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GAMMA-RAY DOSE AND ENERGY ABSORPTION BUILD-UP FACTOR DATA FOR USE IN REACTOR SHIELD CALCULATIONS

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*Air ($N_{78}O_{22}$)
Wood (cellulose, $C_6H_{10}O_5$)
Sand (SiO_2)
Lithium hydride (LiH)

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Tables of infinite medium gamma-ray dose and energy absorption build-up factors given in various references have been collected together. The data tables for beryllium, carbon, aluminum, iron, tin, tungsten, lead, uranium, water, ordinary concrete, magnetite concrete, and barytes concrete have been interpolated linearly on energy to give values at 31 energy levels in the range 0.25 to 10 Mev. Shorter tables are given for air, wood, sand, and lithium hydride. Parametric fit coefficients, which represent the build-up factors as smooth functions of optical distance, have been determined for all energies and materials included in this report. Taylor exponential fit coefficients are given except for those cases where both low energy and low atomic number occur simultaneously; under these conditions cubic and quartic polynomial fits were found to be more accurate. The accuracy of the parametric fits given here is generally better than 10 percent. Brief tables of dose build-up factor data obtained by linear and log-log interpolation of known data with respect to atomic number are included.

GAMMA-RAY DOSE AND ENERGY ABSORPTION BUILD-UP FACTOR DATA FOR USE IN REACTOR SHIELDING CALCULATIONS

O. J. Wallace

I. GENERAL INFORMATION

The numbers known as gamma-ray build-up factors* are used to account for the scattering of gamma rays as they are attentuated in passing through shielding materials. The scattered gamma rays suffer degradation in energy, but contribute very significantly to the dose rate or energy absorption rate at the detector point. The gamma-ray dose rate build-up factor at a detector point F (Figure 1) is defined by the relation

$$B_D = \frac{\text{total dose rate at detector point F}}{\text{uncollided dose rate at detector point F}} \qquad (1)$$

A point isotropic source and an infinite medium are assumed as boundary conditions in most published build-up factor data.

*Note on nomenclature: The nomenclature used throughout this report is based on, and compatible with, that used by Goldstein and Wilkins (Reference 1). This nomenclature has been retained because it is familiar and meaningful to those shielding engineers for which the report is intended. The author is aware of the recommended changes in build-up factor terminology and the controversy that has been engendered thereby (References 1 through 5).

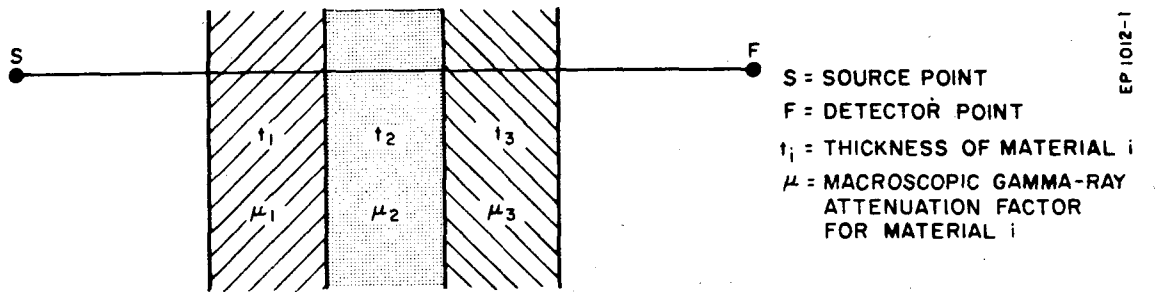

Figure 1. Model for Determining Optical Distance between Gamma-Ray Source Point and Detector

Obviously B_D depends on the energy E_o of the source gammas, the materials between the source point (S) and the detector point (F), and the optical distance (b) between S and F.

If only one element intervenes between S and F, the build-up factor may be related to the atomic number of the element. When several materials are present between S and F, b is given by

$$b = \sum_{i=1}^{N} \mu_i t_i \qquad (2)$$

b is measured in mean-free-path (MFP) lengths (see Reference 1). Here, N is the number of different materials encountered between S and F, t_i is the distance through material i, and μ_i is the corresponding macroscopic gamma-ray attentuation coefficient.

Gamma-ray build-up factors are usually given in tables as functions of the optical distance b (measured in mean-free-path lengths), the initial gamma-ray energy E_o (measured in Mev) and, for elements, the equivalent atomic number Z. For compounds such as water and mixtures such as concrete, an equivalent atomic number may be assigned by comparing the build-up factors of the mixture or compound to those of various elements. However, such an equivalent atomic number may be energy dependent or dependent on the interpolation scheme.

For instance, Goldstein (Reference 1) gives 7.5 as a reasonable equivalent atomic number for water, but Engholm (Reference 6) found that a lower equivalent atomic number for water was indicated at low energies. An equivalent atomic number of 16 may be used for ordinary concrete if linear interpolation of build-up factors on atomic number is the method used to find build-up factors of materials not given in the tables (Tables 3A, 4A, 10A, and 20); however, some other interpolation scheme such as log-log would require assignment of a different equivalent atomic number to ordinary concrete, especially at low energies.

The gamma-ray energy absorption build-up factor is defined similarly to the dose build-up factor

$$B_E = \frac{\text{total energy absorption rate at detector point F}}{\text{uncollided energy absorption rate at detector point F}} \tag{3}$$

and these data are likewise given as functions of b, E_o, and material (or equivalent atomic number, Z).

These gamma-ray build-up factors are important in shielding calculations since they permit the shield designer or engineer to obtain collided dose rates and energy absorption rates using the straightforward point kernel technique, which assumes exponential attenuation. The point kernel equation may be written

$$\phi_{un}(\vec{r}) = \frac{S_o(\vec{r}')e^{-b}}{4\pi\, d^2} \tag{4}$$

where the source point (S) has coordinates $\vec{r}'$ and strength S_o, and the field point or detector point F has coordinates $\vec{r}$. $\phi_{un}(\vec{r})$ is the uncollided flux at $\vec{r}$ from the source S_o at $\vec{r}'$, $d = |\vec{r} - \vec{r}'|$, and b is defined by Equation (2).

The total dose rate is then given by

$$D_{TOT}(\vec{r}) = \phi_{un}(\vec{r})k_D B_D(E_o,b,Z) \tag{5}$$

where k_D is a flux-to-dose conversion factor and B_D is the dose build-up factor. Similarly, the total energy absorption rate is given by

$$EA_{TOT} = \phi_{un}(\vec{r})k_{ea} B_E(E_o,b,Z) \quad . \tag{6}$$

where k_{ea} is an energy absorption coefficient, and B_E is the energy absorption build-up factor.

II. PARAMETRIC REPRESENTATION OF GAMMA-RAY BUILD-UP FACTORS

The point kernel given by Equations (4), (5), and (6) may be integrated numerically over arbitrary source volumes. If the energy (E_o) and equivalent atomic number (Z) are known, a build-up factor may be found corresponding to each value of b calculated during the integration process. One technique that may be used to find the build-up factors is simply to look in existing tables, and to specify some interpolation scheme so that build-up factors not explicitly given in the tables may be found. This technique is used in the SPAN-4 program (Reference 7), which has a library of build-up factor data (as given in Reference 1) stored as an integral part of the program. SPAN-4 uses linear interpolation whenever interpolation on b, E_o, or Z is required. Two of the reasons

this method is used in SPAN-4 are (a) it provides better accuracy than that which could be achieved by any one of the parametric representations available at the time SPAN-4 was written, and (b) it is easy to input data for new materials, since parametric coefficients need not be derived.

Another technique that is widely used to find build-up factors requires that the build-up factors be represented parametrically. In a given problem interpolation with respect to energy (E) and atomic number (Z) is done only once, but interpolation with respect to optical distance (b) is done repetitively; therefore, many representations with b as the parameter have been proposed (Reference 8).

Such parametric representations are convenient for many hand calculations; they are also useful in computer programs since fewer data need to be input and manipulated, and calculating a build-up factor parametrically may be simpler than searching or interpolating available tabulated information. However, unless the parametric fit coefficients are carefully derived, the build-up factors calculated may not be accurate, and the use of build-up factors for a new material requires that parametric fit coefficients be derived first.

A convenient and widely used parametric representation of build-up factors is given by the Taylor exponential fit (References 8, 9, 10, 11, and 12) which uses three parameters

$$B_D = Ae^{-\alpha_1 b} + (1 - A)e^{-\alpha_2 b} \tag{7}$$

where

$B_D = B_D(b, E_o, Z)$

$A = A(E_o, Z)$

$\alpha_1 = \alpha_1(E_o, Z)$

$\alpha_2 = \alpha_2(E_o, Z)$

Equation (5) then becomes

$$D_{TOT}(\vec{r}) = \frac{S_o(\vec{r}')k_D}{4\pi d^2}\left\{Ae^{-(1 + \alpha_1)b} + (1 - A)e^{-(1 + \alpha_2)b}\right\} \tag{8}$$

which is convenient in many hand calculations and is also adaptable for use in computer programs. Since three coefficients cover the complete range of b values, fewer data items need to be input and/or stored to describe the build-up factors for a given material and energy. Also, no explicit interpolation on b is necessary.

This technique was used in the SPAN-3 program (Reference 11). The table of Taylor exponential fit coefficients used by SPAN-3 is given in Reference 11

When the point kernel (Equations (4), (5), and (6)) is integrated over a volumetric source region in any of the geometric situations that may be treated analytically, the build-up factor should be included in the integrand. When Taylor fit coefficients are available, this requirement may be immediately satisfied by using Equation (8) as the integrand, since this replaces an integral containing an exponential with two similar integrals. (See Reference 9, p 412 ff.)

When build-up factor representation for the SPAN-4 program was being investigated, an effort was made to improve the Taylor exponential fit coefficients of Buscaglioni and Manzini (References 8 and 12). Several small computer programs, written to aid in this endeavor, were used to evaluate and improve coefficients for many materials.

It was found that the Taylor exponential fit was not sufficiently accurate for those cases having simultaneously low energies and low atomic numbers (see Appendix). Another parametric representation was need for these cases, and it was required to be uncomplicated. A polynomial representation was chosen for simplicity and ease of use. In most cases, a cubic polynomial requiring only three coefficients is sufficient. A few extreme cases require a quartic representation.

The cubic and quartic polynomial representations are

$$B_D = 1.0 + Ab + \alpha_1 b^2 + \alpha_2 b^3 \tag{9}$$

and

$$B_D = 1.0 + Ab + \alpha_1 b^2 + \alpha_2 b^3 + \alpha_3 b^4 \tag{10}$$

If the polynomial fit for some specific E_o and Z is such that α_2 or α_3 is negative, that fit should not be used for $b > 20$.

Tobias (Reference 13) and Capo (Reference 14) have also published extensive tables of polynomial fits of build-up factor coefficients.

The tables given in Section IV, therefore, give (a) Taylor exponential fit coefficients if they are reasonably accurate representations of the corresponding build-up factor data and (b) cubic or quartic polynomial fits for those cases ($Z \leq 13$, $E_o \leq 2.2$ Mev) where Taylor exponential fits are not satisfactory.

In general, the accuracy requirement established for these tables is that

$$-5\% \leq \frac{\left(\begin{array}{c}\text{build-up factor calculated} \\ \text{from parametric coefficients}\end{array}\right) - \left(\begin{array}{c}\text{build-up factor} \\ \text{from tables}\end{array}\right)}{\text{build-up factor from tables}} \times 100 \leq 10\%$$

for each of the seven standard b values (1.0, 2.0, 4.0, 7.0, 10.0, 15.0, and 20.0 mfp) for which build-up factor data are usually tabulated.

III. SOURCES OF DATA

Reference 1 (Goldstein and Wilkins) has been the primary source of build-up factor data since it was published in 1954. The tables given here for water, aluminum, iron, tin, tungsten, lead, and uranium are based on data from Reference 1, except that data for water at 0.5 and 1.0 Mev is drawn from the newer work of Berger (Reference 15) and Morris and Chilton (Reference 16).

Build-up factor data for ordinary concrete have been published by Chilton (Reference 17) and Clarke and Trubey (Reference 18). Their results agree reasonably well. Engholm (Reference 6) also calculated related concrete build-up factors and obtained good agreement with Clarke and Trubey and with Chilton. Clarke and Trubey also obtained build-up factors for magnetic and barytes concretes. The tables given here for ordinary, magnetite, and barytes concretes are based on Reference 18.

Engholm has also calculated build-up factors for beryllium and carbon at low energies, and has checked some of Goldstein's results using a gamma transport program. In all cases Engholm's results agree reasonably well with Goldstein's Engholm also gives (in Reference 6) log-log plots of dose build-up factors versus atomic number. These plots give smooth and relatively flat curves, which he recommends for finding build-up factors for intermediate atomic numbers. The tables of data for beryllium and carbon come from the log-log plots of Reference 6. At low energies the values plotted were actually calculated, and at higher energies (>2 Mev) they were the result of extrapolation (log-log) of Goldstein's data.

Data for sand, air, and wood come from the work of Clarke (Reference 19), and the dose build-up factor tables for lithium hydride given here were published by Kam and Clarke in Reference 20.

The starting point for the calculation of the Taylor exponential fit coefficients given here was the excellent set of data published by Buscaglioni and Manzini in Reference 12. Without these data, the task of obtaining the results set forth in this report would have been much more difficult.

Build-up factor data are ordinarily tabulated for eight standard energy values (0.5, 1.0, 2.0, 3.0, 4.0, 6.0, 8.0, and 10.0 Mev); but, for the users' convenience, the tabulated data for beryllium, carbon, aluminum, iron, tin, tungsten, lead, uranium, water, and concrete were extrapolated and linearly interpolated to give values at 31 energy levels in the range 0.25 to 10.0 Mev. (Build-up factors at 0.25 Mev are given only for water in the literature; therefore, the user should be aware that the build-up factors given here for other materials at 0.25 Mev are not based on independent calculations or experiment.) Parametric coefficients were derived for all energy levels. Linear interpolation on energy was used because of its simplicity and because it gives reasonably accurate intermediate values for most cases of interest in shielding calculations.

Plots, tables, and much additional useful information can be found in most of the references already cited, especially References 1, 6, 8, 9, 15, and 19. In addition much information and theory are summarized in Reference 21.

IV. TABLES OF DOSE AND ENERGY ABSORPTION BUILD-UP FACTORS AND COEFFICIENTS

TABLE 1A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR BERYLLIUM

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	ALPHA3	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	3.04	9.03	44.18	233.25	742.10	2675.70	6038.00	1.2894 -	.16617	0.75	0.	C	(-5.48,1),(11.52,4),(11.1,7),(-6.04,15)
.50	1.00	2.60	6.80	27.00	101.00	255.00	700.00	1350.00	.7	.7	.2	- .0030	Q	
.60	1.00	2.53	6.40	24.40	88.20	217.20	586.00	1122.00	.666	.667	.168	- .00312	Q	
.70	1.00	2.46	6.00	21.80	75.40	179.40	472.00	894.00	.629	.68155	.12675	- .00247	Q	
.80	1.00	2.39	5.60	19.20	62.60	141.60	358.00	666.00	.6460	.64607	.08740	- .00191	Q	
.90	1.00	2.32	5.20	16.60	49.80	103.80	244.00	438.00	.6240	.65320	.04320	- .00117	Q	
1.00	1.00	2.25	4.80	14.00	37.00	66.00	130.00	210.00	.8007	.53383	.01397	- .00088	Q	
1.25	1.00	2.16	4.45	12.35	31.25	54.75	105.50	167.75	.7862	.45150	.00886	- .00067	Q	
1.50	1.00	2.08	4.10	10.70	25.50	43.50	81.00	125.50	.8325	.34650	.00680	- .00057	Q	(5.31,1),(5.61,15)
1.75	1.00	1.99	3.75	9.05	19.75	32.25	56.50	83.25	.9025	.24150	.00425	- .00044	Q	(8.07,1),(5.54,10),(7.98,15)
2.00	1.00	1.90	3.40	7.40	14.00	21.00	32.00	41.00	.8336	.20318	- .00726		C	(6.82,1),(6.63,10)
2.20	1.00	1.88	3.28	6.90	12.80	19.00	28.60	36.40	.8482	.15594	- .00523		C	(6.63,1),(5.84,20)
2.50	1.00	1.85	3.10	6.15	11.00	16.00	23.50	29.50	.9340	.08017	- .00247		C	(8.74,1),(8.48,20)
2.75	1.00	1.82	2.95	5.52	9.50	13.50	19.25	23.75	.8554	.09281	- .00230		C	
3.00	1.00	1.80	2.80	4.90	8.00	11.00	15.00	18.00	.8554	.03230	- .00162		C	
3.50	1.00	1.77	2.60	4.35	7.00	9.05	12.50	15.00	26.2793 -	.00758	.02652		T	
4.00	1.00	1.75	2.40	3.80	6.00	7.10	10.00	12.00	12.8370 -	.00978	.05574		T	
4.50	1.00	1.74	2.33	3.62	5.52	6.60	8.95	10.65	12.903 -	.00519	.05792		T	
5.00	1.00	1.73	2.25	3.45	5.05	6.10	7.90	9.30	8.8943 -	.00100	.07359		T	
5.50	1.00	1.71	2.17	3.27	4.57	5.60	6.85	7.95	5.4022 -	.02030	.12901		T	
6.00	1.00	1.70	2.10	3.10	4.10	5.10	5.80	6.60	5.8036 -	.00792	.12737		T	
6.30	1.00	1.69	2.07	3.02	3.99	4.93	5.59	6.31	4.6540 -	.01649	.16192		T	
6.50	1.00	1.69	2.05	2.97	3.92	4.82	5.45	6.12	4.1203 -	.02198	.18457		T	
7.00	1.00	1.67	2.00	2.85	3.75	4.55	5.10	5.65	4.0987 -	.01684	.18494		T	
7.50	1.00	1.66	1.95	2.72	3.57	4.27	4.75	5.17	3.9539 -	.01232	.19653		T	(-5.2,1),(5.58,2)
7.65	1.00	1.66	1.94	2.69	3.52	4.19	4.64	5.03	3.2800 -	.02400	.2430		T	(-5.26,1),(5.37,2)
8.00	1.00	1.65	1.90	2.60	3.40	4.00	4.40	4.70	3.1294 -	.02359	.24324		T	(6.46,2),(6.49,20)
8.50	1.00	1.61	1.87	2.52	3.30	3.82	4.25	4.52	3.2813 -	.01631	.23558		T	
9.00	1.00	1.57	1.85	2.45	3.20	3.65	4.10	4.35	3.4765 -	.01313	.20071		T	
9.50	1.00	1.54	1.82	2.37	3.10	3.47	3.95	4.17	3.2444 -	.01356	.21086		T	
10.00	1.00	1.50	1.80	2.30	3.00	3.30	3.80	4.00	3.0132 -	.01398	.22127		T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3
Q signifies quartic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3 + alpha3*b**4

