y05   CAS2M3
Y06   TRA Y02
Y07   TRA Y51

Y10   CLA2M3
Y11   FSB2M3-
Y12   STO 105
Y13   CLA A17
Y14   FSB2M3-
Y15   FCH 105
Y16   STO B05
Y17 1   02Y20

Y20   TSX4902
Y21   STO 105
Y22   CLA B05
Y23   TZE Y53
Y24   CLA2M3
Y25   STO B13
Y26   CLA2M3-
Y27   STO B12

Y30   LXD4B13
Y31   CLA4M4
Y32   LXD4B12
Y33   FSB4M4
Y34   LRS  43
Y35   FMP B05
Y36   FAD4M4
Y37   CAS 105

Y40   TRA Y66
Y41   TRA Y66
Y42   CAL B12
Y43   ACL 425
Y44   SLW B12
Y45   CAL B13
Y46   ACL 425
Y47   SLW B13

Y50 1   02Y30
Y51   STZ B05
Y52   TRA Y17
Y53   CLA2M3
Y54   STO B12
Y55   LXD4B12
Y56   CLA4M4
Y57   CAS 105

Y60   TRA Y66
Y61   TRA Y66
Y62   CAL B12
Y63   ACL 425
Y64   SLW B12
Y65 1   02Y55
Y66   CAL4M4
Y67   ANA 446

Y70   PAX4
Y71   CLA B01
Y72   TMI Z01
Y73 1   02Z34
Y74   CLA2M3
Y75   STO B07
Y76   CLA2M3-
Y77   STO B06

Z00   TRA Z04
Z01   ANA 445
Z02   STO B06
Z03   STO B07
Z04   TRA4Z16
Z05   HTR
Z06   HTR
Z07   TSX4821

Z10   TSX4820
Z11   TSX4817
Z12   TSX4816
Z13   TSX4815
Z14   TSX4814
Z15   TSX4813
Z16   TSX4812
Z17   LXD2X66

Z20   TRA X37
Z21 8    2X73
Z22   STD Y17
Z23   STD Y50
Z24   STD Y65
Z25   STD Y73
Z26   TRA X74
Z27   CLA A17

Z30   CAS D11
Z31   TRA X26
Z32   TRA X26
Z33   TRA Z40
Z34   CLA B05
Z35   TNZ Y74
Z36   STZ B07
Z37 1   12Y76

Z40   CLA A60
Z41   ADD 401
Z42   STO A60
Z43   TRA X24
Z44   CLA A61
Z45   ADD 401
Z46   STO A61
Z47   TRA X24

X00 8       825
X01   SXD4X10
X02   PSE 163
X03   TSX4926
X04   TSX4922
X05   TRA X11
X06   LXD4X10
X07   TRA4   1

X10   HTR
X11   PSE 161
X12   TRA X22
X13   TSX4830
X14   TSX4975
X15 0    2
X16 0      952
X17 0   1

X20 4   41A35
X21   HPR
X22   CLA A37
X23   ADD 401
X24   STO A37
X25   STZ A21
X26   CLA A35
X27   ADD 401

X30   STO A35
X31   CAS D01
X32   NOP
X33   TRA X67
X34   TSX4850
X35   CLA A05
X36   STO A10
X37   LXA4403

X40   LDQ4A04
X41   FMP4A04
X42   STO4A10
X43 2   14X40
X44   CLA A17
X45   TSX4903
X46   TRA X71
X47   LRS  43

X50   FMP C24
X51   STO A22
X52   CLA A33
X53   ADD 401
X54   STO A33
X55   SUB D04
X56   TMI X06
X57   STZ A33

X60   TSX4975
X61 0   3
X62 0       953
X63 0   1
X64 4   41A35
X65   TSX4931
X66   TRA X06
X67   TSX4830

X70   TRA X34
X71   CLA X75
X72   TSX4906
X73   HPR
X74   TRA X34
X75 0       341
X76 8      2X01
X77   RQL 144

Y00   NOP
Y01   STZ X62
Y02   TRA X02

X00 8       826
X01   SXD4X31
X02   TSX4976
X03   TSX4975
X04 0       953
X05 0   1
X06 4   31A35
X07   TSX4925
```

```
X10   TSX4974
X11 0    1
X12 C      956
X13 0   2
X14 0      I0
X15 0      I1
X16 0      I2
X17 0      Y6

X20 0   3
X21 0      963
X22 0 101S00
X23 0   3
X24 C 201V00
X25 0   3
X26 4 201W00
X27   LXD4X31

X30   TRA4   1
X31   HTR


X00 8      827
X01   SXD4X37
X02   STQ  120
X03   STO  121
X04   ARS   22
X05   STO  122
X06   CLA  121
X07   SUB  122

X10   SUB  122
X11   STA  X17
X12   STA  X20
X13   SUB  122
X14   STA  X24
X15   STA  X34
X16   CLA  120
X17   FAD1A0

X20   STO1A0
X21   LDQ  120
X22   FMP  120
X23   STO  123
X24   CLA1A0
X25   STA  124
X26   FAD  123
X27   STO  123

X30   CAL  124
X31   ADD  401
X32   STA  123
X33   CLA  123
X34   STO1A0
X35   LXD4X37
X36   TRA4   1
X37   HTR
```

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X00 8      830
X01   SXD4X30
X02   SXD2X31
X03   SXD1X32
X04   LXA1C26
X05   CLA  C26
X06   ALS    1
X07   STO  140

X10   ADD  C27
X11   STA  X33
X12   CLA1P00
X13   TNZ  X33
X14   CLA  140
X15   SUB  4C2
X16 2   11X07
X17   STZ  A35

X20   TSX4931
X21   CLA  D12
X22   TNZ  Y11
X23   TSX4925
X24   LXD4X30
X25   LXD2X31
X26   LXD1X32
X27   TRA4   1

X30   HTR
X31   HTR
X32   HTR
X33   CLA    0
X34   STO  100
X35   PDX2
X36   ARS   22
X37   STO  101

X40   CLA  100
X41   STA  X55
X42   SUB  101
X43   STA  Y01
X44   SUB  101
X45   STA  X53
X46   SUB  101
X47   STA  X61

X50   CLA  A37
X51   TSX4901
X52   STO  110
X53   CLA2   0
X54   FDH  110
X55   STQ2   0
X56   STQ  100
X57   FMP  100

X60   STO  100
X61   CLA2   0
X62   STO  111
X63   ANA  441
X64   TZE  Y02
X65   TSX4901
X66   STO  112
X67   CLA  111
```

```
X70   FDH  110
X71   STQ  101
X72   CLA  101
X73   FSB  100
X74   FDH  110
X75   STQ  100
X76   CLA  100
X77   TSX4903

Y00   CLA  400
Y01   STO2   0
Y02 2   12X53
Y03   TRA  X14
Y04   CLA  Y10
Y05   TSX4906
Y06   HPR
Y07   TSX4877

Y10 0      941
Y11   CLA  A37
Y12   TSX4901
Y13   STO  110
Y14   LXD2T7*
Y15   CLA2T6
Y16   FDH  110
Y17   STQ2T6

Y20   FMP2T6
Y21   STO  100
Y22   CLA2U6
Y23   ANA  441
Y24   STO  111
Y25   TSX4901
Y26   STO  112
Y27   CLA2U6

Y30   FDH  110
Y31   STQ  101
Y32   CLA  101
Y33   FSB  100
Y34   FDH  112
Y35   STQ  100
Y36   CLA  100
Y37   TSX4903

Y40   CLA  400
Y41   STO2U6
Y42   CLA  111
Y43   STA2U6
Y44 2   12Y15
Y45   TSX4925
Y46   LXD2T7*
Y47   CLA2U6

Y50   ANA  441
Y51   STO2U6
Y52 2   12Y47
Y53   TSX4974
Y54 0    1
Y55 4      U6
Y56   TSX4934
Y57   TRA  X24
```

```
Y60 8    2Y23
Y61   TZE  Y44
Y62   TRA  Y24


X00 8      831
X01   SXD4X33
X02   SXD2X34
X03   SXD1X35
X04   PAX1
X05   CLA1S5
X06   PAX1
X07   PDX2

X10   TSX4902
X11   STO  100
X12   LXA44C1
X13   CLA4Z4
X14   FDH  A15
X15   STQ  101
X16   CLA  101
X17   CAS  100

X20   TRA  X25
X21   TRA  X25
X22 1   14X23
X23 1   11X24
X24 2   12X13
X25   CLA1M1
X26   ANA  C20
X27   LXD4X33

X30   LXD2X34
X31   LXD1X35
X32   TRA4   1
X33   HTR
X34   HTR
X35   HTR
X36 8    2X25
X37   LDQ4Z5

X40   STQ  A15
X41   TRA  X26


X00 8      832
X01   SXD4X63
X02   SXD2X64
X03   PAX4
X04 1   14X05
X05   CLA4M0
X06   PDX2
X07   STD  X47
```

```
X1C  ALS    1
X11  STD X36
X12  STD X67
X13  STD X17
X14 1   14X15
X15  CLA4M0
X16  CAS A22
X17 1   04X73

X20  TRA X67
X21 6   12X67
X22 1   14X23
X23  CLA A22
X24  CAS4M0
X25  TRA X21
X26  TRA X67
X27  CLA4M0

X30  FSB4M0-
X31  STO B05
X32  CLA A22
X33  FSB4M0-
X34  FDH B05
X35  STQ B05
X36 1   04X37
X37  CLA4M0

X4C  FSB4M0-
X41  LRS  43
X42  FMP B05
X43  FAD4M0-
X44  STO A14
X45  CHS
X46  STQ 102
X47 1   04X50

X50  CLA B05
X51  TZE X65
X52  CLA4M0
X53  FSB4M0-
X54  LRS  43
X55  FMP B05
X56  FAD4M0-
X57  LDQ 102

X60  LXD4X63
X61  LXD2X64
X62  TRA4   1
X63  HTR
X64  HTR
X65  CLA4M0
X66  TRA X57
X67 1   04X70

X70  STZ B05
X71  CLA4M0
X72  TRA X44
X73  STZ B05
X74  FDH A22
X75  FMP4M0
X76  TRA X44
X77 8    2X45
```

```
Y00  FAD A15
Y01  FDH A15
Y02  TRA X46


X00 8      833
X01  SXD4X42
X02  LXD4A50
X03  CLA4T7
X04  PAX4
XC5  LXA2401
X06 1   14X07
X07  CLA2E0

X1C  CAS A17
X11  TRA X23
X12  TRA X23
X13 1   12X14
X14 3D122X23
X15 1   14X16
X16  CLA A17
X17  CAS2E0

X20  TRA X13
X21  TRA X23
X22 2   14X23
X23  CLA4T6
X24  FAD A16
X25  STO4T6
X26  CLA4U6
X27  ANA 441

X30  STO 100
X31  LDQ A16
X32  FMP A16
X33  FAD4L6
X34  STO4U6
X35  CLA 100
X36  ADD 401
X37  STA4U6

X40  LXD4X42
X41  TRA4   1
X42  HTR


X00 8      835
X01  TSX4800
X02 9   42X01


X00 8      836
X01  SXD4X32
X02  SXD1X33
X03  LXA1400
X04  LXA4401
X05  CLA4H01
X06  CAS A17
X07  TRA X14
```

```
X10  TRA X14
X11 1   14X12
X12 3H014X14
X13 1G011X05
X14  LXA4401
X15 1   11X16
X16  CLA4G01
X17  CAS A04

X20  TRA X24
X21  TRA X24
X22 1   14X23
X23 7G014X15
X24  CLA D6*
X25  LDQ A16
X26  TSX4827
X27  LXD4X32

X30  LXD1X33
X31  TRA4   1
X32  HTR
X33  HTR


X00 8      837
X01  PSE 144
X02  TRA4   1
```

SOURCE ROUTINE:

