NBS TECHNICAL NOTE 1116

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

SHIELDOSE: A Computer Code for Space-Shielding Radiation Dose Calculations

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t Technical note

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Issued May 1980

National Bureau of Standards Technical Note 1116
Nat. Bur. Stand. (U.S.), Tech. Note 1116, 72 pages (May 1980)
CODEN: NBTNAE

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1980

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price $3.75
(Add 25 percent for other than U.S. mailing).

SHIELDOSE: A Computer Code for Space-Shielding Radiation Dose Calculations[1]

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A computer code, SHIELDOSE, has been developed for the calculation of absorbed dose as a function of depth in aluminum shielding material of spacecraft, given the electron and proton fluences encountered in orbit. Absorbed dose, for small volumes of the detector materials Aℓ, H_2O, Si, and SiO_2, is evaluated in three geometries: (1) in a semi-infinite plane medium, (2) at the transmission surface of a finite-thickness slab, and (3) at the center of a solid sphere. Use of the code is described, and an extensive set of monoenergetic depth-dose data for the various detector materials and geometries is tabulated.

Key words: Computer code; depth-dose data; electrons; electron bremsstrahlung; protons; space shielding.

1. Introduction

The ability to predict absorbed dose within a spacecraft due to a specified radiation environment is important for design and planning considerations pertaining to the reliability of electronic components and to the radiological safety of on-board personnel. This report describes the computer code SHIELDOSE, which evaluates the absorbed dose as a function of depth in aluminum shielding material of spacecraft, given the electron and proton fluences encountered in orbit.

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[1]Work supported by the Office of Naval Research and by the National Space Science Data Center at the NASA Goddard Space Flight Center.

The code makes use of pre-calculated, monoenergetic depth-dose data for an isotropic, broad-beam fluence of radiation incident on uniform aluminum plane media. Such data are particularly suitable for routine dose predictions in situations where the geometrical and compositional complexities of the spacecraft are not known. Furthermore, restricting our consideration to these rather simple geometries has allowed for the development of accurate electron and electron-bremsstrahlung data sets based on detailed transport calculations rather than on more approximate methods. The present version of SHIELDOSE calculates, for arbitrary proton and electron incident spectra, the dose absorbed in small volumes of the detector materials Aℓ, H_2O (tissue-equivalent detector), Si, and SiO_2, in the following aluminum shield geometries: (1) in a semi-infinite plane medium, as a function of depth; (2) at the transmission surface of a plane slab, as a function of slab thickness; and (3) at the center of a solid sphere, as a function of sphere radius.

Section 2 defines a number of pertinent quantities used in the calculations and briefly outlines the methods used for integrating the monoenergetic data over the incident flux spectra. Section 3 gives the meanings and required formats of the various input parameters, and other running instructions for SHIELDOSE. Appendix A is a reprint of a report [1][2] which gives details on the methods with which the monoenergetic depth-dose distributions were calculated. Appendix B comprises tables of the monoenergetic depth-dose data; appendix C gives the input and output listings of a sample run; and appendix D contains a FORTRAN listing of the code.

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[2]Figures in brackets indicate the literature references at the end of this paper.

2. Method

The quantity of interest calculated by SHIELDOSE is the absorbed dose $\mathcal{D}(z)$, as a function of depth z in an aluminum shield, for an arbitrary incident fluence[3] of radiation. The incident fluence can be either protons or electrons. If it is protons, it will be implicitly understood that $\mathcal{D}(z)$ is the proton dose; if electrons, $\mathcal{D}(z)$ is calculated separately for the bremsstrahlung component and the "electron" component (by which we mean the distribution of deposited electron energy never converted to bremsstrahlung photons). Results are calculated for three geometries (see fig. 1):

Case 1. $\underset{\infty}{\mathcal{D}}^{\text{det}}(z)$ is the absorbed dose in a thin detector (of material denoted by "det") at a depth z in a semi-infinite plane aluminium medium. Irradiation is from one side only (the assumed infinite backing effectively insures this).

Case 2. $\underset{-}{\mathcal{D}}^{\text{det}}(z)$ is the absorbed dose in a thin detector at the transmission surface of an aluminum plane slab of thickness z. Irradiation is from one side only.

Case 3. $\underset{\bullet}{\mathcal{D}}^{\text{det}}(z)$ is the absorbed dose in a small detector volume at the center of a solid aluminum sphere of radius z. Irradiation is from all directions.

The detector materials Aℓ, H_2O, Si, and SiO_2 are presently included in the data base.

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[3] We can use the fluence (number per unit area, per unit energy, per unit solid angle) and the flux (number per unit area, per unit energy, per unit solid angle, per unit time) interchangeably. Use of the fluence leads to absorbed dose, and the flux to dose rate.

We define the following quantities:

$\phi(T_o,\theta)$ is the incident fluence, differential in energy T_o and angle θ, having units of $cm^{-2}MeV^{-1}sr^{-1}$. We assume ϕ to be isotropic and drop the explicit dependence on θ.

$\psi_{4\pi}(T_o) = 4\pi\ \phi(T_o)$ is the full-space (4π) incident fluence, having units of $cm^{-2}MeV^{-1}$.

$D_{\bar{\infty}}^{det}(z,T_o)$ is the depth-dose distribution for irradiation by a monoenergetic, omnidirectional beam with energy T_o incident on a semi-infinite medium (case 1 geometry). The depth-dose distribution, normalized to an incident current of 1 cm^{-2} (see appendix A, eqs (1-5)), has units of MeV cm^2/g. $D_{\bar{\infty}}^{det}$ is given separately for the proton, electron, and electron-bremsstrahlung components.

$D_{\bar{-}}^{det}(z,T_o)$ is similar to $D_{\bar{\infty}}^{det}$ but for monoenergetic irradiation of finite-thickness slabs (case 2 geometry), from one side only.

Then

$$\mathcal{D}_{\bar{\infty}}^{det}(z) = \frac{K}{4}\int_0^\infty \psi_{4\pi}(T_o)\ D_{\bar{\infty}}^{det}(z,T_o)\ dT_o \quad , \qquad (1)$$

where $K = 1.6022 \times 10^{-8}$ rads/(MeV g^{-1}), and the factor of 1/4 comes from the relation between the full-space fluence and the incident current (see eq (5) in appendix A). Because the incident fluence $\psi_{4\pi}(T_o)$ typically falls off rather steeply with increasing energy, eq (1) is rewritten

$$\mathcal{D}_{\bar{\infty}}^{det}(z) = \frac{K}{4}\int_{\ell n\ T_{min}}^{\ell n\ T_{max}} T_o\ \psi_{4\pi}(T_o)\ D_{\bar{\infty}}^{det}(z,T_o)\ d(\ell n\ T_o) \quad . \qquad (2)$$

Equation (2) is evaluated numerically using a Simpson's rule, so that

$$\mathcal{D}_{\bar{\infty}}^{det}(z) = \frac{K}{4}\frac{\Delta}{3}\sum_{i=1}^{N} w_i T_i\ \psi_{4\pi}(T_i)\ D_{\bar{\infty}}^{det}(z,T_i) \quad , \qquad (3)$$

where $w_i = 1,4,2,4,2 \ldots 2,4,1$ (N odd),[4] and $\ell n\ T_i = \ell n\ T_{min} + (i-1)\Delta$ with $\Delta = (\ell n\ T_{max} - \ell n\ T_{min})/(N-1)$.

In order to facilitate the interpolation of $D_{\bar{\infty}}^{det}(z,T_o)$ among tabulated values, eq (3) is recast as

$$\mathcal{D}_{\bar{\infty}}^{det}(z) = \frac{K}{4}\frac{\Delta}{3}\sum_{i=1}^{N} w_i T_i\ \psi_{4\pi}(T_i)\ S^{-1}(T_i)\left\{S(T_i)\ D_{\bar{\infty}}^{det}[x(z,T_i),\ T_i]\right\} \quad , \qquad (4)$$

for which the scaling functions are

	S(T)	x(z,T)
protons	$r_o(T)/T$, g cm^{-2} MeV^{-1}	$z/r_o(T)$
electrons	$r_o(T)/T$, g cm^{-2} MeV^{-1}	$z/r_o(T)$
bremsstrahlung	$1/T$, MeV^{-1}	z/T

and where r_o is the mean range evaluated in the continuous-slowing-down approximation. Values of the mean range r_o are given in table 1 for protons [2] and table 2 for electrons [3]. The scaled depth-dose distributions in the curly brackets in eq (4), having a much reduced dependence

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[4] Any $N \geq 2$ can be handled, and the weights w_i are suitably adjusted.

on z and T_o, are tabulated in appendix B. Interpolation is accomplished by fitting with natural cubic splines [4], first in T, then in x.

Values for T_{min} and T_{max} (eq (2) above) are often imposed by the available knowledge of the incident electron or proton fluence $\psi_{4\pi}(T_o)$. If, in the evaluation of eq (4), T_i is outside of the energy range for which the scaled, monoenergetic depth-dose distributions are given, then the curly bracket is evaluated for the nearest energy tabulated, and the energy variation is assumed to be taken care of by the term $S^{-1}(T_i)$. This procedure should cause little error since the tabulated proton data extend from 2 to 5000 MeV, the electron data from 0.1 to 10 MeV, and the bremsstrahlung data from 0.02 to 20 MeV, and should cover incident spectra encountered in space-shielding problems.

