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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 ( $P_0 = 50, 60, 80, 100, 120,$  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,<sup>1</sup> and the comparison substantiated to some degree (see comments in ref. 1) the validity of a NASA Lewis Research Center code<sup>2</sup> (LPSC)\* for calculating shield penetration data of interest to NASA shield

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\*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.<sup>3</sup> 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<sup>4</sup> 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<sup>2</sup>-sec), and the dose from them can be neglected unless very long missions are contemplated. Therefore,

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\*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.<sup>5</sup> This became a necessity in that the intensity and energy spectrum vary markedly from event to event. The time-integrated omnidirectional integral proton spectrum may be represented as

$$J_p(>E) = J_0 \exp [-P(E)/P_0] , \quad (3.1)$$

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,

$J_0, P_0$  = parameters which characterize a particular flare.

Modisette *et al.*<sup>5</sup> give values of the parameters  $J_0$  and  $P_0$  for a large number of flares. They find that  $P_0$  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<sup>2</sup> to  $10^9$  protons/cm<sup>2</sup>. Thus this range of  $P_0$

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.,

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

where  $M_p$  = proton rest-mass energy, are shown in Fig. 1 for  $P_o$  values of 200, 100, and 50 MV, respectively.<sup>6</sup> In this figure all of the flare spectra are normalized to contain  $10^9$  protons/cm<sup>2</sup> 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,<sup>3</sup> 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<sup>3</sup> 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.

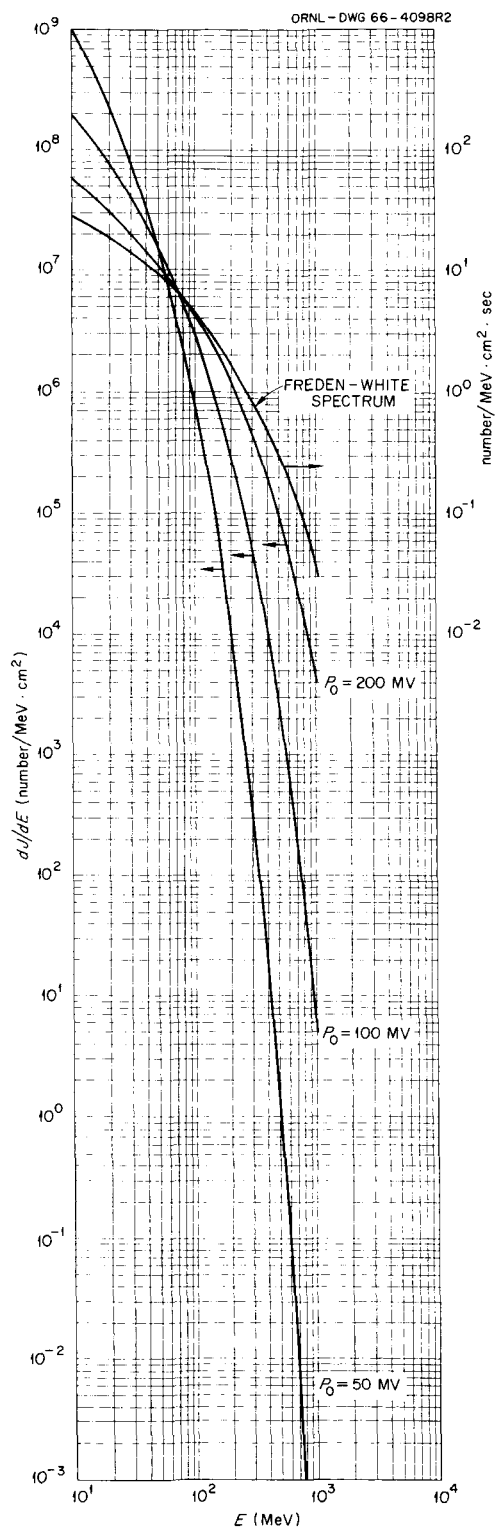


Fig. 1. Spectra of Solar-Flare Protons for  $P_0 = 50, 100,$  and  $200$  MV and Freden-White Spectrum for Protons in Van Allen Belt.