POINT ISOTROPIC SOURCE OF

MONOENERGETIC NEUTRONS

```
X00 8      850
X01  SXD4X25
XC2  LXA4404
X03  CLA4S00
X04  STO4A00
X05 2   14X03
X06  CLA S06
X07  STO A17

X10  CLA S05
X11  ALS  22
X12  STO A50
X13  TSX4904
X14  LXA4403
X15  CLA4B01
X16  STO4A04
X17 2   14X15

X2C  STO A10
X21  CLA S07
X22  STO A16
X23  LXD4X25
X24  TRA4   1
X25  HTR

X26 *      800
```

```
XOC 8      857
X01  TSX4971
XC2 CPC11A0
X03 COC42A1
X04 CPC21A2
X05 COC42A3
X06 0PC31A4
X07 COC42A5

X1C CPC41A6
X11 COC42A7
X12 CPC51B0
X13 CCC42B1
X14 CP061B2
X15 0CC42B3
X16 0PC71B4
X17 CCC42B5

X20 CP1C1B6
X21 COC42B7
X22 CP111C0
X23 00042C1
X24 CP121C2
X25 CCC42C3
X26 CP131C4
X27 C0042C5

X30 CP141C6
X31 CCC42C7
X32 0P151D0
X33 C0042D1
X34 CP161D2
X35 C0042D3
X36 CP171D4
X37 C0042D5

X4C CP201D6
X41 C0042D7
X42 CA341I0
X43 CA341I1
X44 CA341I2
X45 CA461R0
X46 0A461R3
X47 CA541R4

X5C CA231R5
X51 CA231R6
X52 CA541R7
X53 CA541S0
X54 CA541S1
X55 0A541S2
X56 CA241S3
X57 CA461S4

X60 CA251S5
X61 CA261S6
X62 CA541S7
X63 0A261T0
X64 CA541T1
X65 CQC11T2
X66 0A261T3
X67 0A541T4
```

```
X70 CA261T5
X71 CQ021M0
X72 CQC31M1
X73 CQC41M2
X74 CQ051M3
X75 CQC61M4
X76 CA461Y6
X77 CA471Z0

Y00 CA471Z1
Y01 CA541Z2
YC2 CA541Z3
Y03 CDC31Z7
Y04 CA261Z4
Y05 CA261Z5
YC6 CD121EC
Y07 CD121T6

Y1C CA462T7
Y11 CA461R1
Y12 CA542R2
Y13 CD121U6
Y14 4A462U7
Y15  TSX4970

Y16 *    4857

X0C 8     877
X01  PSE 164
X02  TRA X15
X03  CLA A41
X04  STO 110
X05  CLA A44
X06  STO 111
X07  TSX4932

X10  CLA 110
X11  STO A41
X12  CLA 111
X13  STO A44
X14  TSX4835
X15  CLA A37
X16  SUB 401
X17  STO A37

X20  CLA A40
X21  SUB A21
X22  STO A40
X23  TRA X14
X24 8    2X07
X25  TSX4933
X26  TRA X10

X27 *     850
```

```
X00 8     90C
X01  PSE 164
XC2  HTR4  1
XC3  TSX4973
X04 0 611A61
X05 0     A0
XC6 0     A2
XC7 0     A4

X10 0     A6
X11 0     B0
X12 0     B2
X13 0     B4
X14 0     B6
X15 0     C0
X16 0     C2
X17 0     C4

X20 0     C6
X21 0     D0
X22 0     D2
X23 0     D4
X24 0     D6
X25 0     E0
X26 0     T6
X27 4     U6

X30  LXD4457
X31  TRA X02

X00 8     901
XC1  ACL 420
X02  FAD 42C
X03  TRA4  1

X00 8     9C2
X01  LDQ C33
X02  MPY A44
XC3  STO A44
X04  CLA A41
X05  ADD 401
XC6  STA A41
X07  CLA A44

X10  ARS  11
X11  ADC C01
X12  FAD 40C
X13  TRA4  1

XC0 8     704
XC1  SXD4X64
X02  TSX4902
X03  ADD 411
XC4  FSB 421
XC5  CHS
X06  STO B02
X07  TSX4902
```

```
X10  ADD 411
X11  FSB 421
X12  CHS
X13  STO B03
X14  TSX4902
X15  ADD 411
X16  FSB 421
X17  CHS

X20  STO B04
X21  LDQ B03
X22  FMP B03
X23  STO 103
X24  LDQ B04
X25  FMP B04
X26  FAD 103
X27  CAS 421

X30  TRA X07
X31  NOP
X32  STO 103
X33  LDQ B02
X34  FMP B02
X35  FSB 421
X36  CHS
X37  FDH 103

X40  STO 103
X41  CLA 103
X42  TSX4903
X43  TRA X02
X44  STO 103
X45  LDQ B03
X46  FMP 103
X47  STO B03

X50  LDQ B04
X51  FMP 103
X52  STO B04
X53  LXA4403
X54  STZ B10
X55  LDQ4B01
X56  FMP4A04
X57  FAD B10

X60  STO B10
X61 2   14X55
X62  LXD4X64
X63  TRA4  1
X64  HTR

X00 8     905
X01  SXD4X63
XC2  SXD1X64
X03  CLA2R7
X04  STO 11C
X05  CLA2S0
X06  STO 107
X07  CLA2S1
```

```
X10  STO 1C6
X11  LXA4A54
X12  STZ422
X13  STZ423
X14 2   14X12
X15  CLA C03
X16  STO2Z2
X17  LXA4403

X20  STZ 111
X21  STZ 112
X22  LDQ4111
X23  FMP4111
X24  FAD 111
X25  STO 111
X26  LDQ4111
X27  FMP4A04

X30  FAD 112
X31  STO 112
X32 2   14X22
X33  FDH 111
X34  FMP C03
X35  STO 113
X36  LDQ 113
X37  FMP C04

X40  STO 114
X41  LXA4403
X42  LDQ 113
X43  FMP4111
X44  FAD4A04
X45  STO4A04
X46  LDQ4A04
X47  FMP4A04

X50  STO4A10
X51  LDQ 114
X52  FMP4111
X53  FAD4A00
X54  STO4A00
X55 2   14X42
X56  CLA A05
X57  STO A1C

X60  LXD4X63
X61  LXD1X64
X62  TRA4  3
X63  HTR
X64  HTR

XC0 8     906
X01  SXD4X60
X02  STO X3C
X03  STO X35
XC4  STC  62
XC5  PXD1
X06  ARS  22
X07  STC  61
```

```
X10  PXD2
X11  ARS   22
X12  STO   60
X13  CAL  X60
X14  ARS   22
X15  SUB  401
X16  COM
X17  ANA  441

X20  STO   63
X21  CAL  457
X22  ARS   22
X23  SUB  401
X24  COM
X25  ANA  441
X26  STO   57
X27  TSX4975

X30 0NOP
X31 0   41A35
X32 4   51 64
X33  TSX4974
X34 0    1
X35 0NOP
X36 0   41A35
X37 4   51 64

X40  TSX4923
X41  TSX4925
X42  CLA D1C
X43  TZE X52
X44  SUB 401
X45  STO D1C
X46  CLA 400
X47  STC A42

X50  LXD4X6C
X51  TRA4  2
X52  TSX4975
X53 0    2
X54 0     94C
X55 4    2
X56  LXD4X60
X57  TRA4  1

X60  HTR

X00 8     907
XC1  TRA X34
XC2  SXD4Y00
X03  CLA A01
X04  FSB2R7
XC5  STO 112
XC6  CLA A02
X07  FSB2S0
```

```
X10  STO 113
X11  CLA A03
X12  FSB2S1
X13  STC 114
X14  LXA4403
X15  STZ 110
X16  LDQ4115
X17  FMP1T2

X20  FAD1T2
X21  STO4120
X22  FAD1T2
X23  LRS  43
X24  FMP4115
X25  FAD 110
X26  STC 110
X27 1   11X30

X30 2   14X16
X31  FAD1T2
X32  LXD4Y00
X33  TRA4  1
X34  CLA1T2
X35  STC 103
X36  CLA1T2+
X37  STO 1C2

X40  CLA1T2
X41  STO 101
X42  TSX4907
X43  STO 114
X44  LXA4403
X45  STZ 112
X46  STZ 111
X47  LDQ4120

X50  FMP4A04
X51  FAD 112
X52  STO 112
X53  LDC4104
X54  FMP4A1C
X55  FAD 111
X56  STC 111
X57 2   14X47

X60  LDQ 111
X61  FMP 114
X62  STC 113
X63  LDC 112
X64  FMP 112
X65  FSB 113
X66  LXC4Y01
X67  TRA4  1

X70 9   30X20
X71 9   30X22
X72 9   30X31
X73 9   20X4C
X74 9   22X42
X75 8    2X34
X76  SXD4Y01
X77  TRA X35
```

```
YC0  HTR    0
Y01  HTR    C
Y02 8   2X46
Y03  CLA 117
YC4  LDQ 115
Y05  STO 115
Y06  STQ 117
Y07  TRA X47

X00 8     910
X01  SLW 105
X02  SXD4Z37
X03  SXD1Z40
X04  CLA2Z2
X05  TZE X21
X06  FSB B01
X07  STO 113

X10  TZE X12
X11  TPL Y37
X12  CLA2Z3
X13  TZE Y47
X14  FSB B01
X15  STO 113
X16  TZE Y47
X17  TPL Y37

X2C  TRA Y47
X21  CLA A47
X22  TPL X34
X23  CLA2T1
X24  TZE X34
X25  STA X27
X26  PDX1
X27  CLA 400

X3C  STA X31
X31  TSX48C0
X32  TRA X74
X33  TRA Y11
X34  PXD1
X35  ALS   2
X36  PDX4
X37  CAL2T4

X4C  SLW 110
X41  ANA4S3
X42  TZE X52
X43  TSX4911
X44  STO 113
X45  FAD B01
X46  STO2Z2
X47  CLA 113

X50  TMI Y47
X51  TRA Z65
X52  LXA1400
X53  CLA AC1
X54  FSB2R7
X55  STO 101
X56  STO 1C4
X57  CLA A02
```

```
X60  FSB2S0
X61  STO 102
X62  CLA A03
X63  FSB2S1
X64  STO 103
X65 1   14X66
X66 1   11X67
X67 3   31Z05

X70  CAL 110
X71  ANA4S3
X72  TZE X65
X73  TSX4912
X74  TPL X77
X75  STO2Z2
X76  TRA Y47
X77  TSX4903

Y00  CLA 400
Y01  STO 101
Y02  FSB 112
Y03  FDH 111
Y04  STQ 103
Y05  CLS 101
Y06  FSB 112
Y07  FDH 111

Y1C  STQ 104
Y11  LDQ 1C4
Y12  CLA 103
Y13  TQP Y17
Y14  TPL Y34
Y15  STO2Z2
Y16  TRA Y47
Y17  TPL Y22

Y20  STQ 1C0
Y21  TRA Y33
Y22  TLQ Y31
Y23  STO 100
Y24  STQ 1C1
Y25  CLA 101
Y26  FAD B01
Y27  STO2Z3

Y30  TRA Y33
Y31  STQ 100
Y32  TRA Y26
Y33  CLA 100
Y34  STO 113
Y35  FAD B01
Y36  STO2Z2
Y37  CLA A51

Y40  TZE Y57
Y41  CAS 113
Y42  TRA Y53
Y43  NOP
Y44  CLA A31
Y45  TZE Y75
Y46  TRA Y71
Y47  LXD1Z40
```

```
Y50  LXD4Z37
Y51  CAL 105
Y52  TRA4  1
Y53  CLA A51
Y54  STØ A31
Y55  CLA A43
Y56  STØ A30
Y57  CLA 113

Y60  STØ A51
Y61  LXD1Z40
Y62  PXD1
Y63  ARS  22
Y64  STØ 100
Y65  PXD2
Y66  ADD 100
Y67  STØ A43

Y70  TRA Y50
Y71  CLA 113
Y72  CAS A31
Y73  NØP
Y74  TRA Y47
Y75  CLA 113
Y76  STØ A31
Y77  PXD2

Z00  STØ A30
Z01  CLA Z40
Z02  ARS  22
Z03  STA A30
Z04  TRA Y47
Z05  LXA14C3
Z06  STZ 100
Z07  STZ 112

Z10  LDQ1104
Z11  FMP1104
Z12  FAD 100
Z13  STØ 100
Z14  LDQ1104
Z15  FMP4A04
Z16  FAD 112
Z17  STØ 112

Z20 2  11Z10
Z21  LDQ 112
Z22  FMP 112
Z23  FSB 100
Z24  FAD2S2
Z25  TMI X75
Z26  TSX4903
Z27  CLA 400

Z30  STØ 101
Z31  FSB 112
Z32  STØ 103
Z33  CLS 101
Z34  FSB 112
Z35  STØ 104
Z36  TRA Y11
Z37  HTR

Z40  HTR
Z41 8   2Z06
Z42  LXA4401
Z43  TRA Z07
Z44 8   2Z17
Z45 1  14Z20
Z46 8   2Y11
Z47  CLA 103

Z50  CAS C04
Z51  TRA Z55
Z52  NØP
Z53  MAM
Z54  STØ 103
Z55  CLA 104
Z56  CAS C04
Z57  TRA Z63

Z60  NØP
Z61  MAM
Z62  STØ 104
Z63  LDQ 104
Z64  TRA Y12
Z65  CAS C04
Z66  TRA Y37
Z67  TRA Y47

Z70  TRA Y47

X00 8    911
X01  STZ 111
X02  STZ 113
X03  CLA2R7
X04  TZE X13
X05  LDQ2R7
X06  FMP A05
X07  STØ 111

X10  LDQ2R7
X11  FMP A01
X12  STØ 113
X13  CLA2S0
X14  TZE X25
X15  LDQ2S0
X16  FMP A06
X17  FAD 111

X20  STØ 111
X21  LDQ2S3
X22  FMP A02
X23  FAD 113
X24  STØ 113
X25  CLA2S1
X26  TZE X37
X27  LDQ2S1

X30  FMP A07
X31  FAD 111
X32  STØ 111
X33  LDQ2S1
X34  FMP A03
X35  FAD 113
X36  STØ 113
X37  CLA 113

X40  FAD2S2
X41  CHS
X42  FDP 111
X43  DCT
X44  TRA4 33
X45  STØ 113
X46  CLA 113
X47  TRA4  1

X00 8    912
X01 3  11X13
X02  CLA A11
X03  FAD A13
X04  STØ 111
X05  LDQ A05
X06  FMP 101
X07  STØ 112

X10  LDQ A07
X11  FMP 103
X12  TRA X34
X13  CLA A12
X14 3  21X25
X15  FAD A13
X16  STØ 111
X17  LDQ A06

X20  FMP 102
X21  STØ 112
X22  LDQ A07
X23  FMP 103
X24  TRA X34
X25  FAD A11
X26  STØ 111
X27  LDQ A05

X30  FMP 101
X31  STØ 112
X32  LDQ A06
X33  FMP 102
X34  FAD 112
X35  STØ 112
X36  LDQ1104
X37  FMP1104

X40  STØ 100
X41  LDQ1105
X42  FMP1105
X43  FAD 100
X44  FSB2S2
X45  STØ 100
X46  LDQ 100
X47  FMP 111

X50  STØ 100
X51  LDQ 112
X52  FMP 112
X53  FSB 100
X54  TRA4  1

X00 8    913
X01  STØ 103
X02  SXD2Y52
X03  SXD1Y53
X04  PDX2
X05  CAL2R4
X06  ANA C05
X07  PDX1

X10  CAL2T4
X11  SLW 104
X12  ANA1Z0
X13  TNZ Y41
X14  SXD4Y51
X15  CLA A47
X16  TPL X32
X17  CAL2T1

X20  TZE X32
X21  SXD1105
X22  PDX1
X23  STA X24
X24  CLA 400
X25  ADD 402
X26  STA X27
X27  TSX4800

X30  LXD1105
X31  TRA X64
X32  PXD1
X33  ALS   2
X34  PDX4
X35  CAL 104
X36  ANA4S3
X37  TZE X76

X40  STZ 105
X41  CLA2R7
X42  TZE X46
X43  LDQ2R7
X44  FMP A01
X45  STØ 105
X46  CLA2S0
X47  TZE X54

X50  LDQ2S0
X51  FMP A02
X52  FAD 105
X53  STØ 105
X54  CLA2S1
X55  TZE X62
X56  LDQ2S1
X57  FMP A03
```

```
X60   FAD 105
X61   STØ 105
X62   CLA 1C5
X63   FAD2S2
X64   STØ 105
X65   CAL 104
X66   ØRS1Z0
X67   LDQ 105

X7C   TCP Y37
X71   LXD4Y51
X72   LXD2Y52
X73   LXD1Y53
X74   CLA 103
X75   TRA4   1
X76   STZ 105
X77   CAL 104

Y00   ANA4S3+
Y01   TNZ Y10
Y02   CLA A02
Y03   FSB2S0
Y04   STØ 106
Y05   LDQ 106
Y06   FMP 106
Y07   STØ 105

Y10   CAL 104
Y11   ANA4S3
Y12   TNZ Y22
Y13   CLA A01
Y14   FSB2R7
Y15   STØ 106
Y16   LDQ 106
Y17   FMP 1C6

Y20   FAD 105
Y21   STØ 105
Y22   CAL 104
Y23   ANA4S3
Y24   TNZ Y34
Y25   CLA AC3
Y26   FSB2S1
Y27   STØ 106

Y30   LDQ 106
Y31   FMP 1C6
Y32   FAD 105
Y33   STØ 105
Y34   CLA 105
Y35   FSB2S2
Y36   TRA X64
Y37   ØRS1Z1

Y40   TRA X71
Y41   ANA1Z1
Y42   TZE Y45
Y43   LDQ 4C1
Y44   TRA X72
Y45   LDQ C03
Y46   TRA X72
Y47 9  20Y11

Y50 9  3CY23
Y51   HTR
Y52   HTR
Y53   HTR

XCC 8     914
X01   TRA X34
X02   SXD4Y53
X03   CLA A01
X04   STØ 111
X05   STØ 114
X06   CLA A02
X07   STØ 112

X10   CLA A03
X11   STØ 113
X12   LXA4403
X13   STZ 115
X14   LDQ1T2
X15   FMP4114
X16   STØ 116
X17   LDQ1T2

X20   FMP4115
X21   FAD1T2
X22   FAD 116
X23   LRS  43
X24   FMP4114
X25   FAD 115
X26   STØ 115
X27 1   11X30

X30 2   14X14
X31   FAD1T2
X32   LXD4Y53
X33   TRA4   1
X34   SXD4Y54
X35   CLA AC1
X36   STØ 114
X37   STØ 117

X4C   CLA A02
X41   STØ 116
X42   CLA A03
X43   STØ 115
X44   LXA44C1
X45   STZ 110
X46   STZ 111
X47   STZ 112

X50   STZ 113
X51   LCQ1T2
X52   FMP4120
X53   STØ 101
X54   LDQ1T2
X55   FMP4117
X56   FAD1T2
X57   FAD 101

X6C   LRS  43
X61   FMP4120
X62   FAD 113
X63   STØ 113
X64   LCQ1T2
X65   FMP4A04
X66   STØ 1C1
X67   LCQ1T2

X70   FMP4A05
X71   STØ 1C2
X72   FDH 422
X73   STQ 103
X74   CLA 101
X75   FAD 102
X76   LRS  43
X77   FMP4A04

Y00   FAD 111
Y01   STØ 111
YC2   CLA 101
Y03   FAD 103
Y04   LRS  43
Y05   FMP4120
YC6   FAD 112
Y07   STØ 112

Y10   LCQ1T2
Y11   FMP4117
Y12   FAD1T2
Y13   LRS  43
Y14   FMP4A04
Y15   FAD 110
Y16   STØ 11C
Y17 1   11Y2C

Y20 1   14Y55
Y21   CLA 113
Y22   FAD1T2
Y23   STØ 113
Y24   CLA 110
Y25   FDH 422
Y26   STC 1C1
Y27   CLA 101

Y30   FAD 112
Y31   STØ 112
Y32   LCQ 111
Y33   FMP 113
Y34   STØ 113
Y35   LDC 112
Y36   FMP 112
Y37   FSB 113

Y40   LXD4Y54
Y41   TRA4   1
Y42 9   3  X17
Y43 9   6  X21
Y44 9   6  X31
Y45 9   3  X54
Y46 9   6  X56
Y47 9   3  X67

Y50 9   3 Y1C
Y51 9   6 Y12
Y52 9   6 Y22
Y53   HTR
Y54   HTR
Y55 7   34X51
Y56   TRA Y21

XCC 8     915
X01   SXD4Z73
X02   SXD1Z74
X03   CLA A47
X04   TPL Y57
X05   CAL2T1
X06   TZE Y57
X07   PCX1

X1C   ANA 441
X11   SLB C06
X12   TZE X57
X13   CLA A01
X14   FSB2R7
X15   STØ 110
X16   CLA A02
X17   FSB2S0

X20   STØ 1C7
X21   CLA A03
X22   FSB2S1
X23   STØ 106
X24   LXA4401
X25   STZ 111
X26   STZ 112
X27   LDQ1T2

X3C   FMP4111
X31   FAD1T2
X32   STØ 100
X33   LDQ 10C
X34   FMP4A04
X35   FAD 111
X36   STØ 111
X37   LDQ 100

X40   FMP 1C0
X41   FAD 112
X42   STØ 112
X43 1   11X44
X44 1   14Z75
X45   TSX4903
X46   TRA Z51
X47   STØ 100

X50   CLA 111
X51   FDH 100
X52   STQ 101
X53   CLA 101
X54   LXD4Z73
X55   LXD1Z74
X56   TRA4   1
X57   LDQ1T2
```

```
X60  FMP 422
X61  LRS  43
X62  FMP A01
X63  STO 100
X64  LDQ1T2
X65  FMP A02
X66  FAD 100
X67  STO 100

X70  LDQ1T2
X71  FMP A03
X72  FAD1T2
X73  FAD 100
X74  STO 101
X75  LDQ 101
X76  FMP A05
X77  STO 111

Y00  LDQ 101
Y01  FMP 101
Y02  STO 112
Y03  LDQ1T2+
Y04  FMP 422
Y05  LRS  43
Y06  FMP A02
Y07  STO 100

Y10  LDQ1T2
Y11  FMP A01
Y12  FAD 100
Y13  STO 100
Y14  LDQ1T2
Y15  FMP A03
Y16  FAD1T2
Y17  FAD 100

Y20  STO 101
Y21  LDQ 101
Y22  FMP A06
Y23  FAD 111
Y24  STO 111
Y25  LDQ 101
Y26  FMP 101
Y27  FAD 112

Y30  STO 112
Y31  LDQ1T2
Y32  FMP 422
Y33  LRS  43
Y34  FMP A03
Y35  STO 100
Y36  LDQ1T2
Y37  FMP A02

Y40  FAD 100
Y41  STO 100
Y42  LDQ1T2
Y43  FMP A01
Y44  FAD1T2
Y45  FAD 100
Y46  STO 101
Y47  LDQ 101

Y50  FMP A07
Y51  FAD 111
Y52  STO 111
Y53  LDQ 101
Y54  FMP 101
Y55  FAD 112
Y56  TRA X45
Y57  CAL2R4

Y60  ANA C05
Y61  ALS   2
Y62  PDX1
Y63  CAL2T4
Y64  ANA1S3
Y65  TZE Z14
Y66  LDQ2R7
Y67  FMP A05

Y70  STO 111
Y71  LDQ2R7
Y72  FMP2R7
Y73  STO 112
Y74  LDQ2S0
Y75  FMP A06
Y76  FAD 111
Y77  STO 111

Z00  LDQ2S0
Z01  FMP2S0
Z02  FAD 112
Z03  STO 112
Z04  LDQ2S1
Z05  FMP A07
Z06  FAD 111
Z07  STO 111

Z10  LDQ2S1
Z11  FMP2S1
Z12  FAD 112
Z13  TRA X45
Z14  STZ 111
Z15  CAL2T4
Z16  ANA1S3+
Z17  TNZ Z25

Z20  CLA A02
Z21  FSB2S0
Z22  LRS  43
Z23  FMP A06
Z24  STO 111
Z25  CAL2T4
Z26  ANA1S3
Z27  TNZ Z36

Z30  CLA A01
Z31  FSB2R7
Z32  LRS  43
Z33  FMP A05
Z34  FAD 111
Z35  STO 111
Z36  CAL2T4
Z37  ANA1S3

Z40  TNZ Z47
Z41  CLA A03
Z42  FSB2S1
Z43  LRS  43
Z44  FMP A07
Z45  FAD 111
Z46  STO 111
Z47  CLA2S2

Z50  TRA X45
Z51  CLA Z55
Z52  TSX4906
Z53  HPR
Z54  TSX4877
Z55 0     941
Z56 9   3 X31
Z57 9   3 X64

Z60 9   5 X70
Z61 9   6 X72
Z62 9   3 Y10
Z63 9   4 Y14
Z64 9   7 Y16
Z65 9   2 Y31
Z66 9   4 Y36
Z67 9   5 Y42

Z70 9   8 Y44
Z71 9   2 Z26
Z72 9   3 Z37
Z73  HTR
Z74  HTR
Z75 7   34X27
Z76  TRA X45


X00 8     920
X01  CLA1RC
X02  PDX4
X03  LDQ A17
X04  FMP A17
X05  LRS  43
X06  FMP4I2
X07  STO 100

X10  LDQ A17
X11  FMP4I1
X12  FAD 100
X13  FAD4I0
X14  LXD4457
X15  TPL4   1
X16  CLA C17
X17  TRA4   1

X00 8     921
X01  MSE 141
X02  TRA X05
X03  PSE 141
X04  TRA4   1
X05  LXD4A42
X06 7D034X35
X07  LXD4457

X10  TRA X03
X11  SXD2X34
X12  LXA2C22
X13 1   14X14
X14  CLA2A00
X15  STO4Z7
X16 2   12X13
X17 1   14X20

X20  CLA A50
X21  STO4Z7
X22 1   14X23
X23  CLA A62
X24  STO4Z7
X25 1   14X26
X26  CLA A43
X27  STO4Z7

X30  SXD4A42
X31  LXD4457
X32  LXD2X34
X33  TRA X43
X34  HTR
X35  MSE 144
X36  TRA X11
X37  PSE 144

X40  CLS A17
X41  STO A17
X42  TRA X11
X43  CLA A17
X44  SSP
X45  STO A17
X46  TRA4   2


X00 8     922
X01  SXD2X34
X02  MSE 141
X03  NCP
X04  CLA A42
X05  ARS  22
X06  TZE4   1
X07  SUB C23

X10  ALS  22
X11  STD A42
X12  PDX4
X13  LXA2C22
X14 1   14X15
X15  CLA4Z7
X16  STO2A00
X17 2   12X14
```

```
X20 1   24X21
X21   CLA4Z7-
X22   STO A50
X23   CLA4Z7
X24   STO A62
X25   CLA4Z7+
X26   STO A43
X27   SSM

X30   STO A32
X31   LXD4457
X32   LXD2X34
X33   TRA X35
X34   HTR
X35   CLA A17
X36   TPL4   2
X37   SSP

X40   STO A17
X41   PSE 144
X42   TRA4   2

X00 8      923
X01   SXD4X44
X02   CLA A43
X03   ARS   22
X04   STO A32
X05   CLA A50
X06   STZ A53
X07   STA A53

X10   ARS   22
X11   STO A50
X12   CLA A44
X13   STO   77
X14   STZ A44
X15   TSX4974
X16 0   3
X17 0      945

X20 0   2
X21 0 621A00
X22 0   2
X23 0 131B00
X24 0   2
X25 0 301130
X26 0   4
X27 0      Y6

X30 0      Z2
X31 0      Z3
X32 0      Z4
X33 4      Z5
X34   CLA A50
X35   ALS   22
X36   ACL A53
X37   STO A50
```

```
X40   CLA   77
X41   STO A44
X42   LXD4X44
X43   TRA4   1
X44   HTR

X00 8      924
X01   PXD4
X02   LRS   65
X03   CLA X07
X04   TSX4906
X05   HPR
X06   TSX4877
X07 0      955

X00 8      925
X01   SXD4X61
X02   CLA A43
X03   ARS   22
X04   STO A32
X05   CLA A50
X06   STZ A53
X07   STA A53

X10   ARS   22
X11   STO A50
X12   CLA A44
X13   STO   77
X14   STZ A44
X15   TSX4974
X16 0   1
X17 0      950

X20 0      951
X21 0   2
X22 0 621A00
X23 0   2
X24 0 131D00
X25 0   2
X26 0      E0
X27 0      T6

X30 0      U6
X31 0      A0
X32 0      A2
X33 0      A4
X34 0      A6
X35 0      B0
X36 0      B2
X37 0      B4

X40 0      B6
X41 0      C0
X42 0      C2
X43 0      C4
X44 0      C6
X45 0      D0
X46 0      D2
X47 0      D4
```

```
X50 4      D6
X51   CLA A50
X52   ALS   22
X53   ACL A53
X54   STO A50
X55   CLA   77
X56   STO A44
X57   LXD4X61

X60   TRA4   1
X61   HTR    0

X00 8      926
X01   PSE 165
X02   TRA4   1
X03   SXD4X36
X04   STO   51
X05   STQ   50
X06   LXA4403
X07   CLA4D04

X10   CAS4A36
X11   TRA X32
X12   NOP
X13 2   14X07
X14   CLA X36
X15   ARS   22
X16   SUB 401
X17   COM

X20   ANA 441
X21   STO   52
X22   TSX4974
X23 0   2
X24 0      946
X25 0   2
X26 4   31 53
X27   PSE 163

X30   TRA X40
X31   TRA X37
X32   LXD4X36
X33   CLA   51
X34   LDQ   50
X35   TRA4   1
X36   HTR
X37   TSX4925

X40   TSX4923
X41   TRA X32

X00 8      927
X01   SXD4X40
X02   STQ 100
X03   FMP B10
X04   STO 101
X05   LDQ 100
X06   FMP 100
X07   FAD 421
```

```
X10   FAD 101
X11   FAD 101
X12   TSX4903
X13   TRA X41
X14   STO 101
X15   LXA4403
X16   LDQ 100
X17   FMP4B01

X20   FAD4A04
X21   FDH 101
X22   STQ4A04
X23 2   14X16
X24   CLA 101
X25   FDH2T3
X26   STQ 101
X27   FMP A22

X30   STO 102
X31   LDQ 101
X32   FMP 101
X33   LRS   43
X34   FMP A17
X35   LDQ 102
X36   LXD4X40
X37   TRA4   1

X40   HTR
X41   CLA X45
X42   TSX4906
X43   HPR
X44   TSX4877
X45 0      941

X00 8      930
X01   SXD4X44
X02   SXD2X45
X03   SXD1X46
X04   STO 102
X05   CLA B06
X06   TPL X32
X07   TSX4X47

X10   STO 103
X11   CLA B05
X12   TNZ X20
X13   CLA 103
X14   LXD4X44
X15   LXD2X45
X16   LXD1X46
X17   TRA4   1

X20   CLA B07
X21   TPL X41
X22   TSX4X47
X23   STO 104
X24   CLA 104
X25   FSB 103
X26   LRS   43
X27   FMP B05
```

```
X30   FAD 103
X31   TRA X14
X32   CLA B07
X33   TPL X37
X34   LDQ 421
X35   STQ 103
X36   TRA X11
X37   CLA 421

X40   TRA4  1
X41   CLA 421
X42   STO 104
X43   TRA X25
X44   HTR
X45   HTR
X46   HTR
X47   PAX1

X50   PDX2
X51   ANA C21
X52   TNZ X75
X53   CLA1M2
X54   CAS 102
X55   TRA X61
X56   TRA X61
X57 1   11X60

X60 1   12X53
X61   CLA 102
X62   FSB1M2-
X63   STO 105
X64   CLA1M2
X65   FSB1M2-
X66   STO 106
X67   CLA2M2

X70   FSB2M2-
X71   FDH 106
X72   FMP 105
X73   FAD2M2-
X74   TRA4  1
X75   CLA1M2
X76 6   12Y05
X77   STO 105

Y00 1   11Y01
Y01   LDQ 105
Y02   FMP 102
Y03   FAD1M2
Y04   TRA X76
Y05   TRA4  1

X00 8     931
X01   TSX4977
X02 0  2   7
X03 02012X34
X04 02022X35
X05 02032Z7
X06 02042A0
X07 02052A2
```

```
X10 02062A4
X11 02072A6
X12 02102B0
X13 02112B2
X14 02122B4
X15 02132B6
X16 02142C0
X17 02152C2

X20 02162C4
X21 02172C6
X22 02202D0
X23 02212D2
X24 02222D4
X25 02232D6
X26 02242E0
X27 02252T6

X30 42262U6
X31   WEF   7
X32   REW   7
X33   TRA X36
X34 0 62 A62
X35 0 10 B10
X36   LXD4457
X37   TRA4  1

X00 8     932
X01   REW   7
X02   TSX4977
X03 0  1   7
X04 0A361R0
X05 01011R1
X06 01021R3
X07 01031R4

X10 01041R5
X11 01051R6
X12 01061R7
X13 01071S0
X14 01101S1
X15 01111S2
X16 01121S3
X17 01131S4

X20 01141S5
X21 01151S6
X22 01161S7
X23 01171T0
X24 01201T1
X25 01211T2
X26 01221T3
X27 01231T4

X30 01241T5
X31 01251M0
X32 01261M1
X33 01271M2
X34 01301M3
X35 01311M4
X36 41321951
X37   PSE 164
```

```
X40   TRA X44
X41   REW   7
X42   LXD4457
X43   TRA4  1
X44   TSX4977
X45 0  2   7
X46 42011Y02
X47   CLA A40

X50   TZE X41
X51   TSX4977
X52 0       7
X53 02021Y01
X54 02031Z7
X55 02041A0
X56 02051A2
X57 02061A4

X60 02071A6
X61 02101B0
X62 02111B2
X63 02121B4
X64 02131B6
X65 02141C0
X66 02151C2
X67 02161C4

X70 02171C6
X71 02201D0
X72 02211D2
X73 02221D4
X74 02231D6
X75 02241E0
X76 02251T6
X77 42261U6

Y00   TRA X41
Y01 0 10 B10
Y02 0 62 A62

X00 8     933
X01   SXD4X63
X02   CLA D02
X03   STO A27
X04   CLA D03
X05   STO A42
X06   LXA4A54
X07   CAL4R4

X10   ANA 442
X11   STO 101
X12   CAL4R4
X13   ANA 441
X14   TZE X70
X15   CAL X66
X16   ANA 441
X17   ACL X64
```

```
X20   ACL 101
X21   SLW4R4
X22   CAL4S7
X23   TZE X72
X24   STA X25
X25   CAL   0
X26   TNZ X35
X27   SXD4100

X30   CLA X67
X31   TSX4906
X32   HPR
X33   LXD4100
X34   TRA X40
X35   ANA 441
X36   ACL X64
X37   SLW4S7

X40 2   14X07
X41   LXA4A46
X42   CAL4S4
X43   TZE X74
X44   STA X45
X45   CAL   0
X46   TNZ X55
X47   SXD4100

X50   CLA X67
X51   TSX4906
X52   HPR
X53   LXD4100
X54   TRA X60
X55   ANA 441
X56   ACL X64
X57   SLW4S4

X60 2   14X42
X61   LXD4X63
X62   TRA4  1
X63   HTR
X64   TRA   0
X65   TRA4  2
X66   TSX4905
X67 0     947

X70   CAL X65
X71   TRA X20
X72   CAL X65
X73   TRA X37
X74   CAL X62
X75   TRA X57
X76 8   2X05
X77   CLA K01

Y00   STO C01
Y01   CLA K02
Y02   STO C15
Y03   CLA K03
Y04   STO C21
Y05   CLA K04
Y06   STO C33
Y07   LDQ K05
```

```
Y10   STQ C34          X00 8     934
Y11   CLA A37          X01  REW    7
Y12   TNZ X06          X02  TSX4977
Y13   STQ A44          X03 C   2   7
Y14   TRA X06          X04 02011X35
Y15 8    2X03          X05 02021X36
Y16   CLA X31          X06 02031Z7
Y17   STA Y23          X07 02041A0

Y20   CLA Y26          X10 02051A2
Y21   STA Y24          X11 02061A4
Y22   CLA Y27          X12 02071A6
Y23   STO   0          X13 02101B0
Y24   STO   0          X14 02111B2
Y25   TRA Y30          X15 02121B4
Y26   TSX4924          X16 02131B6
Y27   NOP              X17 02141C0

Y30   LXA4A46          X20 02151C2
Y31   CLA4Y6           X21 02161C4
Y32   TZE Y35          X22 02171C6
Y33   ALS  41          X23 02201D0
Y34   ORS4R0           X24 02211D2
Y35 2   14Y31          X25 02221D4
Y36   TRA X04          X26 02231D6
                       X27 02241E0

                       X30 02251T6
                       X31 42261U6
                       X32  REW    7
                       X33  LXD4457
                       X34  TRA4   1
                       X35 0 62 A62
                       X36 0 10 B10
```

