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ESTIMATES OF PRIMARY AND SECONDARY PARTICLE DOSES BEHIND ALUMINUM AND POLYETHYLENE SLABS DUE TO INCIDENT SOLAR-FLARE AND VAN ALLEN BELT PROTONS

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ABSTRACT

Primary proton and secondary particle doses (both physical and biological) behind aluminum and polyethylene slabs of varying thicknesses have been computed for normally incident solar-flare protons with spectra of characteristic rigidities (P_o = 50, 60, 80, 100, 120, and 195 MV) and for the Freden-White spectrum of protons in the Van Allen belt. The computations were performed with a proton penetration code (CCC-64/LPSC) recently developed by the NASA Lewis Research Center.

I. INTRODUCTION

It is known that several intense sources of radiation exist in our space environment which present a hazard to manned space flights, and protection against these radiations must be provided for if man is to venture into space successfully. In order to determine the shielding necessary to reduce the radiation to tolerable limits one must consider the strength and nature of the radiation, the interaction of the radiation with the shield materials, and the effect on an astronaut of the radiation which penetrates the shield.

As part of a continuing study of the interactions of protons with shielding materials, the results obtained with several proton-penetration codes available to the Radiation Shielding Information Center were recently compared,[1] and the comparison substantiated to some degree (see comments in ref. 1) the validity of a NASA Lewis Research Center code[2] (LPSC)* for calculating shield penetration data of interest to NASA shield

*Packaged for distribution by the Radiation Shielding Information Center as CCC-64/LPSC.

designers.* Thus some confidence in the shielding code itself having been established, LPSC was used to estimate the doses behind aluminum and polyethylene slabs that result from protons normally incident on the slabs. The incident spectra were assumed to be those of solar-flare protons and of Freden-White protons.[3] Both primary and secondary particle doses were obtained, and the results are presented in both graphic and tabulated form.

II. LPSC: CODE DESCRIPTION

LPSC calculates the primary and secondary particle doses behind multilayer shields of infinite extent and finite thickness due to a prescribed incident spectrum of protons. Since a very detailed description of the code is given in ref. 2, only a few general comments will be presented here.

The straightahead approximation is used in treating the high-energy "cascade" particles produced from nonelastic collisions -- that is, it is assumed that when a nonelastic collision occurs, the high-energy secondary particles are emitted in the direction of the incident particles. The code assumes that the low-energy "evaporation" secondary neutrons from nonelastic collisions are emitted isotropically and takes into account this angular dependence. Data developed by Bertini[4] for particle production from high-energy nonelastic collisions have been incorporated into the code.

III. RADIATION SOURCES

The radiation environment in space consists of three major components: galactic cosmic rays, solar cosmic rays, and the so-called Van Allen entrapped radiations. Fortunately, however, the intensity of cosmic rays is small ($\approx$ 2 particles/cm^2-sec), and the dose from them can be neglected unless very long missions are contemplated. Therefore,

*It should be noted at this point that for the comparisons presented in ref. 1 the upper limit on the incident flare spectra was 400 MeV, whereas for these calculations the upper limit has been extended to 1 GeV. The error caused by the extension is not known but is probably not large since the higher energy incident protons do not contribute an excessive amount to the total dose.

this paper will consider only doses that result from solar cosmic rays and Van Allen radiations.

Solar cosmic rays are high-energy particles emitted when disturbances of poorly understood origin -- solar flare events -- take place on the sun. These particles present the major radiation hazard for space travel outside the earth's magnetic field. The particle flux is composed of protons, a varying number of alpha particles and a small admixture of heavier nuclei; however, for the purpose of computing dose in these calculations only protons are considered.

A statistical analysis of the solar proton events for the purposes of making dose estimations was carried out by Modisette and co-workers.[5] This became a necessity in that the intensity and energy spectrum vary markedly from event to event. The time-integrated omidirectional integral proton spectrum may be represented as

$$J_p(>E) = J_o \exp\,[-P(E)/P_o] \quad , \tag{3.1}$$

where

$J_p(>E)$ = number of protons per unit area in the flare having kinetic energy greater than E,

$P(E)$ = rigidity
$= pc/Ze$,

p = particle momentum,

c = speed of light,

Z = charge number (1 for protons),

e = electronic charge,

J_o, P_o = parameters which characterize a particular flare.

Modisette et al.[5] give values of the parameters J_o and P_o for a large number of flares. They find that P_o varies between 50 and 200 MV and that the total number of protons with energy greater than 30 MeV varies from 10^6 protons/cm^2 to 10^9 protons/cm^2. Thus this range of P_o

values characterizes the solar-flare spectra which have been considered for the dose computations herein.

The differential kinetic energy spectra obtained by differentiating Eq. 3.1, i.e.,

$$\frac{dJ_p}{dE} = \frac{J_o}{P_o e} \frac{E + M_p}{[E(E + 2M_p)]^{\frac{1}{2}}} \exp\left(- \left[E(E + 2M_p) \right]^{\frac{1}{2}} \Big/ P_o e \right), \quad (3.2)$$

where M_p = proton rest-mass energy, are shown in Fig. 1 for P_o values of 200, 100, and 50 MV, respectively.[6] In this figure all of the flare spectra are normalized to contain 10^9 protons/cm^2 with rigidity greater than the rigidity of a 30-MeV proton.

The entrapped radiation in the earth's magnetic field, that is, the radiation which makes up the Van Allen belts,[3] is reasonably localized and is of primary importance when one considers orbital missions about the earth which repeatedly pass through the belts. This radiation is composed of both protons and electrons, but only the protons are of interest here. To determine the proton spectrum which must be shielded against for a particular mission, it is necessary to know explicitly the orbit for the mission. However, in order to have something specific in mind, the proton spectrum as measured by Freden and White[3] is taken to be roughly representative of the kind of spectrum which must be shielded against in the proton belt. For comparison purposes this spectrum is included in Fig. 1. (Note the Van Allen proton flux scale is shown on the right ordinate of the graph.)

IV. RESULTS

Dose estimates behind varying thicknesses of aluminum and polyethylene slab shields were calculated for solar-flare spectra of characteristic rigidities, P_o = 50, 60, 80, 100, 120, and 195 MV, and for the Freden-White proton spectrum. These results are presented in Figs. 2 and 3 and in Tables 1-14.