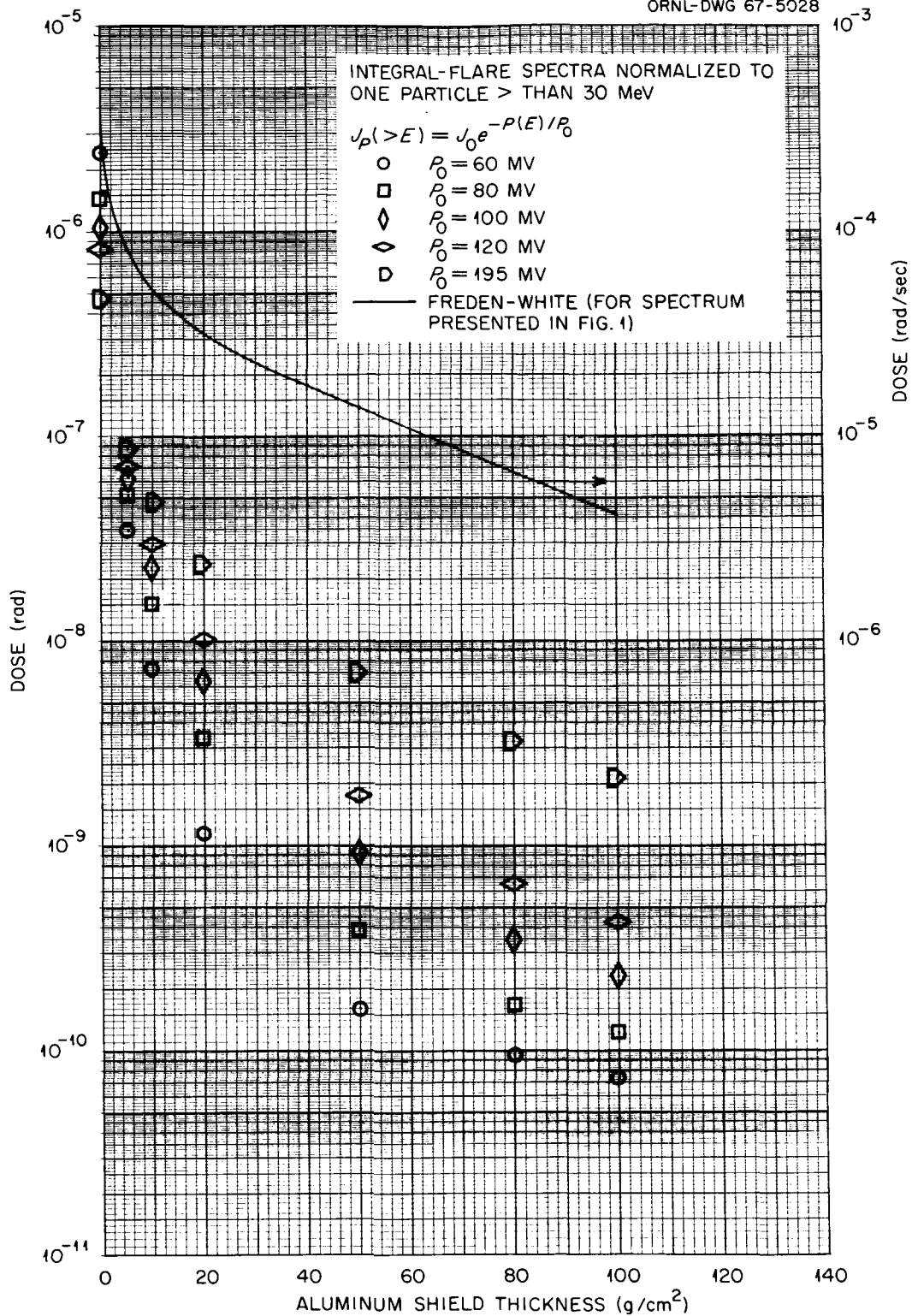


Fig. 2. Total Dose Behind Aluminum Slabs Due to Normally Incident Protons.