V - ORDER OF DATA ON PROBLEM TAPE

R0

R3

R4

R5

R6

R7

S0

S1

S2

S3

S4

S5

S6

S7

T0

T1

T2

T3

T4

T5

M0

M1

M2

M3

M4

R951 (Problem identification remark)

(End of file)

A00

B00

Z7

A0

A2

A4

A6

B0

B2

B4

B6

C0

C2

C4

C6

D0

D2

D4

D6

EO

T6

U6

(End of file)

APPENDIX E: INITIATING CODES MCA, MCB

I - CARD LABEL CONVENTION

Col. 73-74: usual FLOCO labeling (X0-Z7)

75-76: XX for formula 8XX or 9XX

77: blank for formula 8XX
9 for formula 9XX

78-80: code label MCA or MCB.

II - CARD LOADING ORDER OF INITIATING CODE MCA

(Number of cards in parentheses)

1 Advance NBA (card label 1 MCA)

2 A00 (3): Same as for Monte Carlo MCS

3 B00 (1): Working storage space reserved

4 C00 (5): Constants

5 D00 (2): Size parameters (see V below)

6 F00 (1) }
7 J00 (1) }
8 K00 (1) } Space reserved
9 Q00 (1) }
10 R00 (1) }

11 Advance NBA and record origins (card labeled 2 MCA)

12 Remark cards: R930-942 (R932 PREPARED BY USER)

13 Load instructions 860 (card labeled 4 MCA)

14 F860 -- Data assign code (9)

15 Load instructions 906 (card labeled 5 MCA)

16 F906 (5)

17 F905 (1)

18 F901 (1)

19 F903 (9)

20 F907 (4)

21 F914 (4)

22 F913 (10)

23 F855 (2) (labeled XO CRC MCA)

24 F800 (2)

25 F801 (5)

26 F802 (19)

27 F805 (7)

28 F803 (11)

29 F804 (9)

30 F806 (25)

31 F830 (3)

32 F831 (1)

33 F832 (9)

34 F833 (14)

35 F834 (1)

36 F835 (4)

37 F836 (5)

38 F837 (2)

39 F810 (25)

40 F814 (14)

41 F811 (12)

42 F812 (3)

43 F813 (3)

44 F815 (7)

45 F816 (5)

46 F817 (5)

47 F820 (6)

48 Load instructions 865 (card labeled 6 MCA)

49 F865 (6)

50 Load instructions 850 (card labeled 7 MCA)

51 F850 (9): FLOCODE

52 Transition card (labeled 8 MCA)

53 SURFACE CARDS: (see pg. 53)

54 Transition card (labeled TR CRC MCA)

55 CELL CARDS: (see pg. 54)

56 Transition card (labeled TR CRC MCA)

57 ELEMENT CARDS: (see pg. 56)

58 MATERIAL CARDS: (see pg. 56)

III - REMARKS CARDS FOR CODE MCA

930	Error
931	Initiate problem -- GMC 1
932	Problem 18. MA Spectrum -- (10/20/62). Tape 3
933	Cell boundaries -- A -- T -- M -- RHO
934	Element list
935	Material data
936	Problem data blocks
937	Q00 data
940	Initiation completed -- Save tape A06
941	Depress sense 3 to print input data
942	A -- J -- No cells across J from A