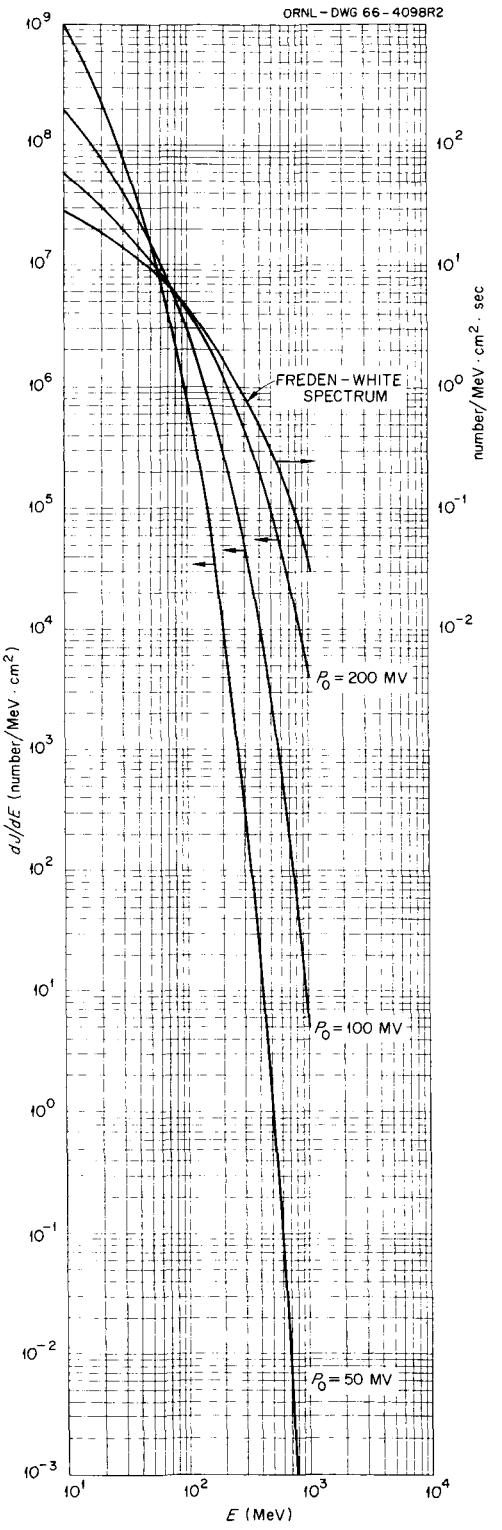

Fig. 1. Spectra of Solar-Flare Protons for P_O = 50, 100, and 200 MV and Freden-White Spectrum for Protons in Van Allen Belt.

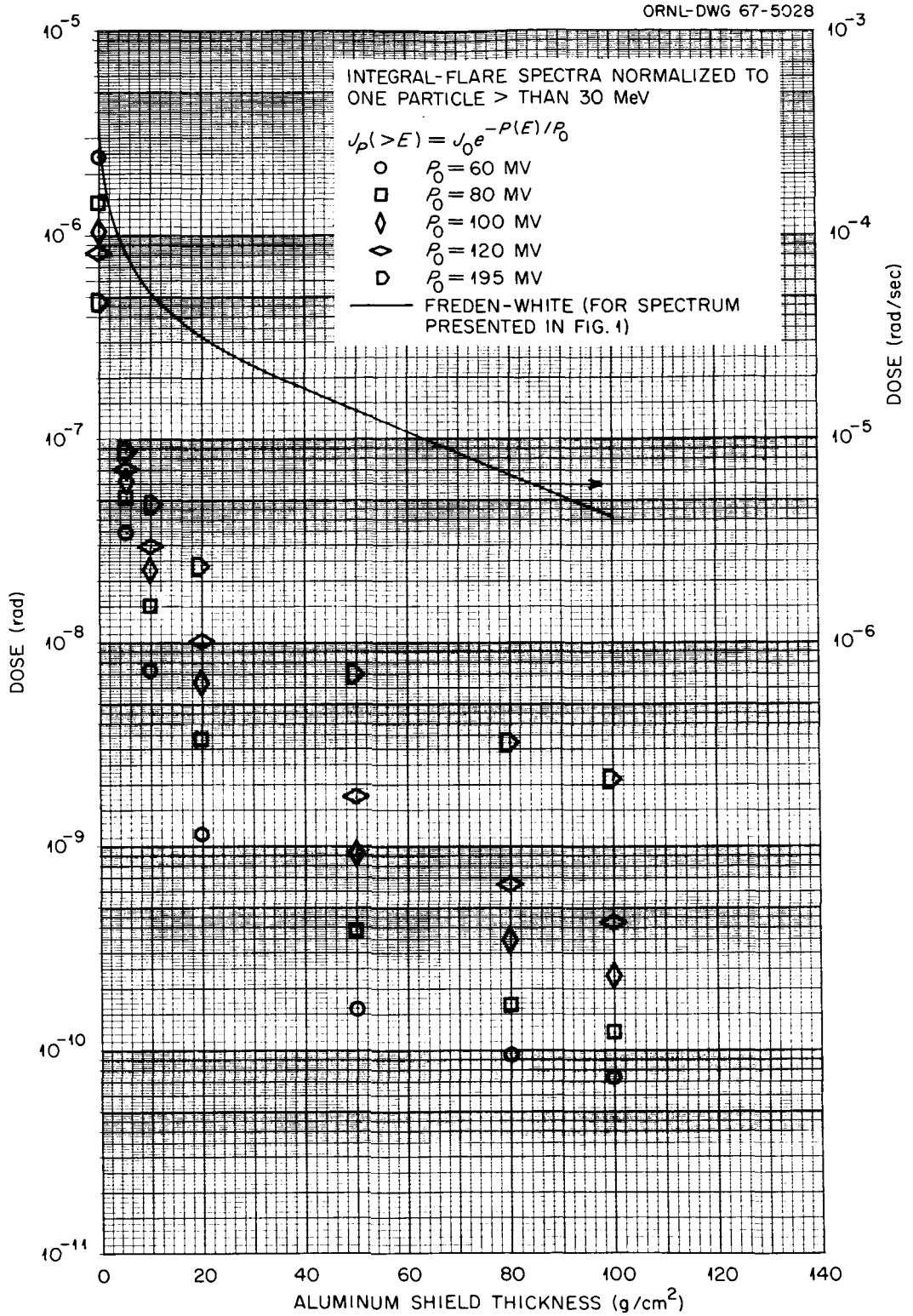

Fig. 2. Total Dose Behind Aluminum Slabs Due to Normally Incident Protons.