TABLE 1B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR BERYLLIUM

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.40	4.80	13.00	38.00	80.00	190.00	360.00	.8771	.48140	.02030	C	
1.00	1.00	2.20	3.70	8.20	19.00	34.00	61.00	99.00	1.045	.2080	0.	C	(6.0,2),(-5.15,10),(6.16,20)
2.00	1.00	1.80	2.90	5.40	10.00	15.00	22.00	31.00	.9749	.03498	0.	C	(11.66,1),(6.54,2),(6.79,15),(11.25,20)

*T signifies Taylor exponential fit Coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 2A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR CARBON (GRAPHITE)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	2.85	6.44	23.43	67.33	177.05	491.18	1024.81	1.3410	.6290	.091	C	(7.4,1),(7.55,2),(7.56,7)
.50	1.00	2.48	5.26	15.60	39.90	87.20	203.00	372.00	.9418	.00060	.014	C	
.60	1.00	2.42	5.01	14.40	36.20	77.04	176.18	319.20	.9947	.51190	.01315	C	
.70	1.00	2.35	4.77	13.20	32.50	66.88	149.36	266.40	.9100	.48680	.00624	C	
.80	1.00	2.29	4.52	12.00	28.80	56.72	122.54	213.60	.9540	.43511	.00326	C	
.90	1.00	2.22	4.28	10.80	25.10	46.56	95.72	160.80	.9317	.35684	.00037	C	
1.00	1.00	2.16	4.03	9.60	21.40	36.40	68.90	108.00	1.0480	.2520	- .00096	C	(6.44,1),(6.37,20)
1.25	1.00	2.09	3.79	8.67	18.62	31.25	57.80	89.12	1.0070	.20506	- .00112	C	(5.79,1),(5.73,20)
1.50	1.00	2.02	3.55	7.74	15.85	26.10	46.70	70.25	1.0178	.14512	- .00053	C	(7.05,1),(7.0,20)
1.75	1.00	1.95	3.32	6.82	13.08	20.95	35.60	51.37	.9431	.11146	- .00120	C	(5.3,1),(5.32,20)
2.00	1.00	1.88	3.08	5.89	10.30	15.80	24.50	32.50	.9264	.06195	- .00125	C	(5.7,1),(5.57,20)
2.20	1.00	1.85	2.98	5.57	9.64	14.52	22.40	29.60	.8851	.05367	- .00110	C	
2.50	1.00	1.81	2.84	5.09	8.65	12.60	19.25	25.25	24.4208	- .03462	.00374	T	(7.33,1),(7.25,20)
2.75	1.00	1.78	2.72	4.70	7.82	11.00	16.62	21.62	20.0139	- .03135	.01230	T	
3.00	1.00	1.75	2.60	4.30	7.00	9.40	14.00	18.00	22.7755	- .01953	.01765	T	
3.50	1.00	1.73	2.40	3.95	6.25	8.10	12.00	15.25	16.1486	- .02135	.02059	T	
4.00	1.00	1.70	2.20	3.60	5.50	6.80	10.00	12.50	12.8374	- .01778	.03484	T	
4.50	1.00	1.67	2.15	3.42	5.15	6.35	9.05	11.22	15.1800	- .00944	.03310	T	
5.00	1.00	1.65	2.10	3.25	4.80	5.90	8.10	9.95	6.8418	- .02507	.07350	T	
5.50	1.00	1.63	2.05	3.08	4.45	5.45	7.15	8.68	7.7175	- .01400	.06790	T	
6.00	1.00	1.60	2.00	2.90	4.10	5.00	6.20	7.40	5.0466	- .01981	.11074	T	
6.30	1.00	1.58	1.97	2.85	3.99	4.86	6.02	7.13	5.4754	- .01649	.10120	T	
6.50	1.00	1.57	1.95	2.83	3.92	4.77	5.90	6.95	5.2129	- .01717	.10780	T	
7.00	1.00	1.55	1.90	2.75	3.75	4.55	5.60	6.50	4.5570	- .01895	.11541	T	
7.50	1.00	1.52	1.85	2.67	3.57	4.32	5.30	6.05	4.7362	- .01336	.11130	T	
7.65	1.00	1.52	1.83	2.65	3.52	4.26	5.21	5.91	3.7037	- .02490	.14474	T	
8.00	1.00	1.50	1.80	2.60	3.40	4.10	5.00	5.60	3.9397	- .01841	.13490	T	
8.50	1.00	1.47	1.77	2.50	3.30	3.92	4.80	5.40	5.0163	- .00680	.09750	T	
9.00	1.00	1.45	1.75	2.40	3.20	3.75	4.60	5.20	4.0900	- .01545	.11460	T	
9.50	1.00	1.42	1.73	2.30	3.10	3.57	4.40	5.00	3.8170	- .01595	.12040	T	
10.00	1.00	1.40	1.70	2.20	3.00	3.40	4.20	4.80	3.5450	- .01645	.12644	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 2B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR CARBON (GRAPHITE)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.39	4.73	12.80	35.60	71.30	163.00	295.00	.820	.49776	.01032	C	
1.00	1.00	2.08	3.73	8.45	18.90	31.80	59.60	93.50	.9010	.280	- .0050	C	
2.00	1.00	1.85	2.98	5.56	10.30	15.10	23.50	31.30	1.0283	.03326	0.	C	(11.44,1),(7.04,2),(11.41,20)

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 3A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR ALUMINUM

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	2.72	5.21	12.75	32.23	63.99	150.89	290.44	1.171	0.4163	0.0108	C	
.50	1.00	2.37	4.24	9.47	21.50	38.90	80.80	141.00	0.976	0.2850	0.	C	
.60	1.00	2.30	4.05	8.89	19.82	35.36	72.22	124.50	0.983	0.2480	0.	C	
.70	1.00	2.23	3.87	8.31	18.14	31.82	63.64	108.00	0.990	0.2110	0.	C	
.80	1.00	2.16	3.68	7.73	16.46	28.28	55.06	91.50	0.998	0.1740	0.	C	
.90	1.00	2.09	3.50	7.15	14.78	24.74	46.48	75.00	1.005	0.1370	0.	C	
1.00	1.00	2.02	3.31	6.57	13.10	21.20	37.90	58.50	1.012	0.1000	0.	C	
1.25	1.00	1.95	3.13	6.08	11.84	18.87	33.10	50.45	0.961	0.813	0.	C	
1.50	1.00	1.88	2.96	5.59	10.57	16.55	28.30	42.40	0.910	0.0626	0.	C	
1.75	1.00	1.82	2.78	5.11	9.31	14.22	23.50	34.35	0.859	0.0439	0.	C	
2.00	1.00	1.75	2.61	4.62	8.05	11.90	18.70	26.30	16.641	-0.0468	0.0026	T	(5.0,1)
2.20	1.00	1.73	2.55	4.45	7.67	11.25	17.56	24.58	15.430	-0.0456	0.0071	T	(5.4,1),(5.2,20)
2.50	1.00	1.70	2.46	4.20	7.09	10.27	15.85	22.00	13.612	-0.0437	0.0138	T	(5.1,1)
2.75	1.00	1.67	2.39	3.99	6.62	9.46	14.42	19.85	12.098	-0.0422	0.0195	T	
3.00	1.00	1.64	2.32	3.78	6.14	8.65	13.00	17.70	10.583	-0.0407	0.0251	T	
3.50	1.00	1.59	2.20	3.50	5.57	7.76	11.55	15.55	9.056	-0.0402	0.0319	T	
4.00	1.00	1.53	2.08	3.22	5.01	6.88	10.10	13.40	7.526	-0.0397	0.0386	T	
4.50	1.00	1.50	2.02	3.09	4.77	6.53	9.57	12.65	7.073	-0.0396	0.0398	T	
5.00	1.00	1.48	1.97	2.96	4.53	6.19	9.03	11.90	6.620	-0.0395	0.0410	T	
5.50	1.00	1.45	1.91	2.83	4.30	5.84	8.50	11.15	6.166	-0.0394	0.0423	T	
6.00	1.00	1.42	1.85	2.70	4.06	5.49	7.97	10.40	5.713	-0.0393	0.0435	T	
6.30	1.00	1.41	1.82	2.65	3.97	5.35	7.76	10.12	5.563	-0.0392	0.0436	T	
6.50	1.00	1.40	1.81	2.62	3.91	5.26	7.62	9.93	5.464	-0.0391	0.0437	T	
7.00	1.00	1.38	1.77	2.53	3.75	5.03	7.26	9.46	5.214	-0.0389	0.0439	T	
7.50	1.00	1.36	1.72	2.45	3.60	4.81	6.91	8.99	4.965	-0.0386	0.0441	T	
7.65	1.00	1.35	1.71	2.43	3.56	4.74	6.81	8.85	4.890	-0.0385	0.0442	T	
8.00	1.00	1.34	1.68	2.37	3.45	4.58	6.56	8.52	4.716	-0.0384	0.0443	T	
8.50	1.00	1.33	1.65	2.31	3.34	4.42	6.33	8.22	4.537	-0.0385	0.0436	T	
9.00	1.00	1.31	1.61	2.24	3.23	4.27	6.09	7.92	4.357	-0.0387	0.0428	T	
9.50	1.00	1.30	1.58	2.18	3.12	4.11	5.86	7.62	4.178	-0.0388	0.0421	T	
10.00	1.00	1.28	1.55	2.12	3.01	3.96	5.63	7.32	3.999	-0.0390	0.0413	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alphal*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alphal*b**2 + alpha2*b**3

TABLE 3B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR ALUMINUM

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	3.09	6.33	16.22	43.33	90.86	210.35	414.29	1.287	0.6290	0.0144	C	
.50	1.00	2.61	4.92	11.40	26.90	49.20	104.00	185.00	1.120	0.3856	0.	C	
.60	1.00	2.52	4.66	10.60	24.52	44.00	92.02	161.82	1.120	0.3326	0.	C	
.70	1.00	2.43	4.41	9.80	22.14	38.80	80.04	138.64	1.120	0.2796	0.	C	
.80	1.00	2.33	4.15	9.00	19.76	33.60	68.06	115.46	1.120	0.2266	0.	C	
.90	1.00	2.24	3.90	8.20	17.38	28.40	56.08	92.28	1.120	0.1736	0.	C	
1.00	1.00	2.15	3.64	7.40	15.00	23.20	44.10	69.10	1.120	0.1206	0.	C	
1.25	1.00	2.06	3.41	6.78	13.41	20.60	38.12	58.90	1.054	0.0975	0.	C	
1.50	1.00	1.97	3.19	6.16	11.81	18.00	32.15	48.70	0.987	0.0743	0.	C	
1.75	1.00	1.89	2.96	5.55	10.22	15.40	26.17	38.50	0.921	0.0512	0.	C	
2.00	1.00	1.80	2.74	4.93	8.63	12.80	20.20	28.30	35.911	-0.0367	-0.0128	T	(5.1,10)
2.20	1.00	1.77	2.67	4.72	8.17	12.03	18.84	26.28	34.445	-0.0341	-0.0101	T	(5.1,10)
2.50	1.00	1.73	2.55	4.40	7.49	10.87	16.80	23.25	32.246	-0.0301	-0.0060	T	
2.75	1.00	1.69	2.46	4.14	6.92	9.90	15.10	20.73	30.414	-0.0268	-0.0027	T	
3.00	1.00	1.66	2.37	3.88	6.35	8.94	13.40	18.20	28.581	-0.0234	0.0007	T	
3.50	1.00	1.60	2.23	3.56	5.70	7.93	11.80	15.85	26.972	-0.0207	0.0022	T	
4.00	1.00	1.54	2.09	3.24	5.05	6.93	10.20	13.50	25.364	-0.0180	0.0036	T	
4.50	1.00	1.50	2.02	3.09	4.77	6.51	9.55	12.60	23.967	-0.0174	0.0040	T	
5.00	1.00	1.47	1.95	2.93	4.48	6.10	8.91	11.71	22.570	-0.0167	0.0044	T	
5.50	1.00	1.43	1.88	2.78	4.20	5.68	8.26	10.81	21.174	-0.0161	0.0048	T	
6.00	1.00	1.40	1.81	2.63	3.92	5.27	7.62	9.92	19.777	-0.0154	0.0052	T	
6.30	1.00	1.39	1.78	2.57	3.82	5.12	7.39	9.61	19.440	-0.0152	0.0049	T	
6.50	1.00	1.38	1.76	2.54	3.75	5.02	7.24	9.41	19.216	-0.0151	0.0048	T	
7.00	1.00	1.35	1.71	2.44	3.58	4.77	6.86	8.90	18.652	-0.0148	0.0044	T	
7.50	1.00	1.33	1.67	2.35	3.42	4.53	6.48	8.39	18.090	-0.0145	0.0040	T	
7.65	1.00	1.33	1.65	2.32	3.37	4.45	6.37	8.24	17.922	-0.0144	0.0039	T	
8.00	1.00	1.31	1.62	2.26	3.25	4.28	6.10	7.88	17.528	-0.0142	0.0037	T	
8.50	1.00	1.30	1.59	2.20	3.14	4.13	5.88	7.59	16.248	-0.0149	0.0036	T	
9.00	1.00	1.28	1.56	2.14	3.04	3.99	5.66	7.31	14.967	-0.0156	0.0036	T	
9.50	1.00	1.27	1.54	2.08	2.93	3.84	5.44	7.02	13.687	-0.0163	0.0035	T	
10.00	1.00	1.25	1.51	2.02	2.83	3.70	5.22	6.74	12.407	-0.0169	0.0035	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 4A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR IRON

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	2.06	3.22	6.40	12.85	21.73	42.17	69.22	48.63800	-.07220	-.05130	T	(6.1,1),(-5.1,10),(6.1,20)
.50	1.00	1.98	3.09	5.98	11.70	19.20	35.40	55.60	40.43700	-.06410	-.03940	T	(5.7,1),(6.3,2),(6.2,20)
.60	1.00	1.96	3.05	5.86	11.40	18.60	33.98	53.02	38.04000	-.06300	-.03680	T	(6.6,1),(7.6,2),(7.2,20)
.70	1.00	1.94	3.01	5.74	11.10	18.00	32.56	50.44	35.64300	-.06180	-.03410	T	(7.1,1),(7.5,2),(7.6,20)
.80	1.00	1.91	2.97	5.63	10.80	17.40	31.14	47.86	33.24600	-.06070	-.03140	T	(7.2,1),(7.7,2),(7.6,20)
.90	1.00	1.89	2.93	5.51	10.50	16.80	29.72	45.28	30.84800	-.05960	-.02880	T	(6.9,1),(7.0,2),(7.1,20)
1.00	1.00	1.87	2.89	5.39	10.20	16.20	28.30	42.70	28.45100	-.05840	-.02610	T	(6.2,1),(5.7,2),(6.0,20)
1.25	1.00	1.84	2.77	5.07	9.46	14.87	25.62	38.30	25.80500	-.05540	-.02100	T	(5.5,1),(6.7,2),(5.5,20)
1.50	1.00	1.81	2.66	4.76	8.72	13.55	22.95	33.90	23.16000	-.05230	-.01580	T	(6.9,2)
1.75	1.00	1.79	2.54	4.44	7.99	12.22	20.27	29.50	20.51400	-.04920	-.01060	T	
2.00	1.00	1.76	2.43	4.13	7.25	10.90	17.60	25.10	17.97400	-.04630	-.00570	T	
2.20	1.00	1.72	2.37	4.01	6.97	10.42	16.78	23.90	17.02300	-.04590	-.00470	T	
2.50	1.00	1.65	2.29	3.82	6.55	9.70	15.55	22.10	15.59600	-.04550	-.00330	T	
2.75	1.00	1.60	2.22	3.66	6.20	9.11	14.52	20.60	14.40700	-.04480	-.00210	T	
3.00	1.00	1.55	2.15	3.51	5.85	8.51	13.50	19.10	13.21800	-.04430	-.00090	T	
3.50	1.00	1.50	2.05	3.27	5.38	7.81	12.35	17.55	11.42100	-.04560	.00040	T	
4.00	1.00	1.45	1.94	3.03	4.91	7.11	11.20	16.00	9.62400	-.04700	.00180	T	
4.50	1.00	1.42	1.88	2.92	4.72	6.84	10.87	15.67	8.68500	-.05060	.00080	T	
5.00	1.00	1.40	1.83	2.80	4.52	6.56	10.54	15.35	8.13225	-.05149	-.00006	T	
5.50	1.00	1.37	1.77	2.69	4.33	6.29	10.22	15.02	6.80600	-.05790	-.00100	T	
6.00	1.00	1.34	1.72	2.58	4.14	6.02	9.89	14.70	5.86700	-.06150	-.00190	T	
6.30	1.00	1.33	1.70	2.53	4.04	5.88	9.68	14.44	5.47300	-.06350	.00160	T	
6.50	1.00	1.32	1.68	2.49	3.98	5.78	9.54	14.27	4.95045	-.06490	.00546	T	
7.00	1.00	1.30	1.64	2.41	3.81	5.54	9.19	13.85	4.32725	-.06820	.01018	T	
7.50	1.00	1.29	1.60	2.32	3.65	5.31	8.85	13.42	3.89900	-.07160	.00930	T	
7.65	1.00	1.28	1.59	2.29	3.60	5.24	8.74	13.30	3.33180	-.07623	.01978	T	
8.00	1.00	1.27	1.56	2.23	3.49	5.07	8.50	13.00	3.24300	-.07500	.02120	T	
8.50	1.00	1.25	1.52	2.16	3.36	4.89	8.26	12.85	2.58210	-.08505	.03087	T	
9.00	1.00	1.23	1.49	2.09	3.24	4.71	8.02	12.70	2.37025	-.08700	.02622	T	
9.50	1.00	1.22	1.45	2.02	3.11	4.53	7.78	12.55	2.12100	-.09300	.03300	T	
10.00	1.00	1.20	1.42	1.95	2.99	4.35	7.54	12.40	1.74700	-.09900	.06630	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 4B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR IRON