IV - FORMULA SET OF INITIATING CODE MCA

```
X00 8      800
X01  TSX4974
X02 0   1
X03 0     931
X04 0     932
X05 4  2
X06  TSX4975
X07 0  1

X10 C     931
X11 C     932
X12 4  2
X13  LXD4457
X14  TRA4  1

X00 8     801
X01  SXD4 77
X02  CLA C01
X03  SUB A54
X04  TPL X07
X05  CLA 401
X06  TSX4906
X07  CLA C02

X10  SUB A46
X11  TPL X14
X12  CLA 402
X13  TSX4906
X14  CLA C03
X15  SUB A25
X16  TPL X21
X17  CLA 403

X20  TSX4906
X21  CLA C04
X22  SUB A26
X23  TPL X26
X24  CLA 404
X25  TSX4906
X26  CLA C05
X27  SUB A15

X30  TRA X33
X31  CLA 405
X32  TSX4906
X33  CLA C03
X34  SUB A34
X35  TPL X40
X36  CLA 406
X37  TSX4906

X4C  LXD4 77
X41  TRA4  1
X42 8   2X01
X43  LXA1400
X44  TRA X02
```

```
X00 8     802
X01  SXD4 77
X02  CLA A54
X03  STO B01
X04  STZ B02
X05  LXA1401
X06  CLA1A0
X07  PAX2

X1C  STA X21
X11 7A542X14
X12  CLA 407
X13  TSX4906
X14  CLA2T4
X15  TZE X20
X16  CLA C06
X17  TSX4906

X20  LDQ 401
X21  RQL   0
X22  STQ2T4
X23  LXA4401
X24  CLA1A0
X25  SUB C23
X26  TMI X30
X27 1   14X25

X30  SXD4Y63
X31  PXD4
X32  ALS   2
X33  STD X70
X34 1   11X35
X35  CLA1A0
X36  STO2S7
X37 1   11X40

X40  CLA1A0+
X41  STO B04
X42  CLA1A0
X43  PAX4
X44  TRA4X55
X45  TRA Y25
X46  TRA X76
X47  TRA X74

X50  TRA X67
X51  TRA X67
X52  TRA X67
X53  TRA X67
X54 1   31X55
X55  CLA1A0-
X56  STO2R7
X57  CLA1A0

X60  STO2S0
X61  CLA1A0+
X62  STO2S1
X63 1   31X64
X64  CLA1A0-
X65  STO2S2
X66  TRA Y44
X67 1C244X70
```

```
X70 1   04X71
X71  CLA2T4
X72  ORS4S3
X73  TRA X54
X74  STO2R4
X75 1C254X70
X76  CLA C26
X77  STO2T1

Y0C  SXD2B03
Y01  CLA B02
Y02  STD2T1
Y03  PDX2
Y04  LXA4407
Y05 1   21Y06
Y06  CLA1A0
Y07  STO2T2

Y10 1   12Y11
Y11 1   11Y12
Y12 2   14Y06
Y13  SXD2B02
Y14  LXD2B03
Y15  CLA1A0
Y16  STO2R7
Y17  CLA1A0+

Y20  STO2S0
Y21 1   31Y22
Y22  CLA1A0-
Y23  STO2S1
Y24  TRA Y44
Y25  CLA C27
Y26  STO2T1
Y27  SXD2B03

Y30  CLA B02
Y31  STD2T1
Y32  PDX2
Y33  LXA4C10
Y34 1   21Y35
Y35  CLA1A0
Y36  STO2T2
Y37 1   12Y40

Y40 1   11Y41
Y41 2   14Y35
Y42  SXD2B02
Y43  LXD2B03
Y44  CLA Y63
Y45  STD2R4
Y46  CLA1A0
Y47  PAX4

Y50 7A464Y55
Y51  SXD4150
Y52  CLA C07
Y53  TSX4906
Y54  LXD4150
Y55  CLA1A0
Y56  LXA4A47
Y57 6   14Y62
```

```
Y60  ADD1A0
Y61 2   14Y60
Y62  PAX4
Y63 1   04Y64
Y64  CAL2T4
Y65  ORS4R5
Y66 1   11Y67
Y67  CLA B04

Y70  SUB 401
Y71  STO B04
Y72  TNZ Y46
Y73  CLA B01
Y74  SUB 401
Y75  STO B01
Y76  TNZ X06
Y77  CLA B02

Z00  ARS  22
Z01  STO Q01
Z02  LXD4 77
Z03  TRA4  1
Z04 8    2Y75
Z05 7D031Y76
Z06  CLA C14
Z07  TSX4906

Z10  TRA Y77
Z11 8    2X04
Z12  CLA 415
Z13  STO B02
Z14  TRA X05
Z15 8    2Y77
Z16  STD T2*
Z17  PDX1

Z20 7D161Z00
Z21  CLA C42
Z22  TSX4906
Z23  CLA B02
Z24  TRA Z00

X00 8      803
X01  SXD4 66
X02  CLA A46
X03  STO B01
X04  LXA1401
X05  CLA1A0
X06  PAX2
X07 7A462X12

X10  CLA C07
X11  TSX4906
X12 1   11X13
X13  CLA1A0
X14  PAX4
X15  STO2R3
X16 7A254X21
X17  CLA C10
```

```
X20   TSX4906
X21 1   11X22
X22   CLA1A0
X23   PAX4
X24   ALS  22
X25   STØ2R0
X26 7A344X31
X27   CLA C11

X30   TSX4906
X31 1   11X32
X32   CLA1A0
X33   NØP
X34   TZE X42
X35   NØP
X36   STA2R0
X37   TMI X44

X40   CLA C31
X41   TRA X43
X42   CLA C30
X43   ØRS2R0
X44 1   11X45
X45   CLA1A0
X46   STØ2S4
X47 1   11X50

X50   LXA4401
X51   CLA1A0
X52   STØ4A00
X53 1   11X54
X54 70024Y13
X55   CLA1A0
X56   ARS  10
X57   ALS  10

X60   ØRS2R3
X61   TSX4805
X62   ACL A47
X63   PAX4
X64   LXA2A47
X65   CLA2Z0
X66   STØ4R6
X67 2   14X70

X70 2   12X65
X71 1   11X72
X72   CLA B01
X73   SUB 401
X74   STØ B01
X75   TNZ X05
X76   LXD4 66
X77   TRA4   1

Y00 8    2X60
Y01   TRA X61
Y02   CLA1A0
Y03   ALS  41
Y04   ØRS2R0
Y05   TRA X61
Y06 8    2X74
Y07 7D031X75
```

```
Y10   CLA C15
Y11   TSX4906
Y12   TRA X76
Y13 1C014X51
Y14 8    2X52
Y15   CLA4Y25
Y16   STA Y20
Y17   CLA1A0

Y20   STØ2Z0
Y21   TRA X53
Y22   STØ2Z2
Y23   STØ2Z1
Y24   STØ2Z3
Y25   HTR

X00 8     804
X01   SXD4Y07
X02   TSX4974
X03 0     1
X04 4     933
X05   CLA 401
X06   STØ 153
X07   LXA1A47

X10 1   11X11
X11   LXA4153
X12   CAL4R3
X13   SLW 150
X14   ANA C33
X15   SLW 151
X16   CLA4R0
X17   ANA 442

X20   ARS  22
X21   STØ 152
X22   STZ 154
X23   TSX4974
X24 0   2
X25 4   51155
X26   LXA24C1
X27   CAL2T4

X30   ANA1R5
X31   TZE X71
X32   ANA1R6
X33   TZE X37
X34   PXD2
X35   SSP
X36   TRA X41
X37   PXD2

X40   SSM
X41   ARS  22
X42   STØ 160
X43   CLA2R2
X44   ADD 153
X45   PAX4
X46   CLA4R1
X47   CLM
```

```
X50   STØ 157
X51   CLA4R1
X52   SSP
X53   LDQ 400
X54   LRS  14
X55   RQL  15
X56   STQ 154
X57   LDQ 400

X60   LRS  14
X61   RQL  15
X62   STQ 155
X63   LDQ 400
X64   LRS  12
X65   RQL  13
X66   STQ 156
X67   TSX4974

X70 4   51161
X71 1   12X72
X72 3A542X76
X73   CLA2T4-
X74   TPL X27
X75 1   11X27
X76   CLA 153
X77   ADD 401

Y00   STØ 153
Y01   CAS A46
Y02   TRA Y05
Y03   NØP
Y04 1   11X11
Y05   LXD4Y07
Y06   TRA4   1
Y07   HTR

X00 8     805
X01   SXD4 63
X02   SXD2B04
X03   SXD1 61
X04   LXA4A47
X05   CAL B04
X06   STZ4Z0
X07 6   14X13

X10   ACL B04
X11   STZ4Z0
X12 2   14X10
X13   SLW  60
X14   PDX1
X15   MSE 142
X16   NØP
X17   LXA2401

X20   CLA 401
X21   STØ B03
X22   CAL 402
X23   SLW 100
X24 1   11X25
X25   ANA1R5
X26   TZE X35
X27   TSX4913
```

```
X30   CAL 100
X31   LXA4B03
X32   TCP X34
X33   TRA X35
X34   ØRS4Z0
X35 1   12X36
X36 3A542X54
X37   MSE 142

X40   TRA X46
X41   CLA B03
X42   ADD 401
X43   STØ B03
X44   CAL 401
X45   TRA X23
X46   CAL 100
X47   ALS   1

X50   SLW 100
X51   TNØ X25
X52   PSE 142
X53   TRA X25
X54   LXD1 61
X55   LXD2B04
X56   LXD4 63
X57   CLA  60

X60   ARS  22
X61   TRA4   1

X00 8     806
X01   SXD4X35
X02   SXD2X36
X03   SXD1X37
X04   LXD4R2*
X05   STZ4R1
X06 2   14X05
X07   LXA1401

X10   CLA A47
X11   SLW 121
X12   LXA2A54
X13   LDQ2R4
X14   LGL  14
X15   CLA 400
X16   LGL   6
X17   ADM 121

X20   PAX4
X21   CAL2T4
X22   ANA4R5
X23   TNZ X40
X24 2   12X13
X25   CLA 121
X26   ADM A47
X27 1   11X30
```

```
X30 7A461X11
X31  LXD4X35
X32  LXD2X36
X33  LXD1X37
X34  TRA4   1
X35  HTR
X36  HTR
X37  HTR

X40  ANA4R6
X41  TZE X46
X42  CLA 411
X43  ALS   7
X44  SLW 122
X45  TRA X47
X46  STZ 122
X47  LXA4A46

X50  STZ4Y6
X51 2   14X50
X52  STZ 123
X53  PXD1
X54  ARS  22
X55  STO 120
X56  ADD2R2
X57  STO 124

X60  LXA1401
X61  CAL A47
X62  STO 125
X63  ACL 126
X64  PAX4
X65  CAL2T4
X66  ANA4R5
X67  TZE Y04

X70  ANA4R6
X71  TZE Y02
X72  CLA 122
X73  TNZ Y04
X74  CLA 125
X75  STO1Y6
X76  CLA 123
X77  ADD 401

Y00  STO 123
Y01  TRA Y04
Y02  CLA 122
Y03  TNZ X74
Y04  CLA 125
Y05  ACM A47
Y06 1   11Y07
Y07 7A461X62

Y10  CLA 123
Y11  TNZ Y23
Y12  PXD2
Y13  ARS  22
Y14  STO 117
Y15  TSX4975
Y16 0   2
Y17 C      942

Y20 C   21121
Y21 4   3
Y22  TRA Y37
Y23  SUB 401
Y24  TNZ Y41
Y25  LXA4A46
Y26  CLA4Y6
Y27  TNZ Y31

Y30 2   14Y26
Y31  PXD4
Y32  ARS  22
Y33  STA 122
Y34  LXA4124
Y35  CLA 122
Y36  STO4R1
Y37  LXA1120

Y40  TRA X24
Y41  SUB 401
Y42  TNZ Y67
Y43  LXA4A46
Y44  CLA4Y6
Y45  TNZ Y47
Y46 2   14Y44
Y47  PXD4

Y50  ARS  22
Y51  STO 100
Y52 2   14Z75
Y53  SXD4100
Y54  CLA 100
Y55  TSX4903
Y56  TRA Y62
Y57  ORA 122

Y60  STO 122
Y61  TRA Y34
Y62  TSX4Z05
Y63  STA 122
Y64  ANA 442
Y65  ALS   6
Y66  TRA Y57
Y67  TSX4Z05

Y70  STO 125
Y71  TSX4903
Y72  TRA Y75
Y73  SSM
Y74  TRA Y57
Y75  CLA 125
Y76  STA 122
Y77  ANA 442

Z00  SSM
Z01  TRA Y65
Z02 8    2X16
Z03  STO 126
Z04  TRA X17
Z05  SXD4Z74
Z06  LXA1120
Z07  LXA4A46

Z10  STZ 100
Z11  STZ 101
Z12  CLA4Y6
Z13  TZE Z62
Z14  CLA1Z3
Z15  FSB4Z3
Z16  STO 104
Z17  LDQ 104

Z20  FMP 104
Z21  STO 105
Z22  CLA1Z1
Z23  FSB4Z1
Z24  STO 104
Z25  LDQ 104
Z26  FMP 104
Z27  FAD 105

Z30  STO 105
Z31  CLA1Z2
Z32  FSB4Z2
Z33  STO 104
Z34  LDQ 104
Z35  FMP 104
Z36  FAD 105
Z37  STO 105

Z40  CLA 100
Z41  TNZ Z46
Z42  CLA 105
Z43  STO 100
Z44  SXD4102
Z45  TRA Z62
Z46  CAS 105
Z47  TRA Z42

Z50  NOP
Z51  CLA 101
Z52  TNZ Z57
Z53  CLA 105
Z54  STO 101
Z55  SXD4103
Z56  TRA Z62
Z57  CAS 105

Z60  TRA Z53
Z61  NOP
Z62 2   14Z12
Z63  CLA 103
Z64  ARS  22
Z65  ANA 441
Z66  STO 103
Z67  CLA 102

Z70  STD 103
Z71  CLA 103
Z72  LXD4Z74
Z73  TRA4   1
Z74  HTR
Z75  CLA4Y6
Z76  TNZ Y53
Z77  TRA Y52

0+00  8    2Z42
0+00     LDQ 100
0+00     STQ 101
0+00     LDQ 102
0+00     STQ 103
0+00     TRA Z43

X00 8     810
X01  SXD4Z10
X02  TSX4974
X03 C   2
X04 C   11J00
X05 4  111K00
X06  LXA2JC1
X07 7A262X13

X10  CLA C12
X11  TSX4906
X12  TRA Z06
X13  CLA K01
X14  TSX4901
X15  STO 100
X16  FAD 421
X17  STO2T3

X20  CLA 100
X21  FDH2T3
X22  STQ 100
X23  FMP 100
X24  STO2S6
X25  CLA B02
X26  ARS  22
X27  STO2T0

X30  CLA B04
X31  STD2T0
X32  CLA K07
X33  TZE X37
X34  TMI Z74
X35  CLS2T0
X36  STO2T0
X37  LXD1B02

X40 1   11X41
X41  CLA K02
X42  ALS  22
X43  STO 100
X44  STD X62
X45  STD X70
X46  STD X77
X47  STD Y11

X50  CLA K03
X51  ALS  17
X52  ACL 100
X53  ACL K01
X54  STO1M0
X55  LXA2401
X56 1   11X57
X57  CLA2C0
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X60  STØ1MC
X61 1  12X62
X62 7  02X56
X63  LXA2401
X64 1  11X65
X65  CLA2C1
X66  STØ1MO
X67 1  12X70

X7C 7  02X64
X71  LXA2401
X72 1  11X73
X73  CLA2C2
X74  NØP
X75  STØ1MO
X76 1  12X77
X77 7  02X72

Y00  LXA2401
Y01 1  11Y02
Y02  CLA2C1
Y03  FSB2C2
Y04  STØ 100
Y05  CLA2C3
Y06  FDH 100
Y07  STQ1MO

Y10 1  12Y11
Y11 7  02Y01
Y12 1  11Y13
Y13  CLA K04
Y14  TZE ZC4
Y15  ALS  22
Y16  ACL K01
Y17  STØ1MC

Y20  STD Y26
Y21  LXA2401
Y22 1  11Y23
Y23  CLA2C4
Y24  SLW1MO
Y25 1  12Y26
Y26 7  02Y22
Y27 1  11Y30

Y30  LXA4K04
Y31  LXA2401
Y32  CLA2C5
Y33  ALS  22
Y34  ACL2C5
Y35  STØ 1C0
Y36  CLA2C4
Y37  TPL Y41

Y40  CLA 401
Y41  CLA2C5
Y42  TZE Z11
Y43  SXD4101
Y44  SXD2102
Y45  SXD1103
Y46  CLA B03
Y47  ARS  22

Y50  LXA2100
Y51  STA 100
Y52  LXA1100
Y53  LXA4401
Y54  CLA2C6
Y55  STØ1M2
Y56 1  11Y57
Y57 1  12Y60

Y60  CAS 421
Y61  NØP
Y62  TRA Y64
Y63 1  14Y54
Y64  LXD2100
Y65  SXD1100
Y66  CLA2C7
Y67  STØ1M2

Y7C 1  11Y71
Y71 1  12Y72
Y72 2  14Y66
Y73  SXD1B03
Y74  LXD4101
Y75  LXD2102
Y76  LXD1103
Y77  CLS 100

Z00  STØ1M0
Z01 1  11Z02
Z02 1  12Z03
Z03 2  14Y32
Z04 2  11Z05
Z05  SXD1B02
Z06  LXD4Z10
Z07  TRA4  1

Z1C  HTR
Z11  CLA 100
Z12  TRA Z00
Z13 8   2Y73
Z14 7D102Y74
Z15  CLA C16
Z16  TSX4906
Z17  TRA ZC5

Z20 8   2X24
Z21  LXA1K02
Z22 7D011Z26
Z23  CLA C13
Z24  TSX4906
Z25  TRA ZC6
Z26  LXA1K04
Z27 3D021Z23

Z30  LXA1K06
Z31 3D111Z23
Z32  LXA1K05
Z33 3D121Z23
Z34  TRA X25
Z35 8   2Y32
Z36  TPL Y33
Z37  SSP

Z40  STØ 100
Z41  CAL 415
Z42  ALS  17
Z43  ØRS 100
Z44  SXD4101
Z45  SXD2102
Z46  SXD1103
Z47  CLA B03

Z50  ARS  22
Z51  LXA2100
Z52  STA 100
Z53  LXA1100
Z54  CLA2C7
Z55  ALS  22
Z56  STD 1C0
Z57  PCX4

Z60  NØP
Z61  CLA2C6
Z62  STØ1M2
Z63 1  12Z64
Z64 1  11Z65
Z65 2  14Z61
Z66  LXD2102
Z67  CLA2C4

Z70  TPL Y73
Z71  CLA 401
Z72  ALS  17
Z73  ØRS 1C0
Z74  CLA 401
Z75  ALS  17
Z76  ØRS2T0
Z77  TRA X35

C+CO  81402810
C+CO   ALS  17
C+00   ØRS 100
C+00  E1413810
0+00  82732810
C+CO  81733810

X00 8     811
X01  SXD4Y35
X02  CLA K06
X03  TZE4  1
X04  LXD1B04
X05 1  11X06
X06  ALS  22
X07  ACL K01

X10  STØ1M3
X11  STD X21
X12  STD X51
X13  LXA24C1
X14 1  11X15
X15  CLA2D0
X16  STØ1M3
X17 1  11X20

X20 1  12X21
X21 7  02X15
X22  STZ 110
X23  CLA B05
X24  STD 110
X25  ARS  22
X26  ADD K05
X27  STA 110

X30  CLA K05
X31  ALS   1
X32  STØ 111
X33  ALS  22
X34  STD 111
X35  LXA24C1
X36  CLA 110
X37  STØ1M3

X4C  STØ2D0
X41  CAL 110
X42  ACL 111
X43  SLW 110
X44  CAL B05
X45  ACL 111
X46  STD B05
X47 1  11X50

X50 1  12X51
X51 7  02X36
X52  CLA 401
X53  STØ B06
X54  TSX4855
X55  CLA R01
X56  SUB K01
X57  TZE X63

X60  CLA C41
X61  TSX49C6
X62  TRA Y32
X63  CLA R02
X64  SUB K10
X65  TNZ X60
X66  CLA R03
X67  SUB K11

X70  TNZ X60
X71  CLA RC4
X72  SUB B06
X73  TNZ X60
X74  LXA4R04
X75  CLA R05
X76  SUB4D1
X77  TNZ X60

Y00  TSX4814
Y01  LXA4R05
Y02  TRA4Y14
Y03  HTR   0
Y04  HTR   0
Y05  TSX4837
Y06  TSX4836
Y07  TSX4835
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Y10   TSX4834
Y11   TSX4833
Y12   TSX4832
Y13   TSX4831
Y14   TSX4830
Y15   LXA4K06
Y16   CAL4D0
Y17   ACL 425

Y20   SLW4D0
Y21 2  14Y16
Y22   CLA K05
Y23   SUB 401
Y24   STØ K05
Y25   TZE Y31
Y26   CLA B06
Y27   ADD 401

Y30   TRA X53
Y31 2  11Y32
Y32   SXD1B04
Y33   LXD4Y35
Y34   TRA4   1
Y35   HTR    0

X00 8     812
X01   SXD4X24
X02   LXD1B02
X03 7D031X06
X04   CLA C20
X05   TSX4906
X06   LXD1B03
X07 7D051X12

X10   CLA C22
X11   TSX4906
X12   LXD1B04
X13 7D061X16
X14   CLA C05
X15   TSX4906
X16   LXD1B05
X17 7D071X22

X20   CLA C23
X21   TSX4906
X22   LXD4X24
X23   TRA4   1
X24   HTR

X00 8     813
X01   CLA B02
X02   STD M0*
X03   ARS  22
X04   STØ Q02
X05   CLA B03
X06   STD M2*
X07   ARS  22

X1C   STØ Q04
X11   CLA B04
X12   STD M3*
X13   ARS  22
X14   STØ Q05
X15   CLA B05
X16   STD M4*
X17   ARS  22

X20   STØ Q06
X21   TRA4   1

X00 8     814
X01   SXD4Y05
X02   CLA RC5
X03   SUB 407
X04   TZE Y06
X05   LXA2K06
X06   CLA2D0
X07   PCX4

X1C   CLA R05
X11   LRS   6
X12   CLA2E0
X13   ARS   6
X14   LLS   6
X15   STØ4M4
X16 2  12X06
X17   CLA K07

X20   TNZ Y03
X21   NØP
X22   LXA4K06
X23   LXA2401
X24   CLA2E1
X25   TMI Y25
X26   ALS  22
X27   ACL2E1

X30   STØ 100
X31   CLA2E4
X32   ALS  17
X33   ØRS 100
X34   CLA2E1
X35   TZE Y23
X36   SXD4101
X37   SXD2102

X40   SXD1103
X41   CLA B03
X42   ARS  22
X43   LXA2100
X44   STA 100
X45   LXA1100
X46   LXA4401
X47   CLA2E2

X50   STØ1M2
X51 1  11X52
X52 1  12X53
X53   CAS 421
X54   NØP
X55   TRA X57
X56 1  14X47
X57   LXD21C0

X60   SXD1100
X61   CLA2E3
X62   STØ1M2
X63 1  11X64
X64 1  12X65
X65 2  14X61
X66   SXD1B03
X67 7D102X73

X7C   CLA C17
X71   TSX4906
X72   TRA Y03
X73   LXD4101
X74   LXD2102
X75   LXD1103
X76   CLS 100
X77   STØ1M3

Y00 1  11Y01
Y01 1  12YC2
Y02 2  14X24
Y03   LXD4Y05
Y04   TRA4   1
Y05   HTR
Y06   LXA2K06
Y07   CLA2D0

Y1C   PDX4
Y11   CLA R05
Y12   LRS   6
Y13   CLA R10
Y14   LRS   6
Y15   CLA2E0
Y16   ARS  14
Y17   LLS  14

Y20   STØ4M4
Y21 2  12Y07
Y22   TRA X17
Y23   CLA 100
Y24   TRA X77
Y25   SSP
Y26   STØ 100
Y27   CLA2E4

Y30   ALS  17
Y31   ØRS 100
Y32   CLA 415
Y33   ALS  17
Y34   ØRS 100
Y35   SXD4101
Y36   SXD2102
Y37   SXD1103

Y40   CLA B03
Y41   ARS  22
Y42   LXA2100
Y43   STA 100
Y44   LXA1100
Y45   CLA2C7
Y46   ALS  22
Y47   STD 1C0

Y50   PDX4
Y51   NØP
Y52   CLA2C6
Y53   STØ1M2
Y54 1  12Y55
Y55 1  11Y56
Y56 2  14Y52
Y57   TRA X66

X00 8     815
X01   SXD4X47
X02   CLA F02
X03   ALS  22
X04   STD F0*
X05   STD F1*
X06   LXA4F02
X07   CLA 400

X1C   FAD4F1
X11 2  14X10
X12   STØ 10C
X13   LXA4F02
X14   CLA4F1
X15   FCH 100
X16   STQ4F1
X17 2  14X14

X20   TSX4974
X21 C  4
X22 0  21F00
X23 C     F0
X24 4     F1
X25   LXD1B06
X26 1  11X56
X27   LXA2F02

X30   CLA2F0
X31   LRS  10
X32   CLA2F1
X33   ARS  10
X34   LLS  10
X35   STØ1M1
X36 1  11X37
X37 2  12X30

X40 2  11X41
X41   SXD1B06
X42 7D041X45
X43   CLA C21
X44   TSX49C6
X45   LXD4X47
X46   TRA4   1
X47   HTR
```

```
X50 8    2X01
X51  LXA4F02
X52 7D174X02
X53  CLA 405
X54  TSX4906
X55  TRA X45
X56  PXD1
X57  ARS  22

X60  STO 101
X61  CLA F02
X62  ALS  22
X63  STD 101
X64  LXA4F01
X65  CLA 101
X66  STO4S5
X67  TRA X27

X00 8     816
X01  SXD4 77
X02  TSX4975
X03 0   2
X04 0     937
X05 0  2
X06 4  61Q00
X07  TSX4974

X10 0   2
X11 0     937
X12 0  2
X13 4  61Q00
X14  LXA4Q02
X15 7D034X20
X16  CLA C20
X17  TSX4906

X20  LXA4Q03
X21 7D044X24
X22  CLA C21
X23  TSX4906
X24  LXA4Q04
X25 7D054X30
X26  CLA C22
X27  TSX4906

X30  LXA4Q05
X31 7D064X34
X32  CLA C05
X33  TSX4906
X34  LXA4Q06
X35 7D074X40
X36  CLA C23
X37  TSX4906

X40  LXD4 77
X41  TRA4  1
X42 8   2X40
X43  TSX4973
X44 4  61Q00
X45  LXD4 77
X46  TRA X41
```

```
X00 8     817
X01  REW    7
X02  TSX4977
X03 0       7
X04 0A362R0
X05 01012R1
X06 01022R3
X07 01032R4

X10 01042R5
X11 01052R6
X12 01062R7
X13 01072S0
X14 01102S1
X15 01112S2
X16 01122S3
X17 01132S4

X20 01142S5
X21 01152S6
X22 01162S7
X23 01172T0
X24 01202T1
X25 01212T2
X26 01222T3
X27 01232T4

X30 01242T5
X31 01252M0
X32 01262M1
X33 01272M2
X34 01302M3
X35 01312M4
X36 41322932
X37  WEF    7

X40  TSX4977
X41 0       7
X42 42012X47
X43  WEF    7
X44  REW    7
X45  LXD4457
X46  TRA4   1
X47 0 62 A62

X00 8     820
X01  SXD4 77
X02  TSX4974
X03 0   1
X04 0      936
X05 0  2
X06 0    1R0
X07 0    1R3

X10 0    1R4
X11 0    1R5
X12 0    1R6
X13 0    1R7
X14 0    1S0
X15 0    1S1
X16 0    1S2
X17 0    1S3
```

```
X20 0    1S4
X21 0    1S5
X22 0    1S6
X23 0    1S7
X24 0    1T0
X25 0    1T1
X26 0    1T2
X27 0    1T3

X30 0     T4
X31 0     T5
X32 0     Z3
X33 0     Z1
X34 0     Z2
X35 0  3
X36 4  611A00
X37  TSX4974

X40 0   1
X41 0     M0
X42 0     M1
X43 0     M2
X44 0     M3
X45 4     M4
X46  TSX4975
X47 0   2

X50 0     940
X51 4   2
X52  TSX4974
X53 0   1
X54 4     940
X55  LXD4 77
X56  TRA4  1

X57 *     865

X00 8     830
X01  SXD4X22
X02  SXD2X23
X03  SXD1X24
X04  LXA1K06
X05  LXA2401
X06  CLA2E0
X07  NOP

X10  CLA2D0
X11  PAX4
X12  CLA2G0
X13  STO4M4
X14 1  12X15
X15 2  11X06
X16  LXD4X22
X17  LXD2X23

X20  LXD1X24
X21  TRA4  1
X22  HTR
X23  HTR
X24  HTR
```

```
X00 8     831
X01  SXD4X05
X02  TSX4830
X03  LXD4X05
X04  TRA4  2
X05  HTR

X00 8     832
X01  SXD4X36
X02  SXD2X37
X03  SXD1X40
X04  CLA R06
X05  TPL X12
X06  CLA 401
X07  ALS  17

X10  STO 100
X11  TRA X13
X12  STZ 100
X13  CLA R06
X14  ALS  22
X15  STD 100
X16  CLA 401
X17  STO 101

X20  LXA1101
X21  CLA1E0
X22  TNZ X41
X23  CLA 101
X24  ADD 401
X25  STO 101
X26  CAS K06
X27  TRA X32

X30  TRA X20
X31  TRA X20
X32  LXD4X36
X33  LXD2X37
X34  LXD1X40
X35  TRA4  3
X36  HTR
X37  HTR

X40  HTR
X41  CLA B05
X42  ARS  22
X43  STA 100
X44  CLA1D0
X45  PAX4
X46  CLA 100
X47  STO4M4

X50  STD X53
X51  LXD4B05
X52  LXD2B05
X53 1  02X54
X54  CLA R06
X55  SLW 102
X56  CLA1G0
X57  PAX1
```

```
X60   CLA1G1
X61   TRA X71
X62 1   11X76
X63   CLA 102
X64   SUB 401
X65   STO 102
X66   TNZ X60
X67   SXD2BC5

X70   TRA X23
X71   STO4M4
X72   CLA1G2
X73   STO2M4
X74 1   14X75
X75 1   12X62
X76 7D131X63
X77   CLA C40

Y00   TSX4906
Y01   TRA X32

X00 8     833
X01   SXD4X36
X02   SXD2X37
X03   SXD1X40
X04   CLA R06
X05   TPL X12
X06   CLA 401
X07   ALS   17

X1C   STO 100
X11   TRA X13
X12   STZ 100
X13   CLA R06
X14   ALS  22
X15   STO 1C0
X16   CLA 401
X17   STO 101

X20   LXA1101
X21   CLA1E0
X22   TNZ X41
X23   CLA 101
X24   ADD 401
X25   STO 101
X26   CAS K06
X27   TRA X32

X30   TRA X20
X31   TRA X20
X32   LXD4X36
X33   LXD2X37
X34   LXD1X40
X35   TRA4   4
X36   HTR
X37   HTR

X40   HTR
X41   LXD4B05
X42   CLA 100
X43   STD X45
X44   LXD2B05
X45 1   02X46
X46   CLA1G0
X47   STO 102

X5C   CLA 4C1
X51   STO 1C3
X52   CLA R06
X53   SLW 104
X54   PXD4
X55   ARS  22
X56   LXA1103
X57   STA1G3

X60   LXA11C2
X61   CLA1G4
X62   PAX1
X63   CLA1G5
X64   TRA Y04
X65 1   11X66
X66   CLA 104
X67   SUB 401

X70   STO 104
X71   TNZ X63
X72   CLA 102
X73   ADD 401
X74   STO 102
X75   CLA 103
X76   ADD 401
X77   STO 103

YCC   CAS R07
Y01   TRA Y11
Y02   TRA Y44
Y03   TRA Y44
Y04   STO4M4
YC5   CLA1G6
Y06   STO2M4
Y07 1   14Y10

Y1C 1   12X65
Y11 7D161Y15
Y12   CLA C40
Y13   TSX4906
Y14   TRA X32
Y15   LXA11C2
Y16 3D151Y12
Y17   PXD2

Y20   ARS  22
Y21   STA 100
Y22   LXA1101
Y23   CLA1D0
Y24   PAX4
Y25   CLA 100
Y26   STO4M4
Y27   LXA1401

Y30   LXA4R07
Y31   CLA1G3
Y32   STO2M4
Y33 1   12Y34
Y34 1   11Y35
Y35 2   14Y31
Y36   SXD2B05
Y37   TRA X23

Y40 8    2X03
Y41   LXA1RC7
Y42 7D141X04
Y43   TRA Y12
Y44 1   04Y45
Y45 1   02X52
Y46 8    2X43
Y47   STD Y44

Y50   STD Y45
Y51   TRA X44

X00 8     834
X01   SXD4XC5
X02   TSX4830
XC3   LXD4X05
X04   TRA4   5
X05   HTR

X00 8     835
X01   SXD4X26
X02   SXD2X27
X03   SXD1X30
X04   LXA1K06
X05   LXA2401
X06   CLA2E0
X07   NOP

X10   CLA2D0
X11   PAX4
X12   CLA RC6
X13   LRS   3
X14   CLA2G0
X15   ARS   3
X16   LLS   3
X17   STO4M4

X20 1   12X21
X21 2   11X06
X22   LXD4X26
X23   LXD2X27
X24   LXD1X30
X25   TRA4   6
X26   HTR
X27   HTR

X30   HTR

X0C 8     836
X01   SXD4X16
X02   SXD2X17
X03   SXD1X20
X04   LXA1K06
X05   LXA2401
X06   CLA2E0
X07   TNZ X21

X10 1   12X11
X11 2   11X06
X12   LXD4X16
X13   LXD2X17
X14   LXD1X20
X15   TRA4   7
X16   HTR
X17   HTR

X20   HTR
X21   CLA2D0
X22   PAX4
X23   CLA B05
X24   ARS  22
X25   STO4M4
X26   PAX4
X27 1   14X30

X30   CLA R06
X31   STO4M4-
X32   CLA R07
X33   STO4M4
X34   CLA R10
X35   STO4M4+
X36 1   24X37
X37   SXD4B05

X40   TRA X10
X41 8    2X07
X42   CLA2E0+
X43   TZE X1C
X44   TRA X21

X00 8     837
X01   SXD4X16
X02   LXA4R10
X03 7   34X07
X04   CLA C13
X05   TSX4906
X06   TRA X14
X07   TRA4X13

X1C   TSX4833
X11   TSX4832
X12   TSX4831
X13   TSX4830
X14   LXD4X16
X15   TRA4 10
X16   HTR
```

```
XC0 8    850
X01  TSX4976
X02  CAL A0*
X03  ANA 441
X04  STO 100
XC5  CLA G7*
X06  SUB 100
X07  STA C35

X10  TSX4855
X11  TSX4800
X12  TSX4801
X13  TSX4802
X14  TSX4855
X15  TSX4803
X16  TSX4804
X17  STZ B02

X20  STZ B04
X21  CLA 415
X22  STO B03
X23  STO B05
X24  CLA A26
X25  STO B01
X26  LXA4C35
X27  STZ4G7

X3C 2  14X27
X31  LXD4A0*
X32  STZ4A0
X33 2  14X32
X34  TSX4974
X35 C    1
X36 4    934
X37  TSX4855

X4C  TSX4810
X41  TSX4811
X42  TSX4812
X43  PSE 165
X44  TRA X47
X45  CLS J01
X46  TSX4906
X47  LXA4C35

X50  STZ4G7
X51 2  14X50
X52  CLA B01
X53  SUB 401
X54  STO B01
X55  TNZ X37
X56  TSX4813
X57  STZ B06

X6C  CLA A25
X61  STO B01
X62  TSX4974
X63 0    1
X64 4    935
X65  TSX4855
X66  TSX4815
X67  CLA B01
```

```
X7C  SUB 401
X71  STO B01
X72  TNZ X65
X73  CLA B06
X74  STD M1*
X75  ARS  22
X76  STO C03
X77  TSX4816

Y00  TSX4817
Y01  TSX4820
Y02  HPR
Y03  TSX4970
Y04 8   2X15
Y05  TSX4806
Y06  TRA X16

Y07 *    4850

X00 8    855
X01  SXD4X11
X02  SXD2X12
X03  SXD1X13
X04  TSX4970
XC5  LXD4X11
X06  LXD2X12
X07  LXD1X13

X1C  TRA4   1
X11  HTR
X12  HTR
X13  HTR

XCC 8    860
X01  TSX4971
X02 CD031A0
X03 0D011C0
X04 0D011C1
X05 0D011C2
X06 CDC11C3
X07 CDC21C4

X10 CD021C5
X11 0D101C6
X12 CD101C7
X13 0D111DC
X14 CD121D1
X15 0D111E0
X16 CD111E1
X17 CD101E2

X2C CD101E3
X21 0D111G0
X22 0D131G1
X23 CD131G2
X24 CD141G3
X25 CD151G4
X26 CD161G5
X27 0D161G6
```

```
X30 0  11G7
X31 0D171F0
X32 CD171F1
X33 CD041M1
X34 CD051M2
X35 CD061M3
X36 CDC71M4
X37 0A461R0

X4C 0A461R3
X41 0A541R4
X42 0A231R5
X43 0A231R6
X44 0A541R7
X45 0A541S0
X46 CA541S1
X47 CA541S2

X50 CA241S3
X51 CA461S4
X52 CA251S5
X53 0A261S6
X54 CA541S7
X55 CA261T0
X56 CA541T1
X57 C4001T2

X6C CA261T3
X61 CA541T4
X62 0A261T5
X63 CA471Z0
X64 CD111E4
X65 CA461R1
X66 CA542R2
X67 CA461Y6

X70 0A461Z3
X71 CA461Z1
X72 4A461Z2
X73  TSX4970

X74 *    486C

X75 *     906

XC0 8    865
X01  TSX4974
X02 C  2
X03 C 571A00
X04 C  2
X05 0  61B00
X06 0  2
X07 C  11J00

X1C C  2
X11 C 121K00
X12 C  2
X13 0  21F00
X14 0  2
X15 C 101RC0
X16 C  2
X17 C 751155
```

```
X20 4  2
X21  TSX4975
X22 C    941
X23 4  3
X24  HPR
X25  PSE 163
X26  TRA X40
X27  CLA K01

X30  TNZ X42
X31  CLA A0*
X32  STO X56
X33  SXD1A0*
X34  TSX4974
X35 4    A0
X36  CLA X56
X37  STO A0*

X4C  LXD4457
X41  TRA4   1
X42  CLA R01
X43  NOP
X44  TSX4974
X45 C    C0
X46 C    C1
X47 C    C2

X50 C    C3
X51 C    C4
X52 C    C5
X53 C    D0
X54 4    D1
X55  TRA X40
X56  HTR

X57 *    850

X00 8    901
X01  ACL 420
X02  FAD 420
X03  TRA4   1

X00 8    903
X01  SXD4X30
X02  SXD2X31
X03  SXD1X32
X04  STO 1CC
X05  PAX4
X06  PCX2
X07  CLA2Y6

X10  PAX1
X11  CLA4Y6
X12  PAX2
X13  LXA44C1
X14 1  11X15
X15 1  12X16
X16  CAL1R5
X17  ANA2R5
```

```
X20  TNZ X33
X21 1  14X22
X22 7A474X14
X23  CLA 100
X24  LXD4X30
X25  LXD2X31
X26  LXD1X32
X27  TRA4  1

X30  HTR
X31  HTR
X32  HTR
X33  SLW 101
X34  CAL1R6
X35  COM
X36  ANA2R6
X37  ANA 101

X40  TNZ X54
X41  CAL2R6
X42  COM
X43  ANA1R6
X44  ANA 101
X45  TZE X21
X46  SLW 102
X47  LDQ 100

X50  RQL  22
X51  STQ 100
X52  NOP
X53  CAL 102
X54  SLW 102
X55  CLA 400
X56 6  14X61
X57  ADD 023

X60 2  14X57
X61  PAX4
X62  CAL 102
X63  LBT
X64  TRA Y03
X65  PXD4
X66  ARS  6
X67  STO 103

X70  CLA 100
X71  ANA 441
X72  ORS 103
X73  CLA 100
X74  ANA 442
X75  ALS  6
X76  ORA 103
X77  LXD4X30

Y00  LXD2X31
Y01  LXD1X32
Y02  TRA4  2
Y03  ARS  1
Y04 1  14X63

X00 8     905
X01 8AO 4BO
X02 8AC 4MO

X00 8     906
X01  SXD4X45
X02  STO 103
X03  CLA X45
X04  ARS  22
X05  SLB 401
X06  COM
X07  ANA 441

X10  STO 100
X11  PXD2
X12  ARS  22
X13  STO 101
X14  PXD1
X15  ARS  22
X16  STO 102
X17  TSX4975

X20 0    2
X21 0     930
X22 0   41104
X23 4  2
X24  TSX4974
X25 0    2
X26 0     930
X27 0   41104

X30 4  2
X31  TSX4865
X32  LXD4X45
X33  HPR
X34  PSE 164
X35  TRA4  1
X36  CLS A0*
X37  ANA 441

X40  ADD Z0*
X41  PAX4
X42  STZ4Z0
X43 2  14X42
X44  TSX4850
X45  HTR

X00 8     907
X01  SXD4120
X02  CLA A01
X03  FSB2R7
X04  STO 121
X05  CLA A02
X06  FSB2S0
X07  STO 122

X10  CLA A03
X11  FSB2S1
X12  STO 123
X13  LXA4403
X14  STZ 124
X15  LDQ4124
X16  FMP1T2
X17  FAD1T2

X20  FAD1T2
X21  LRS  43
X22  FMP4124
X23  FAD 124
X24  STO 124
X25 1  11X26
X26 2  14X15
X27  FAD1T2

X30  LXD4120
X31  LRS  43
X32  TRA4  1
X33 9  3 X17
X34 9  3 X20
X35 9  3 X27

X00 8     913
X01  SXD4 77
X02  SXD1 75
X03  CAL2R4
X04  ANA 034
X05  PDX1
X06  CLA A47
X07  TPL X24

X10  CAL2T1
X11  TZE X24
X12  PDX1
X13  ANA 441
X14  CAS 026
X15  TRA X20
X16  TSX4907
X17  TRA X21

X20  TSX4914
X21  LXD4 77
X22  LXD1 75
X23  TRA4  1
X24  PXD1
X25  ALS  2
X26  PDX4
X27  CAL2T4

X30  ANA4S3
X31  TZE X50
X32  LDQ2R7
X33  FMP A01
X34  STO 110
X35  LDQ2S0
X36  FMP A02
X37  FAD 110

X40  STO 110
X41  LDQ2S1
X42  FMP A03
X43  FAD 110
X44  FAD2S2
X45  STO 110
X46  LDQ 110
X47  TRA X21

X50  STZ 110
X51  CAL2T4
X52  ANA4S3+
X53  TNZ X62
X54  CLA A02
X55  FSB2S0
X56  STO 111
X57  LDQ 111

X60  FMP 111
X61  STO 110
X62  CAL2T4
X63  ANA4S3
X64  TNZ X74
X65  CLA A01
X66  FSB2R7
X67  STO 111

X70  LDQ 111
X71  FMP 111
X72  FAD 110
X73  STO 110
X74  CAL2T4
X75  ANA4S3
X76  TNZ Y06
X77  CLA A03

Y00  FSB2S1
Y01  STO 111
Y02  LDQ 111
Y03  FMP 111
Y04  FAD 110
Y05  STO 110
Y06  CLA 110
Y07  FSB2S2

Y10  TRA X45
Y11 9  2 X63
Y12 9  3 X75

X00 8     914
X01  SXD4120
X02  CLA A01
X03  STO 121
X04  STO 124
X05  CLA A02
X06  STO 122
X07  CLA A03
```

```
X10   STO 123
X11   LXA4403
X12   STZ 125
X13   LDQ1T2
X14   FMP4124
X15   STO 126
X16   LDQ1T2
X17   FMP4125

X20   FAD1T2
X21   FAD 126
X22   LRS  43
X23   FMP4124
X24   FAD 125
X25   STO 125
X26 1   11X27
X27 2   14X13

X30   FAD1T2
X31   LRS  43
X32   LXD4120
X33   TRA4  1
X34 9   3 X16
X35 9   6 X20
X36 9   6 X30
```

