DATA FOR THE CALCULATION OF ALBEDOS FROM CONCRETE IRON, LEAD, AND WATER FOR PHOTONS AND NEUTRONS

by

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ABSTRACT

This report tabulates newly evaluated parameters for several empirical differential dose albedo formulas. The albedos considered are (1) two approximations for the photon albedo, (2) a new approximation for the neutron albedo, and (3) the secondary-photon albedo for incident neutrons. Albedo data is provided for four materials: concrete, iron, lead, and water. Unlike previous compilations of albedo data, modern dosimetric units have been employed. Data are presented for (1) the ambient dose equivalent $H^*(10\text{mm})$ and (2) the effective dose equivalent for anteroposterior (AP) illumination of the ICRP anthropomorphic phantom.

The data in this report has been extracted from the appendices of the dissertation *Calculation of the Albedos for Neutrons and Photons* by R.C. Brockhoff, Kansas State University, 2003.

Chapter 1

Introduction

The calculation of how radiation incident on a surface is reemitted through the surface toward some point of interest is a frequently encountered problem in radiation shielding. Transport techniques are generally required for detailed estimation of reflected doses. But under certain circumstances a simplified approach based on the albedo concept can be used with great effect. These conditions are[1] (1) that the displacement on the surface between the entrance and exit of the radiation is small compared to the problem dimensions, (2) that the reflecting medium is optically thick, and (3) that scattering between the radiation source and surface and between the surface and point of interest is negligible. The use of albedo techniques is central to many radiation streaming codes and has been widely used as an alternative to much more expensive transport calculations.

Key to the albedo technique is the availability of either a large set of albedo data or, preferably, an empirical formula that approximates the albedo over the range of source energies and incident and exit radiation directions involved in a particular problem. Previously proposed neutron and photon albedo approximating formulas have been based on limited energy-angular ranges, a single reflecting material, old cross section data, and, most important, obsolete fluence-to-dose response functions. In this report, differential neutron dose albedo functions, based on modern cross section and response function data, are presented.

1.1 Previous Albedo Studies

1.1.1 The Photon Albedo

One of the first approximate albedo formulas was the two-parameter semi-empirical approximation devised by Chilton and Huddleston to model the photon albedo.[2] The parameters, which depend on the initial photon energy, were obtained by fits to results of Monte Carlo calculations for concrete,[3] and later extended to water, iron, and lead.[4] Because of the limited accuracy of the Chilton-Huddleston formula, Chilton later proposed an improved seven parameter formula[5] that is still widely used in shielding calculations.

Although these two approximations see wide use, the parameters for them are available for very few source energies. Additionally, these approximations are based on air kerma rather than dose equivalent responses, although the albedo, being the ratio of two doses, is for photons relatively insensitive to the type of dose employed.

1.1.2 The Neutron Albedo

There is much data in the literature for neutron albedos and for the associated secondary-photon doses. Early significant contributions included those of Maerker and Muckenthaler,[6] who performed both detailed calculational and experimental evaluations for concrete, and by Allen, Futterer and Wright[7] who make albedo calculations for monoenergetic fast neutrons incident on a variety of materials. French and Wells[8] derived an empirical formula for the azimuthally averaged data of Allen et al., which is restricted to incident directions of less than 70 degrees from the surface normal. Also using the same fast-neutron data, Song, Huddleston and Chilton proposed a fast-neutron formula with azimuthal dependence.[9] Maerker and Muckenthaler in their 1965 study also proposed a 24-parameter formula obtained by a fit to their calculated concrete albedos.[6] Extensive computerized sets of fast-neutron albedo data are also available, such as, SAIL,[10] BREEZE-II,[11] and that of Wang.[12]

A neutron albedo approximation for intermediate-energy neutrons (0.5eV to 0.2 MeV) has been proposed by Coleman et al. for steel-reinforced concrete.[13] Formulas for the thermal-neutron albedo have been proposed by Wells[14] and Maerker and Muckenthaler,[15] and an analytical one-speed transport result by Chandrasekhar[16] has also been studied for use as a thermal-neutron albedo formula.[15,17]

Although not strictly part of the albedo concept, the emergence of secondary gamma photons from a surface upon which neutrons are incident has be studied by Wells,[14] Selph[18] and Cavanaugh,[19] and formulas for the secondary-photon albedo from concrete have been suggested by Wells[14] and Maerker and Muckenthaler.[15] For a more detailed survey of previous studies on the neutron albedo, the reader is referred to Selph[18] and Shultis and Faw.[1]

1.2 Need for Revised Neutron Albedos

Unlike compilations or formulas for albedos for monoenergetic incident photons, it is difficult to interpolate similar neutron albedos because of the many resonances in the neutron cross sections. To account for the usual continuous distribution of fast neutrons, it is preferable to obtain albedos for incident neutrons in various contiguous fast-neutron energy bins. However, many previous fast-neutron albedo studies are for monoenergetic sources and hence are of limited practical utility.

Moreover, most neutron albedo approximating formulas are based on very old neutron interaction data, on only a few incident directions, and are available for only a single reflecting material. For example, Maerker and Muckenthaler's 24-parameter, fast-neutron, dose albedo formula for concrete is based on only four incident angles (45, 50, 75 and 85 degrees with respect to the surface normal) and on old cross section data and the Henderson (tissue kerma) fluence-to-dose response function available before 1962.[6]

Perhaps the most important reason to revisit the neutron albedo is that, unlike photon albedos, neutron dose albedos are extremely dependent on the dose response function used. Previous neutron albedo work has mostly been based on air kerma or the Henderson (tissue kerma) response function. But as seen from Fig. 1, these response functions are quite different from modern neutron response functions. Moreover, the ratios between these various response functions are strong functions of the neutron energy, and, hence, dose albedos calculated with one response function cannot be converted to another by simply multiplying by a single conversion constant (as often can be done for most photon dose albedos).

1.3 THEORY

To calculate the albedo one first finds the current of particles emerging from the plane surface of a homogeneous halfspace that is illuminated uniformly by a plane-parallel, monoenergetic beam of radiation incident on the surface at an angle θ_o with respect to the surface normal $\mathbf{n}$ (see Fig. 2). The incident particle flow, in dose units, across a unit area of the surface is related to the incident fluence Φ_o as

$$J_n^{in} = |\mathbf{n} \bullet \mathbf{\Omega}_o| \Phi_o R(E_o) = \Phi_o \cos\theta_o R(E_o), \tag{1.1}$$

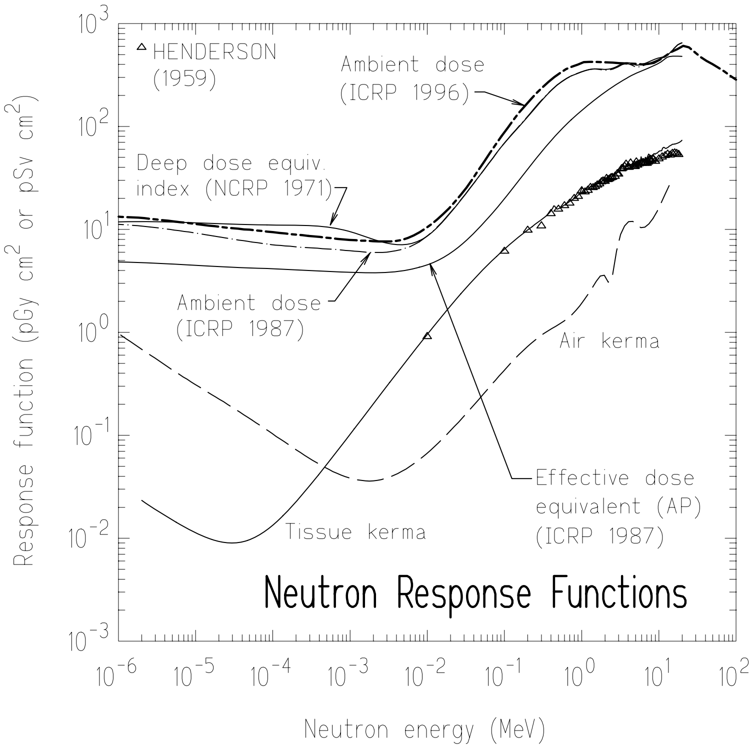

Figure 1.1: Comparison of modern neutron dose functions with kerma response functions, used in much early albedo work. Sources are: Henderson,[20] tissue/air kerma,[1] NCRP-1971,[21] ICRP-1987,[22] ICRP-1996.[23]

where $R(E_o)$ is the fluence-to-dose conversion factor (response function) for the incident radiation of energy E_o. The total flow or current out of a unit area of the surface in a unit solid angle about the direction $\mathbf{\Omega}(\theta, \psi)$, $\mathbf{n}\bullet\mathbf{\Omega} > 0$, again in dose units, can be expressed as

$$J_n^{out}(\theta, \psi) = \int_0^{E_{\max}} J_n^{out}(E, \theta, \psi) R(E)\, dE = \int_0^{E_{\max}} \Phi(E, \theta, \psi) \cos\theta R(E)\, dE, \tag{1.2}$$

where $J_n^{out}(\theta, \psi, E)$ and $\Phi(\theta, \psi, E)$ are, respectively, the angular energy-dependent flow and fluence at the surface, and where $E_{\max}$ is the maximum particle energy.

The differential dose albedo is defined as the ratio of the outward to inward flows,[2] namely,[1,24]

$$\alpha_D(E_o, \theta_o; \theta, \psi) \equiv \frac{J_n^{out}(\theta, \psi)}{J_n^{in}}, \tag{1.3}$$

which, from Eq. (1.2), yields

$$\alpha_D(E_o, \theta_o; \theta, \psi) = \frac{1}{J_n^{in}} \int_0^{E_{\max}} J_n^{out}(\theta, \psi, E) R(E)\, dE. \tag{1.4}$$

[2] Many early albedo studies used slightly different definitions, such as the ratio of outward flow to incident fluence or the ratio of outward fluence to incident fluence, and it is important to distinguish among them when comparing different albedo results.

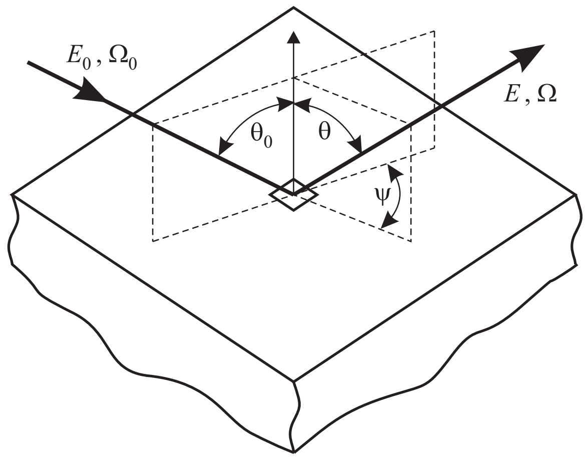

Figure 1.2: Particles incident and reflected from the surface of a halfspace.

For photon albedos, the incident energy E_o is a specified discrete energy. Because photon cross sections vary smoothly with energy above the K-edge, photon albedos are readily interpolated between tabulated energies. By contrast, the many resonances in the neutron albedo preclude interpolation of albedos between discrete energies. For neutrons the albedo of Eq. (1.4) is averaged over various fast-neutron energy intervals or a fission spectrum to obtain albedos for a corresponding range of incident neutron energies by selecting the incident neutron energy from the appropriate distribution.

1.4 MCNP Calculation of the Albedo

We used the general purpose Monte Carlo code MCNP[25] to calculate the albedo reflected from thick slabs of various materials. In particular, we considered a homogeneous cylindrical slab surrounded by a vacuum. The incident neutrons were modeled by a point monodirectional source positioned just inside the center of the circular scoring (reflecting) surface. This was done to facilitate scoring because all particles crossing this surface must be outgoing (reflected) particles. The slab thickness and radius were sufficiently large (1000 cm) so that negligible numbers of neutrons were transmitted through the slab or radial surface. The energy of the source neutrons was sampled uniformly over an energy group or from a fission neutron distribution.

For the albedo calculation, the outgoing current from the reflecting surface must be tallied in terms of the outgoing polar angle θ and the outgoing azimuthal angle ψ. MCNP provides a surface current tally, called the F1 tally, that scores the number of particles crossing a surface in all directions, namely

$$\text{Tally F1} = \int_A \int_{-1}^{1} \int_0^{2\pi} \int_E J(\vec{r}, E, \theta, \psi) R(E) \; dE \; d\!\cos\theta \; d\psi \; dA. \tag{1.5}$$

where $R(E)$ is a user specified response function. However, by default MCNP does not allow the user to bin this current tally in terms of both θ and ψ. Therefore, the tally was modified through the use of the `TALLYX` user routine. This option, which permits the user to modify a tally, was used here to dissagregate the F1 tally for reflected particles into a set of angular bins or subtallies, each of which corresponded to a small range of the θ and ψ reflection directions.

In this study we used $N_\theta = 9$ intervals equally spaced between 0 and 90° in polar angle and $N_\psi = 18$ intervals equally spaced between 0 and 180° in azimuth. Because the reflected photon field is symmetric about $\psi = 180°$, particles reflected with $\psi > 180°$ can be binned in the corresponding $(360° - \psi)$ bin. Thus a total of $N_\theta \times N_\psi = 162$ angular bins were used. The bin number `ibu` corresponding to a particular value of θ and ψ is

$$\texttt{ibu} = \mathrm{int}\left(\frac{\theta N_\theta}{90}\right) + N_\theta\ \mathrm{int}\left(\frac{\psi N_\psi}{180}\right) + 1. \tag{1.6}$$

To score related quantities, such as the outgoing angles for a particle passing through the surface, the user must specify the scoring bin limits on the "FU card". Here the appropriate FU card would be `FU1 1 160i 162`.

The tallies in each scoring bin are normalized to one source photon and thus represent, in the notation of the previous section,

$$\text{tally bin(i)} = \frac{2}{J_n^{in}} \int_{\Delta\cos\theta_i} \int_{\Delta\psi_i} \int_0^\infty J_n^{out}(E,\theta,\psi) R(E)\, d(\cos\theta)\, d\psi\, dE \tag{1.7}$$

where $\Delta\cos\theta\,\Delta\psi$ is the solid angle covered by bin(i). The factor of 2 in this result arises from the ψ-symmetry used in the binning process. Finally, if θ and ψ are the centroid angles of a bin with a tally denoted by $T(\theta,\psi)$, the differential dose albedo is estimated from

$$\alpha_D(E_o, \theta_o; \theta, \psi) = \frac{T(\theta,\psi)}{2\,\Delta\cos\theta\,\Delta\psi}, \tag{1.8}$$

where $\Delta\cos\theta$ varies from bin to bin. Here E_o is the incident photon energy, or, for neutrons, E_o is replaced by ΔE, the energy distribution from which energies of the incident neutrons are uniformly sampled.

