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A USERS MANUAL FOR THE AFWL SPACE RADIATION ENVIRONMENT AND SHIELDING CODES

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Prepared for:

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Air Force Systems Command
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The Air Force Weapons Laboratory (AFWL) Space Radiation Enviroment and Shielding Codes (SPARES) that are used to calculate the natural space radiation enviroment have been intensively modified. The SPARES codes use a satellite's shielding distribution in conjunction with radiation transport calculations to obtain flux-to-dose conversion factors. These factors are then used in conjunction with trajectory and environment data to obtain the dose and dose rate in rad units at specified locations within the

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) satellite over any time period. The dose conversion factors computed by the SPARES codes have been modified to be compatible with other AFWL codes. The latest models of the natural proton and electron space radiation environments have been incorporated. A thorough internal code documentation has been performed using comment cards. All machine language has been replaced with American National Standards Institute (ANSI) FORTAN, and with the exception of data statements, all coding has been converted to ANSI FORTAN. A detailed user's manual has been prepared.

PREFACE

The Air Force Weapons Laboratory (AFWL) Project Officer, Mr. Joseph Janni, would like to express appreciation to Dr. Charles Blank of the Defense Nuclear Agency (DNA) for his interest and support in this effort. Captain George Radke, Jr., of the Air Force Technical Application Center (AFTAC) provided significant coordination and assistance and wrote the HEVPRT code. Captain Roger Case of AFWL/DYS prepared portions of this report and improved the EPENSS and BREMSS codes.

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INTRODUCTION

This report is a user's manual for the Space Radiation Codes used to calculate the natural space radiation environment at the Air Force Weapons Laboratory (AFWL). The original versions of these codes were prepared by the Boeing Company (Ref. 1) under contract with AFWL. Several codes have been completely replaced, and all others have been extensively modified. Many substantive changes were previously made to the codes by AFWL personnel.

The present work incorporates new proton stopping power and range data from Janni's tables (Ref. 2), includes the AE4, AE5, and smoothed-proton Vette maps (Refs. 10, 11), conforms the codes to American Standard FORTRAN (Ref. 12), and completely documents the codes internally by the use of comment cards.

The 80-term International Geomagnetic Reference Field 1965.0 (IGRF 1965.0) was inserted in the INVAR package to replace the old 48-term Jensen and Cain Model. A modified version of ALLMAG (Ref. 11) replaces the old version of MAGNET and allows a more up-to-date and accurate calculation of B. A subroutine package taken from Program MODEL (Ref. 5) was modified to obtain the desired fluxes.

The physics of the transport codes HEVPRT, EPENSS, and BREMSS was not changed, although some of the programming and the card input was changed. The old TRAJECT and DOSRAT codes were merged to form a new code called TANDE. Another new code, DOSMAP, was written to produce a 700-point B-L map of dose rates. The main part of this program was taken from Program MODEL.

The core storage of each code has been reduced. The most notable saving occurred in Program TANDE, which now takes about 131,000 octal locations. Before, program TRAJECT took about 165,000 octal locations and DOSRAT about 145,000 octal locations.

This report contains a brief explanation of the physics, a detailed card input section for running the codes, and sample output.

SECTION II
GENERAL DESCRIPTION

The penetration of an incident radiation field into a spacecraft is dependent upon the type of radiation, the energy spectrum, the shielding characteristics of the spacecraft, and self-shielding provided by the astronauts or by the radiation measuring instruments themselves. In the inner radiation zone, for shielding thicknesses greater than 30 gm/cm^2, primary protons and nuclear secondary radiations are the major contributors to the absorbed dose. Between 5 and 30 gm/cm^2, primary protons and bremsstrahlung are the major dose contributors. For shield thicknesses less than 5 gm/cm^2, penetrating electrons can also contribute significantly to the dose. Any or all of these contributions may be present or absent depending upon the nature and characteristics of the incident radiation field. Although for very thick shields the proportion of secondary radiations can be of importance, the primary dose usually overshadows secondary contributions for unmanned satellites and for manned spacecraft like Gemini, Apollo, Skylab, and Shuttle.

The Space Radiation Codes incorporate best available models of the space radiation environment in conjunction with radiation interaction models to transport the environment through the space vehicle to the dose point of interest, where the rad dose and dose rates are calculated.

To adequately assess the dose due to natural trapped radiation at a given point in a space vehicle, one must specify

1. Orbital parameters
2. Vehicle shielding
3. Date of orbital mission
4. Dose point location
5. Radiation type

Each of the above parameters affect the flux and/or particle type which contributes to the absorbed dose.

Figure 1 schematically shows the general problem-solving procedure using the Space Radiation Codes.

The Space Radiation Codes are a set of five computer codes. Three are used in the transport calculations: HEVPRT is used to transport protons and heavy particles; EPENSS is used for the electron transport; and BREMSS is used for the bremsstrahlung transport. All three use layered shielding information as input and provide dose conversion factors (DCFs). The other two codes use these DCFs to obtain doses and dose rates. DOSMAP has a 700 point B-L grid set in block data. The dose rate at each B-L point is computed and a dose rate map is printed. TANDE will either compute a trajectory, read a point set trajectory from cards, or use a previously computed trajectory stored on tape. It then calculates the dose rate and accumulated dose at each point of the trajectory and prints the results. Table 1 gives the storage requirements and computer time needed for average runs.

The method of using dose conversion factors is accurate, rapid, and well-suited to the calculation of space radiation dose. It has the advantage of separating mission dose calculations into two efficient independent calculations. An incident differential spectrum of a unit flux is first transported through the spacecraft to the dose point for the radiation type under consideration, resulting in a set of dose conversion factors as a function of incident particle energy. The dose at any trajectory point is computed by multiplying the dose conversion factors by the appropriate incident differential energy spectrum, and integrating the product over all incident energies. The accumulated dose is found by summing the dose at each trajectory point throughout the mission. Although many different trajectories may be included in a given study, the radiation transport calculation is performed only once for a given dose point.

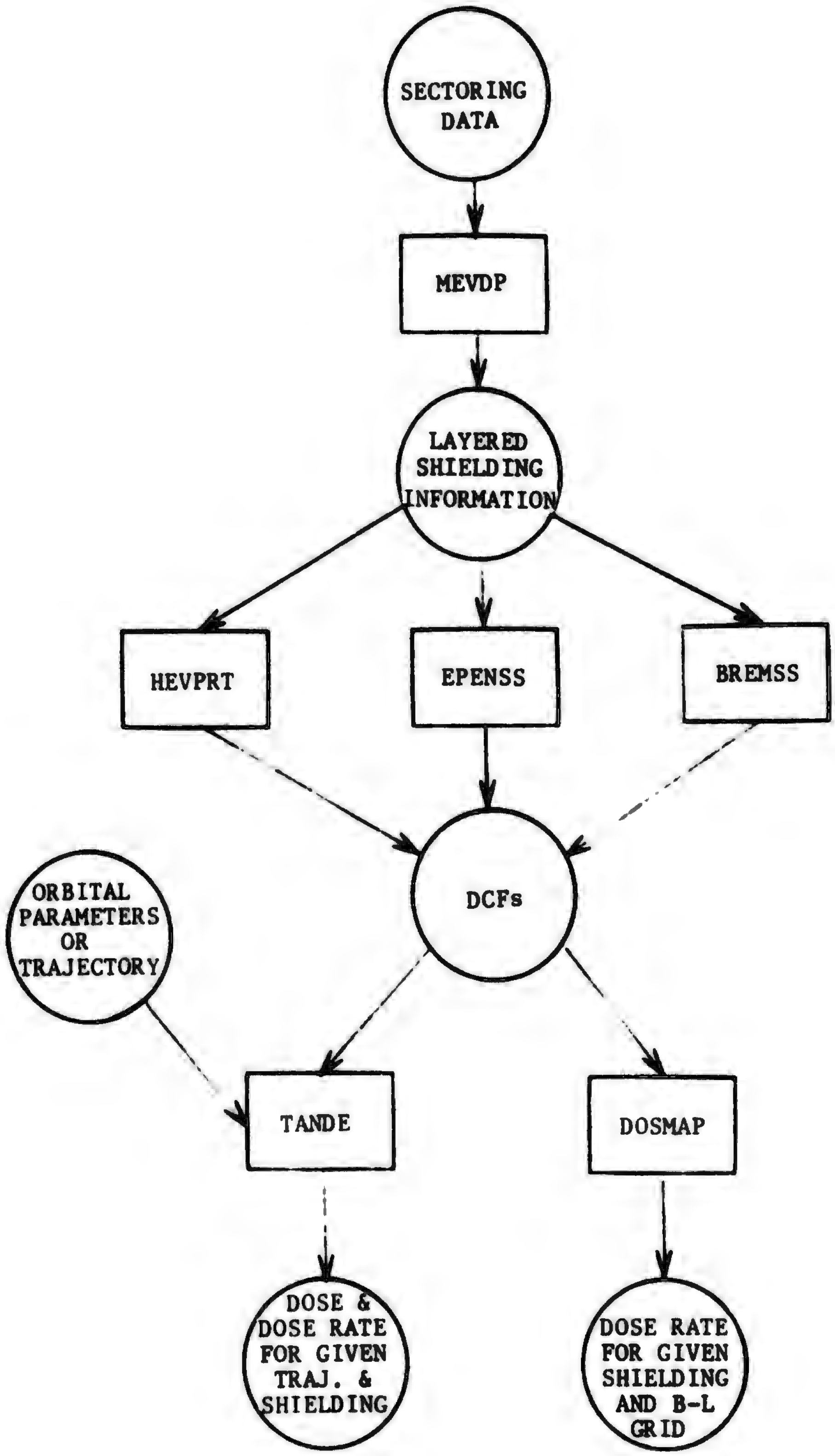


Figure 1. Schematic of Problem-Solving Procedure

TABLE 1. PROGRAM STORAGE AND TIME REQUIREMENTS

PROGRAM	CORE REQ. OCTAL	TIME (min) CP	TIME (min) PP	COMMENTS
HEVPRT	60,000	$\lesssim 1$	$\lesssim 1$	Very fast running.
EPENSS	60,000	$\lesssim 1$	$\lesssim 1$	Very fast running.
BREMSS	70,000	~ 5	~ 5	For a 25-sector, 1-layer problem. Takes about 0.1 min. per sector per layer.
TANDE	131,000	~ 3	~ 3	For a circular polar orbit. 1440 trajectory points in 4300-seconds (0.5-day).
DOSMAP	65,000	~ 1	~ 1	Complete proton, electron, and brems run.

Specifically, the first step in calculating dose conversion factors for all incident particle types is to divide the maximum possible spectral spread into many energy subintervals of a specific width and average energy. A flux-to-dose conversion factor for each shield sector and each energy subinterval is obtained by transporting all subinterval energies through that sector and calculating the dose resulting from the exterior incident unit differential spectrum. The intervals must be selected in a fine grid so that the incident spectra may be approximated accurately by the step function. This is termed the "N-grid approach" and produces a table of energy-dependent dose conversion factors for each sector. These are then summed over the whole vehicle to obtain dose conversion factors which are a function of incident energy.

Once this N-grid calculation is completed for a given shielding configuration, an arbitrary external spectrum can be rapidly folded into the shielding data and a dose calculated. The N-grid dose conversion factors are weighted by the appropriate external differential energy spectra and then summed to produce the rad dose at the selected dose point. This technique is especially useful for parametric studies.

Each radiation type exhibits different scattering, straggling, attenuation, absorption, and energy deposition characterisitics in matter. Although the dose conversion method is applicable to all radiations, differing techniques must be used to obtain dose conversion factors for electrons, photons, and heavy charged particles.

SECTION III

HEVPRT

The HEVPRT code calculates the dose conversion factors for protons or heavier particles. The range-energy technique is used to save computer storage and time. These calculations for the proton DCFs are accurate to within a few percent, neglecting nuclear secondary production from nuclear attenuation effects on the primary beam.

The specific method used treats each material layer independently. A unit flux/MeV particle starts from the exterior and traverses each material layer separately until it reaches the interior dose point. Multilayered shields are treated by transporting the radiation through one layer at a time, and assuming that the flux coming from the nth layer is incident on the n + 1th layer. The particle is transported in this manner through each material layer without averaging the atomic numbers, approximating the thickness of each layer, or otherwise compromising the heavy ion calculation.

Since the stopping power of the heavy particle is a function of its velocity V and the square of its charge, a considerable simplification can be accomplished by using K, the kinetic energy per nucleon of a particle. The stopping power $S_H(K)$ of a heavy particle of kinetic energy K per nucleon is then just Z^2 times the stopping power of a proton with kinetic energy K.

$$S_{ion}(K) = Z^2 S_{proton}(K) \tag{1}$$

At low velocities, the heavy particle begins to capture electrons, and its average charge is reduced. From the data of Neufeld and Snyder (Ref. 13), a correction factor has been developed such that

$$Z^2_{eff} = F(K)Z^2 \quad (2)$$

for helium, carbon, nitrogen, and oxygen. Tabulated values of F(K) are stored in the code and used as required.

In a similar way, a relation between the range of a heavy particle and the range of a proton can be developed, and we have

$$R_{ion}(K) = \frac{M}{Z^2} R_p(K) \quad (3)$$

$R_{ion}(K)$ = range of heavy particle of kinetic energy K per nucleon in gm/cm^2

M_{ion} = weight of the heavy particle, in units of proton mass

Z = charge of heavy particle, in proton charge units

$R_{proton}(K)$ = range of proton of kinetic energy K in gm/cm^2

With these relations, range, and stopping power relations for protons can be converted to heavy ion tables and used in shielding calculations for heavy particles. The procedure for the transport calculations, dose, and dose rate determinations are then identical to those for protons.

The calculations required to calculate proton dose conversion factor begin by subdividing the energy regime of interest (0 to 1000 MeV) into a fine energy grid, G_i, characterized by the midpoints, of each energy bin, $E_{MID_i} = (G_{i+1}+G_i)/2.$, i=1,2,...n-1. The E_{MID_i} array is not used in the explicit calculation of dose, but is stored and used for output of the calculational results.

For a given sector with NL layers of different materials with thickness X_i, i=1, NL, the procedure is as follows:

(1) Two arrays of energy points, A_j and B_j are selected. The selection criteria for these arrays are such that the A_j array adequately covers the external energy regime of interest, and B_j adequately covers that portion of the internal energy regime for which the dE/dX is most rapidly changing in the absorbing material (generally tissue). By combining these two grids, adequate coverage of the external energy spectrum and of the internal energy spectrum (penetrating spectrum) is assured. The minimum penetrating energy is taken as 0.0 MeV, and a dE/dX value equal to that of a 0.1-MeV particle is assumed.

(2) Range-energy calculations are performed on all the energy points in the A_j and B_j arrays as follows:

(a) The A_j (external energy) points are transported through the shielding layers (X_i, i=1, NL) to determine the internal energy values corresponding to these external energy points, and placed in a second array A'_{ij}.

$$A'_{ij} = A_{ij} - EL_{ij}\left(\sum_{k=1}^{NL} X_{ik}\right) \qquad (4)$$

where EL_{ij} is the energy loss of the incident proton in penetrating the shielding of sector i of thickness S_i,

$$X_i = \sum_{k=1}^{NL} X_{ik}$$

Note that not all energies in A_{ij} may penetrate the shielding, and without a second set of energy points, B_{ij}, there could be a serious underestimation of the dose because the region of maximum energy transfer (0 to 14 MeV penetrating energy) would not be correctly accounted for.

(b) A similar set of calculations is performed on the energy points in the B_{ij} array, except the transport is from vehicle interior to its exterior, i.e.,

$$B'_{ij} = B_{ij} + EL_{ij}\left(\sum_{k=1}^{NL} X_{ik}\right) \qquad (5)$$

These calculations adequately cover the regime of maximum dE/dX transfer interior to the vehicle.

(3) The arrays A_{ij}, B_{ij}, A'_{ij}, B'_{ij} are combined to form a composite set of arrays C_{ij} and C'_{ij}, where C'_{ij} are the internal energies corresponding to the external energies C_{ij}. Note that C_{ij} ranges from E_{min} to 1000 MeV, and that E_{min} is the minimum penetrating energy for the sector i. C'_{ij} ranges from 0 to E_{max}, when E_{max} is the internal energy corresponding to the external energy of 1000 MeV. A third array of dE/dX values is established which corresponds to C_{ij}, i.e.,

$$C''_{ij} = dE/dX\Big|_{C'_{ij}} \text{ in the absorber (generally tissue)}$$

(4) The function of D_{ij} is evaluated for all points in the C_{ij} array, where D_{ij} is given by

$$D_{ij} = \int_0^{E(C_{ij})} \frac{dE}{dX}\Big|_{C'_{ij}} dE(C_{ij}) = \int_0^{E} C''_{ij} dE \qquad (6)$$

This function then represents the total absorbed energy at the dose point in the absorber between the internal energy limits 0 and C'_{ij}, and external energy limits 0 to C_{ij} (note that lower external energy of 0 or E_{min} is equivalent, as no energy is transferred to absorber for external energies below E_{min} as particles are stopped in the shield). A series of trapezoidal rule integrations are performed in the evaluation of the D_{ij} function.

(5) The D_{ij} array is next interpolated to fit the energy output grid G_i, $i = 1, \ldots, n$. The results of this interpolation are two arrays, G_i and F_{ij}, where G_i is the output energy grid, and F_{ij} is the total energy loss in the absorber for the energy range of 0 to $E(G_i)$.

(6) The dose conversion factors for sector j and energy bin i, characterized by its midpoint energy E_{MID_i}, are then given by

$$DCF_{ij} = Kd\Omega_j(F_{i+1,j} - F_{ij}) \quad i=1,2,\ldots,n-1 \qquad (7)$$

for the energy grid, E_{MID_i}

$$E_{MID_i} = (G_{i+1} + G_i)/2 \qquad i=1,2,\ldots,n-1 \qquad (8)$$

Note that the quantity $(F_{i+1,j} - F_{ij})$ is just the energy lost between the energy limits of G_{i+1} and G_i, $d\Omega j$ is the solid angle subtended by sector j (normalized, i.e., $\sum_{i=1} d\Omega_i = 1$), and K is a time scale and flux-to-dose conversion factor.

(7) To evaluate the vehicle dose conversion factors, a summation over sectors is performed

$$DCF_i\left(E_{MID_i}\right) = \sum_{j=1}^{NS} DCF_{ij}\left(E_{MID_i}\right) \qquad (9)$$

where NS is the number of sectors in the vehicle.

Figure 2 and Table 2 give the basic input information needed to set up a run. When the absorbing material is tissue and when all of the vehicle materials are on the standard list (Table 3), the deck setup is quite simple. It can be made even simpler when protons are used as the transport particle and the vehicle description resides on Tape 8. Since the same vehicle description is used by the three transport codes HEVPRT, EPENSS, and BREMSS, Section VI explains the vehicle description separately. Program MEVDP (Ref. 14) is explained in Section VI along with the general vehicle description.

Appendix A contains the energy grids needed to input the material proton range data for the materials not on the standard list.

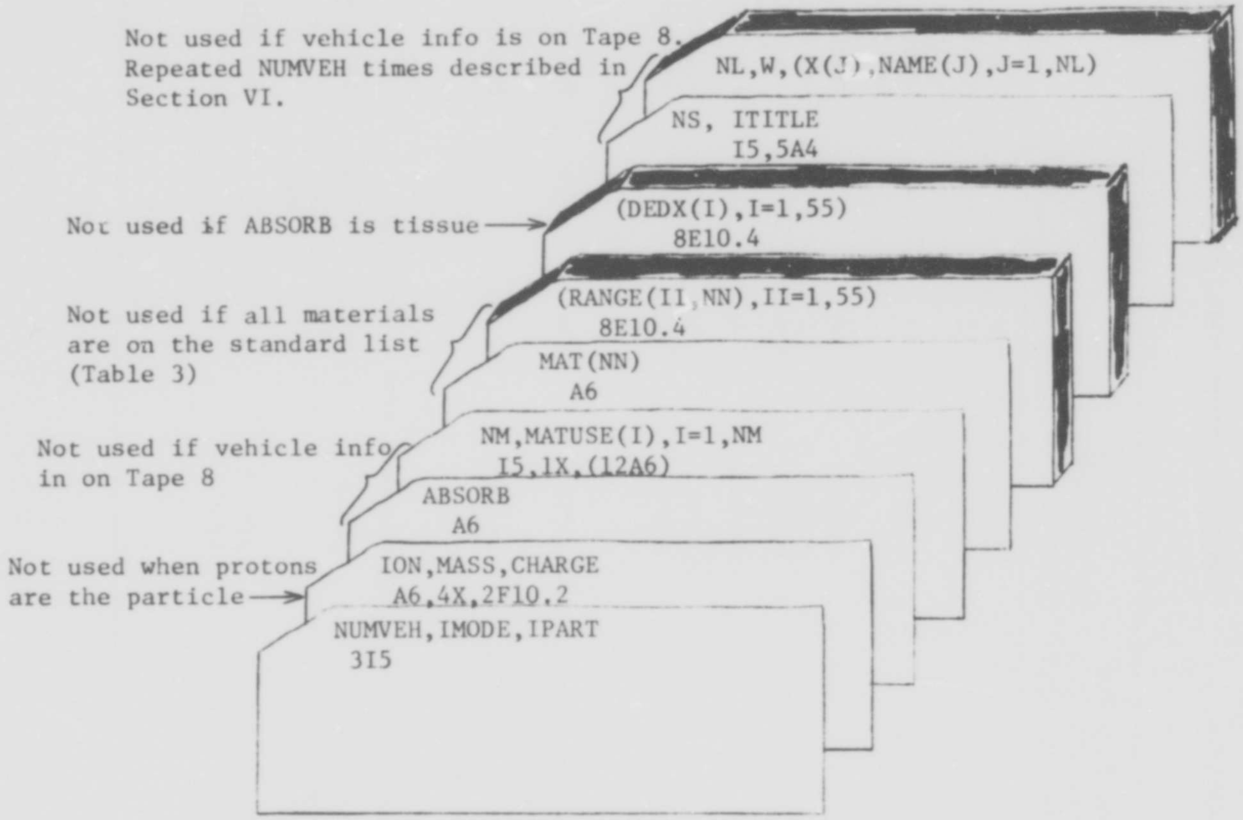


Figure 2. HEVPRT Card Input Schematic

TABLE 2. HEVPRT CARD INPUT

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
1	NUMVEH		HEVPRT	I5	1-5	Number of vehicles to be solved
1	IMODE	= 0	HEVPRT	I5	6-10	Vehicle data stored on cards
		= 1				Vehicle data stored on Tape 8
1	IPART	= 0	HEVPRT	I5	11-15	Transport particles are protons
		= 1				Particles are other than protons
2	ION	IPART = 1	HEVPRT	A6	1-6	Name of transport particle
2	MASS	IPART = 1	HEVPRT	F10.2	11-20	Ion mass (AMU)
2	CHARGE	IPART = 1	HEVPRT	F10.2	21-30	Ion charge
3	ABSORB	IMODE = 0	HEVIN	A6	1-6	Name of absorbing material
4	NM	IMODE = 0	HEVIN	I5	1-5	Number of materials used
4	MATUSE(1)	IMODE = 0	HEVIN	12A6	7-12	Names of materials used
4	MATUSE(2)				13-18	
4	MATUSE(3)→NM				etc	
5	MAT	Material not on standard list	HEVIN	A6	1-6	Name of material
6	RANGE(1)	Material not on standard list	HEVIN	8E10.4	1-10	Proton range values for MAT
6	RANGE(2)				11-20	
6	RANGE(3)→N				etc	
(Repeat 5 and 6 for each material not on the standard list - Table 3)						
7	DEDX(1)	Absorber not tissue	HEVIN	8E10.4	1-10	dE/dX values of absorbing material
7	DEDX(2)				11-20	
7	DEDX(3)→N				etc	
8-9	Vehicle Description	IMODE = 0	HEVPRT VEIN			Described in detail in Section VI
(Repeat 8-9 NUMVEH times)						

TABLE 3. STANDARD MATERIALS IN THE HEVPRT CODE

MATERIAL	HEVPRT NAME	Z	A
Aluminum	AL	13	26.97
Gold	AU	79	197.2
Beryllium	BE	4	9.02
Bone, human	BONE	10	16.2
Calcium	CA	20	40.08
Calcium fluoride	CAFL	38	78.08
Carbon	C	6	12.01
Copper	CU	29	63.57
Iron	FE	26	55.85
Lead	PB	82	207.21
Magnesium	MG	12	24.32
Manganese	MN	25	54.94
Molybdenum	MO	42	95.95
Polyethylene	POLYE	16	128.05
Silicon	SI	14	28.09
Tin	SN	50	118.7
Tissue	TISSUE	6.92	127.2
Zinc	ZN	30	65.38
Water	WATER	8	18
Titonium	TI	22	47.9

SECTION IV.
EPENSS

EPENSS is the electron penetration code which calculates a group of dose conversion factors. The number of electrons of a given energy penetrating a given shield was obtained from the dimensionless length and energy parameters of Seliger (Ref. 15) and Makhov (Ref. 16).

