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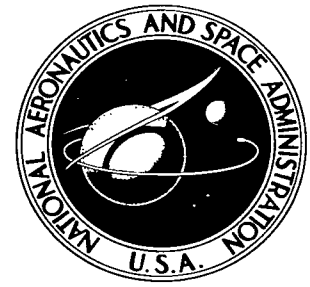

PLANE ISOTROPIC BUILDUP FACTORS FOR BREMSSTRAHLUNG CALCULATIONS

by M. O. Burrell and J. W. Watts

George C. Marshall Space Flight Center
Huntsville, Ala.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • AUGUST 1967

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PLANE ISOTROPIC BUILDUP FACTORS FOR BREMSSTRAHLUNG CALCULATIONS

SUMMARY

Gamma-ray isotropic dose, energy flux, and energy current buildup factors for finite slabs were calculated by Monte Carlo techniques for initial energies ranging from 0.05 MeV to 8.0 MeV with source backings from 0. mfp to 3.0 mfp and source-exit plane distances from 0.5 mfp to 7.0 mfp. Special emphasis was given to thin-source backings and to the energy range from 0.05 MeV to 0.5 MeV for these thin-source backings. Low energies were needed for accurate bremsstrahlung dose calculations and other applications for which they had not been previously available. In comparisons of the calculated finite slab buildup factors to buildup factors for infinite media generated by the moments method, differences of up to 50 percent were observed. These differences were thought to be due mainly to geometric factors.

INTRODUCTION

Bremsstrahlung gamma-ray spectra are extremely peaked toward lower energies (below 0.5 MeV), and most of the bremsstrahlung production takes place near the entrance plane of the shield. For calculations of bremsstrahlung dose rates behind plane slab shields, available gamma-ray dose buildup factors were found to be unsatisfactory. They did not extend to the range of interest and were for infinite or semi-infinite shields. Monte Carlo methods were used to calculate the dose, energy current, and energy flux buildup factors for plane isotropic gamma-ray sources in single homogeneous slabs of aluminum, water, and lead for a variety of gamma-ray energies, slab thicknesses, and source plane positions. Emphasis was given to low energies and thin entrance-source plane distances. One may find it difficult to realize why these calculations should differ from the plane isotropic buildup factors of Goldstein [1]. However, it must be realized that Goldstein's data are for infinite media and, in most cases, were obtained using Equation (1) from point isotropic sources which were generated in a spherical rather than a slab geometry.

$$B^{pl}(E_0, \mu|x|) = \frac{\int_{\mu|x|}^{\infty} \left[B^{pt}(y) e^{-y}/y\right] dy}{E_1(\mu|x|)} \qquad (1)$$

B^{pl} is the plane isotropic buildup factor; E_0 is the energy; $\mu \cdot x$ is the source-exit plane distance in mean free paths; B^{pt} is the point buildup factor; and E_1 is the exponential integral. For example, early calculations by Berger and Doggett [2 - 3] showed that for plane monodirectional sources the infinite media calculations gave a 50 percent larger value than the finite slab case for 1.0 MeV gammas in 1 mfp ($\mu|x|$) of water. The isotropic case could then probably yield even larger differences in some cases. Figure 1 shows a comparison of Goldstein's plane isotropic buildup factors with buildup factors generated by the method described in this report.

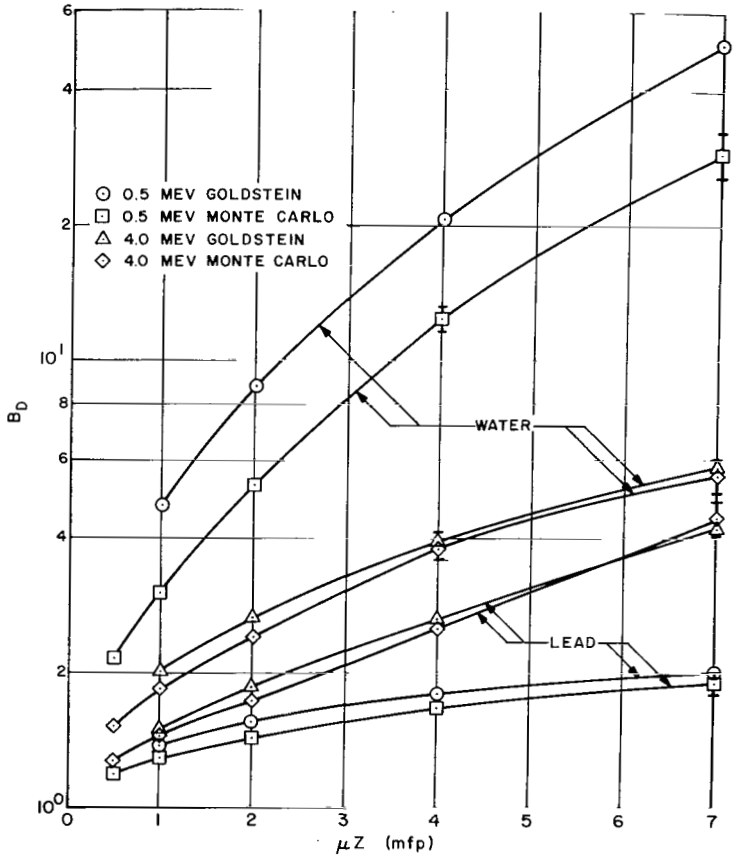

FIGURE 1. A COMPARISON OF GOLDSTEIN'S PLANE ISOTROPIC DOSE BUILDUP FACTORS WITH BUILDUP FACTORS GENERATED BY THE MONTE CARLO METHODS DESCRIBED

METHOD

The Monte Carlo code used is a revised version of a code developed by J. F. Perkins and M. O. Burrell. The modifications to treat isotropic incidence were carried out by C. W. Hill of Lockheed Georgia Company, Marietta, Georgia. The basic geometry is shown in Figure 2.

To improve statistics, more photons were started in the forward direction (toward the exit plane) at angles which were sampled systematically from a forward biased angular distribution function. Two items were incorporated in the path length probability density function used. One was an exponential transformation which stretched path lengths in the forward direction and shrank those in the backward direction. The other was path length truncation which insured that all particles stayed in the slab after each scatter.

It was given by:

$$f(r)dr = \frac{\Sigma(E)e^{-\Sigma(E)r}}{1-e^{-\Sigma(E)Z_t \sec\theta}}dr \quad ; \tag{2}$$

$$\Sigma(E) = (1-m\cos\theta)\,\mu(E) \tag{3}$$

In the above equations E was the photon energy; Z_t was the source-exit plane distance; θ was the photon direction measured from the source plane normal; $\mu(E)$ was the mass attenuation coefficient [4]; and m was a biasing parameter between 0 and 1 (usually ~ . 9) which determined how much the path length would be stretched. Photon path lengths were determined by random sampling from the distribution given by Equation 2. After each scatter, statistical estimation was used to calculate the probability that a photon would cross each of several boundaries established at various distances from the source plane so that effectively several problems could be performed simultaneously. The transmitted scatter dose rate, energy current, and energy flux were calculated from the weighted probabilities by

$$D_s = \frac{1}{n}\sum_{k=1}^{n}\sum_{i=1}^{m_k} E_{ik}\,F(E_{ik})\,W_{ik}\,P_{ik}\sec\theta_{ik} \tag{4}$$