1.5 Results

The MCNP calculated differential dose albedos were used to obtain extensive sets of values for a wide range of incident energies, incident directions, and reflected directions. To make easy use of these results, empirical approximating functions were sought that could accurately reproduce the calculated albedos. The parameters in these empirical albedo functions were estimated by fitting the approximating functions to the MCNP calculated values. A global fit was used that minimized the maximum absolute error between the function and the calculated data.

The range of variables and the materials used in the calculations are summarized below. Then in the following chapters, the empirical approximating functions and tables of their coefficients are presented.

1.5.1 Photon Albedo

In this report, we present more comprehensive sets of parameters for Chilton's two- and seven-parameter photon albedo formulas.[2,5] The MCNP Monte Carlo code was used to obtain albedo data for incident gamma energies of 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.25, 2.0, 4.0, 6.0, 8.0, and 10.0 MeV, for a wide range of incident and reflected directions. The calculated dose albedos were based on three dosimetric response functions, namely, those for exposure, effective dose equivalent (anteroposterior geometry), and ambient dose equivalent. Chilton's two- and seven-parameter formulas were then fit to the MCNP calculated photon albedo values.

The albedo approximating formulas and the the resulting parameters for concrete, lead, iron, and water are presented in Chapter 2. These results have also been published elsewhere.[26]

1.5.2 Neutron Albedo

The MCNP albedo model was also used to calculate the neutron albedo for 9 monodirectional angles of incidence, θ_o, of 5, 15, 25, 35, 45, 55, 65, 75, and 85 degrees on infinite slabs of natural iron, water, natural lead, and NBS 04 concrete. NBS 04 concrete represents "ordinary" concrete as proposed by the American National Standards Institute.[27] The dose albedo was calculated for two response functions, namely the ambient dose equivalent and the effective dose equivalent for anteroposterior geometry.[22] Twelve different incident energy distributions were considered: ten fast-neutron contiguous energy groups with group boundaries of 0.1, 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 6, 8, and 10 MeV, a room-temperature thermal-neutron spectrum, a ^{252}Cf fission neutron spectrum, and monoenergetic 14-Mev neutrons. The MCNP neutron albedo results were then used to find parameters for a new neutron albedo approximation. The new formula and parameter tabulations are presented in Chapter 3.

1.5.3 Secondary-Photon Albedo

The MCNP code was also used to obtain also a set of secondary-photon albedo data based on modern response functions. In general, the secondary-photon albedo is independent of the azimuthal angle as a consequence of the isotropic emission of secondary gamma rays. Also of note is that the magnitude of the secondary-photon albedo is usually considerably less than that of the neutron albedo. Because high accuracy for the secondary-photon albedos is generally not needed, a relatively simple approximation can be used. These MCNP data were used to obtain parameters for a secondary-photon albedo formula proposed by Maerker and Muckenthaler.[6] The results are presented in Chapter 4.

Chapter 2

Parameters for Photon Albedo Approximations

This appendix contains the fit parameters for the approximation of the differential photon albedo data. The first approximation of the differential photon albedo is[2]

$$\alpha_D(E_o, \theta_o; \theta, \psi) = \frac{C(E_o)_e\sigma_{Ce}(E_o, \theta_s) \times 10^{26} + C'(E_o)}{1 + (\cos\theta_o / \cos\theta)}, \tag{2.1}$$

where $C(E_o)$ and $C'(E_o)$ are the fit parameters, and ${}_e\sigma_{Ce}(E_o, \theta)$ is the Klein-Nishina energy scattering cross section per electron given by[1]

$${}_e\sigma_{Ce}(E_o, \theta) = \frac{1}{2} r_e^2 p^2 [1 + p^2 - p(1 - \cos^2\theta)]. \tag{2.2}$$

Here $r_e = 2.8179 \times 10^{-13}$ cm is the classical electron radius and p is the ratio of the incident to final energy of the photon after scattering through an angle θ_s, namely

$$p = \frac{1}{1 + (E_o/m_e c^2)(1 - \cos\theta)}, \tag{2.3}$$

and the scattering angle is determined from[1]

$$\cos\theta_s = \sin\theta_o \, \sin\theta \, \cos\psi - \cos\theta_o \, \cos\theta. \tag{2.4}$$

The second approximation of the differential photon albedo is the seven-parameter approximation by Chilton and Huddleston[5]

$$\alpha_D(E_o, \theta_o; \theta, \psi) = F(E_o, \theta_o; \theta, \psi) \frac{C(E_o)_e\sigma_{Ce}(E_o, \theta) \times 10^{26} + C'(E_o)}{1 + (\cos\theta_o / \cos\theta)(1 + 2E_o \mathrm{vers}\,\theta)^{1/2}}, \tag{2.5}$$

where

$$F(E_o, \theta_o; \theta, \psi) = A_1(E_o) + A_2(E_o)\mathrm{vers}^2\theta_o + A_3(E_o)\mathrm{vers}^2\theta + A_4(E_o)\mathrm{vers}^2\theta_o \mathrm{vers}^2\theta + A_5(E_o)\mathrm{vers}\,\theta_o \mathrm{vers}\,\theta \, \mathrm{vers}\,\psi, \tag{2.6}$$

with the versine defined as $\mathrm{vers}\,\theta = 1 - \cos\theta$.

2.1 Tables of Parameters for Photon Albedos

Tabulated below are tables of parameters need for the albedo approximations of Eqs. (2.1) and (2.5). First a summary of the 4 tables.

- Table 2.1: Parameters for the two-term Chilton-Huddleston approximation given in Eq. (2.1) for the 10-mm $H^*(10)$ ambient dose equivalent albedo. Errors using this formula can exceed 50% in some cases.
- Table 2.2: Parameters for the seven-term Chilton-Huddleston approximation given in Eq. (2.5) of the photon albedo based on the 10-mm $H^*(10)$ ambient dose equivalent. Errors associated with this formula are less than 10% for all cases.
- Table 2.3: Parameters for the seven-term Chilton-Huddleston approximation given in Eq. (2.5) of the exposure albedo. Errors associated with this formula are less than 10% for all cases.
- Table 2.4: Parameters for the seven-term Chilton-Huddleston approximation given in Eq. (2.5) of the photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of photons. Errors associated with this formula are less than 10% for all cases.

Table 2.1: Parameters for the two-term Chilton-Huddleston approximation given in Eq. (2.1) for the 10-mm $H^*(10)$ ambient dose equivalent albedo. Errors using this formula can exceed 50% in some cases.

Energy	Water		Concrete		Iron		Lead	
(MeV)	10^3C	$10^3C'$	10^3C	$10^3C'$	10^3C	$10^3C'$	10^3C	$10^3C'$
0.10	3.83956	156.682	15.0806	53.5702	6.01974	6.30725	-0.99254	71.4260
0.20	12.8933	95.1294	19.5317	56.3968	22.8818	4.52419	2.54139	13.6862
0.40	26.9251	49.4120	31.0515	34.8623	34.9866	10.5355	12.3140	-4.16344
0.60	36.2690	35.5403	38.5117	26.5358	44.7663	10.5212	23.0250	-6.35561
0.80	44.6428	27.7802	46.5630	20.9768	52.9704	9.63214	32.4332	-6.21926
1.00	52.7863	22.5602	54.4830	17.3114	55.7093	8.65893	41.5937	-5.71107
1.25	61.9729	18.5551	65.3668	14.2054	70.5985	7.65120	51.2948	-4.89882
2.00	86.5642	12.6338	86.5215	10.6027	91.4505	7.81777	72.0777	0.65892
4.00	137.182	8.63979	134.941	8.84981	131.920	10.5014	93.2920	7.47707
6.00	172.511	7.47389	162.904	8.47375	148.934	11.5784	107.474	8.80086
8.00	195.014	6.97739	178.589	8.36158	170.405	11.9144	125.587	9.07966
10.00	218.439	6.58747	196.888	8.15070	173.252	11.9926	139.207	9.03810

Table 2.2: Parameters for the seven-term Chilton-Huddleston approximation given in Eq. (2.5) of the photon albedo based on the 10-mm H*(10) ambient dose equivalent. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5	C	C'
				Water			
0.10	1.3617257	-0.6302461	-0.7548435	0.3487884	0.0387338	0.0269001	0.0876417
0.20	1.3799030	-0.6555209	-0.7601835	0.5500521	-0.0479052	0.0305584	0.0632628
0.40	1.5367539	-0.7327976	-0.8710402	0.7666112	-0.0962833	0.0383884	0.0354771
0.60	1.5633930	-0.7458419	-0.9105275	0.7594926	-0.0717221	0.0491238	0.0278394
0.80	1.3804448	-0.6601983	-0.8277516	0.6405534	-0.0277081	0.0676836	0.0269157
1.00	1.5482014	-0.7446776	-0.9601892	0.6874551	0.0190690	0.0722499	0.0208905
1.25	1.1359681	-0.5459062	-0.7307400	0.4956124	0.0435891	0.1192269	0.0250475
2.00	1.3424996	-0.6515288	-0.9310955	0.5441246	0.1503701	0.1538800	0.0166478
4.00	0.8703865	-0.3749605	-0.5999494	0.2264465	0.1610904	0.4219230	0.0229354
6.00	3.1464753	-1.2219207	-2.1183572	0.5183008	0.6429003	0.1588029	0.0064076
8.00	1.4265574	-0.5276517	-0.9715595	0.1799365	0.3220812	0.4445132	0.0145970
10.00	1.7739898	-0.6525564	-1.2111553	0.2015219	0.4378267	0.4105603	0.0122329
				Concrete			
0.10	1.9621245	-0.5219961	-0.7221454	0.3557011	0.0704789	0.0128434	0.0219190
0.20	1.8063321	-0.6451711	-0.7202746	0.5311947	-0.0597505	0.0206374	0.0279548
0.40	1.5832590	-0.6654776	-0.7348977	0.5599818	0.0017012	0.0367782	0.0229049
0.60	1.3728040	-0.5899639	-0.8111057	0.4376957	0.0716138	0.0577440	0.0211169
0.80	2.0684354	-0.9163331	-1.2812262	0.7139508	0.1390697	0.0473738	0.0122853
1.00	1.5654058	-0.6974180	-0.9977901	0.5560148	0.1233789	0.0735547	0.0147291
1.25	1.5428314	-0.6956128	-1.0197941	0.5438550	0.1693153	0.0899439	0.0134019
2.00	0.8340043	-0.3813632	-0.5819863	0.2871745	0.1442294	0.2485217	0.0213318
4.00	1.2842476	-0.5285484	-0.8776104	0.2775152	0.2889089	0.2755386	0.0157605
6.00	1.4202015	-0.5621180	-0.9402475	0.1970816	0.3559883	0.3419013	0.0159622
8.00	0.7881143	-0.3076275	-0.5115098	0.0757433	0.2110672	0.7549249	0.0315733
10.00	2.1564720	-0.8700210	-1.3954837	0.1934908	0.5976625	0.3208531	0.0124725
				Iron			
0.10	5.5554633	1.0639577	-1.4568830	0.1609005	-0.1983818	0.0012109	0.0009521
0.20	1.4104301	0.0910148	-0.2629187	0.1755802	-0.2233651	0.0149810	0.0085231
0.40	2.4059536	-0.6067861	-0.9447265	0.3174070	0.1156774	0.0221123	0.0036179
0.60	1.5671967	-0.5349719	-0.7369135	0.3017382	0.1592063	0.0493866	0.0059864
0.80	1.7113367	-0.6458855	-0.8750434	0.3834039	0.2289272	0.0568578	0.0057884
1.00	0.9652392	-0.3523721	-0.7668976	0.2771355	0.1624708	0.1229448	0.0081734
1.25	4.6244655	-1.9072950	-2.7211661	1.2787578	0.8456823	0.0308826	0.0020409
2.00	1.3508914	-0.5636034	-0.8019336	0.3112480	0.3192191	0.1497107	0.0095091
4.00	2.8376360	-1.1707036	-1.4387863	0.1838764	0.7448482	0.1135459	0.0085831
6.00	2.1302893	-0.9232535	-1.0319384	0.0403568	0.6170256	0.1999437	0.0146281
8.00	1.8565615	-0.8589039	-0.8929193	0.0154593	0.5511765	0.2885945	0.0194317
10.00	2.0916035	-1.0518045	-1.0000926	0.0033478	0.6694216	0.3273868	0.0189695
				Lead			
0.10	4.9584451	-1.7515349	1.6817058	-2.9896727	0.4162037	0.0004766	0.0143503
0.20	9.9692287	4.7407880	-4.5998497	-3.0359361	-0.1646782	0.0001784	0.0016468
0.40	5.4612899	9.9987717	0.4572069	-6.1273360	-4.0829530	0.0009602	0.0002274
0.60	4.6742339	7.5875764	1.6098191	-8.1831169	-1.7704805	0.0028001	-0.0003434
0.80	7.9429183	8.0978727	0.4186038	-9.9881020	-0.0508947	0.0031624	-0.0004100
1.00	9.4371033	5.4510350	-2.1570828	-6.1615019	1.7809757	0.0042821	-0.0004617
1.25	8.4436340	2.4301546	-3.0702102	-3.0727835	2.8598337	0.0071280	-0.0005884
2.00	5.8326950	1.1221220	-2.0970085	-2.2600255	1.0428298	0.0158234	0.0005766
4.00	1.1674039	-0.0791098	-0.3655341	-0.2958221	0.2673976	0.1264428	0.0152532
6.00	1.5988227	-0.3022349	-0.4480048	-0.3851579	0.4220257	0.1256043	0.0147778
8.00	1.8285402	-0.5116981	-0.5637856	-0.4175648	0.5807211	0.1605126	0.0147047
10.00	1.5840275	-0.5389064	-0.5029678	-0.3664431	0.5317907	0.2508782	0.0184704