The analytic expression which forms the basis for the electron penetration code provides 15 percent accuracy in the calculated electron transmission for shield thicknesses less than one-half the electron range. Greater errors occur where large differences exist in the atomic numbers of the shielding materials near the end of the electron range. Results of this procedure were compared to electron Monte Carlo studies, and good agreement was achieved for slabs that had atomic numbers with differences less than 10. For differences in Z as great as 40, a factor of 2 difference was noted for fractional transmissions of 0.05. The main N-grid improvements have been (1) the elimination of repetitive evaluation of electron transmission for a large energy grid and (2) the substitution of simple interpolation and addition to fold incident electron spectra with electron transmission values, rather than repetitive integrations.

The EPENSS code treats the incident spectrum as being subdivided into N energy intervals of width ΔE_j with average midpoint energy E_{MID_j}. A flux-to-dose conversion factor in each sector and for each energy bin ΔE_j is obtained by penetrating all midpoint energies through that sector and calculating the dose from the transmitted spectrum. For each sector there is a minimum energy which will penetrate (the energy whose range equals the total sector thickness); all energy bins with E_{MID_j} less than this energy are not considered. This N-grid approach results in a table of dose conversion factors for each of the midpoint energies for each sector. The total dose transmission from all sectors is the sum of the dose contribution from each sector. The sector dose is the product of (1) the fraction of the free space flux entering that sector (0.25 for an isotropic flux), (2) the dose transmission factor obtained for a multilayer slab shield of the same material composition as the sector, (3) the fraction of the flux scattering to the dose point ($3\pi/16$ for a cosine-squared distribution), and (4) the fraction of the total solid angle subtended by the sector.

Generating the basic N-grid data for a vehicle involves the elemental calculation of the energy spectrum of particles penetrating a one-dimensional shield having several layers of different material composition.

The number of electrons with initial energy E_o and final energy E passing through a thickness X of material Z is

$$N(E_o \to E, X, Z) = N(E_o) T(E_o \to E, X, Z) \tag{10}$$

where

$$T(E_o \to E, X, Z) = Ae^{-b(E_o - E)} = Ae^{b(E - E_o)} \tag{11}$$

an exponential transmission function for material with atomic number Z and thickness X, for initial energy E_o and final energy E.

The two parameters A and b are given the expressions

$$A = T_o(E_o)\, b \left\{ e^{-bE_o} \left(e^{bE_{MAX}} - 1 \right) \right\}^{-1} \tag{12}$$

$$b = \left(\frac{X}{E_o} \right)^{-1.46} \left(\frac{1.53 - 0.0104Z}{E_o} \right) \tag{13}$$

$$T_o\left(E_o\right) = \int_0^{E_{MAX}} T_E(E_o \to E)\, dE \tag{14}$$

$$T_E(E_o \rightarrow E) = e^{-(cE_o)^{\alpha}} \tag{15}$$

$$\alpha = -7(Z-3.25)^{-0.24} \qquad c = \left\{\frac{0.585Z^{-0.271}}{X}\right\}^{0.848} \tag{16}$$

For each successive layer of the shielding in one sector, equations (10) and (11) are used. The energy spectrum of particles penetrating the first layer provides the function, $N(E_o)$, for incidence on the second layer. An effective thickness for the multislab calculation is made using the simplifying assumption that an equivalent thickness of any material that produces an equal attenuation of electrons will also produce an identical energy and angular distribution of electrons. In other words, the number transmission of electrons penetrating a multislab shield consisting of N layers of total thickness

$$\bar{X}_N = \sum_{i=1}^{N} X_i \tag{17}$$

is given by the expression

$$T(X_i, Z_i\{i=1,2,\ldots N\}, E_o) = T(\bar{X}_N, E_o, Z_N) \tag{18}$$

where $\bar{X}_N$ is the "equivalent" thickness mentioned above.

The transmission in the ith slab, of material j with thickness X_i, is determined by using an effective thickness equal to the thickness of slab i plus an additional equivalent attenuation "thickness" equal to that of all previous slabs.

The technique of calculating this effective thickness is necessarily iterative. This "effective" thickness is obtained from the implicit expression

$$T(\bar{X}_{N-1}, E_o, Z_N) = T(X_i\{i=1,2,\ldots,N-1\},\ Z_{N-1}, E_o) \quad (19)$$

where the right side of the expression is obtained from the (i-1)th iteration.

This procedure is repeated for each layer until the energy spectrum of particles penetrating the last layer of shielding is found. From the penetrating spectrum, the dose (rads) per particle flux for each initial energy, E_i, is found for each sector, J, by evaluating

$$D_{ij} = 1.6X10^{-8} \int_0^{E_i} N_T(E_i, E)\ \frac{dE}{dX}(E)dE \quad (20)$$

where

$N_T(E,E_i)$ = energy spectrum of particles penetrating the shielding of sector for one particle of initial energy, E_i, in particles/MeV

$\frac{dE}{dX}(E)$ = energy loss per unit thickness increment in the absorbing medium in MeV cm^2/gm

The values of D_{ij} for all i and j comprise the N-grid results.

The N-grid results are finally summed over all sectors for each energy grid point.

$$D_i = \sum_{j=1}^{NS} D_{ij}\ d\Omega j \quad (21)$$

where $d\Omega j$ is the solid angular weighting factor for the jth sector. To fold in an incident spectrum of particles, a trapezoidal integration over initial energy can be performed.

The operating instructions for EPENSS are straightforward. A large amount of fixed data is associated with EPENSS, which contains the range and dE/dX information for the materials on the standard list (Table 4). Figure 3 and Table 5 show how to set up the card deck for solving problems. These cards are inserted after the fixed data.

If all the materials are on the standard list, and if the vehicle description is stored on Tape 8, it will be necessary only to include the first card. The vehicle input data and a description of Program MEVDP is included in Section VI. Appendix A contains the energy grids needed to input the electron data for the materials not on the standard list.

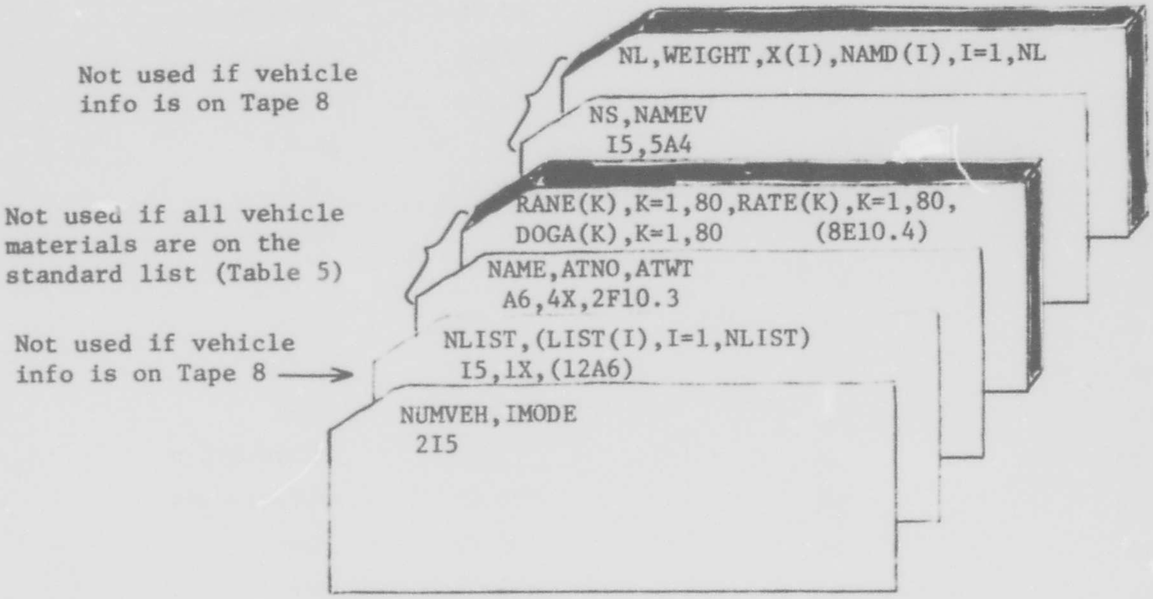


Figure 3. EPENSS Card Input Schematic

TABLE 4. STANDARD MATERIAL LIST FOR EPENSS

PROGRAM SYMBOL	Z	A	MATERIAL
AL	13	26.97	Aluminum
AU	79	197.2	Gold
BE	4	9.02	Beryllium
C	6	12.01	Carbon
CA	20	40.08	Calcium
CR	24	52.01	Chromium
CU	29	63.57	Copper
H_2O	10	18	Water
LUCIT	6.6	100.11	Lucite
MG	12	24.5	Magnesium
MN	25	54.94	Manganese
N	7	14.008	Neon
NI	28	58.71	Nickel
PB	82	207.21	Lead
POLYE	6	12.05	Polyethylene
POLYS	10	128.05	Polystyrene
RENE	28	55.85	Rene
SN	50	118.7	Tin
TISSUE	6.92	127.2	Human Tissue
W	74	183.92	Tungsten

TABLE 5. EPENSS CARD INPUT

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
1	NUMVEH		EPENSS	I5	1-5	Number of vehicles to be solved
1	IMODE	= 0	EPENSS	I5	6-10	Vehicle data stored on cards
		= 1			etc	Vehicle data stored on Tape 8
2	NLIST	IMODE = 0	EPENSS	I5	1-5	Number of materials used
2	LIST(1)	IMODE = 0	EPENSS	12A6	7-12	Names of materials used
2	LIST(2)		EPENSS		13-18	
2	LIST(3)→NLIST				etc	
3	NAME	Material not on	DATA	A6	1-6	Material name
3	ATNO	standard list	DATA	F10.3	11-20	Material atomic number
3	ATWT		DATA	F10.3	21-30	Material atomic weight
4	RANE(1)	Material not on	DATA	8E10.4	1-10	Electron range in material
4	RANE(2)	standard list			11-20	
	RANE(3)→N				etc	
4	RATE(1)		DATA	8E10.4	1-10	Electron dE/dX (collision only)
	RATE(2)				11-20	
	RATE(3)→N				etc	
4	DOGA(1)		DATA	8E10.4	1-10	Electron dE/dX (with brems)
	DOGA(2)				11-20	
	DOGA(3)→N				etc	
(Repeat 3 and 4 for each material not on the standard list (Table 5))						
5-6	Vehicle Description	IMODE = 0	VEIN	-		Described in detail in Section VI
(Repeat 5-6 NUMVEH times)						

SECTION V

BREMSS

Although bremsstrahlung is not in general a major contributor to the dose, it cannot be ignored if a large electron flux is incident upon a vehicle and there is sufficient spacecraft shielding (>5 gm/cm^2) to stop the primary electrons. There are two approximations to the actual bremsstrahlung production which are available in this code: a fast running approximation where the bremsstrahlung is produced totally on the surface of the shield and attenuated through the shielding; and another in which the radiation is produced throughout the volume necessary to stop the incident electrons and then attenuated through the remaining shielding. Expressions obtained from Evans (Ref. 17), Wyard (Ref. 18), and Wu (Ref. 19) are used to predict the rate and energy spectra of the bremsstrahlung. The angular distribution of the emitted bremsstrahlung is taken into account using an energy-dependent angular distribution function. Once produced, the bremsstrahlung is transported through all sectors using an expression which exponentially attenuates the intensity. Empirical dose buildup factors for the shielding materials account for scattering, and the dose is then calculated using gamma flux-to-dose conversion factors. N-grid results analogous to those obtained in the electron penetration code are used to determine the contribution of bremsstrahlung to the total dose.

A series of energy bins, the limits of which are E_u and E_L, are first established. Bremsstrahlung production is then calculated for all energies between E_L and E_u and an electron flux-to-bremsstrahlung dose conversion factor is determined for this energy bin for a given sector shield configuration. The process is continued until all energy bins spanning the energy regime of interest and all sectors are completed.

The expression which is used to predict the dose from bremsstrahlung is

$$D(\gamma) = \int_{0.1}^{\gamma_u} B(\gamma)K(\gamma)A(\gamma)\ H(\gamma) \int_{E_L}^{E_u} N(E)W(E)\ F(E,\gamma)C(E,\gamma)\ dE d\gamma \qquad (22)$$

where

D = photon dose in rads

$H(\gamma)$ = angular distribution function to account for gamma radiation produced which does not reach the dose point because it is originally radiated in the backward direction

E = electron energy (MeV)

$N(E)$ = incident electron differential number spectra (number of electrons having energy between E and $E+\Delta E$ divided by ΔE (particles/MeV)

$W(E)$ = fraction of electron energy converted to photon energy

$F(E,\gamma)$ = total energy of all photons having energy between γ and $\gamma+\Delta\gamma$ divided by $\Delta\gamma$ arising from electrons of energy E (MeV/MeV)

$K(\gamma)$ = function for conversion from photon energy per unit area to units of dose for photons of energy γ

$B(\gamma)$ = dose buildup function

E_u = upper limit of electron energy (MeV)

E_L = lower limit of electron energy (MeV)

γ_u = upper limit of photon energy (MeV)

$A(\gamma)$ and $C(E,\gamma)$ are the energy transmission functions for the surface and volume cases, respectively. (When one function is used, the other is set to unity.)

The N-grid results for the bremsstrahlung code are obtained by establishing an energy grid, E_{MID_i}, where

$$E_{MID_i} = (E_{u_i} + E_{L_i})/2., \quad i=1,2,\ldots,n$$

and using the results of equation (8) for a series of electron energy limits, E_{u_i}, E_{L_i} and sequentially increasing the upper electron energy, i.e., for the nth energy bin characterized by E_{MID_n}, the dose conversion factor is given by

$$DCF_n = \int_{.1}^{E_{u_n}} \int_{E_{L_n}}^{E_{u_n}} \text{(Equation (22))} \tag{23}$$

$$E_{MID_n} = \frac{E_{u_n} + E_{L_n}}{2} \tag{24}$$

The production and attenuation of bremsstrahlung is calculated as follows:

Case 1 - Volume Production: Each sector of the shielding configuration is assumed to be a truncated right circular cone as shown in Figure 4. For a given set of electron and gamma energies E and γ, $\gamma \leq E$, the bremsstrahlung is assumed to be produced uniformly throughout a source thickness of the shield, $X_o(E,\gamma)$, which is equal to the gm/cm^2 thickness which degrades the electron energy E to the lower gamma energy γ. Range-energy relations are used for this calculation of the source thickness $X_o(E,\gamma)$. An analytical expression giving the flux which is received at point P on Figure 4 from a truncated cone source geometry is used to compute the transmission of the uncollided flux received at the detector location. This expression is given by

$$C(E,\gamma) = \frac{1}{2\mu_s(\gamma)} \left\{ E_2(b_1) - E_2(b_3) + \frac{1}{\sec\theta} \left[E_2(b_3 \sec\theta) - E_2(b_1 \sec\theta) \right] \right\} \tag{25}$$

where

$$E_2(X) = \int_X^{\infty} \frac{e^{-X}}{X^2} \, dX \quad \text{(second exponential integral)} \tag{26}$$

$\mu_s(\gamma)$ = attenuation coefficient for gamma energy, γ, in the source layer of the shield

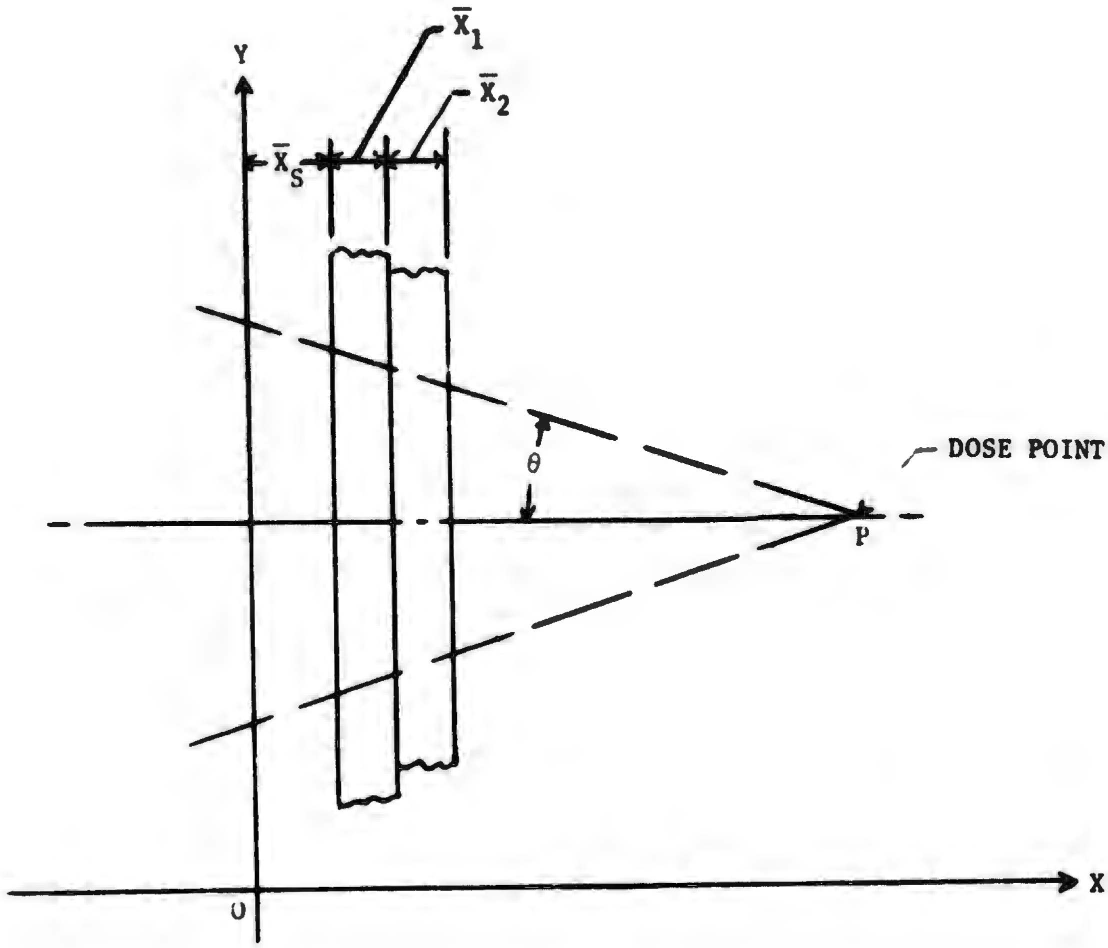


Figure 4. Truncated Right Circular Cone Source with Semi-Infinite Shields

$$b_1(\gamma) = \sum_{i=\ell}^{NL} \mu(\gamma)_i X_i, \quad \ell \text{ is index of the first layer beyond the source layer}^*$$

$$b_3(\gamma) = b_1 + \mu_s X_s, \quad X_s \text{ is the thickness of the source layer}$$

The source function, S_v, is then given by

$$S_v = C(E,\gamma)/X_o(E,\gamma) \tag{27}$$

One must also know the differential energy spectra of the electron-induced gammas, the contribution of scattered radiations to the flux at the detector, and the amount of the electron energy which is converted initially into gamma rays to determine bremsstrahlung dose conversion factors.

The differential gamma energy spectrum is assumed to be roughly independent of the material composition of the shield, and of the form

$$F(E,\gamma) = \frac{4}{5} \left\{ 4\left(1 - \frac{\gamma}{E}\right) - 3\left(\frac{\gamma}{E} \ln \frac{E}{\gamma}\right) \right\} \tag{28}$$

The factor 4/5 is a normalization constant.

To account for scattered radiation reaching the dose point, empirical dose buildup factors are used. For a multilayered shield, the total buildup factor for sector j is as follows:

$$B_j(\mu t, Z, E_\gamma) = \prod_{i=1}^{NL} B_j(\mu_i t_i, Z_i, E_\gamma) \tag{29}$$

---

* $b_1(\gamma)$ may include a portion of the first shield layer (source layer) if the electron energy is such that bremsstrahlung is produced only throughout part of the shield layer.

where $\mu_i t_i$ is the number of mfp's encountered by the radiation beyond the source layer, Z_i is the atomic number of the ith material being traversed, E_γ is the gamma energy, and NL is the number of layers of shielding in this sector.

As shown by Berger and Seltzer (Ref. 20), the energy per electron converted into bremsstrahlung is given by 0.0004 ZE where Z refers to the atomic number of the source layer, and E to the energy of the electron producing the bremsstrahlung.

The angular distribution calculation obtains an improved estimate of the amount of bremsstrahlung which is radiated in the forward 2π direction (normal to a spacecraft wall) due to the isotropically-incident electron flux. A detailed integration was performed to determine the $H(\gamma)$ function. The result of this investigation is a table of percentage of bremsstrahlung radiated in the forward direction as a function of incident electron energy.

The system geometry is shown in Figure 5, where the differential angular intensity formula is also given.