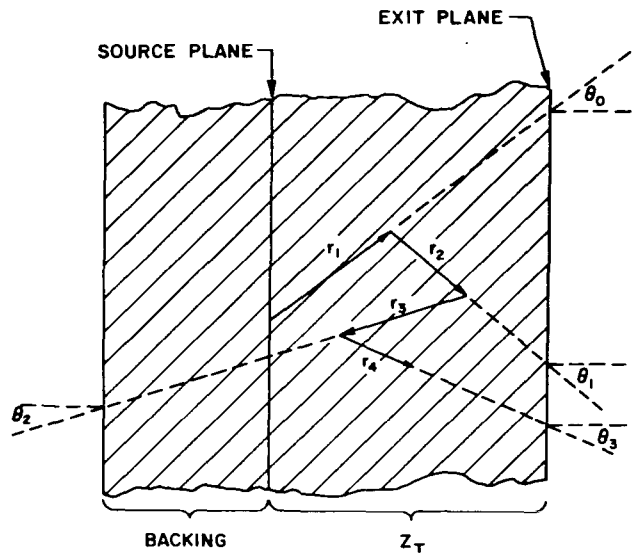

FIGURE 2. THE BASIC GEOMETRY CONFIGURATION USED IN THE CALCULATIONS

$$J_s = \frac{1}{n} \sum_{k=1}^{n} \sum_{i=1}^{m_k} E_{ik} W_{ik} P_{ik} \qquad (5)$$

$$F_s = \frac{1}{n} \sum_{k=1}^{n} \sum_{i=1}^{m_k} E_{ik} W_{ik} P_{ik} \sec \theta_{ik} \quad , \qquad (6)$$

where E_{ik} was the energy of the k^{th} photon after the i^{th} scatter; $F(E_{ik})$ was the energy flux to dose conversion factor [1]; W_{ik} was the photon weight; P_{ik} was the probability that the photon would cross the exit plane traveling the θ_{ik} direction; M_k was the number of scatters of the K^{th} history; and N was the number of the histories. The particle histories were terminated using a Russian Roulette scheme when the particle weight or energy became too small (below 0.01 MeV). The uncollided values were given by

$$D_u = \frac{E_0 F(E_0) E_1 (\mu(E_0) Z_t)}{2} \quad (7)$$

$$J_u = \frac{E_0 E_2 (\mu(E_0) Z_t)}{2} \quad (8)$$

$$F_u = \frac{E_0 E_1 (\mu(E_0) Z_t)}{2} \quad (9)$$

where E_0 was the initial energy and $E_2 (\mu(E_0) Z_t)$ is the second exponential integral. All the buildup factors were defined by the same form as the dose buildup

$$B_D = \frac{D_u + D_s}{D_u} \quad (10)$$

RESULTS

With careful use of biasing, reasonable statistical errors were obtained with 1000-4000 histories. The results of calculations performed for twelve energies ranging from 0. 05 MeV to 8. 0 MeV with six source backings of 0 mfp to 3. 0 mfp and for five source-exit plane distances from 0. 5 mfp to 7. 0 mfp are shown in Tables A-1 through A-IX in the Appendix. (Table X converts mean free paths to centimeters and to grams per centimeters squared.) The least reliable calculations were for water, especially the 7. 0 mfp case which had estimated standard errors of about ±10 percent about the mean for a one sigma error band. All the other calculations were more accurate (errors ranged around 5 percent). The lead results were extremely accurate with errors of less than 1 percent over the majority of the range considered except for 7 mfp and 8 MeV where errors approached 10 percent.

CONCLUSIONS

Figures 3-5 show important results for bremsstrahlung calculations. In Figure 3, aluminum dose buildup factors are plotted as a function of energy for a slab of constant backing for various source-exit plane distances. The most striking feature is that the buildup factors begin to decrease again below about 0. 2 MeV where photoelectric absorption becomes important. Thus Goldstein's results which extend down only to 0. 5 MeV can not be extrapolated very far into the region of interest for bremsstrahlung production accurately. For lead, the photoelectric K-edge at 0. 088 MeV has an interesting effect on the buildup factors for energies immediately above the edge. The dose buildup factors in Table A-XI show a large increase between 0. 08 MeV and 0. 09 MeV. The buildup apparently tends to follow the same pattern as the photoelectric cross section in this region. Figure 4 shows the effect of having finite backing behind the source plane. In it aluminum buildup factors are plotted as a function of backing for a constant source-exit plane distance and various energies. Generally, electrons incident on a slab shield deposit most of their energy near the front surface. Thus, most of the bremsstrahlung is generated there. For lower energies the buildup factors were smaller for thin backing increasing asymptotically to a constant as semi-infinite media conditions were approached. At higher energies scattering became extremely forward in direction and backing had little effect. For higher backing and higher energies the calculated buildup factors were in reasonable agreement with Goldstein's results.

George C. Marshall Space Flight Center
National Aeronautics and Space Administrations
Huntsville, Alabama, May 12, 1967
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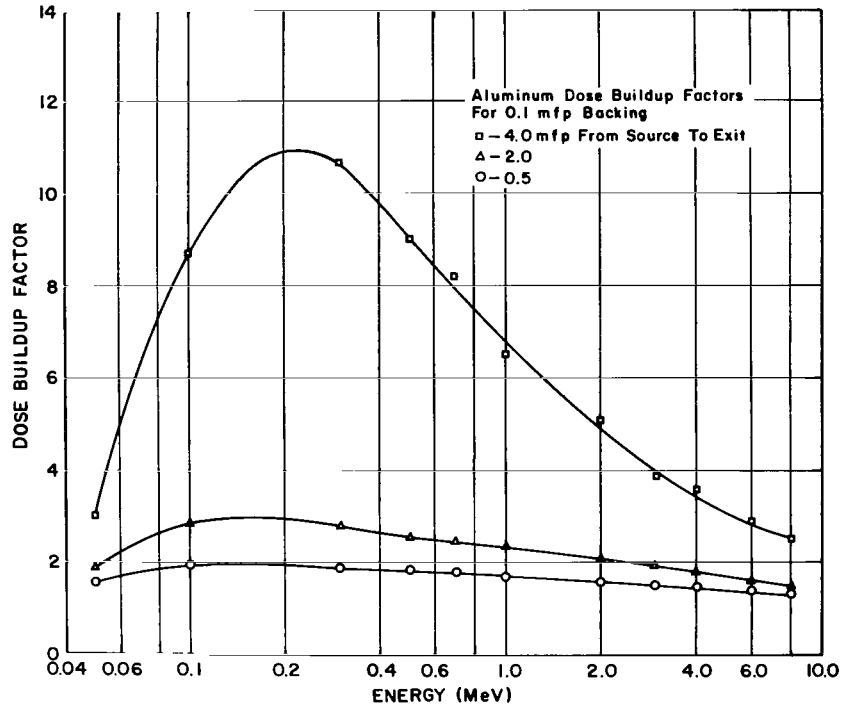