Table 2.3: Parameters for the seven-term Chilton-Huddleston approximation given in Eq. (2.5) of the exposure albedo. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5	C	C′
				Water			
.10	1.3586096	-.6375931	-.7695049	.3899661	.0145883	.0267671	.0878304
.20	1.3119746	-.5963237	-.6907863	.5735516	-.0942599	.0307274	.0531638
.40	2.3751657	-1.0907757	-1.2960658	1.1615659	-.1706545	.0244888	.0168101
.60	1.3889937	-.6553338	-.8028138	.6573983	-.0406173	.0546596	.0216886
.80	1.2760562	-.6087473	-.7668200	.5936596	-.0016190	.0728110	.0197577
1.00	1.2928964	-.6253337	-.8101136	.6002903	.0407582	.0860538	.0168000
1.25	1.2477628	-.6046895	-.8088509	.5455245	.0839926	.1075425	.0151448
2.00	1.4055955	-.6921571	-.9920601	.6008095	.1996165	.1483493	.0109368
4.00	1.1231061	-.4863828	-.7759666	.2974949	.2386731	.3245291	.0133149
6.00	3.0294442	-1.1916997	-2.0560732	.5288490	.7114194	.1649731	.0051286
8.00	1.7856722	-.6489710	-1.2015064	.2101598	.4266715	.3395813	.0091444
10.00	1.2341602	-.4495656	-.8327988	.1295622	.3215636	.5745404	.0139407
				Concrete			
.10	2.2655728	-.5699605	-.8094482	.4178748	.0371352	.0109453	.0172936
.20	1.6949683	-.5547462	-.5992330	.4844729	-.1185760	.0212689	.0220805
.40	1.3435796	-.5462498	-.5870453	.4172515	.0014407	.0432319	.0183002
.60	2.0517762	-.8899382	-1.2181956	.6655313	.1380137	.0386325	.0089115
.80	1.3569489	-.6065834	-.8535765	.4874073	.1172640	.0712430	.0119902
1.00	1.2707169	-.5789384	-.8286383	.4880147	.1300007	.0900976	.0115133
1.25	1.1994619	-.5583798	-.8252732	.4837535	.1674429	.1156413	.0107967
2.00	1.1460696	-.5423999	-.8252173	.4498914	.2361316	.1824432	.0105941
4.00	.8943326	-.3814032	-.6193812	.2159806	.2297621	.3962142	.0175134
6.00	1.4752746	-.5905619	-.9750111	.2168942	.3996525	.3214980	.0123623
8.00	1.5612684	-.6205544	-1.0273554	.1793928	.4432905	.3752498	.0128803
10.00	1.7613302	-.7129767	-1.1343867	.1604449	.5231102	.3833502	.0124392
				Iron			
.10	9.6973886	2.0314617	-2.3917537	.5836748	-.6181753	.0006778	.0004684
.20	2.6213369	.2920946	-.3399050	.4126295	-.6052557	.0075291	.0032689
.40	2.9527881	-.7034345	-1.1149718	.3670291	.1047058	.0175906	.0012507
.60	1.3318353	-.4635119	-.6337755	.2970995	.1438421	.0567444	.0029731
.80	1.5845419	-.6192812	-.8275853	.4219586	.2350798	.0600989	.0029408
1.00	.8560609	-.3238202	-.6907274	.2788114	.1463488	.1350705	.0038228
1.25	.8312222	-.3633895	-.5089620	.2807025	.1822710	.1696448	.0055290
2.00	1.7017341	-.7499151	-1.0527810	.4817455	.4545143	.1199714	.0051730
4.00	1.6201177	-.6886469	-.8402881	.1445351	.4655863	.1985248	.0124658
6.00	1.9036651	-.8471953	-.9277028	.0622700	.5760846	.2225516	.0138852
8.00	1.2577941	-.5925093	-.6052923	.0195367	.3892324	.4198386	.0242292
10.00	1.5327184	-.7784193	-.7264239	.0119841	.4994223	.4288107	.0219759
				Lead			
.10	9.9930058	.5005251	-1.3326408	-7.3052340	-.5158350	-.0000669	.0100954
.20	9.9903345	7.3380179	-5.2155704	-5.7429957	-1.1180123	.0001337	.0015722
.40	1.9058838	3.9187956	.3808926	-2.3085258	-1.7510639	.0024193	.0005094
.60	6.2633324	9.2629881	1.7181484	-9.9079370	-2.1158881	.0021201	-.0003520
.80	9.9996738	8.2984600	-.7154340	-9.2297382	.1831888	.0026014	-.0004021
1.00	9.2402649	4.6356792	-2.1502395	-5.0332556	1.2051446	.0043080	-.0005219
1.25	6.5889821	1.8161441	-2.2752404	-2.1841023	1.7685664	.0086859	-.0007744
2.00	2.4122825	.4030713	-.8395048	-.7556783	.4094319	.0368162	.0011127
4.00	3.9943926	-.3420753	-1.2751004	-.9044930	.9493059	.0364073	.0039813
6.00	1.6084495	-.3337303	-.4704935	-.3648208	.4448709	.1266170	.0130888
8.00	3.4904120	-1.0128771	-1.0804561	-.7369952	1.1206902	.0806690	.0068046
10.00	6.9024363	-2.4249303	-2.3016055	-1.3538153	2.3941250	.0553177	.0037492

Table 2.4: Parameters for the seven-term Chilton-Huddleston approximation given in Eq. (2.5) of the photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of photons. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5	C	C′
				Water			
.10	1.3863848	-.6021944	-.7171826	.3234895	.0283466	.0247098	.0738141
.20	1.3600616	-.6260421	-.7226266	.5172511	-.0425301	.0302954	.0603193
.40	1.3849024	-.6513189	-.7747734	.6661277	-.0726547	.0424929	.0380556
.60	1.5300970	-.7270820	-.8895122	.7403737	-.0481369	.0493084	.0269095
.80	1.3979789	-.6714219	-.8414668	.6531471	-.0101099	.0663148	.0246149
1.00	1.4442450	-.6977744	-.9016196	.6694142	.0285292	.0763619	.0205698
1.25	1.4845772	-.7184207	-.9558252	.6412585	.0754812	.0905808	.0174668
2.00	1.1956178	-.5879138	-.8415561	.5077073	.1501323	.1734355	.0169447
4.00	.9209459	-.3972970	-.6342779	.2499660	.1745050	.3806726	.0193008
6.00	1.3967237	-.5464413	-.9419938	.2562198	.2925006	.3387830	.0126308
8.00	.8507669	-.3168369	-.5831127	.1279143	.1964527	.6909604	.0210747
10.00	1.6762224	-.6162401	-1.1415220	.2205939	.4153257	.4005162	.0112030
				Concrete			
.10	2.4981828	-.6027542	-.8508686	.4683589	.0125804	.0095899	.0160715
.20	1.5084198	-.5359601	-.5961378	.4421856	-.0467282	.0246392	.0329258
.40	1.6546059	-.6944285	-.7665046	.5874381	.0028519	.0349238	.0222758
.60	1.0050956	-.4346069	-.5964057	.3328788	.0520889	.0773375	.0283235
.80	1.3362553	-.5930037	-.8281368	.4845731	.0893720	.0709798	.0185513
1.00	1.3862212	-.6287217	-.8958863	.5217936	.1213557	.0822386	.0155817
1.25	8.0727272	-3.7132201	-5.4291339	3.0893266	.9708790	.0171347	.0023793
2.00	2.7691715	-1.2898074	-1.9596257	1.0324391	.5020356	.0745726	.0059958
4.00	1.2941645	-.5426044	-.8909731	.3089871	.2989477	.2635290	.0142533
6.00	1.2051110	-.4815509	-.8052397	.1987435	.3081896	.3795641	.0169145
8.00	1.3621567	-.5329902	-.8810573	.1537520	.3576294	.3999539	.0161521
10.00	1.4897641	-.6030415	-.9671048	.1673006	.4129645	.4271814	.0159873
				Iron			
.10	9.5635328	2.1535709	-2.2148628	.6362496	-.8069947	.0006597	.0005589
.20	9.7141228	.6256237	-1.8069834	1.2181344	-1.5413320	.0021738	.0012355
.40	1.8425571	-.4616132	-.7213287	.2511070	.0824877	.0285766	.0051372
.60	1.5590018	-.5325163	-.7339519	.3243350	.1488504	.0483876	.0061268
.80	1.1475514	-.4401372	-.5911158	.2824186	.1505503	.0832173	.0082543
1.00	1.1932141	-.4389158	-.9525264	.3617720	.1939907	.0975341	.0060066
1.25	1.7626988	-.7409958	-1.0463610	.5243955	.3453242	.0801142	.0048411
2.00	1.3437814	-.5720249	-.8118090	.3431905	.3272220	.1495263	.0088745
4.00	.9758293	-.4047108	-.4987890	.0815464	.2562267	.3154349	.0229816
6.00	.9207067	-.4004357	-.4486125	.0377052	.2653546	.4330586	.0307044
8.00	1.3290263	-.6163175	-.6399071	.0349355	.3932230	.3705385	.0241035
10.00	1.5940059	-.8018650	-.7660544	.0352280	.5090408	.3919097	.0221501
				Lead			
.10	2.9842589	-1.0779141	1.0600022	-1.7870783	.2495961	.0007582	.0227627
.20	9.9983883	4.6986628	-4.5690465	-2.9675632	-.1655467	.0001784	.0015685
.40	1.2305186	2.2484958	.1228866	-1.4168386	-.9176817	.0042555	.0009667
.60	5.1412210	8.1284828	1.5626746	-8.4425898	-1.9349260	.0025279	-.0003189
.80	8.3600903	8.4244442	.4146148	-9.9999723	-.2036621	.0029424	-.0003864
1.00	2.8241227	1.6017134	-.6255112	-1.7876376	.4142616	.0140885	-.0015587
1.25	.9164695	.2845178	-.3130300	-.3538649	.2804556	.0635260	-.0052907
2.00	1.0398011	.1929365	-.3709861	-.3683538	.1826298	.0872324	.0030265
4.00	4.1394916	-.3002865	-1.3017610	-.9541165	.9373099	.0339384	.0040030
6.00	1.6543949	-.3188405	-.4651516	-.3532985	.4261338	.1135961	.0130339
8.00	2.0158184	-.5690309	-.6187442	-.4157900	.6314095	.1327159	.0119209
10.00	4.7080259	-1.6174051	-1.5300626	-.9638563	1.5949455	.0778010	.0055569

Chapter 3

Parameters for Neutron Albedo Approximations

This appendix contains the fit parameters for the approximation of the differential neutron dose albedo data. The approximation of the differential neutron dose albedo is[28,29]

$$\alpha_D(\Delta E_o, \theta_o; \theta, \psi) = \frac{H(\kappa_1, \cos\theta_o) H(\kappa_2, \cos\theta)}{1 + K_1(E_o, \theta_o; \theta)/\cos\theta} \sum_{i=0}^{N} B_i P_i(\cos\theta_s), \tag{3.1}$$

where

$$K_1(E_o, \theta_o; \theta) = \sum_{i=0}^{2} \cos^i\theta \sum_{j=0}^{2} A_{ij} \cos\theta_o^j. \tag{3.2}$$

Here $H(\kappa, \cos\theta)$ is Chandrasekhar's H-function.[1,16] An approximation of the H-function that is within 5% for κ between 0.8 and 1.0 can be expressed as

$$H(\kappa, \mu) = \frac{A + B\kappa + C\mu + D\mu^2 + E\mu^3}{1 + F\kappa + G\kappa^2 + H\kappa^3 + I\mu}. \tag{3.3}$$

This approximation was obtained by fitting Eq. (3.3) to actual H-function data. Values for the constants are given in the table below.

Table 3.1: Fit parameters for the Chandrasekhar H Function Approximation of Eq. (3.3)

Parameter	Value
A	0.075272288
B	-0.063133359
C	0.021092012
D	-0.026070382
E	0.009381680
F	-3.179279300
G	3.485739800
H	-1.294988700
I	-0.005750418

3.1 Parameters for the Neutron Albedo Approximation

In this section tables of coefficients for the neutron albedo approximation of Eq. (3.1) are presented. First a summary of the tables.

- Table 3.2: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete. Errors associated with this formula are less than 10% for all cases.

- Table 3.3: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron. Errors associated with this formula are less than 10% for all cases.

- Table 3.4: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead. Errors associated with this formula are less than 10% for all cases.

- Table 3.5: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water. Errors associated with this formula are less than 10% for all cases.

- Table 3.6: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm $H^*(10)$ ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete. Errors associated with this formula are less than 10% for all cases.

- Table 3.7: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm $H^*(10)$ ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron. Errors associated with this formula are less than 10% for all cases.

- Table 3.8: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm $H^*(10)$ ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead. Errors associated with this formula are less than 10% for all cases.

- Table 3.9: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm $H^*(10)$ ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water. Errors associated with this formula are less than 10% for all cases.

- Table 3.10: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete. Errors associated with this formula are less than 10% for all cases.

- Table 3.11: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron. Errors associated with this formula are less than 10% for all cases.
- Table 3.12: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead. Errors associated with this formula are less than 10% for all cases.
- Table 3.13: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water. Errors associated with this formula are less than 10% for all cases.

Table 3.2: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete. Errors associated with this formula are less than 10% for all cases.