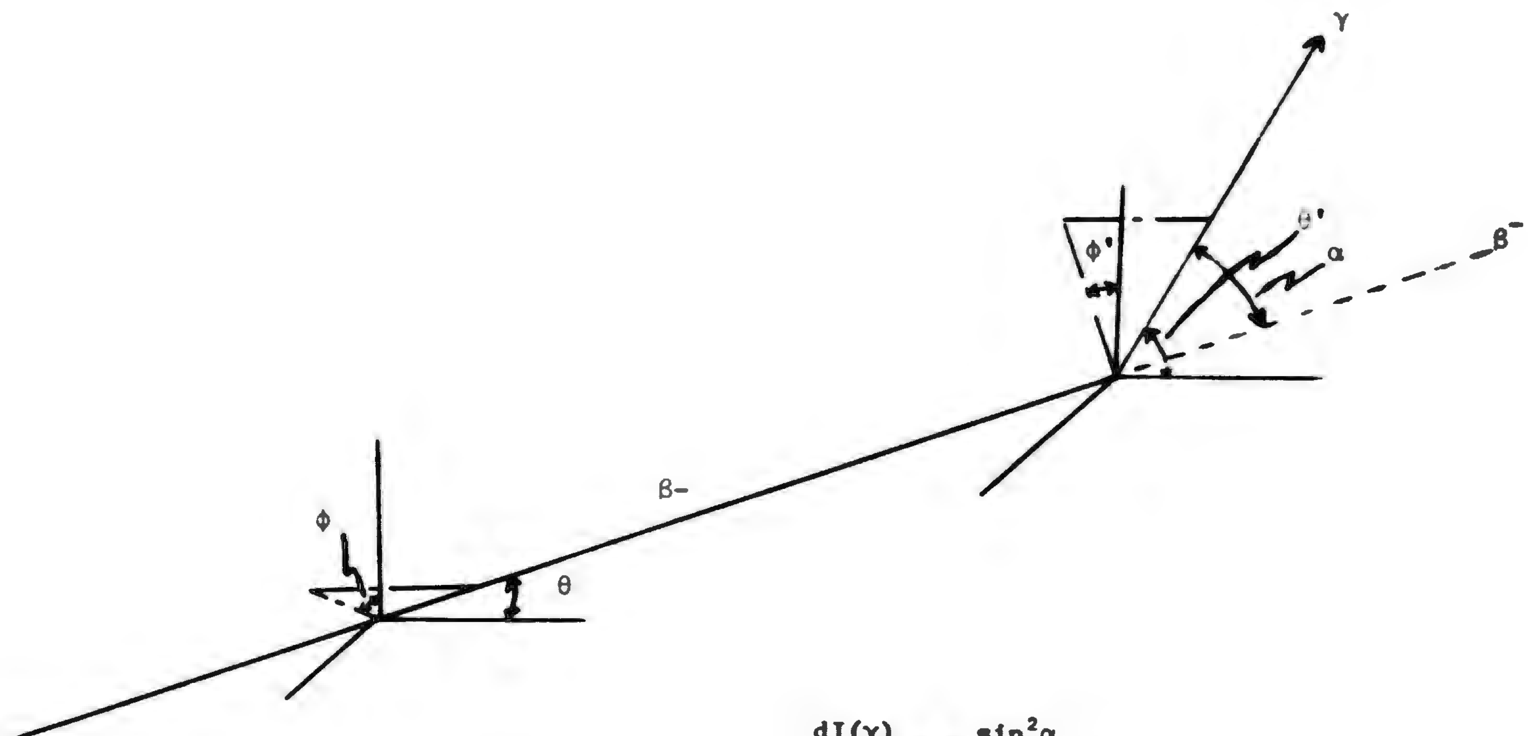
The first quantity of interest is

$$f(\theta) = \frac{\int_{\text{inward}} \frac{dI}{d\Omega}\, d\Omega}{\int \frac{dI}{d\Omega}\, d\Omega} \tag{30}$$

by integrating $f(\theta)$ as a function of $\beta = v/c$ for the electron, a function $f(\beta)$ is obtained which may be used to correct the bremsstrahlung computer code results to account for this angular distribution. The integration is fourfold over the angles labeled θ, θ', ϕ, and ϕ' in Figure 5.

$$f(\beta) = \int_{\text{in}} \frac{K \sin^2\alpha\, d\Omega}{(1-\beta \cos \alpha)^6} \Bigg/ \int_{\text{all space}} \frac{K \sin^2\alpha}{(1-\beta \cos \alpha)^6}\, d\Omega$$

$$f(\beta) = \int_0^{2\pi} d\phi \int_0^{\pi/2} \sin\theta \cos\theta\, d\theta \Bigg/ \int_0^{2\pi} d\phi' \int_0^{\pi/2} \frac{\sin\theta' \sin^2\alpha}{(1-\beta \cos \alpha)^6}\, d\theta' \tag{31}$$



$$\frac{dI(\gamma)}{d\Omega} = K \frac{\sin^2\alpha}{(1-\beta\ \cos\alpha)^5}$$

Figure 5. **Angular Distribution Geometry**

To numerically integrate this, α must be expressed in terms of the integration angles. In Figure 6 from the law of cosines

$$|G|^2 = |D|^2 + |L|^2 - 2|D| \cdot |L| \cos\alpha, \quad |D| = |L| = 1, \quad |G|^2 = 2 - 2\cos\alpha$$

$$|G|^2 = (X_D - X_L)^2 + (Y_D - Y_L)^2 + (Z_D - Z_L)^2,$$

where X_D is the projection of D on the X axis. X_D is obtained from the standard rectangular-to-spherical coordinate system transformation equations, i.e., $X_D = \sin\theta \cos\theta$, since $|\vec{D}| = 1$.

Now $|G|^2 = 2 - 2\cos\alpha$

$\cos\alpha = (2 - |G|^2)/2$

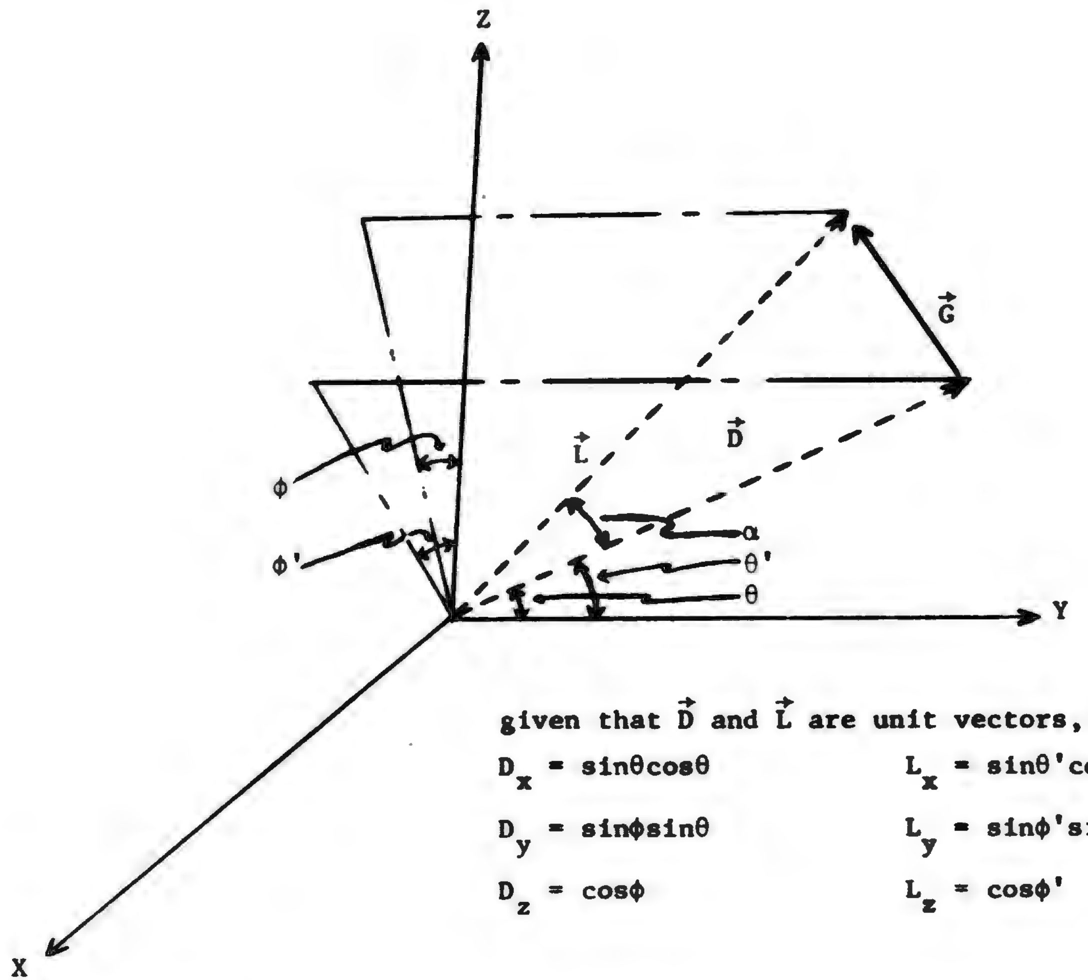
$\cos\alpha = 1 - 1/2\ |G|^2$

Substituting for $|G|^2$ yields the required relationship

$$\alpha = f(\theta,\theta',\phi,\phi')$$

$$\cos\alpha = 1 - 1/2\ \{(\cos\theta - \cos\theta')^2 + (\sin\theta\sin\phi - \sin\theta'\sin\phi')^2 + (\sin\theta\cos\phi - \sin\theta'\cos\phi')^2\}\ . \tag{32}$$

This quantity is then substituted into the integral above, and the quantity $f(\beta)$ calculated. The results are shown on Figure 7 and tabulated in Table 6.



given that $\vec{D}$ and $\vec{L}$ are unit vectors, then

$D_x = \sin\theta\cos\theta \qquad L_x = \sin\theta'\cos\theta'$

$D_y = \sin\phi\sin\theta \qquad L_y = \sin\phi'\sin\theta'$

$D_z = \cos\phi \qquad L_z = \cos\phi'$

Figure 6. Geometry Integration Procedure

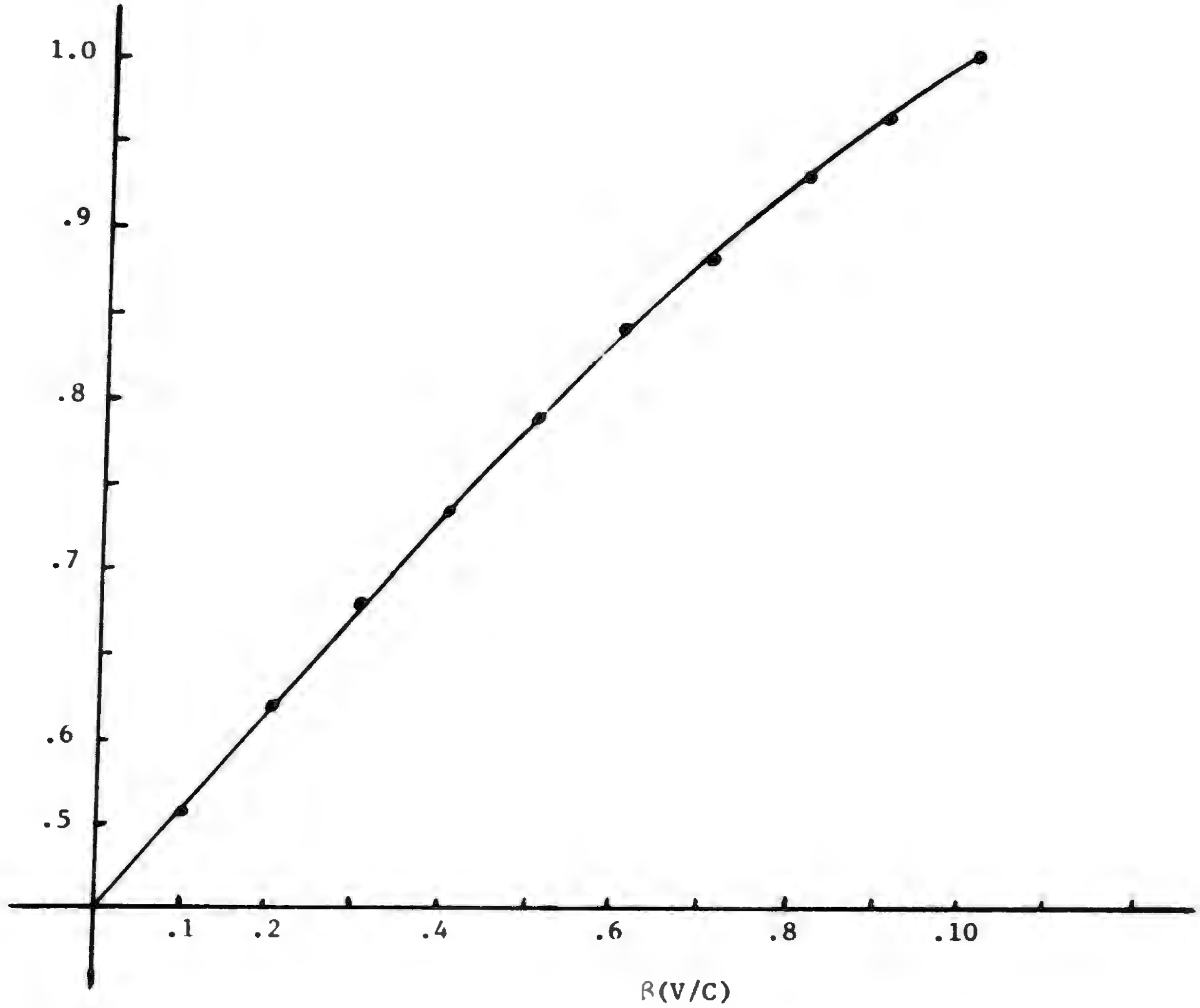


Figure 7. Angular Distribution Function for Bremsstrahlung

TABLE 6. ANGULAR DISTRIBUTION

$\beta = V/C$	$f(\beta)$
0.0	0.5
0.1	0.56
0.2	0.62
0.3	0.68
0.4	0.73
0.5	0.79
0.6	0.84
0.7	0.88
0.8	0.93
0.9	0.96
1.0	1.0

Case II - Surface Production: For the surface production option of the bremsstrahlung code, all the gammas are produced on the surface of the outer shield, and the radiation transport becomes one of simple attenuation. The energy transmission function for this case is

$$A(\gamma) = \prod_{i=1}^{NL} e^{-\mu_i(\gamma)t_i} \qquad (33)$$

corresponding to the C(E,γ) in the volume production case The rest of the calculations are performed in the same manner, and the resulting dose conversion factors are calculated and presented in the same format as in the volume production case.

The card deck set up for BREMSS is explained in Figure 8 and Table 7. If the vehicle information is stored on Tape 8 and all of the materials used are on the standard list (Table 8), only the first card is needed to run a problem. The material attenuation coefficients, buildup factors, and electron data must be entered for each material not on the standard list. There must also be NP vehicle descriptions.

The detailed vehicle description is given in Section VI, as it is the same for all three transport codes. Program MEVDP is also explained there as it writes Tape 8 for use with the transport codes. Appendix A has all of the energy grids for inputting the material information.

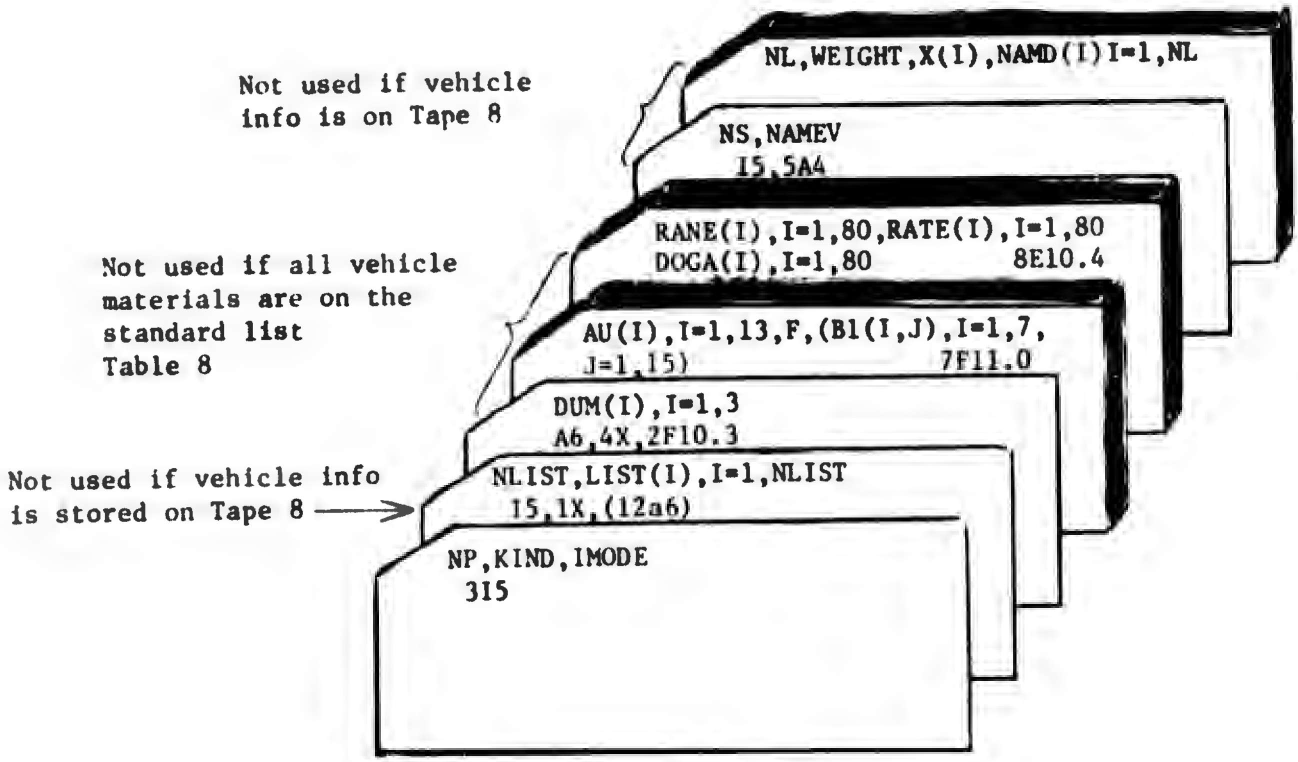


Figure 8. BREM$S Card Input Schematic

TABLE 7. BREMSS CARD INPUT

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
1	NP		BREMSS	I5	1-5	Number of vehicle problems
1	KIND	= 0	BREMSS	I5	6-10	Surface production case
		= 1				Volume production case
1	IMODE	= 0	BREMSS	I5	11-15	Vehicle data on cards
		= 1				Vehicle data on Tape 8
2	NLIST	IMODE = 0	BREMSS	I5	1-5	Number of vehicle materials
2	LIST(1)	IMODE = 0	BREMSS	12A6	7-12	Vehicle material names
2	LIST(2)				13-18	
2	LIST(3)→NLIST				etc	
3	DUM(1)	Material not on standard list	DATA	A6	1-6	Material name
3	DUM(2)		DATA	F10.3	11-20	Material atomic number
3	DUM(3)		DATA	F10.3	21-30	Material atomic weight
4	AU(1)	Material not on standard list	DATA	7F11.0	1-11	Material mass attenuation coefficients
4	AU(2)				12-22	
4	AU(3)→NEN				etc	
4	F		DATA	11.0	67-77	Dummy variable
4	B1(1)		DATA	7F11.0	1-11	Material buildup factors
4	B1(2)				12-22	
4	B1(3)→NMUT				etc	
5	RANE(1)	Material not on standard list	DATA	8E10.4	1-10	Material electron ranges
5	RANE(2)				11-20	
5	RANE(3)→N				etc	
5	RATE(1)		DATA	8E10.4	1-10	Material dE/dX (collision only)
5	RATE(2)				11-20	
5	RATE(3)→N				etc	
5	DOGA(1)		DATA	8E10.4	1-10	Material dE/dX (with BREMSS)
5	DOGA(2)				11-20	
5	DOGA(3)→N				etc	
(Repeat 3, 4, and 5 for all materials not on the standards list - Table 7)						
6-7	Vehicle Description	IMODE = 0	VEIN	-		Described in detail in Section VI
(Repeat 6-7 NP times)						

TABLE 8. STANDARD MATERIAL LIST FOR AFWL BREMSSTRAHLUNG CODE

PROGRAM SYMBOL	Z	A	MATERIAL
AL	13	26.97	Aluminum
AU	79	197.2	Gold
BE	4	9.02	Beryllium
C	6	12.01	Carbon
CA	20	40.08	Calcium
CR	24	52.01	Chromium
CU	29	63.57	Copper
H_2O	10	18.00	Water
LUCIT	6.6	100.11	Lucite
MG	12	24.5	Magnesium
MN	25	54.94	Manganese
N	7	14.008	Neon
NI	28	58.71	Nickel
PB	82	207.21	Lead
POLYE	6	12.05	Polyethylene
POLYS	10	128.05	Polystyrene
RENE	28	55.85	Rene
SN	50	118.7	Tin
TISSUE	6.92	127.2	Human tissue
W	74	183.92	Tungsten

SECTION VI
VEHICLE DESCRIPTION

The three transport codes, HEVPRT, EPENSS, and BREMSS, require the vehicle, through which the external environment is transported to the internal dose point, to be sectored into a series of infinite slab layers. One sector is a portion of the vehicle subtended by a solid angle $d\Omega$, with the center of the coordinate system being the dose point of interest. A ray extending from the dose point at the center of the solid angle encounters the materials of the vehicle between the dose point and the exterior. When these are ordered by material and thickness from the outside to the inside, it is in the layered format needed by the transport codes.

Two ways of inputting this data are available. One is to input the sectoring information on cards. For simple vehicles this is relatively easy. For complicated vehicles the Modified Elemental Volume Dose Program (MEVDP) (Ref. 14) must be used. MEVDP creates a binary tape with the sectored layered information. This tape is then read by the transport codes.

Figure 9 and Table 9 show the input formats for entering the vehicle information on cards. A new vehicle description must be entered for each new problem. The material layers are ordered from the outside to the inside dose point. The solid angle is normalized so that the sum of all the solid angles will equal one. Only a few ray sectors may be needed to describe a simple vehicle while hundreds may be needed to adequately describe a complicated vehicle.

When MEVDP is used, the vehicle is first described by a series of regular geometric shapes (spheres, hemispheres, parallelepipeds, cones, cylinders, ellipsoids, truncated cones, and truncated ellipsoids). The sectoring is begun by choosing a convenient point

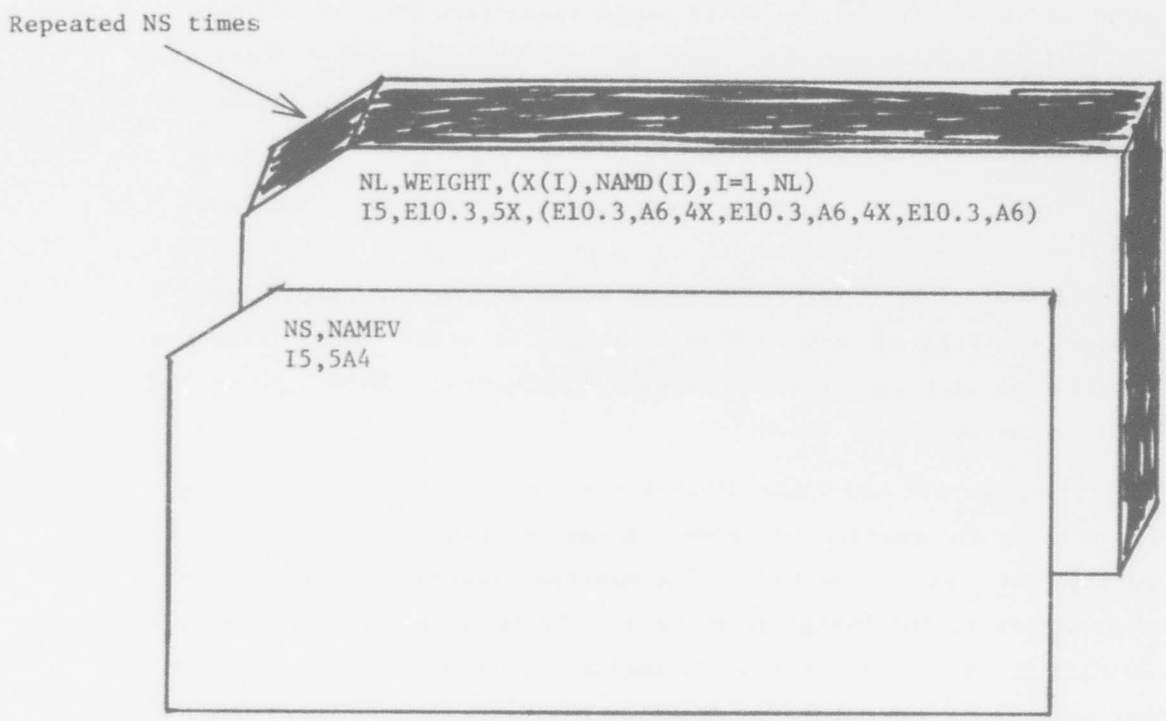


Figure 9. Vehicle Card Input Schematic

TABLE 9. VEHICLE CARD INPUT

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
1	NS	IMODE = 0	VEIN	I5	1-5	Number of sectors in vehicle
1	NAMEV	IMODE = 0	VEIN	5A4	6-25	Vehicle name
2	NL	IMODE = 0	VEIN	I5	1-5	Number of shield layers in the sector
2	WEIGHT	IMODE = 0	VEIN	E10.3	6-15	Solid angle of sector normalized to one
2	X(1)	IMODE = 0	VEIN	E10.3	21-30	Thickness of Ith layer (GM/SQCM)
2	NAMD(1)	IMODE = 0	VEIN	A6	31-36	Material name of Ith layer
2	X(2)				41-50	
2	NAMD(2)				51-56	
2	X(3)				61-70	
2	NAMD(3)				71-76	
2	X(4)				1-10	
2	NAMD(4)				11-16	
2	X(5)				etc	
2	NAMD(5)				etc	

(Repeat 2 NS times)

(Repeat 1 and 2 for each vehicle problem) within the vehicle for the origin of a reference rectangular coordinate system. The spacecraft is then described with respect to this reference system by designating the shape, size, and material density of the various components making up the vehicle. Once set up in this manner, any dose point may be selected either inside or outside of the spacecraft and the vehicle sectored by tracing rays emanating from the dose point (see Fig. 10). The material types and thicknesses encountered as these rays pass through the geometric shapes representing the vehicle are taken to be representative of the material distribution. One sector is generated by each ray traced and consists of one or more parallel slabs of varying thickness and material composition. The vehicle is "mapped" by changing direction cosines of the ray, incrementing these in turn until all 4π steradians have been covered. The increment size determines the solid angle which a sector subtends. For a complex vehicle, this type of analysis may require that a very large number of rays be traced.