FIGURE 3 ALUMINUM DOSE BUILDUP FACTORS AS A FUNCTION OF ENERGY FOR SEVERAL SOURCE-EXIT PLANE DISTANCES

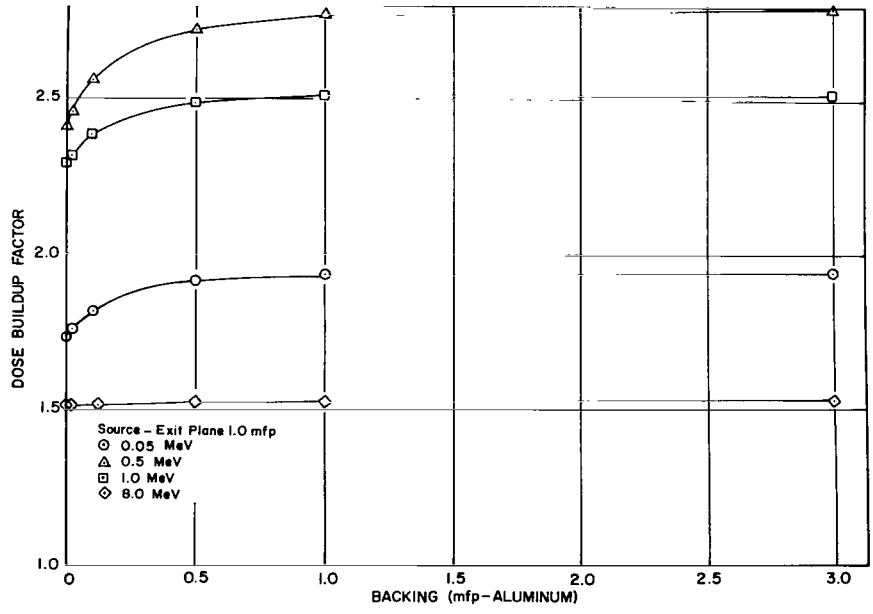

FIGURE 4. ALUMINUM DOSE BUILDUP FACTORS AS A FUNCTION OF BACKING THICKNESS FOR SEVERAL ENERGIES

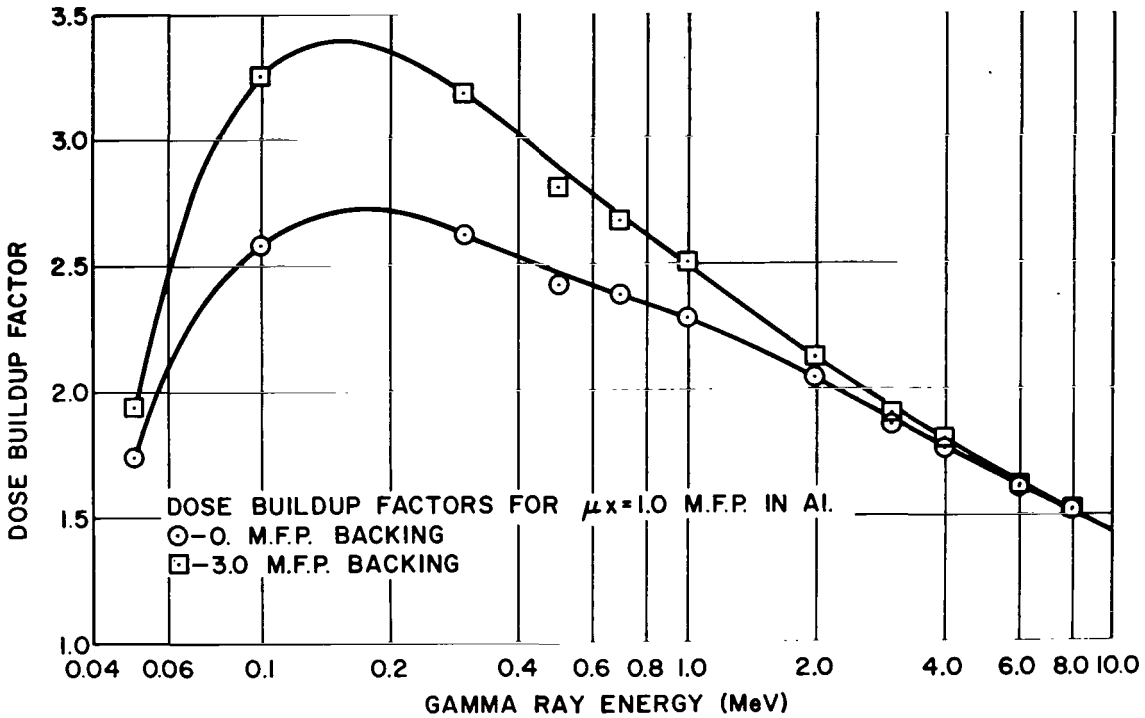

FIGURE 5. ALUMINUM DOSE BUILDUP FACTORS AS A FUNCTION OF ENERGY FOR BACKINGS OF 0. mfp and 3. 0 mfp

APPENDIX:

APPLICABLE TABLES

TABLE A-I. WATER PLANE ISOTROPIC DOSE BUILDUP FACTORS

BACKINGS = 0.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MFV)					
0.05	2.166	3.365	6.936	17.690	34.850
0.10	2.014	3.399	8.351	25.990	87.020
0.30	1.803	2.599	5.444	15.040	36.090
0.50	1.751	2.475	4.368	11.050	27.960
0.70	1.686	2.364	4.195	7.793	18.730
1.00	1.641	2.283	3.708	6.306	14.090
2.00	1.556	2.041	3.017	4.564	8.341
3.00	1.482	1.922	2.554	4.233	6.560
4.00	1.456	1.813	2.377	3.817	5.505
6.00	1.383	1.663	2.062	2.755	4.592
8.00	1.341	1.573	1.914	2.528	3.422

BACKING = 0.02 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MFV)					
0.05	2.283	3.543	7.186	18.340	35.780
0.10	2.112	3.553	8.613	27.000	88.700
0.30	1.841	2.650	5.592	15.150	36.410
0.50	1.798	2.517	4.474	11.210	28.140
0.70	1.721	2.391	4.256	7.937	18.780
1.00	1.972	2.312	3.734	6.335	14.310
2.00	1.575	2.058	3.065	4.572	8.341
3.00	1.502	1.927	2.559	4.234	6.563
4.00	1.472	1.817	2.382	3.817	5.505
6.00	1.390	1.667	2.064	2.755	4.592
8.00	1.347	1.574	1.915	2.528	3.422

BACKING = 0.10 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MFV)					
0.05	2.560	3.934	7.735	19.750	36.920
0.10	2.315	3.863	9.381	29.170	93.980
0.30	1.967	2.860	5.798	15.610	37.820
0.50	1.881	2.633	4.688	11.420	28.260
0.70	1.796	2.491	4.367	8.036	18.850
1.00	1.721	2.363	3.805	6.412	14.370
2.00	1.614	2.091	3.098	4.577	8.342
3.00	1.524	1.950	2.568	4.237	6.563
4.00	1.490	1.827	2.388	3.817	5.505
6.00	1.396	1.670	2.065	2.755	4.592
8.00	1.351	1.580	1.915	2.528	3.422

TABLE A-I. WATER PLANE ISOTROPIC DOSE BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS UZ (M. F. P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MFV)					
0.05	3.102	4.768	9.003	21.810	40.860
0.10	2.866	4.784	11.140	34.520	102.800
0.30	2.204	3.206	6.577	16.950	39.810
0.50	2.055	2.870	5.082	12.020	28.730
0.70	1.922	2.651	4.578	8.204	19.050
1.00	1.816	2.461	3.900	6.508	14.380
2.00	1.680	2.135	3.128	4.587	8.347
3.00	1.555	1.967	2.583	4.239	6.563
4.00	1.505	1.838	2.393	3.818	5.505
6.00	1.405	1.674	2.066	2.756	4.592
8.00	1.359	1.582	1.915	2.528	3.422