	B_0	B_1	B_2	B_3	B_4	B_5
Energy	B_6	B_7	B_8	B_9	B_{10}	B_{11}
(MeV)	B_{12}	$A_{0,0}$	$A_{0,1}$	$A_{0,2}$	$A_{1,0}$	$A_{1,1}$
	$A_{1,2}$	$A_{2,0}$	$A_{2,1}$	$A_{2,2}$	κ_1	κ_2
0.10 to 0.20	0.0367411	0.0095147	0.0098863	0.0068287	0.0033599	0.0015699
	0.0005078	0.0000326	-0.0003710	-0.0001213	0.0001161	0.0000883
	0.0001667	0.0078664	0.5398713	-0.0390681	-0.4691313	0.2199137
	-0.1037968	0.2135760	-0.0122488	-0.1106445	0.8042246	0.9686999
0.20 to 0.40	0.0423712	0.0048673	0.0099964	0.0060542	0.0025969	0.0010120
	0.0006853	0.0007404	0.0005028	-0.0001375	-0.0002423	-0.0000827
	-0.0001289	0.0070957	0.6771135	-0.0543744	-0.3644181	0.0258445
	0.1709625	0.2082043	0.1220717	-0.1023880	0.8229709	0.9727805
0.40 to 0.60	0.0301675	0.0174822	0.0116144	0.0031094	0.0007767	-0.0003406
	-0.0007397	-0.0006530	-0.0004997	-0.0002412	0.0000798	0.0002437
	0.0000221	0.0723953	0.0978213	0.3056866	-0.4293650	-0.0957578
	0.0622070	0.0557796	0.0004394	0.0638993	0.8260067	0.9954453
0.60 to 0.80	0.0422765	0.0195191	0.0099498	0.0060598	0.0028570	0.0016891
	0.0015499	0.0011932	0.0010160	0.0004533	-0.0000350	-0.0008832
	-0.0006331	0.0132923	0.5938434	0.1517493	-0.3174781	0.2454523
	-0.0276932	0.1633691	-0.0901760	-0.2740309	0.8397344	0.9833418
0.80 to 1.00	0.0439186	0.0157430	0.0184362	0.0069378	0.0018952	0.0009476
	-0.0007442	-0.0008260	-0.0004056	-0.0000474	0.0001689	0.0006529
	0.0002836	0.0155157	0.5147689	0.0679360	-0.4384998	0.1593277
	0.1779590	0.3910571	0.0292820	-0.2770177	0.8569101	0.9878104
1.00 to 2.00	0.0533463	0.0267611	0.0334315	0.0096621	0.0048124	0.0008056
	0.0001973	-0.0002943	0.0002056	0.0006993	-0.0005434	-0.0002270
	-0.0004002	-0.0045435	0.9471912	0.0639146	-0.1607181	-0.1815755
	0.1902393	0.1446654	0.1262610	0.4118374	0.9581988	0.9819548
2.00 to 4.00	0.0498237	0.0367688	0.0413227	0.0235396	0.0104825	0.0048196
	0.0018945	0.0004750	0.0000143	0.0000185	-0.0005481	0.0000830
	0.0005681	0.0121344	0.6451692	0.0286664	-0.3308923	-0.0535236
	-0.1325837	0.1665506	0.0376102	0.1100787	0.8094487	0.9718247
4.00 to 6.00	0.0251075	0.0227871	0.0262192	0.0202818	0.0159983	0.0090771
	0.0031501	0.0009347	0.0002043	0.0000857	-0.0000489	0.0001488
	0.0002113	0.0035785	0.4015275	0.0852345	-0.6205468	-0.0135770
	-0.1339852	0.1440857	-0.0719888	0.2645901	0.9034963	0.9926794
6.00 to 8.00	0.0292120	0.0233335	0.0263324	0.0295953	0.0250988	0.0103972
	0.0047369	0.0028073	0.0009665	-0.0001360	-0.0002737	-0.0000945
	-0.0000358	0.0071872	0.5654923	0.0553671	-0.5400554	0.0204622
	0.0841230	0.2979534	-0.0892442	0.0892126	0.8586813	0.9919124
8.00 to 10.0	0.0212160	0.0185849	0.0213830	0.0221647	0.0224562	0.0135541
	0.0075167	0.0040474	0.0007333	-0.0000490	0.0000175	0.0001051
	0.0000355	0.0070916	0.4145974	0.0884066	-0.6457723	0.2549709
	-0.2272040	0.1963066	-0.1284152	0.1762416	0.8439180	0.9848954
thermal	0.0541979	0.0166098	0.0050314	0.0034625	-0.0007054	0.0035282
	-0.0030853	-0.0006300	0.0027495	-0.0002296	0.0005209	0.0000336
	0.0007691	0.0428117	0.5385181	-0.0549625	-0.3687924	-0.1682842
	-0.1106394	0.0708553	-0.0723496	-0.0236882	0.8380482	0.9980718
^{252}Cf	0.0260239	0.0005683	0.0001505	0.0000325	0.0000595	0.0000007
	-0.0000275	0.0000160	-0.0000251	0.0000358	-0.0000162	-0.0000189
	-0.0000354	0.0099893	0.3897155	0.0166041	-0.6168315	0.2982679
	-0.0716184	0.2137052	-0.0661892	0.0484276	0.8569646	0.9923663
14.00	0.0475980	0.0001559	0.0000214	-0.0000664	0.0000548	0.0001023
	0.0000377	0.0000101	-0.0000689	0.0000009	-0.0000311	-0.0000879
	0.0000488	0.0223569	0.4989641	-0.0916818	-0.4625625	0.0667646
	-0.1676700	0.1071829	-0.2856540	0.2362564	0.8321187	0.9933552

Table 3.3: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron. Errors associated with this formula are less than 10% for all cases.

	B_0	B_1	B_2	B_3	B_4	B_5
Energy	B_6	B_7	B_8	B_9	B_{10}	B_{11}
(MeV)	B_{12}	$A_{0,0}$	$A_{0,1}$	$A_{0,2}$	$A_{1,0}$	$A_{1,1}$
	$A_{1,2}$	$A_{2,0}$	$A_{2,1}$	$A_{2,2}$	κ_1	κ_2
0.10 to 0.20	0.0537821	0.0017865	0.0048639	0.0019115	0.0045255	0.0022977
	0.0008683	0.0007441	-0.0003086	0.0005963	0.0003165	0.0004502
	-0.0001300	0.0246777	0.4516944	-0.1270954	-0.4073347	0.6629261
	-0.1184661	0.2479347	0.2815844	-0.4326308	0.8783978	0.9962834
0.20 to 0.40	0.0646326	0.0086021	0.0132017	0.0065028	0.0067316	0.0032212
	0.0016765	0.0014901	0.0004514	0.0001144	-0.0004737	-0.0000104
	-0.0001504	0.0261775	0.5288151	-0.1457721	-0.3122937	0.4753786
	-0.1927494	0.1997239	0.1204702	-0.2217064	0.8109303	0.9880702
0.40 to 0.60	0.0519503	0.0181781	0.0169503	0.0069729	0.0035924	0.0013276
	0.0001314	0.0003312	-0.0004083	-0.0000968	-0.0000028	-0.0000309
	-0.0000520	0.0185948	0.5117475	-0.1082423	-0.3703021	-0.1198960
	-0.0412526	0.0624298	0.1680743	-0.1067455	0.8202116	0.9929994
0.60 to 0.80	0.0671056	0.0116861	0.0228331	0.0065160	0.0029340	0.0012356
	0.0001430	0.0006002	0.0000731	-0.0000025	0.0002633	0.0007497
	0.0006324	0.0281989	0.5423254	-0.1012086	-0.3026381	-0.0819616
	0.0985734	0.1013371	0.0700159	-0.0629955	0.8070648	0.9712664
0.80 to 1.00	0.0477539	0.0234296	0.0254983	0.0082814	0.0020334	0.0016052
	-0.0001570	0.0002696	0.0004464	-0.0002971	-0.0008310	-0.0004763
	-0.0001930	0.0175086	0.4768933	-0.0276307	-0.3423541	-0.0929206
	-0.2813837	-0.0222240	-0.0459232	0.2462069	0.8027924	0.9838462
1.00 to 2.00	0.0454807	0.0212590	0.0334307	0.0165116	0.0075924	0.0030433
	0.0007491	-0.0000965	0.0000731	0.0000925	-0.0003900	-0.0000256
	0.0001407	0.0120872	0.5846308	-0.0058031	-0.3334153	-0.0616537
	-0.3028130	0.1389874	0.1771141	0.3161951	0.8816439	0.9931341
2.00 to 4.00	0.0327095	0.0254366	0.0319754	0.0260907	0.0152440	0.0066091
	0.0022882	0.0006752	-0.0002023	0.0000058	-0.0000931	0.0007700
	0.0006977	0.0139605	0.4144933	-0.0232998	-0.6407421	0.0199073
	-0.1582915	0.2203960	-0.0729636	0.0590572	0.8353041	0.9854888
4.00 to 6.00	0.0226112	0.0257601	0.0316231	0.0301265	0.0219307	0.0126175
	0.0061525	0.0022151	0.0000665	-0.0001539	0.0003178	0.0008788
	0.0005891	0.0097755	0.3234787	-0.0079898	-0.7419680	0.0594374
	-0.1737801	0.2090602	-0.0681803	0.0111492	0.8542458	0.9901631
6.00 to 8.00	0.0227009	0.0297507	0.0379779	0.0374272	0.0306618	0.0212428
	0.0121110	0.0055371	0.0012818	-0.0002037	-0.0000407	0.0003557
	0.0001230	0.0043574	0.3518001	0.0205323	-0.7128190	-0.0149595
	-0.3543422	0.1688007	-0.2043120	0.3950885	0.9048503	0.9777347
8.00 to 10.0	0.0199811	0.0273196	0.0361898	0.0366831	0.0316147	0.0237606
	0.0150417	0.0080399	0.0026525	-0.0004237	-0.0013073	-0.0008760
	-0.0002083	-0.0003687	0.3698973	0.0355455	-0.6979910	-0.2120935
	-0.2670472	0.1474438	0.1195770	0.2713023	0.9298326	0.9891897
thermal	0.0455345	0.0209943	0.0075921	0.0071329	0.0010822	0.0064727
	-0.0024455	0.0009041	0.0049813	0.0000356	0.0008753	0.0007820
	0.0013578	0.0631202	0.2682746	0.1151971	-0.4866621	-0.4639305
	-0.0184464	-0.0042064	0.2267971	-0.2133825	0.8127556	0.9980614
^{252}Cf	0.0389978	0.0263448	0.0290572	0.0168805	0.0096723	0.0046578
	0.0009539	0.0002328	0.0000944	0.0000769	-0.0000970	-0.0000250
	0.0003616	0.0134221	0.5355485	0.1628747	-0.4884334	0.4284689
	-0.2794972	0.2571351	-0.1648760	0.1638437	0.9150549	0.9896433
14.00	0.0364402	0.0260088	0.0341557	0.0260806	0.0169008	0.0088392
	0.0033895	0.0010451	-0.0003129	0.0000059	0.0006453	0.0008801
	0.0003116	0.0109115	0.4608825	-0.0776147	-0.5653223	-0.0176936
	-0.2105574	0.1524764	-0.0594760	0.1886905	0.8109074	0.9800463

Table 3.4: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 B_6 B_{12} $A_{1,2}$	B_1 B_7 $A_{0,0}$ $A_{2,0}$	B_2 B_8 $A_{0,1}$ $A_{2,1}$	B_3 B_9 $A_{0,2}$ $A_{2,2}$	B_4 B_{10} $A_{1,0}$ κ_1	B_5 B_{11} $A_{1,1}$ κ_2
0.10 to 0.20	0.0677467	0.0029166	0.0028654	0.0006444	0.0002013	0.0002646
	-0.0001208	-0.0001893	-0.0000454	-0.0000256	-0.0002718	-0.0001276
	-0.0001923	0.0324402	0.6654338	-0.1196975	-0.2767489	0.0874708
	-0.3424166	0.0967209	-0.3483327	0.3317851	0.8186390	0.9882170
0.20 to 0.40	0.0509949	0.0042217	0.0045283	0.0022160	0.0015266	0.0007451
	0.0001785	-0.0001293	0.0000895	0.0000503	-0.0000990	-0.0001369
	-0.0003443	0.0208603	0.5465633	-0.1127793	-0.4311510	-0.0487716
	-0.0950128	0.1135161	-0.1365076	0.0950868	0.8332118	0.9981327
0.40 to 0.60	0.0394910	0.0051552	0.0064842	0.0044458	0.0039781	0.0016003
	0.0007464	0.0003899	-0.0002676	-0.0001110	-0.0001675	-0.0000072
	-0.0000165	0.0105956	0.4501454	-0.0996759	-0.5432568	-0.2090092
	0.0862122	0.0378256	0.1390623	-0.1221233	0.8715573	0.9933928
0.60 to 0.80	0.0516072	0.0092382	0.0123737	0.0099427	0.0092348	0.0027247
	0.0010066	0.0007107	-0.0004331	-0.0000668	-0.0000355	-0.0000718
	-0.0002900	0.0143655	0.5728504	-0.1197054	-0.4154174	-0.0906619
	-0.2523979	0.0375876	-0.0804342	0.2307915	0.8398252	0.9896933
0.80 to 1.00	0.0657677	0.0148777	0.0199606	0.0180671	0.0166785	0.0029471
	0.0008763	0.0015219	-0.0004437	-0.0004374	-0.0007466	-0.0012450
	-0.0013712	0.0237950	0.7190957	-0.1553704	-0.3253249	0.0368113
	-0.1707990	0.2374419	-0.4620693	0.3119529	0.8115308	0.9927097
1.00 to 2.00	0.0478430	0.0184059	0.0259299	0.0244250	0.0231723	0.0043265
	0.0013445	0.0007378	-0.0003235	0.0004907	-0.0002792	-0.0003940
	-0.0009995	0.0088690	0.6171857	0.0387841	-0.4297126	-0.0168555
	-0.2563269	0.0649453	0.0156443	0.3041158	0.9708289	0.9890600
2.00 to 4.00	0.0333611	0.0251450	0.0357086	0.0361308	0.0346531	0.0166109
	0.0067283	0.0040108	0.0012985	0.0009239	-0.0011857	-0.0014679
	0.0005794	0.0140424	0.3925111	-0.0201460	-0.6745017	-0.1112765
	-0.2466413	0.1976331	-0.3279410	0.5469502	0.8468726	0.9906030
4.00 to 6.00	0.0251318	0.0281323	0.0386186	0.0404370	0.0383241	0.0281203
	0.0168587	0.0094340	0.0043895	0.0007474	-0.0019954	-0.0017360
	-0.0006213	0.0027139	0.4103362	-0.0718211	-0.6688181	-0.4078784
	0.2706494	0.1436354	0.0520120	-0.1132072	0.8713473	0.9937512
6.00 to 8.00	0.0226236	0.0262556	0.0350323	0.0397495	0.0401387	0.0347594
	0.0264722	0.0192900	0.0140586	0.0090921	0.0041435	0.0007612
	-0.0003099	0.0048185	0.4029131	0.0901090	-0.7255821	0.1181850
	-0.5733396	0.1331429	-0.1688053	0.4979571	0.9750893	0.9800329
8.00 to 10.0	0.0182748	0.0185571	0.0228777	0.0265616	0.0288484	0.0279664
	0.0246477	0.0213461	0.0191343	0.0160565	0.0106771	0.0047065
	0.0012370	0.0009918	0.3552024	-0.0678306	-0.7116458	-0.3357922
	0.2033430	0.0486001	0.1281460	-0.1310724	0.8743236	0.9835383
thermal	0.0542597	0.0343076	0.0468660	0.0487256	0.0457851	0.0223083
	0.0119716	0.0094114	0.0040727	0.0013554	-0.0010629	-0.0006866
	-0.0000562	0.0179187	0.6407926	-0.0322560	-0.4328993	-0.0509097
	-0.3227891	0.1327692	0.0116666	0.1039553	0.8890687	0.9764090
^{252}Cf	0.0122805	0.0173355	0.0178382	0.0107358	0.0038932	0.0002838
	-0.0005534	-0.0000984	0.0002139	0.0000579	-0.0000861	-0.0000864
	-0.0000490	0.0076861	0.2791961	0.2276189	-0.7840079	-0.0706620
	0.2633359	0.1987001	0.2086285	-0.2438915	0.9232587	0.9858822
14.00	0.0148943	0.0195667	0.0209860	0.0210988	0.0212938	0.0180991
	0.0124948	0.0075876	0.0036572	0.0009625	-0.0002911	-0.0002781
	-0.0000095	-0.0073550	0.3894447	0.0019808	-0.6584768	-0.2267042
	0.2670048	0.1292766	-0.0060571	0.0400297	0.9073250	0.9956466