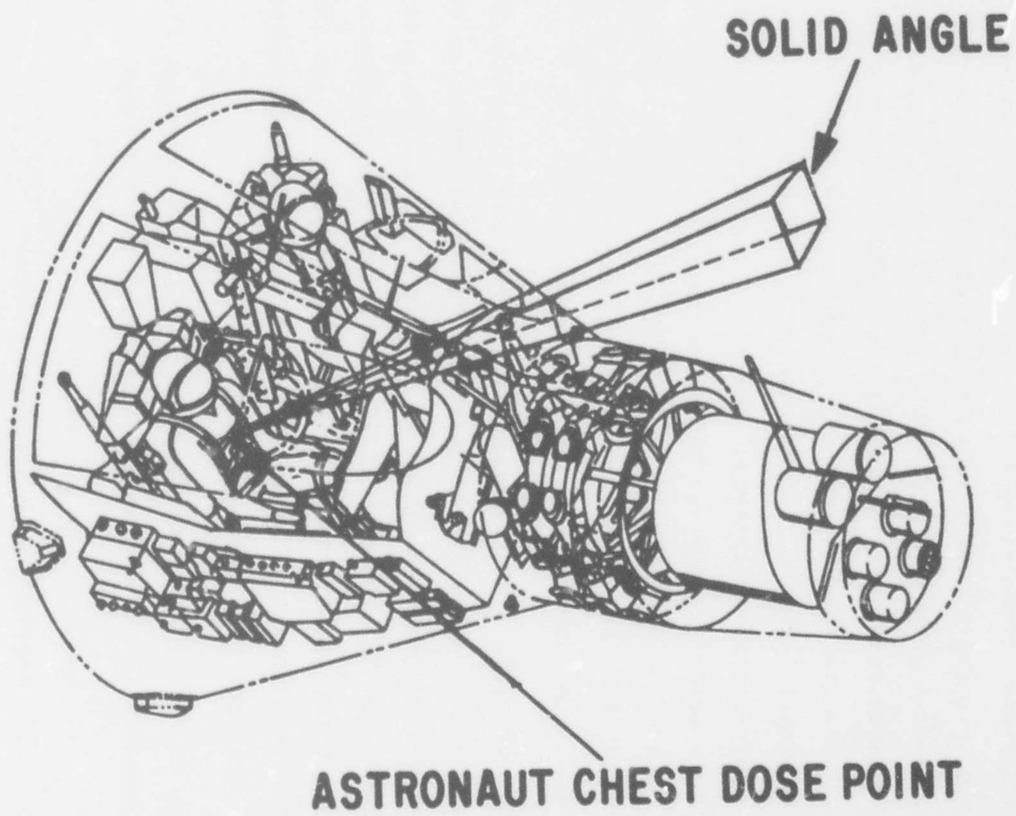


Figure 10. Vehicle Layered Sectoring Schematic

SECTION VII
TANDE

Program TANDE is the code which calculates the trajectory, finds the environment associated with that trajectory, and merges the environment with the Dose Conversion Factors (DCFs) calculated by the transport codes to obtain the dose rate and dose results. TANDE first either calculates a trajectory from the initial orbital parameters, reads a point set trajectory from cards or uses a previously calculated trajectory stored on tape. The trajectory points are then converted to the McIlwain B-L parameters (Ref. 10) by the INVAR subroutine package. Vette's electron and proton flux maps are used to obtain the omnidirectional integral fluxes for the DCF energy grid at each trajectory point. These are then converted to differential fluxes and multiplied by the corresponding DCFs. These are then summed to obtain the dose rate at each trajectory point. The accumulated dose is then obtained by integrating over time.

The calculation of the geographic and magnetic coordinates in the approximation of secularly perturbed Keplerian orbits or the use of point set trajectories (time in seconds after launch, altitude, latitude, and longitude) fulfills the accuracy requirements to within the error limits which are generally associated with the environment. As a result of neglecting other perturbing influences, substantial computer time savings occur.

The secular changes in the orbital elements caused by the earth's oblateness which have been taken into account include

(1) Reduction in orbital period
(2) Regression in the line of nodes
(3) Precession of line of apsides in the orbital plane.

To this order of accuracy the geographic position and time after initial perigee of a satellite are given by

$$r = \frac{\ell}{1 + E \cos\psi} \tag{34}$$

$$\theta = \cos^{-1} \{\sin i \sin(\beta + \psi)\}$$

$$\phi = \begin{cases} \Omega + \tan^{-1}\{\cos i \tan(\beta + \psi)\} \text{ if } \cos(\beta + \psi) > 0 & (35) \\ \Omega + \pi + \tan^{-1}\{\cos i \tan(\beta + \psi)\} \text{ if } \cos(\beta + \psi) < 0 & (36) \end{cases}$$

$$t = \frac{PM}{2\pi} = \frac{P}{2\pi} \{E - \varepsilon \sin E\} \tag{37}$$

(see Figure 11.)

where

r = } geocentric radius

θ = } geocentric colatitude

ϕ = } geocentric longitude

ℓ = semilatus rectum

i = inclination

ε = eccentricity of orbit

P = anomolous period

Ψ = true anomaly

M = mean anomaly

E = eccentric anomaly

Ω = longitude of ascending mode

β = argument of the perigee

The relationships of these quantities (Figure 11) to the input quantities (apogee altitude h_a, perigee altitude h_p, initial latitude Λ_o, initial longitude ϕ_o) which are used to specify an orbit are given by the relationships below (Ref. 21):

$$E = 2 \tan^{-1} \sqrt{\frac{1 - \varepsilon}{1 + \varepsilon}} \tan \frac{\Psi}{2} \tag{38}$$

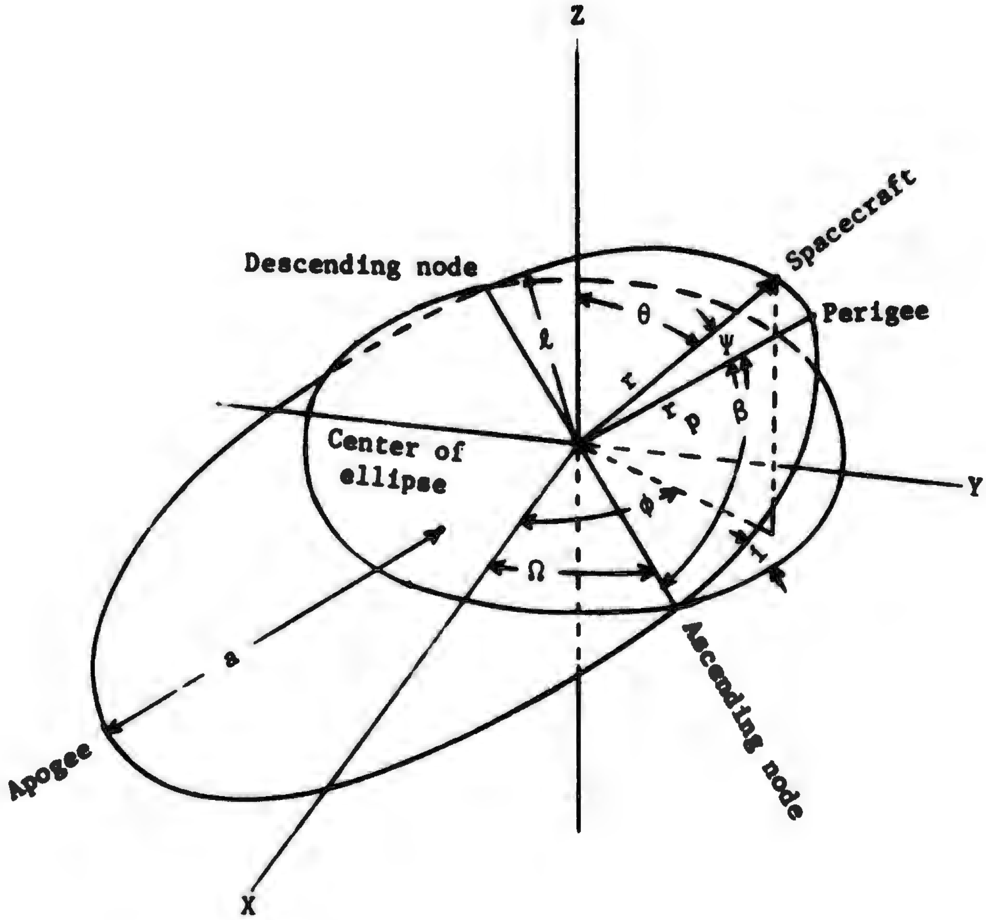


Figure 11. Orbit Geometry

$$\varepsilon = \frac{h_a - h_p}{2R_e + h_a + h_p} = \frac{h_a - h_p}{2a} \quad (39)$$

$$\ell = a(1 - \varepsilon^2) \quad (40)$$

$$P = \frac{2\pi a^{3/2}}{k_e} \frac{1}{1 + (R_e/\ell)^2 J' \sqrt{1 - \varepsilon^2}(1 - \frac{3}{2}\sin^2 i)} \quad (41)$$

$$k_e = 1.9965 \times 10^{-2} (Mm)^{3/2}/sec \quad (42)$$

$$\beta = \beta_o + J'k_e t(R_e/\ell)^2(2 - \frac{5}{2}\sin^2 i)/a^{3/2} \quad (43)$$

$$J' = (3/2)(R_{eq}/R_e)^2 J_2 = 1.63197 \times 10^{-3} \quad (44)$$

$$\Omega = \Omega_o - \omega_e t - J'k_e t(R_e/\ell)^2 \cos i/(a^{3/2}) \quad (45)$$

$$\Omega_o = \phi_o - \tan^{-1}(\cos i \tan \beta_o) \quad (46)$$

$$\beta_o = \sin^{-1}(\cos \theta_o/\sin i) \quad (47)$$

where the initial heading determines the quadrant of the inclination angle i. For example, a southeasterly initial heading places the inclination angle in the fourth quadrant. The quantities R_e and R_{eq} are, respectively, the mean and equatorial radii of the earth.

These expressions give the approximate position for bound orbits. The circular orbit case follows from these by setting $\varepsilon = 0$. Since the resulting equations are quite simple for this special case, extraneous computations of ℓ, ε, E, and α have been avoided by programming the circular case separately.

Once the spacecraft position has been defined either as a point set trajectory or as an analytic Keplerian orbit, the environment must be specified so that dose calculations can be made. In TANDE the environment is specified as a function of B and L, as the use of magnetic coordinates simplifies the description of the environment. B and L values are calculated for each orbital position and saved for use in the environment calculations.

The magnetic coordinates are the magnetic flux density B and the shell parameter L developed by McIlwain and are directly related to the first two invariants to the motion for trapped particle radiation. L is the magnetic shell parameter that labels the shell upon which the guiding center of the trapped particles is adiabatically confined as it drifts around the earth. McIlwain has shown that L is approximately constant along the real magnetic field line. In a dipole field, L is rigorously constant along the field line and has the geometric property of being equal to the equatorial distance from the dipole center to the field line. The B surfaces and L surfaces for a dipole field are shown in Figure 12. For the real field these smooth, symmetrical surfaces are warped and asymmetrical, particularly at low altitudes.

Vette's latest electron and proton maps (Refs. 3 to 9) are used to obtain the omnidirectional integral fluxes at each B-L point. The electron maps used are AE4 for L value greater than 2.8 and AE5 for L values less than or equal to 2.8. A smoothed proton map is used. It is made up of AP1, AP5, AP6, and AP7. A modified version of Program MODEL (Ref. 5) is used by TANDE.

The differential flux is obtained for the bin which has EGRID(I) as the mid-point by

$$\mathrm{DFLUX} = \frac{\mathrm{FLUX}_{i-1} - \mathrm{FLUX}_{i+1}}{\mathrm{EGRID}_{i+1} - \mathrm{EGRID}_{i-1}} \tag{48}$$

where FLUX_i is the integral flux at energy EGRID_i.

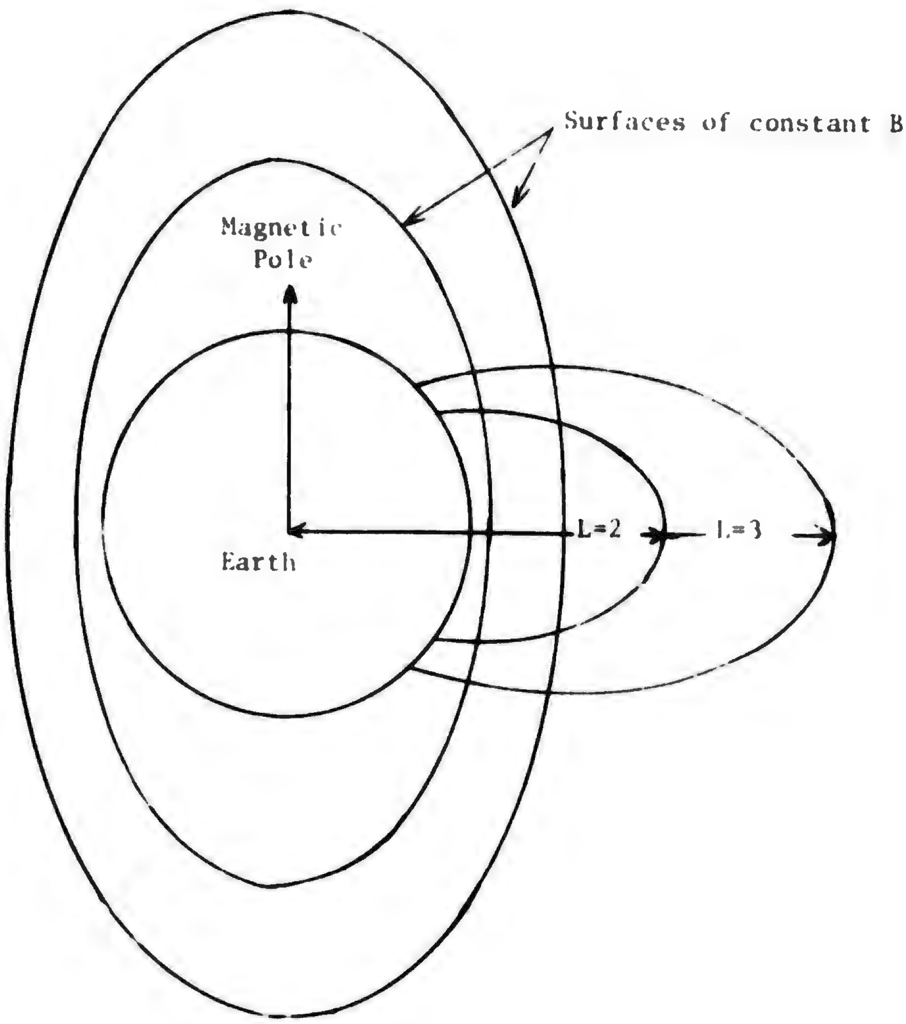


Figure 12. The Geometry of the B-L Coordinate System

The dose rate in rads/hr at this point is given by:

$$\text{DOSE RATE} = \sum_{i=1}^{\text{NGRID}} \text{DCF}_i * \text{DFLUX}_i \qquad (49)$$

where NGRID is the number of DCF energy values. The accumulated dose for a given trajectory is given by:

$$\text{DOSE} = \sum_{i=1}^{N} (T_i - T_{i-1}) \frac{\text{DOSER}_i + \text{DOSER}_{i-1}}{2} \qquad (50)$$

where DOSER_i is the dose rate at time T_i.

The card input deck for TANDE is as shown in Figure 13 and Table 10. Since it is possible to do many different types of problems, the input deck may vary a great deal from one problem to the next. It is possible to save a trajectory with B, L, R, and Lambda already calculated by requesting Tape 7 as a physical tape. This tape may then be run with different shielding dose conversion factors. This saves recomputing the trajectory.

Any combination of proton, electron, and bremsstrahlung DCFs may be used for a given problem. The dose and dose rates for each particle and the total dose and dose rate of all particles used in this problem will be printed when the environment printout is called for. The integral fluxes and fluences for five energies are also printed.

The DCFs are punched by the transport codes and are in the proper format to be read by TANDE. They must be inserted in the proper order when more than one particle is used in a problem. The order is first, protons; second, electrons; and third, bremsstrahlung.

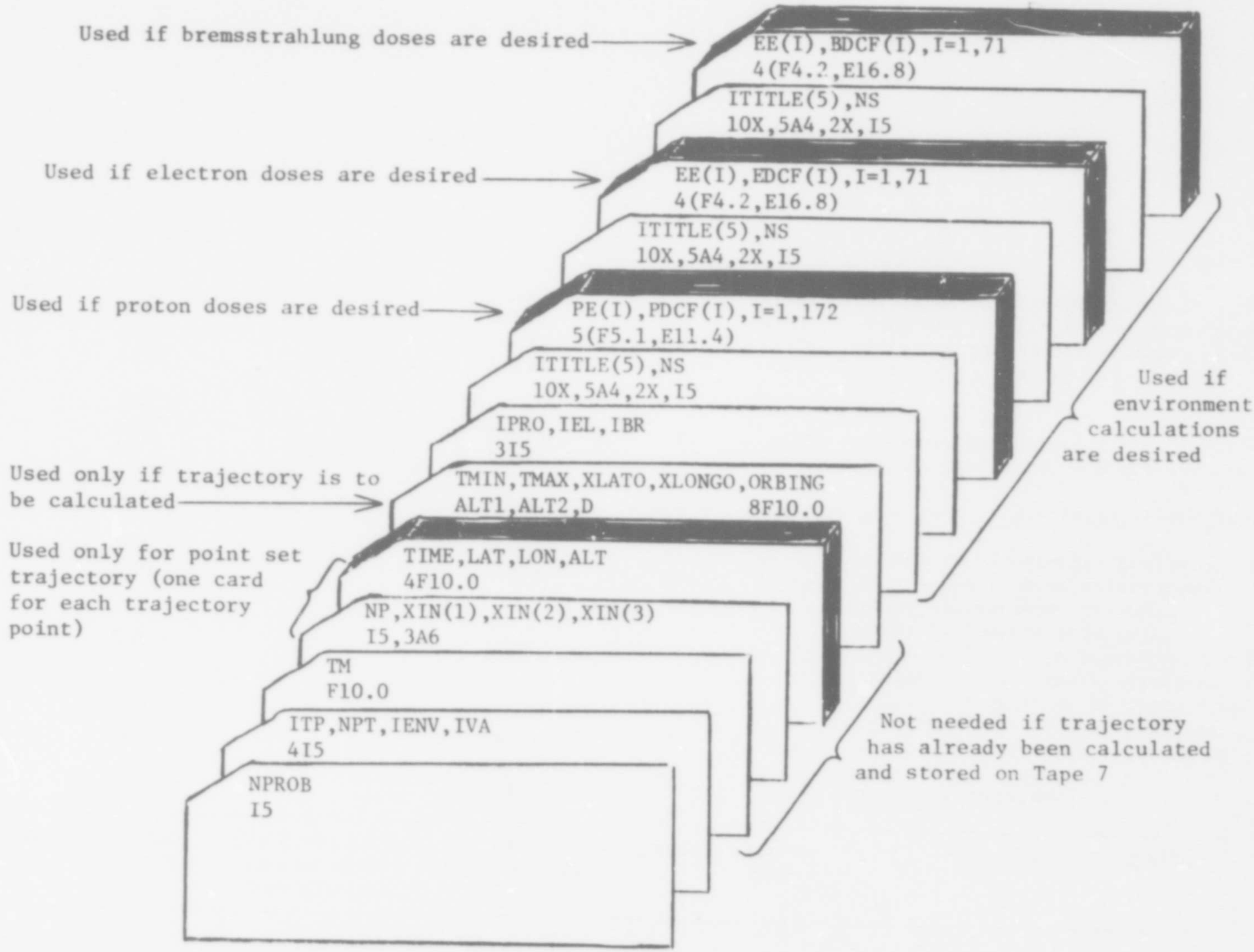


Figure 13. TANDE Card Input Schematic

TABLE 10. TANDE CARD INPUT

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
1	NPROB		TANDE	I5	1-5	Number of problems
2	ITP	= 1	TANDE	I5	1-5	Point set trajectory (entered on cards)
		= 2				Circular orbit to be calculated
		= 3				Elliptical orbit to be calculated
		= 4				Trajectory previously calculated (Tape 7)
2	NPT	= 1	TANDE	I5	6-10	Print trajectory & environment info
		= 2				Print trajectory info only
		= 3				Print environment info only
2	IENV	= 1	TANDE	I5	11-15	Do the environment calculations
2	IVA	= 1	TANDE	I5	16-20	Employ the geographic exclusion test
3	TM	ITP ≠ 4	TANDE	F10.0	1-10	Time used in B-L calculations (years)
4	NP	ITP = 1	PTRAJ	I5	1-5	Number of points in point set trajectory
4	XIN(I), I=1,3	ITP = 1	PTRAJ	3A6	6-23	Title of trajectory
5	TIME	ITP = 1	PTRAJ	F10.0	1-10	Time after insertion in seconds
5	LAT	ITP = 1	PTRAJ	F10.0	11-20	Latitude of trajectory point (degrees)
5	LON	ITP = 1	PTRAJ	F10.0	21-30	Longitude of trajectory point (degrees)
5	ALT	ITP = 1	PTRAJ	F10.0	31-40	Altitude of trajectory point (KM)

(Repeat 5 NP times)

TABLE 10. (CONTINUED)

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
6	TMIN		TANDE	F10.0	1-10	Initial time of calculation (sec. after launch)
6	TMAX		TANDE	F10.0	11-20	Final time of calculation (sec. after launch)
6	XLATO	ITP = 2	TANDE	F10.0	21-30	Insertion latitude
6	XLONGO	or	TANDE	F10.0	31-40	Insertion longitude
6	ORBINC	ITP = 3	TANDE	F10.0	41-50	Orbital inclination
6	ALT1		TANDE	F10.0	51-60	Perigee
6	ALT2		TANDE	F10.0	61-70	Apogee
6	D		TANDE	F10.0	71-80	Increment between trajectory points (in seconds for circular; radians for elliptical)
IENV MUST EQUAL ONE FOR ANY OF THE FOLLOWING CARDS TO BE INCLUDED						
7	IPRO	= 1	ENVIRN	I5	1-5	Proton DCFs provided
7	IEL	= 1	ENVIRN	I5	6-10	Electron DCFs provided
7	IBR	= 1	ENVIRN	I5	11-15	Bremsstrahlung DCFs provided
8	ITITLE	IPRO = 1	DUMMY	5A4	11-30	Title of proton DCFs
8	NS	IPRO = 1	DUMMY	I5	33-37	Number of sectors in shielding analysis
9	PE(1)	IPRO = 1	DUMMY	F5.1	1-5	Proton DCF energy value (172 values)
9	PDCF(1)	IPRO = 1	DUMMY	E11.4	6-16	Proton dose conversion factor for PE(1)
9	PE(2)				17-21	
9	PDCF(2)				22-32	
9	PE(3)→N				etc	
9	PDCF(3)→N					

TABLE 10. (CONTINUED)

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
10	ITITLE	IEL = 1	DUMMY	5A4	11-30	Title of electron DCFs
10	NS	IEL = 1	DUMMY	I5	33-37	Number of sectors in shielding analysis
11	EE(1)	IEL = 1	DUMMY	F4.2	1-4	Electron DCF energy values (71 values)
11	EDCF(1)	IEL = 1	DUMMY	E16.8	5-20	Electron dose conversion factor for EE(1)
11	EE(2)				21-24	
11	EDCF(2)				25-40	
11	EE(3)→N					
11	EDCF(3)→N				etc	
12	ITITLE	IBR = 1	DUMMY	5A4	11-40	Title of Bremsstrahlung DCFs
12	NS	IBR = 1	DUMMY	I5	33-37	Number of sectors in shielding analysis
13	EE(1)	IBR = 1	DUMMY	F4.2	1-4	Brems DCF energy values (71 values)
13	BDCF(1)	IBR = 1	DUMMY	E16.8	5-20	Brems dose conversion factor for EE(1)
13	EE(2)				21-24	
13	BDCF(2)				25-40	
13	EE(3)→N					
13	BDCF(3)→N				etc	

(Repeat 2-10 NPROB times)

SECTION VIII
DOSMAP

Program DOSMAP is a modified version of Vette's Program MODEL (Ref. 5). This program finds the dose rates for 700 B-L points behind a shielding distribution produced by the transport codes. The 700-point B-L grid is given in Appendix B. The dose rate calculation is done the same way as it is done in Program TANDE.