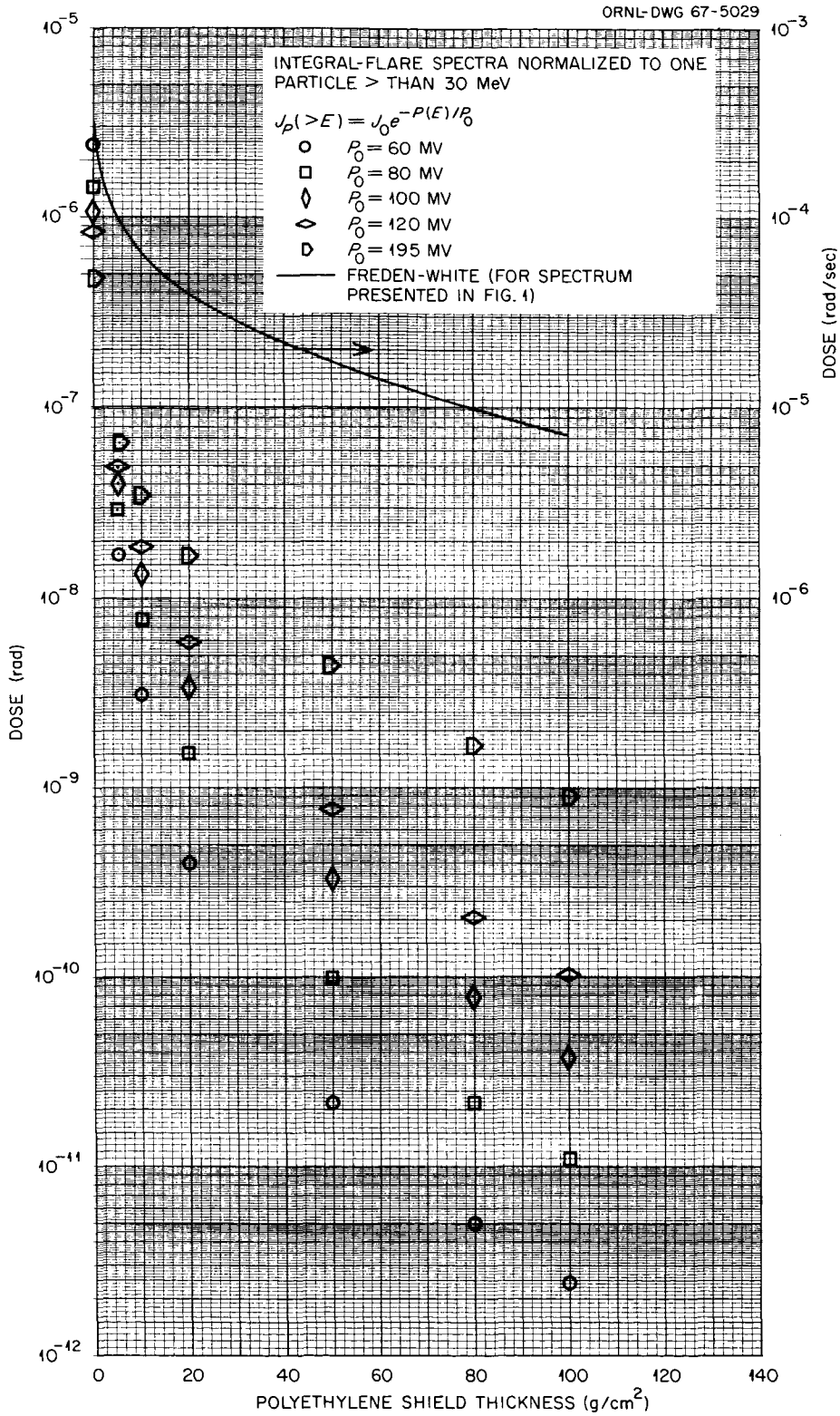

Fig. 3. Total Dose Behind Polyethylene Slabs Due to Normally Incident Protons.

Figures 2 and 3 represent the total dose vs shield thickness for the range of P_o values. These curves are largely self-explanatory. The larger the P_o value the more slowly the dose curve falls off with depth. The dose from the Freden-White spectrum is seen to be somewhat harder than the dose from the flare spectra.

Tables 1-14 (copies of computer output sheets) each show the dose results for a particular solar flare (Tables 1-12) or for the Freden-White spectrum (Tables 13-14). The columns are labeled so as to be self-explanatory. Doses shown in Tables 1-12 represent the dose per flare with the incident integral spectrum normalized to one proton with energy greater than 30 MeV.

Tables 13 and 14 represent the dose per second for the Freden-White spectrum as presented in Fig. 1.

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5. J. Modisette, T. M. Vinson, and A. C. Hardy, Model Solar Proton Environments for Manned Spacecraft Design, NASA-TN-D-2746, National Aeronautics and Space Administration (1965).

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Table 1. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P_0 = 50 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	3.6180E-06								3.6180E-06		3.6180E-06
5.00	2.4117E-08	2.9011E-10	6.7189E-13	1.3594E-10	3.9093E-12	6.5740E-11	2.9079E-10	1.3985E-10	2.4408E-08	2.0559E-10	2.4613E-08
10.00	3.7005E-09	7.1831E-11	5.9504E-13	1.3138E-10	8.8005E-12	5.8736E-11	7.2426E-11	1.4018E-10	3.7729E-09	1.9891E-10	3.9718E-09
20.00	3.5136E-10	1.0289E-11	8.8698E-14	1.1088E-10	1.6295E-11	4.4207E-11	1.0378E-11	1.2718E-10	3.6174E-10	1.7139E-10	5.3313E-10
50.00	5.0666E-12	2.6165E-13	1.0873E-14	6.3724E-11	2.4499E-11	2.5528E-11	2.7252E-13	8.8222E-11	5.3391E-12	1.1375E-10	1.1909E-10
80.00	2.6458E-13	1.9804E-14	7.5962E-15	3.7749E-11	2.2397E-11	1.6765E-11	2.7401E-14	6.0146E-11	2.9198E-13	7.6912E-11	7.7204E-11
100.00	4.8933E-14	4.5318E-15	2.8648E-14	2.7386E-11	1.9210E-11	1.2696E-11	3.3180E-14	4.6596E-11	8.2113E-14	5.9292E-11	5.9374E-11

DOSE--REM

0.00	3.7183E-06								3.7183E-06		3.7183E-06
5.00	2.7729E-08	3.9127E-10	1.0783E-12	8.0190E-10	2.3211E-11	6.5740E-10	3.9235E-10	8.2511E-10	2.8121E-08	1.4825E-09	2.9604E-08
10.00	4.1217E-09	9.6810E-11	8.9373E-13	7.7413E-10	5.2242E-11	5.8736E-10	9.1704E-11	8.2637E-10	4.2134E-09	1.4137E-09	5.6271E-09
20.00	3.8205E-10	1.1495E-11	9.7735E-14	6.5324E-10	9.6715E-11	4.4207E-10	1.1592E-11	7.4995E-10	3.9365E-10	1.1920E-09	1.5857E-09
50.00	5.3893E-12	2.9828E-13	1.2409E-14	3.7634E-10	1.4537E-10	2.5528E-10	3.1069E-13	5.2170E-10	5.7000E-12	7.7699E-10	7.8269E-10
80.00	2.7902E-13	2.3187E-14	8.4818E-15	2.2411E-10	1.3287E-10	1.6765E-10	3.1669E-14	3.5699E-10	3.1069E-13	5.2464E-10	5.2495E-10
100.00	5.1389E-14	5.0531E-15	2.8655E-14	1.6346E-10	1.1396E-10	1.2696E-10	3.3708E-14	2.7741E-10	8.5098E-14	4.0437E-10	4.0446E-10

Table 2. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P_o = 60 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	2.4695E-06								2.4695E-06		2.4695E-06
5.00	3.3966E-08	5.1004E-10	1.7985E-12	1.3827E-10	4.2567E-12	7.3977E-11	5.1184E-10	1.4253E-10	3.4477E-08	2.1651E-10	3.4694E-08
10.00	6.8550E-09	1.6825E-10	1.7274E-12	1.4009E-10	9.9970E-12	6.9393E-11	1.6998E-10	1.5009E-10	7.0250E-09	2.1948E-10	7.2445E-09
20.00	9.2138E-10	3.3976E-11	4.0792E-13	1.2200E-10	1.9251E-11	5.3871E-11	3.4384E-11	1.4125E-10	9.5577E-10	1.9512E-10	1.1509E-09
50.00	2.4899E-11	1.5850E-12	8.5997E-14	7.1573E-11	3.0537E-11	3.1936E-11	1.6710E-12	1.0211E-10	2.6570E-11	1.3405E-10	1.6062E-10
80.00	2.0024E-12	1.8369E-13	6.0990E-14	4.2298E-11	2.8934E-11	2.1539E-11	2.4468E-13	7.1232E-11	2.2471E-12	9.2771E-11	9.5018E-11
100.00	4.7202E-13	5.2925E-14	1.3967E-13	3.0346E-11	2.5364E-11	1.6632E-11	1.9259E-13	5.5710E-11	6.6462E-13	7.2342E-11	7.3006E-11
					DOSE--REM						
0.00	2.5313E-06								2.5313E-06		2.5313E-06
5.00	3.8577E-08	6.6531E-10	2.7850E-12	8.1068E-10	2.5256E-11	7.3977E-10	6.6809E-10	8.3593E-10	3.9245E-08	1.5757E-09	4.0821E-08
10.00	7.5609E-09	2.0832E-10	2.5320E-12	8.1944E-10	5.9295E-11	6.9393E-10	2.1086E-10	8.7873E-10	7.7718E-09	1.5727E-09	9.3444E-09
20.00	9.9408E-10	3.7438E-11	4.4990E-13	7.1234E-10	1.1414E-10	5.3871E-10	3.7888E-11	8.2648E-10	1.0320E-09	1.3652E-09	2.3972E-09
50.00	2.6327E-11	1.7681E-12	1.0148E-13	4.1765E-10	1.8098E-10	3.1936E-10	1.8695E-12	5.9863E-10	2.8197E-11	9.1799E-10	9.4618E-10
80.00	2.1008E-12	2.1172E-13	7.0732E-14	2.4725E-10	1.7144E-10	2.1539E-10	2.8245E-13	4.1868E-10	2.3832E-12	6.3408E-10	6.3646E-10
100.00	4.9332E-13	5.8895E-14	1.3979E-13	1.7784E-10	1.5026E-10	1.6632E-10	1.9868E-13	3.2810E-10	6.9200E-13	4.9442E-10	4.9511E-10