Table 3.5: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 / B_6 / B_{12} / $A_{1,2}$	B_1 / B_7 / $A_{0,0}$ / $A_{2,0}$	B_2 / B_8 / $A_{0,1}$ / $A_{2,1}$	B_3 / B_9 / $A_{0,2}$ / $A_{2,2}$	B_4 / B_{10} / $A_{1,0}$ / κ_1	B_5 / B_{11} / $A_{1,1}$ / κ_2
0.10 to 0.20	0.0140217	0.0210308	0.0203049	0.0129939	0.0054270	0.0012861
	-0.0000420	-0.0002568	-0.0001722	-0.0000440	0.0000556	0.0001320
	0.0000137	0.0037406	0.3870064	0.0981382	-0.5965275	-0.0254380
	-0.0127456	0.0478066	0.0618591	-0.3895951	0.8988318	0.9906620
0.20 to 0.40	0.0134898	0.0173956	0.0191079	0.0127709	0.0051132	0.0007874
	-0.0007689	-0.0008280	-0.0004875	-0.0000733	0.0000521	-0.0000608
	-0.0001386	0.0045700	0.3888151	0.1185423	-0.7000399	0.0926397
	-0.0485032	0.2154571	-0.0192203	-0.0945270	0.8756760	0.9869744
0.40 to 0.60	0.0164717	0.0238032	0.0214430	0.0117294	0.0038561	-0.0002437
	-0.0011927	-0.0004020	0.0000516	0.0002922	0.0002316	0.0000064
	-0.0000174	0.0124547	0.3098409	0.1956857	-0.6703959	0.3417681
	-0.0714287	0.2671956	-0.1051892	-0.2588811	0.8436614	0.9934045
0.60 to 0.80	0.0132009	0.0195881	0.0177373	0.0116792	0.0050276	0.0012936
	0.0002271	0.0002465	0.0002821	0.0000344	-0.0000439	-0.0000785
	-0.0000476	0.0007386	0.4434287	0.0683721	-0.7024223	-0.0313071
	0.3899745	0.2435625	0.0688328	-0.5414930	0.8435583	0.9943124
0.80 to 1.00	0.0216609	0.0263068	0.0304176	0.0196587	0.0088754	0.0033745
	0.0011529	0.0006758	0.0003877	-0.0000859	-0.0006841	-0.0004251
	-0.0001719	0.0065086	0.5062914	0.1964177	-0.5879559	-0.0522828
	0.3271952	0.3947879	0.1786489	-0.1789423	0.8607968	0.9850272
1.00 to 2.00	0.0217495	0.0284605	0.0317238	0.0172929	0.0061944	0.0004216
	-0.0010547	-0.0004129	0.0002865	0.0002717	-0.0002355	-0.0002571
	-0.0001544	0.0089465	0.5436668	0.3012749	-0.5735193	-0.0560894
	0.1372347	0.3699366	0.0488332	0.1769513	0.8691483	0.9868579
2.00 to 4.00	0.0159169	0.0228204	0.0231955	0.0136996	0.0036148	-0.0006411
	-0.0011638	-0.0006053	0.0001831	-0.0000408	-0.0000853	-0.0001168
	0.0000253	0.0119490	0.3025212	0.2794493	-0.6986461	-0.1163927
	0.3385000	0.2464788	0.2481518	-0.3096018	0.8644785	0.9871654
4.00 to 6.00	0.0159158	0.0243568	0.0240491	0.0154673	0.0071818	0.0019279
	-0.0006969	-0.0002755	0.0004158	0.0004624	0.0003954	0.0000005
	-0.0001163	0.0103341	0.3290232	0.2289684	-0.7605241	0.1157997
	-0.1657571	0.2119278	0.0317259	0.0279318	0.8163918	0.9789408
6.00 to 8.00	0.0213089	0.0303393	0.0280174	0.0218784	0.0108932	-0.0000962
	-0.0006866	0.0009951	0.0006537	0.0000782	-0.0003111	-0.0003532
	-0.0002748	0.0055355	0.6642621	0.1762249	-0.7193705	-0.2438961
	0.3024187	0.3968717	0.0847528	0.1167394	0.8723617	0.9784744
8.00 to 10.0	0.0207200	0.0295466	0.0271369	0.0185961	0.0116319	0.0027714
	0.0006004	0.0010802	0.0007772	-0.0001481	-0.0001615	0.0001167
	0.0000126	0.0090728	0.5217060	0.3010734	-0.6443397	-0.1649002
	0.3414246	0.3257154	0.1084897	-0.0521816	0.8659632	0.9839590
thermal	0.0158090	0.0192832	0.0260081	0.0284902	0.0285373	0.0251435
	0.0202136	0.0156487	0.0117256	0.0079078	0.0038690	0.0009524
	-0.0000244	-0.0004401	0.3613049	-0.0325900	-0.7815551	-0.2065461
	0.0626290	0.1661396	-0.1029478	0.2348050	0.9338806	0.9800295
^{252}Cf	0.0329715	0.0328177	0.0394386	0.0409707	0.0425533	0.0438342
	0.0443367	0.0463062	0.0462842	0.0462856	0.0413102	0.0304277
	0.0147546	0.0180793	0.4614206	0.0780337	-0.6918237	0.2724568
	-0.3148288	0.2808234	-0.4250634	0.1721823	0.9418839	0.9940166
14.00	0.0089378	0.0154208	0.0147456	0.0112004	0.0083345	0.0058730
	0.0034077	0.0016681	0.0005478	-0.0000019	-0.0000413	-0.0000423
	0.0000127	0.0015843	0.2020784	0.1269988	-0.8006654	-0.2181540
	0.3497484	0.0781643	0.1499137	-0.3133326	0.8636761	0.9860505

Table 3.6: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm H*(10) ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 / B_6 / B_{12} / $A_{1,2}$	B_1 / B_7 / $A_{0,0}$ / $A_{2,0}$	B_2 / B_8 / $A_{0,1}$ / $A_{2,1}$	B_3 / B_9 / $A_{0,2}$ / $A_{2,2}$	B_4 / B_{10} / $A_{1,0}$ / κ_1	B_5 / B_{11} / $A_{1,1}$ / κ_2
0.10 to 0.20	0.0310058	0.0079036	0.0087912	0.0062737	0.0029994	0.0009364
	0.0000529	-0.0001221	-0.0001975	-0.0000960	0.0000477	0.0000535
	0.0000954	0.0039811	0.5068846	0.0105815	-0.5428182	0.1168724
	0.3424365	0.2091158	0.3370075	-0.5585166	0.9159864	0.9704829
0.20 to 0.40	0.0305840	0.0033702	0.0070808	0.0043717	0.0015211	0.0004325
	0.0003188	0.0003548	0.0002247	0.0000251	-0.0003007	-0.0000684
	-0.0000817	0.0068881	0.4763392	0.0387856	-0.5787132	0.2292421
	0.0207392	0.1804531	0.1076931	-0.0612162	0.9114627	0.9772167
0.40 to 0.60	0.0378538	0.0212337	0.0141692	0.0037221	0.0003630	-0.0004349
	-0.0010647	-0.0005923	-0.0010205	-0.0002173	-0.0000607	0.0005663
	-0.0000469	0.0906067	0.1070549	0.4564914	-0.3424352	0.0523915
	0.0252979	0.0853344	0.0096570	0.1060794	0.9174654	0.9953164
0.60 to 0.80	0.0336213	0.0151799	0.0081274	0.0040338	0.0011740	0.0006816
	0.0007243	0.0006396	0.0006094	0.0001064	-0.0000868	-0.0002743
	-0.0001044	0.0025973	0.5611226	0.0411399	-0.4697157	0.1524706
	0.0026744	0.1334834	-0.0968205	-0.0893064	0.8871664	0.9898409
0.80 to 1.00	0.0521323	0.0181552	0.0222947	0.0075743	0.0020112	0.0013746
	0.0001755	0.0001753	-0.0007409	-0.0006731	-0.0006460	0.0006971
	0.0003944	0.0081107	0.6205748	0.0188183	-0.3031898	0.0370416
	-0.1091755	0.2708193	0.0324836	0.1329039	0.8479228	0.9822085
1.00 to 2.00	0.0426823	0.0191216	0.0264995	0.0075764	0.0030333	0.0018739
	0.0007958	0.0013026	0.0008426	-0.0001858	-0.0003491	-0.0000478
	-0.0001557	0.0155465	0.5072831	0.1025068	-0.4244413	-0.0676436
	-0.0769485	0.0919803	0.0789341	0.1405899	0.8410215	0.9827538
2.00 to 4.00	0.0536824	0.0368921	0.0403338	0.0217656	0.0090350	0.0046990
	0.0021446	0.0005244	0.0001379	0.0001479	-0.0004783	0.0003796
	0.0005167	0.0105851	0.6537740	0.0051540	-0.2736292	-0.1618472
	0.1189543	0.1314398	-0.0932544	0.0772621	0.8234569	0.9856915
4.00 to 6.00	0.0424133	0.0346687	0.0396506	0.0293448	0.0235230	0.0136585
	0.0051490	0.0020811	0.0003325	-0.0001421	-0.0004255	0.0003504
	0.0005509	0.0045969	0.5821891	0.0456769	-0.4186330	-0.1650871
	-0.2687116	0.1078766	-0.2627333	0.6521974	0.8620418	0.9878383
6.00 to 8.00	0.0270956	0.0194425	0.0210710	0.0232430	0.0194952	0.0078456
	0.0034819	0.0018932	0.0004575	-0.0000806	0.0000372	0.0000662
	0.0000925	0.0062071	0.4570325	0.0920852	-0.6049687	0.0548874
	-0.0929804	0.1547564	-0.1318118	0.2333674	0.9162310	0.9897253
8.00 to 10.0	0.0180805	0.0145099	0.0164061	0.0165331	0.0167839	0.0106333
	0.0064786	0.0036072	0.0008010	0.0000491	0.0000519	0.0001539
	0.0000806	0.0037420	0.3646476	0.0001464	-0.6755323	0.0651354
	-0.0711332	0.1228438	-0.2694049	0.2622954	0.8009821	0.9894347
^{252}Cf	0.0492288	0.0288697	0.0315514	0.0161952	0.0082183	0.0045599
	0.0011045	0.0000180	0.0002632	-0.0000838	-0.0001202	0.0000480
	0.0001129	0.0188406	0.5613750	0.0631271	-0.4040545	0.1344005
	-0.1193347	0.1884397	-0.1341707	0.0375134	0.8000004	0.9837270
14.00	0.0457945	0.0257283	0.0337529	0.0240880	0.0149561	0.0073844
	0.0028565	0.0013726	0.0001499	0.0000352	0.0000069	0.0001317
	-0.0002029	0.0142216	0.4789449	-0.0732640	-0.4813939	0.0096573
	-0.4082376	0.0908468	0.0318662	0.2474061	0.8211740	0.9870799

Table 3.7: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm H*(10) ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 / B_6 / B_{12} / $A_{1,2}$	B_1 / B_7 / $A_{0,0}$ / $A_{2,0}$	B_2 / B_8 / $A_{0,1}$ / $A_{2,1}$	B_3 / B_9 / $A_{0,2}$ / $A_{2,2}$	B_4 / B_{10} / $A_{1,0}$ / κ_1	B_5 / B_{11} / $A_{1,1}$ / κ_2
0.10 to 0.20	0.0532938	0.0017214	0.0047599	0.0017235	0.0038739	0.0017985
	0.0008183	0.0009651	-0.0004182	0.0002260	-0.0000209	0.0002403
	-0.0001396	0.0207696	0.4421412	-0.1439761	-0.3949910	0.3493605
	0.0826687	0.1690127	0.4046224	-0.5592011	0.8364217	0.9889952
0.20 to 0.40	0.0428664	0.0057989	0.0089092	0.0043192	0.0046892	0.0021049
	0.0014485	0.0011974	0.0003991	0.0002262	-0.0003519	0.0001614
	0.0000392	0.0166858	0.3420655	-0.1078319	-0.5640892	0.3592397
	-0.2137942	0.1167663	-0.0682997	0.0249608	0.8001289	0.9832264
0.40 to 0.60	0.0498565	0.0169553	0.0158442	0.0065786	0.0035137	0.0013000
	0.0002785	0.0004662	-0.0002562	-0.0000707	0.0000887	0.0002501
	0.0000234	0.0157846	0.5071555	-0.0740615	-0.4392525	0.0066950
	-0.0667203	0.0433824	0.1832674	-0.1338951	0.9221095	0.9879640
0.60 to 0.80	0.0541371	0.0089104	0.0180305	0.0055529	0.0026773	0.0006289
	-0.0005249	-0.0002200	0.0002923	0.0001070	0.0003477	0.0002955
	-0.0000638	0.0249460	0.4319382	-0.0812262	-0.4565376	0.0797066
	-0.0802077	0.1451714	-0.1225046	0.1561723	0.8074403	0.9860243
0.80 to 1.00	0.0273588	0.0133481	0.0144728	0.0051136	0.0017275	0.0010622
	0.0001053	0.0001647	0.0003204	-0.0002975	-0.0007973	-0.0003560
	-0.0004633	0.0095447	0.2918528	-0.0192545	-0.6169142	-0.0820497
	-0.1109212	-0.0183574	0.0455991	0.0641485	0.8594692	0.9881279
1.00 to 2.00	0.0396122	0.0160942	0.0254778	0.0120196	0.0052634	0.0017163
	-0.0000163	-0.0007315	-0.0000126	0.0000443	-0.0000793	0.0001041
	0.0000018	0.0139711	0.4298761	-0.0270629	-0.4854542	0.1253156
	-0.4907624	0.1101582	-0.2390671	0.6185012	0.8405386	0.9948031
2.00 to 4.00	0.0699672	0.0470624	0.0583992	0.0477498	0.0277122	0.0129019
	0.0051368	0.0028880	0.0008639	-0.0002046	-0.0002689	0.0006237
	0.0006355	0.0241450	0.7713394	-0.1091949	-0.3214795	-0.3194750
	0.0104924	0.2157251	0.2203833	-0.2757922	0.8841745	0.9716388
4.00 to 6.00	0.0383584	0.0333513	0.0406763	0.0382366	0.0271660	0.0151085
	0.0071172	0.0021780	-0.0002839	-0.0000926	0.0003122	0.0007226
	0.0005182	0.0076436	0.4048834	-0.0392213	-0.5529857	-0.0688028
	-0.3777743	0.0800085	-0.0077119	0.2373894	0.8427911	0.9886515
6.00 to 8.00	0.0366453	0.0363076	0.0463791	0.0448332	0.0363180	0.0242095
	0.0132009	0.0056037	0.0007640	-0.0009652	-0.0001809	0.0008290
	0.0003877	0.0079033	0.4434946	-0.0716627	-0.5959346	-0.1655178
	-0.1807104	0.1021265	0.0179065	0.0781227	0.8637481	0.9811557
8.00 to 10.0	0.0235136	0.0251327	0.0334662	0.0336685	0.0291116	0.0219503
	0.0140041	0.0075519	0.0028613	0.0002568	-0.0001438	0.0000136
	0.0005766	0.0074658	0.3461263	-0.0148531	-0.7061847	-0.0741588
	-0.3756055	0.0988650	0.0051997	0.2985481	0.8757374	0.9869155
^{252}Cf	0.0459410	0.0242135	0.0329226	0.0331010	0.0318835	0.0149376
	0.0076217	0.0061894	0.0037884	0.0009262	-0.0008405	-0.0001239
	-0.0006190	0.0155636	0.4976990	-0.1072952	-0.5499798	-0.0629111
	-0.2609887	0.1593948	-0.3307752	0.3993058	0.8123170	0.9947029
14.00	0.0128098	0.0174085	0.0166469	0.0083089	0.0014990	-0.0007495
	-0.0004953	0.0004738	0.0004850	-0.0001278	-0.0003312	-0.0002862
	0.0000611	0.0138527	0.1844362	0.2328879	-0.8331926	0.1608196
	-0.0257022	0.1951785	-0.1405954	0.0531641	0.8620238	0.9869965