The card deck setup is as shown in Figure 14 and Table 11. Any combination of shielding distributions for protons, electrons, or bremsstrahlung may be used in a given problem. The dose rate map will be the sum of whichever particles are called for. When both electron and brems DCFs are used in the same problem, their DCFs are added so that Vette's electron maps only need be called once to get the dose rate for electrons and bremsstrahlung.

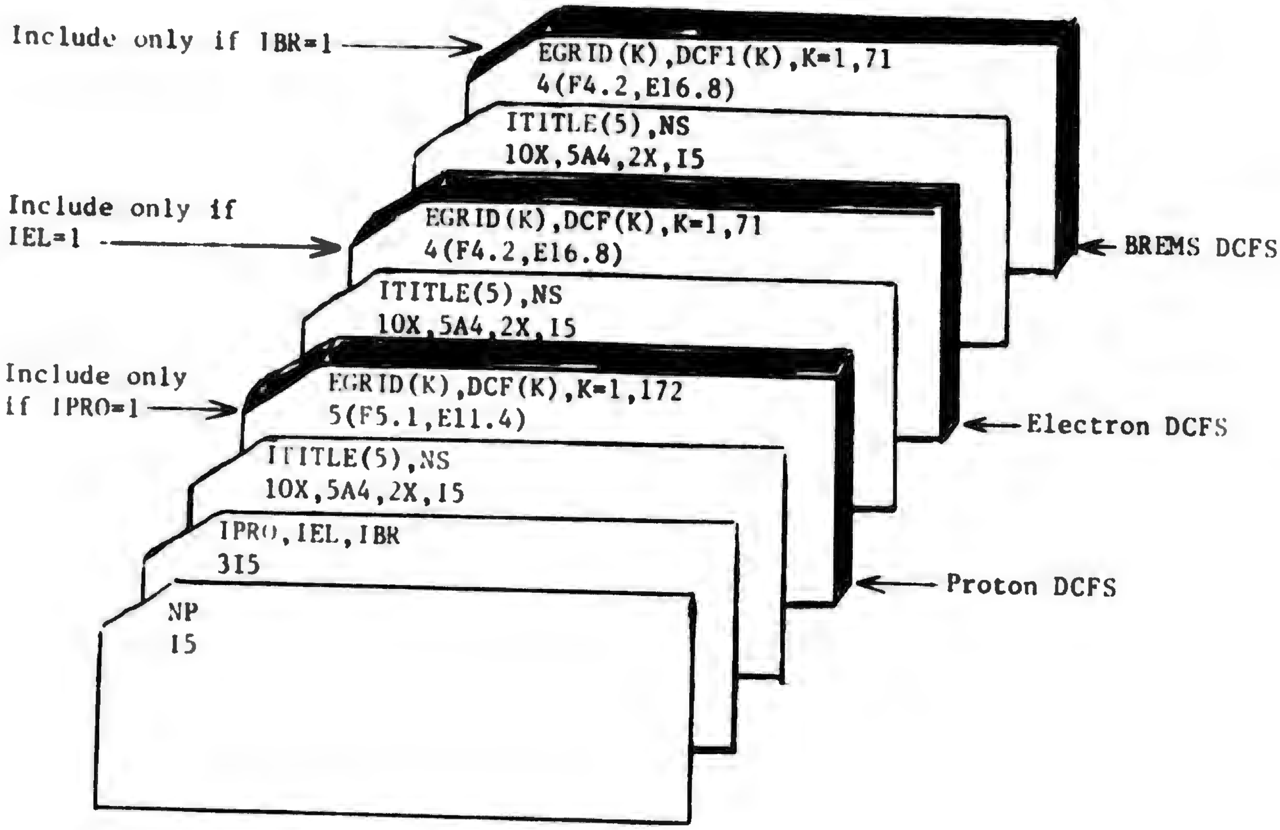


Figure 14. DOSMAP Card Input Schematic

TABLE 11. DOSMAP CARD INPUT

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
1	NP		DOSMAP	I5		Number of problems
2	IPRO	= 1	DOSMAP	I5		Proton shielding provided
2	IEL	= 1	DOSMAP	I5		Electron shielding provided
2	IBR	= 1	DOSMAP	I5		Bremsstrahlung shielding provided
3	ITITLE	IPRO = 1	DUMMY	5A4	11-30	Title of proton DCFs
3	NS	IPRO = 1	DUMMY	I5	33-37	Number of sectors in shielding analysis
4	PE(1)	IPRO = 1	DUMMY	F5.1	1-5	Proton DCF energy value (172 values)
4	PDCF(1)	IPRO = 1	DUMMY	E11.4	6-16	Proton dose conversion factor for PE(1)
4	PE(2)				17-21	
4	PDCF(2)				22-32	
4	PE(3)→N				etc	
4	PDCF(3)→N					
5	ITITLE	IEL = 1	DUMMY	5A4	11-30	Title of electron DCFs
5	NS	IEL = 1	DUMMY	I5	33-37	Number of sectors in shielding analysis
6	EE(1)	IEL = 1	DUMMY	F4.2	1-4	Electron DCF energy values (71 values)
6	EDCF(1)	IEL = 1	DUMMY	E16.8	5-20	Electron dose conversion factor for EE(1)
6	EE(2)				21-24	
6	EDCF(2)				25-40	
6	EE(3)→N					
6	EDCF(3)→N				etc	

TABLE 11. (CONTINUED)

CARD SEQUENCE	VARIABLE NAME	CONDITION FOR INCLUSION OR PARAMETER VALUE	ROUTINE WHERE VARIABLE READ	FORMAT	CARD COLUMNS	VARIABLE DESCRIPTION
7	ITITLE	IBR = 1	DUMMY	5A4	11-30	Title of Bremsstrahlung DCPs
7	NS	IBR = 1	DUMMY	I5	33-37	Number of sectors in shielding analysis
8	EE(1)	IBR = 1	DUMMY	F4.2	1-4	Brems DCF energy values (71 values)
8	BDCF(1)	IBR = 1	DUMMY	E16.8	5-20	Brems dose conversion factor for EE(1)
8	EE(2)				21-24	
8	BDCF(2)				25-40	
8	EE(3)→N				etc	
8	BDCF(3)→N					

(Repeat 2-8 NPROB times)

APPENDIX A

ENERGY GRIDS

Proton Range and dE/dX Energy Grids for HEVPRT

0., .1, .15,

.2	to	.9	by	.1	MeV Increments
1.2	to	2.8	by	.4	MeV Increments
3.4	to	4.6	by	.6	MeV Increments
5.5	to	10.0	by	1.5	MeV Increments
13.	to	19.	by	3.	MeV Increments
24.	to	36.	by	6.	MeV Increments
45.	to	75.	by	15.	MeV Increments
100.	to	580.	by	30.	MeV Increments
620.	to	860.	by	60.	MeV Increments
1000.					

Mass Attenuation Coefficient Energy Grid for BREMSS

.01, .02, .05, .1, .2, .5, 1., 2., 3., 4., 6., 8., 10.

Buildup Factor Mean-Free-Paths for Each Mass Attenuation Coefficient Energy Used in BREMSS

1, 2, 4, 7, 10, 15, 20

Proton DCF Energy Grid

1. to 179. by 2. MeV Increments

185. to 995. by 10. MeV Increments

Electron and Bremsstrahlung DCF Energy Grid

.1 to 1.0 by .05 MeV Increments

1.1 to 5.0 by .1 MeV Increments

5.25 to 8.0 by .25 MeV Increments

Electron Range and DE/DX Energy Grids for EPENSS and BREMSS

.01 to .10 by .005 MeV Increments

.15 to 1.0 by .05 MeV Increments

1.1 to 2.0 by .1 MeV Increments

2.2 to 3.0 by .2 MeV Increments

3.5 to 10.0 by .5 MeV Increments

20. to 60.0 by 10. MeV Increments

80. ,

100. to 600. by 100. MeV Increments

800., 1000.

APPENDIX B

B-L GRID FOR DOSMAP

B VALUES FOR L 1.20	B VALUES FOR L 1.25	B VALUES FOR L 1.30
.1804	.1596	.1419
.1830	.1630	.1470
.1850	.1670	.1510
.1870	.1710	.1560
.1900	.1740	.1610
.1920	.1780	.1660
.1950	.1820	.1700
.1970	.1860	.1750
.1990	.1890	.1800
.2020	.1930	.1850
.2040	.1970	.1890
.2070	.2000	.1940
.2090	.2040	.1990
.2110	.2080	.2040
.2140	.2110	.2080
.2160	.2150	.2130
.2180	.2190	.2180
.2210	.2230	.2230
.2250	.2260	.2270
.2280	.2300	.2320

B VALUES FOR L 1.35	B VALUES FOR L 1.40	B VALUES FOR L 1.45
.1267	.1136	.1022
.1320	.1200	.1100
.1380	.1260	.1170
.1440	.1330	.1240
.1490	.1400	.1310
.1550	.1460	.1390
.1610	.1530	.1460
.1660	.1590	.1530
.1720	.1660	.1610
.1780	.1720	.1680
.1830	.1790	.1750
.1890	.1850	.1830
.1940	.1920	.1900
.2000	.1980	.1970
.2060	.2050	.2040
.2110	.2110	.2120
.2170	.2180	.2190
.2230	.2240	.2260
.2280	.2310	.2340
.2340	.2370	.2410

B VALUES FOR L 1.50	B VALUES FOR L 1.60	B VALUES FOR L 1.70
.0923	.0761	.0634
.1000	.0850	.0740
.1080	.0950	.0840
.1160	.1040	.0950
.1240	.1130	.1050
.1320	.1220	.1150
.1400	.1320	.1260
.1480	.1410	.1360
.1560	.1500	.1470
.1640	.1590	.1570
.1720	.1690	.1670
.1800	.1780	.1780
.1880	.1870	.1880
.1960	.1960	.1990
.2040	.2060	.2090
.2120	.2150	.2190
.2200	.2240	.2300
.2280	.2330	.2400
.2360	.2430	.2510
.2440	.2520	.2610

B VALUES FOR L 1.80	B VALUES FOR L 1.90	B VALUES FOR L 2.00
.0534	.0454	.0390
.0650	.0570	.0520
.0760	.0690	.0640
.0870	.0810	.0770
.0990	.0930	.0890
.1100	.1050	.1010
.1210	.1170	.1140
.1320	.1290	.1270
.1440	.1410	.1400
.1550	.1530	.1520
.1660	.1650	.1650
.1780	.1770	.17[illegible]0
.1890	.1890	.1900
.2000	.2010	.2030
.2120	.2130	.2150
.2230	.2250	.2280
.2340	.2370	.2400
.2450	.2490	.2530
.2570	.2610	.2650
.2680	.2730	.2780

B VALUES FOR L 2.20	B VALUES FOR L 2.40	B VALUES FOR L 2.60
.0293	.0225	.0177
.0430	.0370	.0340
.0570	.0520	.0500
.0710	.0670	.0650
.0850	.0820	.0810
.0990	.0960	.0970
.1130	.1110	.1130
.1270	.1260	.1290
.1410	.1410	.1450
.1550	.1550	.1610
.1690	.1700	.1770
.1830	.1850	.1930
.1970	.2000	.2090
.2110	.2140	.2250
.2250	.2290	.2400
.2390	.2440	.2560
.2530	.2590	.2720
.2670	.2730	.2880
.2810	.2880	.3040
.2900	.3030	.3200

B VALUES FOR L 2.80	B VALUES FOR L 3.00	B VALUES FOR L 3.20
.0142	.0115	.0095
.0310	.0200	.0200
.0480	.0300	.0300
.0660	.0400	.0400
.0830	.0500	.0500
.1000	.0700	.0700
.1170	.1000	.1000
.1340	.1200	.1200
.1510	.1500	.1500
.1690	.1900	.1900
.1860	.2200	.2200
.2030	.2600	.2600
.2200	.2900	.2900
.2370	.3200	.3300
.2540	.3600	.3600
.2710	.3900	.4000
.2890	.4300	.4300
.3060	.4700	.4800
.3220	.5200	.5200
.3400	.5800	.5850

B VALUES FOR L 3.40	B VALUES FOR L 3.60	B VALUES FOR L 4.00
.0079	.0067	.0049
.0100	.0100	.0100
.0300	.0300	.0200
.0400	.0400	.0400
.0500	.0500	.0500
.0700	.0700	.0700
.1000	.1000	.0900
.1200	.1200	.1200
.1500	.1500	.1500
.1900	.1900	.1900
.2200	.2200	.2200
.2600	.2600	.2600
.2900	.2900	.3000
.3300	.3300	.3300
.3600	.3700	.3700
.4000	.4000	.4000
.4300	.4400	.4400
.4800	.4800	.4800
.5200	.5300	.5300
.5880	.5930	.5960

B VALUES FOR L 4.50	B VALUES FOR L 5.00	B VALUES FOR L 5.50
.0034	.0025	.0019
.0100	.0100	.0100
.0200	.0200	.0200
.0300	.0300	.0300
.0500	.0500	.0400
.0700	.0700	.0700
.0900	.0900	.0900
.1200	.1200	.1200
.1500	.1500	.1500
.1900	.1900	.1900
.2200	.2200	.2200
.2600	.2600	.2600
.3000	.3000	.3000
.3300	.3300	.3300
.3700	.3700	.3700
.4000	.4000	.4000
.4400	.4400	.4400
.4900	.4900	.4900
.5300	.5400	.5400
.5990	.6000	.6010

B VALUES FOR L 6.00	B VALUES FOR L 6.50	B VALUES FOR L 7.00
.0014	.0011	.0009
.0100	.0100	.0100
.0200	.0200	.0200
.0300	.0300	.0300
.0400	.0400	.0400
.0700	.0700	.0700
.0900	.0900	.0900
.1200	.1200	.1200
.1500	.1500	.1500
.1900	.1900	.1900
.2200	.2200	.2200
.2600	.2600	.2600
.3000	.3000	.3000
.3300	.3300	.3300
.3700	.3700	.3700
.4000	.4000	.4000
.4400	.4400	.4400
.4900	.4900	.4900
.5400	.5400	.5400
.6010	.6020	.6020

B VALUES FOR L 7.50	B VALUES FOR L 8.00	B VALUES FOR L 8.50
.0007	.0006	.0005
.0100	.0100	.0100
.0200	.0200	.0200
.0300	.0300	.0300
.0400	.0400	.0400
.0700	.0700	.0700
.0900	.0900	.0900
.1200	.1200	.1200
.1500	.1500	.1500
.1900	.1900	.1900
.2200	.2200	.2200
.2600	.2600	.2600
.3000	.3000	.3000
.3300	.3300	.3300
.3700	.3700	.3700
.4100	.4100	.4100
.4400	.4400	.4400
.4900	.4900	.4900
.5400	.5400	.5400
.6030	.6030	.6035

B VALUES FOR L 9.00	B VALUES FOR L 9.50	B VALUES FOR L 10.00
.0004	.0004	.0003
.0100	.0100	.0100
.0200	.0200	.0200
.0300	.0300	.0300
.0400	.0400	.0400
.0700	.0700	.0700
.0900	.0900	.0900
.1200	.1200	.1200
.1500	.1500	.1500
.1900	.1900	.1900
.2200	.2200	.2200
.2600	.2600	.2600
.3000	.3000	.3000
.3300	.3300	.3300
.3700	.3700	.3700
.4100	.4100	.4100
.4400	.4400	.4400
.4900	.4900	.4900
.5400	.5400	.5400
.6035	.6040	.6040

B VALUES FOR L 10.50	B VALUES FOR L 11.00
.0003	.0002
.0100	.0100
.0200	.0200
.0300	.0300
.0400	.0400
.0700	.0700
.0900	.0900
.1200	.1200
.1500	.1500
.1900	.1900
.2200	.2200
.2600	.2600
.3000	.3000
.3300	.3300
.3700	.3700
.4100	.4100
.4400	.4400
.4900	.4900
.5400	.5400
.6040	.6040

APPENDIX C
SAMPLE INPUT AND OUTPUT

The following pages contain sample input and output for two sample problems. The two shielding vehicles are a simplified aluminum equivalent Apollo Command/Service Module and a "test case" vehicle consisting of five sectors of aluminum and tissue.

HEVPRT SAMPLE INPUT

```
    2     0     0
TISSUE
    2 AL     TISSUE
    5 CHECK
    2 .2               1.         AL         5.         TISSUE
    2 .2               2.         AL         5.         TISSUE
    2 .2               3.         AL         5.         TISSUE
    2 .2               4.         AL         5.         TISSUE
    2 .2               5.         AL         5.         TISSUE
   19 APOLLO
    1 .0027            1.68       AL
    1 .1498            1.81       AL
    1 .0176            3.6        AL
    1 .0038            4.1        AL
    1 .0030            4.2        AL
    1 .0145            5.0        AL
    1.0106             5.7        AL
    1 .0259            7.1        AL
    1 .0650            7.5        AL
    1 .1483            8.5        AL
    1 .0170            9.7        AL
    1 .0837            10.6       AL
    1 .0529            11.0       AL
    1 .0439            13.0       AL
    1 .0712            13.9       AL
    1 .0615            15.6       AL
    1 .0196            17.7       AL
    1 .0577            22.0       AL
    1 .1518            28.0       AL
```

HEVPRT SAMPLE INPUT

SECTORING INFORMATION
VEHICLE NAME APOLLO

```
*************************************************
SECTOR NUMBER    1         NAME          I.D.      X
                       1   AL             1      1.65

*************************************************
SECTOR NUMBER    2         NAME          I.D.      X
                       1   AL             1      1.81

*************************************************
SECTOR NUMBER    3         NAME          I.D.      X
                       1   AL             1      3.60

*************************************************
SECTOR NUMBER    4         NAME          I.D.      X
                       1   AL             1      4.10

*************************************************
SECTOR NUMBER    5         NAME          I.D.      X
                       1   AL             1      4.20

*************************************************
SECTOR NUMBER    6         NAME          I.D.      X
                       1   AL             1      5.00

*************************************************
SECTOR NUMBER    7         NAME          I.D.      X
                       1   AL             1      5.70

*************************************************
SECTOR NUMBER    8         NAME          I.D.      X
                       1   AL             1      7.10

*************************************************
SECTOR NUMBER    9         NAME          I.D.      X
                       1   AL             1      7.50

*************************************************
SECTOR NUMBER   10         NAME          I.D.      X
                       1   AL             1      8.50

*************************************************
SECTOR NUMBER   11         NAME          I.D.      X
                       1   AL             1      9.70

*************************************************
SECTOR NUMBER   12         NAME          I.D.      X
                       1   AL             1     10.60

*************************************************
SECTOR NUMBER   13         NAME          I.D.      X
                       1   AL             1     11.00

*************************************************
SECTOR NUMBER   14         NAME          I.D.      X
                       1   AL             1     13.00

*************************************************
```

THE DOSE CONVERSION FACTORS LISTED BELOW ARE FOR THE APOLLO VEHICLE WHICH HAS 19 SECTORS.
THIS CALCULATION WAS RUN ON 07/24/74 . THE ABSORBER MATERIAL IS TISSUE
THE ENERGIES GIVEN BELOW ARE IN UNITS OF MEV AND THE DOSE CONVERSION FACTORS ARE IN UNITS OF (RAD/HR.)/(proton /CM**2-SEC).
A TOTAL RAD DOSE MAY BE OBTAINED BY MULTIPLYING THE DOSE CONVERSION FACTORS BY THE DIFFERENTIAL INCIDENT PROTON SPECTRAL
VALUES AT THE CORRESPONDING ENERGIES, AND THEN INTEGRATING THE RESULTING FUNCTION OVER THE INCIDENT PROTON ENERGY GRID VALUES.
THIS WILL RESULT IN UNITS OF RADS/HR. DUE TO AN INCIDENT PROTON FLUX WHICH MUST BE IN UNITS OF PROTONS/CM**2-SEC.