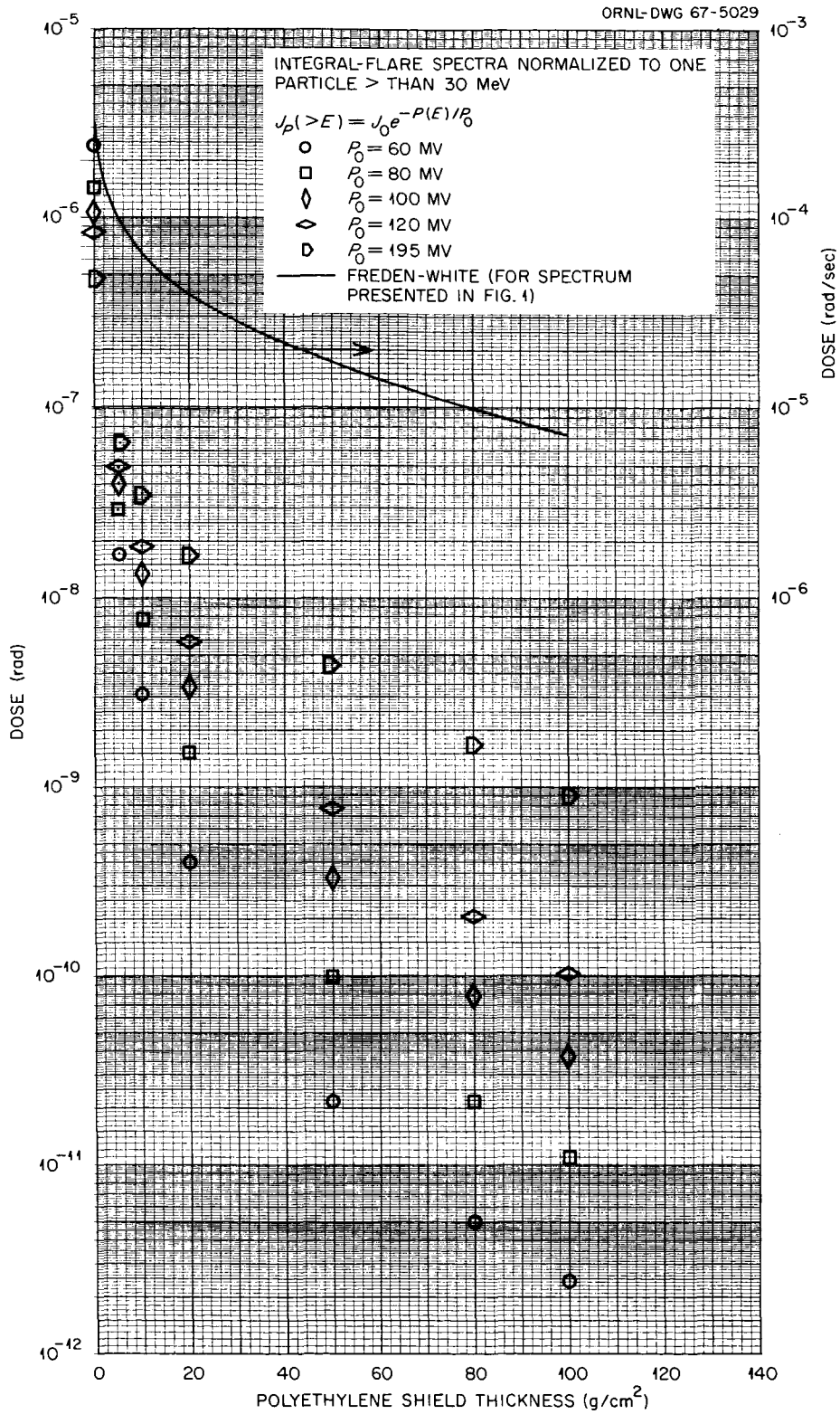


Fig. 3. Total Dose Behind Polyethylene Slabs Due to Normally Incident Protons.

Figures 2 and 3 represent the total dose vs shield thickness for the range of  $P_0$  values. These curves are largely self-explanatory. The larger the  $P_0$  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 2. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P<sub>0</sub> = 60 MW

SHIELD THICKNESS GM/CM <sup>2</sup>	DOSE--RAD											TOTAL NEUTRON DOSE (1)+(2)THRU(6)
	PRIMARY PROTON (1)	SECONDARY PROTON HIGHER GENERATION (2)	FIRST GENERATION (3)	HIGHER GENERATION (4)	NEUTRON GENERATION (5)	NEUTRON (6)	SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)+(4)+(5)+(6)	TOTAL NEUTRON (1)+(2)+(3)+(4)+(5)+(6)	TOTAL DOSE	
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	3.4694E-08
10.00	6.5550E-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	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	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	1.6062E-10
80.00	2.0024E-12	1.8369E-13	6.0990E-14	4.2298E-11	2.8924E-11	2.1539E-11	2.4468E-13	7.1232E-11	2.2471E-12	9.2771E-11	9.5018E-11	9.5018E-11
100.00	4.7202E-13	5.2925E-14	1.3567E-13	3.0346E-11	2.5364E-11	1.6632E-11	1.9259E-13	5.5710E-11	6.6452E-13	7.2342E-11	7.3006E-11	7.3006E-11
0.00	2.5313E-06								2.5313E-06		2.5313E-06	
5.00	3.8577E-08	6.5531E-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	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	7.7719E-09	1.5727E-09	9.3444E-09	9.3444E-09
20.00	5.9408E-10	3.7438E-11	4.4690E-13	7.1234E-10	1.1414E-10	5.3871E-10	3.7889E-11	8.2648E-10	1.0370E-09	1.3652E-09	2.3972E-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	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	6.3646E-10
100.00	4.9332E-13	5.8895E-14	1.3979E-13	1.7784E-10	1.5026E-10	1.6632E-10	1.9866E-13	3.2810E-10	6.9200E-13	4.9442E-10	4.9511E-10	4.9511E-10