A more likely situation is that information on the incident flux spectra extends only over an energy region more limited than those above. For example, current model predictions of the terrestrial radiation environment [5] typically give spectral information over the energy ranges 0.1 to 10 MeV for electrons 0.5 to 500 MeV for trapped protons, and 10 to 200 MeV for solar-flare protons. If $\psi_{4\pi}(T_o)$ is entered into SHIELDOSE in numerical form, care should be taken in choosing values of T_{min} and T_{max} in order to avoid the automatic cubic-spline extrapolation of $\psi_{4\pi}(T_o)$ which can occasionally result in significant, and quite peculiar, components in the incident energy spectrum. It should be kept in mind that the final results neglect those contributions to the dose from radiation with $T_o < T_{min}$ and $T_o > T_{max}$. This can be particularly important for depths $z < r_o(T_{min})$. Some results of test calculations using

$$\psi_{4\pi}(T_o) = \frac{1}{\alpha} e^{-T_o/\alpha} , \qquad (5)$$

are given in table 3 which shows, at various depths z and for various values of the e-folding energy α, the effect on $\mathcal{D}_{\infty}^{Al}(z)$ of different choices of T_{min} and T_{max}.

The discussion above outlines the calculation of $\mathcal{D}_{\infty}^{det}(z)$ for a semi-infinite medium. The calculation of $\mathcal{D}_{-}^{det}(z)$ for finite-thickness slabs is similar but based on $D_{-}^{det}(z,T_0)$. The results for the dose at the center of a solid sphere of radius z are obtained from (see also eq (10) in appendix A)

$$\mathcal{D}_{\bullet}^{det}(z) = 2\mathcal{D}_{\infty}^{det}(z)\left\{1 - \frac{d \log \mathcal{D}_{\infty}^{det}(z')}{d \log z'}\bigg|_{z'=z}\right\}, \qquad (5)$$

where the logarthmic derivative is evaluated using a cubic-spline fit of $\log \mathcal{D}_{\infty}^{det}(z)$. We have found that $N = 301$ for protons and $N = 101$ for electrons gives distributions of $\mathcal{D}_{\infty}^{det}(z)$ sufficiently smooth to give reasonably smooth results for $\mathcal{D}_{\bullet}^{det}(z)$.

3. Input Parameters

The format of the input deck is (using FORTRAN notation):

IDET, NUT, IPRNT	3I6
[scaled monoenergetic depth-dose data set][5]	not user supplied
IMAX, IUNT	2I6
(Z(I), I=1, IMAX)	6F12.5
EMINS, EMAXS, EMINP, EMAXP, NPTSP, EMINE, EMAXE, NPTSE	4F10.3, I6, 2F10.3, I6

[5]This rather lengthy data set, about 13,400 words of information, should be permanently stored on tape or disk. Although its position in the input stream is as indicated above, it is read from unit NUT.

The following block of input data can be repeated for each set of incident spectra:

COMMENT	72H
JSMAX, JPMAX, JEMAX, EUNIT, TINTER	3I6, IP2E12.5
(EPSS(J), J=1, JSMAX)	1P6E12.4
(SS(J), J=1, JSMAX)	1P6E12.4
(EPSP(J), J=1, JPMAX)	1P6E12.4
(SP(J), J=1, JPMAX)	1P6E12.4
(EPSE(J), J=1, JEMAX)	1P6E12.4
(SE(J), J=1, JEMAX)	1P6E12.4

The meaning of the input parameters is as follows:

IDET = 1 , detector material is Aℓ.

2 , detector material is H_2O.

3 , detector material is Si.

4 , detector material is SiO_2.

NUT is the unit from which the scaled depth-dose data set is read.

IPRNT = 1 , input monoenergetic depth-dose data is listed in printout.

2 , input monoenergetic depth-dose data is not listed in printout.

IMAX is the number of depths z for which dose calculation is desired (IMAX $\leq$ 50).

IUNT = 1 , depth z in mils.[6]

2 , depth z in g/cm^2.

3 , depth z in mm.

Z is simultaneously the IMAX depths (case 1 geometry), thicknesses (case 2 geometry), and sphere radii (case 3 geometry) in units specified by IUNT. No Z-value can be 0 because of a log Z interpolation performed in the bremsstrahlung calculation. Furthermore, $0 < Z \leq 30$ g/cm^2, due to the extent of the bremsstrahlung data.

EMINS is the lower limit T_{min} for the integration over the incident solar-flare-proton spectrum (see eq (2)).

EMAXS is the upper limit T_{max} for the integration over the incident solar-flare-proton spectrum (see eq (2)).

EMINP is the lower limit T_{min} for the integration over the incident trapped-proton spectrum (see eq (2)).

EMAXP is the upper limit T_{max} for the integration over the incident trapped-proton spectrum (see eq (2)).

NPTSP is the number of points used in the numerical evaluation of the integral over the incident proton spectrum, for

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[6] 1 mil = 0.001 inch = 0.0254 mm. For aluminum, with a density of 2.70 g/cm^3, 1 mil = 0.00686 g/cm^2.

which the integration extends from min(EMINS, EMINP) to max(EMAXS, EMAXP). Note that EMINS, EMAXS, EMINP, and EMAXP may be slightly adjusted to the nearest mesh-energy values. (NPTSP ≤ 301, recommend NPTSP = 301).

EMINE is the lower limit T_{min} for the integration over the incident electron spectrum (see eq (2)).

EMAXE is the upper limit T_{max} for the integration over the incident electron spectrum (see eq (2)).

NPTSE is the number of points used in the numerical evaluation of the integral over the incident electron spectrum (NPTSE ≤ 101, recommend NPTSE = 101).

COMMENT is any identifying message.

JSMAX is the number of energies for which the incident solar-flare-proton spectrum is read in (JSMAX ≤ 101). If JSMAX ≤ 2, no solar-flare-proton results are calculated.

JPMAX is the number of energies for which the incident trapped-proton spectrum is read in (JPMAX ≤ 101). If JPMAX ≤ 2, no trapped-proton results are calculated.

JEMAX is the number of energies for which the incident electron spectrum is read in (JEMAX ≤ 101). If JEMAX ≤ 2, no electron and bremsstrahlung results are calculated.

EUNIT is the conversion factor from (unit energy)$^{-1}$ to MeV^{-1}, where (unit energy)$^{-1}$ pertains to the units in which the incident proton and electron flux spectra are read. For example, if the incident spectra are read in units of keV^{-1}, then EUNIT = 1000; if read in units of MeV^{-1} then EUNIT = 1 (if the EUNIT field is left blank or if EUNIT $\leq$ 0, then SHIELDOSE assumes EUNIT = 1).

TINTER is the time interval (e.g., mission duration) for which results are desired. TINTER is in units of (unit time), where (unit time)$^{-1}$ pertains to the units in which the incident trapped-proton and electron flux spectra are read. For example, if incident spectra are read in units of sec^{-1}, then TINTER = 1 gives the absorbed dose for a 1-sec irradiation; TINTER = 3.1536×10^{7} gives dose for one year (365 days); etc. If the TINTER field is left blank or if TINTER $\leq$ 0, then SHIELDOSE assumes TINTER = 1. Note that TINTER does not pertain to the incident solar-flare-proton fluence spectrum which is assumed to be the result of a statistical analysis relating the probability of the incident solar-flare-proton fluence to the mission duration [6].

EPSS are the JSMAX energies in MeV (in ascending order) for which the incident solar-flare-proton fluence spectrum is read. If JSMAX $\leq$ 2, this array is not read in.

SS are the values (at energies EPSS) of the full-space (4π), omnidirectional solar-flare-proton incident fluence spectrum in units of cm^{-2} (unit energy)$^{-1}$.

EPSP are the JPMAX energies in MeV (in ascending order) for which the incident trapped-proton flux spectrum is read. If JPMAX ≤ 2, this array is not read in.

SP are the values (at energies EPSP) of the full-space (4π), omnidirectional trapped-proton incident flux spectrum in units of cm^{-2} (unit energy)$^{-1}$ (unit time)$^{-1}$.

EPSE are the JEMAX energies in MeV (in ascending order) for which the incident electron fluence spectrum is read.

SE are the values (at energies EPSE) of the full-space (4π), omnidirectional incident electron fluence spectrum in units of cm^{-2} (unit energy)$^{-1}$ (unit time)$^{-1}$.

Note the following option which pertains to the solar-flare-proton, trapped-proton, and electron incident spectra:

If EPS(1) ≤ 0 (but JMAX ≥ 3), then the incident spectrum is assumed to be $\psi_{4\pi}(T_o) = (C/\alpha) \exp(-T_o/\alpha)$, with α(MeV) = S(1) and C = S(2). The units for C are cm^{-2} for the solar-flare-proton fluence spectrum,

and cm^{-2} (unit time)$^{-1}$ for the trapped-proton and electron flux spectra. This option may be particularly useful for the solar-flare-proton spectrum for which, in the active years 1977-1983, the spectrum is characterized by α = 26.5 MeV for anomalously large events and by α = 63.3 MeV for ordinary events [6]. Values of C can be obtained from information on the corresponding integral spectrum $I(> T_0)$, via $C = I(> T_0) \exp(T_0/\alpha)$. If the entered value $S(2) \leq 0$, then SHIELDOSE sets C = 1.

The code is written to process quickly many incident spectra in a single run. For example, using an IBM 360/91 computer and with NPTSP = 301, NPTSE = 101 and IMAX = 48, approximately 10 sec is required for setting up internal matrices and ~ 1 sec for each input proton and electron spectrum set. The storage requirement is ~ 80 K words.

It is, in general, necessary to suppress underflow diagnostics which interrupt, and can eventually terminate, a run. Underflow conditions are not detected by the code itself and should therefore be suppressed using the appropriate options available at the particular computing installation. For the IBM system used by the author, this is accomplished by the "CALL ERRSET" instruction at the beginning of the main routine listed in appendix D.