EXTERNAL ENERGY	DOSE CONVERSION FACTOR	EXTERNAL ENERGY	DOSE CONVERSION FACTOR	EXTERNAL ENERGY	DOSE CONVERSION FACTOR	EXTERNAL ENERGY	DOSE CONVERSION FACTOR
1.	0.	87.	.4512E-03	173.	.5366E-03	575.	.1498E-02
3.	0.	89.	.3839E-03	175.	.5284E-03	585.	.1486E-02
5.	0.	91.	.1036E-02	177.	.5206E-03	595.	.1474E-02
7.	0.	93.	.8371E-03	179.	.5130E-03	605.	.1463E-02
9.	0.	95.	.6678E-03	185.	.4194E-02	615.	.1451E-02
11.	0.	97.	.5972E-03	195.	.3177E-02	625.	.1440E-02
13.	0.	99.	.6416E-03	205.	.2882E-02	635.	.1429E-02
15.	0.	101.	.5563E-03	215.	.2714E-02	645.	.1420E-02
17.	0.	103.	.7628E-03	225.	.2593E-02	655.	.1412E-02
19.	0.	105.	.9284E-03	235.	.2491E-02	665.	.1405E-02
21.	0.	107.	.8470E-03	245.	.2407E-02	675.	.1398E-02
23.	0.	109.	.7250E-03	255.	.2331E-02	685.	.1391E-02
25.	0.	111.	.6651E-03	265.	.2265E-02	695.	.1385E-02
27.	0.	113.	.6200E-03	275.	.2206E-02	705.	.1379E-02
29.	0.	115.	.6578E-03	285.	.2152E-02	715.	.1374E-02
31.	0.	117.	.7487E-03	295.	.2103E-02	725.	.1369E-02
33.	0.	119.	.6444E-03	305.	.2058E-02	735.	.1363E-02
35.	0.	121.	.9666E-03	315.	.2017E-02	745.	.1358E-02
37.	.1812E-04	123.	.7792E-03	325.	.1979E-02	755.	.1353E-02
39.	.1214E-02	125.	.7075E-03	335.	.1943E-02	765.	.1348E-02
41.	.5796E-03	127.	.6674E-03	345.	.1911E-02	775.	.1344E-02
43.	.4576E-03	129.	.8490E-03	355.	.1879E-02	785.	.1339E-02
45.	.3784E-03	131.	.8075E-03	365.	.1851E-02	795.	.1335E-02
47.	.3321E-03	133.	.7156E-03	375.	.1824E-02	805.	.1330E-02
49.	.3042E-03	135.	.6750E-03	385.	.1798E-02	815.	.1326E-02
51.	.2796E-03	137.	.6433E-03	395.	.1774E-02	825.	.1322E-02
53.	.2570E-03	139.	.7064E-03	405.	.1752E-02	835.	.1318E-02
55.	.2371E-03	141.	.6510E-03	415.	.1731E-02	845.	.1315E-02
57.	.3544E-03	143.	.6231E-03	425.	.1710E-02	855.	.1311E-02
59.	.2715E-03	145.	.6028E-03	435.	.1691E-02	865.	.1307E-02
61.	.2748E-03	147.	.5854E-03	445.	.1673E-02	875.	.1304E-02
63.	.2522E-03	149.	.5705E-03	455.	.1656E-02	885.	.1301E-02
65.	.2354E-03	151.	.5590E-03	465.	.1639E-02	895.	.1299E-02
67.	.2720E-03	153.	.5486E-03	475.	.1624E-02	905.	.1297E-02
69.	.2795E-03	155.	.5387E-03	485.	.1609E-02	915.	.1295E-02
71.	.2473E-03	157.	.6859E-03	495.	.1594E-02	925.	.1293E-02
73.	.2862E-03	159.	.7193E-03	505.	.1581E-02	935.	.1291E-02
75.	.2587E-03	161.	.6402E-03	515.	.1568E-02	945.	.1290E-02
77.	.2366E-03	163.	.6075E-03	525.	.1555E-02	955.	.1288E-02
79.	.2225E-03	165.	.5834E-03	535.	.1543E-02	965.	.1286E-02
81.	.2118E-03	167.	.5657E-03	545.	.1532E-02	975.	.1285E-02
83.	.3628E-03	169.	.5550E-03	555.	.1520E-02	985.	.1283E-02
85.	.6090E-03	171.	.5455E-03	565.	.1509E-02	995.	.1281E-02

EPENSS SAMPLE INPUT

```
 2      0
 2  AL       TISSUE
 5  CHECK
 2  .2                   1.          AL          5.          TISSUE
 2  .2                   2.          AL          5.          TISSUE
 2  .2                   3.          AL          5.          TISSUE
 2  .2                   4.          AL          5.          TISSUE
 2  .2                   5.          AL          5.          TISSUE
19  APOLLO
 1  .0027                1.68        AL
 1  .1498                1.81        AL
 1  .0176                3.6         AL
 1  .0038                4.1         AL
 1  .0030                4.2         AL
 1  .0145                5.0         AL
 1.0136                  5.7         AL
 1  .0259                7.1         AL
 1  .0550                7.5         AL
 1  .1483                8.5         AL
 1  .0178                9.7         AL
 1  .0937               10.6         AL
 1  .0529               11.0         AL
 1  .0439               13.0         AL
 1  .0712               13.9         AL
 1  .0615               15.6         AL
 1  .0196               17.7         AL
 1  .0577               22.0         AL
 1  .1518               28.0         AL
```

SECTORING INFORMATION
VEHICLE NAME - APOLLO

SECTOR NUMBER		NAME	X
1	1	AL	1.60
2	1	AL	1.81
3	1	AL	3.60
4	1	AL	4.10
5	1	AL	4.20
6	1	AL	5.00
7	1	AL	5.70
8	1	AL	7.10
9	1	AL	7.50
10	1	AL	8.50
11	1	AL	9.70
12	1	AL	10.60
13	1	AL	11.00
14	1	AL	13.00

EPENSS SAMPLE OUTPUT

THE DOSE CONVERSION FACTORS LISTED BELOW ARE FOR THE APOLLO VEHICLE WHICH HAS 19 SECTORS.
THIS CALCULATION WAS RUN ON 11/19/74
THE ENERGIES GIVEN BELOW ARE IN UNITS OF MEV AND THE DOSE CONVERSION FACTORS ARE IN UNITS OF (RAD/HR.)/(ELECTRON/CM**2-SEC).
A TOTAL RAD DOSE MAY BE OBTAINED BY MULTIPLYING THE DOSE CONVERSION FACTORS BY THE DIFFERENTIAL INCIDENT ELECTRON SPECTRAL
VALUES AT THE CORRESPONDING ENERGIES, AND THEN INTEGRATING THE RESULTING FUNCTION OVER THE INCIDENT ELECTRON ENERGY GRID VALUES.
THIS WILL RESULT IN UNITS OF RADS/HR. DUE TO AN INCIDENT ELECTRON FLUX WHICH MUST BE IN UNITS OF ELECTRONS/CM**2-SEC.

ENERGY	D.C.F.	ENERGY	D.C.F.
.10	0.	2.70	0.
.15	0.	2.80	.105012E-10
.20	0.	2.90	.192637E-10
.25	0.	3.00	.720712E-09
.30	0.	3.10	.127535E-08
.35	0.	3.20	.216344E-08
.40	0.	3.30	.329506E-08
.45	0.	3.40	.497743E-08
.50	0.	3.50	.714689E-08
.55	0.	3.60	.932074E-08
.60	0.	3.70	.129777E-07
.65	0.	3.80	.156696E-07
.70	0.	3.90	.236361E-07
.75	0.	4.00	.249718E-07
.80	0.	4.10	.296345E-07
.85	0.	4.20	.345269E-07
.90	0.	4.30	.395548E-07
.95	0.	4.40	.447550E-07
1.00	0.	4.50	.505571E-07
1.10	0.	4.60	.553633E-07
1.20	0.	4.70	.616855E-07
1.30	0.	4.80	.659776E-07
1.40	0.	4.90	.712291E-07
1.50	0.	5.00	.131245E-06
1.60	0.	5.25	.222581E-06
1.70	0.	5.50	.232651E-06
1.80	0.	5.75	.311105E-06
1.90	0.	6.00	.339703E-06
2.00	0.	6.25	.335568E-06
2.10	0.	6.50	.360445E-06
2.20	0.	6.75	.384230E-06
2.30	0.	7.00	.403774E-06
2.40	0.	7.25	.430592E-06
2.50	0.	7.50	.451539E-06
2.60	0.	7.75	.472221E-06
		[illegible]	[illegible]

BREMSS SAMPLE INPUT

```
2    0    0
2 AL     TISSUE
5 CHECK
2 .2              1.        AL        5.        TISSUE
2 .2              2.        AL        5.        TISSUE
2 .2              3.        AL        5.        TISSUE
2 .2              4.        AL        5.        TISSUE
2 .2              5.        AL        5.        TISSUE
19 APOLLO
1 .0027           1.68      AL
1 .1498           1.81      AL
1 .0176           3.6       AL
1 .0038           4.1       AL
1 .0030           4.2       AL
1 .0145           5.0       AL
1.0106            5.7       AL
1 .0259           7.1       AL
1 .0650           7.5       AL
1 .1483           8.5       AL
1 .0170           9.7       AL
1 .0837           10.6      AL
1 .0529           11.0      AL
1 .0439           13.0      AL
1 .0712           13.9      AL
1 .0615           15.6      AL
1 .0196           17.7      AL
1 .0577           22.0      AL
1 .1518           28.0      AL
```

BREMSS SAMPLE OUTPUT

MATERIAL AL Z 13.00

ENERGY	ATT.NU COEFF
.01	.2680E+02
.02	.3490E+01
.05	.7500E+00
.10	.1690E+00
.20	.1220E+00
.50	.8460E-01
1.00	.6140E-01
2.00	.4320E-01
3.00	.3540E-01
4.00	.3100E-01
6.00	.2650E-01
8.00	.2430E-01
10.00	.2300E-01

BUILDUP COEFFICIENTS

ENERGY	1.	2.	4.	7.	10.	15.	20.
.010000	1.001000	1.002000	1.004000	1.006000	1.008000	1.011000	1.013000
.020000	1.007000	1.013000	1.024000	1.037000	1.047000	1.060000	1.070000
.050000	1.080000	1.160000	1.270000	1.390000	1.480000	1.600000	1.700000
.100000	1.350000	1.670000	2.280000	3.070000	3.830000	5.040000	6.250000
.200000	1.710000	2.620000	4.680000	9.250000	14.600000	24.200000	37.700000
.500000	2.370000	4.240000	9.470000	21.500000	38.900000	80.800000	141.000000
1.000000	2.020000	3.310000	6.570000	13.100000	21.200000	37.900000	53.500000
2.000000	1.750000	2.610000	4.620000	8.050000	11.900000	18.700000	26.300000
3.000000	1.640000	2.320000	3.790000	6.140000	8.650000	13.000000	17.700000
4.000000	1.530000	2.080000	3.220000	5.010000	6.580000	10.100000	13.400000
6.000000	1.420000	1.850000	2.700000	4.060000	5.490000	7.970000	10.400000
8.000000	1.340000	1.680000	2.370000	3.450000	4.580000	6.560000	8.520000
10.000000	1.280000	1.550000	2.120000	3.010000	3.960000	5.630000	7.320000

BREMSS SAMPLE OUTPUT

ELECTRON DATA

ENERGY	RANGE	DE/DX	STOPPING POWER
.010	.351900E-03	.165700E+02	.165800E+02
.015	.737400E-03	.122500E+02	.122600E+02
.020	.116500E-02	.983500E+01	.989300E+01
.025	.171600E-02	.837200E+01	.838000E+01
.030	.235600E-02	.731600E+01	.732500E+01
.035	.308000E-02	.653500E+01	.654300E+01
.040	.386300E-02	.593200E+01	.594000E+01
.045	.476200E-02	.545100E+01	.545900E+01
.050	.571400E-02	.505900E+01	.506700E+01
.055	.683500E-02	.473300E+01	.474100E+01
.060	.782200E-02	.445600E+01	.446500E+01
.065	.897400E-02	.422000E+01	.422800E+01
.070	.101900E-01	.401400E+01	.402300E+01
.075	.114600E-01	.383400E+01	.384300E+01
.080	.127900E-01	.367600E+01	.368400E+01
.085	.141700E-01	.353400E+01	.354300E+01
.090	.156100E-01	.340300E+01	.341700E+01
.095	.171000E-01	.328400E+01	.330300E+01
.100	.186400E-01	.319100E+01	.320000E+01
.150	.364100E-01	.252600E+01	.253600E+01
.200	.577200E-01	.218300E+01	.219900E+01
.250	.816500E-01	.198600E+01	.199800E+01
.300	.107700E+00	.184300E+01	.186100E+01
.350	.135300E+00	.175700E+01	.177100E+01
.400	.164000E+00	.169100E+01	.170600E+01
.450	.193800E+00	.164100E+01	.165300E+01
.500	.224300E+00	.160300E+01	.162100E+01
.550	.255400E+00	.157400E+01	.159300E+01
.600	.287100E+00	.155100E+01	.157100E+01
.650	.319100E+00	.153200E+01	.155300E+01
.700	.351400E+00	.151700E+01	.154000E+01
.750	.384000E+00	.150300E+01	.152900E+01
.800	.416800E+00	.149600E+01	.152100E+01
.850	.449800E+00	.148800E+01	.151400E+01
.900	.482600E+00	.148200E+01	.150900E+01
.950	.516000E+00	.147700E+01	.150500E+01
1.000	.549300E+00	.147300E+01	.150200E+01
1.100	.615900E+00	.146800E+01	.149900E+01
1.200	.682600E+00	.146500E+01	.149800E+01
1.300	.749300E+00	.146300E+01	.149900E+01

ENERGY	RANGE	DE/DX	STOPPING POWER
1.400	.816000E+00	.146300E+01	.150200E+01
1.500	.882500E+00	.146400E+01	.150500E+01
1.600	.948900E+00	.145600E+01	.150900E+01
1.700	.101500E+01	.146800E+01	.151300E+01
1.800	.108100E+01	.147000E+01	.151800E+01
1.900	.114700E+01	.147300E+01	.152300E+01
2.000	.121200E+01	.147600E+01	.152800E+01
2.200	.134300E+01	.148200E+01	.153900E+01
2.400	.147200E+01	.148900E+01	.155000E+01
2.600	.160100E+01	.149500E+01	.156200E+01
2.800	.172900E+01	.150200E+01	.157300E+01
3.000	.185500E+01	.150800E+01	.158400E+01
3.500	.216800E+01	.152300E+01	.161200E+01
4.000	.247600E+01	.153700E+01	.163900E+01
4.500	.277800E+01	.154900E+01	.166600E+01
5.000	.307600E+01	.156100E+01	.169200E+01
5.500	.336900E+01	.157100E+01	.171700E+01
6.000	.365800E+01	.158100E+01	.174100E+01
6.500	.394400E+01	.159000E+01	.176500E+01
7.000	.422500E+01	.159800E+01	.178900E+01
7.500	.450300E+01	.160600E+01	.181200E+01
8.000	.477700E+01	.161300E+01	.183500E+01
8.500	.504800E+01	.162000E+01	.185700E+01
9.000	.531500E+01	.162600E+01	.188000E+01
9.500	.558000E+01	.163200E+01	.190200E+01
10.000	.584100E+01	.163700E+01	.192400E+01
20.000	.105400E+02	.170900E+01	.234100E+01
30.000	.144800E+02	.174700E+01	.274500E+01
40.000	.178800E+02	.177300E+01	.314600E+01
50.000	.208700E+02	.179200E+01	.354700E+01
60.000	.235500E+02	.180800E+01	.394900E+01
80.000	.281600E+02	.183100E+01	.475400E+01
100.000	.320400E+02	.184900E+01	.555900E+01
200.000	.455500E+02	.190200E+01	.961400E+01
300.000	.542300E+02	.193300E+01	.136900E+02
400.000	.606200E+02	.195400E+01	.177700E+02
500.000	.656900E+02	.197100E+01	.218500E+02
600.000	.698800E+02	.198400E+01	.259400E+02
800.000	.765800E+02	.200500E+01	.341200E+02
1000.000	.818400E+02	.202200E+01	.423000E+02

BREMSS SAMPLE OUTPUT

```
               SECTORING INFORMATION
              VEHICLE NAME -  CHECK

*****************************************************
SECTOR NUMBER      1             NAME          X
                          1      AL            1.00
                          2      TISSUE        5.00

*****************************************************
SECTOR NUMBER      2             NAME          X
                          1      AL            2.00
                          2      TISSUE        5.00

*****************************************************
SECTOR NUMBER      3             NAME          X
                          1      AL            3.00
                          2      TISSUE        5.00

*****************************************************
SECTOR NUMBER      4             NAME          X
                          1      AL            4.00
                          2      TISSUE        5.00

*****************************************************
SECTOR NUMBER      5             NAME          X
                          1      AL            5.00
                          2      TISSUE        5.00
```

BREMSS SAMPLE OUTPUT

```
ELECTRON BREMSSTRAHLUNG [illegible] WITH [illegible] REDUCTION OPTION
THE DOSE CONVERSION FACT[illegible] FOR THE CHECK [illegible] VEHICLE WHICH HAS [illegible] CTOPS.
THIS CALCULATION WAS [illegible]
THE [illegible] GIVEN [illegible] IN UNITS OF [illegible] AND THE DOSE CONVERSION FACTORS ARE IN UNITS OF (RAD/HR.)/(ELECTRON/CM**2-SEC).
A TOTAL [illegible] MAY BE [illegible] BY MULTIPLYING THE DOSE CONVERSION FACTORS BY THE DIFFERENTIAL INCIDENT ELECTRON SPECTRAL
VALUES AT THE CORRESPONDING [illegible], AND THEN INTEGRATING THE RESULTING FUNCTION OVER THE INCIDENT ELECTRON ENERGY GRID VALUES.
THIS WILL RESULT IN UNITS OF [illegible]/HR, DUE TO AN INCIDENT ELECTRON FLUX WHICH MUST BE IN UNITS OF ELECTRONS/CM**2-SEC.
```

ENERGY	D.C.F.	ENERGY	D.C.F.
.10	[illegible]-12	[illegible]	[illegible]
.15	[illegible]-11	2.60	.714552-08
.20	[illegible]-11	[illegible]	[illegible]
.25	[illegible]-11	[illegible]	[illegible]
.30	[illegible]	[illegible]	[illegible]
.35	[illegible]	[illegible]	[illegible]
.40	[illegible]	[illegible]	[illegible]
.45	[illegible]	[illegible]	[illegible]-07
.50	[illegible]	[illegible]	[illegible]-07
.55	[illegible]	[illegible]	[illegible]-07
.60	[illegible]	[illegible]	[illegible]-07
.65	[illegible]	[illegible]	[illegible]-07
.70	[illegible]	[illegible]	[illegible]-07
.75	[illegible]	[illegible]	[illegible]-07
.80	[illegible]	[illegible]	[illegible]-07
.85	[illegible]	[illegible]	[illegible]-07
.90	[illegible]	[illegible]	[illegible]-07
.95	[illegible]	[illegible]	[illegible]-07
1.00	[illegible]	[illegible]	[illegible]-07
1.10	[illegible]	[illegible]	[illegible]-07
1.20	[illegible]	[illegible]	[illegible]-07
1.30	[illegible]	[illegible]	[illegible]-07
1.40	[illegible]	[illegible]	[illegible]-07
1.50	[illegible]	[illegible]	[illegible]-07
1.60	[illegible]	[illegible]	[illegible]-07
1.70	[illegible]	[illegible]	[illegible]-07
1.80	[illegible]	[illegible]	[illegible]-07
1.90	[illegible]-08	[illegible]	[illegible]-07
2.00	[illegible]	[illegible]	[illegible]-07
2.10	[illegible]	[illegible]	[illegible]-07
2.20	[illegible]	[illegible]	[illegible]-07
2.30	[illegible]	[illegible]	[illegible]-06
2.40	[illegible]	[illegible]	[illegible]-06
2.50	[illegible]	[illegible]	[illegible]-06
2.60	[illegible]	7.75	[illegible]-06
		[illegible]	[illegible]