DOSE--REM

Table 3. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for  $P_0 = 80$  MW

SHIELD THICKNESS GM/CM <sup>2</sup>	DOSE--RAD										
	PRIMARY PROTON (1)	SECONDARY PROTON GENERATION (2)	HIGHER GENERATION (3)	FIRST GENERATION (4)	HIGHER GENERATION (5)	NEUTRON (6)	SECONDARY PROTON (2)+(3)	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	4.8024E-12	8.6146E-11	1.0541E-09	1.5444E-10	5.0784E-08	2.4059E-10	5.1023E-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	1.7054E-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<sub>0</sub> = 100 MV

SHIELD THICKNESS GM/C**2	DOSE--RAD										
	PRIMARY PROTON (1)	SECONDARY PROTON FIRST GENERATION (2)	HIGHER GENERATION (3)	CASCADE FIRST GENERATION (4)	NEUTRON HIGHER GENERATION (5)	EVAPORATION NEUTRON (6)	SECONDARY PROTON (2)+(3)	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	1.4056E-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	4.8816E-12	9.5647E-11	6.8812E-11	4.9209E-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	1.3669E-10	5.3109E-11	1.7746E-10	2.3057E-10
0.00	1.0719E-06									1.0719E-06	1.0719E-06
5.00	6.7541E-08	2.0040E-09	1.9607E-11	9.5172E-10	3.1798E-11	9.6417E-10	2.0236E-09	9.8352E-10	6.9865E-08	1.9477E-09	7.1913E-08
10.00	2.3248E-08	1.2021E-09	2.2513E-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	5.7545E-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	1.8570E-09	2.5140E-09
80.00	1.0999E-10	1.9037E-11	6.1325E-12	5.3107E-10	4.0413E-10	4.9209E-10	2.5169E-11	9.3521E-10	1.3515E-10	1.4273E-09	1.5624E-09
100.00	4.2092E-11	8.9854E-12	4.3970E-12	3.9427E-10	3.8511E-10	4.0568E-10	1.3386E-11	7.7938E-11	5.5479E-11	1.1851E-09	1.2405E-09

DOSE--REM

Table 5. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Aluminum for P<sub>0</sub> = 120 MV

SHIELD THICKNESS GM/CM**2	DOSE--RAD											TOTAL DOSE
	PRIMARY PROTON (1)	SECONDARY PROTON HIGHER GENERATION (2)	FIRST HIGHER GENERATION (3)	FIRST HIGHER GENERATION (4)	NEUTRON HIGHER GENERATION (5)	NEUTRON (6)	SECONDARY PROTON (2)+(3)	CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE	
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-10	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	5.0099E-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	
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	1.9475E-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	5.6260E-10	5.7436E-10	4.4415E-11	1.1456E-09	1.6930E-10	1.7200E-09	1.8893E-09	

DOSE--REM



Table 6. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses  
Of Aluminum for Po = 195 MW