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Table 1. Proton range $r_o(T_o)$ as a function of proton energy T_o. Values are from reference [2].

T_o(MeV)	r_o(g/cm^2)	T_o(MeV)	r_o(g/cm^2)
2	1.147×10^{-2}	100	9.975
3	2.181×10^{-2}	150	2.026×10^{1}
4	3.500×10^{-2}	200	3.320×10^{1}
5	5.094×10^{-2}	300	6.547×10^{1}
6	6.974×10^{-2}	400	1.043×10^{2}
8	1.157×10^{-1}	500	1.482×10^{2}
10	1.703×10^{-1}	600	1.959×10^{2}
15	3.458×10^{-1}	800	2.994×10^{2}
20	5.739×10^{-1}	1000	4.102×10^{2}
30	1.177	1500	7.046×10^{2}
40	1.963	2000	1.010×10^{3}
50	2.920	3000	1.627×10^{3}
60	4.039	4000	2.239×10^{3}
80	6.728	5000	2.843×10^{3}

Table 2. Electron range $r_o(T_o)$ as a function of electron energy T_o. Values are from reference [3].

T_o(MeV)	r_o(g/cm^2)	T_o(MeV)	r_o(g/cm^2)
0.01	3.519×10^{-4}	1.0	5.493×10^{-1}
0.015	7.074×10^{-4}	1.5	8.825×10^{-1}
0.02	1.165×10^{-3}	2.0	1.212
0.03	2.356×10^{-3}	3.0	1.855
0.04	3.883×10^{-3}	4.0	2.476
0.05	5.714×10^{-3}	5.0	3.076
0.06	7.822×10^{-3}	6.0	3.658
0.08	1.279×10^{-2}	8.0	4.777
0.10	1.864×10^{-2}	10	5.841
0.15	3.641×10^{-2}	15	8.305
0.20	5.772×10^{-2}	20	1.054×10^{1}
0.30	1.077×10^{-1}	30	1.448×10^{1}
0.40	1.640×10^{-1}	40	1.788×10^{1}
0.50	2.243×10^{-1}	50	2.087×10^{1}
0.60	2.871×10^{-1}	60	2.355×10^{1}
0.80	4.168×10^{-1}	80	2.816×10^{1}
		100	3.204×10^{1}

Table 3. Fraction of dose $\mathcal{D}_{-\infty}^{Al}(z)$ contributed by incident spectral energies below T_c. The quantity given corresponds to the ratio

$$\int_0^{T_c} D_{-\infty}^{Al}(z,T_o)\ \exp(-T_o/\alpha)\ dT_o \Big/ \int_0^{\infty} D_{-\infty}^{Al}(z,T_o)\ \exp(-T_o/\alpha)\ dT_o \quad ,$$

and is given for various depths z in g/cm^2 and for various α and T_c in MeV. For any z and α, the fraction of the dose contributed by $T_{min} \leq T_o \leq T_{max}$ is the difference between the value tabulated for $T_c = T_{max}$ and that for $T_c = T_{min}$. Results are given for protons, electrons, and bremsstrahlung.

PROTONS

$z(g/cm^2)$ \ T_c(MeV)	2	5	10	200	500	1000	2000	5000
				α = 10 MeV				
0.03	0.00	0.15	0.63	1.00	1.00	1.00	1.00	1.00
0.3	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
3	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
30	0.00	0.00	0.00	0.51	0.92	0.96	0.99	1.00
				α = 20 MeV				
0.03	0.00	0.10	0.47	1.00	1.00	1.00	1.00	1.00
0.3	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
3	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
30	0.00	0.00	0.00	0.27	0.97	0.99	0.99	1.00
				α = 50 MeV				
0.03	0.00	0.06	0.31	1.00	1.00	1.00	1.00	1.00
0.3	0.00	0.00	0.00	0.99	1.00	1.00	1.00	1.00
3	0.00	0.00	0.00	0.97	1.00	1.00	1.00	1.00
30	0.00	0.00	0.00	0.10	0.99	1.00	1.00	1.00
				α = 100 MeV				
0.03	0.00	0.05	0.24	0.96	1.00	1.00	1.00	1.00
0.3	0.00	0.00	0.00	0.95	1.00	1.00	1.00	1.00
3	0.00	0.00	0.00	0.86	0.99	1.00	1.00	1.00
30	0.00	0.00	0.00	0.05	0.95	1.00	1.00	1.00
				α = 200 MeV				
0.03	0.00	0.03	0.18	0.87	0.98	1.00	1.00	1.00
0.3	0.00	0.00	0.00	0.83	0.97	1.00	1.00	1.00
3	0.00	0.00	0.00	0.69	0.95	1.00	1.00	1.00
30	0.00	0.00	0.00	0.03	0.81	0.99	1.00	1.00

Table 3. (Continued)

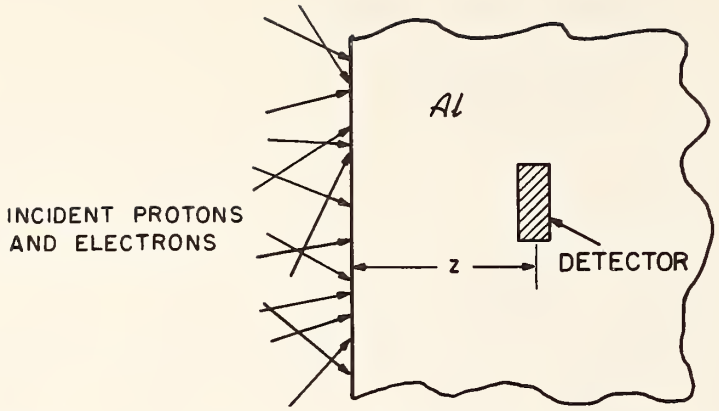
ELECTRONS

$z(g/cm^2)$ \ T_c(MeV)	0.1	0.2	0.5	2	5	10	20	50
				α = 0.25 MeV				
0.03	0.00	0.05	0.71	1.00	1.00	1.00	1.00	1.00
0.3	0.00	0.00	0.00	0.98	1.00	1.00	1.00	1.00
3	0.00	0.00	0.00	0.00	0.01	1.00	1.00	1.00
				α = 0.50 MeV				
0.03	0.00	0.03	0.48	0.98	1.00	1.00	1.00	1.00
0.3	0.00	0.00	0.00	0.84	1.00	1.00	1.00	1.00
3	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00
				α = 1 MeV				
0.03	0.00	0.01	0.29	0.85	0.99	1.00	1.00	1.00
0.3	0.00	0.00	0.00	0.57	0.98	1.00	1.00	1.00
3	0.00	0.00	0.00	0.00	0.00	0.95	1.00	1.00
				α = 2 MeV				
0.03	0.00	0.01	0.16	0.62	0.92	0.99	1.00	1.00
0.3	0.00	0.00	0.00	0.33	0.84	0.99	1.00	1.00
3	0.00	0.00	0.00	0.00	0.00	0.71	1.00	1.00
				α = 4 MeV				
0.03	0.00	0.00	0.09	0.39	0.72	0.92	1.00	1.00
0.3	0.00	0.00	0.00	0.17	0.59	0.89	1.00	1.00
3	0.00	0.00	0.00	0.00	0.00	0.43	1.00	1.00

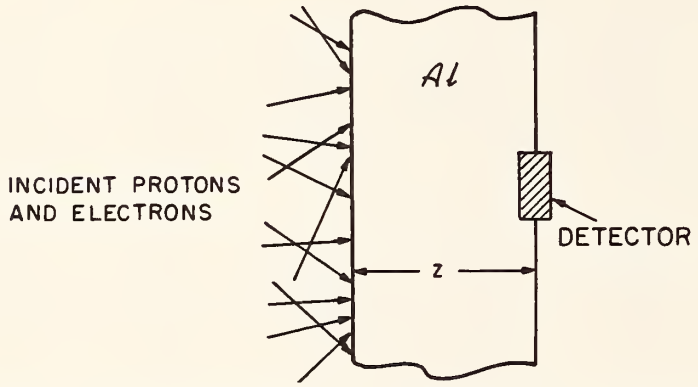
Table 3. (Continued)