BACKING = 1.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	3.304	5.064	9.522	22.510	42.180
0.10	3.142	5.230	12.130	36.550	106.100
0.30	2.296	3.396	6.844	17.450	40.930
0.50	2.121	2.974	5.218	12.180	28.850
0.70	1.974	2.723	4.641	8.261	20.690
1.00	1.844	2.508	3.960	6.518	14.400
2.00	1.668	2.143	3.132	4.588	8.347
3.00	1.558	1.971	2.587	4.240	6.563
4.00	1.509	1.840	2.394	3.818	5.505
6.00	1.406	1.675	2.066	2.756	4.592
8.00	1.359	1.583	1.915	2.528	3.422

BACKING = 3.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	3.414	5.227	9.932	22.960	42.820
0.10	3.361	5.641	12.710	37.550	108.800
0.30	2.371	3.534	7.025	17.630	41.410
0.50	2.152	3.020	5.274	12.240	28.880
0.70	1.995	2.751	4.682	8.280	20.700
1.00	1.855	2.523	3.975	6.525	14.400
2.00	1.673	2.145	3.134	4.588	8.347
3.00	1.559	1.971	2.587	4.240	6.563
4.00	1.509	1.840	2.394	3.818	5.505
6.00	1.406	1.675	2.066	2.756	4.592
8.00	1.360	1.583	1.915	2.528	3.422

TABLE A-II. LEAD PLANE ISOTROPIC DOSE BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.011	1.015	1.022	1.032	1.037
0.10	1.015	1.030	1.054	1.151	1.989
0.30	1.090	1.140	1.209	1.294	1.366
0.50	1.172	1.283	1.420	1.674	1.907
0.70	1.251	1.428	1.627	2.009	2.247
1.00	1.335	1.512	1.834	2.316	2.831
2.00	1.367	1.560	1.923	2.603	4.096
3.00	1.302	1.497	1.906	2.767	3.678
4.00	1.254	1.440	1.717	2.522	4.454
6.00	1.177	1.299	1.590	2.221	3.644
8.00	1.134	1.237	1.435	1.957	3.143

BACKING = 0.02 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.012	1.015	1.022	1.032	1.037
0.10	1.016	1.032	1.057	1.165	2.078
0.30	1.091	1.142	1.209	1.294	1.366
0.50	1.175	1.286	1.421	1.674	1.907
0.70	1.258	1.432	1.628	2.009	2.247
1.00	1.343	1.515	1.835	2.317	2.831
2.00	1.376	1.564	1.923	2.603	4.096
3.00	1.306	1.501	1.908	2.767	3.678
4.00	1.260	1.441	1.717	2.522	4.454
6.00	1.180	1.301	1.590	2.221	3.644
8.00	1.135	1.241	1.437	1.958	3.144

BACKING = 0.10 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.013	1.016	1.023	1.032	1.037
0.10	1.019	1.036	1.065	1.189	2.264
0.30	1.094	1.144	1.209	1.295	1.366
0.50	1.178	1.289	1.422	1.674	1.907
0.70	1.263	1.436	1.629	2.009	2.247
1.00	1.351	1.522	1.835	2.317	2.831
2.00	1.381	1.570	1.924	2.603	4.096
3.00	1.311	1.507	1.909	2.767	3.678
4.00	1.265	1.445	1.718	2.523	4.454
6.00	1.185	1.304	1.591	2.222	3.644
8.00	1.139	1.244	1.437	1.959	3.144

TABLE A-II. LEAD PLANE ISOTROPIC DOSE BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.014	1.017	1.024	1.033	1.038
0.10	1.023	1.043	1.078	1.236	2.599
0.30	1.097	1.145	1.210	1.295	1.366
0.50	1.182	1.291	1.422	1.674	1.907
0.70	1.269	1.437	1.629	2.009	2.247
1.00	1.356	1.524	1.836	2.317	2.831
2.00	1.387	1.572	1.925	2.603	4.096
3.00	1.315	1.511	1.910	2.767	3.678
4.00	1.268	1.447	1.719	2.523	4.454
6.00	1.191	1.306	1.592	2.222	3.644
8.00	1.142	1.246	1.439	1.959	3.144

BACKING = 1.00 MEAN FREE PATHS

UZ (M.F.P)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.015	1.017	1.024	1.033	1.038
0.10	1.024	1.046	1.083	1.260	2.669
0.30	1.097	1.145	1.210	1.295	1.366
0.50	1.182	1.291	1.422	1.674	1.907
0.70	1.269	1.438	1.629	2.009	2.247
1.00	1.356	1.524	1.836	2.317	2.831
2.00	1.387	1.572	1.925	2.603	4.096
3.00	1.315	1.511	1.910	2.767	3.678
4.00	1.269	1.448	1.719	2.523	4.454
6.00	1.191	1.306	1.593	2.222	3.644
8.00	1.142	1.246	1.439	1.959	3.144

BACKING = 3.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.015	1.017	1.024	1.033	1.038
0.10	1.024	1.047	1.085	1.269	2.737
0.30	1.097	1.145	1.210	1.295	1.366
0.50	1.182	1.291	1.422	1.674	1.907
0.70	1.269	1.438	1.629	2.009	2.247
1.00	1.356	1.524	1.836	2.317	2.831
2.00	1.387	1.572	1.925	2.603	4.096
3.00	1.315	1.511	1.910	2.767	3.678
4.00	1.269	1.448	1.719	2.523	4.454
6.00	1.191	1.306	1.593	2.222	3.644
8.00	1.142	1.246	1.439	1.959	3.144

TABLE A-III. ALUMINUM PLANE ISOTROPIC DOSE BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.457	1.730	2.203	2.940	3.663
0.10	1.780	2.576	4.265	8.290	15.260
0.30	1.738	2.621	4.490	10.220	22.040
0.50	1.702	2.410	4.213	8.847	19.720
0.70	1.687	2.382	3.683	8.076	15.690
1.00	1.624	2.288	3.473	6.482	12.150
2.00	1.539	2.051	2.823	5.104	7.373
3.00	1.481	1.858	2.622	3.846	6.153
4.00	1.464	1.771	2.427	3.593	4.513
6.00	1.388	1.610	2.046	2.884	4.164
8.00	1.304	1.514	1.909	2.492	3.768

BACKING = 0.02 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.499	1.757	2.236	2.956	3.676
0.10	1.834	2.666	4.417	8.441	15.360
0.30	1.788	2.663	4.611	10.330	22.340
0.50	1.742	2.457	4.275	8.916	20.000
0.70	1.723	2.423	3.711	8.150	16.050
1.00	1.649	2.317	3.503	6.508	12.160
2.00	1.555	2.064	2.833	5.108	7.373
3.00	1.491	1.870	2.628	3.846	6.153
4.00	1.479	1.775	2.433	3.593	4.513
6.00	1.396	1.613	2.048	2.884	4.164
8.00	1.309	1.516	1.909	2.492	3.768