Table 3. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P_o = 80 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	1.4634E-06								1.4634E-06		1.4634E-06
5.00	4.9730E-08	1.0478E-09	6.3023E-12	1.4964E-10	4.8074E-12	8.6146E-11	1.0541E-09	1.5444E-10	5.0784E-08	2.4059E-10	5.1025E-08
10.00	1.4155E-08	5.0265E-10	6.8686E-12	1.6684E-10	1.2102E-11	8.8451E-11	5.0952E-10	1.7894E-10	1.4665E-08	2.6739E-10	1.4932E-08
20.00	2.9425E-09	1.5681E-10	2.8973E-12	1.5792E-10	2.5084E-11	7.4031E-11	1.5970E-10	1.8301E-10	3.1022E-09	2.5704E-10	3.3593E-09
50.00	1.7463E-10	1.5630E-11	1.2154E-12	1.0124E-10	4.4610E-11	4.7041E-11	1.6845E-11	1.4585E-10	1.9148E-10	1.9289E-10	3.8437E-10
80.00	2.4104E-11	3.0543E-12	8.9795E-13	6.2051E-11	4.5568E-11	3.3360E-11	3.9523E-12	1.0762E-10	2.8056E-11	1.4098E-10	1.6903E-10
100.00	7.7028E-12	1.1813E-12	1.1205E-12	4.5047E-11	4.1736E-11	2.6688E-11	2.3018E-12	8.6784E-11	1.0005E-11	1.1347E-10	1.2348E-10

DOSE--REM

0.00	1.4946E-06								1.4946E-06		1.4946E-06
5.00	5.5525E-08	1.3059E-09	9.2017E-12	8.6742E-10	2.8438E-11	8.6146E-10	1.3151E-09	8.9586E-10	5.6841E-08	1.7573E-09	5.8598E-08
10.00	1.5402E-08	6.0801E-10	9.6126E-12	9.6265E-10	7.1620E-11	8.8451E-10	6.1762E-10	1.0343E-09	1.6019E-08	1.9188E-09	1.7938E-08
20.00	3.1403E-09	1.7049E-10	3.1874E-12	9.0678E-10	1.4834E-10	7.4031E-10	1.7368E-10	1.0551E-09	3.3139E-09	1.7954E-09	5.1094E-09
50.00	1.8312E-10	1.6969E-11	1.4979E-12	5.7775E-10	2.6352E-10	4.7041E-10	1.8467E-11	8.4127E-10	2.0158E-10	1.3117E-09	1.5133E-09
80.00	2.5105E-11	3.4292E-12	1.0962E-12	3.5295E-10	2.6900E-10	3.3360E-10	4.5254E-12	6.2194E-10	2.9631E-11	9.5554E-10	9.8517E-10
100.00	7.9962E-12	1.3201E-12	1.1247E-12	2.5590E-10	2.4628E-10	2.6688E-10	2.4448E-12	5.0218E-10	1.0441E-11	7.6906E-10	7.7950E-10

Table 4. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P_o = 100 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	1.0520E-06								1.0520E-06		1.0520E-06
5.00	6.1559E-08	1.6565E-09	1.4056E-11	1.6599E-10	5.3849E-12	9.6417E-11	1.6705E-09	1.7137E-10	6.3229E-08	2.6779E-10	6.3497E-08
10.00	2.1565E-08	1.0071E-09	1.7032E-11	2.0061E-10	1.4345E-11	1.0657E-10	1.0242E-09	2.1496E-10	2.2589E-08	3.2153E-10	2.2911E-08
20.00	5.8321E-09	4.1285E-10	1.0074E-11	2.0641E-10	3.1665E-11	9.6102E-11	4.2292E-10	2.3808E-10	6.2550E-09	3.3418E-10	6.5892E-09
50.00	5.5570E-10	6.5138E-11	6.3465E-12	1.4765E-10	6.2739E-11	6.6250E-11	7.1484E-11	2.1039E-10	6.2719E-10	2.7664E-10	9.0383E-10
80.00	1.0611E-10	1.7307E-11	4.8818E-12	9.5647E-11	6.8812E-11	4.9205E-11	2.2189E-11	1.6446E-10	1.2830E-10	2.1366E-10	3.4197E-10
100.00	4.0733E-11	8.0161E-12	4.3597E-12	7.1271E-11	6.5619E-11	4.0568E-11	1.2376E-11	1.3689E-10	5.3109E-11	1.7746E-10	2.3057E-10

DOSE--REM

0.00	1.0719E-06								1.0719E-06		1.0719E-06
5.00	6.7941E-08	2.0040E-09	1.9607E-11	9.5172E-10	3.1798E-11	9.6417E-10	2.0236E-09	9.8352E-10	6.9965E-08	1.9477E-09	7.1913E-08
10.00	2.3248E-08	1.2021E-09	2.2913E-11	1.1427E-09	8.4627E-11	1.0657E-09	1.2250E-09	1.2274E-09	2.4473E-08	2.2931E-09	2.6766E-08
20.00	6.1783E-09	4.4655E-10	1.1023E-11	1.1668E-09	1.8656E-10	9.6102E-10	4.5758E-10	1.3534E-09	6.6358E-09	2.3144E-09	8.9503E-09
50.00	5.7945E-10	6.9556E-11	8.0001E-12	8.2553E-10	3.6893E-10	6.6250E-10	7.7557E-11	1.1945E-09	6.5700E-10	1.9570E-09	2.5140E-09
80.00	1.0999E-10	1.9037E-11	6.1325E-12	5.3107E-10	4.0413E-10	4.9205E-10	2.5169E-11	9.3521E-10	1.3515E-10	1.4273E-09	1.5624E-09
100.00	4.2092E-11	8.9894E-12	4.3970E-12	3.9427E-10	3.8511E-10	4.0568E-10	1.3386E-11	7.7938E-10	5.5479E-11	1.1851E-09	1.2405E-09