BREMSSTRAHLUNG

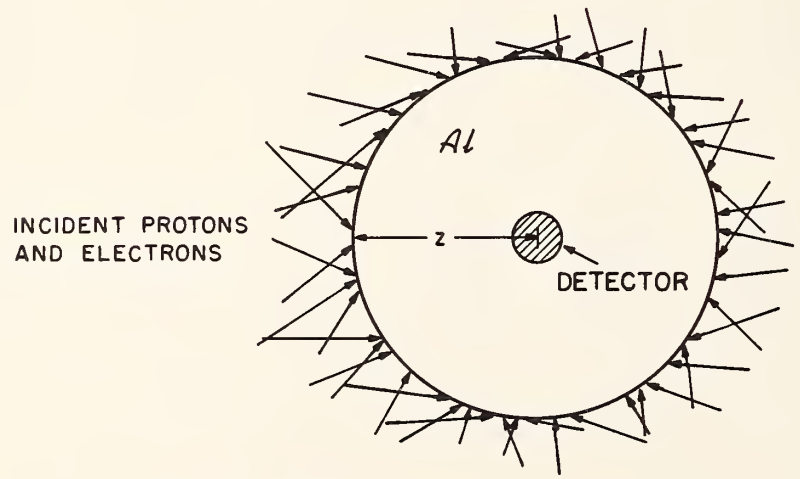
$z(g/cm^2)$ \ T_c(MeV)	0.1	0.2	0.5	2	5	10	20	50
				α = 0.25 MeV				
0.03	0.02	0.12	0.68	1.00	1.00	1.00	1.00	1.00
0.3	0.01	0.06	0.33	0.99	1.00	1.00	1.00	1.00
3	0.00	0.04	0.30	0.98	1.00	1.00	1.00	1.00
30	0.00	0.01	0.16	0.97	1.00	1.00	1.00	1.00
				α = 0.50 MeV				
0.03	0.01	0.05	0.40	0.96	1.00	1.00	1.00	1.00
0.3	0.00	0.01	0.09	0.85	1.00	1.00	1.00	1.00
3	0.00	0.01	0.07	0.74	1.00	1.00	1.00	1.00
30	0.00	0.00	0.03	0.62	0.99	1.00	1.00	1.00
				α = 1 MeV				
0.03	0.00	0.02	0.19	0.74	0.98	1.00	1.00	1.00
0.3	0.00	0.00	0.02	0.51	0.95	1.00	1.00	1.00
3	0.00	0.00	0.01	0.29	0.86	1.00	1.00	1.00
30	0.00	0.00	0.00	0.18	0.79	0.99	1.00	1.00
				α = 2 MeV				
0.03	0.00	0.01	0.08	0.40	0.97	1.00	1.00	1.00
0.3	0.00	0.00	0.01	0.22	0.70	0.96	1.00	1.00
3	0.00	0.00	0.00	0.07	0.44	0.88	1.00	1.00
30	0.00	0.00	0.00	0.03	0.32	0.82	1.00	1.00
				α = 4 MeV				
0.03	0.00	0.00	0.02	0.15	0.41	0.72	0.96	1.00
0.3	0.00	0.00	0.00	0.08	0.34	0.70	0.96	1.00
3	0.00	0.00	0.00	0.01	0.14	0.51	0.92	1.00
30	0.00	0.00	0.00	0.00	0.07	0.37	0.84	1.00



CASE 1. SEMI-INFINITE MEDIUM; ABSORBED DOSE IN DETECTOR DENOTED AS $\mathcal{D}_{\infty}^{det}(z)$



CASE 2. FINITE-THICKNESS SLAB; ABSORBED DOSE IN DETECTOR DENOTED AS $\mathcal{D}_{-}^{det}(z)$



CASE 3. SOLID SPHERE; ABSORBED DOSE IN DETECTOR DENOTED AS $\mathcal{D}_{\bullet}^{det}(z)$

Fig. 1. Geometries considered in SHIELDOSE calculations. Isotropic, broad-beam fluxes of protons and electrons are assumed incident on aluminum targets; absorbed dose is calculated for small volumes of detector materials Aℓ, H_2O, Si, and SiO_2.

IEEE Transactions on Nuclear Science, Vol. NS-26, No. 6, December 1979

ELECTRON, ELECTRON-BREMSSTRAHLUNG AND PROTON DEPTH-DOSE DATA FOR SPACE-SHIELDING APPLICATIONS*

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Abstract

A data set has been developed, consisting of depth-dose distributions for omni-directional electron and proton fluxes incident on aluminum shields. The principal new feature of this work is the accurate treatment, based on detailed Monte Carlo calculations, of the electron-produced bremsstrahlung component. Results covering the energy region of interest in space-shielding calculations have been obtained for the absorbed dose (a) as a function of depth in a semi-infinite medium, (b) at the edge of slab shields, and (c) at the center of a solid sphere. The dose to a thin tissue-equivalent detector was obtained as well as that in aluminum. Various results and comparisons with other work are given.

Introduction

The longer durations of currently planned and future satellite missions, and the increasing preference for the use of radiation-sensitive CMOS (Complimentary Metal-Oxide-Semiconductor) devices, make more acute the problem of predicting the radiation dose at points in the spacecraft.[1] Such predictions depend on (a) knowledge of the spectra of electrons and protons incident on the spacecraft; (b) details of the geometrical and compositional complexities of the spacecraft; and (c) an accurate description of the transport of the radiation through the spacecraft material.

Improvements in space-shielding calculations are desirable in all three of these areas. The uncertainty in the information of the Earth's radiation environment is presently approaching a level of about a factor of two, and should improve further as more comprehensive experimental data are accumulated and theoretical models are refined. The complexities of the spacecraft configuration can, in principle, be taken into account by Monte Carlo transport calculations in complicated geometry[2] or by irradiations of satellite mock-ups. However, a far less costly alternative is the use of approximate methods[3] based on data obtained for simple geometries.

In this paper, calculated results are presented on the penetration of electrons and protons in aluminum, as summarized in terms of depth-dose data, for conditions pertinent to space-shielding problems. The principal new feature of this work is the accurate treatment of the production and transport of electron-produced bremsstrahlung photons which are more penetrating than the electrons themselves. Information on the bremsstrahlung tail can be particularly important for geostationary orbits in which satellites encounter few or no trapped protons, and for which the dose penetrating through thick shields is completely due to the bremsstrahlung.

*Work supported by the Office of Naval Research and the National Space Science Data Center at the NASA Goddard Space Flight Center.

Although the basic calculations were done for semi-infinite aluminum targets, consideration has been given also to other simple configurations, namely the dose at the edge of finite aluminum slabs and the dose at the center of uniform, solid aluminum spheres. In addition, the dose has been calculated in thin tissue-equivalent detectors embedded in or at the edge of the aluminum target.

Method of Calculation

Electrons and Bremsstrahlung

The electron calculations make use of the Monte Carlo code ETRAN which treats the following processes: i) electron energy loss, including energy-loss straggling (fluctuations) due both to multiple inelastic scattering by atomic electrons and to the emission of bremsstrahlung photons; ii) angular deflections of electrons due to multiple elastic scattering by atoms; iii) penetration and diffusion of the secondary bremsstrahlung photons; and iv) penetration and diffusion of energetic secondary electrons produced in electron-electron knock-on collisions (delta rays) and in the interaction of bremsstrahlung photons with the medium (pair, Compton, and photoelectrons).

Details of the Monte Carlo model and of the cross sections used have been given elsewhere[4-7], along with numerous comparisons with experimental results. These will not be discussed here, except for the following improvement. The ETRAN bremsstrahlung results, based on the use of a set of empirically-corrected Bethe-Heitler bremsstrahlung cross sections[6], were adjusted to reflect the exact calculations of the bremsstrahlung production cross section of Pratt, Tseng, et al[8]. Comparisons, using both the ETRAN and Pratt cross-section data sets for aluminum, of the electron mean energy loss per unit pathlength due to the emission of bremsstrahlung (see, e.g., reference 11) and of the total energy radiated in the course of slowing down (in the continuous-slowing-down approximation) give a multiplicative correction factor for the ETRAN results that is very close to unity for electron source energies $T_0 \geq 1$ MeV, and is 0.96, 0.94, 0.92, 0.89, and 0.82 at 0.5, 0.2, 0.1, 0.05, and 0.02 MeV, respectively.

Protons

The main emphasis on this work was the calculation of the dose from electrons. However, it was considered desirable to include some corresponding results for protons so that one can put the contributions from the two types of radiation into proper perspective. For this purpose, we limited ourselves to a simple treatment that included Coulomb interactions but neglected nuclear interactions. The error incurred by this simplification is generally no greater than 10-20% for shields up to ~ 30 g/cm^2.

The proton calculations were done in the straight-ahead, continuous-slowing-down approximation using the stopping-power and range data of Barkas and Berger.[9] Alsmiller et al[10] have shown that the neglect of angular deflections and range straggling is negligible in space-shielding calculations.

Initial and Boundary Conditions

The calculations were made for radiation whose fluence is isotropic and which is incident on a semi-infinite, uniform aluminum plane medium. The radiation is assumed to be incident over a large area, so that the transport problem reduces to a one-dimensional one, with the depth z as the only spatial variable. Radiation crossing out through the plane boundary ($z = 0$) was considered lost to the medium (backscattered).

Let $\varphi(T_o,\theta)$ be the incident fluence, differential in initial energy T_o and in angle θ. The fluence, having units of $cm^{-2}MeV^{-1}sr^{-1}$, pertains to the number of particles crossing through a unit area perpendicular to the incident particle vector. The current of particles crossing into the medium, per unit area of the plane boundary, is then

$$j(T_o,\theta) = \varphi(T_o,\theta)\cos\theta\ , \quad 0 \leq \theta \leq \pi/2, \qquad (1)$$

where θ is the angle of incidence with respect to the normal to the plane. The current j has the same units as the fluence φ.

For the purposes of normalization, we define the integrated incident 4π fluence as*

$$\Phi_{4\pi} = 2\pi \int_0^\infty dT_o \int_0^\pi \sin\theta d\theta\ \varphi(T_o,\theta)\ ,$$

or

$$\Phi_{4\pi} = 4\pi \int_0^\infty dT_o\ \varphi(T_o)\ , \qquad (2)$$

since φ is assumed isotropic. $\Phi_{4\pi}$ has the units cm^{-2}. Only particles with $0 \leq \theta \leq \pi/2$ cross into a semi-infinite plane medium, so we define the integrated incident 2π fluence as

$$\Phi_{2\pi} = 2\pi \int_0^\infty dT_o \int_0^{\pi/2} \sin\theta d\theta\ \varphi(T_o,\theta)$$

$$= 2\pi \int_0^\infty dT_o\ \varphi(T_o) \qquad (3)$$

and the total incident current as

$$J = 2\pi \int_0^\infty dT_o \int_0^{\pi/2} \sin\theta d\theta\ j(T_o,\theta)$$

$$= 2\pi \int_0^\infty dT_o \int_0^{\pi/2} \sin\theta d\theta \cos\theta\ \varphi(T_o,\theta)$$

$$= \pi \int_0^\infty dT_o\ \varphi(T_o) \qquad (4)$$

Thus,

$$\Phi_{4\pi} = 2\Phi_{2\pi} = 4J \qquad (5)$$

*A factor 2π comes from the integration over the azimuthal angle.