SHIELD THICKNESS GM/CM**2	DOSE--RAD											
	PRIMARY PROTON (1)	SECONDARY PROTON FIRST GENERATION (2)	PROTON HIGHER GENERATION (3)	NEUTRON HIGHER GENERATION (4)	CASCADE NEUTRON FIRST GENERATION (5)	NEUTRON SECONDARY PROTON (6)	TOTAL SECONDARY NEUTRON (7)	TOTAL CASCADE NEUTRON (8)	TOTAL PROTON (9)	TOTAL NEUTRON (10)	TOTAL DOSE (11)	
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	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	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	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	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	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	2.1493E-09
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-10	4.6123E-09	1.3127E-09	9.2518E-08	2.5177E-09	9.5035E-08	9.5035E-08
10.00	4.5665E-08	4.5931E-09	1.6470E-10	1.8666E-09	1.4371E-10	1.6185E-10	4.7578E-09	2.0103E-09	5.0423E-08	3.6288E-09	5.4051E-08	5.4051E-08
20.00	2.0513E-08	3.1869E-09	1.5694E-10	2.4270E-09	3.8203E-10	1.8441E-10	3.3438E-09	2.8090E-09	2.3857E-08	4.6531E-09	2.8510E-08	2.8510E-08
50.00	4.8927E-09	1.2547E-09	2.3521E-10	2.5054E-09	1.0545E-09	1.7575E-10	1.4900E-09	3.5599E-09	6.3826E-09	5.3174E-09	1.1700E-08	1.1700E-08
80.00	1.7533E-09	6.0324E-10	2.0705E-10	2.0091E-09	1.4402E-09	1.5547E-10	8.1029E-10	3.4492E-09	2.5636E-09	5.0039E-09	7.5675E-09	7.5675E-09
100.00	5.6035E-10	4.1450E-10	9.5599E-11	1.6659E-09	1.5522E-09	1.4159E-10	5.1010E-10	3.2181E-09	1.4704E-09	4.6340E-09	6.1044E-09	6.1044E-09

Table 7. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P<sub>0</sub> = 50 MV

SHIELD THICKNESS GM/CM**2	DOSE--RAD											
	PRIMARY PROTON (1)	SECONDARY PROTON FIRST GENERATION (2)	SECONDARY PROTON HIGHER GENERATION (3)	PROTON FIRST GENERATION (4)	NEUTRON HIGHER GENERATION (5)	NEUTRON SECONDARY GENERATION (6)	TOTAL PROTON (2)+(3)	TOTAL NEUTRON (4)+(5)	TOTAL CASCADE NEUTRON (1)+(2)+(3)+(4)+(5)+(6)	TOTAL PROTON	TOTAL NEUTRON	TOTAL CCSE
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	3.0844E-10	1.1362E-10	1.0701E-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	6.2821E-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	4.8150E-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	6.8456E-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	8.0264E-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<sub>0</sub> = 60 MW

SHIELD THICKNESS G/M <sup>2</sup> *2	DOSE--RAD										TOTAL NEUTRON DOSE	
	PRIMARY PROTON (1)	SECONDARY PROTON FIRST GENERATION (2)	HIGHER GENERATION (3)	FIRST GENERATION (4)	CASCADE NEUTRON SECONDARY PROTON (5)	HIGHER GENERATION (6)	NEUTRON SECONDARY PROTON (7)	EVAPORATION NEUTRON (8)	TOTAL CASCADE NEUTRON (9)	TOTAL FRACTN (10)		
0.00	2.4695E-06										2.4695E-06	2.4695E-06
5.00	1.6509E-08	5.6077E-10	1.4124E-11	1.1071E-12	9.3066E-12	1.2452E-11	5.7490E-10	1.2001E-10	1.7084E-08	1.3247E-10	1.7217E-08	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	2.0373E-09	1.1039E-10	2.1477E-09	2.1477E-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	3.4000E-10	6.7744E-11	4.0854E-10	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	2.2083E-11
80.00	2.9454E-13	4.7128E-14	1.2609E-13	1.6355E-12	2.3319E-12	3.7139E-13	1.7322E-13	4.1674E-12	4.6776E-13	4.5388E-12	5.0066E-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	2.4451E-12
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	1.9909E-08	1.9909E-08
10.00	3.1213E-09	1.7453E-10	2.1416E-11	4.6510E-10	9.4280E-11	1.0853E-10	1.9595E-10	5.7938E-10	3.3172E-09	6.8790E-10	4.0051E-09	4.0051E-09
20.00	3.3419E-10	2.7661E-11	2.6662E-12	2.5032E-10	1.0356E-10	6.7088E-11	3.0328E-11	3.5391E-10	3.6452E-10	4.2099E-10	7.6551E-10	7.6551E-10
50.00	5.6719E-12	7.6118E-13	2.3334E-13	4.1796E-11	4.0876E-11	1.3600E-11	9.9452E-13	8.2674E-11	6.6664E-12	9.6274E-11	1.0294E-10	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	2.7653E-11	2.7653E-11
100.00	5.5650E-14	1.0699E-14	1.8492E-13	4.4765E-12	6.6616E-12	1.8474E-12	1.9562E-13	1.1338E-11	2.5127E-13	1.3166E-11	1.3437E-11	1.3437E-11