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	3.47	6.21	13.27	28.42	49.57	98.82	166.71	66.013	-0.0813	-0.0447	T	(5.7,2),(5.8,20)
.50	1.00	2.80	4.84	9.97	20.40	34.20	64.30	101.00	44.303	-0.0720	-0.0302	T	(6.5,1),(6.8,2),(-5.1,10),(6.8,20)
.60	1.00	2.68	4.59	9.38	19.04	31.74	59.20	92.50	41.429	-0.0703	-0.0284	T	(6.6,1),(6.7,2),(-5.4,10),(5.8,20)
.70	1.00	2.56	4.34	8.78	17.68	29.28	54.10	84.00	38.555	-0.0687	-0.0266	T	(6.8,1),(6.7,2),(-5.7,10),(5.2,20)
.80	1.00	2.43	4.08	8.19	16.32	26.82	49.00	75.50	35.682	-0.0670	-0.0248	T	(6.9,1),(6.6,2),(-5.7,10),(5.1,20)
.90	1.00	2.31	3.83	7.59	14.96	24.36	43.90	67.00	32.808	-0.0653	-0.0230	T	(7.1,1),(6.5,2),(-5.5,10),(5.7,20)
1.00	1.00	2.19	3.58	7.00	13.60	21.90	38.80	58.50	29.934	-0.0637	-0.0212	T	(7.2,1),(6.5,2),(7.2,20)
1.25	1.00	2.09	3.34	6.38	12.18	19.40	33.92	50.72	28.247	-0.0582	-0.0174	T	(6.1,1),(5.4,2),(-6.4,10)
1.50	1.00	1.98	3.11	5.76	10.75	16.90	29.05	42.95	26.559	-0.0527	-0.0136	T	(5.3,1),(-6.7,10),(-5.9,15)
1.75	1.00	1.88	2.88	5.15	9.33	14.40	24.17	35.17	24.872	-0.0473	-0.0098	T	(5.2,10)
2.00	1.00	1.78	2.64	4.53	7.90	11.90	19.30	27.40	23.252	-0.0420	-0.0061	T	(5.5,2),(6.2,20)
2.20	1.00	1.74	2.55	4.35	7.53	11.28	18.24	25.88	21.281	-0.0425	-0.0047	T	
2.50	1.00	1.68	2.42	4.07	6.97	10.36	16.65	23.60	18.325	-0.0431	-0.0026	T	(5.6,2),(6.7,20)
2.75	1.00	1.63	2.32	3.84	6.51	9.59	15.32	21.70	15.861	-0.0437	-0.0008	T	(5.5,20)
3.00	1.00	1.58	2.21	3.61	6.05	8.82	14.00	19.80	13.398	-0.0442	0.0009	T	
3.50	1.00	1.52	2.08	3.32	5.47	7.96	12.55	18.25	11.336	-0.0469	0.0006	T	
4.00	1.00	1.45	1.95	3.03	4.90	7.10	11.10	16.70	9.261	-0.0495	0.0003	T	
4.50	1.00	1.41	1.87	2.87	4.61	6.66	10.49	15.70	8.209	-0.0522	0.0005	T	
5.00	1.00	1.38	1.79	2.70	4.31	6.22	9.88	14.70	7.157	-0.0550	0.0008	T	
5.50	1.00	1.34	1.71	2.54	4.02	5.79	9.28	13.70	6.104	-0.0577	0.0011	T	
6.00	1.00	1.30	1.63	2.38	3.73	5.35	8.67	12.70	5.052	-0.0604	0.0014	T	
6.30	1.00	1.29	1.60	2.32	3.62	5.18	8.40	12.35	4.875	-0.0611	-0.0007	T	
6.50	1.00	1.28	1.59	2.28	3.54	5.07	8.22	12.12	4.758	-0.0616	-0.0021	T	
7.00	1.00	1.25	1.54	2.18	3.36	4.79	7.78	11.55	4.464	-0.0627	-0.0056	T	
7.50	1.00	1.23	1.49	2.09	3.17	4.51	7.33	10.97	4.169	-0.0639	-0.0089	T	
7.65	1.00	1.23	1.48	2.06	3.12	4.43	7.20	10.80	4.081	-0.0642	-0.0100	T	
8.00	1.00	1.21	1.45	1.99	2.99	4.23	6.89	10.40	3.875	-0.0650	-0.0124	T	
8.50	1.00	1.20	1.42	1.94	2.89	4.09	6.71	10.27	3.682	-0.0677	-0.0177	T	
9.00	1.00	1.18	1.40	1.88	2.80	3.96	6.53	10.14	3.488	-0.0703	-0.0230	T	
9.50	1.00	1.17	1.38	1.83	2.70	3.82	6.35	10.02	3.295	-0.0730	-0.0283	T	
10.00	1.00	1.16	1.35	1.78	2.61	3.69	6.17	9.89	3.101	-0.0756	-0.0336	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 5A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR TIN

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	1.52	1.97	2.76	3.77	4.63	6.11	6.80	7.523	-0.0067	0.0654	T	
.50	1.00	1.56	2.08	3.09	4.57	6.04	8.64	10.80	11.440	-0.0180	0.0319	T	
.60	1.00	1.58	2.12	3.22	4.89	6.60	9.65	12.40	11.437	-0.0229	0.0287	T	
.70	1.00	1.59	2.17	3.35	5.21	7.16	10.66	14.00	11.434	-0.0279	0.0255	T	
.80	1.00	1.61	2.21	3.48	5.53	7.73	11.68	15.60	11.432	-0.0328	0.0224	T	
.90	1.00	1.62	2.26	3.61	5.85	8.29	12.69	17.20	11.429	-0.0377	0.0192	T	
1.00	1.00	1.64	2.30	3.74	6.17	8.85	13.70	18.80	11.426	-0.0427	0.0161	T	
1.25	1.00	1.62	2.27	3.69	6.09	8.77	13.67	18.92	10.759	-0.0454	0.0158	T	
1.50	1.00	1.60	2.23	3.63	6.02	8.69	13.65	19.05	10.091	-0.0481	0.0155	T	
1.75	1.00	1.59	2.20	3.58	5.94	8.61	13.62	19.17	9.424	-0.0509	0.0153	T	
2.00	1.00	1.57	2.17	3.53	5.87	8.53	13.60	19.30	8.783	-0.0535	0.0150	T	
2.20	1.00	1.55	2.13	3.45	5.75	8.41	13.54	19.46	8.106	-0.0577	0.0162	T	(5.6,20)
2.50	1.00	1.52	2.06	3.33	5.57	8.22	13.45	19.70	7.091	-0.0639	0.0179	T	(5.7,2),(7.7,20)
2.75	1.00	1.49	2.01	3.23	5.43	8.06	13.37	19.90	6.246	-0.0692	0.0194	T	(5.6,2),(7.3,20)
3.00	1.00	1.46	1.96	3.13	5.28	7.91	13.30	20.10	5.400	-0.0744	0.0208	T	
3.50	1.00	1.42	1.88	2.97	5.05	7.66	13.25	20.65	4.448	-0.0848	0.0234	T	(6.9,20)
4.00	1.00	1.38	1.81	2.82	4.82	7.41	13.20	21.20	3.496	-0.0952	0.0260	T	
4.50	1.00	1.35	1.75	2.71	4.66	7.29	13.60	23.17	3.123	-0.1057	0.0157	T	
5.00	1.00	1.32	1.69	2.59	4.49	7.17	14.00	25.15	2.750	-0.1162	0.0055	T	(5.6,20)
5.50	1.00	1.29	1.63	2.48	4.33	7.06	14.40	27.12	2.378	-0.1268	-0.0048	T	(5.1,20)
6.00	1.00	1.26	1.57	2.37	4.17	6.94	14.80	29.10	2.005	-0.1373	-0.0150	T	
6.30	1.00	1.25	1.55	2.32	4.08	6.83	14.84	29.83	1.869	-0.1427	-0.0154	T	
6.50	1.00	1.24	1.53	2.29	4.02	6.75	14.87	30.32	1.779	-0.1462	-0.0157	T	(5.7,20)
7.00	1.00	1.22	1.49	2.21	3.87	6.56	14.95	31.55	1.553	-0.1551	-0.0164	T	
7.50	1.00	1.21	1.46	2.13	3.72	6.38	15.02	32.77	1.327	-0.1640	-0.0172	T	(6.2,20)
7.65	1.00	1.20	1.45	2.11	3.67	6.32	15.05	33.14	1.259	-0.1667	-0.0174	T	(5.4,20)
8.00	1.00	1.19	1.42	2.05	3.57	6.19	15.10	34.00	1.101	-0.1729	-0.0179	T	
8.50	1.00	1.18	1.39	1.98	3.42	5.94	14.45	33.85	1.003	-0.1777	-0.0095	T	
9.00	1.00	1.16	1.37	1.92	3.28	5.70	13.80	33.70	0.904	-0.1824	-0.0012	T	
9.50	1.00	1.15	1.34	1.86	3.13	5.45	13.15	33.55	0.806	-0.1872	0.0072	T	
10.00	1.00	1.14	1.31	1.79	2.99	5.21	12.50	33.40	0.708	-0.1920	0.0155	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 5B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR TIN

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	2.33	3.50	5.53	8.36	10.60	14.85	19.40	7.387	-0.0481	0.1558	T	
.50	1.00	2.25	3.38	5.51	8.58	11.60	17.00	22.50	8.405	-0.0514	0.1108	T	
.60	1.00	2.22	3.34	5.50	8.73	12.00	17.86	23.74	9.385	-0.0491	0.0879	T	
.70	1.00	2.20	3.30	5.49	8.87	12.40	18.72	24.98	14.317	-0.0374	0.0447	T	
.80	1.00	2.17	3.26	5.49	9.02	12.80	19.58	26.22	14.473	-0.0401	0.0395	T	
.90	1.00	2.15	3.22	5.48	9.16	13.20	20.44	27.46	18.969	-0.0359	0.0229	T	
1.00	1.00	2.12	3.18	5.47	9.31	13.60	21.30	28.70	18.518	-0.0400	0.0201	T	
1.25	1.00	2.02	3.02	5.19	8.85	12.95	20.40	27.55	17.599	-0.0413	0.0173	T	
1.50	1.00	1.92	2.86	4.91	8.39	12.30	19.50	26.40	16.680	-0.0427	0.0146	T	
1.75	1.00	1.83	2.70	4.63	7.94	11.65	18.60	25.25	15.761	-0.0440	0.0118	T	
2.00	1.00	1.73	2.54	4.35	7.48	11.00	17.70	24.10	14.879	-0.0453	0.0091	T	
2.20	1.00	1.68	2.44	4.14	7.11	10.49	17.20	23.32	16.131	-0.0443	0.0016	T	
2.50	1.00	1.61	2.28	3.82	6.55	9.71	16.45	22.15	19.136	-0.0422	-0.0078	T	(5.1,20)
2.75	1.00	1.55	2.16	3.56	6.08	9.07	15.83	21.17	34.182	-0.0374	-0.0200	T	(5.2,1),(6.4,2),(6.8,20)
3.00	1.00	1.49	2.03	3.30	5.62	8.43	15.20	20.20	45.528	-0.0373	-0.0245	T	(6.2,1),(8.4,2),(7.7,4),(8.52,20)
3.50	1.00	1.41	1.88	2.98	5.04	7.62	14.20	19.65	17.989	-0.0504	-0.0252	T	(5.7,1),(7.6,2),(7.65,4),(5.6,7),(7.6,20)
4.00	1.00	1.34	1.74	2.67	4.47	6.80	13.20	19.10	11.711	-0.0623	-0.0319	T	(6.1,2),(6.8,4),(5.4,7),(-5.3,15),(6.3,20)
4.50	1.00	1.31	1.67	2.52	4.22	6.44	12.62	19.52	9.745	-0.0713	-0.0416	T	
5.00	1.00	1.27	1.59	2.36	3.97	6.09	12.05	19.95	4.549	-0.0907	-0.0343	T	
5.50	1.00	1.24	1.52	2.21	3.72	5.73	11.47	20.37	2.739	-0.1085	-0.0279	T	
6.00	1.00	1.21	1.45	2.06	3.47	5.38	10.90	20.80	1.667	-0.1290	-0.0196	T	
6.30	1.00	1.20	1.43	2.01	3.36	5.23	10.72	20.80	1.543	-0.1337	-0.0090	T	
6.50	1.00	1.19	1.41	1.98	3.28	5.13	10.60	20.80	1.460	-0.1369	-0.0079	T	(5.9,20)
7.00	1.00	1.17	1.38	1.90	3.10	4.88	10.30	20.80	1.254	-0.1448	-0.0053	T	(7.7,20)
7.50	1.00	1.16	1.34	1.82	2.91	4.63	10.00	20.80	1.048	-0.1527	-0.0026	T	(6.5,20)
7.65	1.00	1.15	1.33	1.80	2.86	4.55	9.91	20.80	0.986	-0.1550	-0.0019	T	(5.3,20)
8.00	1.00	1.14	1.31	1.74	2.73	4.38	9.70	20.80	0.841	-0.1605	0.	T	
8.50	1.00	1.13	1.29	1.70	2.64	4.23	9.48	20.67	0.790	-0.1636	0.0116	T	
9.00	1.00	1.13	1.27	1.66	2.55	4.08	9.25	20.55	0.739	-0.1667	0.0232	T	
9.50	1.00	1.12	1.26	1.62	2.47	3.93	9.03	20.42	0.688	-0.1698	0.0347	T	
10.00	1.00	1.11	1.24	1.58	2.38	3.78	8.81	20.30	0.637	-0.1728	0.0463	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 6A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR TUNGSTEN

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	1.20	1.33	1.47	1.55	1.60	1.65	1.71	1.574	-0.0055	0.2813	T	
.50	1.00	1.28	1.50	1.84	2.24	2.61	3.12	3.59	2.575	-0.0169	0.1304	T	
.60	1.00	1.31	1.57	1.99	2.52	3.02	3.75	4.34	2.746	-0.0216	0.1320	T	(-5.1,15),(-5.5,20)
.70	1.00	1.34	1.63	2.13	2.79	3.42	4.37	5.09	2.916	-0.0263	0.1336	T	(-7.0,15),(-5.7,20)
.80	1.00	1.38	1.70	2.28	3.07	3.83	5.00	5.85	3.087	-0.0310	0.1352	T	(-7.2,15)
.90	1.00	1.41	1.76	2.42	3.34	4.23	5.62	6.60	3.258	-0.0357	0.1368	T	(-6.2,15)
1.00	1.00	1.44	1.83	2.57	3.62	4.64	6.25	7.35	3.428	-0.0404	0.1384	T	
1.25	1.00	1.43	1.83	2.61	3.74	4.80	6.70	8.16	3.553	-0.0437	0.1236	T	
1.50	1.00	1.43	1.84	2.64	3.86	4.95	7.16	8.97	3.679	-0.0469	0.1088	T	
1.75	1.00	1.42	1.84	2.68	3.97	5.11	7.61	9.79	3.804	-0.0502	0.0940	T	
2.00	1.00	1.42	1.85	2.72	4.09	5.27	8.07	10.60	3.924	-0.0533	0.0798	T	
2.20	1.00	1.41	1.83	2.69	4.07	5.40	8.39	11.30	4.084	-0.0556	0.0666	T	
2.50	1.00	1.39	1.80	2.65	4.04	5.59	8.86	12.35	4.323	-0.0590	0.0469	T	
2.75	1.00	1.38	1.77	2.62	4.02	5.76	9.26	13.22	4.523	-0.0618	0.0305	T	
3.00	1.00	1.36	1.74	2.59	4.00	5.92	9.66	14.10	4.722	-0.0647	0.0140	T	
3.50	1.00	1.32	1.68	2.50	4.01	6.09	10.83	17.50	5.121	-0.0766	-0.0158	T	
4.00	1.00	1.29	1.62	2.41	4.03	6.27	12.00	20.90	5.520	-0.0866	-0.0457	T	
4.50	1.00	1.27	1.57	2.32	3.92	6.28	12.92	24.75	8.0244	- .09864	- .07764	T	
5.00	1.00	1.24	1.52	2.24	3.81	6.28	13.85	28.60	1.6985	- .14366	- .01674	T	
5.50	1.00	1.22	1.48	2.15	3.71	6.28	14.77	32.45	1.8680	- .15160	- .09253	T	
6.00	1.00	1.20	1.43	2.07	3.60	6.29	15.70	36.30	1.273	-0.1726	-0.1218	T	
6.30	1.00	1.19	1.41	2.03	3.52	6.16	15.62	37.14	1.182	-0.1777	-0.0965	T	(5.3,4),(6.4,7),(5.8,10),(7.9,20)
6.50	1.00	1.19	1.40	2.00	3.46	6.07	15.57	37.70	1.0089	- .18120	- .06366	T	
7.00	1.00	1.17	1.38	1.94	3.32	5.84	15.45	39.10	.8712	- .18980	- .00748	T	
7.50	1.00	1.16	1.35	1.87	3.19	5.62	15.32	40.50	.7344	- .19850	.00846	T	
7.65	1.00	1.15	1.34	1.86	3.15	5.56	15.29	40.92	0.771	-0.2011	0.0174	T	(6.5,7),(7.0,10),(5.4,20)
8.00	1.00	1.14	1.32	1.81	3.05	5.40	15.20	41.90	0.664	-0.2071	0.0469	T	
8.50	1.00	1.13	1.30	1.77	2.94	5.21	14.90	41.25	0.625	-0.2097	0.0478	T	
9.00	1.00	1.13	1.28	1.73	2.83	5.02	14.60	40.60	0.587	-0.2123	0.0486	T	
9.50	1.00	1.12	1.27	1.68	2.73	4.84	14.30	39.95	0.548	-0.2148	0.0494	T	
10.00	1.00	1.11	1.25	1.64	2.62	4.65	14.00	39.30	0.509	-0.2174	0.0502	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 7A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR LEAD

