Letters to the Editor

Concrete Buildup Factors Based on the American National Standard for Flux-to-Dose-Rate Conversion

It has been traditional for gamma-ray buildup factors used for radiation protection purposes to be based on the type of dose known as "exposure" or some closely related concept such as "air kerma." This convention has persisted so long because "exposure" (used in its narrow sense) has been usually accepted as an adequate basis of radiological hazard for x-ray and gamma-ray photons.

With the publication of the American National (ANSI) Standard[1] "Neutron and Gamma-Ray Flux-to-Dose-Rate Factors," a positive step has been taken to get away from the exposure concept toward the more realistic one of the maximum dose equivalent in an idealized tissue phantom, in assessing radiation hazards from these two types of penetrating radiation. It is tempting to suggest, as some have done, that the buildup factors for x-ray and gamma-ray photons should be recalculated in the context of this new standard approach to biological dose and dose-rate calculations. Unfortunately, these factors are not entirely consistent with what is recommended by the International Commission on Radiation Units and Measurements (ICRU), also a standard setting entity, in that the phantom prescribed by the latter organization is a sphere,[2] whereas the phantom visualized in the ANSI standard is a slab. (The ICRU calls the concept based on the spherical phantom a "dose equivalent index.") The numerical differences in the factors under the two different approaches are probably not great; but before undertaking a large new program of buildup-factor calculations, the ANSI standard should be revised to be consistent with the ICRU specification. It is understood that research workers are already considering the problem of photon fluence-to-dose-equivalent-index conversion factors based on the ICRU sphere, and results should become available shortly.

Meanwhile, in the interim it is possible to use the ANSI Standard as the basis for a temporary adjustment to the old buildup factors. For example, Shure[3] has provided correction factors for the point source/buildup factors for water, iron, and lead originally given by Goldstein and Wilkins.[4] In similar fashion, we have calculated corrections over a limited energy range and for limited penetration distances to buildup factors for concrete provided by Eisenhauer and Simmons[5] (see Table I.)

TABLE I

Ratio of "Standard Biological Dose" Buildup Factor to Air Kerma Buildup Factor for Point Source in Concrete

	Energy Group of Photon Source (MeV)		
mfp	8 to 10	4 to 5	1.5 to 2
1	1.04	1.05	1.07
2	1.05	1.07	1.11
4	1.06	1.08	1.16
7	1.06	1.09	1.16

The method of calculation was very similar to that of Shure and involved the folding of ANISN flux calculations for a point source into the conversion factors provided in the ANSI Standard. The results are quite comparable to those of Shure, and generally fall between his results for water and for iron. They are somewhat closer to his results for water, as one would expect since the average Z of concrete is closer to that of water than to the Z of iron.

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[1] "Neutron and Gamma-Ray Flux-to-Dose Rate Factors," American National Standard ANSI/ANS-6.1.1-1977 (N666), American Nuclear Society, La Grange Park, Illinois (Mar. 17, 1977).

[2] "Radiation Quantities and Units," ICRU Report 19, International Commission on Radiation Units and Measurements, Washington, D.C. (July 1, 1971).

[3] K. SHURE, *Nucl. Sci. Eng.*, **69**, 532 (1979).

[4] H. GOLDSTEIN and J. E. WILKINS, Jr., "Calculations of the Penetration of Gamma Rays," NYO-3075, Nuclear Development Associates (1954).

[5] C. M. EISENHAUER and G. L. SIMMONS, *Nucl. Sci. Eng.*, **56**, 263 (1975).