V - PARAMETER BLOCK D00: Sizes of variable length data blocks in Initiating code.

D01	Maximum $N(V^k)$ permitted = Size (C0, C1, C2, C3)
D02	Maximum $N(E^{el})$ permitted = Size (C4, C5)
D03	Size (A0 = B0 = M0)
D04	Size (M1)
D05	Size (M2)
D06	Size (M3)
D07	Size (M4)
D10	Size (C6, C7, E2, E3) = [Larger of D02, D11] × [Maximum number of angles tabulated]
D11	Maximum $N(E^{inel})$ permitted = Size (D0, E0, E1, G0)
D12	Maximum $N(\nu)$ permitted = Size (D1)
D13	Size (G1, G2) = [C(D11)] × [Δ_{Max} = maximum number of final energies tabulated]
D14	Size (G3) = Maximum number of angles tabulated for a (T = 3) reaction
D15	Size (G4) = [C(D11)] × [C(D14)]
D16	Size (G5, G6) = [C(D15)] × Δ_{Max}
D17	Size (F0, F1) = Maximum number of isotopes per material

VI - CARD LOADING ORDER OF INITIATING CODE MCB

(Number of cards in parentheses)

Formulas starred are identical to the similarly numbered formulas of Initiating code MCA.

1	* Advance NBA (card label 1 MCA)
2	* A00 (3): Same as for Monte Carlo MCS
3	Q00 (2): (Card labeled XOQ0 + binary card punched by MCA)

4 * BOO (1)

5 * COO (5)

6 * DOO (2)

7 * FOO (1)

8 * JOO (1)

9 * KOO (1)

10 * ROO (1)

11 * Advance NBA and record origins (card labeled 2 MCA)

12 * Remark cards R930-942 (Problem identification remark R932 PREPARED BY USER)

13 * Load instructions 860 (card labeled 4 MCA)

14 F860 -- Data assign (6)

15 * Load instructions 960 (card labeled 5 MCA)

16 * F906 (5)

17 F905 (1)

18 * F901 (1)

19 * F903 (9)

20 * F907 (4)

21 * F914 (4)

22 * F913 (10)

23 * F855 (2)

24 * F800 (2)

25 * F801 (5)

26 * F802 (19)

27 * F805 (7)

28 F803 (11)

29 * F804 (9)

30 * F806 (25)

31 * F816 (5)

32 * F817 (5)

33 * F820 (6)

34 Load instructions 865 (card labeled 6 MCB)

35 F865 (4)

36 Load instructions 850 (card labeled 7 MCB)

37 F850 (4): FLOCODE

38 Transition card (labeled 8 MCB)

39 SURFACE CARDS: (see pg. 53)

40 Transition card (labeled TR CRC MCA)

41 CELL CARDS: (see pg. 54)

42 Transition card (labeled TR CRC MCA)

VII - INITIATING CODE ERROR LIST

S(XX): Size of data block XX. A size error (ex. Error type 14) corrected by changing parameter block DOO.

L(XX): Location in data block XX of quantity detected to be in error. Depressing SS3 and pressing the start causes the first L(XX) words of data block XX to be printed.

Error Type:	Error:	C(1):	C(2):	Location:
1	J > 432: (Parameter block A00)			F801.6
2	A > 2048: (Parameter block A00)			F801.13
3	M > 256: (Parameter block A00)			F801.20
4	K > 72: (Parameter block A00)			F801.25
5	N_m > C(D17): (Material cards)			F815.54
6	T > 256: (Parameter block A00)			F801.37
7	j > J: (Surface cards)	L(A0)	j	F802.13
8	j specified twice: (Surface cards)	L(A0)	j	F802.17
9	a > A: (Surface cards: a in decrement 150_8)	L(A0)	j	F802.153
	(Cell cards)	L(B0)	a	F803.11
10	m > M: (Cell cards)	L(B0)	a	F803.20
11	t > T: (Cell cards)	L(B0)	a	F803.30
12	k > K: (Element cards)		k	F810.11
13	$N(v^k)$ > C(D01): (Element cards)	$N(v^k)$	k	F810.224
	T' > 3 in inelastic reaction T = 7 (Element cards)			F837.5
14	S(A0) > C(D03)	S(A0)		F802.207
15	S(B0) > C(D03)	S(B0)		F803.11
16	S(C6, C7) > C(D10)	S(C6) = S(C7)	L(M2)	F810.216
17	S(E2, E3) > C(D10)		S(E2) = S(E3)	F814.71
18	S(M0) > C(D03)	K_1 = S(M0)		F812.5,F816.17
19	S(M1) > C(D04)	M' = S(M1)		F815.44,F816.23
20	S(M2) > C(D05)	L = S(M2)		F812.11,F816.27
21	S(G1, G2) > C(D13)	S(G1) = S(G2)		F832.100
	S(G5, G6) > C(D16)	S(G5) = S(G6)		F833.113

Error Type:	Error:	C(1):	C(2):	Location:
22	Reaction data for wrong element	K_2 = L(M3)	$N(E^{inel})$	F811.61
23	S(T2) > C(D16)	S(T2)		F802.222
32	S(M3) > C(D06)	K_2 = S(M3)		F812.15,F816.33
36	S(M4) > C(D07)	N = S(M4)		F812.21,F816.37

APPENDIX F: REACTION DENSITY CODE MCR

I - With the problem tape of a completed FLOCODE 2 version of the Monte Carlo code MCS on tape unit A06 (logical tape 7), the code MCR is read from cards into the computer. A reaction card -- parameter block R00 (see Section A, below) -- is read for each isotope (k) for which a reaction calculation is desired. For each such (k) the collision density as a function of cell and energy is read from the problem tape, multiplied by the energy-dependent probability of the specified reaction in each cell (zero if cell (a) does not contain isotope (k)), and listed off-line in the format indicated in Section B below. The problem tape is rewound and the above procedure is repeated for each R00 card read.