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	1.17	1.29	1.40	1.49	1.53	1.57	1.72	1.34200	-.01080	.04100	T	
.50	1.00	1.24	1.42	1.69	2.00	2.27	2.65	3.10	1.67700	-.03080	.30900	T	
.60	1.00	1.27	1.47	1.80	2.20	2.56	3.08	3.65	1.93800	-.03170	.27400	T	
.70	1.00	1.29	1.53	1.92	2.41	2.86	3.51	4.20	2.09000	-.03575	.21510	T	
.80	1.00	1.32	1.58	2.03	2.61	3.15	3.95	4.76	2.46100	-.03340	.15300	T	
.90	1.00	1.34	1.64	2.15	2.82	3.45	4.38	5.31	2.72300	-.03420	.16900	T	
1.00	1.00	1.37	1.69	2.26	3.02	3.74	4.81	5.86	2.98400	-.03500	.13400	T	
1.25	1.00	1.37	1.71	2.32	3.18	4.01	5.32	6.65	3.05150	-.04025	.12210	T	
1.50	1.00	1.38	1.72	2.38	3.34	4.29	5.84	7.43	4.00425	-.03490	.07480	T	
1.75	1.00	1.38	1.74	2.45	3.50	4.56	6.35	8.21	4.83000	-.03315	.05525	T	
2.00	1.00	1.39	1.76	2.51	3.66	4.84	6.87	9.00	5.42100	-.03480	.04300	T	
2.20	1.00	1.38	1.74	2.49	3.68	4.93	7.18	9.66	5.45300	-.03870	.03600	T	none
2.50	1.00	1.37	1.72	2.47	3.70	5.07	7.65	10.65	5.50000	-.04450	.02500	T	
2.75	1.00	1.35	1.70	2.45	3.73	5.19	8.05	11.47	5.54000	-.04940	.01500	T	
3.00	1.00	1.34	1.68	2.43	3.75	5.30	8.44	12.30	5.58000	-.05420	.00600	T	
3.50	1.00	1.30	1.62	2.34	3.68	5.37	9.12	14.30	4.73900	-.06940	-.00800	T	
4.00	1.00	1.27	1.56	2.25	3.61	5.44	9.80	16.30	3.89700	-.08470	-.02300	T	
4.50	1.00	1.25	1.52	2.18	3.54	5.50	10.80	20.40	2.36500	-.11360	-.03200	T	
5.00	1.00	1.23	1.48	2.11	3.47	5.56	11.80	24.50	1.47800	-.14140	-.01300	T	
5.50	1.00	1.20	1.44	2.04	3.41	5.63	12.80	28.60	1.35100	-.15510	-.07500	T	
6.00	1.00	1.18	1.40	1.97	3.34	5.69	13.80	32.70	.92600	-.17860	-.04600	T	
6.30	1.00	1.17	1.38	1.94	3.27	5.60	13.84	34.68	.84200	-.18730	-.04700	T	
6.50	1.00	1.17	1.37	1.91	3.23	5.53	13.87	35.67	.74670	-.19320	-.04410	T	
7.00	1.00	1.16	1.35	1.85	3.11	5.38	13.95	38.65	.58230	-.20780	-.04845	T	
7.50	1.00	1.15	1.32	1.80	3.00	5.22	14.02	41.62	.45720	-.22230	-.05130	T	
7.65	1.00	1.15	1.32	1.78	2.97	5.18	14.05	42.52	.34950	-.23803	-.07700	T	
8.00	1.00	1.14	1.30	1.74	2.89	5.07	14.10	44.60	.36800	-.23690	-.05600	T	
8.50	1.00	1.13	1.28	1.70	2.80	4.89	13.70	43.25	.35400	-.23770	-.04900	T	
9.00	1.00	1.13	1.26	1.66	2.70	4.70	13.30	41.90	.34000	-.23860	-.04200	T	
9.50	1.00	1.12	1.25	1.62	2.61	4.52	12.90	40.55	.32500	-.23940	-.03500	T	
10.00	1.00	1.11	1.23	1.58	2.52	4.34	12.50	39.20	.31100	-.24020	-.02700	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 7B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR LEAD

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	1.38	1.51	1.59	1.55	1.51	1.55	1.60	1.644	0.0024	0.006	T	
.50	1.00	1.51	1.80	2.19	2.61	3.01	3.52	4.30	2.030	-0.0374	0.5064	T	
.60	1.00	1.56	1.91	2.43	3.04	3.61	4.37	5.38	2.462	-0.0384	0.4424	T	(7.4,2),(7.9,4)
.70	1.00	1.61	2.03	2.67	3.46	4.21	5.22	6.46	2.750	-0.0415	0.2838	T	
.80	1.00	1.66	2.14	2.91	3.89	4.81	6.08	7.54	3.161	-0.0425	0.2358	T	
.90	1.00	1.71	2.26	3.15	4.31	5.41	6.93	8.62	3.760	-0.0415	0.2504	T	(7.0,2),(8.8,4),(5.5,7)
1.00	1.00	1.76	2.37	3.39	4.74	6.01	7.78	9.70	4.192	-0.0426	0.1864	T	
1.25	1.00	1.71	2.30	3.33	4.73	6.09	8.10	10.27	4.775	-0.0413	0.1536	T	(7.9,4),(7.6,7),(5.2,10)
1.50	1.00	1.67	2.23	3.27	4.72	6.16	8.41	10.85	4.555	-0.0440	0.1267	T	
1.75	1.00	1.62	2.17	3.20	4.71	6.24	8.73	11.42	4.456	-0.0437	0.1143	T	
2.00	1.00	1.58	2.10	3.14	4.70	6.32	9.05	12.00	6.502	-0.0375	0.0563	T	
2.20	1.00	1.54	2.03	3.01	4.53	6.14	8.97	12.12	6.640	-0.0396	0.0451	T	
2.50	1.00	1.47	1.91	2.82	4.27	5.88	8.85	12.30	6.848	-0.0427	0.0282	T	
2.75	1.00	1.42	1.82	2.66	4.06	5.65	8.75	12.45	7.021	-0.0454	0.0141	T	
3.00	1.00	1.37	1.73	2.50	3.85	5.43	8.65	12.60	7.194	-0.0480	0.0	T	
3.50	1.00	1.30	1.61	2.29	3.55	5.11	8.55	13.25	4.132	-0.0694	0.0	T	
4.00	1.00	1.24	1.49	2.09	3.25	4.79	8.46	13.90	2.529	-0.0909	0.0	T	
4.50	1.00	1.21	1.44	1.99	3.09	4.64	8.71	15.80	1.672	-0.1152	0.0058	T	
5.00	1.00	1.19	1.39	1.89	2.94	4.49	8.96	17.70	1.237	-0.1348	0.0267	T	
5.50	1.00	1.16	1.34	1.80	2.78	4.35	9.21	19.60	1.029	-0.1472	0.0172	T	
6.00	1.00	1.14	1.29	1.70	2.63	4.20	9.46	21.50	0.772	-0.1660	0.0382	T	
6.30	1.00	1.13	1.28	1.67	2.57	4.09	9.33	21.72	0.713	-0.1716	0.0325	T	
6.50	1.00	1.13	1.27	1.65	2.52	4.02	9.24	21.87	0.674	-0.1754	0.0287	T	
7.00	1.00	1.12	1.25	1.60	2.42	3.85	9.03	22.25	0.576	-0.1847	0.0191	T	(5.5,15),(5.5,20)
7.50	1.00	1.11	1.23	1.55	2.31	3.67	8.81	22.62	0.479	-0.1941	0.0096	T	
7.65	1.00	1.11	1.22	1.53	2.28	3.62	8.75	22.74	0.449	-0.1969	0.0067	T	
8.00	1.00	1.10	1.21	1.50	2.21	3.50	8.60	23.00	0.381	-0.2035	0.	T	
8.50	1.00	1.09	1.20	1.47	2.14	3.35	8.24	22.35	0.329	-0.2113	-0.0079	T	
9.00	1.00	1.09	1.18	1.44	2.06	3.21	7.88	21.70	0.276	-0.2192	-0.0158	T	(5.6,15),(6.6,20)
9.50	1.00	1.08	1.17	1.41	1.99	3.06	7.51	21.05	0.224	-0.2271	-0.0236	T	(5.6,20)
10.00	1.00	1.08	1.16	1.38	1.92	2.92	7.15	20.40	0.171	-0.2350	-0.0315	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 8A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR URANIUM

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	1.00	1.17	1.23	1.26	1.29	1.28	1.30	1.130	-0.0105	0.6513	T	(7.3,20)
.50	1.00	1.17	1.30	1.48	1.67	1.85	2.08	2.36	1.444	-0.0246	0.3517	T	
.60	1.00	1.20	1.35	1.58	1.84	2.07	2.40	2.79	1.571	-0.0274	0.3266	T	
.70	1.00	1.23	1.40	1.68	2.00	2.30	2.72	3.21	1.699	-0.0302	0.3016	T	
.80	1.00	1.25	1.46	1.78	2.17	2.52	3.03	3.64	1.826	-0.0330	0.2765	T	
.90	1.00	1.28	1.51	1.88	2.33	2.75	3.35	4.06	1.954	-0.0358	0.2514	T	
1.00	1.00	1.31	1.56	1.98	2.50	2.97	3.67	4.49	2.081	-0.0386	0.2264	T	
1.25	1.00	1.31	1.58	2.04	2.65	3.21	4.09	4.99	2.452	-0.0375	0.1915	T	(6.4,4),(6.0,7)
1.50	1.00	1.32	1.60	2.10	2.79	3.46	4.51	5.48	2.823	-0.0365	0.1565	T	(6.4,2),(8.8,4),(8.5,7),(6.3,10),(5.1,20)
1.75	1.00	1.32	1.62	2.17	2.94	3.70	4.94	5.98	3.194	-0.0354	0.1216	T	(5.4,2),(7.4,4),(7.1,7),(5.1,10)
2.00	1.00	1.33	1.64	2.23	3.09	3.95	5.36	6.48	3.550	-0.0344	0.0881	T	
2.20	1.00	1.32	1.63	2.23	3.13	4.06	5.68	7.16	3.817	-0.0374	0.0724	T	
2.50	1.00	1.31	1.61	2.22	3.18	4.23	6.16	8.18	4.216	-0.0419	0.0489	T	(5.5,4),(6.0,7)
2.75	1.00	1.30	1.59	2.21	3.22	4.37	6.57	9.03	4.550	-0.0457	0.0294	T	
3.00	1.00	1.29	1.58	2.21	3.27	4.51	6.97	9.88	4.883	-0.0495	0.0098	T	
3.50	1.00	1.27	1.54	2.15	3.24	4.58	7.49	11.29	3.841	-0.0659	0.0068	T	(5.3,20)
4.00	1.00	1.24	1.50	2.09	3.21	4.66	8.01	12.70	2.800	-0.0824	0.0037	T	
4.50	1.00	1.22	1.46	2.03	3.15	4.69	8.71	15.27	1.807	-0.1091	0.0231	T	
5.00	1.00	1.20	1.43	1.97	3.08	4.73	9.40	17.85	1.365	-0.1298	0.0484	T	
5.50	1.00	1.18	1.39	1.91	3.02	4.76	10.10	20.42	1.098	-0.1467	0.1958	T	
6.00	1.00	1.16	1.36	1.85	2.96	4.80	10.80	23.00	0.975	-0.1589	0.2110	T	
6.30	1.00	1.15	1.35	1.82	2.91	4.73	10.86	23.75	0.910	-0.1638	0.1835	T	
6.50	1.00	1.15	1.34	1.80	2.87	4.69	10.90	24.25	0.882	-0.1671	0.1652	T	
7.00	1.00	1.14	1.31	1.75	2.78	4.58	11.00	25.50	0.788	-0.1754	0.1194	T	
7.50	1.00	1.13	1.29	1.71	2.70	4.47	11.10	26.75	0.695	-0.1836	0.0736	T	
7.65	1.00	1.13	1.29	1.69	2.67	4.44	11.13	27.12	0.667	-0.1861	0.0598	T	
8.00	1.00	1.12	1.27	1.66	2.61	4.36	11.20	28.00	0.602	-0.1919	0.0277	T	
8.50	1.00	1.11	1.25	1.62	2.52	4.21	11.02	28.12	0.551	-0.1972	0.0260	T	
9.00	1.00	1.10	1.23	1.58	2.43	4.07	10.85	28.25	0.500	-0.2025	0.0243	T	
9.50	1.00	1.10	1.22	1.55	2.35	3.92	10.67	28.37	0.450	-0.2078	0.0226	T	
10.00	1.00	1.09	1.20	1.51	2.26	3.78	10.50	28.50	0.399	-0.2131	0.0208	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 9A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR WATER

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	3.09	7.14	23.00	72.90	166.00	456.00	982.00	1.335	0.6924	0.0835	C	
.50	1.00	2.46	4.61	12.90	32.80	63.10	141.00	252.00	0.983	0.4805	0.0052	C	
.60	1.00	2.39	4.47	11.96	29.48	55.90	122.88	218.04	0.995	0.4095	0.0042	C	
.70	1.00	2.33	4.43	10.91	26.16	48.70	104.76	184.08	1.001	0.3386	0.0036	C	
.80	1.00	2.26	4.19	9.77	22.84	41.50	86.64	150.12	1.004	0.2845	0.0021	C	
.90	1.00	2.20	3.95	8.72	19.52	34.30	68.52	116.16	1.002	0.2215	0.0010	C	
1.00	1.00	2.13	3.71	7.68	16.20	27.10	50.40	82.20	1.048	0.1575	0.00	C	
1.25	1.00	2.05	3.47	6.98	14.26	23.42	42.67	68.57	1.007	0.1241	0.0	C	
1.50	1.00	1.98	3.24	6.28	12.33	19.75	34.95	54.95	0.966	0.0907	0.0	C	
1.75	1.00	1.90	3.00	5.58	10.39	16.07	27.22	41.32	0.926	0.0574	0.0	C	
2.00	1.00	1.83	2.77	4.88	8.46	12.40	19.50	27.70	13.369	*0.0521	0.0166	T	
2.20	1.00	1.80	2.76	4.69	8.01	11.65	18.16	25.56	12.917	*0.0488	0.0197	T	
2.50	1.00	1.76	2.69	4.39	7.34	10.51	16.15	22.35	12.239	*0.0438	0.0243	T	
2.75	1.00	1.72	2.51	4.15	6.79	9.57	14.47	19.67	11.675	*0.0397	0.0282	T	
3.00	1.00	1.69	2.42	3.91	6.23	8.63	12.80	17.00	11.110	*0.0355	0.0321	T	
3.50	1.00	1.63	2.30	3.63	5.68	7.78	11.38	14.95	11.137	*0.0305	0.0312	T	
4.00	1.00	1.58	2.17	3.34	5.13	6.94	9.97	12.90	11.163	*0.0254	0.0303	T	
4.50	1.00	1.55	2.10	3.19	4.84	6.50	9.25	11.89	10.469	*0.0236	0.0331	T	
5.00	1.00	1.52	2.04	3.05	4.56	6.06	8.53	10.87	9.774	*0.0218	0.0359	T	
5.50	1.00	1.49	1.97	2.91	4.28	5.62	7.81	9.86	9.079	*0.0200	0.0388	T	
6.00	1.00	1.46	1.91	2.76	3.99	5.18	7.09	8.85	8.385	*0.0182	0.0416	T	
6.30	1.00	1.45	1.88	2.71	3.89	5.04	6.88	8.56	7.822	*0.0194	0.0460	T	
6.50	1.00	1.44	1.87	2.67	3.83	4.95	6.73	8.37	7.447	*0.0202	0.0490	T	
7.00	1.00	1.42	1.82	2.58	3.66	4.71	6.37	7.90	6.510	*0.0223	0.0563	T	
7.50	1.00	1.40	1.78	2.49	3.50	4.48	6.02	7.42	5.572	-0.0243	0.0636	T	
7.65	1.00	1.39	1.77	2.46	3.45	4.41	5.91	7.28	5.291	*0.0249	0.0658	T	
8.00	1.00	1.38	1.74	2.40	3.34	4.25	5.66	6.95	4.635	*0.0263	0.0710	T	
8.50	1.00	1.37	1.71	2.35	3.25	4.12	5.47	6.71	4.362	*0.0272	0.0750	T	
9.00	1.00	1.35	1.69	2.29	3.16	3.98	5.28	6.46	4.090	*0.0281	0.0791	T	
9.50	1.00	1.34	1.66	2.24	3.06	3.85	5.09	6.22	3.817	*0.0290	0.0831	T	
10.00	1.00	1.33	1.63	2.19	2.97	3.72	4.90	5.98	3.545	*0.0299	0.0872	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 9B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR WATER