Table 3.8: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm H*(10) ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 / B_6 / B_{12} / $A_{1,2}$	B_1 / B_7 / $A_{0,0}$ / $A_{2,0}$	B_2 / B_8 / $A_{0,1}$ / $A_{2,1}$	B_3 / B_9 / $A_{0,2}$ / $A_{2,2}$	B_4 / B_{10} / $A_{1,0}$ / κ_1	B_5 / B_{11} / $A_{1,1}$ / κ_2
0.10 to 0.20	0.0558987	0.0023528	0.0024396	0.0006283	0.0002252	0.0005829
	-0.0000269	-0.0000076	0.0000198	-0.0000241	-0.0000023	0.0000176
	0.0000056	0.0211978	0.5874357	-0.1463577	-0.3633696	-0.2294366
	0.0281927	0.0666451	-0.0789938	0.0592571	0.8116018	0.9912418
0.20 to 0.40	0.0500629	0.0042147	0.0045578	0.0019449	0.0015217	0.0009231
	0.0002355	-0.0000006	0.0000737	-0.0000236	-0.0000842	0.0000151
	-0.0001222	0.0171735	0.5094106	-0.1322565	-0.4581400	-0.1971223
	-0.0238649	0.0226677	-0.0800756	0.0924186	0.8022838	0.9830990
0.40 to 0.60	0.0572949	0.0072558	0.0093308	0.0064029	0.0060143	0.0020942
	0.0005229	0.0002147	-0.0003718	-0.0001010	-0.0002718	-0.0000931
	-0.0000863	0.0151566	0.6345752	-0.1400677	-0.3631013	-0.1609658
	-0.0181668	0.0556704	-0.0204593	0.0473351	0.8779085	0.9912042
0.60 to 0.80	0.0374910	0.0064014	0.0086570	0.0073005	0.0066616	0.0015417
	0.0004225	0.0004135	-0.0004770	-0.0000946	0.0000506	-0.0002702
	-0.0005456	0.0106124	0.4169844	-0.0916683	-0.5844201	-0.1010548
	-0.1155415	0.0328702	-0.0593905	0.1271705	0.8536718	0.9887343
0.80 to 1.00	0.0584633	0.0130224	0.0183176	0.0161752	0.0149129	0.0038738
	0.0014475	0.0009744	-0.0004953	-0.0000157	-0.0000858	-0.0000673
	-0.0007575	0.0158747	0.6515040	-0.1677025	-0.3263391	-0.3792064
	0.1666693	0.0526834	0.1836432	-0.1818777	0.8018481	0.9938379
1.00 to 2.00	0.0530010	0.0188155	0.0267216	0.0250196	0.0237658	0.0055260
	0.0016786	0.0009315	-0.0002921	0.0003044	-0.0003449	0.0000121
	-0.0006660	0.0197107	0.5819071	-0.0596983	-0.3944350	-0.2676750
	-0.0459249	0.0385525	0.3035811	-0.1487739	0.8542292	0.9925053
2.00 to 4.00	0.0397078	0.0267902	0.0383964	0.0381639	0.0359253	0.0168128
	0.0065428	0.0031976	0.0011212	0.0001523	-0.0011819	-0.0005838
	0.0003421	0.0106837	0.4601275	-0.0459297	-0.6127313	-0.2896862
	-0.2001542	0.0771358	0.0189377	0.3086182	0.9307469	0.9831710
4.00 to 6.00	0.0429480	0.0390275	0.0537080	0.0568942	0.0538668	0.0404909
	0.0254998	0.0156083	0.0085227	0.0033289	-0.0009162	-0.0014155
	-0.0006500	0.0070241	0.4809715	-0.0589891	-0.5612269	-0.2228249
	-0.3539149	0.0308492	0.0258892	0.2674945	0.8908337	0.9806583
6.00 to 8.00	0.0338077	0.0308618	0.0413024	0.0467627	0.0471813	0.0410459
	0.0313908	0.0232711	0.0170424	0.0112588	0.0047711	0.0005880
	-0.0006031	-0.0056719	0.5490080	-0.1058596	-0.5172456	-0.5892470
	0.0002879	-0.0241546	0.3607939	0.1003439	0.9443846	0.9975493
8.00 to 10.0	0.0198070	0.0140910	0.0175012	0.0213214	0.0231222	0.0225639
	0.0199688	0.0171652	0.0148174	0.0132233	0.0097253	0.0051359
	0.0019843	0.0081692	0.2576149	-0.0022423	-0.7766307	-0.3020114
	0.1691786	-0.0049809	0.3300473	-0.3745058	0.9147022	0.9732737
^{252}Cf	0.0111404	0.0133828	0.0146153	0.0148671	0.0149662	0.0131436
	0.0096794	0.0062412	0.0034405	0.0015927	0.0006972	0.0002460
	-0.0000275	0.0043138	0.1994782	0.0061004	-0.8403319	0.0224057
	-0.0203116	0.0870102	-0.1643755	0.0782730	0.8010939	0.9826734
14.00	0.0396915	0.0374025	0.0501896	0.0557815	0.0559450	0.0501798
	0.0406900	0.0314361	0.0230933	0.0149423	0.0062647	0.0011605
	-0.0019741	0.0191170	0.5675920	0.1735340	-0.6088180	-0.0213167
	-0.4895494	0.2610349	0.3805100	-0.0003166	0.9800740	0.9948286

Table 3.9: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the neutron albedo based on the 10-mm H*(10) ambient dose equivalent response function. Results obtained using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 / B_6 / B_{12} / $A_{1,2}$	B_1 / B_7 / $A_{0,0}$ / $A_{2,0}$	B_2 / B_8 / $A_{0,1}$ / $A_{2,1}$	B_3 / B_9 / $A_{0,2}$ / $A_{2,2}$	B_4 / B_{10} / $A_{1,0}$ / κ_1	B_5 / B_{11} / $A_{1,1}$ / κ_2
0.10 to 0.20	0.0129219	0.0203124	0.0203507	0.0133489	0.0052986	0.0005921
	-0.0009612	-0.0007030	-0.0001533	0.0000032	-0.0000561	-0.0001328
	-0.0000893	0.0036126	0.4117485	0.0827997	-0.6838040	0.0550869
	0.0334064	0.1729190	0.1066032	-0.4833454	0.8967318	0.9901377
0.20 to 0.40	0.0184540	0.0243669	0.0266709	0.0175327	0.0064331	0.0004416
	-0.0011766	-0.0005657	-0.0002026	-0.0000695	-0.0002964	-0.0005765
	-0.0003576	0.0120361	0.4492530	0.1897889	-0.6425737	-0.0350966
	0.2890114	0.3064913	-0.0450006	-0.3401521	0.8451869	0.9562095
0.40 to 0.60	0.0115668	0.0166603	0.0147648	0.0076651	0.0021182	-0.0005477
	-0.0009023	-0.0001264	0.0001958	0.0002109	0.0001216	-0.0000306
	0.0000077	0.0079243	0.2082212	0.1332742	-0.7846735	0.0996876
	0.0948313	0.1604304	0.0968823	-0.3261282	0.8592585	0.9824912
0.60 to 0.80	0.0182030	0.0269427	0.0237484	0.0142403	0.0046316	0.0001613
	-0.0004657	-0.0000652	0.0001062	-0.0002561	-0.0002065	0.0000119
	0.0000239	0.0049888	0.4634968	0.3571756	-0.6575601	0.2666836
	0.0507981	0.1954288	0.1470037	-0.5248015	0.9595597	0.9688572
0.80 to 1.00	0.0141696	0.0166203	0.0180389	0.0098593	0.0023972	-0.0005659
	-0.0011356	-0.0006341	-0.0002396	-0.0001605	-0.0003385	-0.0001092
	-0.0000137	0.0056358	0.2789036	0.1977545	-0.7653953	0.0953145
	0.0376798	0.2119139	0.1314868	-0.0684558	0.9245704	0.9800317
1.00 to 2.00	0.0164421	0.0207049	0.0215597	0.0092660	0.0007758	-0.0020370
	-0.0015547	-0.0001573	0.0005514	0.0002771	-0.0001149	-0.0000278
	0.0001882	0.0077076	0.3279836	0.2694326	-0.7092761	-0.1326348
	0.1940659	0.2269972	0.1750762	-0.0551756	0.9105451	0.9915097
2.00 to 4.00	0.0226896	0.0313581	0.0291665	0.0135662	0.0003836	-0.0025622
	-0.0009443	0.0008327	0.0009503	-0.0002490	-0.0004774	-0.0001232
	0.0004094	0.0103071	0.4304798	0.4783325	-0.6627982	0.0418333
	-0.1594746	0.2574273	-0.0209579	0.3672793	0.9669937	0.9876719
4.00 to 6.00	0.0165370	0.0238119	0.0210479	0.0106129	0.0034434	0.0010876
	0.0007730	0.0015651	0.0011396	0.0001474	-0.0001968	-0.0001304
	0.0000037	0.0121924	0.2629612	0.2150514	-0.7965685	-0.0144339
	0.1634773	0.1745254	0.0287459	-0.1913277	0.8380902	0.9891834
6.00 to 8.00	0.0148640	0.0201575	0.0163847	0.0111439	0.0051654	0.0010073
	0.0021364	0.0027179	0.0010844	0.0000464	0.0000689	0.0001915
	0.0002195	0.0110018	0.2889479	0.2411449	-0.8271057	-0.2590476
	0.2762631	0.1484251	0.4382038	-0.5486105	0.9078802	0.9725868
8.00 to 10.0	0.0149725	0.0203694	0.0171314	0.0105427	0.0065417	0.0029309
	0.0022414	0.0018008	0.0003975	-0.0001573	-0.0000975	0.0000669
	0.0000906	0.0091251	0.3496518	0.2914835	-0.7279292	-0.2725006
	0.6601474	0.1653099	0.5326599	-0.7786617	0.9327370	0.9961565
^{252}Cf	0.0371479	0.0258430	0.0307108	0.0308909	0.0317781	0.0326513
	0.0323403	0.0323324	0.0322866	0.0313035	0.0258584	0.0166355
	0.0064871	-0.0072767	0.4471703	-0.0214340	-0.5745561	0.4863048
	-1.3685842	-0.0238093	-0.7921728	1.5318002	0.8808124	0.9998973
14.00	0.0128763	0.0209132	0.0192572	0.0143676	0.0111819	0.0087258
	0.0056577	0.0028383	0.0008183	0.0000196	0.0000215	-0.0000210
	-0.0000637	0.0009609	0.3134141	0.1612224	-0.7289138	-0.4863645
	0.7385826	0.0801827	0.4249718	-0.6998956	0.9121793	0.9937053

Table 3.10: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete. Errors associated with this formula are less than 10% for all cases.

	B_0	B_1	B_2	B_3	B_4	B_5
Energy	B_6	B_7	B_8	B_9	B_{10}	B_{11}
(MeV)	B_{12}	$A_{0,0}$	$A_{0,1}$	$A_{0,2}$	$A_{1,0}$	$A_{1,1}$
	$A_{1,2}$	$A_{2,0}$	$A_{2,1}$	$A_{2,2}$	κ_1	κ_2
0.10 to 0.20	0.0408473	0.0104863	0.0115277	0.0075391	0.0029901	0.0008237
	-0.0001145	-0.0000071	-0.0002238	-0.0000518	-0.0000899	0.0000916
	0.0001534	0.0066857	0.5925267	-0.0427004	-0.4124147	0.1573309
	-0.0816890	0.2371957	0.1335896	-0.1297537	0.8024749	0.9771798
0.20 to 0.40	0.0343749	0.0038561	0.0079840	0.0037168	0.0005182	-0.0005032
	-0.0000900	0.0003560	0.0003872	-0.0001878	-0.0002862	-0.0001403
	-0.0001879	-0.0005914	0.5443345	-0.0713879	-0.4742719	-0.1881539
	0.2535555	0.1600045	0.2108158	-0.0337297	0.8429226	0.9926092
0.40 to 0.60	0.0463148	0.0262991	0.0176753	0.0040060	-0.0003308	-0.0010769
	-0.0004665	0.0002373	-0.0001775	-0.0007452	-0.0001828	0.0005541
	0.0005681	0.0893279	0.3336526	0.2059550	-0.1805005	-0.0912245
	0.0399232	0.1745455	-0.6796408	0.8936342	0.8430666	0.9978002
0.60 to 0.80	0.0385934	0.0173526	0.0086119	0.0049374	0.0027894	0.0016943
	0.0019712	0.0019028	0.0010988	0.0006297	0.0002642	-0.0004169
	-0.0002035	0.0134565	0.4929404	0.1997311	-0.4103292	0.3179910
	-0.1764854	0.1382782	-0.1359962	-0.1396971	0.8935962	0.9886894
0.80 to 1.00	0.0454248	0.0160391	0.0184039	0.0072149	0.0014427	0.0005170
	-0.0008962	-0.0004188	-0.0001346	0.0000816	-0.0000251	0.0004478
	0.0003537	0.0144234	0.4626877	0.0800875	-0.4000383	0.2393774
	-0.1049201	0.1625831	0.1231064	-0.2465398	0.8300226	0.9788117
1.00 to 2.00	0.0513749	0.0247336	0.0317723	0.0090860	0.0041486	0.0000419
	0.0002222	0.0003003	0.0004225	0.0005142	-0.0007989	-0.0002360
	-0.0001669	0.0072024	0.7522088	0.0573492	-0.2158815	-0.2368396
	0.0621842	0.1453888	0.1471377	0.2750945	0.8798493	0.9925969
2.00 to 4.00	0.0314422	0.0229416	0.0247789	0.0138947	0.0056993	0.0025892
	0.0004867	-0.0003472	-0.0002642	-0.0001649	-0.0002184	0.0001475
	0.0002218	0.0164763	0.3546337	0.0644264	-0.6734904	0.2885451
	-0.1670260	0.2478459	-0.3234550	0.1426459	0.8351277	0.9866288
4.00 to 6.00	0.0226270	0.0197946	0.0229153	0.0179155	0.0140000	0.0080587
	0.0030908	0.0011483	0.0003189	0.0001400	0.0000726	0.0002939
	0.0001002	0.0049369	0.3230407	0.1655170	-0.6644186	-0.0254575
	-0.0471666	0.0621181	0.2785351	-0.1308785	0.9601418	0.9881905
6.00 to 8.00	0.0266547	0.0197744	0.0217359	0.0250463	0.0209749	0.0083454
	0.0035886	0.0024355	0.0008850	0.0001218	0.0000083	0.0002367
	0.0002433	0.0100937	0.3924743	0.1602252	-0.5987615	0.1606509
	-0.0553349	0.1719290	-0.0291119	-0.0550142	0.8918299	0.9855429
8.00 to 10.0	0.0131345	0.0109722	0.0123127	0.0126618	0.0130128	0.0079420
	0.0043478	0.0024230	0.0006884	0.0001235	-0.0000764	-0.0001727
	-0.0000383	0.0037012	0.2368079	0.0383624	-0.7791502	-0.0560416
	0.0767806	0.0860455	0.1089614	-0.1065632	0.8236903	0.9896561
^{252}Cf	0.0289674	0.0187554	0.0206549	0.0117929	0.0065009	0.0033112
	0.0008745	0.0001633	0.0001411	0.0000385	-0.0000110	0.0000034
	0.0000760	0.0101215	0.3728288	0.0483226	-0.6081457	0.0750461
	-0.0777531	0.1271142	0.0141860	-0.0298756	0.8186389	0.9881051
14.00	0.0325212	0.0214190	0.0274917	0.0212611	0.0130343	0.0070471
	0.0029692	0.0014170	0.0007229	0.0000131	0.0001554	0.0001219
	-0.0002497	0.0109786	0.3664974	-0.0032516	-0.5888438	0.0455010
	-0.1245443	0.0758218	0.1640445	-0.1698607	0.8767760	0.9884847