DOSE--REM

Table 9. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P<sub>0</sub> = 80 MW

SHIELD THICKNESS GM/CM**2	DOSE--RA												
	PRIMARY PROTON (1)	SECONDARY FIRST GENERATION (2)	SECONDARY FIRST GENERATION (3)	SECONDARY FIRST GENERATION (4)	FIRST HIGHER GENERATION (5)	NEUTRON PRCTCN (6)	ICAL NEUTRON (2)+(3)	ICAL NEUTRON (4)+(5)	ICAL CASCADE NEUTRON (4)+(5)	ICAL PRCTCN	TOTAL NEUTRON	ICIAL DOSE (1)TRPL(6)	
0.00	1.4634E-06										1.4634E-06		1.4634E-06
5.00	2.8126E-08	1.2114E-09	3.6409E-11	1.2522E-10	1.1130E-11	1.5429E-11	1.2478E-09	1.3641E-10	1.3641E-10	2.9374E-08	1.5184E-10	2.9526E-08	2.9526E-08
10.00	7.1614E-09	4.6668E-10	3.8205E-11	1.0878E-10	2.1424E-11	1.4477E-11	5.0488E-10	1.3020E-10	1.3020E-10	7.6622E-09	1.4468E-10	7.8109E-09	7.8109E-09
20.00	1.2661E-09	1.3507E-10	1.1930E-11	6.8161E-11	2.7684E-11	1.0130E-11	1.4700E-10	9.5845E-11	9.5845E-11	1.4132E-09	1.0598E-10	1.5191E-09	1.5191E-09
50.00	5.2851E-11	9.2140E-12	2.3310E-12	1.7672E-11	1.5754E-11	2.8432E-12	1.1545E-11	3.3426E-11	3.3426E-11	6.4396E-11	3.6269E-11	1.0007E-10	1.0007E-10
80.00	5.3239E-12	1.1621E-12	1.4553E-12	5.9397E-12	7.0900E-12	1.0292E-12	2.6175E-12	1.3030E-11	1.3030E-11	7.9414E-12	1.4059E-11	2.2000E-11	2.2000E-11
100.00	1.3768E-12	2.9107E-13	1.3014E-12	3.1817E-12	4.2450E-12	6.0380E-13	1.5925E-12	7.4266E-12	7.4266E-12	2.9693E-12	8.0304E-12	1.1000E-11	1.1000E-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	7.2207E-10	6.5745E-11	1.5429E-10	1.5497E-09	7.8782E-10	7.8782E-10	3.2342E-08	9.4211E-10	3.3284E-08	3.3284E-08
10.00	7.6731E-09	5.4431E-10	5.8469E-11	6.2161E-10	1.2635E-10	1.4477E-10	6.0278E-09	7.4796E-10	7.4796E-10	8.2758E-09	8.9272E-10	9.1686E-09	9.1686E-09
20.00	1.3356E-09	1.5079E-10	1.4278E-11	3.6394E-10	1.6281E-10	1.0130E-10	1.6507E-09	5.4675E-10	5.4675E-10	1.5007E-09	6.4480E-10	2.1447E-09	2.1447E-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	1.8765E-10	6.7722E-11	2.1608E-10	2.6381E-10	2.6381E-10
80.00	5.5106E-12	1.3402E-12	1.6970E-12	3.1177E-11	4.1004E-11	1.0292E-11	3.0372E-12	7.2181E-11	7.2181E-11	8.5478E-12	8.2472E-11	9.1021E-11	9.1021E-11
100.00	1.4210E-12	3.3347E-13	1.3131E-12	1.6396E-11	2.4425E-11	6.0380E-12	1.6466E-12	4.0821E-11	4.0821E-11	3.0675E-12	4.6859E-11	4.9927E-11	4.9927E-11

Table 10. Dose (rad per flare or rem per flare) Behind Varying Shield Thicknesses of Polyethylene for P<sub>0</sub> = 100 MW