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	3.03	6.48	21.80	68.10	154.00	421.00	906.00	1.323	0.6448	0.0759	C	
.50	1.00	2.44	4.41	12.50	31.30	59.60	130.00	232.00	1.025	0.4392	0.0047	C	
.60	1.00	2.37	4.57	11.62	28.14	52.80	113.34	200.06	.998	0.4009	0.0028	C	
.70	1.00	2.29	4.32	10.54	24.98	46.00	96.68	168.12	1.008	0.3332	0.0021	C	
.80	1.00	2.22	4.18	9.65	21.82	39.20	80.02	136.18	1.012	0.2656	0.0016	C	
.90	1.00	2.14	3.93	8.57	18.66	32.40	63.36	104.24	1.012	0.1980	0.0008	C	
1.00	1.00	2.07	3.59	7.59	15.50	25.60	46.70	72.30	1.035	0.1334	0.0	C	
1.25	1.00	2.01	3.40	6.94	13.79	22.42	40.02	61.37	0.972	0.1093	0.0	C	
1.50	1.00	1.96	3.20	6.29	12.08	19.25	33.35	50.45	0.938	0.0901	0.0	C	
1.75	1.00	1.91	3.01	5.64	10.38	16.07	26.67	39.52	0.928	0.0538	0.0	C	
2.00	1.00	1.85	2.92	4.99	8.67	12.90	20.00	28.60	22.082	•0.0421	• .0006	T	
2.20	1.00	1.83	2.76	4.81	8.25	12.14	18.68	26.46	20.931	•0.0392	.0036	T	
2.50	1.00	1.80	2.67	4.54	7.62	11.01	16.70	23.25	19.204	•0.0347	.0101	T	
2.75	1.00	1.77	2.59	4.32	7.09	10.06	15.05	20.57	17.765	•0.0310	.0154	T	
3.00	1.00	1.74	2.52	4.10	6.57	9.12	13.40	17.90	16.326	•0.0273	.0208	T	
3.50	1.00	1.66	2.35	3.73	5.88	8.06	11.75	15.45	13.828	•0.0263	.0255	T	None
4.00	1.00	1.59	2.18	3.37	5.18	7.01	10.10	13.00	11.330	•0.0253	.0303	T	
4.50	1.00	1.56	2.11	3.22	4.88	6.55	9.34	11.96	10.067	•0.0255	.0368	T	
5.00	1.00	1.52	2.03	3.06	4.58	6.09	8.58	10.91	8.805	•0.0257	.0434	T	
5.50	1.00	1.49	1.96	2.91	4.28	5.64	7.83	9.87	7.543	•0.0259	.0500	T	
6.00	1.00	1.46	1.89	2.76	3.98	5.18	7.07	8.83	6.280	•0.0261	.0566	T	
6.30	1.00	1.45	1.87	2.71	3.89	5.04	6.86	8.56	5.985	•0.0266	.0599	T	
6.50	1.00	1.44	1.85	2.67	3.83	4.95	6.73	8.37	5.788	•0.0269	.0628	T	
7.00	1.00	1.42	1.81	2.59	3.67	4.73	6.38	7.91	5.297	•0.0276	.0675	T	
7.50	1.00	1.40	1.78	2.50	3.52	4.50	6.04	7.46	4.805	•0.0284	.0729	T	
7.65	1.00	1.39	1.77	2.48	3.47	4.44	5.94	7.32	4.658	•0.0286	.0746	T	
8.00	1.00	1.38	1.74	2.42	3.36	4.28	5.70	7.00	4.314	•0.0291	.0784	T	
8.50	1.00	1.36	1.70	2.35	3.24	4.11	5.46	6.69	4.138	•0.0288	.0788	T	
9.00	1.00	1.34	1.67	2.27	3.12	3.94	5.21	6.38	3.962	•0.0285	.0791	T	
9.50	1.00	1.33	1.63	2.20	3.00	3.77	4.97	6.07	3.786	•0.0282	.0795	T	
10.00	1.00	1.31	1.60	2.13	2.88	3.60	4.73	5.76	3.610	•0.0279	.0799	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alphal*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alphal*b**2 + alpha2*b**3

TABLE 10A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR ORDINARY CONCRETE

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	2.53	4.73	11.27	27.41	53.45	123.47	233.86	1.2295	.29141	.01134	C	
.50	1.00	2.25	3.94	8.58	18.90	33.70	69.10	119.00	.9760	.24225	0.	C	
.60	1.00	2.19	3.79	8.11	17.56	30.88	62.28	105.92	.9338	.21080	0.	C	
.70	1.00	2.14	3.64	7.64	16.22	28.06	55.46	92.84	.9405	.17935	0.	C	
.80	1.00	2.08	3.48	7.16	14.88	25.24	48.64	79.76	.9481	.14790	0.	C	
.90	1.00	2.03	3.33	6.69	13.54	22.42	41.82	66.68	.9547	.11645	0.	C	
1.00	1.00	1.97	3.18	6.22	12.20	19.60	35.00	53.60	.9614	.08900	0.	C	
1.25	1.00	1.91	3.03	5.79	11.08	17.55	30.75	46.47	.9462	.07262	0.	C	(5.4,1),(-5.3,7),(5.4,20)
1.50	1.00	1.86	2.89	5.35	9.97	15.50	26.50	39.35	.8645	.05634	0.	C	
1.75	1.00	1.80	2.74	4.92	8.85	13.45	22.25	32.22	.8160	.03951	0.	C	
2.00	1.00	1.75	2.59	4.49	7.74	11.40	18.00	25.10	18.3051	- .04212	.00286	T	
2.20	1.00	1.73	2.54	4.35	7.42	10.85	16.98	23.54	15.4300	- .04332	.00887	T	
2.50	1.00	1.70	2.45	4.13	6.93	10.01	15.45	21.20	17.0150	- .03714	.00828	T	
2.75	1.00	1.67	2.39	3.95	6.53	9.32	14.17	19.25	16.3323	- .03376	.01176	T	
3.00	1.00	1.64	2.32	3.77	6.13	8.63	12.90	17.30	10.5830	- .04070	.02516	T	
3.50	1.00	1.60	2.23	3.56	5.69	7.94	11.75	15.60	9.0550	- .04020	.03196	T	
4.00	1.00	1.56	2.14	3.35	5.26	7.25	10.60	13.90	10.1601	- .03176	.03088	T	
4.50	1.00	1.54	2.09	3.24	5.04	6.91	10.03	13.10	9.5485	- .03168	.03184	T	
5.00	1.00	1.52	2.04	3.13	4.82	6.56	9.46	12.30	9.2680	- .02962	.03286	T	
5.50	1.00	1.49	1.99	3.01	4.60	6.22	8.90	11.50	8.6324	- .02955	.03384	T	
6.00	1.00	1.47	1.94	2.90	4.38	5.87	8.33	10.70	7.7125	- .02947	.03915	T	
6.30	1.00	1.46	1.92	2.87	4.32	5.78	8.19	10.52	7.5100	- .02940	.04142	T	
6.50	1.00	1.46	1.91	2.84	4.28	5.72	8.10	10.40	6.5568	- .03323	.04807	T	
7.00	1.00	1.45	1.89	2.79	4.18	5.57	7.87	10.11	7.2996	- .02917	.03951	T	
7.50	1.00	1.43	1.87	2.73	4.08	5.42	7.64	9.81	6.2062	- .03281	.04851	T	
7.65	1.00	1.43	1.86	2.72	4.05	5.37	7.57	9.73	6.6015	- .03080	.04426	T	
8.00	1.00	1.42	1.84	2.68	3.98	5.27	7.41	9.52	6.3666	- .03072	.04436	T	
8.50	1.00	1.41	1.81	2.63	3.89	5.15	7.23	9.28	5.8981	- .03272	.04796	T	
9.00	1.00	1.39	1.79	2.59	3.81	5.03	7.05	9.04	5.6641	- .03289	.04929	T	
9.50	1.00	1.38	1.77	2.54	3.72	4.91	6.87	8.81	5.8492	- .03104	.04426	T	
10.00	1.00	1.37	1.74	2.50	3.64	4.79	6.69	8.57	5.5986	- .03120	.04746	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alphal*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alphal*b**2 + alpha2*b**3

TABLE 10B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR ORDINARY CONCRETE

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	3.03	6.20	15.94	40.66	80.26	188.88	360.41	1.5444	.47175	.01656	C	
.50	1.00	2.54	4.74	10.90	24.80	44.90	93.50	162.00	1.1200	.32776	0.	C	
.60	1.00	2.45	4.49	10.12	22.62	40.46	82.94	142.10	1.1200	.28271	0.	C	
.70	1.00	2.36	4.24	9.35	20.44	36.02	72.38	122.20	1.1200	.23766	0.	C	
.80	1.00	2.27	4.00	8.57	18.26	31.58	61.82	102.30	1.0640	.19261	0.	C	
.90	1.00	2.18	3.75	7.80	16.08	27.14	51.26	82.40	1.0640	.15624	0.	C	
1.00	1.00	2.09	3.50	7.02	13.90	22.70	40.70	62.50	1.0301	.12630	0.	C	
1.25	1.00	2.02	3.30	6.44	12.46	20.02	35.27	53.52	1.0013	.08775	0.	C	
1.50	1.00	1.94	3.09	5.87	11.03	17.35	29.85	44.55	.9376	.06567	0.	C	
1.75	1.00	1.86	2.89	5.29	9.59	14.67	24.42	35.57	.8664	.04609	0.	C	
2.00	1.00	1.79	2.69	4.71	8.16	12.00	19.00	26.60	50.2754	- .03119	- .01472	T	
2.20	1.00	1.76	2.62	4.54	7.78	11.36	17.84	24.80	32.7227	- .03239	- .00707	T	
2.50	1.00	1.72	2.52	4.28	7.20	10.40	16.10	22.10	43.5321	- .02558	- .00750	T	
2.75	1.00	1.69	2.43	4.06	6.73	9.60	14.65	19.85	34.9761	- .02412	- .00283	T	
3.00	1.00	1.66	2.35	3.84	6.25	8.80	13.20	17.60	28.5010	- .02340	.00076	T	
3.50	1.00	1.61	2.24	3.59	5.75	8.02	11.90	15.75	26.9720	- .02070	.00220	T	None
4.00	1.00	1.56	2.14	3.35	5.26	7.25	10.60	13.90	32.9732	- .01440	.00360	T	
4.50	1.00	1.53	2.08	3.22	5.01	6.86	9.97	13.02	32.3554	- .01305	.00440	T	
5.00	1.00	1.51	2.02	3.09	4.76	6.47	9.34	12.15	27.0840	- .01336	.00316	T	
5.50	1.00	1.48	1.97	2.97	4.52	6.09	8.71	11.27	29.6436	- .01047	.00048	T	
6.00	1.00	1.46	1.91	2.84	4.27	5.70	8.08	10.40	26.6989	- .01001	.00728	T	
6.30	1.00	1.45	1.89	2.80	4.20	5.60	7.93	10.20	27.2160	- .00988	.00686	T	
6.50	1.00	1.45	1.88	2.78	4.16	5.53	7.83	10.06	26.9010	- .00961	.00672	T	
7.00	1.00	1.43	1.85	2.72	4.04	5.37	7.57	9.73	26.1128	- .01036	.00572	T	
7.50	1.00	1.41	1.82	2.66	3.93	5.20	7.32	9.39	24.4215	- .01087	.00560	T	
7.65	1.00	1.41	1.81	2.64	3.90	5.16	7.25	9.29	25.0908	- .01080	.00487	T	
8.00	1.00	1.40	1.79	2.60	3.82	5.04	7.07	9.06	24.5302	- .01065	.00499	T	
8.50	1.00	1.39	1.77	2.56	3.75	4.94	6.92	8.87	21.9348	- .01192	.00504	T	
9.00	1.00	1.38	1.75	2.52	3.68	4.85	6.78	8.68	20.9538	- .01248	.00468	T	
9.50	1.00	1.37	1.74	2.49	3.62	4.75	6.63	8.49	18.4774	- .01345	.00490	T	
10.00	1.00	1.36	1.72	2.45	3.55	4.66	6.49	8.30	17.3698	- .01436	.00490	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 11A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR MAGNETITE CONCRETE

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	2.25	3.77	7.86	17.11	30.67	64.37	114.16	73.5706	- .08664	- .06985	T	(7.1,1),(7.5,2),(7.7,20)
.50	1.00	2.09	3.40	6.79	13.90	23.60	45.50	74.90	47.5890	- .07371	- .05046	T	(6.8,1),(6.4,2),(7.1,20)
.60	1.00	2.05	3.31	6.55	13.26	22.30	42.42	69.06	46.5545	- .07092	- .04784	T	(6.7,1),(6.2,2),(6.7,20)
.70	1.00	2.01	3.23	6.32	12.62	21.00	39.34	63.22	44.5537	- .06798	- .04433	T	(7.2,1),(6.9,2),(-5.4,10),(6.4,20)
.80	1.00	1.98	3.14	6.08	11.98	19.70	36.26	57.38	35.7161	- .06677	- .03833	T	(6.7,1),(6.2,2),(-5.0,10),(6.4,20)
.90	1.00	1.94	3.06	5.85	11.34	18.40	33.18	51.54	39.6195	- .06112	- .03617	T	(7.0,1),(6.5,2),(6.5,20)
1.00	1.00	1.90	2.97	5.61	10.70	17.10	30.10	45.70	44.4846	- .05548	- .03425	T	(6.5,1),(5.6,2),(6.5,20)
1.25	1.00	1.85	2.85	5.28	9.88	15.57	26.95	40.40	27.3786	- .05681	- .02394	T	(5.4,1),(5.1,2),(5.7,20)
1.50	1.00	1.80	2.74	4.96	9.07	14.05	23.80	35.10	28.4521	- .05108	- .02162	T	
1.75	1.00	1.76	2.62	4.63	8.25	12.52	20.65	29.80	24.6148	- .04674	- .01431	T	
2.00	1.00	1.71	2.51	4.31	7.44	11.00	17.50	24.50	22.4675	- .03935	- .00519	T	
2.20	1.00	1.69	2.46	4.18	7.17	10.54	16.66	23.22	23.8322	- .03672	- .00517	T	
2.50	1.00	1.66	2.38	3.99	6.75	9.84	15.40	21.30	21.0546	- .03624	- .00264	T	
2.75	1.00	1.63	2.32	3.84	6.41	9.26	14.35	19.70	18.7291	- .03584	- .00126	T	
3.00	1.00	1.60	2.26	3.68	6.07	8.68	13.30	18.10	17.8443	- .03544	- .00121	T	
3.50	1.00	1.56	2.17	3.48	5.66	8.02	12.20	16.50	18.9780	- .03020	.00066	T	
4.00	1.00	1.52	2.08	3.28	5.25	7.37	11.10	14.90	13.4736	- .03525	.00252	T	
4.50	1.00	1.50	2.03	3.16	5.03	7.02	10.52	14.07	14.4317	- .03263	.00081	T	
5.00	1.00	1.48	1.98	3.05	4.81	6.67	9.94	13.25	12.8697	- .03495	- .00005	T	(5.7,20)
5.50	1.00	1.45	1.93	2.93	4.58	6.33	9.36	12.43	11.3094	- .03734	- .00046	T	(-5.3,7),(8.3,20)
6.00	1.00	1.43	1.88	2.82	4.36	5.98	8.78	11.60	19.967	- .02145	- .00023	T	
6.30	1.00	1.42	1.86	2.78	4.29	5.88	8.63	11.39	18.6345	- .02161	.00224	T	
6.50	1.00	1.41	1.85	2.76	4.25	5.81	8.52	11.25	16.4521	- .02090	.00646	T	
7.00	1.00	1.40	1.82	2.70	4.13	5.65	8.27	10.90	7.5689	- .03708	.01612	T	
7.50	1.00	1.38	1.79	2.64	4.02	5.48	8.01	10.55	6.4789	- .03784	.02576	T	
7.65	1.00	1.38	1.78	2.62	3.99	5.44	7.94	10.44	6.1515	- .03947	.02858	T	
8.00	1.00	1.37	1.76	2.58	3.91	5.32	7.76	10.20	5.2827	- .04269	.03523	T	
8.50	1.00	1.36	1.73	2.53	3.81	5.17	7.54	9.91	4.6735	- .04527	.05188	T	
9.00	1.00	1.34	1.71	2.47	3.71	5.03	7.31	9.63	3.4930	- .05655	.06118	T	
9.50	1.00	1.33	1.68	2.42	3.62	4.88	7.09	9.34	3.5244	- .05339	.07526	T	
10.00	1.00	1.32	1.66	2.37	3.52	4.74	6.87	9.06	2.9029	- .05959	.09716	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 11B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR MAGNETITE CONCRETE

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	3.22	5.95	13.32	30.38	55.56	119.33	213.96	61.9615	- .09847	- .06184	T	(9.25,1),(8.5,2),(9.4,20)
.50	1.00	2.65	4.65	9.84	20.90	36.10	70.90	118.00	37.5751	- .08589	- .03965	T	(9.1,1),(8.1,2),(9.0,20)
.60	1.00	2.55	4.42	9.24	19.38	33.18	64.36	106.06	81.6932	- .07225	- .05276	T	(8.2,1),(6.9,2),(8.2,20)
.70	1.00	2.44	4.18	8.63	17.86	30.26	57.82	94.12	44.2056	- .07565	- .04159	T	(8.2,1),(7.1,2),(7.9,20)
.80	1.00	2.34	3.95	8.03	16.34	27.34	51.28	82.18	41.5001	- .07182	- .03786	T	(8.1,1),(7.0,2),(7.3,20)
.90	1.00	2.23	3.71	7.42	14.82	24.42	44.74	70.24	51.5623	- .06425	- .03910	T	(7.4,1),(6.3,2),(7.7,20)
1.00	1.00	2.13	3.48	6.82	13.30	21.50	38.20	58.30	33.8182	- .06316	- .02736	T	(7.7,1),(6.5,2),(7.8,20)
1.25	1.00	2.05	3.28	6.28	12.01	19.15	33.47	50.52	30.8869	- .05968	- .02378	T	(6.5,1),(5.5,1),(6.5,20)
1.50	1.00	1.96	3.08	5.75	10.72	16.80	28.75	42.75	27.8869	- .05533	- .01904	T	(5.3,1),(5.3,20)
1.75	1.00	1.88	2.88	5.21	9.44	14.45	24.02	34.97	24.8720	- .04966	- .01225	T	
2.00	1.00	1.80	2.68	4.68	8.15	12.10	19.30	27.20	27.9024	- .03780	- .00701	T	
2.20	1.00	1.77	2.60	4.50	7.76	11.45	18.16	25.46	27.6653	- .03612	- .00634	T	
2.50	1.00	1.71	2.49	4.22	7.17	10.49	16.45	22.85	24.7387	- .03448	- .00325	T	
2.75	1.00	1.67	2.39	3.99	6.69	9.68	15.02	20.67	22.2054	- .03277	- .00048	T	
3.00	1.00	1.63	2.30	3.76	6.20	8.87	13.60	18.50	18.7572	- .03315	.00126	T	
3.50	1.00	1.58	2.18	3.50	5.68	8.06	12.25	16.55	15.8620	- .03517	.00066	T	
4.00	1.00	1.52	2.07	3.24	5.17	7.24	10.90	14.60	15.0859	- .03279	.00034	T	
4.50	1.00	1.51	2.00	3.10	4.90	6.82	10.21	13.62	13.6407	- .03366	.00036	T	
5.00	1.00	1.49	1.94	2.96	4.63	6.41	9.51	12.65	11.8926	- .03547	.00065	T	(6.0,20)
5.50	1.00	1.48	1.87	2.82	4.36	5.99	8.82	11.67	8.8986	- .03304	.01984	T	
6.00	1.00	1.46	1.81	2.68	4.09	5.57	8.13	10.70	8.3079	- .03052	.02160	T	
6.30	1.00	1.44	1.79	2.64	4.01	5.46	7.96	10.46	8.3079	- .03052	.02160	T	
6.50	1.00	1.43	1.78	2.61	3.97	5.38	7.84	10.31	8.3079	- .03052	.02160	T	
7.00	1.00	1.40	1.74	2.54	3.84	5.20	7.55	9.91	8.6250	- .02700	.02328	T	
7.50	1.00	1.37	1.71	2.48	3.72	5.01	7.26	9.52	8.1711	- .02700	.02328	T	
7.65	1.00	1.36	1.70	2.46	3.68	4.96	7.17	9.40	8.1711	- .02700	.02328	T	
8.00	1.00	1.34	1.68	2.41	3.59	4.83	6.97	9.13	7.7171	- .02800	.02328	T	
8.50	1.00	1.33	1.66	2.37	3.51	4.72	6.80	8.90	7.9657	- .02457	.02496	T	
9.00	1.00	1.32	1.64	2.33	3.44	4.60	6.62	8.67	7.5445	- .02548	.02496	T	
9.50	1.00	1.31	1.63	2.29	3.36	4.49	6.45	8.45	7.2632	- .02700	.02328	T	
10.00	1.00	1.30	1.61	2.25	3.28	4.38	6.28	8.22	6.8092	- .02800	.02328	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 12A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR BARYTES CONCRETE