Table 5. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P_o = 120 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	8.2368E-07								8.2368E-07		8.2368E-07
5.00	6.9341E-08	2.2423E-09	2.4511E-11	1.8100E-10	5.9222E-12	1.0370E-10	2.2668E-09	1.8692E-10	7.1608E-08	2.9062E-10	7.1898E-08
10.00	2.7924E-08	1.6072E-09	3.2611E-11	2.3323E-10	1.6506E-11	1.2153E-10	1.6398E-09	2.4974E-10	2.9564E-08	3.7127E-10	2.9935E-08
20.00	9.0099E-09	7.9857E-10	2.3927E-11	2.5793E-10	3.8411E-11	1.1702E-10	8.2250E-10	2.9635E-10	9.8324E-09	4.1336E-10	1.0246E-08
50.00	1.1783E-09	1.7224E-10	1.9540E-11	2.0506E-10	8.3642E-11	8.7518E-11	1.9178E-10	2.8870E-10	1.3701E-09	3.7622E-10	1.7463E-09
80.00	2.7945E-10	5.5990E-11	1.5559E-11	1.4075E-10	9.7668E-11	6.7869E-11	7.1548E-11	2.3842E-10	3.5100E-10	3.0628E-10	6.5729E-10
100.00	1.2126E-10	2.9245E-11	1.1449E-11	1.0790E-10	9.6475E-11	5.7436E-11	4.0694E-11	2.0437E-10	1.6195E-10	2.6181E-10	4.2376E-10

DOSE--REM

0.00	8.3784E-07								8.3784E-07		8.3784E-07
5.00	7.5883E-08	2.6564E-09	3.3009E-11	1.0265E-09	3.4849E-11	1.0370E-09	2.6894E-09	1.0613E-09	7.8572E-08	2.0983E-09	8.0671E-08
10.00	2.9901E-08	1.9000E-09	4.2515E-11	1.3120E-09	9.6987E-11	1.2153E-09	1.9425E-09	1.4090E-09	3.1843E-08	2.6244E-09	3.4467E-08
20.00	9.4932E-09	8.6162E-10	2.6023E-11	1.4367E-09	2.2527E-10	1.1702E-09	8.8764E-10	1.6619E-09	1.0381E-08	2.8321E-09	1.3213E-08
50.00	1.2236E-09	1.8185E-10	2.4889E-11	1.1250E-09	4.8917E-10	8.7518E-10	2.0674E-10	1.6141E-09	1.4303E-09	2.4893E-09	3.9196E-09
80.00	2.8862E-10	6.0623E-11	1.9855E-11	7.6461E-10	5.7015E-10	6.7869E-10	8.0477E-11	1.3348E-09	3.6910E-10	2.0135E-09	2.3825E-09
100.00	1.2489E-10	3.2801E-11	1.1613E-11	5.8300E-10	5.6760E-10	5.7436E-10	4.4415E-11	1.1456E-09	1.6930E-10	1.7200E-09	1.8893E-09

Table 6. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P_o = 195 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	4.7860E-07								4.7860E-07		4.7860E-07
5.00	8.1865E-08	3.9827E-09	7.8415E-11	2.3269E-10	7.9664E-12	1.2050E-10	4.0611E-09	2.4065E-10	8.5926E-08	3.6115E-10	8.6287E-08
10.00	4.3294E-08	3.9825E-09	1.3478E-10	3.4687E-10	2.4907E-11	1.6185E-10	4.1173E-09	3.7178E-10	4.7412E-08	5.3363E-10	4.7945E-08
20.00	1.9705E-08	2.9710E-09	1.4666E-10	4.5783E-10	6.6469E-11	1.8441E-10	3.1176E-09	5.2430E-10	2.2823E-08	7.0871E-10	2.3531E-08
50.00	4.7545E-09	1.2151E-09	1.8498E-10	4.8433E-10	1.8434E-10	1.7575E-10	1.4000E-09	6.6867E-10	6.1545E-09	8.4442E-10	6.9989E-09
80.00	1.7110E-09	5.7561E-10	1.5981E-10	3.9418E-10	2.5242E-10	1.5547E-10	7.3542E-10	6.4660E-10	2.4464E-09	8.0207E-10	3.2485E-09
100.00	9.3921E-10	3.7397E-10	9.2576E-11	3.2955E-10	2.7240E-10	1.4159E-10	4.6655E-10	6.0195E-10	1.4058E-09	7.4354E-10	2.1493E-09

DOSE--REM

0.00	4.8509E-07								4.8509E-07		4.8509E-07
5.00	8.7905E-08	4.5143E-09	9.7963E-11	1.2666E-09	4.6110E-11	1.2050E-09	4.6123E-09	1.3127E-09	9.2518E-08	2.5177E-09	9.5035E-08
10.00	4.5665E-08	4.5931E-09	1.6470E-10	1.8666E-09	1.4371E-10	1.6185E-09	4.7578E-09	2.0103E-09	5.0423E-08	3.6288E-09	5.4051E-08
20.00	2.0513E-08	3.1869E-09	1.5694E-10	2.4270E-09	3.8203E-10	1.8441E-09	3.3438E-09	2.8090E-09	2.3857E-08	4.6531E-09	2.8510E-08
50.00	4.8927E-09	1.2547E-09	2.3521E-10	2.5054E-09	1.0545E-09	1.7575E-09	1.4900E-09	3.5599E-09	6.3826E-09	5.3174E-09	1.1700E-08
80.00	1.7533E-09	6.0324E-10	2.0705E-10	2.0091E-09	1.4402E-09	1.5547E-09	8.1029E-10	3.4492E-09	2.5636E-09	5.0039E-09	7.5675E-09
100.00	9.6035E-10	4.1450E-10	9.5599E-11	1.6659E-09	1.5522E-09	1.4159E-09	5.1010E-10	3.2181E-09	1.4704E-09	4.6340E-09	6.1044E-09

Table 7. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P_0 = 50 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	3.6180E-06								3.6180E-06		3.6180E-06
5.00	1.0393E-08	3.0196E-10	6.6811E-12	1.0556E-10	8.2537E-12	1.0783E-11	3.0864E-10	1.1382E-10	1.0721E-08	1.2460E-10	1.0826E-08
10.00	1.3408E-09	5.6712E-11	6.1195E-12	7.4082E-11	1.3168E-11	9.0638E-12	6.2831E-11	8.7250E-11	1.4036E-09	9.6314E-11	1.4999E-09
20.00	9.9389E-11	6.4266E-12	6.0876E-13	3.4987E-11	1.3193E-11	5.2469E-12	7.0354E-12	4.8180E-11	1.0642E-10	5.3427E-11	1.5985E-10
50.00	8.4614E-13	8.7160E-14	3.1916E-14	4.6613E-12	4.1844E-12	8.7003E-13	1.1908E-13	8.8456E-12	9.6522E-13	9.7157E-12	1.0681E-11
80.00	2.8107E-14	3.7005E-15	1.9123E-14	9.1118E-13	1.1514E-12	1.9522E-13	2.2824E-14	2.0625E-12	5.0930E-14	2.2578E-12	2.3087E-12
100.00	3.8645E-15	5.5657E-16	4.2454E-14	3.6377E-13	5.1726E-13	8.6215E-14	4.3011E-14	8.8104E-13	4.6875E-14	9.6725E-13	1.0141E-12

