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American Nuclear Society

neutron and gamma-ray fluence-to-dose factors

an American National Standard

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Table 6

Polynomial Coefficients in the Analytic Fit of $h_E(E)$ for Neutrons*

Neutron Energy Bounds	Coefficients C_0	C_1	C_2	C_3	C_4
AP Exposure[a]					
$E \leq 0.01$ MeV	3.430895E+00[b]	7.725710E-01	9.834081E-02	4.903466E-03	8.149667E-05
$E > 0.01$ MeV	4.952167E+00	6.644235E-01	-1.017445E-01	-1.496004E-03	3.636748E-03
PA Exposure					
$E \leq 0.2$ MeV	3.687778E+00	1.240448E+00	1.888331E-01	1.164621E-02	2.516630E-04
$0.2 < E \leq 1$ MeV	3.965468E+00	1.012777E+00	3.608077E-01	-5.689570E-02	-2.047265E-01
$E > 1$ MeV	3.965468E+00	1.078553E+00	3.607919E-01	-4.288176E-01	9.411842E-02
LAT Exposure					
$E \leq 0.01$ MeV	8.677172E-01	2.290812E-01	2.457221E-02	7.646448E-04	0.0
$E > 0.01$ MeV	3.577644E+00	1.005248E+00	~~-4.227422E+00~~ -4.227422E-02	-2.054736E-02	4.461858E-04
ROT Exposure					
$E \leq 0.01$ MeV	2.436148E+00	6.502219E-01	8.819417E-02	4.752092E-03	8.782611E-05
$E > 0.01$ MeV	4.216783E+00	8.470534E-01	-6.771566E-02	-1.213208E-02	1.829400E-03

*Polynomial coefficients in analytic fit: $h_E(E) = 10^{-12} \times \exp(C_0 + C_1X + C_2X^2 + C_3X^3 + C_4X^4)$ Sv-cm², E = energy (MeV), and X = ln(E).
[a]If the orientation of the receptor with respect to the radiation field is unknown, AP exposure geometry should be used.
[b]Read as 3.430895×10^{00}.

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American National Standard for Neutron and Gamma-Ray Fluence-to-Dose Factors

Secretariat
American Nuclear Society

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Foreword

(This Foreword is not a part of American National Standard for Neutron and Gamma-Ray Fluence-to-Dose Factors, ANSI/ANS-6.1.1-1991, but is included for information purposes only.)

In 1977, the American Nuclear Society (ANS) published American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors (ANSI/ANS-6.1.1-1977), which provided the means for computing dose equivalent values pertinent to radiation protection from externally incident neutron and gamma-ray flux values calculated in the process of shield analysis and design. That standard, unchanged and in effect for 12 years, has been revised as recommended by Working Group ANS-6.1.1. The revision process has awaited the availability of internationally accepted data to replace those originally recommended by the National Council on Radiation Protection and Measurement (NCRP) and incorporated in the previous standard. Such data, conforming to definitions propounded by the International Commission on Radiological Protection (ICRP) and the International Committee on Radiation Units and Measurements (ICRU), have since become available and have been considered as replacements for the previous standard.

This standard provides guidelines for computing the biologically relevant dosimetric quantity in neutron and gamma-ray radiation fields pertinent to shield design. The data presented in this standard relate fluence to a quantity that is considered to be proportional to biological damage in human tissue and that is used as the basis for limiting the radiation exposure to keep the risk of occurrence of stochastic, somatic effects to the individual to within acceptable levels. That quantity is the effective dose equivalent received by an individual over a specified time interval. Tables are presented containing factors relating fluence to effective dose equivalent for monoenergetic gamma rays and neutrons, and procedures are specified for representing the tabulated data in analytical form and for computing the effective dose equivalent due to gamma rays and neutron fields having broad spectral distributions.

The membership of Working Group ANS-6.1.1 is as follows:

D. C. Kaul, Chairman, *Science Applications International Corporation*
M. Ehrlich *National Institute of Standards and Technology*
D. R. Harris, *Rensselaer Polytechnic Institute*
W. C. Hopkins, *Bechtel Power Corporation*
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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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A. Weitzberg, Vice Chairman

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Contents

Figures

Tables

Neutron and Gamma-Ray Fluence-to-Dose Factors

1. Scope

This standard presents data recommended for computing the biologically relevant dosimetric quantity in neutron and gamma-ray radiation fields. Specifically, this standard is intended for use by shield designers to calculate effective dose equivalent. Values are given for effective dose equivalent per unit fluence for neutron energies from 1 eV to 14 MeV and for gamma-ray energies from 0.01 to 12 MeV. Establishing maximum permissible exposure limits is outside the scope of this standard.

2. Purpose

The purpose of this standard is to assist those involved in the design or analysis of radiation facilities by providing the means to determine whether calculated fluence levels satisfy radiation exposure limits recommended by the International Commission on Radiological Protection (ICRP) or specified by regulatory agencies. The limits to which this standard is relevant are those intended to restrict the occurrence of stochastic, somatic effects to the individual to an acceptable level. Use of this standard in assessing the likelihood of nonstochastic effects, typically applications in which the dose equivalent is far in excess of occupational exposure guidelines, is not recommended, nor is this standard intended for use in testing or calibrating instruments.

3. Definitions

Definitions given below are based on information contained in Radiation Quantities and Units, International Committee on Radiation Units and Measurements (ICRU) Report 33, [1][1] and Recommendations of the International Commission on Radiological Protection, ICRP Publication 26 [2]. These definitions are adequate for the purposes of this standard, although not necessarily complete.

absorbed dose (D). The quotient of $d\bar{\varepsilon}$ by $d\bar{m}$, where $d\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass $d\bar{m}$:

$$D = \frac{d\bar{\varepsilon}}{d\bar{m}} \quad . \tag{1}$$

The special name for the unit of absorbed dose is the gray (Gy):

$$1\,\mathrm{Gy} = 1\,\mathrm{J \cdot kg^{-1}} \quad . \tag{2}$$

dose equivalent (H). The product of the absorbed dose (D), the quality factor (Q), and modifying factor (N):

$$H = DQN \quad , \tag{3}$$

where N is the product of all modifying factors specified by the ICRP. Such factors might, for example, take account of absorbed dose rate and fractionalization. At present, the ICRP has assigned the value of 1 to the factor N. The special name for the unit of dose equivalent is the sievert (Sv):

$$1\,\mathrm{Sv} = 1\,\mathrm{J \cdot kg^{-1}} \quad . \tag{4}$$

quality factor (Q). A factor that approximately accounts for the effect of the microscopic distribution of absorbed energy on biological detriment. It is defined as a function of the collision stopping power (L_∞) in water at the point of interest. Values of Q as a function of L_∞ can be obtained from a full logarithmic interpolation of data in Table 1.

The data given in this standard are based on the L_∞–Q relationship given in Table 1. They *do not* account for the position taken by the ICRP in Statement from the 1985 Paris Meeting of the International Commission on Radiological Protection, ICRP Publication 45 [3], in which an immediate increase by a factor of two is recommended in the quality factor for neutrons. This recommendation is under review by national and international commissions on radiation protection and is subject to change during the projected life of this standard.

effective dose equivalent (H_E). The sum of products, of the form

[1]Numbers in brackets refer to corresponding numbers in Section 7, References.