SHIELD THICKNESS G/M <sup>2</sup> **2	DOSE--RAD												
	PRIMARY PROTON (1)	SECONDARY PROTON HIGHER GENERATION (2)	PROTON HIGHER GENERATION (3)	FIRST GENERATION (4)	NEUTRON HIGHER GENERATION (5)	NEUTRON (6)	ICASCADE NEUTRON PRACTCN (2)+(3)	ICASCADE NEUTRON (4)+(5)	ICASCADE NEUTRON (1)+(2)+(3)+(4)+(5)+(6)	TOTAL NEUTRON	ICOTAL PRACTCN	ICOTAL NEUTRON	ICOTAL DOSE
0.00	1.3520E-06									1.0520E-06			1.0520E-06
5.00	3.8165E-08	1.9523E-09	6.6362E-11	1.4222E-10	1.2827E-10	1.8258E-11	2.6187E-09	1.5610E-10	4.0184E-08	1.7436E-10	4.0355E-08	1.7436E-10	4.0355E-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	1.8462E-10	1.3255E-08	1.8462E-10	1.3255E-08
20.00	2.8899E-09	5.8747E-10	5.5310E-11	1.0215E-10	3.9636E-11	1.4146E-11	4.2278E-10	1.4179E-10	3.3126E-09	1.5594E-10	3.3126E-09	1.5594E-10	3.3126E-09
50.00	2.0512E-10	4.5871E-11	1.0692E-11	3.6167E-11	2.9600E-11	5.0626E-12	5.6764E-11	6.5767E-11	2.6188E-10	7.0829E-11	2.6188E-10	7.0829E-11	2.6188E-10
80.00	2.9594E-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	4.5169E-11	3.3602E-11	4.5169E-11
100.00	9.5462E-12	2.5050E-12	4.8442E-12	8.8515E-12	1.1065E-12	1.4631E-11	7.3492E-12	1.9916E-11	1.6895E-11	2.1379E-11	1.6895E-11	2.1379E-11	1.6895E-11
0.00	1.1719E-06									1.0719E-06			1.0719E-06
5.00	4.1573E-08	2.3393E-09	9.9038E-11	8.1579E-10	7.5775E-10	1.8258E-11	2.4384E-09	8.9157E-10	4.3811E-08	1.0741E-09	4.3811E-08	1.0741E-09	4.3811E-08
10.00	1.2980E-08	1.1029E-09	1.1177E-10	7.8505E-10	1.5906E-10	1.8244E-11	1.2147E-09	9.4411E-10	1.4195E-08	1.1266E-09	1.4195E-08	1.1266E-09	1.4195E-08
20.00	3.1294E-09	4.3120E-10	4.1887E-11	5.6375E-10	2.3194E-10	1.4146E-11	4.7309E-10	7.9569E-10	3.5025E-09	9.3715E-10	3.5025E-09	9.3715E-10	3.5025E-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	2.7450E-10	4.1233E-10	2.7450E-10
80.00	3.3615E-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	4.8466E-11	1.9239E-10	4.8466E-11
100.00	9.3148E-12	2.7725E-12	4.9468E-12	4.4163E-11	6.3002E-11	1.4631E-11	7.7213E-12	1.0717E-10	1.7536E-11	1.2180E-10	1.7536E-11	1.2180E-10	1.7536E-11

DOSE--REM

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

SHIELD THICKNESS GM/CM**2	DOSE--RAD											TOTAL DOSE
	PRIMARY PROTON (1)	--SECONDARY PROTON HIGHER GENERATION (2)	FIRST HIGHER GENERATION (3)	---CASCADE NEUTRON HIGHER GENERATION (4)	NEUTRON (5)	NEUTRON (6)	SECONDARY PROTON (2)+(3)	ICIAL NEUTRON (4)+(5)	ICIAL CASCADE NEUTRON (4)+(5)	ICIAL FRCTN (1)+(2)+(3)+(4)+(5)+(6)	TOTAL NEUTRON	
0.00	9.2319E-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	1.9420E-10	4.8664E-08	4.8664E-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	1.8967E-08
20.00	4.9051E-09	7.8585E-10	7.5778E-11	1.4092E-10	5.1926E-11	1.8163E-11	8.6162E-10	1.9285E-10	5.7667E-09	2.1102E-10	5.5778E-09	5.5778E-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	7.8240E-10
80.00	9.2472E-11	3.1449E-11	2.0633E-11	3.0189E-11	3.1163E-11	3.9909E-12	5.2083E-11	6.1372E-11	1.4455E-10	6.5363E-11	2.0992E-10	2.0992E-10
100.00	3.5983E-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	1.0223E-10	1.0223E-10
0.00	8.3734E-07								8.3734E-07		8.3734E-07	
5.00	4.9193E-08	3.1255E-09	1.4468E-10	8.9682E-10	8.3705E-11	2.0541E-11	3.2702E-09	9.8054E-10	5.2463E-08	1.1860E-09	5.3264E-08	5.3264E-08
10.00	1.8115E-08	1.7630E-09	1.7534E-10	9.4224E-10	1.8812E-10	2.1587E-11	1.9384E-09	1.1304E-09	1.9953E-08	1.3462E-09	2.1200E-08	2.1200E-08
20.00	5.1185E-09	8.7145E-10	8.8981E-11	7.6292E-10	3.0223E-10	1.8163E-11	9.6043E-10	1.0651E-09	6.0789E-09	1.2468E-09	7.3257E-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	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	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	3.1041E-10