BACKING = 0.10 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.551	1.817	2.298	3.002	3.704
0.10	1.951	2.827	4.581	8.693	15.530
0.30	1.876	2.795	4.928	10.700	22.580
0.50	1.821	2.559	4.398	9.032	20.150
0.70	1.795	2.476	3.802	8.236	16.060
1.00	1.701	2.383	3.550	6.566	12.200
2.00	1.581	2.085	2.846	5.114	7.373
3.00	1.519	1.882	2.635	3.848	6.154
4.00	1.489	1.788	2.440	3.595	4.513
6.00	1.402	1.620	2.049	2.884	4.164
8.00	1.316	1.519	1.910	2.492	3.768

TABLE A-III. ALUMINUM PLANE ISOTROPIC DOSE BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.650	1.915	2.380	3.061	3.748
0.10	2.168	3.124	4.927	9.161	16.240
0.30	2.055	3.050	5.270	11.310	23.150
0.50	1.950	2.723	4.648	9.337	20.270
0.70	1.903	2.614	3.992	8.376	16.170
1.00	1.785	2.482	3.646	6.610	12.210
2.00	1.619	2.126	2.865	5.119	7.375
3.00	1.547	1.902	2.639	3.852	6.156
4.00	1.508	1.800	2.445	3.595	4.513
6.00	1.409	1.625	2.050	2.884	4.164
8.00	1.321	1.524	1.912	2.492	3.768

BACKING = 1.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.670	1.933	2.400	3.080	3.755
0.10	2.242	3.212	5.051	9.271	16.380
0.30	2.113	3.135	5.372	11.430	23.270
0.50	1.989	2.772	4.708	9.426	20.320
0.70	1.939	2.650	4.029	8.444	16.180
1.00	1.808	2.509	3.684	6.623	12.210
2.00	1.627	2.133	2.869	5.120	7.375
3.00	1.549	1.904	2.642	3.852	6.156
4.00	1.510	1.801	2.445	3.595	4.513
6.00	1.409	1.625	2.050	2.884	4.164
8.00	1.321	1.524	1.912	2.492	3.768

BACKING = 3.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.677	1.939	2.409	3.087	3.759
0.10	2.267	3.246	5.120	9.323	16.430
0.30	2.147	3.173	5.414	11.490	23.310
0.50	2.007	2.796	4.759	9.448	20.330
0.70	1.952	2.665	4.039	8.455	16.180
1.00	1.814	2.517	3.688	6.627	12.210
2.00	1.628	2.135	2.870	5.121	7.375
3.00	1.550	1.905	2.642	3.852	6.156
4.00	1.511	1.801	2.445	3.595	4.513
6.00	1.409	1.625	2.050	2.884	4.164
8.00	1.321	1.524	1.912	2.492	3.768

TABLE A-IV. ALUMINUM PLANE ISOTROPIC ENERGY FLUX BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.292	1.470	1.793	2.309	2.751
0.10	1.605	2.165	3.401	6.210	11.130
0.30	1.650	2.410	3.985	8.818	18.290
0.50	1.612	2.204	3.659	7.534	15.890
0.70	1.574	2.150	3.279	6.512	12.840
1.00	1.504	2.041	3.044	5.507	9.724
2.00	1.423	1.811	2.390	4.028	5.693
3.00	1.362	1.640	2.173	3.093	4.885
4.00	1.301	1.555	2.024	2.888	3.680
6.00	1.257	1.437	1.739	2.406	3.378
8.00	1.203	1.370	1.676	2.100	3.075

BACKING = 0.02 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.313	1.489	1.814	2.320	2.761
0.10	1.652	2.230	3.530	6.307	11.200
0.30	1.695	2.443	4.092	8.930	18.580
0.50	1.651	2.249	3.710	7.596	16.130
0.70	1.608	2.188	3.308	6.583	13.070
1.00	1.526	2.068	3.071	5.531	9.731
2.00	1.434	1.821	2.398	4.030	5.693
3.00	1.368	1.648	2.175	3.094	4.885
4.00	1.309	1.557	2.027	2.888	3.680
6.00	1.262	1.438	1.740	2.406	3.378
8.00	1.205	1.371	1.676	2.100	3.075

BACKING = 0.10 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.358	1.530	1.856	2.349	2.780
0.10	1.746	2.359	3.666	6.501	11.310
0.30	1.789	2.574	4.281	9.282	18.770
0.50	1.727	2.350	3.831	7.710	16.260
0.70	1.668	2.242	3.378	6.654	13.080
1.00	1.572	2.124	3.115	5.579	9.749
2.00	1.455	1.837	2.407	4.034	5.694
3.00	1.385	1.657	2.180	3.094	4.885
4.00	1.315	1.564	2.032	2.889	3.680
6.00	1.266	1.442	1.741	2.406	3.378
8.00	1.210	1.372	1.676	2.100	3.075

TABLE A-IV. ALUMINUM PLANE ISOTROPIC ENERGY FLUX BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.434	1.598	1.909	2.386	2.810
0.10	1.937	2.598	3.908	6.846	11.790
0.30	1.990	2.841	4.606	9.811	19.340
0.50	1.871	2.525	4.067	7.977	16.380
0.70	1.771	2.375	3.559	6.781	13.180
1.00	1.654	2.216	3.196	5.616	9.763
2.00	1.486	1.871	2.422	4.038	5.695
3.00	1.405	1.671	2.183	3.098	4.886
4.00	1.329	1.572	2.035	2.889	3.680
6.00	1.269	1.445	1.741	2.406	3.378
8.00	1.212	1.374	1.677	2.100	3.075

BACKING = 1.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.448	1.610	1.923	2.400	2.815
0.10	2.006	2.672	4.005	6.922	11.890
0.30	2.062	2.940	4.709	9.933	19.440
0.50	1.922	2.580	4.134	8.065	16.430
0.70	1.812	2.415	3.600	6.836	13.190
1.00	1.680	2.244	3.217	5.625	9.764
2.00	1.494	1.877	2.424	4.039	5.695
3.00	1.407	1.673	2.185	3.098	4.886
4.00	1.331	1.572	2.035	2.890	3.680
6.00	1.270	1.445	1.741	2.406	3.378
8.00	1.213	1.374	1.677	2.100	3.075

BACKING = 3.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.453	1.614	1.929	2.404	2.817
0.10	2.028	2.702	4.064	6.957	11.920
0.30	2.105	2.980	4.752	9.991	19.470
0.50	1.944	2.607	4.183	8.086	16.440
0.70	1.828	2.432	3.610	6.846	13.200
1.00	1.687	2.253	3.220	5.630	9.764
2.00	1.495	1.878	2.425	4.039	5.695
3.00	1.407	1.673	2.185	3.098	4.886
4.00	1.331	1.572	2.035	2.890	3.680
6.00	1.270	1.445	1.741	2.406	3.378
8.00	1.213	1.374	1.677	2.100	3.075

TABLE A-V. WATER PLANE ISOTROPIC ENERGY FLUX BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.659	2.306	3.963	8.713	15.180
0.10	1.765	2.640	5.312	13.580	38.556
0.30	1.683	2.423	4.635	12.000	26.062
0.50	1.625	2.241	3.765	8.753	21.792
0.70	1.576	2.124	3.573	6.438	14.398
1.00	1.531	2.015	3.187	5.242	11.326
2.00	1.406	1.790	2.524	3.678	6.180
3.00	1.367	1.665	2.152	3.319	4.915
4.00	1.330	1.590	2.008	2.942	4.322
6.00	1.268	1.466	1.763	2.362	3.734
8.00	1.220	1.401	1.649	2.147	2.792