DOSE--REM

0.00	3.7183E-06								3.7183E-06		3.7183E-06
5.00	1.1667E-08	3.9962E-10	1.0654E-11	6.1873E-10	4.8946E-11	1.0783E-10	4.1028E-10	6.6767E-10	1.2077E-08	7.7551E-10	1.2853E-08
10.00	1.4654E-09	7.0531E-11	9.7527E-12	4.3292E-10	7.8039E-11	9.0638E-11	8.0284E-11	5.1095E-10	1.5457E-09	6.0159E-10	2.1473E-09
20.00	1.0652E-10	7.2313E-12	7.2312E-13	2.0336E-10	7.8098E-11	5.2469E-11	7.9544E-12	2.8146E-10	1.1448E-10	3.3393E-10	4.4841E-10
50.00	8.9088E-13	9.8562E-14	3.5145E-14	2.6571E-11	2.4675E-11	8.7003E-12	1.3371E-13	5.1246E-11	1.0246E-12	5.9946E-11	6.0971E-11
80.00	2.9404E-14	4.3592E-15	2.1218E-14	5.0769E-12	6.7602E-12	1.9522E-12	2.5577E-14	1.1837E-11	5.4981E-14	1.3789E-11	1.3844E-11
100.00	4.0280E-15	6.9717E-16	4.2491E-14	1.9973E-12	3.0279E-12	8.6215E-13	4.3178E-14	5.0252E-12	4.7206E-14	5.8874E-12	5.9346E-12

Table 8. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P_o = 60 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	2.4695E-06								2.4695E-06		2.4695E-06
5.00	1.6509E-08	5.6077E-10	1.4124E-11	1.1071E-10	9.3066E-12	1.2452E-11	5.7490E-10	1.2001E-10	1.7084E-08	1.3247E-10	1.7217E-08
10.00	2.8796E-09	1.4410E-10	1.3567E-11	8.3607E-11	1.5933E-11	1.0853E-11	1.5767E-10	9.9540E-11	3.0373E-09	1.1039E-10	3.1477E-09
20.00	3.1389E-10	2.4684E-11	2.2265E-12	4.3506E-11	1.7533E-11	6.7088E-12	2.6910E-11	6.1039E-11	3.4060E-10	6.7746E-11	4.0854E-10
50.00	5.4146E-12	6.8373E-13	2.0724E-13	7.4607E-12	6.9566E-12	1.3600E-12	8.9097E-13	1.4417E-11	6.3056E-12	1.5777E-11	2.2083E-11
80.00	2.9454E-13	4.7128E-14	1.2609E-13	1.8355E-12	2.3319E-12	3.7139E-13	1.7322E-13	4.1674E-12	4.6776E-13	4.5388E-12	5.0066E-12
100.00	5.3612E-14	8.8592E-15	1.8457E-13	8.3429E-13	1.1790E-12	1.8474E-13	1.9343E-13	2.0133E-12	2.4704E-13	2.1961E-12	2.4451E-12

DOSE--REM

0.00	2.5312E-06								2.5312E-06		2.5312E-06
5.00	1.8340E-08	7.2111E-10	2.2297E-11	6.4542E-10	5.5125E-11	1.2452E-10	7.4341E-10	7.0054E-10	1.9084E-08	8.2506E-10	1.9906E-08
10.00	3.1213E-09	1.7453E-10	2.1416E-11	4.8510E-10	9.4286E-11	1.0853E-10	1.9595E-10	5.7938E-10	3.3172E-09	6.8790E-10	4.0051E-09
20.00	3.3419E-10	2.7661E-11	2.6662E-12	2.5033E-10	1.0358E-10	6.7088E-11	3.0328E-11	3.5391E-10	3.6452E-10	4.2099E-10	7.8551E-10
50.00	5.6719E-12	7.6118E-13	2.3334E-13	4.1796E-11	4.0878E-11	1.3600E-11	9.9452E-13	8.2674E-11	6.6664E-12	9.6274E-11	1.0294E-10
80.00	3.0676E-13	5.5162E-14	1.4307E-13	1.0010E-11	1.3624E-11	3.7139E-12	1.9823E-13	2.3635E-11	5.0500E-13	2.7348E-11	2.7853E-11
100.00	5.5650E-14	1.0699E-14	1.8492E-13	4.4765E-12	6.8618E-12	1.8474E-12	1.9562E-13	1.1338E-11	2.5127E-13	1.3186E-11	1.3437E-11

Table 9. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P_o = 80 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY F FIRST GENERATION (2)	h OTON--- HER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	1.4634E-06								1.4634E-06		1.4634E-06
5.00	2.8126E-08	1.2114E-09	3.6409E-11	1.252EE-10	1.113CE-11	1.5429E-11	1.2478E-09	1.3641E-10	2.9374E-08	1.518 4E-10	2.9526E-08
10.00	7.1614E-09	4.6668E-10	3.8205E-11	1.C878E-10	2.1424E-11	1.4477E-11	5.C488E-10	1.3020E-10	7.6662E-09	1.446EE-10	7.81C5E-09
20.00	1.2661E-09	1.35C7E-10	1.1930E-11	6.8161E-11	2.7684E-11	1.C13CE-11	1.47C0E-10	9.5845E-11	1.4132E-09	1.C59EE-10	1.5191E-09
50.00	5.2851E-11	9.2140E-12	2.3310E-12	1.7673E-11	1.5754E-11	2.8432E-12	1.1545E-11	3.3426E-11	6.4396E-11	3.6269E-11	1.CCC7E-10
80.00	5.3239E-12	1.1621E-12	1.4553E-12	5.9397E-12	7.C9CCE-12	1.C292E-12	2.6175E-12	1.3030E-11	7.9414E-12	1.4059E-11	2.2CCCE-11
100.00	1.3768E-12	2.9107E-13	1.3014E-12	3.1817E-12	4.245CE-12	6.C38CE-13	1.5925E-12	7.4266E-12	2.9693E-12	8.C3C4E-12	1.1CCCE-11

DOSE--REM

0.00	1.4946E-06								1.4946E-06		1.4946E-06
5.00	3.0792E-08	1.4938E-09	5.5933E-11	7.22C7E-10	6.5745E-11	1.5429E-10	1.5497E-09	7.8782E-10	3.2342E-08	9.4211E-10	3.3284E-08
10.00	7.6731E-09	5.4431E-10	5.8469E-11	6.2161E-10	1.2635E-10	1.4477E-10	6.C278E-10	7.4796E-10	8.2758E-09	8.9273E-10	9.1666E-09
20.00	1.3356E-09	1.5079E-10	1.4278E-11	3.8394E-10	1.62E1E-10	1.013CE-10	1.6507E-10	5.4675E-10	1.5CC7E-09	6.48C5E-10	2.14E7E-09
50.00	5.4973E-11	1.0052E-11	2.6972E-12	9.5785E-11	9.1867E-11	2.8432E-11	1.2750E-11	1.8765E-10	6.7722E-11	2.16C8E-10	2.83E1E-10
80.00	5.5106E-12	1.3402E-12	1.6970E-12	3.1177E-11	4.1CC4E-11	1.C292E-11	3.C372E-12	7.2181E-11	8.5478E-12	8.2473E-11	9.1C21E-11
100.00	1.4210E-12	3.3547E-13	1.3131E-12	1.6396E-11	2.4425E-11	6.C38CE-12	1.6466E-12	4.0821E-11	3.0675E-12	4.6859E-11	4.9927E-11