Results for Monoenergetic Radiation

Electron Component

Electron depth-dose curves and spectra were calculated for incident energies T_o = 0.1, 0.2, 0.5, 1, 2, 3, 5, 7, and 10 MeV, based on samples of 10,000 incident electrons in each case. The histories of all generations of electrons were followed down to an energy of $T_o/32$, at which point the deposition of the small amount of residual energy was treated approximately. Photon histories were followed down to an energy of 2 keV.

In addition to the depth-dose distributions, the electron fluence spectra $F_e(T,z;T_o)$, as a function of spectral energy T and depth z, set up within the medium were calculated for those electrons traveling in the forward direction (forward fluence denoted as F_e^{for}) as well as for electrons traveling in all directions (total fluence denoted as F_e^{tot}). The data were obtained for depths z up to the electron mean range** $r_o(T_o)$, the region in which the energy deposition is dominated by ionization (and excitation) losses of the primary electrons. Typical electron fluence spectra are shown in Fig. 1, for T_o = 1 MeV, at both a depth near the entrance plane and a depth well into the medium. It can be seen that there is a sizeable backscattered component (the difference between the F_e^{tot} and the F_e^{for} curves) and a noticeable build-up of low-energy electrons.

Using the notation of Jordan,[12] we let $D_\infty^{Al}(z,T_o)$ be the aluminum dose as a function of depth z in the semi-infinite medium as directly calculated. The dose in thin tissue-equivalent detectors (very thin water layers) was obtained according to***

$$D_\infty^{H_2O}(z,T_o) = D_\infty^{Al}(z,T_o)$$

$$\times \frac{\int_\Delta^{T_o} F_e^{tot}(T,z;T_o)\, L^{H_2O}(T,\Delta)\, dT + N(z)\Delta}{\int_\Delta^{T_o} F_e^{tot}(T,z;T_o)\, L^{Al}(T,\Delta)\, dT + N(z)\Delta}\ , \qquad (6)$$

where $L(T,\Delta)$ is the electron restricted stopping power[11] which includes only energy transfers less than Δ (in our case, $\Delta = T_o/32$). In Eq. 6, $N(z)$ is the number of electrons per unit depth falling below the cut-off energy Δ (the so-called track-ends).

Similarly, the dose $D_-(z,T_o)$ at the edge of finite slabs of thickness z was approximated by

**The mean range, also called the csda range because it is derived in the continuous-slowing-down approximation, is defined as the integral of the reciprocal of the total stopping power over the energy range from the initial energy T_o down to some very small cut-off energy. Reference 11 contains an extensive tabulation of electron range values.

***This expression is closely related to the Spencer-Attix[13] cavity-ionization theory.

$$D_{-}^{Al}(z,T_o) = D_{\infty}^{Al}(z,T_o) \frac{\int_{\Delta}^{T_o} F_e^{for}(T,z;T_o)\, L^{Al}(T,\Delta)dT + N(z)\Delta/2}{\int_{\Delta}^{T_o} F_e^{tot}(T,z;T_o)\, L^{Al}(T,\Delta)dT + N(z)\Delta} \quad (7)$$

and by

$$D_{-}^{H_2O}(z,T_o) = D_{\infty}^{Al}(z,T_o) \frac{\int_{\Delta}^{T_o} F_e^{for}(T,z;T_o)\, L^{H_2O}(T,\Delta)\, dT + N(z)\Delta/2}{\int_{\Delta}^{T_o} F_e^{tot}(T,z;T_o)\, L^{Al}(T,\Delta)\, dT + N(z)\Delta} \quad (8)$$

In Eqs. 7 and 8, for the forward-moving electrons we use N(z)/2 in the track-end term since we find that at low spectral energies the fluence is nearly equally divided between the forward- and the backward-moving electrons.

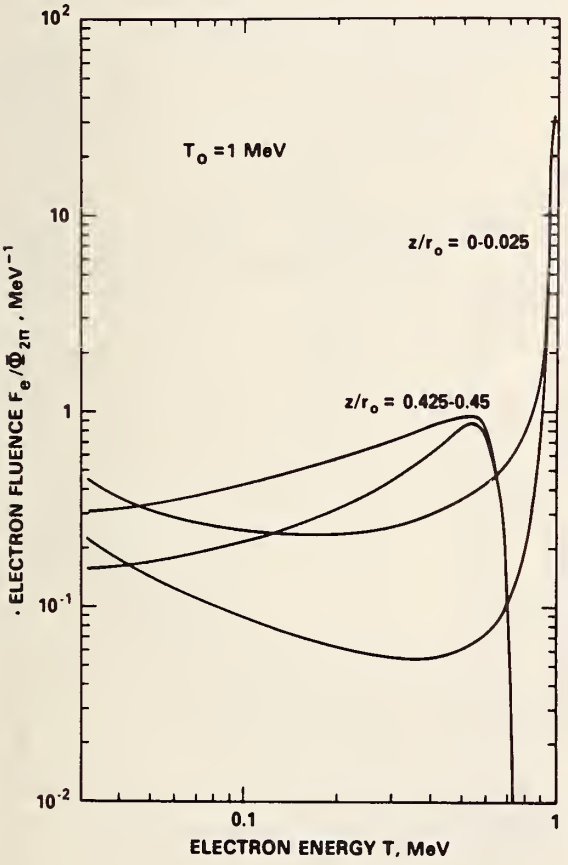

FIG. 1. Electron spectra in a semi-infinite aluminum medium bombarded by a 1-MeV, isotropic electron beam. Calculated spectra F_e, as a function of electron spectral energy T, are shown for the depth intervals $0 \leq z \leq 0.025\ r_o$ and $0.425 \leq z \leq 0.45\ r_o$ where r_o is the electron mean range. At each depth, the lower curve is for electrons traveling in the forward direction, the upper curve includes electrons traveling in all directions.

Bremsstrahlung Component

In order to obtain statistically significant results for the bremsstrahlung contribution to the dose, this contribution was not taken directly from the output of the ETRAN calculations, but indirectly in the following manner. A feature of the Monte Carlo code was exploited which allows for an arbitrary number of bremsstrahlung photons per electron to be generated. This is compensated by the use of weight factors to correct back to the true production rate. In this way, separate calculations were made of the photon spectrum $F_\gamma(k,z;T_o)$ as a function of photon spectral energy k and depth z for T_o = 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 and 20 MeV, and for depths up to 30 g/cm^2. These results are based on sample sizes of 10,000 incident electrons and from 115,000 to 160,000 emitted bremsstrahlung photons.

Figure 2 gives typical forward and total photon fluence spectra for T_o = 1 MeV. At a shallow depth (~ 0.45 g/cm^2, still within the electron range), soft bremsstrahlung photons are evident in the spectra with energies $k \lesssim 10$ keV. At larger depths, the spectrum hardens due to the strong photoelectric absorption of low-energy photons.

The bremsstrahlung dose was then obtained from

$$D_{\infty}^{Al}(z,T_o) = \int_0^{T_o} F_\gamma^{tot}(k,z;T_o)\, k\, \frac{\mu_{en}^{Al}(k)}{\rho}\, dk \ ,$$

$$D_{\infty}^{H_2O}(z,T_o) = \int_0^{T_o} F_\gamma^{tot}(k,z;T_o)\, k\, \frac{\mu_{en}^{H_2O}(k)}{\rho}\, dk \ ,$$

$$D_{-}^{Al}(z,T_o) = \int_0^{T_o} F_\gamma^{for}(k,z;T_o)\, k\, \frac{\mu_{en}^{Al}(k)}{\rho}\, dk \ ,$$

$$D_{-}^{H_2O}(z,T_o) = \int_0^{T_o} F_\gamma^{for}(k,z;T_o)\, k\, \frac{\mu_{en}^{H_2O}(k)}{\rho}\, dk \ , \quad (9)$$

where μ_{en}/ρ is the photon mass energy-absorption coefficient tabulated by Hubbell[14].

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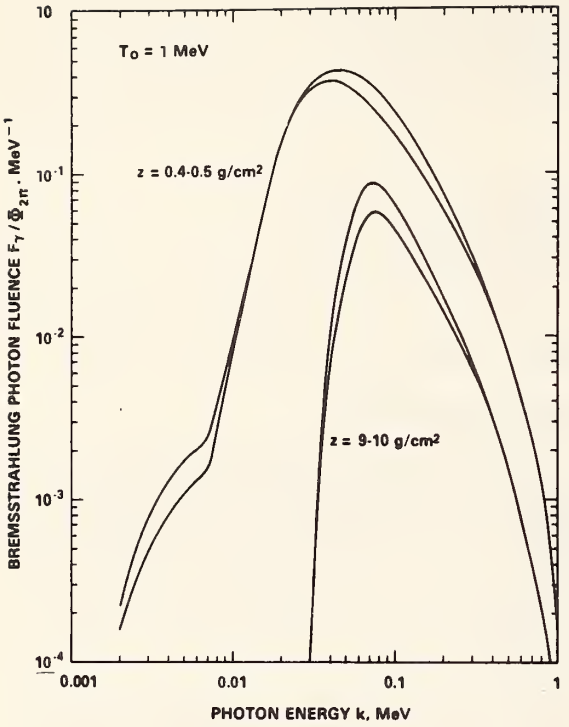

FIG. 2. Bremsstrahlung spectra in a semi-infinite aluminum medium bombarded by a 1-MeV, isotropic electron beam. Calculated spectra F_γ, as a function of bremsstrahlung photon spectral energy k, are shown for the depth intervals $0.4 \leq z \leq 0.5$ g/cm² and $9 \leq z \leq 10$ g/cm². At each depth, the lower curve is for photons traveling in the forward direction, the upper curve includes photons traveling in all directions.