DOSMAP SAMPLE INPUT

```
  2
  1    0    0
         APOLLO                          19    07/23/74
  1.00.            3.00.            5.00.            7.00.            9.00.
 11.00.           13.00.           15.00.           17.00.           19.00.
 21.00.           23.00.           25.00.           27.00.           29.00.
 31.00.           33.00.           35.00.           37.0 .1812E-04   39.0 .1214E-02
 41.0 .5796E-03   43.0 .4576E-03   45.0 .3704E-03   47.0 .3321E-03   49.0 .3042E-03
 51.0 .2796E-03   53.0 .2570E-03   55.0 .2371E-03   57.0 .3544E-03   59.0 .2715E-03
 61.0 .2748E-03   63.0 .2522E-03   65.0 .2354E-03   67.0 .2720E-03   69.0 .2795E-03
 71.0 .2479E-03   73.0 .2862E-03   75.0 .2587E-03   77.0 .2366E-03   79.0 .2225E-03
 81.0 .2119E-03   83.0 .3628E-03   85.0 .6090E-03   87.0 .4512E-03   89.0 .3839E-03
 91.0 .1036E-02   93.0 .8371E-03   95.0 .6678E-03   97.0 .5972E-03   99.0 .6416E-03
101.0 .5563E-03  103.0 .7628E-03  105.0 .9284E-03  107.0 .8470E-03  109.0 .7250E-03
111.0 .6651E-03  113.0 .6200E-03  115.0 .6578E-03  117.0 .7487E-03  119.0 .6444E-03
121.0 .9666E-03  123.0 .7792E-03  125.0 .7075E-03  127.0 .6674E-03  129.0 .8490E-03
131.0 .8075E-03  133.0 .7156E-03  135.0 .6750E-03  137.0 .6433E-03  139.0 .7064E-03
141.0 .6518E-03  143.0 .6231E-03  145.0 .6028E-03  147.0 .5854E-03  149.0 .5705E-03
151.0 .5590E-03  153.0 .5486E-03  155.0 .5387E-03  157.0 .6559E-03  159.0 .7193E-03
161.0 .6402E-03  163.0 .6075E-03  165.0 .5834E-03  167.0 .5657E-03  169.0 .5550E-03
171.0 .5455E-03  173.0 .5366E-03  175.0 .5284E-03  177.0 .5206E-03  179.0 .5130E-03
185.0 .4194E-02  195.0 .3177E-02  205.0 .2882E-02  215.0 .2714E-02  225.0 .2593E-02
235.0 .2491E-02  245.0 .2407E-02  255.0 .2331E-02  265.0 .2265E-02  275.0 .2206E-02
285.0 .2152E-02  295.0 .2103E-02  305.0 .2058E-02  315.0 .2017E-02  325.0 .1979E-02
335.0 .1943E-02  345.0 .1911E-02  355.0 .1879E-02  365.0 .1851E-02  375.0 .1824E-02
385.0 .1798E-02  395.0 .1774E-02  405.0 .1752E-02  415.0 .1731E-02  425.0 .1710E-02
435.0 .1691E-02  445.0 .1673E-02  455.0 .1656E-02  465.0 .1639E-02  475.0 .1624E-02
485.0 .1609E-02  495.0 .1594E-02  505.0 .1581E-02  515.0 .1568E-02  525.0 .1555E-02
535.0 .1543E-02  545.0 .1532E-02  555.0 .1520E-02  565.0 .1509E-02  575.0 .1498E-02
585.0 .1486E-02  595.0 .1474E-02  605.0 .1463E-02  615.0 .1451E-02  625.0 .1440E-02
635.0 .1429E-02  645.0 .1420E-02  655.0 .1412E-02  665.0 .1405E-02  675.0 .1398E-02
685.0 .1391E-02  695.0 .1385E-02  705.0 .1379E-02  715.0 .1374E-02  725.0 .1369E-02
735.0 .1363E-02  745.0 .1358E-02  755.0 .1353E-02  765.0 .1348E-02  775.0 .1344E-02
785.0 .1339E-02  795.0 .1335E-02  805.0 .1330E-02  815.0 .1326E-02  825.0 .1322E-02
835.0 .1318E-02  845.0 .1315E-02  855.0 .1311E-02  865.0 .1309E-02  875.0 .1309E-02
885.0 .1309E-02  895.0 .1309E-02  905.0 .1309E-02  915.0 .1309E-02  925.0 .1309E-02
935.0 .1309E-02  945.0 .1308E-02  955.0 .1308E-02  965.0 .1308E-02  975.0 .1308E-02
985.0 .1308E-02  995.0 .1308E-02
   0    1    0
         APOLLO                          19    07/23/74
 .10  0.                .15  0.                .20  0.                .25  0.
 .30  0.                .35  0.                .40  0.                .45  0.
 .50  0.                .55  0.                .60  0.                .65  0.
 .70  0.                .75  0.                .80  0.                .85  0.
 .90  0.                .95  0.               1.00  0.               1.10  0.
1.20  0.               1.30  0.               1.40  0.               1.50  0.
1.60  0.               1.70  0.               1.80  0.               1.90  0.
2.00  0.               2.10  0.               2.20  0.               2.30  0.
2.40  0.               2.50  0.               2.60  0.               2.70  0.
2.80    .10501244E-092.90    .19263683E-093.00    .72071153E-083.10    .12253528E-07
3.20    .20634434E-073.30    .32950634E-073.40    .49774256E-073.50    .71468861E-07
3.60    .98297360E-073.70    .12977679E-063.80    .16589603E-063.90    .20606056E-06
4.00    .24971777E-064.10    .29634285E-064.20    .34526877E-064.30    .39594836E-06
4.40    .44786570E-064.50    .50057125E-064.60    .55369294E-064.70    .60686458E-06
4.80    .65977619E-064.90    .71228079E-065.00    .76417971E-065.25    .89032431E-06
5.50    .10196431E-055.75    .11244203E-056.00    .12388334E-056.25    .13423583E-05
6.50    .14417799E-056.75    .15367997E-057.00    .16323144E-057.25    .17203685E-05
7.50    .18061546E-057.75    .18888041E-058.00    .19690676E-05
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THIS IS A DOSE RATE MAP (RADS/HR) FOR 700 B-L POINTS. IF ONLY PROTONS ARE RUN, THEN A 520 POINT MAP IS PRODUCED

THE FOLLOWING PARTICLES WERE RUN IN THIS DOSE MAP FOR THE APOLLO VEHICLE WITH 19 SECTORS
PROTONS

B	L 1.20	B	L 1.25	B	L 1.30	B	L 1.35	B	L 1.40	B	L 1.45
.1804	.573E+00	.1596	.141E+01	.1413	.343E+01	.1267	.461E+01	.1136	.623E+01	.1022	.671E+01
.1838	.489E+00	.1630	.121E+01	.1470	.295E+01	.1320	.402E+01	.1200	.541E+01	.1090	.567E+01
.1850	.434E+00	.1670	.102E+01	.1510	.263E+01	.1380	.345E+01	.1260	.473E+01	.1170	.487E+01
.1870	.394E+00	.1710	.952E+00	.1560	.228E+01	.1440	.295E+01	.1330	.405E+01	.1240	.419E+01
.1900	.319E+00	.1740	.745E+00	.1610	.197E+01	.1490	.259E+01	.1400	.347E+01	.1310	.360E+01
.1920	.292E+00	.1780	.624E+00	.1660	.170E+01	.1550	.222E+01	.1460	.304E+01	.1390	.303E+01
.1950	.234E+00	.1820	[illegible]	.1700	.152E+01	.1610	.188E+01	.1530	.260E+01	.1460	.255E+01
.1970	.207E+00	.1860	.381E+00	.1750	.131E+01	.1660	.163E+01	.1590	.226E+01	.1530	.221E+01
.1990	.180E+00	.1890	.314E+00	.1800	.109E+01	.1720	.135E+01	.1660	.190E+01	.1610	.184E+01
.2020	.125E+00	.1930	.236E+00	.1850	.915E+00	.1780	.107E+01	.1720	.164E+01	.1680	.152E+01
.2040	.971E-01	.1970	.173E+00	.1890	.783E+00	.1830	.880E+00	.1790	.134E+01	.1750	.125E+01
.2070	.662E-01	.2000	.137E+00	.1940	.596E+00	.1890	.693E+00	.1850	.103E+01	.1830	.939E+00
.2090	.469E-01	.2040	.963E-01	.1990	.447E+00	.1940	.552E+00	.1920	.832E+00	.1900	.776E+00
.2110	.310E-01	.2080	.673E-01	.2040	.332E+00	.2000	.394E+00	.1980	.657E+00	.1970	.578E+00
.2140	.154E-01	.2110	.514E-01	.2080	.262E+00	.2060	.270E+00	.2050	.493E+00	.2040	.410E+00
.2160	.951E-02	.2150	.345E-01	.2130	.166E+00	.2110	.193E+00	.2110	.359E+00	.2120	.274E+00
.2190	.594E-02	.2190	.206E-01	.2180	.958E-01	.2170	.121E+00	.2180	.210E+00	.2190	.167E+00
.2210	.278E-02	.2230	.106E-01	.2230	.416E-01	.2230	.652E-01	.2240	.120E+00	.2260	.909E-01
.2250	.905E-03	.2260	.584E-02	.2270	.179E-01	.2280	.323E-01	.2310	.407E-01	.2340	[illegible]
.2280	.450E-03	.2300	.230E-02	.2320	.517E-02	.2340	.101E-01	.2370	.119E-01	.2410	.129E-01

B	L 1.50	B	L 1.50	B	L 1.70	B	L 1.80	B	L 1.90	B	L 2.00
.0923	.723E+01	.0761	.739E+01	.0634	.565E+01	.0534	.378E+01	.0454	.217E+01	.0330	.146E+01
.1000	.616E+01	.0850	.586E+01	.0740	.411E+01	.0650	.263E+01	.0570	.150E+01	.0520	.943E+00
.1080	.522E+01	.0950	.452E+01	.0840	.304E+01	.0760	.187E+01	.0690	.104E+01	.0640	.648E+00
.1160	.442E+01	.1040	.353E+01	.0950	.236E+01	.0870	.146E+01	.0810	.796E+00	.0770	.473E+00
.1240	.374E+01	.1130	.295E+01	.1050	.192E+01	.0990	.111E+01	.0930	.610E+00	.0890	.354E+00
.1320	.317E+01	.1220	.244E+01	.1150	.155E+01	.1100	.862E+00	.1050	.467E+00	.1010	.272E+00
.1400	.271E+01	.1320	.197E+01	.1260	.123E+01	.1210	.700E+00	.1170	.378E+00	.1140	.225E+00
.1480	.232E+01	.1410	.162E+01	.1360	.103E+01	.1320	.577E+00	.1290	.311E+00	.1270	.187E+00
.1560	.199E+01	.1530	.137E+01	.1470	.824E+00	.1440	.467E+00	.1410	.255E+00	.1400	[illegible]
.1640	.170E+01	.1590	.112E+01	.1570	.671E+00	.1550	.385E+00	.1530	.210E+00	.1520	[illegible]
.1720	.142E+01	.1690	.884E+00	.1670	.546E+00	.1660	.317E+00	.1650	.173E+00	.1650	.108E+00
.1800	.111E+01	.1780	.715E+00	.1780	.435E+00	.1780	.256E+00	.1770	.141E+00	.1770	.891E-01
.1880	.855E+00	.1870	.579E+00	.1880	.343E+00	.1890	.196E+00	.1890	.107E+00	.1900	.660E-01
.1960	.660E+00	.1960	.453E+00	.1990	.255E+00	.2000	.140E+00	.2010	.787E-01	.2030	.476E-01
.2040	.508E+00	.2060	.327E+00	.2090	.182E+00	.2120	.975E-01	.2130	.590E-01	.2150	.350E-01
.2120	.342E+00	.2150	.220E+00	.2190	.128E+00	.2230	.669E-01	.2250	.405E-01	.2280	.237E-01
.2200	.211E+00	.2240	.141E+00	.2300	.792E-01	.2340	.425E-01	.2370	.260E-01	.2400	.150E-01
.2280	.119E+00	.2330	.797E-01	.2400	.463E-01	.2450	.249E-01	.2490	.150E-01	.2530	.859E-02
.2360	.515E-01	.2430	.379E-01	.2510	.206E-01	.2570	.117E-01	.2610	.663E-02	.2650	.308E-02
.2440	.142E-01	.2520	.135E-01	.2610	.674E-02	.2680	.338E-02	.2730	.189E-02	.2780	.516E-03

THIS IS A DOSE RATE MAP (RADS/HR) FOR 700 B-L POINTS. IF ONLY PROTONS ARE RUN, THEN A 520 POINT MAP IS PRODUCED

THE FOLLOWING PARTICLES WERE RUN IN THIS DOSE MAP FOR THE APOLLO VEHICLE WITH 19 SECTORS
ELECTRONS

B	L 1.20	B	L 1.25	B	L 1.30	B	L 1.35	B	L 1.40	B	L 1.45
.1804	.274E-03	.1596	.776E-02	.1419	.256E-01	.1267	.345E-01	.1136	.429E-01	.1022	.457E-01
.1830	.217E-03	.1630	.651E-02	.1470	.226E-01	.1320	.316E-01	.1200	.393E-01	.1100	.407E-01
.1850	.181E-03	.1670	.529E-02	.1510	.205E-01	.1380	.285E-01	.1260	.362E-01	.1170	.366E-01
.1870	.148E-03	.1710	.422E-02	.1560	.181E-01	.1440	.258E-01	.1330	.329E-01	.1240	.330E-01
.1900	.883E-04	.1740	.299E-02	.1610	.160E-01	.1490	.237E-01	.1400	.299E-01	.1310	.297E-01
.1920	.662E-04	.1780	.188E-02	.1660	.137E-01	.1550	.214E-01	.1460	.276E-01	.1390	.263E-01
.1950	.434E-04	.1820	.118E-02	.1700	.998E-02	.1610	.191E-01	.1530	.251E-01	.1460	.212E-01
.1970	.328E-04	.1860	.729E-03	.1750	.657E-02	.1660	.144E-01	.1590	.203E-01	.1530	.165E-01
.1990	.249E-04	.1890	.500E-03	.1800	.413E-02	.1720	.101E-01	.1650	.153E-01	.1610	.123E-01
.2020	.164E-04	.1930	.295E-03	.1850	.261E-02	.1780	.669E-02	.1720	.114E-01	.1680	.342E-02
.2040	.124E-04	.1970	.159E-03	.1890	.174E-02	.1830	.464E-02	.1790	.789E-02	.1750	.715E-02
.2070	.746E-05	.2000	.103E-03	.1940	.101E-02	.1890	.293E-02	.1850	.559E-02	.1830	.512E-02
.2090	.405E-05	.2040	.626E-04	.1990	.562E-03	.1940	.194E-02	.1920	.365E-02	.1900	.373E-02
.2110	.194E-05	.2080	.356E-04	.2040	.291E-03	.2000	.112E-02	.1980	.246E-02	.1970	.267E-02
.2140	.453E-06	.2110	.226E-04	.2080	.159E-03	.2060	.590E-03	.2050	.145E-02	.2040	.190E-02
.2160	.120E-05	.2150	.116E-04	.2130	.785E-04	.2110	.317E-03	.2110	.951E-03	.2120	.138E-02
.2180	.673E-09	.2190	.292E-05	.2180	.301E-04	.2170	.126E-03	.2180	.400E-03	.2190	.627E-03
.2210	0.	.2230	.228E-06	.2230	.107E-04	.2230	.416E-04	.2240	.169E-03	.2250	.304E-03
.2250	0.	.2260	0.	.2270	.786E-05	.2280	.127E-04	.2310	.379E-04	.2340	.732E-04
.2290	0.	.2300	0.	.2320	0.	.2340	0.	.2370	.112E-05	.2410	0.

B	L 1.50	B	L 1.60	B	L 1.70	B	L 1.80	B	L 1.90	B	L 2.00
.0923	.446E-01	.0761	.303E-01	.0634	.139E-01	.0534	.286E-02	.0454	.535E-03	.0390	.163E-03
.1000	.391E-01	.0850	.241E-01	.0740	.105E-01	.0650	.195E-02	.0570	.316E-03	.0520	.852E-04
.1080	.323E-01	.0950	.189E-01	.0840	.911E-02	.0760	.135E-02	.0690	.204E-03	.0640	.539E-04
.1160	.274E-01	.1040	.147E-01	.0950	.584E-02	.0870	.941E-03	.0810	.137E-03	.0770	.356E-04
.1240	.225E-01	.1130	.113E-01	.1050	.431E-02	.0990	.661E-03	.0930	.944E-04	.0890	.267E-04
.1320	.177E-01	.1220	.864E-02	.1150	.326E-02	.1100	.483E-03	.1050	.692E-04	.1010	.212E-04
.1400	.139E-01	.1320	.651E-02	.1260	.240E-02	.1210	.360E-03	.1170	.492E-04	.1140	.162E-04
.1480	.109E-01	.1410	.505E-02	.1360	.184E-02	.1320	.270E-03	.1290	.363E-04	.1270	.115E-04
.1560	.857E-02	.1500	.391E-02	.1470	.137E-02	.1440	.199E-03	.1410	.269E-04	.1400	.849E-05
.1640	.667E-02	.1590	.304E-02	.1570	.105E-02	.1550	.150E-03	.1530	.212E-04	.1520	.616E-05
.1720	.516E-02	.1690	.226E-02	.1670	.803E-03	.1660	.112E-03	.1650	.172E-04	.1650	.429E-05
.1800	.394E-02	.1780	.173E-02	.1760	.587E-03	.1780	.813E-04	.1770	.140E-04	.1770	.298E-05
.1880	.296E-02	.1870	.126E-02	.1880	.441E-03	.1890	.598E-04	.1890	.104E-04	.1900	.194E-05
.1960	.217E-02	.1960	.950E-03	.1990	.309E-03	.2000	.427E-04	.2010	.713E-05	.2030	.140E-05
.2040	.154E-02	.2060	.641E-03	.2090	.221E-03	.2120	.288E-04	.2130	.466E-05	.2150	.853E-06
.2120	.103E-02	.2150	.431E-03	.2190	.150E-03	.2230	.201E-04	.2250	.260E-05	.2280	.466E-06
.2200	.637E-03	.2240	.272E-03	.2300	.890E-04	.2340	.143E-04	.2370	.142E-05	.2400	.167E-06
.2280	.340E-03	.2330	.149E-03	.2400	.473E-04	.2450	.949E-05	.2490	.505E-06	.2530	.525E-07
.2360	.128E-03	.2430	.510E-04	.2510	.164E-04	.2570	.256E-05	.2610	.515E-07	.2650	.605E-09
.2440	.113E-04	.2520	.386E-05	.2610	.435E-06	.2680	0.	.2730	0.	.2780	0.

TANDE SAMPLE OUTPUT

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THE DOSES AND DOSE RATES ARE CALCULATED BEHIND SHIELDING PROVIDED BY THE  APOLLO              VEHICLE WITH    19 SECTORS

  THIS ELLIPTICAL ORBIT HAS BEEN EXAMINED AT    337 POINTS.
  THE GEOGRAPHIC EXCLUSION TEST HAS BEEN EMPLOYED.

                      INITIAL LATITUDE (DEG.)                      -32.000
                      INITIAL LONGITUDE (DEG.)                     -54.000
                      ORBITAL INCLINATION (DEG.)                    45.000
                      PERIGEE (KM.)                                900.000
                      APOGEE (KM.)                                1000.000
                      PSI STEP (RADIANS)                              .030
                      STARTING TIME (SEC.)                           0.000
                      ENDING TIME (SEC.)                         10000.000
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TANDE SAMPLE OUTPUT

THE INTEGRAL ELECTRON FLUXES ARE PARTICLES/CM**2-SEC AND THE INTEGRAL ELECTRON FLUENCES ARE IN PARTICLES/CM**2

TIME (SEC)	FLUX E .GT.	FLUENCE .10MEV	FLUX E .GT.	FLUENCE .50MEV	FLUX E .GT.	FLUENCE 1.00MEV	FLUX E .GT.	FLUENCE 2.00MEV	FLUX E .GT.	FLUENCE 3.00MEV	R (E.R.)	LAMBDA (DEG)
29.4	.140E+08	.434E+09	.293E+07	.859E+08	.130E+07	.404E+08	.394E+06	.116E+08	.271E+05	.794E+06	1.250	15.18
58.7	.145E+08	.860E+09	.298E+07	.173E+09	.142E+07	.821E+08	.405E+06	.235E+08	.279E+05	.161E+07	1.250	14.52
88.1	.140E+08	.129E+10	.312E+07	.265E+09	.150E+07	.126E+09	.427E+06	.360E+08	.295E+05	.240E+07	1.250	13.89
117.4	.152E+08	.174E+10	.330E+07	.362E+09	.160E+07	.173E+09	.456E+06	.494E+08	.313E+05	.340E+07	1.250	13.28
146.8	.153E+08	.219E+10	.344E+07	.463E+09	.168E+07	.222E+09	.479E+06	.634E+08	.330E+05	.437E+07	1.249	12.70
176.1	.162E+08	.266E+10	.375E+07	.573E+09	.185E+07	.277E+09	.524E+06	.780E+08	.360E+05	.542E+07	1.249	12.14
205.5	.171E+08	.317E+10	.407E+07	.692E+09	.203E+07	.336E+09	.573E+06	.956E+08	.392E+05	.657E+07	1.248	11.61
234.9	.148E+08	.368E+10	.353E+07	.796E+09	.176E+07	.388E+09	.498E+06	.110E+09	.343E+05	.758E+07	1.246	11.10
264.2	.129E+08	.398E+10	.306E+07	.886E+09	.153E+07	.433E+09	.433E+06	.123E+09	.299E+05	.846E+07	1.245	10.60
293.6	.107E+08	.429E+10	.256E+07	.961E+09	.128E+07	.470E+09	.365E+06	.134E+09	.255E+05	.921E+07	1.243	10.13
323.0	.914E+07	.456E+10	.219E+07	.103E+10	.110E+07	.503E+09	.311E+06	.143E+09	.210E+05	.985E+07	1.241	9.67
352.3	.883E+07	.488E+10	.192E+07	.108E+10	.960E+06	.531E+09	.272E+06	.151E+09	.190E+05	.104E+08	1.238	9.22
381.7	.721E+07	.501E+10	.172E+07	.113E+10	.859E+06	.556E+09	.243E+06	.158E+09	.169E+05	.109E+08	1.236	8.79
411.1	.662E+07	.520E+10	.158E+07	.118E+10	.780E+06	.579E+09	.223E+06	.165E+09	.154E+05	.114E+08	1.233	8.36
440.5	.623E+07	.539E+10	.140E+07	.122E+10	.741E+06	.601E+09	.209E+06	.171E+09	.144E+05	.118E+08	1.231	7.93
469.9	.570E+07	.555E+10	.136E+07	.126E+10	.679E+06	.621E+09	.191E+06	.176E+09	.131E+05	.122E+08	1.229	7.31
499.3	.422E+07	.568E+10	.101E+07	.129E+10	.507E+06	.636E+09	.143E+06	.181E+09	.989E+04	.125E+08	1.226	6.91
528.7	.305E+07	.577E+10	.740E+06	.131E+10	.371E+06	.647E+09	.105E+06	.184E+09	.736E+04	.127E+08	1.222	6.51
558.1	.220E+07	.583E+10	.536E+06	.133E+10	.269E+06	.655E+09	.763E+05	.186E+09	.536E+04	.128E+08	1.219	6.09
587.5	.163E+07	.588E+10	.398E+06	.134E+10	.199E+06	.661E+09	.566E+05	.188E+09	.396E+04	.129E+08	1.215	5.65
617.0	.122E+07	.592E+10	.297E+06	.135E+10	.148E+06	.665E+09	.419E+05	.189E+09	.289E+04	.130E+08	1.212	5.19
646.4	.895E+06	.594E+10	.218E+06	.136E+10	.109E+06	.668E+09	.307E+05	.190E+09	.212E+04	.131E+08	1.208	4.71
675.8	.684E+06	.596E+10	.167E+06	.136E+10	.832E+05	.671E+09	.235E+05	.190E+09	.161E+04	.131E+08	1.205	4.21
705.3	.506E+06	.598E+10	.123E+06	.136E+10	.615E+05	.672E+09	.174E+05	.191E+09	.119E+04	.132E+08	1.201	3.67
734.7	.389E+06	.599E+10	.948E+05	.137E+10	.473E+05	.674E+09	.133E+05	.191E+09	.912E+03	.132E+08	1.197	3.07
764.2	.240E+06	.600E+10	.621E+05	.137E+10	.319E+05	.675E+09	.945E+04	.192E+09	.719E+03	.132E+08	1.194	2.42
793.7	.142E+06	.600E+10	.391E+05	.137E+10	.207E+05	.675E+09	.650E+04	.192E+09	.559E+03	.132E+08	1.191	1.69
823.1	.826E+05	.600E+10	.242E+05	.137E+10	.132E+05	.676E+09	.440E+04	.192E+09	.426E+03	.133E+08	1.187	.75
852.6	.536E+05	.601E+10	.165E+05	.137E+10	.924E+04	.676E+09	.321E+04	.192E+09	.342E+03	.133E+08	1.184	0.00
882.1	.340E+05	.601E+10	.110E+05	.137E+10	.631E+04	.676E+09	.229E+04	.192E+09	.260E+03	.133E+08	1.180	0.00
911.6	.226E+05	.601E+10	.762E+04	.137E+10	.446E+04	.676E+09	.160E+04	.192E+09	.213E+03	.133E+08	1.177	0.00