Table 10. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P_o = 100 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	---EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	1.0520E-06								1.0520E-06		1.0520E-06
5.00	3.8165E-08	1.9523E-09	6.6382E-11	1.4323E-10	1.2867E-11	1.8258E-11	2.0187E-09	1.5610E-10	4.0184E-08	1.7436E-10	4.0356E-08
10.00	1.2209E-08	9.6973E-10	7.5715E-11	1.3951E-10	2.7074E-11	1.8244E-11	1.0454E-09	1.6659E-10	1.3255E-08	1.8483E-10	1.3439E-08
20.00	2.8899E-09	3.8747E-10	3.5310E-11	1.0215E-10	3.9636E-11	1.4146E-11	4.2278E-10	1.4179E-10	3.3126E-09	1.5594E-10	3.4686E-09
50.00	2.0512E-10	4.5871E-11	1.0892E-11	3.6167E-11	2.9600E-11	5.0626E-12	5.6764E-11	6.5767E-11	2.6188E-10	7.0829E-11	3.3271E-10
80.00	2.9894E-11	8.3302E-12	6.9442E-12	1.4920E-11	1.6453E-11	2.2289E-12	1.5274E-11	3.1373E-11	4.5169E-11	3.3602E-11	7.8771E-11
100.00	9.5462E-12	2.5050E-12	4.8442E-12	8.8515E-12	1.1069E-11	1.4631E-12	7.3492E-12	1.9916E-11	1.6895E-11	2.1379E-11	3.8275E-11

DOSE--REM

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	---EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	1.0719E-06								1.0719E-06		1.0719E-06
5.00	4.1373E-08	2.3393E-09	9.9058E-11	8.1579E-10	7.5775E-11	1.8258E-10	2.4384E-09	8.9157E-10	4.3811E-08	1.0741E-09	4.4885E-08
10.00	1.2980E-08	1.1029E-09	1.1177E-10	7.8505E-10	1.5966E-10	1.8244E-10	1.2147E-09	9.4411E-10	1.4195E-08	1.1266E-09	1.5321E-08
20.00	3.0294E-09	4.3120E-10	4.1887E-11	5.6375E-10	2.3194E-10	1.4146E-10	4.7309E-10	7.9569E-10	3.5025E-09	9.3715E-10	4.4396E-09
50.00	2.1235E-10	4.9404E-11	1.2752E-11	1.9047E-10	1.7124E-10	5.0626E-11	6.2157E-11	3.6171E-10	2.7450E-10	4.1233E-10	6.8684E-10
80.00	3.0815E-11	9.4562E-12	8.1954E-12	7.5877E-11	9.4229E-11	2.2289E-11	1.7652E-11	1.7011E-10	4.8466E-11	1.9239E-10	2.4086E-10
100.00	9.8148E-12	2.7725E-12	4.9488E-12	4.4163E-11	6.3002E-11	1.4631E-11	7.7213E-12	1.0717E-10	1.7536E-11	1.2180E-10	1.3933E-10

Table 11. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P_o = 120 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	8.2319E-07								8.2319E-07		8.2319E-07
5.00	4.5707E-08	2.6628E-09	9.9688E-11	1.5939E-10	1.4263E-11	2.0541E-11	2.7625E-09	1.7366E-10	4.8470E-08	1.9426E-10	4.6664E-08
10.00	1.7042E-08	1.5780E-09	1.2301E-10	1.7001E-10	3.2154E-11	2.1587E-11	1.7010E-09	2.0217E-10	1.8743E-08	2.2375E-10	1.8967E-08
20.00	4.9051E-09	7.8585E-10	7.5778E-11	1.4093E-10	5.1928E-11	1.8163E-11	8.6162E-10	1.9285E-10	5.7667E-09	2.1102E-10	5.9778E-09
50.00	4.9619E-10	1.3552E-10	3.1799E-11	6.3186E-11	4.7872E-11	7.8326E-12	1.6732E-10	1.1106E-10	6.6351E-10	1.1869E-10	7.8240E-10
80.00	9.2472E-11	3.1449E-11	2.0633E-11	3.0189E-11	3.1183E-11	3.9909E-12	5.2083E-11	6.1372E-11	1.4455E-10	6.5363E-11	2.0992E-10
100.00	3.3983E-11	1.0749E-11	1.2720E-11	1.9234E-11	2.2826E-11	2.8466E-12	2.3469E-11	4.2061E-11	5.7453E-11	4.4907E-11	1.0236E-10

DOSE--REM

0.00	8.3734E-07								8.3734E-07		8.3734E-07
5.00	4.9193E-08	3.1255E-09	1.4468E-10	8.9683E-10	8.3705E-11	2.0541E-10	3.2702E-09	9.8054E-10	5.2463E-08	1.1866E-09	5.3649E-08
10.00	1.8315E-08	1.7630E-09	1.7534E-10	9.4224E-10	1.8812E-10	2.1587E-10	1.9384E-09	1.1304E-09	1.9953E-08	1.3462E-09	2.1300E-08
20.00	5.1185E-09	8.7145E-10	8.8981E-11	7.6292E-10	3.0223E-10	1.8163E-10	9.6043E-10	1.0651E-09	6.0789E-09	1.2466E-09	7.3257E-09
50.00	5.1190E-10	1.4461E-10	3.7339E-11	3.2466E-10	2.7473E-10	7.8325E-11	1.8195E-10	5.9939E-10	6.9385E-10	6.7772E-10	1.3716E-09
80.00	9.5033E-11	3.5188E-11	2.4438E-11	1.4964E-10	1.7694E-10	3.9909E-11	5.9626E-11	3.2658E-10	1.5466E-10	3.6649E-10	5.2115E-10
100.00	3.4843E-11	1.1626E-11	1.3180E-11	9.3542E-11	1.2875E-10	2.8466E-11	2.4806E-11	2.2230E-10	5.9650E-11	2.5076E-10	3.1041E-10

Table 12. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P_o = 195 MV

DOSE--RAD

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON---EVAPORATION FIRST GENERATION (4)	HIGHER GENERATION (5)	NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	4.7861E-07								4.7861E-07		4.7861E-07
5.00	6.0990E-08	4.7632E-09	2.2715E-10	2.1287E-10	1.8191E-11	2.6647E-11	4.9903E-09	2.3106E-10	6.5980E-08	2.5771E-10	6.6239E-08
10.00	3.0664E-08	4.0573E-09	3.5640E-10	2.7926E-10	4.8343E-11	3.1396E-11	4.4137E-09	3.2754E-10	3.5077E-08	3.5893E-10	3.5436E-08
20.00	1.2906E-08	3.1385E-09	3.8888E-10	3.0642E-10	9.8917E-11	3.1912E-11	3.5274E-09	4.0534E-10	1.6434E-08	4.3725E-10	1.6871E-08
50.00	2.5602E-09	1.1500E-09	2.9446E-10	2.2817E-10	1.4886E-10	2.1076E-11	1.4445E-09	3.7703E-10	4.0247E-09	3.9811E-10	4.4228E-09
80.00	7.6887E-10	4.2903E-10	2.0032E-10	1.4765E-10	1.3691E-10	1.4889E-11	6.2935E-10	2.8455E-10	1.3982E-09	2.9944E-10	1.6977E-09
100.00	3.6918E-10	1.8887E-10	1.1284E-10	1.0988E-10	1.1951E-10	1.2745E-11	3.0171E-10	2.2831E-10	6.7089E-10	2.4106E-10	9.1195E-10