BACKING = 0.02 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.721	2.393	4.084	8.973	15.480
0.10	1.834	2.747	5.465	14.050	39.401
0.30	1.719	2.471	4.781	12.090	26.281
0.50	1.665	2.285	3.849	8.888	21.912
0.70	1.610	2.150	3.622	6.551	14.433
1.00	1.559	2.041	3.210	5.266	11.473
2.00	1.419	1.803	2.549	3.681	6.180
3.00	1.378	1.668	2.154	3.320	4.917
4.00	1.339	1.592	2.011	2.942	4.322
6.00	1.271	1.468	1.764	2.362	3.734
8.00	1.224	1.402	1.649	2.147	2.792

BACKING = 0.10 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.878	2.594	4.322	9.421	15.880
0.10	2.002	2.965	5.890	15.050	41.671
0.30	1.844	2.666	4.966	12.410	27.298
0.50	1.746	2.393	4.027	9.073	22.002
0.70	1.676	2.243	3.715	6.621	14.474
1.00	1.606	2.087	3.270	5.309	11.500
2.00	1.447	1.828	2.573	3.684	6.180
3.00	1.393	1.682	2.160	3.321	4.917
4.00	1.349	1.599	2.015	2.942	4.322
6.00	1.275	1.469	1.764	2.362	3.734
8.00	1.226	1.405	1.649	2.147	2.792

TABLE A-V. WATER PLANE ISOTROPIC ENERGY FLUX BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	2.172	2.987	4.822	10.150	17.060
0.10	2.387	3.519	6.760	16.930	45.241
0.30	2.079	2.990	5.576	13.430	28.403
0.50	1.932	2.616	4.362	9.458	22.319
0.70	1.797	2.396	3.893	6.751	14.602
1.00	1.702	2.176	3.347	5.372	11.510
2.00	1.484	1.861	2.593	3.689	6.183
3.00	1.415	1.694	2.170	3.323	4.917
4.00	1.359	1.606	2.017	2.942	4.322
6.00	1.281	1.471	1.765	2.362	3.734
8.00	1.230	1.406	1.649	2.147	2.792

BACKING = 1.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	2.280	3.125	5.017	10.440	17.500
0.10	2.578	3.780	7.221	17.770	46.778
0.30	2.178	3.169	5.783	13.820	29.207
0.50	2.008	2.717	4.479	9.573	22.420
0.70	1.848	2.465	3.949	6.788	15.633
1.00	1.730	2.222	3.396	5.380	11.516
2.00	1.491	1.867	2.596	3.690	6.183
3.00	1.418	1.697	2.172	3.323	4.917
4.00	1.362	1.607	2.018	2.942	4.322
6.00	1.282	1.472	1.765	2.362	3.734
8.00	1.231	1.406	1.649	2.147	2.792

BACKING = 3.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	2.336	3.193	5.171	10.610	17.670
0.10	2.704	3.970	7.470	18.200	47.776
0.30	2.256	3.275	5.926	13.950	29.431
0.50	2.042	2.760	4.522	9.613	22.439
0.70	1.871	2.489	3.986	6.800	15.637
1.00	1.742	2.234	3.408	5.385	11.516
2.00	1.496	1.869	2.597	3.690	6.183
3.00	1.419	1.697	2.172	3.323	4.917
4.00	1.362	1.607	2.018	2.942	4.322
6.00	1.282	1.472	1.765	2.362	3.734
8.00	1.231	1.406	1.649	2.147	2.792

TABLE A-VI. LEAD PLANE ISOTROPIC ENERGY FLUX
. BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.008	1.012	1.016	1.025	1.028
0.10	1.012	1.021	1.041	1.112	1.812
0.30	1.082	1.123	1.186	1.269	1.331
0.50	1.159	1.249	1.382	1.601	1.805
0.70	1.219	1.357	1.542	1.901	2.115
1.00	1.279	1.435	1.736	2.190	2.605
2.00	1.281	1.452	1.793	2.347	3.572
3.00	1.222	1.374	1.699	2.373	3.130
4.00	1.178	1.321	1.551	2.192	3.704
6.00	1.124	1.218	1.444	1.918	2.949
8.00	1.091	1.640	1.323	1.696	2.538

BACKING = 0.02 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.008	1.012	1.016	1.025	1.028
0.10	1.013	1.023	1.044	1.125	1.881
0.30	1.084	1.124	1.186	1.269	1.331
0.50	1.161	1.251	1.382	1.601	1.805
0.70	1.225	1.361	1.542	1.901	2.115
1.00	1.285	1.437	1.737	2.190	2.605
2.00	1.286	1.455	1.793	2.347	3.572
3.00	1.224	1.376	1.700	2.373	3.130
4.00	1.182	1.321	1.551	2.192	3.704
6.00	1.126	1.219	1.444	1.918	2.949
8.00	1.091	1.166	1.324	1.697	2.538

BACKING = 0.10 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.009	1.012	1.017	1.025	1.028
0.10	1.015	1.026	1.051	1.144	2.038
0.30	1.087	1.126	1.186	1.269	1.331
0.50	1.164	1.254	1.383	1.601	1.805
0.70	1.229	1.363	1.543	1.901	2.115
1.00	1.291	1.443	1.737	2.190	2.605
2.00	1.290	1.459	1.793	2.347	3.572
3.00	1.227	1.380	1.701	2.373	3.130
4.00	1.184	1.323	1.552	2.192	3.704
6.00	1.128	1.221	1.445	1.919	2.949
8.00	1.093	1.167	1.325	1.697	2.538

TABLE A-VI. LEAD PLANE ISOTROPIC ENERGY FLUX BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.010	1.013	1.018	1.025	1.029
0.10	1.018	1.032	1.061	1.183	2.321
0.30	1.090	1.127	1.186	1.269	1.331
0.50	1.167	1.255	1.383	1.601	1.805
0.70	1.234	1.364	1.543	1.901	2.115
1.00	1.295	1.445	1.738	2.190	2.605
2.00	1.295	1.460	1.794	2.347	3.572
3.00	1.229	1.382	1.702	2.373	3.130
4.00	1.186	1.325	1.552	2.192	3.704
6.00	1.130	1.222	1.445	1.919	2.949
8.00	1.094	1.168	1.325	1.697	2.538

BACKING = 1.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.010	1.014	1.018	1.025	1.029
0.10	1.019	1.034	1.066	1.203	2.380
0.30	1.090	1.127	1.186	1.269	1.331
0.50	1.168	1.255	1.383	1.601	1.805
0.70	1.234	1.365	1.543	1.901	2.115
1.00	1.295	1.445	1.738	2.190	2.605
2.00	1.295	1.460	1.794	2.347	3.572
3.00	1.229	1.382	1.702	2.373	3.130
4.00	1.186	1.325	1.552	2.192	3.704
6.00	1.130	1.222	1.445	1.919	2.949
8.00	1.094	1.168	1.325	1.697	2.538

BACKING = 3.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.010	1.014	1.018	1.026	1.029
0.10	1.020	1.035	1.068	1.212	2.443
0.30	1.090	1.127	1.186	1.269	1.331
0.50	1.168	1.255	1.383	1.601	1.805
0.70	1.234	1.365	1.543	1.901	2.115
1.00	1.295	1.445	1.738	2.190	2.605
2.00	1.295	1.460	1.794	2.347	3.572
3.00	1.229	1.382	1.702	2.373	3.130
4.00	1.186	1.325	1.552	2.192	3.704
6.00	1.130	1.222	1.445	1.919	2.949
8.00	1.094	1.168	1.325	1.697	2.538