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*
.25	1.00	1.72	2.41	3.88	6.35	9.04	13.87	18.97	14.9820	- .03496	.01311	T
.50	1.00	1.72	2.43	3.95	6.51	9.33	14.50	20.20	15.6630	- .03714	.00897	T
.60	1.00	1.72	2.44	4.02	6.71	9.70	15.26	21.42	14.3010	- .04151	.01036	T
.70	1.00	1.72	2.46	4.09	6.90	10.08	16.02	22.64	14.3010	- .04370	.00966	T
.80	1.00	1.72	2.47	4.15	7.10	10.45	16.78	23.86	13.6200	- .04370	.01386	T
.90	1.00	1.72	2.49	4.22	7.29	10.83	17.54	25.08	15.8080	- .04680	.00196	T
1.00	1.00	1.72	2.50	4.29	7.49	11.20	18.30	26.30	14.1440	- .05148	.00336	T
1.25	1.00	1.69	2.45	4.16	7.21	10.71	17.37	24.82	13.3120	- .05148	.00364	T
1.50	1.00	1.67	2.39	4.03	6.92	10.23	16.45	23.35	12.2580	- .05025	.00966	T
1.75	1.00	1.64	2.34	3.91	6.64	9.74	15.52	21.87	12.2580	- .04807	.00966	T
2.00	1.00	1.62	2.29	3.78	6.36	9.26	14.60	20.40	10.5830	- .04884	.01631	T
2.20	1.00	1.60	2.25	3.70	6.19	8.99	14.14	19.70	9.5247	- .05087	.02009	T
2.50	1.00	1.57	2.19	3.57	5.93	8.58	13.45	18.65	9.5247	- .04884	.01889	T
2.75	1.00	1.55	2.15	3.46	5.72	8.24	12.87	17.77	9.0550	- .04824	.02073	T
3.00	1.00	1.53	2.10	3.36	5.51	7.90	12.30	16.90	7.6130	- .05122	.02961	T
3.50	1.00	1.49	2.02	3.20	5.20	7.42	11.50	15.80	7.6130	- .04925	.02536	T
4.00	1.00	1.46	1.95	3.04	4.89	6.95	10.70	14.70	6.6200	- .05122	.02961	T
4.50	1.00	1.44	1.91	2.94	4.70	6.66	10.25	14.10	5.9580	- .05319	.03384	T
5.00	1.00	1.41	1.86	2.84	4.51	6.38	9.80	13.50	6.3666	- .04942	.02656	T
5.50	1.00	1.39	1.81	2.74	4.32	6.09	9.35	12.90	5.6592	- .05184	.03101	T
6.00	1.00	1.37	1.77	2.64	4.13	5.80	8.90	12.30	5.4234	- .05184	.02885	T
6.30	1.00	1.36	1.75	2.61	4.07	5.71	8.78	12.16	5.4234	- .05184	.02656	T
6.50	1.00	1.36	1.74	2.58	4.02	5.65	8.69	12.07	4.9518	- .05376	.03329	T
7.00	1.00	1.34	1.71	2.52	3.92	5.50	8.49	11.85	5.1300	- .05265	.02463	T
7.50	1.00	1.33	1.69	2.47	3.81	5.36	8.28	11.62	4.7500	- .05460	.02665	T
7.65	1.00	1.33	1.68	2.45	3.78	5.31	8.22	11.56	4.7500	- .05460	.02463	T
8.00	1.00	1.32	1.66	2.41	3.71	5.21	8.08	11.40	4.7500	- .05460	.02460	T
8.50	1.00	1.31	1.63	2.36	3.61	5.06	7.86	11.12	4.5600	- .05460	.02460	T
9.00	1.00	1.30	1.61	2.30	3.51	4.91	7.64	10.85	4.3700	- .05460	.02460	T
9.50	1.00	1.28	1.59	2.25	3.42	4.77	7.43	10.57	4.1800	- .05460	.02665	T
10.00	1.00	1.27	1.56	2.20	3.32	4.62	7.21	10.30	3.9900	- .05460	.02665	T

Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))

None

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)

TABLE 12B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR BARYTES CONCRETE

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
.25	1.00	2.78	4.14	6.76	11.09	15.68	24.10	33.07	159.8799	- .00807	.00124	T	(-10.4,1),(5.1,7)
.50	1.00	2.47	3.75	6.40	10.90	15.80	25.00	35.10	72.3257	- .01937	.00024	T	
.60	1.00	2.40	3.65	6.30	10.84	15.84	25.30	35.76	59.9270	- .02338	- .00195	T	
.70	1.00	2.33	3.56	6.19	10.78	15.88	25.60	36.42	39.8533	- .03457	- .00478	T	(-5.1,1)
.80	1.00	2.27	3.46	6.09	10.72	15.92	25.90	37.08	33.5772	- .04020	- .00684	T	
.90	1.00	2.20	3.37	5.98	10.66	15.96	26.20	37.74	33.5772	- .04020	- .00388	T	
1.00	1.00	2.13	3.27	5.88	10.60	16.00	26.50	38.40	33.5772	- .04257	- .00885	T	
1.25	1.00	2.04	3.09	5.50	9.81	14.72	24.20	34.85	34.8208	- .04020	- .01020	T	
1.50	1.00	1.95	2.92	5.12	9.02	13.45	21.90	31.30	33.5772	- .03784	- .00885	T	
1.75	1.00	1.86	2.74	4.74	8.23	12.17	19.60	27.75	24.7387	- .03879	- .00247	T	
2.00	1.00	1.77	2.57	4.36	7.44	10.90	17.30	24.20	18.3250	- .04310	- .00266	T	
2.20	1.00	1.73	2.49	4.19	7.11	10.38	16.42	22.92	24.7387	- .03448	- .00338	T	
2.50	1.00	1.67	2.38	3.94	6.61	9.60	15.10	21.00	21.9900	- .03448	- .00221	T	
2.75	1.00	1.63	2.28	3.73	6.19	8.95	14.00	19.40	15.2955	- .03986	.00084	T	
3.00	1.00	1.58	2.19	3.52	5.78	8.30	12.90	17.80	15.2955	- .03752	.00084	T	
3.50	1.00	1.52	2.08	3.27	5.31	7.58	11.70	16.15	11.8926	- .04129	.00133	T	
4.00	1.00	1.47	1.96	3.03	4.84	6.86	10.50	14.50	10.0198	- .04400	.00048	T	
4.50	1.00	1.44	1.89	2.89	4.58	6.47	9.88	13.62	10.0198	- .04125	.00119	T	
5.00	1.00	1.41	1.83	2.76	4.32	6.07	9.25	12.75	14.1658	- .03025	.00024	T	
5.50	1.00	1.37	1.77	2.62	4.07	5.68	8.63	11.87	14.1658	- .02915	- .00040	T	
6.00	1.00	1.34	1.70	2.49	3.81	5.29	8.01	11.00	10.3024	- .03500	- .00040	T	
6.30	1.00	1.33	1.68	2.45	3.74	5.18	7.84	10.79	10.3024	- .03430	- .00040	T	
6.50	1.00	1.33	1.67	2.42	3.69	5.11	7.73	10.64	10.3024	- .03430	- .00122	T	
7.00	1.00	1.31	1.64	2.35	3.56	4.92	7.46	10.28	6.3122	- .04880	- .00488	T	(5.9,20)
7.50	1.00	1.30	1.61	2.29	3.44	4.74	7.18	9.93	6.3122	- .04714	- .00514	T	
7.65	1.00	1.29	1.60	2.27	3.41	4.69	7.10	9.82	6.4390	- .04593	- .00536	T	
8.00	1.00	1.28	1.58	2.22	3.32	4.56	6.91	9.57	6.2090	- .04593	- .00536	T	
8.50	1.00	1.27	1.56	2.18	3.24	4.44	6.73	9.35	6.0868	- .04593	- .00619	T	
9.00	1.00	1.27	1.54	2.14	3.16	4.32	6.56	9.14	5.4250	- .04875	- .00606	T	
9.50	1.00	1.26	1.52	2.10	3.09	4.21	6.38	8.92	5.2312	- .04875	- .00606	T	
10.00	1.00	1.25	1.50	2.06	3.01	4.09	6.21	8.71	5.0375	- .04875	- .00656	T	

*T signifies Taylor exponential fit coefficients

Build-up factor = A*exp(-alphal*b) + (1-A)*exp(-alpha2*b)

TABLE 13A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR AIR ($N_{78}O_{22}$)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.42	4.65	11.5	27.9	52.6	114.	205.	0.913	0.4456	0.0	C	
1.00	1.00	2.06	3.49	7.18	14.5	23.8	43.1	66.6	1.012	0.1200	0.0	C	
2.00	1.00	1.80	2.72	4.79	8.31	12.2	19.3	26.8	19.969	+0.0421	0.0016	T	
3.00	1.00	1.68	2.41	3.94	6.38	8.93	13.3	17.6	14.816	+0.0305	0.0213	T	
4.00	1.00	1.60	2.22	3.47	5.41	7.38	10.6	13.8	10.160	+0.0298	0.0367	T	None
6.00	1.00	1.52	2.02	3.02	4.50	5.97	8.37	10.7	7.712	+0.0275	0.0457	T	
8.00	1.00	1.47	1.92	2.81	4.14	5.44	7.58	9.69	6.602	+0.0288	0.0509	T	
10.00	1.00	1.43	1.84	2.66	3.86	5.06	7.02	8.97	5.598	+0.0312	0.0557	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 13B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR AIR ($N_{78}O_{22}$)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.38	4.51	11.0	26.4	49.5	107.	192.	0.840	0.4242	0.0	C	
1.00	1.00	2.04	3.43	7.01	14.1	23.1	41.7	64.5	1.008	0.1146	0.0	C	
2.00	1.00	1.79	2.70	4.74	8.20	12.0	19.0	26.4	43.093	+0.0312	-0.0115	T	None
3.00	1.00	1.67	2.39	3.89	6.30	8.81	13.1	17.3	38.584	+0.0175	0.0006	T	
4.00	1.00	1.60	2.20	3.44	5.36	7.30	10.5	13.7	35.509	+0.0117	0.0050	T	
6.00	1.00	1.51	2.01	3.00	4.47	5.93	8.31	10.6	27.688	+0.0100	0.0070	T	
8.00	1.00	1.46	1.91	2.79	4.10	5.38	7.49	9.58	24.539	+0.0121	0.0048	T	
10.00	1.00	1.43	1.85	2.67	3.88	5.09	7.07	9.04	19.805	-0.0137	0.0057	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 14A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR WOOD (CELLULOSE, $C_6H_{10}O_5$)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.43	4.71	11.7	28.7	54.3	119.	214.	0.853	0.4643	0.0	C	
1.00	1.00	2.07	3.51	7.26	14.7	24.1	43.8	67.9	1.036	0.1228	0.0	C	
2.00	1.00	1.81	2.74	4.82	8.35	12.3	19.4	26.9	19.969	-0.0421	0.0022	T	
3.00	1.00	1.69	2.42	3.96	6.39	8.93	13.2	17.5	13.229	-0.0326	0.0263	T	
4.00	1.00	1.61	2.23	3.49	5.42	7.39	10.6	13.8	10.160	-0.0300	0.0367	T	None
6.00	1.00	1.52	2.03	3.03	4.52	5.99	8.38	10.7	7.713	-0.0275	0.0478	T	
8.00	1.00	1.48	1.94	2.84	4.17	5.48	7.63	9.76	6.602	-0.0288	0.0509	T	
10.00	1.00	1.44	1.86	2.69	3.91	5.12	7.11	9.10	5.398	-0.0331	0.0578	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 14B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR WOOD (CELLULOSE, $C_6H_{10}O_5$)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.36	4.44	10.7	25.8	48.4	105.	188.	0.840	0.4049	0.0	C	
1.00	1.00	2.03	3.40	6.93	13.9	22.8	41.2	63.8	1.008	0.1146	0.0	C	
2.00	1.00	1.79	2.69	4.72	8.16	12.0	18.9	26.2	43.093	-0.0312	-0.0115	T	
3.00	1.00	1.68	2.40	3.91	6.31	8.82	13.1	17.2	37.155	-0.0175	0.0010	T	
4.00	1.00	1.61	2.22	3.48	5.41	7.37	10.6	13.8	32.241	-0.0126	0.0049	T	None
6.00	1.00	1.52	2.03	3.04	4.53	6.00	8.40	10.7	27.688	-0.0100	0.0073	T	
8.00	1.00	1.48	1.94	2.84	4.17	5.48	7.62	9.75	26.832	-0.0098	0.0062	T	
10.00	1.00	1.45	1.88	2.73	3.98	5.21	7.24	9.27	19.805	-0.0144	0.0057	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 15A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR SAND (SiO_2)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.34	4.27	9.82	22.6	41.2	86.8	152.	0.927	0.3135	0.	C	
1.00	1.00	2.02	3.33	6.67	13.3	21.6	39.0	60.2	1.012	0.1000	0.	C	
2.00	1.00	1.78	2.66	4.65	8.07	11.9	18.9	26.3	16.641	-0.0468	0.0026	T	
3.00	1.00	1.66	2.37	3.87	6.31	8.89	13.3	17.8	12.170	-0.0366	0.0251	T	
4.00	1.00	1.58	2.18	3.42	5.38	7.40	10.8	14.1	10.160	-0.0318	0.0328	T	None
6.00	1.00	1.49	1.97	2.95	4.46	5.96	8.44	10.9	6.856	-0.0334	0.0478	T	
8.00	1.00	1.43	1.87	2.73	4.05	5.36	7.52	9.64	6.367	-0.0310	0.0487	T	
10.00	1.00	1.39	1.77	2.55	3.72	4.89	6.81	8.71	5.599	-0.0312	0.0496	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 15B. GAMMA-RAY ENERGY ABSORPTION BUILD-UP FACTORS FOR SAND (SiO_2)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with Corresponding b values (% Error, b(mfp))
0.50	1.00	2.50	4.78	11.5	27.0	49.8	106.	187.	1.064	0.4049	0.	C	
1.00	1.00	2.09	3.52	7.19	14.4	23.7	42.8	66.3	1.064	0.1146	0.	C	
2.00	1.00	1.80	2.72	4.79	8.34	12.3	19.5	27.3	43.093	-0.0330	-0.0134	T	
3.00	1.00	1.67	2.38	3.90	6.35	8.95	13.4	17.9	28.581	-0.0234	0.0007	T	
4.00	1.00	1.58	2.17	3.41	5.35	7.36	10.7	14.1	35.509	-0.0135	0.0037	T	None
6.00	1.00	1.47	1.95	2.90	4.35	5.82	8.22	10.6	27.687	-0.1001	0.0070	T	
8.00	1.00	1.42	1.83	2.66	3.91	5.16	7.22	9.25	23.662	-0.0114	0.0052	T	
10.00	1.00	1.38	1.76	2.51	3.66	4.80	6.68	8.53	17.369	-0.0152	0.0047	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

TABLE 16A. GAMMA-RAY DOSE BUILD-UP FACTORS FOR LITHIUM HYDRIDE (LiH)

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00	A	ALPHA1	ALPHA2	Type*	Error Magnitudes Greater than 5% Paired with corresponding b values (% Error, b(mfp))
0.50	1.00	2.56	5.66	17.8	52.9	110.	261.	496.	0.659	0.8108	0.0182	C	
1.00	1.00	2.08	3.76	08.48	18.1	30.6	57.3	91.	0.943	0.2142	-0.0014	C	
2.00	1.00	1.80	2.72	4.77	8.23	12.2	18.9	26.	21.364	-0.0353	0.0079	T	(1,7.1),(2,6.0)
3.00	1.00	1.65	2.33	3.72	5.88	8.09	11.8	15.5	23.914	-0.0176	0.0115	T	
4.00	1.00	1.58	2.13	3.29	4.99	6.69	9.48	12.2	16.689	-0.0151	0.0209	T	
6.00	1.00	1.48	1.92	2.77	3.97	5.12	6.99	8.81	5.804	-0.0277	0.0665	T	
8.00	1.00	1.42	1.80	2.51	3.51	4.47	6.03	7.57	4.925	-0.0258	0.0809	T	
10.00	1.00	1.38	1.73	2.38	3.29	4.18	5.62	7.06	4.786	-0.0230	0.0799	T	

*T signifies Taylor exponential fit coefficients
Build-up factor = A*exp(-alpha1*b) + (1-A)*exp(-alpha2*b)
C signifies cubic polynomial fit coefficients
Build-up factor = 1.0 + A*b + alpha1*b**2 + alpha2*b**3

V. EXAMPLES OF LINEAR AND LOG-LOG INTERPOLATION OF DOSE BUILD-UP FACTOR TABLES ON ATOMIC NUMBER

Linear interpolation of build-up factor tables on atomic number is allowed by SPAN-4 (Reference 7), while Engholm recommends (Reference 6) log-log interpolation. Engholm gives plots of build-up factors versus atomic number that support his recommendation, particularly at low atomic numbers.