941.2	.155E+05	.601E+10	.543E+04	.137E+10	.323E+04	.676E+09	.126E+04	.192E+09	.171E+03	.133E+08	1.174	.57
970.7	.110E+05	.601E+10	.396E+04	.137E+10	.239E+04	.677E+09	.956E+03	.192E+09	.137E+03	.133E+08	1.170	2.60
1000.2	.860E+04	.601E+10	.313E+04	.137E+10	.191E+04	.677E+09	.771E+03	.192E+09	.113E+03	.133E+08	1.167	3.48
1029.8	.676E+04	.601E+10	.247E+04	.137E+10	.151E+04	.677E+09	.613E+03	.192E+09	.913E+02	.133E+08	1.164	4.38
1059.3	.453E+04	.601E+10	.164E+04	.137E+10	.108E+04	.677E+09	.407E+03	.192E+09	.607E+02	.133E+08	1.161	5.31
1088.9	.341E+04	.601E+10	.128E+04	.137E+10	.724E+03	.677E+09	.289E+03	.192E+09	.413E+02	.133E+08	1.159	6.25
1118.5	.264E+04	.601E+10	.822E+03	.137E+10	.490E+03	.677E+09	.191E+03	.192E+09	.250E+02	.133E+08	1.156	7.22
1148.1	.170E+04	.601E+10	.543E+03	.137E+10	.317E+03	.677E+09	.119E+03	.192E+09	.149E+02	.133E+08	1.154	8.22
1177.7	.109E+04	.601E+10	.325E+03	.137E+10	.184E+03	.677E+09	.657E+02	.192E+09	.730E+01	.133E+08	1.151	9.23
1207.3	.592E+03	.601E+10	.161E+03	.137E+10	.883E+02	.677E+09	.296E+02	.192E+09	.290E+01	.133E+08	1.149	10.26
1236.9	.251E+03	.601E+10	.613E+02	.137E+10	.321E+02	.677E+09	.909E+01	.192E+09	0.	.133E+08	1.147	11.31
1266.6	.617E+02	.601E+10	.133E+02	.137E+10	.665E+01	.677E+09	.187E+01	.192E+09	0.	.133E+08	1.145	12.38
1296.2	.166E+02	.601E+10	.345E+01	.137E+10	.169E+01	.677E+09	0.	.192E+09	0.	.133E+08	1.144	13.45
1325.9	.142E+01	.601E+10	0.	.137E+10	0.	.677E+09	0.	.192E+09	0.	.133E+08	1.142	14.53
1355.5	0.	.601E+10	0.	.137E+10	0.	.677E+09	0.	.192E+09	0.	.133E+08	1.141	15.62
1385.2	0.	.601E+10	0.	.137E+10	0.	.677E+09	0.	.192E+09	0.	.133E+08	1.140	16.71
1414.9	0.	.601E+10	0.	.137E+10	0.	.677E+09	0.	.192E+09	0.	.133E+08	1.139	17.80
1444.6	0.	.601E+10	0.	.137E+10	0.	.677E+09	0.	.192E+09	0.	.133E+08	1.138	18.88
1474.3	0.	.601E+10	0.	.137E+10	0.	.677E+09	0.	.192E+09	0.	.133E+08	1.138	19.97

TANDF SAMPLE OUTPUT

THE INTEGRAL PROTON FLUXES ARE PARTICLES/CM**2-SEC AND THE INTEGRAL PROTON FLUENCES ARE IN PARTICLES/CM**2

TIME (SEC)	FLUX E .GT.	FLUENCE 1.00MEV	FLUX E .GT.	FLUENCE 15.00MEV	FLUX E .GT.	FLUENCE 31.00MEV	FLUX E .GT.	FLUENCE 51.00MEV	FLUX E .GT.	FLUENCE 101.00MEV	R (E.R.)	LAMBDA (DEG)
29.4	.301E+05	.804E+06	.605E+04	.201E+06	.514E+04	.151E+06	.307E+04	.114E+06	.240E+04	.727E+05	1.250	15.18
58.7	.317E+05	.181E+07	.730E+04	.410E+06	.540E+04	.312E+06	.406E+04	.233E+06	.262E+04	.150E+06	1.250	14.52
88.1	.333E+05	.279E+07	.795E+04	.651E+06	.576E+04	.481E+06	.414E+04	.354E+06	.268E+04	.225E+06	1.250	13.89
117.4	.348E+05	.381E+07	.860E+04	.903E+06	.607E+04	.655E+06	.422E+04	.470E+06	.274E+04	.309E+06	1.250	13.28
146.8	.361E+05	.487E+07	.929E+04	.118E+07	.630E+04	.846E+06	.429E+04	.604E+06	.279E+04	.391E+06	1.249	12.70
176.1	.377E+05	.596E+07	.985E+04	.147E+07	.663E+04	.104E+07	.437E+04	.732E+06	.285E+04	.475E+06	1.249	12.14
205.5	.384E+05	.711E+07	.102E+05	.176E+07	.679E+04	.124E+07	.443E+04	.862E+06	.290E+04	.560E+06	1.248	11.61
234.9	.356E+05	.815E+07	.920E+04	.203E+07	.616E+04	.142E+07	.404E+04	.981E+06	.263E+04	.637E+06	1.246	11.10
264.2	.330E+05	.912E+07	.835E+04	.228E+07	.563E+04	.159E+07	.372E+04	.109E+07	.242E+04	.708E+06	1.245	10.60
293.6	.306E+05	.100E+08	.763E+04	.250E+07	.520E+04	.174E+07	.346E+04	.119E+07	.225E+04	.774E+06	1.243	10.13
323.0	.284E+05	.109E+08	.701E+04	.271E+07	.482E+04	.188E+07	.325E+04	.129E+07	.211E+04	.836E+06	1.241	9.67
352.3	.267E+05	.116E+08	.653E+04	.290E+07	.453E+04	.201E+07	.300E+04	.138E+07	.202E+04	.895E+06	1.238	9.22
381.7	.240E+05	.124E+08	.595E+04	.308E+07	.410E+04	.214E+07	.280E+04	.146E+07	.191E+04	.951E+06	1.236	8.79
411.1	.232E+05	.131E+08	.550E+04	.324E+07	.391E+04	.225E+07	.273E+04	.154E+07	.181E+04	.100E+07	1.233	8.36
440.5	.210E+05	.137E+08	.509E+04	.339E+07	.366E+04	.236E+07	.260E+04	.162E+07	.173E+04	.106E+07	1.231	7.93
469.5	.202E+05	.143E+08	.465E+04	.353E+07	.340E+04	.246E+07	.245E+04	.169E+07	.164E+04	.110E+07	1.229	7.31
499.3	.191E+05	.149E+08	.433E+04	.365E+07	.320E+04	.255E+07	.235E+04	.176E+07	.159E+04	.115E+07	1.226	6.91
528.7	.180E+05	.154E+08	.402E+04	.377E+07	.302E+04	.264E+07	.225E+04	.183E+07	.153E+04	.120E+07	1.222	6.51
558.1	.170E+05	.159E+08	.375E+04	.388E+07	.286E+04	.273E+07	.217E+04	.189E+07	.149E+04	.124E+07	1.219	6.09
587.5	.160E+05	.164E+08	.350E+04	.398E+07	.271E+04	.281E+07	.209E+04	.195E+07	.145E+04	.128E+07	1.215	5.65
617.0	.150E+05	.168E+08	.323E+04	.408E+07	.255E+04	.288E+07	.201E+04	.201E+07	.140E+04	.132E+07	1.212	5.19
646.4	.144E+05	.172E+08	.307E+04	.417E+07	.245E+04	.295E+07	.197E+04	.207E+07	.139E+04	.136E+07	1.208	4.71
675.8	.137E+05	.176E+08	.288E+04	.425E+07	.234E+04	.302E+07	.192E+04	.213E+07	.136E+04	.140E+07	1.205	4.21
705.3	.129E+05	.180E+08	.269E+04	.433E+07	.223E+04	.309E+07	.186E+04	.218E+07	.133E+04	.144E+07	1.201	3.67
734.7	.124E+05	.184E+08	.255E+04	.441E+07	.215E+04	.315E+07	.183E+04	.223E+07	.132E+04	.148E+07	1.197	3.07
764.2	.884E+04	.186E+08	.194E+04	.447E+07	.164E+04	.320E+07	.141E+04	.228E+07	.104E+04	.151E+07	1.194	2.42
793.7	.607E+04	.188E+08	.142E+04	.451E+07	.121E+04	.323E+07	.105E+04	.231E+07	.787E+03	.154E+07	1.191	1.69
823.1	.413E+04	.189E+08	.104E+04	.454E+07	.892E+03	.326E+07	.776E+03	.233E+07	.591E+03	.155E+07	1.187	.75
852.6	.290E+04	.190E+08	.774E+03	.456E+07	.669E+03	.328E+07	.556E+03	235E+07	.452E+03	.157E+07	1.184	0.00
882.1	.209E+04	.191E+08	.590E+03	.458E+07	.512E+03	.330E+07	[illegible]	.236E+07	.352E+03	.158E+07	1.180	0.00
911.6	.156E+04	.191E+08	.460E+03	.459E+07	.402E+03	.331E+07	.356E+03	.237E+07	.280E+03	.159E+07	1.177	0.00
941.2	.119E+04	.192E+08	.366E+03	.460E+07	.322E+03	.332E+07	.286E+03	.238E+07	.226E+03	.159E+07	1.174	.57
970.7	.930E+03	.192E+08	.295E+03	.461E+07	.261E+03	.332E+07	.233E+03	.239E+07	.184E+03	.160E+07	1.170	2.60
1000.2	.777E+03	.192E+08	.250E+03	.462E+07	.222E+03	.333E+07	.199E+03	.239E+07	.157E+03	.160E+07	1.167	3.48
1029.8	.661E+03	.192E+08	.214E+03	.463E+07	.191E+03	.334E+07	.172E+03	.240E+07	.135E+03	.161E+07	1.164	4.38
1059.3	.569E+03	.192E+08	.185E+03	.463E+07	.165E+03	.334E+07	.150E+03	.240E+07	.115E+03	.161E+07	1.161	5.31
1088.9	.544E+03	.193E+08	.173E+03	.464E+07	.155E+03	.335E+07	.141E+03	.241E+07	.106E+03	.161E+07	1.159	6.25
1118.5	.522E+03	.193E+08	.161E+03	.464E+07	.146E+03	.335E+07	.133E+03	.241E+07	.955E+02	.162E+07	1.156	7.22
1148.1	.580E+03	.193E+08	.127E+03	.464E+07	.117E+03	.335E+07	.109E+03	.241E+07	.712E+02	.162E+07	1.154	8.22
1177.7	.537E+03	.193E+08	.104E+03	.465E+07	.961E+02	.336E+07	.889E+02	.242E+07	.495E+02	.162E+07	1.151	9.23
1207.3	.556E+03	.193E+08	.651E+02	.465E+07	.501E+02	.336E+07	.512E+02	.242E+07	.196E+02	.162E+07	1.149	10.26
1236.9	.591E+03	.193E+08	.366E+02	.465E+07	.310E+02	.336E+07	.254E+02	.242E+07	.594E+01	.162E+07	1.147	11.31
1266.6	.664E+03	.194E+08	.154E+02	.465E+07	.129E+02	.336E+07	.103E+02	.242E+07	.227E+01	.162E+07	1.145	12.38
1296.2	.441E+03	.194E+08	.101E+02	.465E+07	.816E+01	.336E+07	.619E+01	.242E+07	.150E+01	.162E+07	1.144	13.45
1325.9	.303E+03	.194E+08	.818E+01	.465E+07	.556E+01	.336E+07	.344E+01	.242E+07	.100E+01	.162E+07	1.142	14.53
1355.5	.210E+03	.194E+08	.750E+01	.465E+07	.414E+01	.336E+07	.100E+01	.242E+07	0.	.162E+07	1.141	15.62
1385.2	.173E+03	.194E+08	.773E+01	.465E+07	.363E+01	.336E+07	.134E+01	.242E+07	0.	.162E+07	1.140	16.71
1414.5	.130E+03	.194E+08	.736E+01	.465E+07	.304E+01	.336E+07	0.	.242E+07	0.	.162E+07	1.139	17.80
1444.6	.106E+03	.194E+08	.731E+01	.465E+07	.304E+01	.336E+07	0.	.242E+07	0.	.162E+07	1.138	18.88
1474.3	.635E+02	.194E+08	.649E+01	.465E+07	.206E+01	.336E+07	0.	.242E+07	0.	.162E+07	1.138	19.97

TANDE SAMPLE OUTPUT

TIME (SEC)	LATIT (DEG)	LONG (DEG)	ALT (KM)	B (GAUSS)	L (E.R.)	PROTON DOSE RATE (RADS/HR)	PROTON DOSE (RAD)	ELECTRON DOSE RATE (RADS/HR)	ELECTRON DOSE (RAD)	BREMS DOSE RATE (RADS/HR)	BREMS DOSE (RAD)	TOTAL DOSE RATE (RADS/HR)	TOTAL DOSE (RAD)
0.	-32.00	306.00	900.0	.1771	1.350	.705E+00	0.	.705E-03	0.	.279E-01	0.	.734E+00	0.
29.4	-31.04	307.55	900.0	.1754	1.342	.754E+00	.555E-02	.729E-03	.505E-05	.288E-01	.231E-03	.784E+00	.619E-02
58.7	-30.06	309.07	900.1	.1739	1.334	.798E+00	.123E-01	.740E-03	.119E-04	.295E-01	.460E-03	.829E+00	.120E-01
88.1	-29.06	310.55	900.2	.1727	1.327	.840E+00	.190E-01	.782E-03	.181E-04	.311E-01	.715E-03	.872E+00	.197E-01
117.4	-28.03	312.30	900.4	.1717	1.320	.886E+00	.260E-01	.822E-03	.247E-04	.331E-01	.977E-03	.920E+00	.270E-01
146.8	-27.03	313.43	900.6	.1710	1.313	.934E+00	.334E-01	.859E-03	.315E-04	.347E-01	.125E-02	.969E+00	.347E-01
176.2	-25.94	314.82	900.8	.1704	1.306	.970E+00	.412E-01	.925E-03	.388E-04	.379E-01	.155E-02	.101E+01	.428E-01
205.5	-24.87	316.19	901.1	.1700	1.300	.993E+00	.492E-01	.993E-03	.466E-04	.414E-01	.187E-02	.104E+01	.511E-01
234.9	-23.79	317.53	901.4	.1698	1.294	.903E+00	.569E-01	.873E-03	.542E-04	.360E-01	.219E-02	.939E+00	.592E-01
264.2	-22.69	318.86	901.8	.1697	1.288	.826E+00	.640E-01	.765E-03	.609E-04	.314E-01	.246E-02	.858E+00	.665E-01
293.6	-21.58	320.14	902.2	.1697	1.282	.762E+00	.705E-01	.656E-03	.667E-04	.264E-01	.270E-02	.789E+00	.732E-01
323.0	-20.45	321.41	902.7	.1700	1.277	.707E+00	.768E-01	.565E-03	.717E-04	.226E-01	.290E-02	.730E+00	.794E-01
352.3	-19.32	322.66	903.2	.1703	1.271	.650E+00	.828E-01	.493E-03	.760E-04	.199E-01	.307E-02	.679E+00	.852E-01
381.7	-18.17	323.89	903.7	.1707	1.266	.602E+00	.872E-01	.430E-03	.798E-04	.177E-01	.322E-02	.620E+00	.905E-01
411.1	-17.02	325.11	904.3	.1713	1.260	.559E+00	.919E-01	.397E-03	.832E-04	.162E-01	.336E-02	.576E+00	.953E-01
440.5	-15.86	326.31	904.9	.1719	1.254	.521E+00	.953E-01	.369E-03	.863E-04	.153E-01	.349E-02	.536E+00	.999E-01
469.9	-14.69	327.49	905.6	.1727	1.249	.479E+00	.100E+00	.335E-03	.892E-04	.149E-01	.361E-02	.493E+00	.104E+00
499.3	-13.51	328.66	906.3	.1735	1.244	.447E+00	.104E+00	.253E-03	.916E-04	.104E-01	.371E-02	.458E+00	.108E+00
528.7	-12.33	329.82	907.0	.1744	1.238	.410E+00	.108E+00	.189E-03	.934E-04	.764E-02	.378E-02	.425E+00	.112E+00
558.1	-11.14	330.96	907.8	.1754	1.233	.391E+00	.111E+00	.139E-03	.947E-04	.553E-02	.384E-02	.396E+00	.115E+00
587.5	-9.94	332.09	908.6	.1764	1.227	.365E+00	.114E+00	.182E-03	.957E-04	.409E-02	.388E-02	.370E+00	.118E+00
617.0	-8.74	333.22	909.5	.1775	1.222	.339E+00	.117E+00	.745E-04	.964E-04	.304E-02	.391E-02	.342E+00	.121E+00
646.4	-7.54	334.34	910.4	.1786	1.216	.321E+00	.120E+00	.544E-04	.970E-04	.222E-02	.393E-02	.323E+00	.124E+00
675.8	-6.33	335.45	911.3	.1798	1.211	.300E+00	.122E+00	.413E-04	.973E-04	.170E-02	.394E-02	.302E+00	.126E+00
705.3	-5.12	336.55	912.3	.1810	1.206	.280E+00	.125E+00	.303E-04	.976E-04	.125E-02	.396E-02	.281E+00	.129E+00
734.7	-3.91	337.65	913.3	.1823	1.201	.264E+00	.127E+00	.231E-04	.979E-04	.961E-03	.397E-02	.265E+00	.131E+00
764.2	-2.69	338.75	914.3	.1836	1.196	.195E+00	.129E+00	.190E-04	.980E-04	.659E-03	.397E-02	.196E+00	.133E+00
793.7	-1.48	339.84	915.3	.1850	1.192	.139E+00	.130E+00	.155E-04	.982E-04	.430E-03	.398E-02	.140E+00	.134E+00
823.1	-.26	340.93	916.4	.1865	1.187	.987E-01	.131E+00	.125E-04	.983E-04	.287E-03	.398E-02	.990E-01	.135E+00
852.6	.96	342.02	917.6	.1880	1.184	.717E-01	.132E+00	.105E-04	.984E-04	.205E-03	.398E-02	.719E-01	.136E+00
882.1	2.17	343.12	918.7	.1897	1.180	.534E-01	.132E+00	.866E-05	.985E-04	.143E-03	.398E-02	.535E-01	.136E+00
911.6	3.39	344.21	919.9	.1914	1.177	.418E-01	.133E+00	.721E-05	.985E-04	.103E-03	.398E-02	.411E-01	.137E+00
941.2	4.60	345.31	921.1	.1932	1.175	.323E-01	.133E+00	.690E-05	.986E-04	.761E-04	.398E-02	.323E-01	.137E+00
970.7	5.81	346.41	922.3	.1951	1.173	.268E-01	.133E+00	.447E-05	.986E-04	.572E-04	.399E-02	.260E-01	.137E+00
1000.2	7.02	347.52	923.6	.1971	1.171	.223E-01	.133E+00	.418E-05	.987E-04	.459E-04	.399E-02	.224E-01	.137E+00
1029.8	8.23	348.63	924.9	.1992	1.171	.196E-01	.134E+00	.336E-05	.987E-04	.364E-04	.399E-02	.196E-01	.138E+00
1059.3	9.43	349.75	926.2	.2015	1.171	.174E-01	.134E+00	.228E-05	.987E-04	.242E-04	.399E-02	.174E-01	.138E+00
1088.9	10.63	350.86	927.5	.2040	1.172	.171E-01	.134E+00	.174E-05	.987E-04	.174E-04	.399E-02	.171E-01	.138E+00
1118.5	11.82	352.02	928.8	.2065	1.175	.175E-01	.134E+00	.127E-05	.987E-04	.116E-04	.399E-02	.176E-01	.138E+00
1148.1	13.01	353.17	930.2	.2092	1.178	.163E-01	.134E+00	.894E-06	.988E-04	.739E-05	.399E-02	.163E-01	.138E+00
1177.7	14.19	354.33	931.6	.2120	1.182	.155E-01	.134E+00	.495E-06	.988E-04	.419E-05	.399E-02	.155E-01	.138E+00
1207.3	15.36	355.51	933.0	.2150	1.187	.108E-01	.134E+00	.107E-06	.988E-04	.193E-05	.399E-02	.108E-01	.138E+00
1236.9	16.53	356.70	934.4	.2180	1.193	.570E-02	.134E+00	.436E-08	.988E-04	.660E-06	.399E-02	.578E-02	.139E+00
1266.5	17.69	357.91	935.8	.2212	1.201	.264E-02	.134E+00	0.	.988E-04	.120E-06	.399E-02	.264E-02	.139E+00
1296.2	18.83	359.13	937.3	.2246	1.209	.167E-02	.134E+00	0.	.988E-04	.221E-07	.399E-02	.167E-02	.139E+00
1325.8	19.97	.37	938.7	.2280	1.219	.121E-02	.134E+00	0.	.988E-04	.281E-10	.399E-02	.121E-02	.139E+00
1355.5	21.10	1.63	940.2	.2314	1.230	.603E-03	.134E+00	0.	.988E-04	0.	.399E-02	.603E-03	.139E+00
1385.2	22.21	2.92	941.7	.2350	1.243	.546E-03	.134E+00	0.	.988E-04	0.	.399E-02	.546E-03	.139E+00
1414.9	23.32	4.22	943.1	.2386	1.257	.454E-03	.134E+00	0.	.988E-04	0.	.399E-02	.454E-03	.139E+00
1444.6	24.41	5.55	944.6	.2422	1.272	.454E-03	.135E+00	0.	.988E-04	0.	.399E-02	.454E-03	.139E+00

REFERENCES

1. Barton, J. A. et al., Computer Codes for Space Radiation Environment and Shielding, WL-TDR-64-71, Vols. I and II. Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico (August 1964)

2. Janni, J. F., Calculations of Energy Loss, Range, Pathlength, Straggling, Multiple Scattering, and the Probability of Inelastic Nuclear Collisions for 0.1- to 10000.- MeV Protons, AFWL-TR-65-150, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico (September 1966)

3. Singley, G. W. and Vette, J. I., The AE-4 Model of the Outer Radiation Zone Electron Environment, NSSDC-72-06, National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Md. (August 1972)

4. Teague, M. J. and Vette, J. I., The Inner Zone Electron Model AE-5, NSSDC-72-10, National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Md. (November 1972)

5. Teague, M. J., Stein, J. and Vette, J. I., The Use of the Inner-Zone Electron Model AE-5 and Associated Computer Programs, NSSDC-72-11, National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Md. (November 1972)

6. Vette, J. I., Models of the Trapped Radiation Environment Volume I: Inner Zone Protons and Electrons, NASA SP-3024 National Aeronautics and Space Administration, Washington, D. C. (1966)

7. King, J. H., Models of the Trapped Radiation Environment Volume IV: Low Energy Protons, NASA SP-3024, National Aeronautics and Space Administration, Washington, D. C. (1967)

8. Lavine, J. P. and Vette, J. I., Models of the Trapped Radiation Environment Volume V: Inner Belt Protons, NASA SP-3024, National Aeronautics and Space Administration, Washington, D. C. (1969)

9. Lavine, J. P. and Vette, J. I., Models of the Trapped Radiation Environment Volume VI: High Energy Protons, NASA SP-3024, National Aeronautics and Space Administration, Washington, D. C. (1970)

REFERENCES (Continued)

10. McIlwain, C. E., "Coordinates for Mapping the Distribution of Magnetically Trapped Particles," J. Geophys. Res., 66, pp. 3681-3692 (1961)

11. Stassinopoulous, E. G. and Mead, G. D., ALLMAG, GDALMAG, LINTRA: Computer Programs for Geomagnetic Field and Field-Line Calculations, NSSDC-72-12, National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Md. (February 1972)

12. American Standard Fortran, USA Standard X3.9-1966 Fortran, United States of America Standards Institute, New York (March 1966)

13. Neufield, J. and Snyder, W., "Estimates of Energy Dissipation by Heavy Charged Particles in Tissue," Selected Topics in Radiation Dosimetry, International Atomic Energy Agency, Kaerntnerring Vienna, Austria (1961

14. Liley, B. and Hamilton, S. C., Modified Elemental Volume Dose Program (MEVDP), AFWL-TR-69-68, Air Force WEapons Laboratory, Kirtland Air Force Base, New Mexico (March 1971)

15. Seliger, H. H., "Transmission of Positrons and Electrons," Physical Review, 100, pp. 1029-1037 (1955)

16. Makhov, A. F., "Penetration of Electrons into Solids," Fizika Tverdoge Tela, 2, p. 2161 (1960)

17. Evans, R. D., Principles for the Calculation of Bremmstrahlung Radiation Dose Rates in Space Vehicles, NASA Report 63270-05-01, National Aeronautics and Space Administration, Washington, D. C. (July 1961)

18. Wyard, S. J., "Intensity Distribution of Bremsstrahlung from Beta Rays," Proc. Phys. Soc. A65, p. 377, London (1952)

19. Wu, C. S., "The Continuous X-Rays Excited by the Beta Particles of P^{32}," Physical Review, 59, p. 481 (1941)

20. Berger, M. and Seltzer, S., "Penetration of Electrons and Associated Bremsstrahlung through Aluminum Targets," Protection Against Space Radiation, NASA SP-169, National Aeronautics and Space Adminstration, Washington, D. C. (1968)

21. Jensen, Townsend, Cork and Kraft, Design Guide to Orbital Flight, McGraw-Hill, New York (1962)