TABLE A-VII. ALUMINUM PLANE ISOTROPIC ENERGY CURRENT BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.370	1.595	1.984	2.607	3.210
0.10	1.743	2.493	4.037	7.705	14.140
0.30	1.785	2.739	4.786	11.116	24.090
0.50	1.729	2.476	4.411	9.391	21.210
0.70	1.717	2.406	3.748	8.313	16.270
1.00	1.606	2.257	3.425	6.387	11.950
2.00	1.482	1.937	2.619	4.621	6.624
3.00	1.414	1.729	2.358	3.387	5.393
4.00	1.390	1.641	2.173	3.122	3.941
6.00	1.322	1.503	1.843	2.538	3.593
8.00	1.250	1.420	1.746	2.202	3.239

BACKING = 0.02 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.393	1.612	2.007	2.618	3.220
0.10	1.793	2.575	4.176	7.833	14.230
0.30	1.839	2.785	4.924	11.243	24.420
0.50	1.771	2.528	4.480	9.470	21.520
0.70	1.755	2.449	3.779	8.399	16.690
1.00	1.631	2.286	3.455	6.415	11.950
2.00	1.496	1.948	2.628	4.624	6.624
3.00	1.421	1.739	2.362	3.388	5.393
4.00	1.401	1.644	2.177	3.122	3.941
6.00	1.328	1.506	1.844	2.538	3.593
8.00	1.253	1.421	1.746	2.202	3.239

BACKING = 0.10 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.437	1.653	2.050	2.652	3.240
0.10	1.898	2.719	4.321	8.054	14.380
0.30	1.939	2.933	5.280	11.673	24.680
0.50	1.859	2.641	4.620	9.601	21.690
0.70	1.825	2.507	3.877	8.491	16.700
1.00	1.682	2.351	3.504	6.474	11.990
2.00	1.518	1.965	2.639	4.629	6.624
3.00	1.444	1.748	2.368	3.389	5.393
4.00	1.409	1.654	2.182	3.123	3.941
6.00	1.333	1.510	1.845	2.539	3.593
8.00	1.258	1.423	1.746	2.202	3.239

TABLE A-VII. ALUMINUM PLANE ISOTROPIC ENERGY CURRENT BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.506	1.720	2.105	2.692	3.272
0.10	2.088	2.976	4.614	8.464	14.980
0.30	2.144	3.224	5.671	12.366	25.350
0.50	2.006	2.828	4.904	9.954	21.840
0.70	1.934	2.657	4.085	8.649	16.830
1.00	1.768	2.452	3.600	6.520	12.010
2.00	1.551	2.002	2.655	4.633	6.626
3.00	1.465	1.763	2.371	3.392	5.394
4.00	1.423	1.661	2.185	3.124	3.941
6.00	1.336	1.513	1.845	2.539	3.593
8.00	1.261	1.425	1.747	2.202	3.239

BACKING = 1.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.519	1.733	2.119	2.705	3.277
0.10	2.151	3.050	4.717	8.558	15.100
0.30	2.210	3.321	5.790	12.516	25.490
0.50	2.055	2.885	4.974	10.059	21.890
0.70	1.972	2.696	4.127	8.725	16.840
1.00	1.792	2.480	3.639	6.534	12.010
2.00	1.558	2.008	2.658	4.635	6.626
3.00	1.467	1.765	2.374	3.392	5.395
4.00	1.424	1.663	2.185	3.124	3.941
6.00	1.337	1.513	1.845	2.539	3.593
8.00	1.261	1.426	1.747	2.202	3.239

BACKING = 3.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.522	1.736	2.125	2.709	3.279
0.10	2.171	3.078	4.778	8.600	15.130
0.30	2.250	3.364	5.838	12.583	25.530
0.50	2.075	2.913	5.032	10.086	21.900
0.70	1.987	2.714	4.138	8.736	16.840
1.00	1.799	2.489	3.643	6.538	12.010
2.00	1.558	2.010	2.659	4.635	6.626
3.00	1.467	1.765	2.374	3.392	5.395
4.00	1.424	1.663	2.186	3.124	3.941
6.00	1.337	1.513	1.845	2.539	3.593
8.00	1.261	1.426	1.747	2.202	3.239

TABLE A-VIII. WATER PLANE ISOTROPIC ENERGY
CURRENT BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.864	2.630	4.729	10.700	19.320
0.10	1.948	3.110	6.879	17.520	54.363
0.30	1.856	2.709	5.668	15.440	34.907
0.50	1.778	2.541	4.537	11.510	27.996
0.70	1.694	2.387	4.233	7.904	19.103
1.00	1.625	2.251	3.635	6.128	13.771
2.00	1.497	1.926	2.773	4.136	7.464
3.00	1.414	1.787	2.308	3.713	5.623
4.00	1.381	1.674	2.134	3.283	4.729
6.00	1.317	1.546	1.862	2.432	3.944
8.00	1.280	1.470	1.731	2.257	2.964

BACKING = 0.02 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.937	2.735	4.870	11.030	19.740
0.10	2.030	3.230	7.053	18.170	55.367
0.30	1.897	2.763	5.828	15.540	35.173
0.50	1.827	2.586	4.647	11.670	28.190
0.70	1.730	2.415	4.297	8.059	19.148
1.00	1.654	2.280	3.661	6.159	13.973
2.00	1.513	1.940	2.814	4.143	7.464
3.00	1.431	1.791	2.311	3.714	5.625
4.00	1.393	1.677	2.137	3.283	4.729
6.00	1.322	1.548	1.864	2.432	3.944
8.00	1.284	1.470	1.731	2.257	2.964

BACKING = 0.10 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	2.108	2.961	5.144	11.660	20.250
0.10	2.203	3.467	7.571	19.380	58.295
0.30	2.035	2.991	6.040	15.950	36.708
0.50	1.918	2.712	4.871	11.890	28.311
0.70	1.808	2.522	4.409	8.161	19.210
1.00	1.703	2.330	3.730	6.234	14.027
2.00	1.546	1.969	2.841	4.146	7.465
3.00	1.447	1.807	2.319	3.716	5.625
4.00	1.406	1.685	2.141	3.283	4.729
6.00	1.326	1.550	1.865	2.432	3.944
8.00	1.287	1.474	1.731	2.257	2.964

TABLE A-VIII. WATER PLANE ISOTROPIC ENERGY CURRENT BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	2.412	3.388	5.743	12.550	21.960
0.10	2.617	4.102	8.656	22.080	63.258
0.30	2.299	3.356	6.802	17.230	38.427
0.50	2.108	2.965	5.278	12.400	28.727
0.70	1.941	2.688	4.618	8.326	19.397
1.00	1.798	2.428	3.822	6.330	14.041
2.00	1.584	2.005	2.865	4.153	7.469
3.00	1.471	1.820	2.329	3.718	5.625
4.00	1.416	1.691	2.144	3.283	4.729
6.00	1.332	1.553	1.865	2.432	3.944
8.00	1.291	1.475	1.731	2.257	2.964