The tables given here were obtained using both interpolation schemes, and the results may be easily compared. If data from these tables are used in shielding calculations the user should remember that the numbers were obtained by interpolation and not by calculation.

The atomic numbers chosen here for interpolation are primarily those that identify shielding materials included in the SPAN-4 attenuation coefficient library. A notable exception to this is the equivalent atomic number 5.75, which was found to give a reasonable approximation of the dose build-up factors of lithium hydride (Table 16A) when linear interpolation was applied to the data for beryllium and carbon (References 6 and 20). Two other exceptions are the atomic numbers 16 and 23, which were chosen because the tables that are obtained by linear interpolation on these numbers give values close to those found by Clarke and Trubey (Reference 18) for ordinary and magnetite concrete, respectively.

TABLE 17. DOSE BUILD-UP FACTORS FOR BORON: EQUIVALENT ATOMIC NO. = 5

Linear Interpolation, H-C

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	2.94	7.73	34.80	150.29	459.57	1583.44	3531.40
.50	1.00	2.54	6.03	21.30	70.45	171.10	451.50	861.00
1.00	1.00	2.20	4.41	11.80	29.20	51.20	99.45	159.00
2.00	1.00	1.89	3.24	6.65	12.15	18.40	28.25	36.75
3.00	1.00	1.77	2.70	4.60	7.50	10.20	14.50	18.00
4.00	1.00	1.73	2.30	3.70	5.75	6.95	10.00	12.25
6.00	1.00	1.65	2.05	3.00	4.10	5.05	6.00	7.00
8.00	1.00	1.57	1.85	2.60	3.40	4.05	4.70	5.15
10.00	1.00	1.45	1.75	2.25	3.00	3.35	4.00	4.40

Log-Log Interpolation, H-C

.25	1.00	2.93	7.50	31.79	117.72	337.25	1052.64	2275.07
.50	1.00	2.53	5.90	19.96	60.58	141.28	354.19	664.14
1.00	1.00	2.20	4.36	11.37	27.37	47.57	91.66	145.64
2.00	1.00	1.89	3.22	6.53	11.82	17.96	27.63	36.08
3.00	1.00	1.77	2.69	4.56	7.43	10.09	14.44	18.00
4.00	1.00	1.72	2.29	3.69	5.72	6.93	10.00	12.27
6.00	1.00	1.64	2.04	2.99	4.10	5.04	6.02	7.03
8.00	1.00	1.57	1.84	2.60	3.40	4.05	4.72	5.18
10.00	1.00	1.44	1.74	2.24	3.00	3.35	4.02	4.42

TABLE 18. DOSE BUILD-UP FACTORS FOR LITHIUM HYDRIDE: EQUIVALENT ATOMIC NO. = 5.75

Linear Interpolation, Be-C

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	2.87	6.76	26.27	88.07	247.68	764.25	1651.46
.50	1.00	2.49	5.45	17.02	47.54	108.18	265.12	494.25
1.00	1.00	2.17	4.13	10.15	23.35	40.10	76.54	120.75
2.00	1.00	1.88	3.12	6.08	10.76	16.45	25.44	33.56
3.00	1.00	1.76	2.62	4.38	7.13	9.60	14.12	18.00
4.00	1.00	1.71	2.22	3.62	5.56	6.84	10.00	12.44
6.00	1.00	1.61	2.01	2.92	4.10	5.01	6.15	7.30
8.00	1.00	1.52	1.81	2.60	3.40	4.09	4.92	5.49
10.00	1.00	1.41	1.71	2.21	3.00	3.39	4.15	4.70

Log-Log Interpolation, Be-C

.25	1.00	2.87	6.67	25.16	76.71	205.79	586.83	1234.50
.50	1.00	2.49	5.40	16.52	43.99	97.60	231.17	425.89
1.00	1.00	2.17	4.10	9.99	22.67	38.75	73.65	115.81
2.00	1.00	1.88	3.11	6.03	10.64	16.28	25.20	33.30
3.00	1.00	1.76	2.62	4.36	7.10	9.56	14.10	18.00
4.00	1.00	1.71	2.22	3.62	5.55	6.83	10.00	12.45
6.00	1.00	1.61	2.01	2.92	4.10	5.01	6.16	7.31
8.00	1.00	1.52	1.81	2.60	3.40	4.09	4.93	5.50
10.00	1.00	1.41	1.71	2.21	3.00	3.39	4.16	4.71

TABLE 19. DOSE BUILD-UP FACTORS FOR OXYGEN: EQUIVALENT ATOMIC NO. = 8.0

Linear Interpolation, C-Al

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	2.81	6.09	20.38	57.30	144.75	393.95	814.99
.50	1.00	2.45	4.97	13.85	34.64	73.40	168.09	306.00
1.00	1.00	2.12	3.82	8.73	19.03	32.06	60.04	93.86
2.00	1.00	1.84	2.95	5.53	9.66	14.69	22.84	30.73
3.00	1.00	1.72	2.52	4.15	6.75	9.19	13.71	17.91
4.00	1.00	1.65	2.17	3.49	5.36	6.82	10.03	12.76
6.00	1.00	1.55	1.96	2.84	4.09	5.14	6.71	8.26
8.00	1.00	1.45	1.77	2.53	3.41	4.24	5.45	6.43
10.00	1.00	1.37	1.66	2.18	3.00	3.56	4.61	5.52

Log-Log Interpolation, C-Al

.25	1.00	2.80	5.95	18.68	51.19	121.24	316.61	641.06
.50	1.00	2.44	4.85	12.96	31.70	64.58	144.09	259.29
1.00	1.00	2.11	3.75	8.34	17.83	29.77	55.16	85.97
2.00	1.00	1.83	2.90	5.38	9.40	14.22	22.16	30.04
3.00	1.00	1.71	2.49	4.10	6.67	9.11	13.62	17.89
4.00	1.00	1.63	2.15	3.45	5.31	6.83	10.04	12.83
6.00	1.00	1.53	1.94	2.82	4.09	5.18	6.81	8.40
8.00	1.00	1.44	1.75	2.51	3.42	4.27	5.53	6.55
10.00	1.00	1.35	1.64	2.17	3.00	3.60	4.68	5.62

TABLE 20. DOSE BUILD-UP FACTORS FOR SULPHUR: EQUIVALENT ATOMIC NO. = 16.0

Linear Interpolation, Al-Fe

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	2.57	4.75	11.28	27.76	54.24	125.80	239.39
.50	1.00	2.28	3.97	8.66	19.24	34.35	70.32	121.29
1.00	1.00	1.99	3.21	6.30	12.43	20.05	35.68	54.85
2.00	1.00	1.75	2.57	4.51	7.87	11.67	18.45	26.02
3.00	1.00	1.62	2.28	3.72	6.07	8.62	13.12	18.02
4.00	1.00	1.51	2.05	3.18	4.99	6.93	10.35	14.00
6.00	1.00	1.40	1.82	2.67	4.08	5.61	8.41	11.39
8.00	1.00	1.32	1.65	2.34	3.46	4.69	7.01	9.55
10.00	1.00	1.26	1.52	2.08	3.01	4.05	6.07	8.49

Log-Log Interpolation, Al-Fe

.25	1.00	2.50	4.51	10.37	24.47	46.30	102.99	189.01
.50	1.00	2.25	3.86	8.25	17.92	31.48	63.10	106.70
1.00	1.00	1.97	3.18	6.19	12.15	19.56	34.72	53.24
2.00	1.00	1.75	2.55	4.47	7.80	11.59	18.36	25.93
3.00	1.00	1.61	2.27	3.70	6.05	8.61	13.15	18.11
4.00	1.00	1.51	2.04	3.16	4.98	6.95	10.42	14.13
6.00	1.00	1.40	1.81	2.66	4.08	5.64	8.50	11.54
8.00	1.00	1.32	1.64	2.33	3.46	4.72	7.09	9.67
10.00	1.00	1.26	1.51	2.07	3.00	4.07	6.14	8.57

TABLE 21. DOSE BUILD-UP FACTORS FOR VANADIUM: EQUIVALENT ATOMIC NO. = 23

Linear Interpolation, Al-Fe

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	2.21	3.68	7.87	17.32	31.48	67.26	120.27
.50	1.00	2.07	3.36	6.79	13.96	23.75	45.88	75.31
1.00	1.00	1.90	2.99	5.66	10.87	17.35	30.52	46.35
2.00	1.00	1.76	2.47	4.24	7.43	11.13	17.85	25.38
3.00	1.00	1.57	2.19	3.57	5.92	8.54	13.38	18.78
4.00	1.00	1.47	1.97	3.07	4.93	7.06	10.95	15.40
6.00	1.00	1.36	1.75	2.61	4.12	5.90	9.45	13.71
8.00	1.00	1.29	1.59	2.26	3.48	4.96	8.05	11.97
10.00	1.00	1.22	1.45	1.99	2.99	4.26	7.10	11.23

Log-Log Interpolation, Al-Fe

.25	1.00	2.16	3.51	7.23	15.12	26.30	52.84	89.21
.50	1.00	2.04	3.27	6.49	13.03	21.75	40.96	65.55
1.00	1.00	1.90	2.96	5.58	10.66	16.99	29.80	45.15
2.00	1.00	1.76	2.46	4.21	7.39	11.07	17.79	25.31
3.00	1.00	1.57	2.18	3.56	5.90	8.53	13.41	18.84
4.00	1.00	1.46	1.96	3.06	4.93	7.07	11.00	15.51
6.00	1.00	1.35	1.74	2.60	4.13	5.92	9.52	13.83
8.00	1.00	1.28	1.58	2.25	3.48	4.98	8.12	12.06
10.00	1.00	1.21	1.44	1.98	2.99	4.28	7.16	11.30

TABLE 22. DOSE BUILD-UP FACTORS FOR CHROMIUM: EQUIVALENT ATOMIC NO. = 24

Linear Interpolation, Al-Fe

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	2.13	3.40	6.93	14.29	24.62	48.86	81.69
.50	1.00	2.02	3.20	6.31	12.55	20.83	38.94	61.91
1.00	1.00	1.89	2.94	5.51	10.50	16.71	29.27	44.28
2.00	1.00	1.76	2.45	4.18	7.34	11.01	17.72	25.24
3.00	1.00	1.56	2.17	3.54	5.88	8.53	13.44	18.93
4.00	1.00	1.46	1.96	3.05	4.92	7.08	11.07	15.68
6.00	1.00	1.35	1.73	2.59	4.13	5.96	9.65	14.12
8.00	1.00	1.28	1.57	2.25	3.49	5.01	8.25	12.38
10.00	1.00	1.21	1.43	1.97	2.99	4.30	7.29	11.67

Log-Log Interpolation, Al-Fe

.25	1.00	2.16	3.53	7.38	15.83	28.23	58.90	103.25
.50	1.00	2.04	3.27	6.52	13.21	22.23	42.38	68.74
1.00	1.00	1.89	2.95	5.57	10.65	16.97	29.78	45.13
2.00	1.00	1.76	2.46	4.21	7.37	11.05	17.77	25.28
3.00	1.00	1.56	2.18	3.55	5.89	8.53	13.42	18.88
4.00	1.00	1.46	1.96	3.06	4.93	7.07	11.03	15.60
6.00	1.00	1.35	1.74	2.60	4.13	5.94	9.59	14.04
8.00	1.00	1.28	1.58	2.25	3.48	4.99	8.20	12.31
10.00	1.00	1.21	1.44	1.98	2.99	4.29	7.25	11.62

TABLE 23. DOSE BUILD-UP FACTORS FOR NICKEL: EQUIVALENT ATOMIC NO. = 28.0

Linear Interpolation, Fe-Sn

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	2.02	3.12	6.10	12.09	20.30	39.16	64.02
.50	1.00	1.95	3.01	5.74	11.11	18.10	33.17	51.87
1.00	1.00	1.85	2.84	5.25	9.86	15.59	27.08	40.71
2.00	1.00	1.74	2.41	4.08	7.13	10.70	17.27	24.62
3.00	1.00	1.54	2.13	3.48	5.80	8.46	13.48	19.18
4.00	1.00	1.44	1.93	3.01	4.90	7.13	11.37	16.43
6.00	1.00	1.33	1.71	2.56	4.14	6.10	10.30	15.90
8.00	1.00	1.26	1.55	2.22	3.50	5.16	9.05	14.75
10.00	1.00	1.20	1.41	1.94	2.99	4.42	7.95	14.15

Log-Log Interpolation, Fe-Sn

.25	1.00	1.99	3.05	5.82	11.18	18.24	33.88	53.21
.50	1.00	1.93	2.95	5.55	10.52	16.84	30.17	46.18
1.00	1.00	1.84	2.82	5.17	9.64	15.13	26.07	38.91
2.00	1.00	1.74	2.40	4.06	7.08	10.60	17.09	24.36
3.00	1.00	1.54	2.13	3.46	5.78	8.44	13.48	19.21
4.00	1.00	1.44	1.92	3.01	4.90	7.14	11.41	16.52
6.00	1.00	1.33	1.70	2.56	4.14	6.12	10.35	15.88
8.00	1.00	1.26	1.54	2.21	3.50	5.19	9.07	14.50
10.00	1.00	1.19	1.41	1.93	2.99	4.44	7.98	13.87

TABLE 24. DOSE BUILD-UP FACTORS FOR COPPER: EQUIVALENT ATOMIC NO. = 29.0

Linear Interpolation, Fe-Sn

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	1.99	3.06	5.94	11.71	19.59	37.66	61.42
.50	1.00	1.93	2.96	5.62	10.81	17.55	32.05	50.00
1.00	1.00	1.84	2.82	5.18	9.70	15.28	26.47	39.71
2.00	1.00	1.74	2.40	4.05	7.08	10.60	17.10	24.38
3.00	1.00	1.54	2.13	3.46	5.78	8.43	13.47	19.22
4.00	1.00	1.44	1.92	3.00	4.90	7.15	11.45	16.65
6.00	1.00	1.33	1.70	2.55	4.14	6.13	10.50	16.50
8.00	1.00	1.26	1.54	2.21	3.50	5.21	9.32	15.62
10.00	1.00	1.19	1.41	1.93	2.99	4.46	8.16	15.02

Log-Log Interpolation, Fe-Sn

.25	1.00	1.96	2.97	5.56	10.47	16.79	30.54	46.98
.50	1.00	1.90	2.89	5.36	10.00	15.83	27.97	42.29
1.00	1.00	1.83	2.78	5.07	9.38	14.64	25.07	37.23
2.00	1.00	1.73	2.38	4.02	7.00	10.46	16.86	24.02
3.00	1.00	1.53	2.12	3.44	5.75	8.41	13.47	19.26
4.00	1.00	1.44	1.92	2.99	4.89	7.16	11.51	16.77
6.00	1.00	1.33	1.69	2.54	4.14	6.16	10.58	16.48
8.00	1.00	1.26	1.54	2.20	3.50	5.24	9.36	15.26
10.00	1.00	1.19	1.40	1.92	2.99	4.48	8.20	14.63

TABLE 25. DOSE BUILD-UP FACTORS FOR ZIRCONIUM: EQUIVALENT ATOMIC NO. = 40.0

Linear Interpolation, Fe-Sn

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	1.75	2.49	4.28	7.55	11.75	21.14	32.81
.50	1.00	1.73	2.50	4.29	7.54	11.52	19.79	29.47
1.00	1.00	1.74	2.55	4.43	7.85	11.91	19.78	28.76
2.00	1.00	1.65	2.28	3.78	6.44	9.52	15.27	21.72
3.00	1.00	1.50	2.04	3.29	5.52	8.16	13.38	19.68
4.00	1.00	1.41	1.86	2.91	4.86	7.28	12.37	19.03
6.00	1.00	1.29	1.63	2.46	4.16	6.56	12.75	23.10
8.00	1.00	1.22	1.48	2.13	3.54	5.72	12.35	25.25
10.00	1.00	1.16	1.36	1.86	2.99	4.85	10.43	24.65

Log-Log Interpolation, Fe-Sn

.25	1.00	1.69	2.33	3.68	5.73	7.85	11.81	15.01
.50	1.00	1.69	2.38	3.87	6.30	8.96	13.98	18.89
1.00	1.00	1.72	2.49	4.24	7.32	10.88	17.55	24.87
2.00	1.00	1.63	2.26	3.72	6.31	9.27	14.85	21.11
3.00	1.00	1.49	2.02	3.25	5.47	8.11	13.37	19.75
4.00	1.00	1.40	1.85	2.89	4.85	7.31	12.48	19.26
6.00	1.00	1.29	1.62	2.44	4.16	6.61	12.90	23.05
8.00	1.00	1.22	1.47	2.11	3.54	5.78	12.41	24.49
10.00	1.00	1.16	1.35	1.84	2.99	4.90	10.52	23.82

TABLE 26. DOSE BUILD-UP FACTORS FOR HAFNIUM: EQUIVALENT ATOMIC NO. = 72.0

Linear Interpolation, Sn-W

Energy (Mev)	b(mfp) 0.	1.00	2.00	4.00	7.00	10.00	15.00	20.00
.25	1.00	1.23	1.38	1.58	1.73	1.85	2.02	2.13
.50	1.00	1.30	1.55	1.94	2.43	2.90	3.58	4.19
1.00	1.00	1.46	1.87	2.67	3.83	4.99	6.87	8.30
2.00	1.00	1.43	1.88	2.79	4.24	5.54	8.53	11.33
3.00	1.00	1.37	1.76	2.63	4.11	6.09	9.96	14.60
4.00	1.00	1.30	1.64	2.44	4.10	6.37	12.10	20.92
6.00	1.00	1.20	1.44	2.09	3.65	6.34	15.62	35.70
8.00	1.00	1.14	1.33	1.83	3.09	5.47	15.19	41.24
10.00	1.00	1.11	1.25	1.65	2.65	4.70	13.87	38.81

Log-Log Interpolation, Sn-W

.25	1.00	1.22	1.37	1.54	1.65	1.72	1.81	1.88
.50	1.00	1.30	1.53	1.91	2.35	2.77	3.35	3.88
1.00	1.00	1.45	1.86	2.64	3.76	4.85	6.60	7.85
2.00	1.00	1.43	1.87	2.77	4.19	5.45	8.37	11.05
3.00	1.00	1.37	1.75	2.62	4.08	6.04	9.88	14.45
4.00	1.00	1.30	1.63	2.44	4.08	6.34	12.08	20.92
6.00	1.00	1.20	1.44	2.09	3.64	6.33	15.64	35.74
8.00	1.00	1.14	1.33	1.83	3.08	5.45	15.19	41.29
10.00	1.00	1.11	1.25	1.65	2.64	4.69	13.89	38.86

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APPENDIX. WATER, ALUMINUM, AND ORDINARY CONCRETE BUILD-UP FACTORS CALCULATED USING TAYLOR EXPONENTIAL COEFFICIENTS (WITH ERRORS)

Since the user may have compelling reasons for using Taylor exponential build-up factor coefficients, even in cases where they are markedly inaccurate, the following detailed tables are given for the useful materials water, aluminum, and ordinary concrete. Using these tables, a good estimate of the error introduced into a calculation by using Taylor coefficients (e.g., to represent water buildup at 0.55 Mev) may be obtained. The main tables of Taylor coefficients given here fit the middle range of b-values best. Since the coefficient A is large compared to unity in all cases where the errors are extreme, the user may reduce the error at either end of the range (at the expense of more error in the middle) simply by changing the coefficient A in an obvious way. Such coefficients are also given in this Appendix.

