LETTERS TO THE EDITORS

Additional Exponential Representations of Gamma-Ray Build-Up Factors

Additional exponential representations of gamma-ray build-up factors have been developed for application in shield design which are of the form proposed by Taylor(*1*)

$$B(b) = Ae^{-\alpha_1 b} + (1-A)\, e^{-\alpha_2 b}. \quad (1)$$

Here $B(b)$ is the build-up factor for a point isotropic source at a penetration of b mean free paths and A, α_1, and α_2, are parameters which are functions of energy and material obtained by fitting the moments method results(*2*).

The parameters A, α_1, and α_2 have been tabulated for dose rate build-up factors for several materials and for energy absorption build-up factors for iron and water(*3*). Additional parameters have been evaluated, using moments method results for dose rate in uranium and energy absorption in aluminum, tin, and lead for gamma-ray energies between 0.5 and 10 Mev, and are presented in Table I. The worst errors listed are for 10 mean free paths or less since the procedure starts (A and $-\alpha_1$ are determined) by fitting the build-up factors at greater penetrations. For energy absorption in aluminum, the worst error indicated for energies less than 3 Mev is that at 1 mean free path. Shown in parentheses are the errors when the results at 1 mean free path are excluded.

For a given gamma-ray energy, A, α_1, and α_2 show a smooth variation as a function of atomic number. The build-up factors obtained using interpolated parameters (A, α_1, and α_2) for dose in tungsten compare favorably with build-up factors interpolated directly from moments

TABLE I

PARAMETERS FOR EXPONENTIAL REPRESENTATION OF GAMMA-RAY BUILD-UP FACTORS

Energy (Mev)	0.5	1.0	2.0	3.0	4.0	6.0	8.0	10.0
				Uranium—Dose Rate				
A	1.48	1.90	2.98	2.38	2.00	1.00	0.66	0.49
$-\alpha_1$	0.0225	0.0436	0.039	0.0708	0.0922	0.157	0.187	0.202
α_2	0.312	0.298	0.130	0.103	0.069	0.07	0.116	0.093
Worst error (%)	1.1	2.7	3.6	3.8	2.8	1.1	3.0	4.0
				Aluminum—Energy absorption				
A	16.8	10.6	7.2	4.90	4.35	3.30	2.78	2.42
$-\alpha_1$	0.12	0.0937	0.0684	0.0656	0.0566	0.055	0.0521	0.0512
α_2	0.0418	0.0652	0.0970	0.133	0.123	0.122	0.121	0.115
Worst error (%)	45(2.8)	23(8.5)	15.7(6.9)	9.5(5.9)	6.6(5.2)	4.4	3.2	3.0
				Tin—Energy absorption				
A	7.3	8.5	6.9	6.48	4.23	1.59	0.94	0.698
$-\alpha_1$	0.0562	0.0592	0.0626	0.0574	0.0755	0.129	0.156	0.169
α_2	0.144	0.0962	0.0839	0.0477	0.0310	0.0146	0	0.0713
Worst error (%)	2.6	7.3	11	10	7.4	2.6	3.7	3.9
				Lead—Energy absorption				
A	2.09	4.51	6.51	7.20	2.718	0.778	0.365	0.173
$-\alpha_1$	0.035	0.0377	0.0377	0.048	0.0875	0.166	0.206	0.235
α_2	0.450	0.161	0.0549	0	0	0.0526	0	−0.0304
Worst error (%)	2.6	3.4	2.5	1.5	2.4	0.9	2.0	0.9

TABLE II

DOSE BUILD-UP FACTOR FOR TUNGSTEN FOR 6 MEV GAMMA RAYS

Mean free paths	Interpolated values of moments method results	Values using Eq. (1) and interpolated parameters
1	1.20	1.21
4	2.02	2.08
7	3.50	3.64
10	6.01	6.03
15	15.1	14.5
20	35.3	35.0

method results, as can be seen in Table II. Comparisons at other values of atomic number and at other energies indicate that interpolated values of the parameters reproduce both dose rate and energy absorption build-up factors to within an average error of 5% and a maximum error of 20%.

REFERENCES

1. J. J. Taylor, Application of gamma-ray build-up data to shield design, WAPD-RM-217 (January, 1954).
2. H. Goldstein and J. E. Wilkins, Jr., Calculations of the penetration of gamma rays. NYO-3075 (June 30, 1954).
3. H. Goldstein, "Fundamental Aspects of Reactor Shielding." Addison-Wesley, Reading, Massachusetts, 1959.