Comment on "Concrete Buildup Factors Based on the American National Standard for Flux-to-Dose-Rate Conversion"

Chilton and Brown have raised two issues in their Letter.[1] We will take their latter point first and agree that correction

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[1] A. B. CHILTON and R. W. BROWN, "Concrete Buildup Factors Based on the American National Standard for Flux-to-Dose-Rate Conversion," *Nucl. Sci. Eng.*, **73**, 301 (1980).

factors for the published buildup factors are welcome in that they provide information consistent with the American National (ANSI) Standard. The question in regard to the "dose equivalent index," H_I, is more profound. This quantity, the maximum dose equivalent within a 30-cm-diam tissue sphere, was defined by the International Commission on Radiation Units and Measurements in 1971, but it appears to us that the industry has not as yet reached a consensus as to its application. Because the expression of the industry's position is an important input in the course of the development and approval of a standard, this question will be considered when this ANSI standard (ANSI/ANS-6.1.1-1977) is reviewed. By then, conversion factors based on the recommendations of the National Committee on Radiation Protection and Measurement or other competent authority should be available to those involved in the review and revision of the standard.

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Polynomial Expression for the Neutron Escape Probability from an Absorbing Body

In a recent paper,[1] an approximate expression for the escape probability was derived in the form

$$P(\tau) = \frac{1 - e^{-\tau}}{\tau} - A\tau e^{-\tau} = P_0(\tau) + P_A(\tau) \ ,$$

where τ is the optical mean chord length of the body and A is chosen so that the approximation be exact for $\tau = 1$. The validity of this approximation was demonstrated by the examples of the simplest geometries such as sphere, slab, and cylinder. Then, Lux et al.[2] considered $A = A(\tau)$ as a function of τ instead of being constant. In this way, they further improved the results when compared with exact results for slab and cylinder. After all these improvements, the maximum error in the probabilities is ~0.7%.

TABLE I

The Coefficients for Sphere, Slab, and Infinite Solid Cylinder

Coefficients	Sphere	Slab	Cylinder
G_0	1.018916	0.981945	0.964132
G_1	-0.783758	-0.916012	-0.226278
G_2	0.536125	0.354657	-2.153280
G_3	-1.008946	-0.138498	4.240849
G_4	-3.336077	-1.177880	-5.079923
G_5	9.212776	1.340848	2.261080
G_6	-5.177525	-0.513780	0
G_7	-8.921067	0.842021	0
G_8	13.664571	-1.977204	0
G_9	-5.207047	1.211139	0

Since the neutron escape probability from an absorbing body plays a very important role in the reactor physics calculations, the need arises to calculate this probability as accurately as possible without spending much computer time. An effort was made in this direction, and it was found that this probability can be expressed in terms of a polynomial. This expression is in terms of $\Sigma\bar{l}/(1 + \Sigma\bar{l})$, where Σ is the total macroscopic cross section and $\bar{l}$ is the mean chord length of

TABLE II

Relative Errors (%) of Different Approximations to the Escape Probability in the Case of a Sphere

τ	P(exact)	Wigner et al.	Reference 1[a]	Reference 1[b]	Polynomial
0.2	0.8960	-7.0	0.01	-0.01	0.10
0.4	0.8069	-11.40	0.07	-0.13	~0
0.6	0.7304	-14.43	0.14	-0.13	0
0.8	0.6643	-16.36	0.24	-0.08	0
1.0	0.6070	-17.63	0.35	0.00	0
2.0	0.4110	-18.79	1.07	0.69	0
3.0	0.3024	-17.33	1.65	1.36	0
4.0	0.2363	-15.36	1.92	1.74	0
5.0	0.1929	-13.58	1.89	1.79	0
6.0	0.1626	-12.12	1.68	1.62	0
7.0	0.1403	-10.91	1.45	1.42	0
8.0	0.1233	-9.89	1.21	1.21	0
9.0	0.1099	-9.01	1.03	1.03	0
10.0	0.0991	-8.27	0.87	0.87	0

[a] $A = 0.0625$.
[b] $A = 0.0684$.

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[1] Y. A. CHAO and A. S. MARTINEZ, *Nucl. Sci. Eng.*, **66**, 254 (1978).

[2] I. LUX and I. VIDOVSZKY, *Nucl. Sci. Eng.*, **69**, 442 (1979).