Basic Set of Depth-Dose Distributions

Using the methods described above, a set of depth-dose distributions for aluminum shields were generated for monoenergetic sources. The distributions were smoothed in z and T_0. The overall uncertainty of the final results, including the uncertainties in cross sections used and those due to statistical fluctuations and smoothing of the Monte Carlo data, is estimated to be 10%.

The aluminum dose expressed in rads*, as a function of T_0 for fixed depths, is shown for a semi-infinite medium in Fig. 3 for protons** and in Fig. 4 for electrons. The electron curves include contributions from primary and secondary knock-on electrons and from secondary electrons set in motion by bremsstrahlung photons. At z = 0, the proton dose reduces to the stopping power. However, for the semi-infinite medium, the electron dose at z = 0 is larger than the stopping power due to backscattering from greater depths.

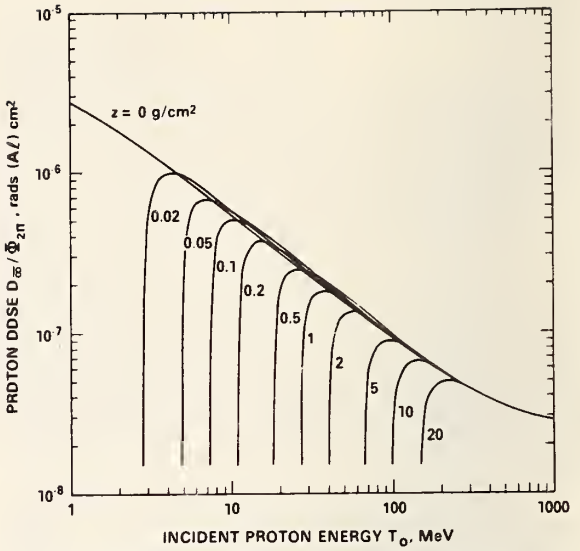

FIG. 3. Proton dose for fixed depths z in a semi-infinite aluminum medium, plotted as a function of incident energy T_0. The calculated results D_∞ are given in terms of the dose per unit 2π isotropic incident fluence.

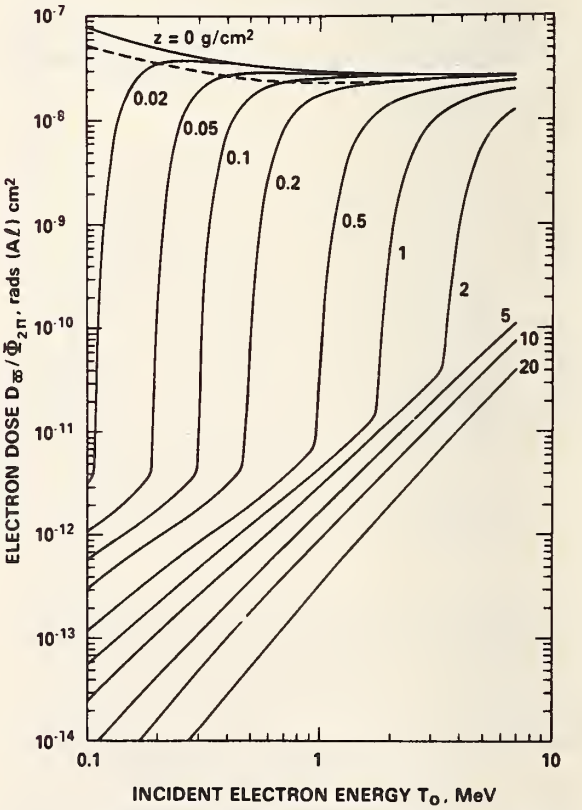

FIG. 4. Electron dose for fixed depths z in a semi-infinite aluminum medium, plotted as a function of incident energy T_0. The calculated results D_∞ are given in terms of the dose per unit 2π isotropic incident fluence. The dashed curve is the zero-depth dose based only on the stopping power and neglects backscattering from greater depths.

*A rad = 10^2 Gy = 1.602 x 10^8 MeV/g. The detector material will be specified within parentheses in the unit of dose, e.g., rads (Aℓ).

**In the straight-ahead approximation, $D_- = D_\infty$ for protons.

In Fig. 5, the electron dose as a function of T_0, at $z = 0$, 0.5 and 5 g/cm^2, is compared for the cases of the aluminum dose in a semi-infinite aluminum medium, the aluminum dose at the edge of finite aluminum slabs, and the tissue dose in a semi-infinite aluminum medium. For very thin slabs the dose is less than the stopping power because of the escape of energy in the form of energetic knock-on electrons. We find that except for the region where the bremsstrahlung dominates, the tissue dose is roughly a factor 1.3* larger than the aluminum dose and that the dose for finite slabs is roughly 0.7 of that for a semi-infinite medium (there are variations with z and T_0 of as much as $\sim \pm$ 20% from this approximate value for the $0_-/0_\infty$ ratio). However, for the bremsstrahlung component, the situation is more complicated because of the strong variation with photon energy and detector material of the mass energy-absorption coefficient.

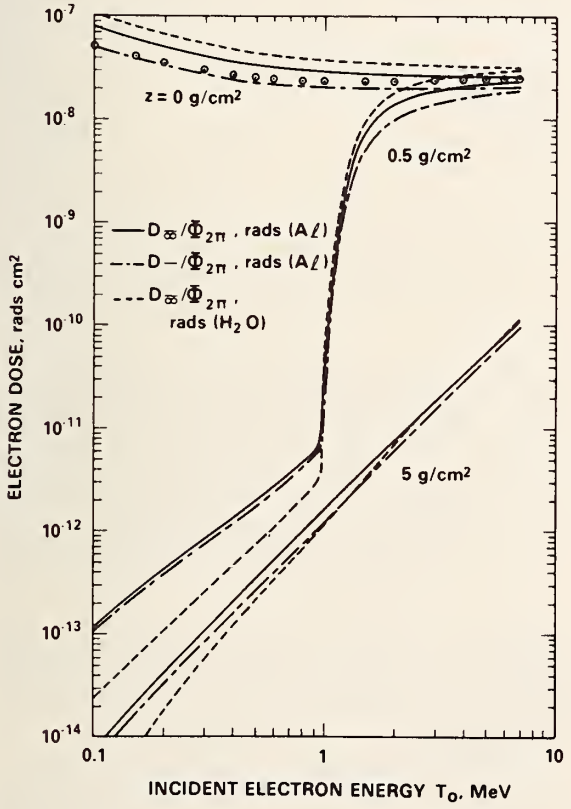

FIG. 5. Comparison of electron dose distributions in semi-infinite aluminum media and at the edge of finite aluminum slabs, for both aluminum and tissue-equivalent detectors. Solid curves pertain to the aluminum dose 0_- at depths z in a semi-infinite aluminum medium; dot-dashed curves pertain to the aluminum dose 0_- at the edge of aluminum slabs of thickness z; dashed curves pertain to the tissue dose D_∞ at depths z in a semi-infinite aluminum medium. The points for $z = 0$ are based only on the stopping power.

Measurements were made by Van Gunten[15] of the aluminum dose in hollow aluminum cubes, one face of which was irradiated by monoenergetic, isotropic electron beams. Those measurements made directly behind and at the center of the irradiated face would seem to closely correspond to 0_-, except possibly for a small additional contribution backscattered from the other sides of the cube. The calculated results are compared in Table I to the properly normalized[16] data of Van Gunten. For T_0 = 1, 2 and 3 MeV, the agreement is good, within the stated uncertainty of 10% for the experimental data. However, there is a discrepancy at 4 MeV where the measured doses are consistently lower than the calculated ones. We can find no ready explanation for this discrepancy.

TABLE I. Comparison of calculated and measured dose behind aluminum slab shields irradiated by monoenergetic, isotropic electron beams. The experimental results of Van Gunten[15] and the calculated results are given in units of 10^{-7} rads (Aℓ), and are normalized to a unit 2π isotropic incident fluence. Results are given for various incident electron energies T_0 and shield thickness z.

T_0(MeV)	z(mils[a])	Exptl. Dose	Calc. Dose
1	30	0.110 ± 0.011	0.115
1	60	0.00781 ± 0.0078	0.00701
2	30	0.164 ± 0.016	0.167
2	60	0.118 ± 0.012	0.120
2	125	0.0163 ± 0.0016	0.0153
3	30	0.169 ± 0.017	0.181
3	60	0.155 ± 0.016	0.153
3	125	0.0812 ± 0.0081	0.0859
4	30	0.149 ± 0.015	0.189
4	60	0.136 ± 0.014	0.168
4	125	0.0915 ± 0.0092	0.122
4	250	0.0146 ± 0.0015	0.0252

[a] 1 mil = 0.00686 g/cm^2 of aluminum

Calculations for Arbitrary Incident Spectra

The monoenergetic-source results have been incorporated into a computer code SHIELOOSE** which rapidly performs the necessary interpolation and integration for any incident spectrum.

Slab Shields

The results from the approximate proton calculations are compared in Fig. 6 with those calculated by Burrell[17] and by Alsmiller[18] for aluminum slabs. The SHIELOOSE results are no more than 10-20% higher than these other results which include the effects of nuclear interactions. Such a discrepancy is consistent with the findings of Santoro et al[19] who tested the effects of nuclear collisions and secondary particles in proton space-shielding calculations.