A - Parameter block <u>R00</u>: Isotope reaction specification.

R01	k = Isotope number
R02	Z = Atomic number of isotope (k)
R03	A = Mass number of isotope (k)
R04	N(T) = C(D12) = Number of tally energies in MCS
R05	P = Print parameter (see below)

R06	0
R07	0
R10	$N(\nu)$ = Number of inelastic reactions on isotope (k).

Print parameter P:

P = 0: Print all reactions

P = 1: Suppress total collision print

P = 2: Suppress elastic collision print

P = 4: Suppress absorption collision print

P = 8: Suppress inelastic collision print

(May combine several P's by logical "or": for example, to obtain absorption listing only -- $P = 1 + 2 + 8 = 11_{10} = 13_8$ = 1011 binary.)

B - Print format:

For each R00 card read, the reaction data is written off-line for every reaction on isotope (k) -- except those specifically suppressed by the print parameter P -- in the order

T = 1: Total collisions on isotope (k)

T = 0: Variance in total collisions on isotope (k)

T = 2: Absorptions on isotope (k)

T = 3: Elastic collisions on isotope (k)

$T = (3 + \nu)$: Inelastic reaction (ν) on isotope (k)

T is the print label and is included in the heading of each reaction printed. The print format is as follows:

1) Problem identification remark (F932 of MCA).

2) Reaction identification (1-line):

$$\left[k,\ Z,\ A,\ N(T),\ P,\ T,\ \sum_{a,g},\ N(\nu)\right]$$

3) Total number of reactions (identified by k,T) per source neutron $= \sum_{a,g}$.

4) Summed data and cross sections: Let $\psi_{a,\bar{g}}$ be the number of reactions in cell a in energy interval $\bar{g}$ per source neutron.

$$\psi_{\bar{g}} = (a - \text{sum})_{\bar{g}} = \sum_{a=1}^{A} \psi_{a,\bar{g}}$$

$$\psi_{a} = (\bar{g} - \text{sum})_{a} = \sum_{\bar{g}=1}^{N(T)} \psi_{a,\bar{g}}$$

$$\sum_{a,g} = \sum_{a=1}^{A} \psi_{a} = \sum_{\bar{g}=1}^{N(T)} \psi_{\bar{g}} = \sum_{a=1}^{A} \sum_{\bar{g}=1}^{N(T)} \psi_{a,\bar{g}}$$

Energy $E_{\bar{g}}$:	$\psi_{\bar{g}}$:	ψ_a:	X X X X
↓	↓	↓	(Cross section data -- not used)
$\bar{g}$	$\bar{g}$	a	

5) Cell-energy reaction distribution $\psi_{a,\bar{g}}$

a (cell number) →

$\bar{g}$ ↓ (energy).

II - CODE MCR CARD LOADING ORDER

(Number of cards in parentheses)

1 Items 1-15 of MCS loading order (see Appendix D-II)

2 R00 (1)

3 Advance NBA and record origins (card labeled 1 MCR1)

4 Remark cards: R950-962 (11)

5 Load instructions 857 (card labeled 4 MCR1)

6 F857 -- Data assign code (11)

7 Load instructions 903 (card labeled 5 MCR1)

8 Subroutine LA S800 (2)

9 Load instructions 801 (card labeled 2 MCR1)

10 F801 (5)

11 F832 (9)

12 F840 (9)

13 F803 (4)

14 F817 (11)

15 F932 (9) (same as MCS)

16 F802 (10)

17 F804 (3)

18 F805 (3)

19 F806 (3)

20 F807 (3)

21 F820 (14)

22 Load instructions 800 (card labeled 3 MCR1)

23 F800: FLOCODE (4)

24 Transition card (labeled TR FC MCR1)

25 Additional R00 cards, each followed by a transition card

III - REMARKS CARDS FOR CODE MCR

950 MRC reaction listing

951

952 K -- Z -- A -- Number tally energies

953 Total collisions per source neutron =

954 Total absorptions per source neutron =

955 Total elastic collisions per source neutron =

956 Total reactions (NU =) per source neutron =

957 Energy -- (A - SUM)(G) -- (G - SUM)(A) -- SIGMA Tot. (EL), ABS.)

960 Space -- Energy reaction distribution -- (A across, G down)

961 Total number of neutrons processed =

962 Variance in total collisions per source neutron =

IV - FORMULA SET OF REACTION CODE MCR

```
X00 8      857
X01  TSX4971
X02 CP011A0
X03 C  42A1
X04 0P021A2
X05 C  42A3
X06 CP031A4
X07 C  42A5

X1C CP041A6
X11 C  42A7
X12 CP051B0
X13 C  42B1
X14 CP061B2
X15 C  42B3
X16 CP071B4
X17 0  42B5

X20 CP101B6
X21 C  42B7
X22 CP111C0
X23 C  42C1
X24 CP121C2
X25 C  42C3
X26 CP131C4
X27 C  42C5

X30 0P141C6
X31 C  42C7
X32 CP151D0
X33 C  42D1
X34 CP161D2
X35 C  42D3
X36 CP171D4
X37 C  42D5

X4C 0P201D6
X41 C  42D7
X42 CA461R0
X43 0A461R3
X44 CA541R4
X45 CA231R5
X46 CA231R6
X47 0A541R7

X50 CA541S0
X51 CA541S1
X52 0A541S2
X53 CA241S3
X54 CA461S4
X55 CA251S5
X56 0A261S6
X57 CA541S7

X6C 0A261T0
X61 CA541T1
X62 CQ011T2
X63 CA261T3
X64 CA541T4
X65 0A261T5
X66 CQC21M0
X67 CQ031M1

X70 CQ041M2
X71 0QC51M3
X72 CQ061M4
X73 CA261Z4
X74 0A261Z5
X75 0D031Z7
X76 CR041P0
X77 CA462P1

Y00 CR041P2
Y01 CR041P3
Y02 0A462P4
Y03 CR041P5
Y04 CA461P6
Y05 CR041P7
Y06 0R041Q0
Y07 CR041Q1

Y10 CR041Q2
Y11 CD121T6
Y12 CA462T7
Y13 CD121E0
Y14 CD121U6
Y15 4A462U7
Y16  TSX4970

Y17 *    4857

Y20 *     903
Y21 8     903

Y22 *     801

XC0 8     801
X01  SXD4X41
X02  LXD1T7*
X03  CLA1T6
X04  FDH A37
X05  STQ1P0
X06  FMP1P0
X07  STO 100

X10  CLA1U6
X11  FDH A37
X12  STQ 101
X13  CLA 101
X14  FSB 100
X15  FDH A37
X16  STQ 102
X17  CLA 102

X20  TSX4903
X21  CLA 400
X22  STO1T6
X23 2  11X03
X24  LXA4R04
X25  CLA4E0
X26  STO4E0+
X27  CLA4E0

X30  FAD4E0+
X31  SUB 411
X32  STO4P2
X33 2  14X27
X34  LXD1T7*
X35  STZ1U6
X36 2  11X35
X37  LXD4X41

X4C  TRA4  1
X41  HTR

X00 8    832
X01  SXD4X63
X02  SXD2X64
X03  PAX4
X04 1  14X05
X05  CLA4M0
X06  PCX2
X07  STD X47

X1C  ALS  1
X11  STD X36
X12  STD X67
X13  STD X17
X14 1  14X15
X15  CLA4M0
X16  CAS A22
X17 1  04X73

X20  TRA X67
X21 6  12X67
X22 1  14X23
X23  CLA A22
X24  CAS4M0
X25  TRA X21
X26  TRA X67
X27  CLA4M0

X30  FSB4M0-
X31  STO B05
X32  CLA A22
X33  FSB4M0-
X34  FCH B05
X35  STQ B05
X36 1  04X37
X37  CLA4M0

X4C  FSB4M0-
X41  LRS  43
X42  FMP B05
X43  FAD4M0-
X44  STO A14
X45  CHS
X46  STQ 102
X47 1  04X50

X50  CLA B05
X51  TZE X65
X52  CLA4M0
X53  FSB4M0-
X54  LRS  43
X55  FMP B05
X56  FAD4M0-
X57  LDQ A14

X60  LXD4X63
X61  LXD2X64
X62  TRA4  1
X63  HTR
X64  HTR
X65  CLA4M0
X66  TRA X57
X67 1  04X70

X70  STZ B05
X71  CLA4M0
X72  TRA X44
X73  STZ B05
X74  FDH A22
X75  FMP4M0
X76  TRA X44
X77 8   2X45

Y00  FAD A15
Y01  FDH A15
Y02  TRA X46

X00 8    840
X01  SXD4X44
X02  LXA4RC6
X03 2  34X52
X04  CLA4X51
X05  STZ 150
X06  STA X24
X07  CLA R07

X1C  STO 151
X11  TSX4974
X12 C    1
X13 C     950
X14 0     951
X15 C    1
X16 0     952
X17 C 101R00

X20 C   1
X21 C     961
X22 C  11A36
X23 0   1
X24 0     953
X25 C  21152
X26 C   1
X27 C     957
```

```
X30 C      P2
X31 C      P5
X32 0      P6
X33 0      P7
X34 C      Q0
X35 C      Q1
X36 C      Q2
X37 C   1

X4C C      960
X41 4      P3
X42  LXD4X44
X43  TRA4   1
X44  HTR
X45 0      956
X46 C      955
X47 C      954

X50 C      953
X51 C      962
X52  PXD4
X53  ARS  22
X54  STO  150
X55  CLA  X45
X56  TRA  X06
X57 8    2X02

X60 3   14X03
X61  CLA4X51
X62  STA  Y00
X63  CLA  R07
X64  STO  151
X65  TSX4975
X66 0    2
X67 C      950

X70 C      951
X71 0   1
X72 0      952
X73 C  101R00
X74 C   1
X75 0      961
X76 0   11A36
X77 C   1

Y00 C      953
Y01 0   11152
Y02 4   2
Y03  LXA4R06
Y04  TRA  X03

X00 8      803
X01  SXD4X33
X02  LXA4R04
X03  STZ4P5
X04 2   14X03
X05  LXA4A46
X06  STZ4P6
X07 2   14X06

X1C  STZ R07
X11  LXD1T7*
X12  LXA4A46
X13  LXA2R04
X14  CLA1P3
X15  FAD R07
X16  STO R07
X17  CLA1P3

X20  FAD2P5
X21  STO2P5
X22  CLA1P3
X23  FAD4P6
X24  STO4P6
X25 2  11X26
X26 2  12X14
X27 2  14X13

X30  TSX4840
X31  LXD4X33
X32  TRA4  1
X33  HTR

X00 8    817
X01  SXD4Y13
XC2  SXD2Y14
X03  SXD1Y15
X04  STZ A15
X05  STZ 102
X06  PAX1
X07  CLA1S5

X1C  PAX1
X11  ANA 442
X12  STO 103
X13  CLA1M1
X14  STO 104
X15  ANA C20
X16  PAX4
X17  CLA4T0

X2C  PAX4
X21 1  14X22
X22  CLA4M0
X23  STO 105
X24  STD X42
X25  STD X45
X26  STD X64
X27  PDX2

X30 1  14X31
X31  CLA A22
X32  CAS4M0
X33  TRA X50
X34  TRA X45
X35  CLA 105
X36  ANA 445
X37  TZE X45

X4C  CLA4M0
X41  FDH A22
X42 1  04X43
X43  FMP4M0
X44  TRA X72
X45 1  04X46
X46  CLA4M0
X47  TRA X72

X50 6  12X45
X51 1  14X52
X52  CLA A22
X53  CAS4M0
X54  TRA X50
X55  TRA X45
X56  CLA4M0
X57  FSB4M0-

X60  STO 105
X61  CLA A22
X62  FSB4M0-
X63  STO 106
X64 1  04X65
X65  CLA4M0
X66  FSB4M0-
X67  FDH 105

X70  FMP 106
X71  FAD4M0-
X72  LRS  43
X73  FMP 104
X74  FAD A15
X75  STO A15
X76  LXD4102
X77 1  14Y00

YC0  SXD4102
Y01  STO4Z4
Y02  CLA 103
Y03  SUB 415
Y04  TZE Y06
Y05 1  11X12
Y06  LXD4Y13
Y07  LXD2Y14

Y1C  LXD1Y15
Y11  LDQ A15
Y12  TRA4  1
Y13  HTR
Y14  HTR
Y15  HTR
Y16 8  2X72
Y17  STQ 105

Y20  TRA X73
Y21 8  2Y01
Y22  CLA 105
Y23  STO4Z5
Y24  TRA Y02

X00 8    932
X01  REW   7
X02  TSX4977
X03 C  1   7
X04 CA361R0
X05 C1C21R3
X06 C1031R4
X07 C1041R5

X1C C1C51R6
X11 C1061R7
X12 01071S0
X13 01101S1
X14 C1111S2
X15 C1121S3
X16 C1131S4
X17 01141S5

X20 C1151S6
X21 C1161S7
X22 C1171T0
X23 C1201T1
X24 C1211T2
X25 C1221T3
X26 01231T4
X27 C1241T5

X30 C1251M0
X31 01261M1
X32 C1271M2
X33 C1301M3
X34 01311M4
X35 41321951
X36  TRA Y00
X37  REW   7

X40  LXD4457
X41  TRA4   1
X42  TSX4977
X43 C  2   7
X44 42011Y03
X45  CLA A40
X46  TZE X37
X47  TSX4977

X50 C       7
X51 C2021X77
X52 C2031Z7
X53 C2041A0
X54 C2051A2
X55 02061A4
X56 C2071A6
X57 C2101B0

X60 C2111B2
X61 02121B4
X62 C2131B6
X63 C2141C0
X64 02151C2
X65 02161C4
X66 C2171C6
X67 C2201D0
```

```
X70 C2211D2
X71 C2221D4
X72 C2231D6
X73 C2241E0
X74 C2251T6
X75 42261U6
X76  TRA X37
X77 C 10 B10

Y00  PSE 164
Y01  TRA X42
Y02  TRA X37
Y03 C 61 A61

X00 8    802
X01  SXD4X36
X02  LXD1T7*
X03  LXA2A46
X04  CLA2R3
X05  ANA C20
X06  PAX4
X07  CLA4S5

X10  PAX4
X11  ARS  22
X12  STØ 150
X13  CLA4M1
X14  ANA C20
X15  SUB R01
X16  TZE X43
X17 2  14X20

X20  CLA 150
X21  SUB 401
X22  TNZ X12
X23  LXA4R04
X24  STZ1P0
X25  STZ1P3
X26 2  11X27
X27 2  14X24

X30 2  12X04
X31  CLA R05
X32  LBT
X33  TRA X37
X34  LXD4X36
X35  TRA4  1
X36  HTR
X37  CLA 401

X40  STØ R06
X41  TSX4803
X42  TRA X34
X43  LXA4R04
X44  SXD4151
X45  CLA4P2
X46  TSX4903
X47  CLA 400
```

```
X50  LRS  43
X51  FMP C24
X52  STØ A22
X53  CLA2R3
X54  ANA C20
X55  TSX4817
X56  LXA4150
X57  CLA4Z4

X60 7  14X62
X61  FSB4Z4-
X62  FDH A15
X63  FMP1P0
X64  STØ1P0
X65  STØ1P3
X66  CLA4Z5
X67  LXD4151

X70  STØ4P7
X71 2  11X72
X72 2  14X44
X73  TRA X30
X74 8  2X10
X75  STD X76
X76 1  04X77
X77 2  14X11

Y00 8  2X62
Y01  STQ  77
Y02  FMP1T6
Y03  STØ1U6
Y04  LDQ  77
Y05  TRA X63
Y06 8  2X41
Y07  CLA 400

Y10  STØ R06
Y11  LXD4T7*
Y12  CLA4U6
Y13  STØ4P3
Y14 2  14Y12
Y15  TSX4803
Y16  TRA X42

X00 8    804
X01  SXD4X10
X02  CLA R05
X03  ARS  2
X04  LBT
X05  TRA X11
X06  LXD4X10
X07  TRA4  1

X10  HTR
X11  LXD4T7*
X12  LXA2A46
X13  LXA1R04
X14  CLA1Q1
X15  FDH1P7
X16  FMP4P0
X17  STØ4P3
```

```
X20 2  14X21
X21 2  11X14
X22 2  12X13
X23  CLA 402
X24  STØ R06
X25  TSX4803
X26  TRA X06

X00 8    805
X01  SXD4X10
X02  CLA R05
X03  ARS  1
X04  LBT
X05  TRA X11
X06  LXD4X10
X07  TRA4  1

X10  HTR
X11  LXD4T7*
X12  LXA2A46
X13  LXA1R04
X14  CLA1Q0
X15  FDH1P7
X16  FMP4P0
X17  STØ4P3

X20 2  14X21
X21 2  11X14
X22 2  12X13
X23  CLA 403
X24  STØ R06
X25  TSX4803
X26  TRA X06

X00 8    806
X01  SXD4X26
X02  LXA1R04
X03  LXA2R01
X04  CLA1P2
X05  TSX4903
X06  CLA 400
X07  LRS  43

X10  FMP C24
X11  STØ A22
X12  CLA2T0
X13  TSX4832
X14  STQ1Q1
X15  STØ 152
X16  CLA1P7
X17  FSB1Q1

X20  LRS  43
X21  FMP 152
X22  STØ1Q0
X23 2  11X04
X24  LXD4X26
X25  TRA4  1
X26  HTR
```

```
X00 8    807
X01  SXD4X22
X02  LXD1T7*
X03  LXA2A46
X04  LXA4R04
X05  CLA4P7
X06  FSB4Q0
X07  FSB4Q1

X10  FDH4P7
X11  FMP1P0
X12  STØ1P0
X13 2  11X14
X14 2  14X05
X15 2  12X04
X16  CLA 403
X17  STØ R06

X20  LXD4X22
X21  TRA4  1
X22  HTR

X00 8    820
X01  SXD4Y42
X02  CLA R10
X03  TZE4  1
X04  CLA R05
X05  ARS  3
X06  LBT
X07  TRA X11

X10  TRA4  1
X11  LXA1R04
X12  LXA4R01
X13  CLA4T0
X14  PDX2
X15 1  12X16
X16  CLA2M3
X17  STØ B11

X20  STD X45
X21  STD X54
X22  PDX4
X23 1  12X24
X24  CLA2M3
X25  CAS1P2
X26  TRA X53
X27  TRA X53

X30 6  14X53
X31 1  12X32
X32  CLA1P2
X33  CAS2M3
X34  TRA X30
X35  TRA X53
X36  CLA2M3
X37  FSB2M3-
```

```
X40   STO 1C5
X41   CLA1P2
X42   FSB2M3-
X43   FDH 105
X44   STQ1P2
X45 1  C2X46
X46   CLA2M3
X47   STO1Q0

X50   CLA2M3-
X51   STO1Q1
X52   TRA X57
X53   STZ1P2
X54 1  C2X55
X55   CLA2M3
X56   STO1Q0
X57 2  11X12

X6C   CLA R06
X61   ADD 401
X62   STO RC6
X63   LXA1R04
X64   CLA1P2
X65   TZE Y04
X66   CLA1Q0
X67   PCX4

X70   LDQ4M4
X71   STQ 1C0
X72   CLA1C1
X73   PDX4
X74   CLA 100
X75   FSB4M4
X76   LRS  43
X77   FMP1P2

Y00   FAD4M4
Y01   STO 100
YC2   STO1P7
Y03   TRA Y10
Y04   CLA1Q0
Y05   PCX4
YC6   CLA4M4
Y07   TRA Y01

Y1C 2  11X64
Y11   LXD4T7*
Y12   LXA2A46
Y13   LXA1R04
Y14   LCQ1P7
Y15   FMP4P0
Y16   STO4P3
Y17 2  14Y20

Y20 2  11Y14
Y21 2  12Y13
Y22   TSX4803
Y23   CLA R10
Y24   SUB 401
Y25   STO R10
Y26   TZE Y40
Y27   LXA1R04

Y30   CAL1QC
Y31   ACL 415
Y32   SLW1Q0
Y33   CAL1Q1
Y34   ACL 415
Y35   SLW1C1
Y36 2  11Y30
Y37   TRA X60

Y40   LXD4Y42
Y41   TRA4  1
Y42   HTR
Y43 8   2X20
Y44   STZ1P7
Y45   STZ1Q2
Y46   TRA X21
Y47 8   2YC1

Y5C   FSB1Q2
Y51   TMI Y55
Y52   LDQ 1C0
Y53   STQ1C2
Y54   TRA Y02
Y55   CLA 400
Y56   TRA Y02

Y57 *     800


XCC 8     800
X01   NOP
X02   LXD4P1*
X03   STZ4P0
XC4   STZ4P3
X05 2  14X03
X06   LXD4P2*
X07   STZ4P2

X1C   STZ4P5
X11   STZ4P7
X12   STZ4C0
X13   STZ4Q1
X14   STZ4Q2
X15 2  14X07
X16   LXD4P6*
X17   STZ4P6

X20 2  14X17
X21   TSX4932
X22   CLA A37
X23   ACL 420
X24   FAD 400
X25   STO A37
X26   TSX4801
X27   TSX48C2

X30   TSX4806
X31   TSX4804
X32   TSX4805
X33   TSX4807
X34   TSX4820
X35   TSX4970

X36 *    4800

X37 *    4800


X00 8     800
X01   TSX4932
X02   TSX4826
X03   TSX4933
X04   TSX4825
X05   PSE 163
X06   TSX4926
X07   TSX4810

X10   TRA X04
X11   TSX4833
X12   CLA A40
X13   ADD 401
X14   STO A40
X15   CLA A21
X16   ACD 401
X17   STO A21

X20   PSE 163
X21   TSX4926
X22   TSX4824
X23   TRA X04
X24   PSE 163
X25   TSX4926
X26   TRA X07


END OF FILE A3
          END OF FILE TAPE 2
```

APPENDIX G: MONTE CARLO CODE MCH

I - CARD LABEL CONVENTION

Col. 73-74: usual FLOCO labeling (X0-Z7)

75-76: XX for formula 8XX or 9XX

77: blank for formula 8XX

9 for formula 9XX

78-80: code label MCH.