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

SHIELD THICKNESS GM/CM <sup>2</sup>	DOSE--RAD										TOTAL DOSE	
	PRIMARY PROTON	SECONDARY PROTON-- FIRST GENERATION (2)	HIGHER GENERATION (3)	FIRST GENERATION (4)	HIGHER GENERATION (5)	NEUTRON (6)	ICIAL SECONDARY PRCTCN (2)+(3)	ICIAL CASCADE NEUTRON (4)+(5)	ICIAL PRCTCN (1)+(2)+(3)+(4)+(5)+(6)	TOTAL NEUTRON		
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	6.6233E-08	
10.00	3.3664E-08	4.0573E-09	3.5640E-10	2.7920E-10	4.8343E-11	3.1390E-11	4.4137E-09	3.2754E-10	3.5077E-08	3.5893E-10	3.5434E-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	
30.00	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	4.4222E-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	1.0860E-10	1.1951E-10	1.2745E-11	3.0171E-10	2.2831E-10	6.7089E-10	2.4106E-10	9.1195E-10	
0.00	4.8510E-07								4.8510E-07		4.8510E-07	
5.00	6.4597E-08	5.3523E-09	3.0479E-10	1.1432E-10	1.0314E-10	2.6647E-10	5.6570E-09	1.2489E-09	7.0254E-08	1.5154E-09	7.1765E-08	
10.00	3.2006E-08	4.3719E-09	4.6073E-10	1.4672E-10	2.7770E-10	3.1390E-10	4.8327E-09	1.7449E-09	3.6839E-08	2.0566E-09	3.6696E-08	
20.00	1.3332E-08	3.4323E-09	4.4434E-10	1.5605E-10	5.6295E-10	3.1912E-10	3.8766E-09	2.1234E-09	1.7209E-08	2.4425E-09	1.9651E-08	
30.00	2.6419E-09	1.2032E-09	3.4130E-10	1.0966E-10	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	

DOSE--REM

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

SHIELD THICKNESS GM/CM*2	DOSE--RAD /SEC									
	PRIMARY PROTON (1)	SECONDARY PROTON FIRST GENERATION (2)	FIRST HIGHER GENERATION (3)	CASCADE NEUTRON FIRST HIGHER GENERATION (4)	NEUTRON EVAPORATION (6)	TOTAL SECONDARY PROTON (2)+(3)	TOTAL CASCADE NEUTRON (4)+(5)	TOTAL PROTON (1)+(2)+(3)	TOTAL NEUTRON (4)+(5)+(6)	TOTAL DOSE
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
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
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
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
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
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
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	5.5051E-08	1.4339E-06	6.4570E-06	1.7122E-06	1.0500E-04	3.1461E-06
10.00	5.8526E-05	7.6967E-06	4.3778E-07	2.6480E-06	2.2107E-07	2.1006E-06	8.1345E-06	2.8696E-06	6.6661E-05	4.9703E-06
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
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
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	1.0804E-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

DOSE--REM /SEC



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

SHIELD THICKNESS GM/CM*2	DCS E--RAD/SEC												
	PRIMARY PROTON (1)	SECONDARY PROTON FIRST GENERATION (2)	HIGHER GENERATION (3)	FIRST HIGHER GENERATION (4)	HIGHER GENERATION (5)	NEUTRON (6)	NEUTRON (7)	NEUTRON (8)	SECONDARY PROTON (9)	CASCADE NEUTRON (10)	TOTAL PROTON (11)	TOTAL NEUTRON (12)	TOTAL DOSE (13)
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		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		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		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		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		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		4.0402E-06
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		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		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		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		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		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		7.5062E-06