Electron results for simple exponential incident spectra $\varphi(T_0) = (1/2\pi\alpha)\exp(-T_0/\alpha)$ are given in Fig. 7 and are compared to those of Watts and Burrell[20]. When the bremsstrahlung component is omitted the curves are generally in good agreement as should be expected, since both calculations are based on data obtained (independently) using ETRAN. In order to indicate the effect of bremsstrahlung on the depth-dose distribution, curves including this component are given also in Fig. 7.

*This factor can be estimated simply from stopping power tables. Based on the calculated fluence spectra, we find values from about 1.24 to 1.34.

**This code will be available from the Radiation Shielding Information Center, Oak Ridge National Laboratory, and from the National Space Science Data Center, Goddard Space Flight Center.

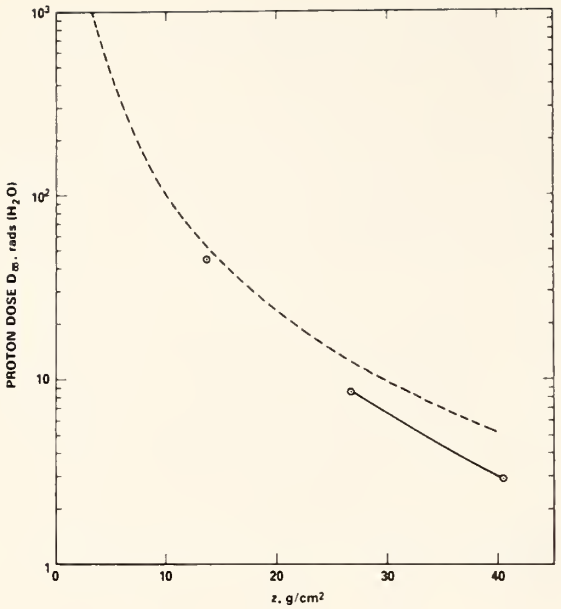

FIG. 6. Comparison of proton depth-dose distributions D_{∞} in aluminum slab shields. The dashed curve is from the present calculations, the solid curve from Alsmiller[18], and the points from Burrell[17]. All results were calculated for an incident, isotropic proton fluence (in $cm^{-2}Mev^{-1}sr^{-1}$) of $\varphi(T_0) = 2.5 \times 10^{11}\ T_0^{-2.07}$ for $5 \leq T_0 \leq 60$ MeV and $\varphi(T_0) = 5.486 \times 10^{14}\ T_0^{-3.95}$ for $60 < T_0 \leq 1000$ MeV, and pertain to irradiation from one side only.

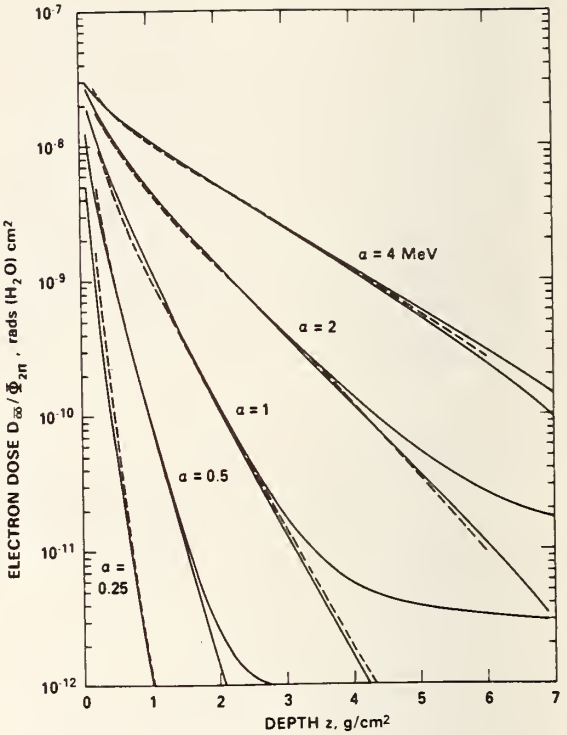

FIG. 7. Electron dose D_{∞} as a function of depth z in a semi-infinite aluminum medium. Results are for exponential incident spectra, $\varphi(T_0) = \text{const.} \times \exp(-T_0/\alpha)$, and are given in terms of the dose per unit 2π isotropic incident fluence. Dashed curves are from calculations of Watts and Burrell[20] based on ETRAN depth-dose data; solid curves are from present calculations (upper curves include bremsstrahlung component, lower curves do not).

Previous bremsstrahlung calculations in space-shielding problems have been done in various ways, but generally have been based on the straight-ahead approximation. As an example, we compare in Fig. 8 our results with those of Watts and Burrell[20] for exponential incident electron spectra. These authors considered a number of models describing the energy and angular distributions of the emitted bremsstrahlung and give various results ranging from those from their most elaborate treatment to a simple order-of-magnitude estimate (based in part on our older Monte Carlo data" pertaining to the energy content of bremsstrahlung beams emerging from aluminum targets). As seen in Fig. 8, these results disagree with the SHIELDOSE results by as much as a factor of two; however, it turns out that their more approximate results fortuitously agree to within ~ 30%.

Spherical Shields

In application to spacecraft there is usually interest in geometries other than those of simple slab targets. Calculations for complicated geometries are beyond the scope of this work. However, results have been obtained for the dose at the center of uniform solid spheres using slab depth-dose distributions. This is accomplished using the relation

$$D_{\bullet}(z) \cong 2\, D_{\infty}(z) \left\{ 1 - \frac{d \log D_{\infty}(z')}{d \log z'} \,\middle|_{z' = z} \right\}, \quad (10)$$

where $D_{\bullet}(z)$ is the dose at the center of a sphere of radius z. This relationship, which has been suggested by Jordan[12] and references cited by him, is exact for an isotropic fluence of particles in the straight-ahead approximation.* The factor of $2 = \Phi_{4\pi}/\Phi_{2\pi}$ in Eq. 10 merely takes into account that a sphere is irradiated from all directions while the semi-infinite medium is irradiated only from one side.

Proton doses at centers of spheres are shown in Fig. 9, where our results are compared with those calculated by Burrell[17] and Hill[21]. The overestimate by ~ 10-20% for large radius z of our results, is -- as in the slab case -- attributable to our neglect of attenuation due to nuclear interactions.

In the case of electrons and bremsstrahlung, the use of Eq. 10 is, because of multiple scattering effects, more approximate. Jordan[12] has made Monte Carlo calculations specifically for the slab and spherical geometries in order to validate Eq. 10, at least up to depths where the bremsstrahlung contribution is still

*Eq. 10 is given by Jordan[12] in terms of the dose $D_{=}$ between two finite slab shields each of thickness z, rather than in terms of the dose D_{∞} in a semi-infinite medium. For protons in the straight-ahead approximation, $D_{=} = D_{\infty}$; for electrons, except for very small z where some differences in the backscattering becomes evident, $D_{=} \cong D_{\infty}$.

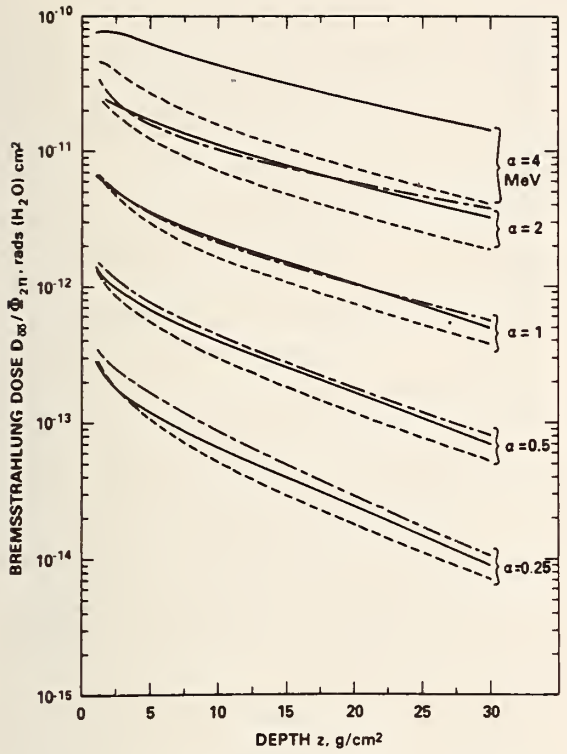

FIG. 8. Bremsstrahlung dose D_∞ as a function of depth z in a semi-infinite aluminum medium. Results are for exponential incident spectra with an e-folding energy α, and are given in terms of the dose per unit 2π isotropic incident fluence. Solid curves are from present calculations; broken curves are from the straight-ahead calculations of Watts and Burrell[20] (dashed curves from their most elaborate treatment, dot-dashed curves are their most approximate estimate).