Table 3.11: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 / B_6 / B_{12} / $A_{1,2}$	B_1 / B_7 / $A_{0,0}$ / $A_{2,0}$	B_2 / B_8 / $A_{0,1}$ / $A_{2,1}$	B_3 / B_9 / $A_{0,2}$ / $A_{2,2}$	B_4 / B_{10} / $A_{1,0}$ / κ_1	B_5 / B_{11} / $A_{1,1}$ / κ_2
0.10 to 0.20	0.0568429	0.0015149	0.0068734	0.0023982	0.0043801	0.0016820
	0.0018035	0.0010615	0.0006176	0.0007871	0.0005067	0.0002892
	0.0000844	0.0230846	0.4220951	-0.1088425	-0.3994379	0.3380446
	-0.3322614	0.1417577	-0.1271229	0.3447472	0.8016368	0.9745416
0.20 to 0.40	0.0523719	0.0066613	0.0110934	0.0057544	0.0062124	0.0023975
	0.0011664	0.0013980	0.0007373	0.0008228	-0.0001473	-0.0001449
	0.0001065	0.0144399	0.4979964	-0.1933688	-0.4102329	-0.1909041
	0.2581546	0.1476519	0.1690086	-0.0057345	0.8434144	0.9937817
0.40 to 0.60	0.0534273	0.0179220	0.0163902	0.0063928	0.0043072	0.0019719
	0.0003388	0.0005212	-0.0002045	-0.0000602	0.0000603	0.0003732
	0.0003147	0.0199295	0.5298851	-0.1275858	-0.3749754	-0.0114290
	-0.1909801	0.1057822	-0.1540832	0.2291274	0.8283215	0.9938819
0.60 to 0.80	0.0593197	0.0099974	0.0179086	0.0053489	0.0022476	0.0015789
	0.0003802	-0.0006042	0.0001950	-0.0002589	0.0002961	0.0003258
	-0.0003119	0.0262756	0.4773376	0.0192400	-0.3221910	-0.0425475
	-0.0008560	0.1199833	0.6133251	-0.4137975	0.9038994	0.9961417
0.80 to 1.00	0.0460497	0.0225927	0.0235697	0.0090690	0.0024160	0.0025661
	0.0008129	0.0010475	0.0008852	-0.0001305	-0.0002191	0.0001839
	-0.0001824	0.0287243	0.3877288	0.0220669	-0.4448413	0.0192785
	-0.1155411	0.0476764	0.1612655	-0.2605198	0.8063052	0.9926504
1.00 to 2.00	0.0463256	0.0198328	0.0315461	0.0155356	0.0063178	0.0033682
	0.0011165	-0.0003117	0.0009552	0.0002319	-0.0001357	0.0008954
	0.0004728	0.0217155	0.4612206	-0.0235658	-0.4613664	0.1628475
	-0.4139751	0.1867534	-0.2852810	0.5006344	0.8060189	0.9929897
2.00 to 4.00	0.0319822	0.0240653	0.0299269	0.0245318	0.0145782	0.0061161
	0.0019217	0.0005330	-0.0001427	-0.0002997	0.0001585	0.0004786
	-0.0000395	0.0094594	0.3567609	-0.0189374	-0.6189120	0.0533492
	-0.3771898	0.1172449	-0.0592861	0.2264626	0.8121362	0.9920111
4.00 to 6.00	0.0311202	0.0322847	0.0392007	0.0374224	0.0267277	0.0145373
	0.0061496	0.0016319	-0.0009911	-0.0006718	0.0005903	0.0014972
	0.0006128	0.0037169	0.4887296	0.1404870	-0.5313507	-0.1621853
	-0.0608073	0.1214923	0.3243723	-0.1478205	0.9956701	0.9890763
6.00 to 8.00	0.0293766	0.0350098	0.0444944	0.0435552	0.0353236	0.0240140
	0.0134828	0.0059363	0.0010265	-0.0007456	-0.0001054	0.0005293
	0.0003039	0.0044523	0.4064240	0.0182216	-0.6097999	-0.0439605
	-0.1481358	0.1346028	0.1089944	-0.1170025	0.9214035	0.9922382
8.00 to 10.0	0.0180459	0.0221398	0.0291719	0.0296781	0.0255324	0.0191193
	0.0117248	0.0059113	0.0017783	-0.0002506	-0.0005930	-0.0003172
	0.0000989	0.0082261	0.2617093	-0.0072733	-0.8043919	-0.1652719
	0.0687994	0.1336617	0.2049553	-0.2731498	0.8463153	0.9898653
^{252}Cf	0.0354560	0.0211746	0.0279465	0.0299684	0.0283494	0.0145690
	0.0077927	0.0059876	0.0031060	0.0017138	-0.0001127	-0.0006790
	-0.0002239	0.0193838	0.3505887	0.0363657	-0.6837616	0.1853267
	-0.2045798	0.1508270	-0.1265085	-0.0556778	0.8979883	0.9889073
14.00	0.0191063	0.0265232	0.0260131	0.0141949	0.0038800	-0.0005194
	-0.0012382	-0.0003472	-0.0000409	-0.0002643	-0.0003089	-0.0001611
	0.0000523	0.0050577	0.4402911	0.1924246	-0.6296414	-0.2990575
	0.3331869	0.1994503	0.3547496	-0.3638150	0.8226101	0.9870746

Table 3.12: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 / B_6 / B_{12} / $A_{1,2}$	B_1 / B_7 / $A_{0,0}$ / $A_{2,0}$	B_2 / B_8 / $A_{0,1}$ / $A_{2,1}$	B_3 / B_9 / $A_{0,2}$ / $A_{2,2}$	B_4 / B_{10} / $A_{1,0}$ / κ_1	B_5 / B_{11} / $A_{1,1}$ / κ_2
0.10 to 0.20	0.0596784	0.0024067	0.0025928	0.0007143	0.0003239	0.0002651
	-0.0003241	0.0000825	0.0000189	0.0001480	-0.0001957	-0.0003250
	-0.0001831	0.0307043	0.5157136	-0.0621758	-0.3607364	-0.0483732
	-0.2479412	-0.0366587	-0.0249382	0.0633334	0.8089745	0.9737098
0.20 to 0.40	0.0536825	0.0039887	0.0047238	0.0023946	0.0019095	0.0009368
	-0.0000215	-0.0002377	-0.0001252	0.0001787	0.0001571	0.0000433
	-0.0001502	0.0173537	0.5556270	-0.1204979	-0.3940833	-0.2674783
	0.0083136	0.0268270	0.0999070	-0.0414282	0.8467611	0.9934494
0.40 to 0.60	0.0543604	0.0064972	0.0084808	0.0061420	0.0054459	0.0019318
	0.0001346	-0.0002016	-0.0005187	-0.0000504	-0.0002691	-0.0002948
	-0.0002020	0.0195214	0.5740569	-0.1076477	-0.3906276	-0.0267561
	-0.2707539	0.0667427	-0.1065998	0.2031284	0.8376536	0.9933723
0.60 to 0.80	0.0640486	0.0110098	0.0145681	0.0120736	0.0105640	0.0028754
	0.0003718	0.0004318	-0.0003753	-0.0001336	-0.0007477	-0.0010760
	-0.0004461	0.0215236	0.6215711	-0.1413273	-0.3383169	-0.1923645
	-0.1184964	-0.0287436	-0.0329263	0.0578552	0.8001291	0.9725478
0.80 to 1.00	0.0470709	0.0105540	0.0147262	0.0131360	0.0114795	0.0040377
	0.0014879	0.0009161	-0.0000491	0.0000868	-0.0001026	-0.0001982
	-0.0000463	0.0189149	0.4881384	-0.0460112	-0.4900331	0.1343392
	-0.4486175	0.0722081	0.0361637	0.1247298	0.8401004	0.9973103
1.00 to 2.00	0.0455273	0.0164001	0.0226093	0.0221640	0.0209105	0.0048985
	0.0016389	0.0013618	0.0002216	0.0005286	-0.0004481	-0.0004674
	-0.0007024	0.0215951	0.4303992	0.0057742	-0.5158449	-0.1893856
	0.0399987	0.0534463	0.3792592	-0.3835921	0.8373343	0.9919382
2.00 to 4.00	0.0417337	0.0301093	0.0423679	0.0426211	0.0409219	0.0195849
	0.0069506	0.0034664	0.0011697	0.0014436	-0.0019316	-0.0017599
	0.0013095	0.0205131	0.4053877	-0.0204260	-0.6392210	-0.1867500
	-0.1891727	0.1861932	-0.1196378	0.2422830	0.8005747	0.9894552
4.00 to 6.00	0.0320653	0.0337992	0.0467075	0.0489004	0.0461703	0.0340584
	0.0207995	0.0124605	0.0059833	0.0015924	-0.0020223	-0.0014333
	-0.0003863	0.0081198	0.4206825	-0.0306972	-0.6295637	-0.1396278
	-0.2965053	0.1025650	-0.1520412	0.3112409	0.8476574	0.9764702
6.00 to 8.00	0.0217335	0.0233497	0.0310036	0.0353703	0.0359431	0.0310623
	0.0233237	0.0173708	0.0131471	0.0086342	0.0035213	0.0004557
	-0.0002169	0.0093983	0.3115752	0.0165465	-0.8073941	0.3467391
	-0.5364872	0.1915838	-0.5558231	0.5057818	0.9182236	0.9923471
8.00 to 10.0	0.0317734	0.0277296	0.0346244	0.0414767	0.0446533	0.0430745
	0.0383716	0.0331839	0.0287483	0.0241876	0.0163691	0.0075452
	0.0023867	0.0079334	0.5131364	0.0632784	-0.5938230	-0.6543282
	0.2386619	-0.0001430	0.9096192	-0.7577798	0.9714024	0.9810601
^{252}Cf	0.0133791	0.0164457	0.0176789	0.0177942	0.0180367	0.0158738
	0.0114456	0.0072695	0.0039888	0.0017181	0.0006207	0.0003104
	0.0000593	0.0051798	0.2457094	0.0448864	-0.7872536	0.0246639
	-0.0110643	0.1243713	-0.0181114	-0.0617095	0.8302872	0.9950136
14.00	0.0156762	0.0167995	0.0226667	0.0246402	0.0246916	0.0218221
	0.0177252	0.0138237	0.0101814	0.0068559	0.0032037	0.0008209
	-0.0000863	-0.0017766	0.2944829	-0.0820118	-0.7568651	-0.2291516
	0.0381871	0.0746803	-0.1049030	0.2179326	0.8073983	0.9940445

Table 3.13: Parameters for the twenty-four term approximation (see Eq. (3.1)) of the Henderson neutron albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water. Errors associated with this formula are less than 10% for all cases.

Energy (MeV)	B_0 B_6 B_{12} $A_{1,2}$	B_1 B_7 $A_{0,0}$ $A_{2,0}$	B_2 B_8 $A_{0,1}$ $A_{2,1}$	B_3 B_9 $A_{0,2}$ $A_{2,2}$	B_4 B_{10} $A_{1,0}$ κ_1	B_5 B_{11} $A_{1,1}$ κ_2
0.10 to 0.20	0.0282607	0.0441202	0.0430371	0.0269307	0.0096100	-0.0009326
	-0.0050668	-0.0068269	-0.0085389	-0.0106890	-0.0108141	-0.0078304
	-0.0035639	0.0089448	0.6662746	0.1545642	-0.3649386	0.1294430
	-0.1674157	0.1745347	-0.1612282	-0.4784872	0.8083284	0.9736149
0.20 to 0.40	0.0179639	0.0230319	0.0237332	0.0128132	0.0023964	-0.0019188
	-0.0018544	-0.0004572	-0.0000668	-0.0002295	-0.0004848	-0.0005756
	-0.0001268	-0.0076456	0.5422834	0.0370519	-0.5861273	-0.3235804
	0.0959577	0.2394104	-0.0211091	0.2964672	0.8430818	0.9969264
0.40 to 0.60	0.0216005	0.0302312	0.0257632	0.0119361	0.0020901	-0.0018405
	-0.0011323	0.0006902	0.0006702	-0.0001005	-0.0004735	-0.0003653
	-0.0001254	0.0082387	0.5134147	0.0764600	-0.6237431	0.0718603
	0.0487440	0.3864337	-0.0798125	-0.1161001	0.8410516	0.9967477
0.60 to 0.80	0.0160666	0.0232418	0.0192183	0.0101824	0.0025005	0.0001384
	0.0007822	0.0009672	0.0003386	-0.0002106	-0.0001584	0.0000132
	0.0000301	0.0045522	0.3404430	0.1943719	-0.6343792	-0.0191611
	0.0888724	0.1040349	0.1179312	-0.4317697	0.8096378	0.9844092
0.80 to 1.00	0.0240637	0.0281241	0.0298094	0.0163487	0.0048927	0.0010811
	0.0003052	0.0006221	0.0004479	-0.0001619	-0.0000656	0.0001954
	0.0006091	0.0094304	0.4732614	0.2220274	-0.5651481	-0.0116242
	0.0534291	0.3317525	0.0558582	0.0242120	0.8280327	0.9852899
1.00 to 2.00	0.0181101	0.0225734	0.0238239	0.0109764	0.0026056	-0.0005971
	-0.0006403	0.0001167	0.0004196	0.0002532	0.0000833	0.0001750
	0.0001365	-0.0001668	0.4779250	0.1941302	-0.6355354	-0.2893666
	0.2061325	0.2289638	0.1188863	0.2021970	0.9023832	0.9913900
2.00 to 4.00	0.0151472	0.0215002	0.0211302	0.0117899	0.0027411	-0.0004422
	-0.0007694	-0.0001466	0.0001893	0.0000308	-0.0001641	-0.0000072
	0.0001078	0.0065534	0.3103542	0.2671002	-0.7308382	-0.1800325
	0.4559000	0.1731892	0.2890834	-0.3706792	0.9481624	0.9890062
4.00 to 6.00	0.0175151	0.0258543	0.0249069	0.0152510	0.0071735	0.0024562
	0.0000917	0.0002497	0.0003539	0.0002651	0.0002349	-0.0000497
	-0.0000307	-0.0019135	0.4986356	0.2832587	-0.6332342	-0.6681857
	0.7093829	0.1933468	0.8579530	-0.5203027	0.9511541	0.9999297
6.00 to 8.00	0.0310783	0.0424566	0.0369728	0.0272961	0.0122690	-0.0018720
	-0.0019478	0.0005804	-0.0001848	-0.0005567	-0.0003243	-0.0002971
	-0.0003460	0.0080843	0.7923437	0.6242861	-0.5136205	-0.8560690
	0.5136434	0.3532789	0.9610540	-0.2934714	0.9600402	0.9736708
8.00 to 10.0	0.0179757	0.0252587	0.0224828	0.0149914	0.0089911	0.0021640
	0.0004975	0.0009320	0.0005972	-0.0000059	-0.0001551	-0.0000442
	0.0000961	0.0172308	0.2976437	0.4716632	-0.7622217	0.2514628
	0.0639793	0.2692690	0.0396489	-0.1046634	0.9574637	0.9907365
^{252}Cf	0.0552567	0.0450798	0.0531871	0.0550070	0.0574887	0.0595465
	0.0602102	0.0630350	0.0642641	0.0668842	0.0606592	0.0437319
	0.0208147	0.0326367	0.5266359	0.5344915	-0.4226910	0.4975843
	-0.2715181	0.3159427	-0.2708678	-0.3639156	0.9998305	0.9979644
14.00	0.0130847	0.0217954	0.0202216	0.0147346	0.0108353	0.0079128
	0.0050068	0.0028258	0.0011537	0.0001682	-0.0001057	-0.0001960
	-0.0000191	0.0058144	0.2308690	0.2740448	-0.7751903	0.0666098
	0.0786978	0.1224670	-0.1653614	0.0408180	0.9468828	0.9849126