BACKING = 1.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	2.507	3.533	5.964	12.880	22.470
0.10	2.796	4.367	9.212	23.070	65.147
0.30	2.396	3.547	7.049	17.700	39.393
0.50	2.178	3.070	5.412	12.540	28.847
0.70	1.996	2.761	4.680	8.382	20.621
1.00	1.825	2.474	3.879	6.339	14.053
2.00	1.591	2.010	2.869	4.155	7.469
3.00	1.473	1.823	2.332	3.718	5.625
4.00	1.419	1.693	2.144	3.283	4.729
6.00	1.332	1.553	1.865	2.432	3.944
8.00	1.292	1.476	1.731	2.257	2.964

BACKING = 3.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	2.554	3.606	6.139	13.090	22.700
0.10	2.917	4.569	9.500	23.590	66.660
0.30	2.467	3.667	7.215	17.850	39.735
0.50	2.209	3.113	5.460	12.600	28.877
0.70	2.017	2.788	4.720	8.397	20.631
1.00	1.835	2.487	3.891	6.345	14.053
2.00	1.595	2.012	2.870	4.155	7.469
3.00	1.474	1.823	2.332	3.718	5.625
4.00	1.419	1.693	2.144	3.283	4.729
6.00	1.332	1.553	1.865	2.432	3.944
8.00	1.292	1.476	1.731	2.257	2.964

TABLE A-IX. LEAD PLANE ISOTROPIC ENERGY CURRENT BUILDUP FACTORS

BACKING = 0.00 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.010	1.013	1.019	1.028	1.033
0.10	1.015	1.030	1.053	1.147	1.972
0.30	1.092	1.144	1.207	1.299	1.372
0.50	1.174	1.285	1.423	1.677	1.911
0.70	1.249	1.425	1.622	2.000	2.236
1.00	1.325	1.496	1.807	2.276	2.773
2.00	1.335	1.507	1.839	2.461	3.815
3.00	1.265	1.432	1.786	2.522	3.323
4.00	1.217	1.372	1.599	2.283	3.873
6.00	1.148	1.248	1.486	1.993	3.110
8.00	1.111	1.195	1.356	1.755	2.660

BACKING = 0.02 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.010	1.013	1.019	1.029	1.033
0.10	1.016	1.031	1.056	1.161	2.058
0.30	1.094	1.146	1.207	1.299	1.372
0.50	1.177	1.288	1.424	1.677	1.911
0.70	1.256	1.429	1.622	2.000	2.236
1.00	1.332	1.498	1.808	2.276	2.773
2.00	1.342	1.511	1.840	2.461	3.815
3.00	1.268	1.434	1.788	2.522	3.323
4.00	1.222	1.373	1.599	2.283	3.873
6.00	1.150	1.250	1.487	1.994	3.110
8.00	1.112	1.197	1.357	1.755	2.660

BACKING = 0.10 MEAN FREE PATHS UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.011	1.014	1.020	1.029	1.033
0.10	1.018	1.035	1.064	1.184	2.239
0.30	1.097	1.148	1.208	1.299	1.372
0.50	1.180	1.292	1.425	1.677	1.911
0.70	1.261	1.432	1.623	2.000	2.236
1.00	1.339	1.505	1.808	2.276	2.773
2.00	1.346	1.516	1.840	2.461	3.815
3.00	1.272	1.439	1.789	2.522	3.323
4.00	1.225	1.376	1.600	2.283	3.873
6.00	1.153	1.252	1.487	1.994	3.110
8.00	1.114	1.199	1.358	1.755	2.660

TABLE A-IX. LEAD PLANE ISOTROPIC ENERGY CURRENT BUILDUP FACTORS (Concluded)

BACKING = 0.50 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.012	1.015	1.021	1.029	1.033
0.10	1.022	1.042	1.076	1.229	2.563
0.30	1.100	1.149	1.208	1.299	1.372
0.50	1.184	1.293	1.425	1.677	1.911
0.70	1.267	1.434	1.624	2.000	2.236
1.00	1.344	1.507	1.810	2.276	2.773
2.00	1.352	1.518	1.841	2.461	3.815
3.00	1.275	1.442	1.790	2.522	3.323
4.00	1.228	1.377	1.601	2.283	3.873
6.00	1.157	1.253	1.488	1.994	3.110
8.00	1.116	1.200	1.359	1.755	2.660

BACKING = 1.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.012	1.015	1.021	1.029	1.033
0.10	1.023	1.044	1.081	1.252	2.630
0.30	1.100	1.149	1.208	1.299	1.372
0.50	1.184	1.293	1.425	1.677	1.911
0.70	1.267	1.434	1.624	2.000	2.236
1.00	1.344	1.507	1.810	2.276	2.773
2.00	1.352	1.518	1.841	2.461	3.815
3.00	1.275	1.442	1.790	2.522	3.323
4.00	1.228	1.378	1.601	2.283	3.873
6.00	1.157	1.253	1.488	1.994	3.110
8.00	1.116	1.200	1.359	1.755	2.660

BACKING = 3.00 MEAN FREE PATHS

UZ (M.F.P.)	0.5	1.0	2.0	4.0	7.0
ENERGY (MEV)					
0.05	1.012	1.015	1.021	1.029	1.033
0.10	1.023	1.045	1.083	1.261	2.693
0.30	1.100	1.149	1.208	1.299	1.372
0.50	1.184	1.293	1.425	1.677	1.911
0.70	1.267	1.434	1.624	2.000	2.236
1.00	1.344	1.507	1.810	2.276	2.773
2.00	1.352	1.518	1.841	2.461	3.815
3.00	1.275	1.442	1.790	2.522	3.323
4.00	1.228	1.378	1.601	2.283	3.873
6.00	1.157	1.253	1.488	1.994	3.110
8.00	1.116	1.200	1.359	1.755	2.660

TABLE A-X. MEAN FREE PATH TO SLAB THICKNESS CONVERSION FOR ALUMINUM, LEAD, AND WATER

ENERGY	1.0 mfp	Aluminum	1.0 mfp	Lead	1.0 mfp Water
(MeV)	(cm)	(gm/cm^2)	(cm)	(gm/cm^2)	(cm)
0.05	1.161	3.135	0.01108	1.256	4.744
0.1	2.315	6.251	0.01586	1.799	5.984
0.3	3.596	9.709	0.2315	2.625	8.421
0.5	4.404	11.89	0.5764	6.536	10.35
0.7	5.101	13.77	0.8858	10.04	11.98
1.0	6.032	16.29	1.280	14.52	14.17
2.0	8.573	23.15	1.955	22.17	20.27
3.0	10.49	28.32	2.115	23.98	25.23
4.0	11.91	32.16	2.120	24.04	29.31
6.0	13.92	37.58	2.027	22.99	36.
8.0	15.24	41.15	1.917	21.74	41.22

TABLE A-XI. DOSE BUILDUP FACTORS AROUND THE LEAD K-EDGE (0.088 MeV) SOURCE-EXIT PLANE DISTANCE 7.0 mfp

Energy (MeV) \ Backing (mfp)	0.0	0.02	0.1	0.5	1.0	3.0
0.05	1.037	1.037	1.037	1.038	1.038	1.038
0.07	1.105	1.105	1.105	1.105	1.105	1.105
0.08	1.115	1.116	1.116	1.116	1.116	1.116
0.09	5.677	5.810	6.134	6.557	6.675	6.747
0.1	1.989	2.078	2.264	2.599	2.669	2.737
0.3	1.366	1.366	1.366	1.366	1.366	1.366

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NASA-Langley, 1967 —— 24 M423

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