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Re: "Thermal Neutron Flux Depression by Absorbing Foils" and "Flux Perturbations by Thermal Neutron Detectors"

Having received a number of useful comments about these two papers (*1*, *2*), the authors would like to point out some corrections and limits of applicability of the two methods.

In the first paper, (*1*) the last line of paragraph 6 on page 301 should read . . . "identical with the $\frac{3}{4}$ term in Eq. (7) as long as $g \gg 1$." In Figs. 1, 2, and 3 the ordinates should all be scaled up by a factor of 10, i.e., they should run from 7.6–8.6, 1.8–2.3, and 3.0–5.5 respectively. Equation (40) should read:

$$\frac{\bar{\phi}}{\phi_0} = \frac{[\frac{1}{2} - E_3(\tau)]/\tau}{1 + [\frac{1}{2} - E_3(\tau)] \cdot g_S\left(a, \frac{L}{\lambda}\right) \cdot \dfrac{g_v(L/\lambda,\ \tau)}{g_S(a = \infty, L/\lambda)}}$$

It should be noted that the variational method of the first paper should give exactly correct results for the cases of coins with very large radii. On the other hand, for zero radii coins Eq. (30) is zero although this does not give the expected flux ratio of 1.0 when inserted in Eq. (40). Thus for zero or small radii the equation above breaks down. However, this failure is due to the fact that the self-shielding factor $[\frac{1}{2} - E_3(\tau)]/\tau$ is computed assuming that the foil radius a is much greater than its thickness t. One may avoid this difficulty by using the self-shielding factor computed by Skyrme for the case $a \backsim t$. In that case, one would employ the expression $\tau\{1 - \tau\,[A(g) - \frac{1}{2} \ln \sigma\tau]\}$ in place of $[\frac{1}{2} - E_3(\tau)]$ in the equation above. $A(g)$, according to Skyrme, is given by

$$\text{for} \qquad A(g) = \tfrac{3}{4} + 1/12\,\pi\, g^3 + O(1/g^4)$$
$$g = a \textstyle\sum_{ad} \gg 1$$

and

$$A(g) = 1/(\pi\, g) - \tfrac{1}{2} E_1(2g) + \tfrac{1}{2}\,(1 - \ln 2) + O(g)$$

for $g \ll 1$. Since these equations for $A(g)$ were derived assuming $\tau \ll 1$, such an approximation has not the domain of validity possessed by the corrected form of Eq. (40).

The integral method of the second paper suffers from just the opposite difficulty. For very small radii coins the method works very well since integration over a very small volume of smooth functions proceeds with no difficulties. However, integration over large radii coins with a large number of radial points rapidly becomes very time-con-

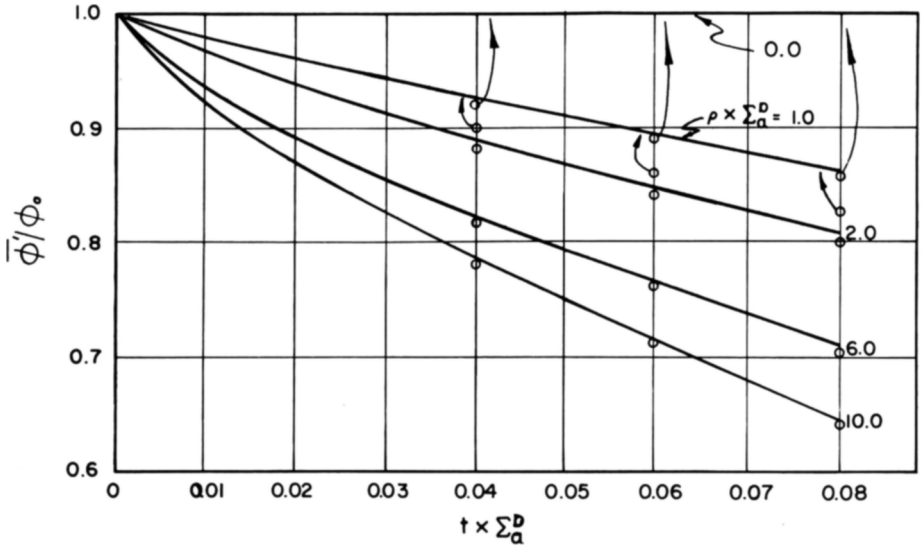

Fig. 1. The average normalized scalar flux in a coinshaped detector in water for various radii ρ and thicknesses as calculated by the variational and the integral methods. O variational method; —— integral method.