II - PARAMETER AND DATA BLOCKS CHANGED FROM CODE MCS

1) Parameter blocks D00, R00 (see Chapter VIII-A).

2) Data blocks E1, E2 (E3): (see Chapter VIII-A).

(E2, E3 a two-dimensional block.)

3) Data block P0: Total cross section averaged over tally energy intervals stored here during data process routine.

$$C[(P0)_{\bar{g}}] = \overline{\sigma_{k,\bar{g}}^{Tot}}, \qquad [\bar{g} = 1, 2, \cdots, N(T) = C(D12)]$$

$$S(P0) = N(T) = C(D12)$$

4) Data block P1: Reaction cross section averaged over tally energy intervals stored here during data process routine.

$$C[(P1)_{\bar{g}}] = \overline{\sigma_{k,\bar{g}}^{React}} , \qquad [\bar{g} = 1, 2, \cdots, N(T) = C(D12)]$$

S(P1) = N(T) = C(D12)

5) Data blocks P2, P3: Energy-summed reaction flux, $\overline{\psi_{n,\bar{j}}^{React}}$, a function of surface $\bar{j}$ and position n, stored here for printing during data process routine.

$$C[(P2)_{n,\bar{j}}] = \overline{\psi_{n,\bar{j}}^{React}} , \qquad [n = 1, 2, \cdots, N(P) ;$$

$$\bar{j} = 1, 2, \cdots, N(J)]$$

S(P2) = N(P) = C(D14) ; S(P3) = N(J) = C(D13) : a two-dimensional data block.

6) Data blocks T5, T6, T7: Flux $\psi_{\bar{g},n,\bar{j}}$ as a function of energy, $\bar{g}$, position, n, and tallied surface, $\bar{j}$.

$$C[(T5)_{\bar{g},n,\bar{j}}] = \psi_{\bar{g},n,\bar{j}} , \qquad [\bar{g} = 1, \cdots, N(T) ;$$

$$n = 1, \cdots, N(P) ; \; \bar{j} = 1, \cdots, N(J)]$$

S(T5) = N(T) = C(D12) ; S(T6) = N(P) = C(D14) ;

S(T7) = N(J) = C(D13) ; a three-dimensional data block.

7) Data block U4: $\bar{j}(j) \neq 0$ if the flux across surface (j) is to be tallied; $\bar{j}(j) = 0$ otherwise. (See data block E1.)

$$C[(U4)_j] = \bar{j}(j) , \qquad (j = 1, 2, \cdots, J)$$

$$S(U4) = J = C(A54)$$

8) Data blocks U5, U6, U7: Same as T5, T6, T7 (see 6) above) except accumulate $\psi^2_{g,n,\bar{j}}$ instead of $\psi_{g,n,\bar{j}}$.

III - CODE MCH CARD LOADING ORDER

(Number of cards in parentheses)

1 Advance NBA (card label 1 MCH)

2 DOO (2)

3 GOO

4 HOO

5 POO

6 ROO

7 SOO

8 VOO

9 WOO

10 AOO (1)

11 BOO (1)

12 COO (4)

13 EOO (5)

14 FOO (5)

15 KOO (2)

16 QOO (1)

17 Advance NBA and record origins (cards labeled 2 MCH, 3 MCH)

18 Remark cards: R940-965 (28)

19 Load instructions 800 (card labeled FCP MCH)

20 F800 -- FLOCODE "prime" (2 cards + transition)

21 Load instructions 857 (card labeled 4 MCH)

22 F857 -- Data assign code (13)

23 Load instructions 903 (card labeled 5 MCH)

24 Subroutine LA S800 (2)

25 Load instructions 916 (card labeled 6 MCH)

26 Subroutine LA S820 (2)

27 Load instructions 917 (card labeled 7 MCH)

28 Subroutine LA S816 (4)

29 Load instructions 901 (card labeled 8 MCH)

30 (MCS items 27 through 34 -- see Appendix D)

31 F931 (5)

32 (MCS items 36 through 50 -- see Appendix D)

33 F934 (4)

34 (MCS items 53 through 73 -- see Appendix D)

35 F834 (9)

36 F933 (14)

37 F824 (21)

38 F826 (6)

39 F827 (4)

40 F851 (10)

41 F852 (12)

42 F855 (23)

43 F856 (5)

44 F830 (19)

45 F836 (4)

46 F837 (1)

47 F825 (9)

48 SPECIAL TALLY ROUTINES: F860-876 (see pg. 11)

49 Load instructions 877 (card labeled 9 MCH)

50 F877 (3)

51 Load instructions 850 (card labeled 10 MCH)

52 SOURCE ROUTINE F850

53 Load instructions 800 (card labeled 11 MCH)

54 F800: FLOCODE (3)

55 E0

56 E1

57 E2

58 I0

59 I1

90 I2

91 Y6

92 Transition card (labeled TRANS MCH)

Quantities 30-47 usually replaced by a binary deck of 182 cards.

IV - REMARKS CARDS FOR CODE MCH

950	MCH tally print -- (A00, D00, flux data -- Surfaces, positions, energies, flux, variance.)
952	Problem finished -- Press start to continue. Save tape A06 and on-line listing if finished.
956	Importance coefficients -- (I0, I1, I2, Y6)
960	MCH reaction listing -- K -- Reaction -- Number of neutrons
961	(Surfaces, positions, tally energies, average energies, reaction probabilities per collision, energy -- Summed flux and variance.)
962	MCH data process -- Problem -- Number neutrons -- Average flux -- Average variance
963	Source data -- (S00, V00, W00, G00, H00)
964	Energy -- Summed flux = PSI(N,J)
965	Energy -- Summed variance = VAR(N,J)