TABLE 27. DETAILED EVALUATION OF TAYLOR EXPONENTIAL COEFFICIENT REPRESENTATION OF DOSE BUILD-UP FACTORS FOR WATER

Dose Build-up Factors

Energy (Mev)	b(mfp) 1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	Coefficients A	Alpha 1	Alpha 2
0.50	2.46		4.91		12.90		32.80		63.10		141.00		252.00				
1.00	2.13		3.71		7.68		16.20		27.10		50.40		82.20				
2.00	1.83		2.77		4.88		8.46		12.40		19.50		27.70				
3.00	1.69		2.42		3.91		6.23		8.68		12.80		17.00				
4.00	1.58		2.17		3.34		5.13		6.94		9.97		12.90				
6.00	1.46		1.91		2.76		3.99		5.18		7.09		8.85				
8.00	1.38		1.74		2.40		3.34		4.25		5.66		6.95				
10.00	1.33		1.63		2.19		2.97		3.72		4.90		5.98				

Calculated Dose Build-up Factors (with Percentage Errors) for Minimum Errors at Middle of b-Range

(Mev)		%		%		%		%		%		%		%	A	Alpha 1	Alpha 2
0.50	3.31	34.5	6.12	24.67	13.60	5.5	31.17	-5.0	60.02	-4.8	150.82	7.0	339.86	34.86	98.81319	-0.11604	-0.09594
1.00	2.43	13.9	4.03	8.6	7.84	2.1	15.39	-5.0	25.74	-5.0	51.67	2.5	93.59	13.9	34.17618	-0.08059	-0.04255
2.00	1.92	4.9	2.87	3.7	4.90	0.3	8.25	-2.5	12.04	-2.9	19.59	0.4	29.06	4.9	13.36870	-0.05214	0.01662
3.00	1.72	1.8	2.45	1.0	3.91	0.0	6.17	-1.0	8.51	-1.4	12.67	-1.0	17.27	1.6	11.11000	-0.03550	0.03206
4.00	1.59	0.7	2.18	0.4	3.35	0.4	5.11	-0.3	6.89	-0.8	9.89	-0.8	13.01	0.9	11.16300	-0.02543	0.03025
6.00	1.46	-0.3	1.90	-0.5	2.77	0.2	4.01	0.4	5.19	0.2	7.06	-0.4	8.86	0.1	8.38500	-0.01820	0.04164
8.00	1.37	-0.5	1.73	-0.5	2.41	0.5	3.36	0.6	4.24	-0.2	5.63	-0.6	6.97	0.3	4.63500	-0.02633	0.07097
10.00	1.32	-0.7	1.63	-0.3	2.20	0.4	2.99	0.6	3.72	-0.1	4.86	-0.7	6.00	0.4	3.54500	-0.02991	0.08717

Calculated Dose Build-up Factors (with Percentage Errors) for Minimum Errors at Ends of b-Range

Energy (Mev)	b(mfp) 1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	Coefficients A	Alpha 1	Alpha 2
0.50	2.73	11.2	4.85	-1.2	10.50	-19.0	23.60	-28.0	45.14	-28.4	112.80	-20.0	253.60	0.6	73.20000	-0.11604	-0.09594
0.50	2.55	3.8	4.44	-9.5	9.50	-26.7	21.20	-35.4	40.38	-36.0	100.70	-28.6	225.90	-10.4	65.00000	-0.11604	-0.09594
1.00	2.26	6.0	3.67	-1.0	7.00	-8.5	13.70	-15.6	22.80	-16.0	45.60	-9.5	82.4	0.3	30.00000	-0.08059	-0.04255

TABLE 28. DETAILED EVALUATION OF TAYLOR EXPONENTIAL COEFFICIENT REPRESENTATION OF DOSE BUILD-UP FACTORS FOR ALUMINUM

Dose Build-up Factors

Energy	b(mfp)													Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.00	%	A	Alpha 1	Alpha 2
0.50	2.37		4.24		9.47		21.50		38.90		80.80		141.00				
1.00	2.02		3.31		6.57		13.10		21.20		37.90		58.50				
2.00	1.75		2.61		4.62		8.05		11.90		18.70		26.30				
3.00	1.64		2.32		3.78		6.14		8.65		13.00		17.70				
4.00	1.53		2.08		3.22		5.01		6.88		10.10		13.40				
6.00	1.42		1.85		2.70		4.06		5.49		7.97		10.40				
8.00	1.34		1.68		2.37		3.45		4.58		6.56		8.52				
10.00	1.28		1.55		2.12		3.01		3.96		5.63		7.32				

Calculated Dose Build-up Factors (with Percentage Errors) for Minimum Errors at Middle of b-Range

(Mev)		%		%		%		%		%		%		%	A	Alpha 1	Alpha 2
0.50	2.70	13.9	4.68	10.3	9.62	1.6	20.16	-6.2	35.82	-7.9	79.18	-2.0	157.54	11.7	49.15700	-0.09610	-0.06548
1.00	2.22	10.1	3.57	7.9	6.68	1.6	12.53	-4.3	20.14	-5.0	37.91	0.0	64.37	10.0	48.06200	-0.06207	-0.03865
2.00	1.84	5.0	2.71	3.9	4.58	-0.8	7.73	-4.0	11.33	-4.8	18.52	-0.9	27.57	4.8	16.64140	-0.04680	0.00255
3.00	1.68	2.3	2.37	2.0	3.79	0.2	6.03	-1.8	8.44	-2.4	12.90	-0.7	18.07	2.1	10.58300	-0.04066	0.02514
4.00	1.55	1.4	2.11	1.3	3.23	0.3	4.96	-1.0	6.76	-1.7	10.00	-1.0	13.64	1.8	7.52600	-0.03973	0.03860
6.00	1.43	0.7	1.86	0.5	2.73	1.0	4.05	-0.3	5.42	-1.4	7.85	-1.5	10.57	1.7	5.71300	-0.03934	0.04347
8.00	1.35	0.4	1.69	0.7	2.39	0.7	3.44	-0.2	4.54	-1.0	6.47	-1.3	8.63	1.3	4.71600	-0.03837	0.04431
10.00	1.28	0.0	1.56	0.8	2.13	0.6	3.01	-0.1	3.92	-1.0	5.56	-1.2	7.41	1.2	3.99900	-0.03900	0.04130

Calculated Dose Build-up Factors (with Percentage Errors) for Minimum Errors at Ends of b-Range

Energy	b(mfp)													Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.00	%	A	Alpha 1	Alpha 2
0.50	2.5	5.3	4.2	-0.1	8.6	-9.4	17.80	-17.0	31.6	-18.8	69.6	-13.8	138.30	-1.9	43.00000	-0.09610	-0.06548
1.00	2.1	4.7	3.3	1.0	6.2	-6.0	11.50	-12.1	18.4	-13.0	34.6	-8.6	58.70	0.4	43.70000	-0.06207	-0.03865

TABLE 29. DETAILED EVALUATION OF TAYLOR EXPONENTIAL COEFFICIENT REPRESENTATION OF ENERGY ABSORPTION BUILD-UP FACTORS FOR WATER

Energy Absorption Build-up Factors

Energy (Mev)	b(mfp) 1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	Coefficients A	Alpha 1	Alpha 2
0.50	2.44		4.81		12.50		31.30		59.60		130.00		232.00				
1.00	2.07		3.59		7.59		15.5		25.6		46.7		72.3				
2.00	1.85		2.82		4.99		8.67		12.90		20.00		28.60				
3.00	1.74		2.52		4.10		6.57		9.12		13.40		17.90				
4.00	1.59		2.18		3.37		5.18		7.01		10.10		13.00				
6.00	1.46		1.89		2.76		3.98		5.18		7.07		8.83				
8.00	1.38		1.74		2.42		3.36		4.28		5.70		7.00				
10.00	1.31		1.60		2.13		2.88		3.60		4.73		5.76				

Calculated Energy Absorption Build-up Factors (with Percentage Errors) for Minimum Errors at Middle of b-Range

(Mev)		%		%		%		%		%		%		%	A	Alpha 1	Alpha 2
0.50	3.26	33.5	5.99	24.5	13.18	5.4	29.78	-4.9	56.64	-5.0	139.62	7.4	309.17	33.3	58.77966	-0.11812	-0.08478
1.00	2.41	16.5	3.98	10.9	7.66	1.0	14.79	-4.6	24.34	-4.9	47.59	1.9	84.00	16.2	30.99818	-0.76930	-0.03497
2.00	1.94	4.7	2.91	3.3	5.00	0.2	8.48	-2.2	12.43	-3.6	20.25	1.3	29.92	4.6	22.08190	-0.04212	-0.00064
3.00	1.77	1.6	2.54	0.8	4.11	0.1	6.51	-0.9	9.00	-1.3	13.36	-0.3	18.06	0.9	16.32600	-0.02728	0.02080
4.00	1.60	0.5	2.19	0.6	3.38	0.4	5.16	-0.3	6.96	-0.8	9.99	-1.1	13.14	1.1	11.33000	-0.02527	0.03027
6.00	1.46	-0.2	1.90	0.6	2.76	0.0	3.99	0.1	5.15	-0.5	7.03	-0.6	8.88	0.6	6.28000	-0.02610	0.05658
8.00	1.38	-0.2	1.74	-0.0	2.43	0.2	3.38	0.5	4.26	-0.5	5.66	-0.8	7.04	0.5	4.31400	-0.02914	0.07839
10.00	1.30	-0.6	1.59	-0.5	2.14	0.5	2.90	0.6	3.60	-0.1	4.70	-0.7	5.78	0.3	3.61000	-0.02790	0.07990

Calculated Energy Absorption Build-up Factors (with Percentage Errors) for Minimum Errors at Ends of b-Range

Energy (Mev)	b(mfp) 1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	Coefficients A	Alpha 1	Alpha 2
0.50	2.71	11.1	4.8	-0.6	10.20	-18.3	22.70	-27.3	43.0	-27.9	105.4	-18.9	232.8	0.3	44.00000	-0.11812	-0.08478
0.50	2.52	3.6	4.4	-9.0	9.20	-26.3	20.40	-34.9	38.4	-35.6	93.8	-27.8	206.9	-10.8	39.00000	-0.11812	-0.08478
1.00	2.23	7.9	3.6	0.5	6.80	-10.1	13.10	-15.8	21.4	-16.4	41.7	-10.8	73.4	1.6	27.00000	-0.07693	-0.03497

TABLE 30. DETAILED EVALUATION OF TAYLOR EXPONENTIAL COEFFICIENT REPRESENTATION OF ENERGY ABSORPTION BUILD-UP FACTORS FOR ALUMINUM

Energy Absorption Build-up Factors

Energy	b(mfp)														Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	A	Alpha 1	Alpha 2
0.50	2.61		4.92		11.40		26.90		49.20		104.00		185.00				
1.00	2.15		3.64		7.40		15.00		23.20		44.10		69.10				
2.00	1.80		2.74		4.93		8.63		12.80		20.20		28.30				
3.00	1.66		2.37		3.88		6.35		8.94		13.40		18.20				
4.00	1.54		2.09		3.24		5.05		6.93		10.20		13.50				
6.00	1.40		1.81		2.63		3.92		5.27		7.62		9.92				
8.00	1.31		1.62		2.26		3.25		4.28		6.10		7.88				
10.00	1.25		1.51		2.02		2.83		3.70		5.22		6.74				

Calculated Energy Absorption Build-up Factors (with Percentage Errors) for Minimum Errors at Middle of b-Range

(Mev)		%		%		%		%		%		%		%	A	Alpha 1	Alpha 2
0.50	3.10	18.9	5.58	13.5	11.89	4.3	25.68	-4.5	46.72	-5.0	106.98	2.9	219.91	18.9	76.57370	-0.09956	-0.07533
1.00	2.38	10.7	3.91	7.4	7.46	0.8	14.24	-5.0	23.17	-0.1	44.37	0.6	76.51	10.7	59.31546	-0.06398	-0.04261
2.00	1.89	5.1	2.83	3.3	4.84	-1.8	8.24	-4.5	12.15	-5.1	19.97	-1.1	29.72	5.0	35.91120	-0.03671	-0.01282
3.00	1.70	2.3	2.41	1.7	3.89	0.2	6.23	-1.8	8.75	-2.2	13.34	-0.5	18.48	1.6	28.58100	-0.02343	0.00073
4.00	1.55	0.6	2.11	0.7	3.24	0.1	5.01	-0.7	6.87	-0.9	10.15	-0.5	13.69	1.4	25.36400	-0.01800	0.00361
6.00	1.40	0.3	1.81	0.1	2.64	0.5	3.92	0.0	5.24	-0.5	7.55	-0.9	9.99	0.7	19.77700	-0.01543	0.00516
8.00	1.31	0.1	1.63	0.4	2.27	0.2	3.25	0.0	4.27	-0.2	6.05	-0.9	7.93	0.6	17.52800	-0.01421	0.00366
10.00	1.25	0.2	1.51	-0.2	2.03	0.5	2.84	0.3	3.69	-0.4	5.18	-0.8	6.78	0.6	12.40700	-0.01695	0.00351

Calculated Energy Absorption Build-up Factors (with Percentage Errors) for Minimum Errors at Ends of b-Range

Energy	b(mfp)														Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	A	Alpha 1	Alpha 2
0.50	2.78	6.7	4.9	-0.7	10.2	-10.3	21.9	-18.6	39.7	-19.3	90.6	-12.9	185.90	0.5	64.50000	-0.09956	-0.07533
1.00	2.25	4.6	3.6	-0.2	6.8	-7.5	13.0	-13.5	21.0	-9.3	40.2	-8.8	69.20	0.2	53.50000	-0.06398	-0.04261

TABLE 31. DETAILED EVALUATION OF TAYLOR EXPONENTIAL COEFFICIENT REPRESENTATION OF DOSE BUILD-UP FACTORS FOR ORDINARY CONCRETE AT LOW ENERGIES

Dose Build-up Factors

Energy	b(mfp)														Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	A	Alpha 1	Alpha 2
0.50	2.25		3.94		8.58		18.9		33.7		69.1		119.0				
1.00	1.97		3.18		6.22		12.2		19.6		35.0		53.6				
Calculated Dose Build-up Factors (with Percentage Errors) for Minimum Errors at Middle of b-Range																	
0.50	2.56	13.8	4.37	10.9	8.84	3.0	18.25	-3.5	32.0	-5.0	69.3	0.3	135.0	13.5	66.34600	-0.08797	-0.06717
1.00	2.15	9.3	3.40	7.4	6.30	1.5	11.70	-4.0	18.7	-4.7	34.8	-0.6	58.6	9.3	28.54000	-0.06635	-0.02881
Calculated Dose Build-up Factors (with Percentage Errors) for Minimum Errors at Ends of b-Range																	
Energy	b(mfp)														Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	A	Alpha 1	Alpha 2
0.50	2.37	5.5	3.96	0.5	7.9	-8.0	16.1	-14.5	28.2	-16.3	60.9	-11.9	118.5	-0.4	58.00000	-0.08797	-0.06717
1.00	2.05	4.2	3.20	0.8	5.8	-6.0	10.8	-11.6	17.1	-12.6	31.8	-9.1	53.5	-0.1	26.00000	-0.06635	-0.02881

TABLE 32. DETAILED EVALUATION OF TAYLOR EXPONENTIAL COEFFICIENT REPRESENTATION OF ENERGY ABSORPTION BUILD-UP FACTORS FOR ORDINARY CONCRETE AT LOW ENERGIES

Energy Absorption Build-up Factor

Energy	b(mfp)														Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	A	Alpha 1	Alpha 2
0.50	2.54		4.74		10.90		24.8		44.9		93.5		162.0				
1.00	2.09		3.50		7.02		13.9		22.7		40.7		62.5				
Calculated Energy Absorption Build-up Factors (with Percentage Errors) for Minimum Errors at Middle of b-Range																	
0.50	3.00	18.2	5.34	12.7	11.20	2.9	23.8	-3.9	42.7	-4.9	95.4	2.0	191.40	18.0	64.89000	-0.09620	-0.06874
1.00	2.31	10.6	3.76	7.4	7.09	1.0	13.4	-3.8	21.5	-5.1	40.6	-0.1	69.17	10.7	40.10600	-0.06522	-0.03494
Calculated Energy Absorption Build-up Factors (with Percentage Errors) for Minimum Errors at Ends of b-Range																	
Energy	b(mfp)														Coefficients		
(Mev)	1.0	%	2.0	%	4.0	%	7.0	%	10.0	%	15.0	%	20.0	%	A	Alpha 1	Alpha 2
0.50	2.71	6.8	4.71	-0.5	9.7	-10.7	20.5	-17.3	36.6	-18.5	81.5	-12.8	163.3	0.8	55.00000	-0.09620	-0.06870
1.00	2.20	4.4	3.50	-0.5	6.5	-7.6	12.1	-12.7	19.5	-14.2	36.6	-9.9	62.3	-0.4	36.00000	-0.06520	-0.03490

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