Chapter 4

Parameters for Secondary-Photon Approximations

The MCNP code was used to obtain also a set of secondary-photon albedo data based on modern response functions.[1] The secondary albedo arises from the production inelastic and capture gamma rays that are radiated from the reflecting surface. In general, the secondary-photon albedo is independent of the azimuthal angle as a consequence of the isotropic emission of secondary gamma rays. Also of note is that the magnitude of the secondary-photon dose albedo is usually considerably less than that of the neutron dose albedo and, consequently, a high accuracy approximation for the secondary-photon albedo is generally not needed.

The empirical approximation of the differential secondary-photon dose albedo used here is that proposed by Maerker and Muckenthaler,[6] namely

$$\alpha_{D_2}^{(n,\gamma)}(\theta_o, \theta) = \cos^{A_1}(\theta)(A_2 + A_3\cos(\theta_o) + A_4\cos^2(\theta_o)A_5. \tag{4.1}$$

where the parameters A_1, A_2, A_3, A_4, and A_5 are functions of the reflecting media and the energy of the incident neutrons. This approximation can produce errors in some cases that exceed 20% of the MCNP calculated values. Thus when the reflected secondary photon dose is not dwarfed by the reflected neutron dose, more accurate methods may have to be used.

4.1 Coefficients for the Secondary-Photon Albedo

This section presents tables of the parameters in Eq. (4.1) that were obtained by fitting this approximating equation to MCNP albedo results for the secondary photon dose. First a summary of the tables.

- Table 3.1: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on concrete.
- Table 3.2: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on iron.
- Table 3.3: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated

[1] For photon energies above 100 keV, the various photon response functions are nearly equal, but at low energies significant differences occur.[1]

in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on lead.

- Table 3.4: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on water.
- Table 3.5: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete.
- Table 3.6: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron.
- Table 3.7: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead.
- Table 3.8: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water.

Table 4.1: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on concrete.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	1.2251468	0.0244704	0.0492298	-0.0139381	0.1115075
0.20 to 0.40	1.2312173	0.0382557	0.0728755	-0.0178280	0.0334618
0.40 to 0.60	1.2465343	0.0566632	0.0230508	0.0334666	0.0191218
0.60 to 0.80	1.2598252	0.0516362	0.1092739	-0.0271548	0.0137100
0.80 to 1.00	1.2596647	0.3457001	0.6278656	-0.1596085	0.0015772
1.00 to 2.00	1.1835890	0.0215553	0.0244932	-0.0055013	0.0226385
2.00 to 4.00	0.9302703	0.0965355	0.0155189	-0.0228828	0.0079061
4.00 to 6.00	0.8155854	0.6318846	-0.4807632	0.2377993	0.0017701
6.00 to 8.00	0.6953283	0.1176576	-0.1137153	0.0515859	0.0142176
8.00 to 10.0	0.6189852	0.0438972	-0.0430205	0.0181101	0.0561712
thermal	0.6655248	0.5093092	0.4784400	-0.1576664	0.1053226
^{252}Cf	0.9323229	0.3482235	-0.1363502	0.1003944	0.0026425
14.00	0.6113197	0.0728122	-0.0481110	0.0082567	0.0341440

Table 4.2: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on iron.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	0.8710743	0.0797620	0.0120419	-0.0287338	0.0099508
0.20 to 0.40	0.8836678	0.1742562	-0.0932990	0.0442706	0.0020455
0.40 to 0.60	0.8955561	0.6438627	-0.4678769	0.3001452	0.0003028
0.60 to 0.80	0.8724657	0.0408169	-0.0282661	0.0108720	0.0052592
0.80 to 1.00	0.8770500	8.3514328	-9.8536100	4.8210826	0.0000662
1.00 to 2.00	0.8257488	0.5569490	-0.6178252	0.2497904	0.0019963
2.00 to 4.00	0.7695332	2.3030035	-2.4190037	0.9158955	0.0007948
4.00 to 6.00	0.7104058	0.0418370	-0.0444250	0.0166866	0.0766489
6.00 to 8.00	0.6944658	0.0919063	-0.1026560	0.0403242	0.0449133
8.00 to 10.0	0.6915188	0.8185335	-0.9923991	0.4217865	0.0061020
thermal	0.4737152	0.8095560	-0.0572335	-0.0013854	0.2898302
^{252}Cf	0.7539093	0.0844316	-0.0897748	0.0342908	0.0220616
14.00	0.7332955	0.6370363	-0.8658730	0.4122701	0.0061452

Table 4.3: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on lead.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	0.9621408	0.0743082	-0.1046940	0.0744989	0.0012377
0.20 to 0.40	1.0087917	0.4655106	-0.5433951	0.2900578	0.0001053
0.40 to 0.60	0.9889426	0.0224481	-0.0339542	0.0212531	0.0024170
0.60 to 0.80	0.9656463	0.7833453	-1.0802637	0.5530955	0.0001113
0.80 to 1.00	0.9707490	0.0289457	-0.0432212	0.0237198	0.0026265
1.00 to 2.00	0.9177297	2.1745727	-3.4996209	1.8672628	0.0001154
2.00 to 4.00	0.8235922	1.0025156	-1.4573236	0.7075629	0.0007692
4.00 to 6.00	0.7934989	1.8551555	-2.9603820	1.4864856	0.0011888
6.00 to 8.00	0.8063422	0.1566196	-0.2711856	0.1447060	0.0220095
8.00 to 10.0	0.8146378	0.0293868	-0.0516014	0.0278125	0.1193333
thermal	0.8283303	0.1766881	-0.1575702	0.0814234	0.1146051
^{252}Cf	0.8161706	0.0563876	-0.0887288	0.0448796	0.0170483
14.00	0.8523101	0.0947697	-0.1601377	0.0834415	0.0190064

Table 4.4: Parameters for the five term approximation (see Eq. (4.1)) of the secondary-photon albedo based on the effective dose in an anthropomorphic phantom of an adult irradiated in AP geometry by a plane parallel beam of neutrons. Results are for neutrons incident on water.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	0.6388776	0.0487953	0.1390402	-0.0437256	0.0818028
0.20 to 0.40	0.6637982	0.0851111	0.2292753	-0.0729601	0.0266027
0.40 to 0.60	0.6867675	0.0593353	0.1627581	-0.0529712	0.0253296
0.60 to 0.80	0.7105665	0.0279022	0.0895744	-0.0357269	0.0437585
0.80 to 1.00	0.7322555	0.0097584	0.0277489	-0.0109596	0.1084777
1.00 to 2.00	0.7673881	0.1444688	0.4639908	-0.2144744	0.0054993
2.00 to 4.00	0.8402552	0.0328599	0.1101252	-0.0623736	0.0190932
4.00 to 6.00	0.9093888	0.0541582	0.1914711	-0.1258215	0.0098298
6.00 to 8.00	0.7677557	0.1410829	0.1520253	-0.1252073	0.0050784
8.00 to 10.0	0.6074991	0.0292048	0.0006828	-0.0073666	0.0374298
thermal	0.3450067	0.3790261	0.7546664	-0.2058531	0.0451361
^{252}Cf	0.7850721	0.0172006	0.0546228	-0.0284132	0.0439700
14.00	0.5990620	0.0694251	-0.0148203	-0.0067386	0.0180419

Table 4.5: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on concrete.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	1.2256033	0.0638375	0.1287182	-0.0365617	0.0137941
0.20 to 0.40	1.2328238	0.0218045	0.0417456	-0.0102296	0.0203584
0.40 to 0.60	1.2478099	0.1814403	0.0733548	0.1078396	0.0022300
0.60 to 0.80	1.2597181	0.0507181	0.1065247	-0.0262779	0.0056767
0.80 to 1.00	1.2604353	0.0218006	0.0396005	-0.0101063	0.0109961
1.00 to 2.00	1.1804842	0.0345058	0.0422212	-0.0119163	0.0077079
2.00 to 4.00	0.9267063	0.5350051	0.0652701	-0.1112095	0.0010900
4.00 to 6.00	0.8145848	0.4692991	-0.3926117	0.2092658	0.0022836
6.00 to 8.00	0.6978850	0.1410359	-0.1356589	0.0612874	0.0117359
8.00 to 10.0	0.6228144	0.0861592	-0.0837287	0.0349653	0.0250683
thermal	0.6683126	0.2879494	0.2936914	-0.1094149	0.0998052
^{252}Cf	0.9308342	0.0430707	-0.0140312	0.0095817	0.0139569
14.00	0.6149221	0.0851669	-0.0743139	0.0271471	0.0294899

Table 4.6: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on iron.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	0.8727888	0.3910898	-0.1651363	0.0705975	0.0006783
0.20 to 0.40	0.8868781	0.1682039	-0.0892619	0.0421833	0.0007284
0.40 to 0.60	0.8977394	0.0637598	-0.0159727	0.0013926	0.0010851
0.60 to 0.80	0.8745456	0.1903683	-0.1307043	0.0501842	0.0004495
0.80 to 1.00	0.8765674	0.0403735	-0.0417100	0.0173702	0.0060748
1.00 to 2.00	0.8257353	0.8330504	-0.9675792	0.4149715	0.0007585
2.00 to 4.00	0.7707039	0.0321307	-0.0335682	0.0126081	0.0442171
4.00 to 6.00	0.7122030	0.5731707	-0.6470894	0.2664282	0.0054015
6.00 to 8.00	0.6969441	0.0559594	-0.0626762	0.0247631	0.0735622
8.00 to 10.0	0.6942459	0.1688198	-0.1956101	0.0782608	0.0261653
thermal	0.4764265	0.7414173	0.0931285	-0.1350677	0.1645858
^{252}Cf	0.7553329	1.1404155	-1.1852769	0.4367836	0.0010909
14.00	0.7365907	0.7625878	-0.9469593	0.4063371	0.0051079

Table 4.7: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on lead.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	0.9625199	1.5401880	-2.1370354	1.5138557	0.0000189
0.20 to 0.40	1.0064926	8.8446321	-9.9999504	5.2171597	0.0000019
0.40 to 0.60	0.9896619	8.0910301	-9.9999886	5.0190039	0.0000024
0.60 to 0.80	0.9639104	7.0908947	-9.9279041	5.1394620	0.0000051
0.80 to 1.00	0.9711326	0.0958014	-0.1438290	0.0793675	0.0003579
1.00 to 2.00	0.9178385	0.3052734	-0.4916002	0.2621346	0.0004646
2.00 to 4.00	0.8245898	0.3646463	-0.5314746	0.2586226	0.0016356
4.00 to 6.00	0.7945315	0.1351111	-0.2158038	0.1084514	0.0156090
6.00 to 8.00	0.8075593	1.9551373	-3.3866832	1.8079202	0.0017540
8.00 to 10.0	0.8159494	0.0736450	-0.1292748	0.0696660	0.0422499
thermal	0.8293945	0.9605026	-0.8077921	0.3992487	0.0109283
^{252}Cf	0.8174528	0.0310898	-0.0489764	0.0248023	0.0206109
14.00	0.8536811	0.0453257	-0.0766899	0.0400009	0.0404982

Table 4.8: Parameters for the five term approximation (see Eq. (4.1)) of the ambient dose equivalent secondary-photon albedo using fits based on the minimization of the maximum deviation. Results are for neutrons incident on water.

Energy (MeV)	A_1	A_2	A_3	A_4	A_5
0.10 to 0.20	0.6407247	0.0593760	0.1594001	-0.0452385	0.0226027
0.20 to 0.40	0.6655912	0.0094389	0.0252501	-0.0079355	0.0858675
0.40 to 0.60	0.6886491	0.0164475	0.0474505	-0.0165714	0.0348122
0.60 to 0.80	0.7123201	0.0230588	0.0749818	-0.0302738	0.0220694
0.80 to 1.00	0.7340014	0.0432483	0.1365578	-0.0597300	0.0108535
1.00 to 2.00	0.7691070	0.0241902	0.0775496	-0.0357483	0.0184533
2.00 to 4.00	0.8417001	0.2769863	0.9282053	-0.5249802	0.0017484
4.00 to 6.00	0.9106550	0.0213192	0.0754003	-0.0494900	0.0240043
6.00 to 8.00	0.7757766	0.6343027	0.7231793	-0.5882518	0.0011233
8.00 to 10.0	0.6168484	0.2000332	0.0335462	-0.0756631	0.0047815
thermal	0.3471366	0.0873124	0.1643816	-0.0394940	0.1095107
^{252}Cf	0.7872421	0.0460545	0.1462282	-0.0758350	0.0109788
14.00	0.6069419	0.1044084	-0.0126468	-0.0186599	0.0118985

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