DOSE--REM

0.00	4.8510E-07								4.8510E-07		4.8510E-07
5.00	6.4597E-08	5.3523E-09	3.0479E-10	1.1436E-09	1.0514E-10	2.6647E-10	5.6570E-09	1.2489E-09	7.0254E-08	1.5154E-09	7.1769E-08
10.00	3.2006E-08	4.3719E-09	4.6073E-10	1.4672E-09	2.7776E-10	3.1396E-10	4.8327E-09	1.7449E-09	3.6839E-08	2.0586E-09	3.8898E-08
20.00	1.3332E-08	3.4323E-09	4.4434E-10	1.5609E-09	5.6295E-10	3.1912E-10	3.8766E-09	2.1234E-09	1.7209E-08	2.4425E-09	1.9651E-08
50.00	2.6419E-09	1.2032E-09	3.4130E-10	1.0966E-09	8.3017E-10	2.1076E-10	1.5445E-09	1.9269E-09	4.1864E-09	2.1377E-09	6.3241E-09
80.00	7.8503E-10	4.6304E-10	2.3516E-10	6.8657E-10	7.5482E-10	1.4889E-10	6.9820E-10	1.4414E-09	1.4832E-09	1.5903E-09	3.0735E-09
100.00	3.7628E-10	1.9647E-10	1.2100E-10	4.9786E-10	6.5582E-10	1.2745E-10	3.1747E-10	1.1537E-09	6.9375E-10	1.2811E-09	1.9749E-09

Table 13. Dose (rad per sec or rem per sec) Behind Varying Shield Thicknesses of Aluminum Due to Freden and White Proton Spectrum

DOSE--RAD /SEC

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	3.2238E-04								3.2238E-04		3.2238E-04
5.00	9.2783E-05	5.6589E-06	1.7340E-07	3.1869E-07	1.1510E-08	1.4339E-07	5.8323E-06	3.3020E-07	9.8616E-05	4.7359E-07	9.9089E-05
10.00	5.5954E-05	6.8357E-06	3.7165E-07	5.1925E-07	3.9278E-08	2.1006E-07	7.2074E-06	5.5853E-07	6.3162E-05	7.6859E-07	6.3930E-05
20.00	3.0191E-05	6.7596E-06	5.1991E-07	7.6773E-07	1.1661E-07	2.6849E-07	7.2795E-06	8.8434E-07	3.7471E-05	1.1528E-06	3.8624E-05
50.00	1.0495E-05	4.3443E-06	8.0065E-07	9.9795E-07	3.8581E-07	3.1286E-07	5.1449E-06	1.3838E-06	1.5640E-05	1.6966E-06	1.7337E-05
80.00	5.0054E-06	2.5891E-06	4.6821E-07	9.2841E-07	5.8345E-07	3.1580E-07	3.0573E-06	1.5119E-06	8.0627E-06	1.8277E-06	9.8904E-06
100.00	3.2033E-06	1.7487E-06	5.9140E-07	8.3412E-07	6.6891E-07	3.0952E-07	2.3401E-06	1.5030E-06	5.5433E-06	1.8126E-06	7.3559E-06

DOSE--REM /SEC

0.00	3.2555E-04								3.2555E-04		3.2555E-04
5.00	9.8541E-05	6.2500E-06	2.0696E-07	1.6471E-06	6.5051E-08	1.4339E-06	6.4570E-06	1.7122E-06	1.0500E-04	3.1461E-06	1.0814E-04
10.00	5.8526E-05	7.6967E-06	4.3778E-07	2.6486E-06	2.2107E-07	2.1006E-06	8.1345E-06	2.8696E-06	6.6661E-05	4.9703E-06	7.1631E-05
20.00	3.1167E-05	7.1937E-06	5.5173E-07	3.8463E-06	6.5313E-07	2.6849E-06	7.7454E-06	4.4995E-06	3.8913E-05	7.1844E-06	4.6097E-05
50.00	1.0723E-05	4.4284E-06	9.9466E-07	4.8571E-06	2.1514E-06	3.1286E-06	5.4230E-06	7.0085E-06	1.6146E-05	1.0137E-05	2.6283E-05
80.00	5.0979E-06	2.6892E-06	5.0360E-07	4.4581E-06	3.2474E-06	3.1580E-06	3.1928E-06	7.7056E-06	8.2907E-06	1.0864E-05	1.9154E-05
100.00	3.2589E-06	1.8078E-06	1.0818E-06	3.9766E-06	3.7228E-06	3.0952E-06	2.8896E-06	7.6994E-06	6.1485E-06	1.0795E-05	1.6943E-05

Table 14. Dose (rad per sec or rem per sec) Behind Varying Shield Thicknesses of Polyethylene Due to Freden and White Proton Spectrum

DOSE--RAD/SEC

SHIELD THICKNESS GM/CM**2	PRIMARY PROTON (1)	--SECONDARY PROTON--- FIRST GENERATION (2)	HIGHER GENERATION (3)	---CASCADE NEUTRON--- FIRST GENERATION (4)	HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE (1)THRU(6)
0.00	3.2240E-04								3.2240E-04		3.2240E-04
5.00	7.3203E-05	6.7799E-06	3.9204E-07	2.9566E-07	2.3759E-08	3.4132E-08	7.1720E-06	3.1942E-07	8.0375E-05	3.5356E-07	8.0728E-05
10.00	4.2427E-05	7.1762E-06	7.7543E-07	4.4014E-07	7.1119E-08	4.2903E-08	7.9516E-06	5.1126E-07	5.0379E-05	5.5416E-07	5.0933E-05
20.00	2.1992E-05	7.3732E-06	1.2307E-06	5.7414E-07	1.7305E-07	4.9140E-08	8.6039E-06	7.4718E-07	3.0596E-05	7.9632E-07	3.1392E-05
50.00	6.7290E-06	4.4863E-06	1.3338E-06	5.8512E-07	3.6791E-07	4.3687E-08	5.8201E-06	9.5303E-07	1.2549E-05	9.9672E-07	1.3546E-05
80.00	2.7222E-06	2.2390E-06	9.4432E-07	4.5839E-07	4.2259E-07	3.9011E-08	3.1833E-06	8.8098E-07	5.9055E-06	9.2000E-07	6.8255E-06
100.00	1.5269E-06	1.1450E-06	5.4989E-07	3.7033E-07	4.1023E-07	3.7884E-08	1.6949E-06	7.8056E-07	3.2218E-06	8.1844E-07	4.0402E-06

DOSE--REM /SEC

0.00	3.2556E-04								3.2556E-04		3.2556E-04
5.00	7.6829E-05	7.4300E-06	4.9230E-07	1.4986E-06	1.3394E-07	3.4132E-07	7.9223E-06	1.6326E-06	8.4751E-05	1.9739E-06	8.6725E-05
10.00	4.3935E-05	7.5678E-06	9.2827E-07	2.1726E-06	3.9703E-07	4.2903E-07	8.4960E-06	2.5697E-06	5.2431E-05	2.9987E-06	5.5429E-05
20.00	2.2553E-05	7.9245E-06	1.3794E-06	2.7361E-06	9.5352E-07	4.9140E-07	9.3039E-06	3.6896E-06	3.1857E-05	4.1810E-06	3.6038E-05
50.00	6.8479E-06	4.6317E-06	1.5147E-06	2.6444E-06	1.9839E-06	4.3687E-07	6.1464E-06	4.6282E-06	1.2994E-05	5.0651E-06	1.8059E-05
80.00	2.7672E-06	2.3582E-06	1.0928E-06	2.0206E-06	2.2641E-06	3.9011E-07	3.4510E-06	4.2846E-06	6.2182E-06	4.6748E-06	1.0893E-05
100.00	1.5498E-06	1.1701E-06	5.9850E-07	1.6140E-06	2.1950E-06	3.7884E-07	1.7686E-06	3.8090E-06	3.3184E-06	4.1878E-06	7.5062E-06