American Nuclear Society

gamma -ray attenuation coefficients and buildup factors for engineering materials

an American National Standard

published by the
American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA

ANSI/ANS-6.4.3-1991

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American National Standard for Gamma-Ray Attenuation Coefficients and Buildup Factors for Engineering Materials

Secretariat
American Nuclear Society

Prepared by the
American Nuclear Society
Standards Committee
Working Group ANS-6.4.3

Published by the
American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60525 USA

Approved August 26, 1991
by the
American National Standards Institute, Inc.

American National Standard

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Published by

American Nuclear Society
555 North Kensington Avenue, La Grange Park, Illinois 60525 USA

Printed in the United States of America

Foreword

(This foreword is not a part of American National Standard for Gamma-Ray Attenuation Coefficients and Buildup Factors for Engineering Materials, ANSI/ANS-6.4.3-1991.)

It came to the attention of Subcommittee ANS-6, Radiation Protection and Shielding, of the American Nuclear Society Standards Committee, following the 1979 Three-Mile Island accident, that gamma-ray attenuation data for several needed materials, especially for the lower energies, was lacking. It was also known by the subcommittee that data available in the literature are not always in good agreement. Therefore, it was felt by the subcommittee that an evaluated standard reference data set would be useful to engineers involved in radiation accident response as well as for routine shield design.

During 1980, Working Group ANS-6.4, charged with the oversight of standards on shielding materials, organized a meeting to consider developing the needed standard. At this meeting the first scope was drafted and a decision made that a new working group, later designated ANS-6.4.3, be formed to develop the proposed standard. Following this meeting, a chairman was identified and members with special expertise and experience were recruited.

Early in the work, the group decided that the best set of available buildup factors were those computed at the National Bureau of Standards, now the National Institute of Standards and Technology (NIST), only a fraction of which had been published. These covered a broad energy range and covered the range of materials needed from atomic number 4 (Be) to 92 (U). Before accepting the data, however, the group undertook a validation process by making Monte Carlo and other transport theory calculations and comparing with reported values in the literature. During the validation process many changes were made, and data for additional materials were obtained from calculations performed in Japan and India. In 1989, the buildup factors for the heavy elements (Mo and above) were recalculated in Japan to make use of the latest cross section data and to obtain detailed results above the absorption edges.

In view of the fact that there are several standard gamma-ray response functions and the whole subject is under review by the International Commission on Radiological Protection, the working group that developed American National Standard for Neutron and Gamma-Ray Fluence-to-Dose Factors, ANSI/ANS-6.1.1-1991, and others, the group decided to present exposure and energy absorption buildup factors.

It was recognized by the working group that most uses of buildup factors are for point kernel calculations that assume radiation leakage from a shield and energy absorption in a phantom. This configuration is a significant departure from the infinite medium that is assumed when determining the buildup factors, especially in the case of a heavy-element shield such as lead. Therefore, a table of correction factors is presented to provide a means of taking this into account. Data for correcting the buildup factors for coherent scattering became available in 1989, and tables for this purpose have also been added to the standard.

The attenuation and energy absorption coefficients were relatively easy to obtain; they were obtained from published and unpublished data of the NIST Photon and Charged-Particle Data Center, a unit of the National Standard Reference Data System.

The membership of Working Group ANS-6.4.3 is as follows:

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The roster of ANS-6, Radiation Protection and Shielding, at the time of its approval of this standard was as follows:

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Consensus Committee N17, Research Reactors, Reactor Physics, Radiation Shielding, and Computational Methods, had the following membership at the time it reviewed and approved this standard:

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Gamma-Ray Attenuation Coefficients and Buildup Factors for Engineering Materials

1. Scope

This standard presents evaluated gamma-ray elemental attenuation coefficients and single-material buildup factors for selected engineering materials for use in shielding calculations of structures in power plants and other nuclear facilities. The data cover the energy range 0.015-15 MeV and up to 40 mean free paths (mfp). These data are intended to be standard reference data for use in radiation analyses employing point-kernel methods.

2. Definitions

Attenuation coefficient. Of a substance, for a parallel beam of specified radiation: the quantity μ, in the expression μdx for the fraction removed by attenuation in passing through a thin layer of thickness dx of that substance. It is a function of the energy of the radiation. As dx is expressed in terms of length, mass per unit area, moles or atoms per unit area, μ is called the linear, mass, molar, or atomic attenuation coefficient, respectively.

Energy absorption coefficient. Of a substance, for a parallel beam of specified radiation: the quantity μ_{en} in the expression $\mu_{en}dx$ for the fraction of energy absorbed in passing through a thin layer of thickness dx of that substance. It is a function of energy of the radiation. As dx is expressed in terms of length, mass per unit area, moles per unit area, or atoms per unit area, μ_{en} is called the linear, mass, molar, or atomic energy absorption coefficient.

> **Note:** It is that part of the attenuation coefficient resulting from energy absorption only and is equal to the product of the energy transfer coefficient and $1-g$, where g is the fraction of the energy of secondary charged particles that is lost to bremsstrahlung in the material.

Buildup factor. In the passage of radiation through a medium, the ratio of the total value of a specified radiation quantity at any point to the contribution to that value from radiation reaching the point without having undergone a collision.

Buildup factor, exposure, B_D. A photon buildup factor in which the quantity of interest is exposure. The energy response function is that of absorption in air.

Buildup factor, energy absorption, B_A. A photon buildup factor in which the quantity of interest is the absorbed or deposited energy in the shield medium. The energy response function is that of absorption in the material.

Correction factor, shield-tissue interface. A correction factor to be applied to the basic infinite-medium exposure buildup factor to correct for the scattering in a tissue phantom after emerging from a shield.

Fitting function, Taylor. A buildup factor function of distance from the source in the form:

$$B(E,x) = A_1\exp(-a_1x)+A_2\exp(-a_2x) \qquad (1)$$

where x is the distance from the source in mean free paths and parameters A_1, a_1, and a_2 are functions of the attenuating medium and the source energy, E. The fourth parameter, A_2, is constrained to equal $1 - A_1$.

Fitting function, G-P (Geometric Progression). A buildup factor function of distance from the source in the form:

$$B(E,x) = 1+(b-1)(K^x-1)/(K-1) \quad \text{for } K\neq1 \text{ and}$$
$$B(E,x) = 1+(b-1)x \quad \text{for } K=1 . \qquad (2)$$

$$K(E,x) = cx^a + d\,[\tanh(x/X_k - 2) - \tanh(-2)] \,/\, [1 - \tanh(-2)] , \qquad (3)$$

where x is the distance from the source in mean free paths and b is the value of the buildup factor at 1 mfp. The variation of parameter K with penetration represents the photon dose multiplication and change in the shape of the spectrum from that at 1 mfp, which determined the value of b. Equation (3) represents the dependence of K on x; a, c, d, and X_k are fitting parameters that