V - FORMULAS OF MONTE CARLO CODE MCH DIFFERING FROM THOSE OF CODE MCS

```
X00 8      800
X01  REW     7
X02  TSX4977
X03 C  1     7
X04 01011X10
X05 41021X11
X06  REW     7
X07  TSX4970

X10 0 62 A62
X11 0   7 U07

X12 *     4800

X13 *      857

X00 8      800
X01  TSX4932
X02  TSX4826
X03  TSX4933
X04  TSX4825
X05  PSE 163
X06  TSX4926
X07  TSX4810

X10  TRA X04
X11  NOP
X12  CLA A40
X13  ADD 401
X14  STO A40
X15  CLA A21
X16  ADD 401
X17  STO A21

X20  PSE 163
X21  TSX4926
X22  TSX4824
X23  TRA X04
X24  PSE 163
X25  TSX4926
X26  TRA X07

X27 *     4800

X30 *      857
X31 *      140
X32 *      800
X33 *      100
X34 *      801
X35 *     1500

X00 8      826
X01  SXD4X50
X02  TSX4976
X03  TSX4975
X04 C      951
X05 C  1
X06 C      953
X07 0  1
```

```
X10 4  31A35
X11  TSX4925
X12  LXA4401
X13  CLA V02
X14  TZE X21
X15  CLA 421
X16  CAS4V00
X17 1  14X16

X20  NOP
X21  SXD4X37
X22  SXD4X41
X23  TSX4974
X24 C    1
X25 0      956
X26 0  1
X27 C      I0

X30 0      I1
X31 C      I2
X32 C      Y6
X33 C  2
X34 0      963
X35 0 101S00
X36 C  2
X37 C  01V00

X40 C  2
X41 C  01W00
X42 C  2
X43 CG011G01
X44 C  2
X45 4H011H01
X46  LXD4X50
X47  TRA4   1

X50  HTR

X00 8      830
X01  SXD4Y45
X02  SXD2Y46
X03  SXD1Y47
X04  CLA A37
X05  TSX4901
X06  STO B03
X07  LXA1C26

X10  CLA C26
X11  ALS    1
X12  STO 140
X13  ADD C27
X14  STA Y50
X15  CLA1P00
X16  TNZ Y50
X17  CLA 140

X20  SUB 402
X21 2  11X12
X22  STZ A35
X23  TSX4931
X24  LXD1T7*
X25  CLA1T5
X26  FDH B03
X27  STQ1T5
```

```
X30  CLA1U5
X31  STO 100
X32  FDH B03
X33  STQ1U5
X34  CLA 100
X35  STA1U5
X36 2  11X25
X37  TSX4925

X40  STZ 110
X41  STZ 111
X42  LXD1T7*
X43  LXD2P3*
X44  LXD4T5*
X45  CLA 400
X46  FAD1T5
X47 6  11X50

X50 2  14X46
X51  STO2P2
X52  FAD 111
X53  STO 111
X54 2  12X44
X55  TSX4974
X56 C    1
X57 C      964

X60 0  1
X61 4      P2
X62  LXD1T7*
X63  LXD2P3*
X64  LXD4T5*
X65  CLA 400
X66  FAD1U5
X67 6  11X70

X70 2  14X66
X71  STO 100
X72  LDQ2P2
X73  FMP2P2
X74  STO 101
X75  CLA 100
X76  FSB 101
X77  FDH B03

Y00  STQ 102
Y01  CLA 102
Y02  TSX4903
Y03  CLA 400
Y04  STO2P2
Y05  FAD 110
Y06  STO 110
Y07 2  12X64

Y10  TSX4974
Y11 0    2
Y12 C      965
Y13 C  1
Y14 4      P2
Y15  CLA A37
Y16  STO 112
Y17  CLA A36
```

```
Y20  STO 113
Y21  TSX4975
Y22 C  2
Y23 0      962
Y24 C  41114
Y25 4  2
Y26  CLA R01
Y27  TNZ Z10

Y30  LXD2T7*
Y31  CLA2U5
Y32  ANA 441
Y33  STO2U5
Y34 2  12Y31
Y35  TSX4974
Y36 0    1
Y37 4      U5

Y40  TSX4934
Y41  LXD4Y45
Y42  LXD2Y46
Y43  LXD1Y47
Y44  TRA4   1
Y45  HTR    0
Y46  HTR    0
Y47  HTR    0

Y50  CLA    0
Y51  STO 100
Y52  PDX2
Y53  ARS   22
Y54  STO 101
Y55  CLA 100
Y56  STA Y67
Y57  SUB 101

Y60  STA Z05
Y61  SUB 101
Y62  STA Y65
Y63  SUB 101
Y64  STA Y73
Y65  CLA2   0
Y66  FDH B03
Y67  STQ2   0

Y70  STQ 100
Y71  FMP 100
Y72  STO 100
Y73  CLA2   0
Y74  FDH B03
Y75  STQ 101
Y76  CLA 101
Y77  FSB 100

Z00  FDH B03
Z01  STQ 100
Z02  CLA 100
Z03  TSX4903
Z04  CLA 400
Z05  STO2   0
Z06 2  12Y65
Z07  TRA X17
```

```
Z10   LXA1401
Z11   LXA2R01
Z12 1   11Z13
Z13   CLA1R00
Z14   STO B01
Z15 1   11Z16
Z16   CLA1R00
Z17   STO B02

Z20   TSX4856
Z21 2   12Z12
Z22   TRA Y30

X00 8     834
X01   SXD4X25
X02   SXD1X26
X03   TSX4915
X04   SSP
X05   STO 101
X06   CLA A16
X07   FDH 101

X10   STQ 102
X11   CLA2U4
X12   TSX4X27
X13   MSE 144
X14   TRA X22
X15   PSE 144
X16   CLA2U4
X17   TPL X22

X20   ARS  22
X21   TSX4X27
X22   LXD4X25
X23   LXD1X26
X24   TRA4   2
X25   HTR    0
X26   HTR    0
X27   SXD4X76

X30   PAX4
X31   CLA4T7
X32   STO 100
X33   CLA4E3
X34   PAX4
X35 1   14X36
X36   LXA1401
X37   CLA D14

X40   TMI X77
X41   CLA A03
X42   CAS4E2
X43 1   11Y01
X44   NOP
X45   CLA1T6
X46   ADD 100
X47   ALS  22
```

```
X50   STD X57
X51   LXA4401
X52   LXA1D12
X53   CLA A17
X54   CAS4E0
X55 2   11Y04
X56   NOP
X57 1   04X60

X60   CLA 102
X61   FAD4T5
X62   STO4T5
X63   CLA4U5
X64   STO 103
X65   LDQ 102
X66   FMP 102
X67   FAD4U5

X70   STO4U5
X71   CLA 103
X72   ADD 401
X73   STA4U5
X74   LXD4X76
X75   TRA4   1
X76   HTR    0
X77   CLA A02

Y00   TRA X42
Y01 7D141Y03
Y02 2   11X45
Y03 1   14X42
Y04 1   14X54

X00 8     840
X01   PSE 144
X02   TRA4   2

X00 8     851
X01   SXD4X76
X02   SXD2X77
X03   SXD1Y00
X04   LXD4P3*
X05   STZ4P2
X06 2   14X05
X07   LXD1T7*

X10   LXD2P3*
X11   LXD4T5*
X12   LDQ1T5
X13   FMP4P1
X14   FAD2P2
X15   STO2P2
X16 6   11X21
X17 2   14X12
```

```
X20 2   12X11
X21   TSX4974
X22 C    1
X23 C      951
X24 C    1
X25 C      960
X26 C    31B00
X27 C    1

X30 C      961
X31 C       E1
X32 C       E2
X33 C       E0
X34 C       P0
X35 C       P1
X36 4       P2
X37   LXD1T7*

X40   LXD2P3*
X41   LXD4T5*
X42   LDQ2P2
X43   FMP2P2
X44   STO 100
X45   STZ 101
X46   LDQ4P1
X47   FMP4P1

X50   LRS  43
X51   FMP1U5
X52   FAD 101
X53   STO 101
X54 6   11X55
X55 2   14X46
X56   CLA 101
X57   FSB 100

X60   FDH B03
X61   STQ 102
X62   CLA 102
X63   TSX4903
X64   CLA 400
X65   TNZ Y01
X66 2   12X41
X67   TSX4974

X70 C    1
X71 4       P2
X72   LXD4X76
X73   LXD2X77
X74   LXD1Y00
X75   TRA4   1
X76   HTR
X77   HTR

Y00   HTR
Y01   FDH2P2
Y02   STQ2P2
Y03   TRA X66
Y04 8    2X03
Y05   CLA A37
Y06   TSX4901
Y07   STO B03
```

```
Y10   TRA X04

X00 8     852
X01   SXD4Y24
X02   SXD2Y25
X03   SXD1Y26
X04   LXA1D12
X05   CLA B02
X06   SLB 403
X07   STO 130

X10   STZ 131
X11   LXD2B05
X12 1   12X13
X13   CLA2M3
X14   STO B06
X15   STD X42
X16   STD X72
X17   PDX4

X20 1   12X21
X21   CLA2M3
X22   CAS 140
X23   TRA X72
X24   TRA X72
X25 6   14X72
X26 1   12X27
X27   CLA 140

X30   CAS2M3
X31   TRA X25
X32   TRA X72
X33   CLA2M3
X34   FSB2M3-
X35   STO 105
X36   CLA 140
X37   FSB2M3-

X40   FDH 105
X41   STQ 132
X42 1   02X43
X43   CLA2M3
X44   PDX4
X45   CLA2M3-
X46   PDX2
X47   CLA4M4

X50   FSB2M4
X51   LRS  43
X52   FMP 132
X53   FAD2M4
X54   STO 133
X55   FSB 131
X56   TMI X70
X57   LDQ 133
```

```
X60   STQ 131
X61   STO 134
X62   CLA 130
X63   SUB 401
X64   STO 130
X65   TZE Y13
X66 1   14X67
X67 1   12X47

X70   CLA 400
X71   TRA X61
X72 1  02X73
X73   CLA2M3
X74   PDX4
X75   CLA4M4
X76   STO 133
X77   FSB 131

Y00   TMI Y11
Y01   LDQ 133
Y02   STQ 131
Y03   STO 134
Y04   CLA 130
YC5   SUB 401
Y06   STO 130
Y07   TZE Y13

Y1C 1   14X75
Y11   CLA 400
Y12   TRA Y03
Y13   LDQ 134
Y14   FMP1P1
Y15   STO1P1
Y16 2   11X05
Y17   NOP

Y20   LXD4Y24
Y21   LXD2Y25
Y22   LXD1Y26
Y23   TRA4  1
Y24   HTR
Y25   HTR
Y26   HTR
Y27 8    2X07

Y30   CLA1E0
Y31   FAD1E0+
Y32   SUB 411
Y33   STO 140
Y34   TRA X10

XC0 8      855
X01   SXD4Y23
X02   SXD2Y24
X03   STQ B04
X04   TSX4903
X05   CLA 400
X06   LRS  43
XC7   FMP C24

X1C   STO B03
X11   CLA B04
X12   TSX4903
X13   CLA 400
X14   LRS  43
X15   FMP C24
X16   STO B04
X17   FSB B03

X2C   STO B06
X21   LXA4B05
X22   CLA4M0+
X23   STO 121
X24   STD X52
X25   STD Y40
X26   STD Y51
X27   STD Y56

X30   STD Y61
X31   STD Y64
X32   STD Y71
X33   STD Z12
X34   LXA2401
X35   STZ 14C
X36   STZ 141
X37   STZ 142

X4C   CLA B03
X41   STO 110
X42   TSX4Y25
X43   LXA4403
X44   CLA4103
X45   STO4133
X46 2   14X44
X47   CLA B06

X5C   TZE Z47
X51 1   12X52
X52 3   02Y01
X53   LXD4103
X54 1   14X55
X55   CLA4M0
X56   CAS B04
X57   TRA Y01

X6C   TRA Y01
X61   FSB 110
X62   STO 111
X63   CLA4M0
X64   STO 110
X65   TSX4Y25
X66   LXA4403
X67   CLA4103

X70   FAD4133
X71   FCH 422
X72   FMP 111
X73   FAD4143
X74   STO4143
X75   CLA4103
X76   STO4133
X77 2   14X67

Y00   TRA X51
Y01   CLA B04
Y02   FSB 110
Y03   STO 111
Y04   CLA B04
YC5   STO 110
Y06   TSX4Y25
Y07   LXA44C3

Y1C   CLA4103
Y11   FAD4133
Y12   FDH 422
Y13   FMP 111
Y14   FAD4143
Y15   FDH B06
Y16   STQ4143
Y17 2   14Y10

Y20   LXD4Y23
Y21   LXD2Y24
Y22   TRA4  1
Y23   HTR   0
Y24   HTR   0
Y25   SXD4Z46
Y26   LXA4B05
Y27 1   24Z60

Y30   CLA 110
Y31   CAS4M0
Y32   TRA Y70
Y33   TRA Y55
Y34   CLA4M0
Y35   FCH 110
Y36   STQ 122
Y37   SXD4103

Y4C 1   04Y41
Y41   CLA 121
Y42   ANA 445
Y43   TZE Y47
Y44   LDQ4M0
Y45   FMP 122
Y46   TRA Y50
Y47   CLA4M0

Y5C   STO 102
Y51 1   04Y52
Y52   LDQ4M0
Y53   FMP 122
Y54   TRA Y63
Y55   SXD4103
Y56 1   04Y57
Y57   CLA4M0

Y60   STO 1C2
Y61 1   04Y62
Y62   CLA4M0
Y63   STO 100
Y64 1   04Y65
Y65   CLA4M0
Y66   STO 101
Y67   TRA Z37

Y70 1   12Y71
Y71 3   02Y55
Y72 1   14Y73
Y73   CLA 110
Y74   CAS4M0
Y75   TRA Y70
Y76   TRA Y55
Y77 2   14Z00

ZC0 2   12Z01
Z01   SXD4103
Z02   FSB4M0
Z03   STO 122
Z04   CLA4M0+
Z05   FSB4M0
Z06   STO 123
Z07   CLA 122

Z10   FDH 123
Z11   STQ 122
Z12 1   04Z13
Z13   CLA4M0+
Z14   FSB4M0
Z15   LRS  43
Z16   FMP 122
Z17   FAD4M0

Z20   STO 102
Z21 1   04Z22
Z22   CLA4M0+
Z23   FSB4M0
Z24   LRS  43
Z25   FMP 122
Z26   FAD4M0
Z27   STO 10C

Z30 1   04Z31
Z31   CLA4M0+
Z32   FSB4M0
Z33   LRS  43
Z34   FMP 122
Z35   FAD4M0
Z36   STO 101
Z37   CLA 102

Z4C   FSB 100
Z41   LRS  43
Z42   FMP 101
Z43   STO 101
Z44   LXD4Z46
Z45   TRA4  1
Z46   HTR   0
Z47   LXA4403

Z50   CLA4133
Z51   STO4143
Z52 2   14Z50
Z53   TRA Y20
Z54 8    2X33
Z55   STD Z21
Z56   STD Z30
Z57   TRA X34
```

```
Z60   LXA2401
Z61   TRA Y30


X00 8     856
X01   SXD4X33
X02   SXD2X34
X03   SXD1X35
X04   LXA4B01
X05   CLA4T0
X06   STO B05
X07   LXA1D12

X10   CLA1E0
X11   STO1E0+
X12   CLA1E0
X13   LDQ1E0+
X14   TSX4855
X15   CLA 142
X16   STO1P0
X17   LXA4B02

X20 3   34X36
X21   CLA4143
X22   STO1P1
X23 2   11X12
X24   LXA4B02
X25 3   34X42
X26   TSX4851
X27   LXD4X33

X30   LXD2X34
X31   LXD1X35
X32   TRA4    1
X33   HTR     0
X34   HTR     0
X35   HTR     0
X36   CLA   142
X37   FSB   141

X40   FSB   140
X41   TRA   X22
X42   TSX4852
X43   TRA   X26


X00 8      857
X01   TRA  X07
X02   NOP
X03   NOP
X04   NOP
X05   NOP
X06   NOP
X07   TSX4971
```

```
X10 0P011A0
X11 0   42A1
X12 0P021A2
X13 0   42A3
X14 0P031A4
X15 0   42A5
X16 0P041A6
X17 0   42A7

X20 0P051B0
X21 0   42B1
X22 0P061B2
X23 0   42B3
X24 0P071B4
X25 0   42B5
X26 0P101B6
X27 0   42B7

X30 0P111C0
X31 0   42C1
X32 0P121C2
X33 0   42C3
X34 0P131C4
X35 0   42C5
X36 0P141C6
X37 0   42C7

X40 0P151D0
X41 0   42D1
X42 0P161D2
X43 0   42D3
X44 0P171D4
X45 0   42D5
X46 0P201D6
X47 0   42D7

X50 0A341I0
X51 0A341I1
X52 0A341I2
X53 0A461R0
X54 0A461R3
X55 0A541R4
X56 0A231R5
X57 0A231R6

X60 0A541R7
X61 0A541S0
X62 0A541S1
X63 0A541S2
X64 0A241S3
X65 0A461S4
X66 0A251S5
X67 0A261S6

X70 0A541S7
X71 0A261T0
X72 0A541T1
X73 00011T2
X74 0A261T3
X75 0A541T4
X76 00021M0
X77 00031M1
```

```
Y00 00041M2
Y01 00051M3
Y02 00061M4
Y03 0A461Y6
Y04 0A471Z0
Y05 0A471Z1
Y06 0A541Z2
Y07 0A541Z3

Y10 0A261Z4
Y11 0A261Z5
Y12 0D031Z7
Y13 0D121E0
Y14 0D141E2
Y15 0D132E3
Y16 0D121T5
Y17 0D142T6

Y20 0D133T7
Y21 0D121U5
Y22 0D142U6
Y23 0D133U7
Y24 0A541U4
Y25 0D121P0
Y26 0D121P1
Y27 0D141P2

Y30 0D132P3
Y31 4D131E1
Y32   TSX4970
Y33 0   7 U07
Y34 0  62 A62

Y35 *     4857

Y36 *      903
Y37 8      903

Y40 *      916
Y41 8      916

Y42 *      917
Y43 8      917

Y44 *      901


X00 8      925
X01   SXD4X65
X02   CLA  A43
X03   ARS   22
X04   STO  A32
X05   CLA  A50
X06   STZ  A53
X07   STA  A53
```

```
X10   ARS   22
X11   STO  A50
X12   CLA  A44
X13   STO  X66
X14   STZ  A44
X15   TSX4974
X16 0     1
X17 0      951

X20 0   2
X21 0      950
X22 0 621A00
X23 0   2
X24 0 141D00
X25 0   2
X26 0      E1
X27 0      E2

X30 0      E0
X31 0      T5
X32 0    1
X33 0      U5
X34 0    1
X35 0      A0
X36 0      A2
X37 0      A4

X40 0      A6
X41 0      B0
X42 0      B2
X43 0      B4
X44 0      B6
X45 0      C0
X46 0      C2
X47 0      C4

X50 0      C6
X51 0      D0
X52 0      D2
X53 0      D4
X54 4      D6
X55   CLA  A50
X56   ALS   22
X57   ACL  A53

X60   STO  A50
X61   CLA  X66
X62   STO  A44
X63   LXD4X65
X64   TRA4   1
X65   HTR
X66   HTR


X00 8      931
X01   TSX4977
X02 0   2   7
X03 02012X37
X04 02022X40
X05 02032Z7
X06 02042A0
X07 02052A2
```

```
X10 02062A4
X11 02072A6
X12 02102B0
X13 02112B2
X14 02122B4
X15 02132B6
X16 02142C0
X17 02152C2

X20 02162C4
X21 02172C6
X22 02202D0
X23 02212D2
X24 02222D4
X25 02232D6
X26 02242E0
X27 02252E1

X30 02262E2
X31 02272T5
X32 42302U5
X33   WEF    7
X34   REW    7
X35   LXD4457
X36   TRA4   1
X37 0 62 A62

X40 0 10 B10


X00 8      932
X01   REW    7
X02   TSX4977
X03 0   1    7
X04 0A361R0
X05 01031R3
X06 01041R4
X07 01051R5

X10 01061R6
X11 01071R7
X12 01101S0
X13 01111S1
X14 01121S2
X15 01131S3
X16 01141S4
X17 01151S5

X20 01161S6
X21 01171S7
X22 01201T0
X23 01211T1
X24 01221T2
X25 01231T3
X26 01241T4
X27 01251M0
```

```
X30 01261M1
X31 01271M2
X32 01301M3
X33 01311M4
X34 41321951
X35  PSE 164
X36  TRA X41
X37  LXD4457

X40  TRA4  1
X41  TSX4977
X42 0  2   7
X43 42011Y01
X44  CLA A40
X45  TZE X37
X46  TSX4977
X47 0      7

X50 02021Y02
X51 02031Z7
X52 02041A0
X53 02051A2
X54 02061A4
X55 02071A6
X56 02101B0
X57 02111B2

X60 02121B4
X61 02131B6
X62 02141C0
X63 02151C2
X64 02161C4
X65 02171C6
X66 02201D0
X67 02211D2

X70 02221D4
X71 02231D6
X72 02241E0
X73 02251E1
X74 02261E2
X75 02271T5
X76 42301U5
X77  REW   7

Y00  TRA X37
Y01 0 62 A62
Y02 0 10 B10


X00 8     933
X01  SXD4Y25
X02  CLA D02
X03  STO A27
X04  CLA D03
X05  STO A42
X06  CLA X63
X07  STA X13
```

```
X10  CLA Y32
X11  STA X14
X12  CLA Y33
X13  STO   0
X14  STO   0
X15  LXA4A46
X16  CLA4Y6
X17  TZE X22

X20  ALS  41
X21  ORS4R0
X22 2  14X16
X23  CLA K01
X24  STO C01
X25  CLA K02
X26  STO C15
X27  CLA K03

X30  STO C21
X31  CLA K04
X32  STO C33
X33  LDQ K05
X34  STQ C34
X35  CLA A37
X36  TNZ X40
X37  STQ A44

X40  LXA4A54
X41  CAL4R4
X42  ANA 442
X43  STO 101
X44  CAL4R4
X45  ANA 441
X46  TZE Y34
X47  CAL Y30

X50  ANA 441
X51  ACL Y26
X52  ACL 101
X53  SLW4R4
X54  CAL4S7
X55  TZE Y36
X56  STA X57
X57  CAL   0

X60  TNZ X67
X61  SXD4100
X62  CLA Y42
X63  TSX4906
X64  HPR
X65  LXD4100
X66  TRA X72
X67  ANA 441
```

```
X70  ACL Y26
X71  SLW4S7
X72 2  14X41
X73  LXA4A46
X74  CAL4S4
X75  TZE Y40
X76  STA X77
X77  CAL   0

Y00  TNZ Y07
Y01  SXD4100
Y02  CLA Y42
Y03  TSX4906
Y04  HPR
Y05  LXD4100
Y06  TRA Y12
Y07  ANA 441

Y10  ACL Y26
Y11  SLW4S4
Y12 2  14X74
Y13  LXA4D13
Y14  CLA4E1
Y15  PAX2
Y16  CAL Y31
Y17  ANA 441

Y20  ACL Y26
Y21  SLW2S7
Y22 2  14Y14
Y23  LXD4Y25
Y24  TRA4  1
Y25  HTR
Y26  TRA   0
Y27  TRA4  2

Y30  TSX4905
Y31  TSX4834
Y32  TSX4924
Y33  NOP
Y34  CAL Y27
Y35  TRA X52
Y36  CAL Y27
Y37  TRA X71

Y40  CAL Y24
Y41  TRA Y11
Y42 C     947
Y43 8    2Y21
Y44  CLA4E1
Y45  TMI Y52
Y46  PXD4
Y47  ARS  22

Y50  STA2U4
Y51  TRA Y22
Y52  PXD4
Y53  STD2U4
Y54  CLA2U4
Y55  SSM
Y56  STO2U4
Y57  TRA Y22
```

```
X00 8     934
X01  TSX4977
X02 0  2   7
X03 02011X36
X04 02021X37
X05 C2031Z7
X06 02041A0
X07 C2051A2

X10 02061A4
X11 C2071A6
X12 02101B0
X13 02111B2
X14 02121B4
X15 02131B6
X16 02141C0
X17 02151C2

X20 02161C4
X21 02171C6
X22 02201D0
X23 02211D2
X24 C2221D4
X25 02231D6
X26 02241E0
X27 02251E1

X30 02261E2
X31 C2271T5
X32 42301U5
X33  REW   7
X34  LXD4457
X35  TRA4  1
X36 0 62 A62
X37 0 10 B10
```

VI - INITIATING CODE MCI CARD LOADING ORDER

(Number of cards in parentheses)

1 Advance NBA (card label 1 MCI)

2 LOO (1)

3 QOO (2)

4 AOO (1)

5 BOO (1): Working storage space reserved

6 COO (5): Constants

7 DOO (2): Size parameters

8 FOO (1)

9 JOO (1)

10 KOO (1)

11 ROO (1)

(items 8–11: Space reserved)

12 Advance NBA and record origins (card labeled 2 MCI)

13 Remark cards: R930-944 (R932 PREPARED BY USER)

14 Load instructions 850 (card labeled FCP MCI)

15 F850: FLOCODE "prime" (5 cards + transition)

16 Load instructions 860 (card labeled 4 MCI)

17 F860: Data assign (6)

18 Load instructions 906 (card labeled 5 MCI)

19 (MCA items 16 through 30 -- see Appendix E)

20 F815 (7)

21 F816 (5)

22 F817 (6)

23 F820 (7)

24 Load instructions 865 (card labeled 6 MCI)

25 F865 (4)

26 Load instructions 850 (card labeled 7 MCI)

27 F850 (6): FLOCODE

28 Transition card (labeled TRAN MCI)

29 SURFACE CARDS: (see pg. 53)

30 Transition card (labeled TR CRC MCA)

31 CELL CARDS: (see pg. 54)

32 Transition card (labeled TR CRC MCA)

33 MATERIAL CARDS: (see pg. 56)

VII - REMARKS CARDS FOR CODE MCI

931 Initiate problem -- MCH

936 Problem data blocks -- (R0, R3, R4, R5, R6, R7, S0, S1)

943 (S2, S3, S4, S5, S6, S7, T0, T1)

944 (T2, T3, T4, X(A), Y(A), Z(A)).

VIII - FORMULAS OF INITIATING CODE MCI DIFFERING FROM THOSE OF CODE MCA

```
X00 8     816
X01  SXD4 77
X02  TSX4975
X03 0    2
X04 0     937
X05 0  2
X06 4  61Q00
X07  TSX4974

X10 0    2
X11 0     937
X12 0  2
X13 4  61Q00
X14  LXA4Q02
X15 7D034X20
X16  CLA C20
X17  TSX4906

X20  LXA4Q03
X21 7D044X24
X22  CLA C21
X23  TSX4906
X24  LXA4Q04
X25 7D054X30
X26  CLA C22
X27  TSX4906

X30  LXA4Q05
X31 7D064X34
X32  CLA C05
X33  TSX4906
X34  LXA4Q06
X35 7D074X40
X36  CLA C23
X37  TSX4906

X40  LXD4 77
X41  TRA4  1

X00 8    817
X01  REW  7
X02  TSX4977
X03 0     7
X04 01012X47
X05 01022X50
X06 0A362R0
X07 01032R3

X10 01042R4
X11 01052R5
X12 01062R6
X13 01072R7
X14 01102S0
X15 01112S1
X16 01122S2
X17 01132S3
```

```
X20 01142S4
X21 01152S5
X22 01162S6
X23 01172S7
X24 01202T0
X25 01212T1
X26 01222T2
X27 01232T3

X30 01242T4
X31 01252M0
X32 01262M1
X33 01272M2
X34 01302M3
X35 01312M4
X36 41322932
X37  WEF    7

X40  TSX4977
X41 0       7
X42 42012X47
X43  WEF    7
X44  REW    7
X45  LXD4457
X46  TRA4   1
X47 0 62 A62

X50 0  7 Q07

X00 8     820
X01  SXD4X52
X02  TSX4974
X03 0  1
X04 0     936
X05 0     R0
X06 0     R3
X07 0     R4

X10 0     R5
X11 0     R6
X12 0     R7
X13 0     S0
X14 0     S1
X15 0  2
X16 0     943
X17 0     S2

X20 0     S3
X21 0     S4
X22 0     S5
X23 0     S6
X24 0     S7
X25 0     T0
X26 0     T1
X27 0  2
```

```
X30 0      944
X31 0      T2
X32 0      T3
X33 0      T4
X34 0      Z3
X35 0      Z1
X36 0      Z2
X37 0  3

X40 4 611A00
X41  TSX4975
X42 0  2
X43 0     940
X44 4
X45  TSX4974
X46 0  1
X47 4     940

X50  LXD4X52
X51  TRA4  1
X52  HTR
X53 8  2X50
X54  PSE 164
X55  TRA X51
X56  TSX4974
X57 0  1

X60 0      M0
X61 0      M1
X62 0      M2
X63 0      M3
X64 4      M4
X65  LXD4X52
X66  TRA X51
```

FLOCODE "PRIME"

(TO SET PARAMETER BLOCK A00 PRIOR TO DATA ASSIGN)

```
X00 8     850
X01  CLA L01
X02  STO A36
X03  CLA L02
X04  STO A54
X05  CLA L03
X06  STO A46
X07  STO A34

X10  ADD 401
X11  STO 100
X12  CLA L04
X13  STO A25
X14  CLA L05
X15  STO A56
X16  CLA L06
X17  STO A57
```

```
X20  LXA4401
X21  CLA L02
X22  SUB C23
X23  TMI X25
X24 1  14X22
X25  PXD4
X26  ARS  22
X27  SSM

X30  STO A47
X31  SSP
X32  ADD 401
X33  ALS   2
X34  STO A24
X35  LDQ 100
X36  MPY A47
X37  STQ 100

X40  CLA 100
X41  SSP
X42  STO A23
X43  TSX4970

X44 *     4850

X45 *      860

X00 8      850
X01  TSX4355
X02  TSX4800
X03  TSX4801
X04  TSX4802
X05  TSX4855
X06  TSX4803
X07  TSX4806

X10  TSX4804
X11  NOP
X12  TSX4977
X13 0       2
X14 01151S6
X15 01171T0
X16 01221T3
X17 01251M0

X20 01271M2
X21 01301M3
X22 41311M4
X23  NOP
X24  STZ 806
X25  CLA A25
X26  STO 801
X27  TSX4974

X30 0     1
X31 4      935
X32  REW   2
X33  TSX4855
X34  TSX4815
X35  CLA 801
X36  SUB 401
X37  STO 801
```

```
X40   TNZ X33
X41   CLA B06
X42   STD M1*
X43   ARS  22
X44   STO Q03
X45   TSX4816
X46   TSX4817
X47   TSX4820

X50   HPR
X51   TSX4970

X52 *    4850



X00 8    860
X01   TSX4971
X02  0D031A0
X03  0D171F0
X04  0D171F1
X05  0Q021M0
X06  0D041M1
X07  0Q041M2

X10  0Q051M3
X11  0Q061M4
X12  0A461R0
X13  0A461R1
X14  0A542R2
X15  0A461R3
X16  0A541R4
X17  0A231R5

X20  0A231R6
X21  0A541R7
X22  0A541S0
X23  0A541S1
X24  0A541S2
X25  0A241S3
X26  0A461S4
X27  0A251S5

X30  0A261S6
X31  0A541S7
X32  0A261T0
X33  0A541T1
X34  04001T2
X35  0A261T3
X36  0A541T4
X37  0A471Z0
```

```
X40 0A461Z1
X41 0A461Z2
X42 0A461Z3
X43 4A461Y6
X44  TSX4970

X45 *   4860

X46 *    906



X00 8    865
X01  TSX4974
X02 0  2
X03 0 571A00
X04 0  2
X05 0  61B00
X06 0  2
X07 0 751155

X10 4  2
X11  TSX4975
X12 0    941
X13 4  3
X14  HPR
X15  PSE 163
X16  TRA X26
X17  CLA A0*

X20  STO X30
X21  SXD1A0*
X22  TSX4974
X23 4    A0
X24  CLA X30
X25  STO A0*
X26  LXD4457
X27  TRA4  1

X30  HTR

X31 *    850



X00 8    905
X01 8A0 4B0
```