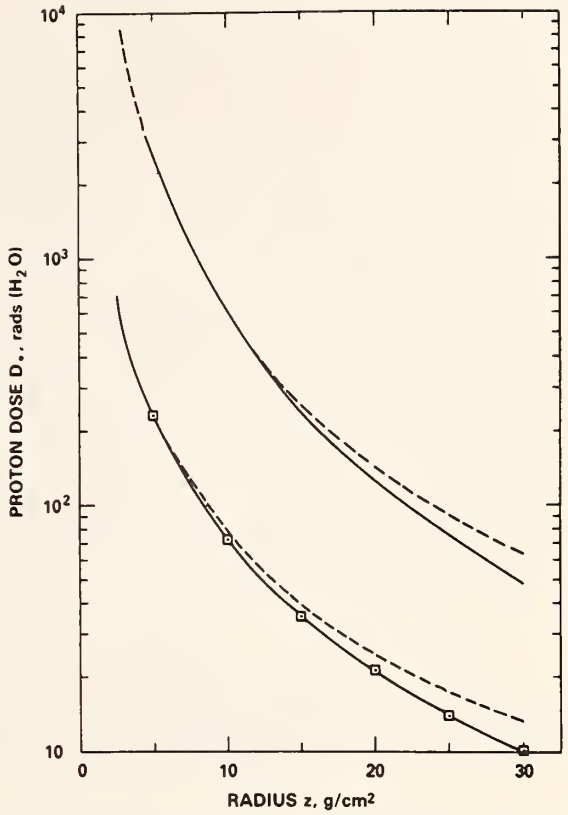

FIG. 9. Proton dose at the centers of aluminum spheres $D_\bullet$, as a function of sphere radius z. Dashed curves are from present calculations; solid curves are from those of Burrell[17]; and points are from Hill[21]. Upper set of results are for an incident, isotropic proton fluence (in $cm^{-2}MeV^{-1}sr^{-1}$) of $\varphi(T_0) = 5.486 \times 10^{14} T_0^{-3.95}$; the lower set are for $\varphi(T_0) = 1.257 \times 10^{12} T_0^{-3.12}$. Irradiation of the sphere is assumed to be from all directions.

small. Shown in Fig. 10 are his Monte Carlo results both for D_∞ and $D_\bullet$ for the fission spectrum, $\varphi(T_0) = \text{const} \times \exp\{-0.575\ T_0 - 0.055\ T_0^2\}$. Shown also are our results* based on our Monte Carlo calculations for D_∞ and the use of Eq. 10 for $D_\bullet$. The disagreement (~ 10%) in $D_\bullet$ for small z is evidently due to our use of D_∞ rather than $D_=$, while the disagreement (again ~ 10%) at large z for both D_∞ and $D_\bullet$ apparently is the result of using different Monte Carlo calculations.

The ratio of the sphere dose to the slab dose is plotted in Fig. 11 for the fission spectrum and for an exponential spectrum with α = 0.5 MeV. Shown also is the ratio derived from Jordan's data for the fission spectrum. We make the following observations pertinent to space-shielding calculations: (a) Using Eq. 10 for electrons appears to be an approximation good to within ~ 10-20%. This is not to say that the straight-ahead approximation per se, i.e., neglecting angular deflections, is accurate for describing electron penetration, but rather that, for the incident electron distributions of interest, electron penetration can be described by some functions (details of which we need not know) as if the electrons move along straight lines. (b) The argument in favor of using the results of Eq. 10 for the bremsstrahlung tail is the success of some form of the straight-ahead approximation in describing at least the shape of the depth-dose distribution as demonstrated, for example, in Fig. 8. (c) Whereas $D_\bullet/D_\infty$ is less than about 6 to 8 for protons, this ratio is as large as 13 for electrons and about 3 in the bremsstrahlung tail.

*Our dose in silicon was extimated from the dose in aluminum by multiplying by 1.03, which takes into account the electron stopping-power ratio. For the bremsstrahlung component also included in the results, this factor should actually be somewhat larger but has little effect on the comparison.

Realistic Spectra

Finally, we give an example of SHIELDOSE results for incident spectra kindly provided by E.G. Stassinopoulos of NASA/GSFC using the radiation-environment models and orbit-integration codes[22] developed at the National Space Science Data Center. Figure 12 shows the one-year aluminum dose, both D_∞ and $D_\bullet$, for the omni-directional, orbit-integrated, trapped electron fluence for a geostationary orbit with an altitude of 35790 km, an inclination of 0°, and for a parking longitude of 160°W. The spectrum, shown in the insert of Fig. 12,

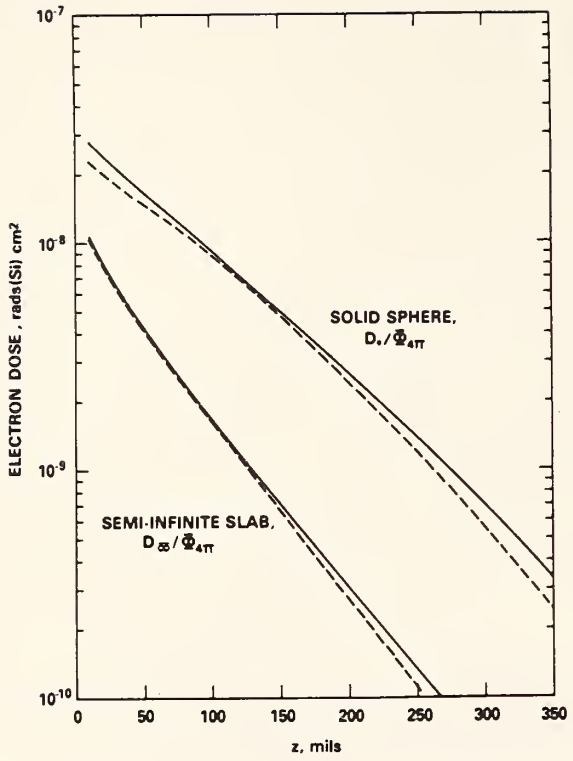

FIG. 10. Comparison of the electron dose in a semi-infinite medium (at depth z) and at the centers of spheres (radius z). Results are for aluminum targets (100 mils = 0.686 g/cm²) irradiated by an isotropic electron fluence having a fission spectrum, $\varphi(T_0) = 0.057 \exp(-0.575\ T_0 - 0.055\ T_0^2)\ cm^{-2}MeV^{-1}sr^{-1}$. Dashed curves are Jordan's[12] results from Monte Carlo calculations for each geometry. Solid curves are the present results based on Monte Carlo calculations for the semi-infinite medium and on the use of Eq. 10 for the spheres.

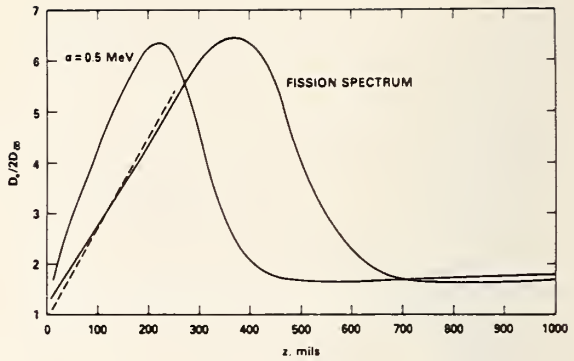

FIG. 11. Ratio of the electron dose D_z at centers of aluminum spheres (radius z) to twice the dose D_∞ in a semi-infinite aluminum medium (at depth z). The results, pertaining to aluminum detectors, are plotted out to large z where the bremsstrahlung dominates. Solid curves are our results based on Eq. 10 and are given both for incident electrons with a fission spectrum and for electrons with an exponential spectrum characterized by an e-folding energy α = 0.5 MeV. Dashed curve is the fission-spectrum results of Jordan[12] who considered explicitly the two geometries.

was calculated for the epoch 1979.0 using the AE17-HI model. The solar proton fluence for this orbit and period is $\varphi(T_0) = 9.25 \times 10^8 \exp(-T_0/26.5\ MeV)\ cm^{-2}MeV^{-1}sr^{-1}$, and corresponds to one anomalously large event predicted at the 95% confidence level.

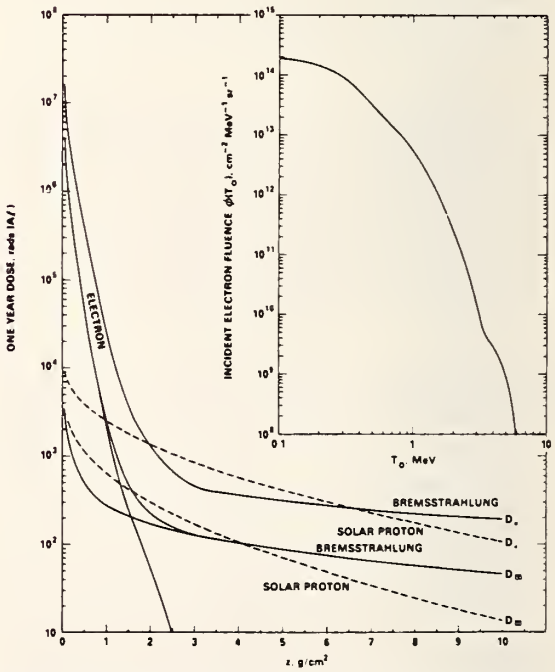

FIG. 12. Depth-dose distributions in aluminum targets for the radiation encountered during one year in a geostationary orbit. The orbit parameters and incident radiation spectra, are described in the text; the incident electron fluence is given in the insert. Results are given both for the dose D_∞ at depth z in a semi-infinite medium and for the dose D_z at the center of a sphere of radius z. The solar-proton dose, for 1 anomalously-large event, is given by the dashed curves.

Acknowledgements

The author would like to thank E.G. Stassinopoulos, who suggested this work, and Martin Berger for many helpful discussions and suggestions.

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Appendix B. Monoenergetic depth-dose data.

Scaled, monoenergetic depth-dose distributions are given in the following tables. The results are normalized to a unit incident current ($1\ cm^{-2}$) of particles crossing into the plane aluminum medium, and pertain to particles with an isotropic angular distribution incident from one side only. The dose, absorbed in thin detectors of various materials of interest as given both as a function of depth z in a semi-infinite medium, $D_{\overline{\infty}}^{det}(z)$, and as a function of thickness z at the transmission surface of a finite thickness slab, $D_{-}^{det}(z)$. Reference can be made to figure 1 for a further indication of irradiation and target geometry. The scaling is done in terms of the mean (c.s.d.a.) range $r_o(T_o)$ in g/cm^2 (given in tables 1 and 2 of the main text) and incident energy, T_o in MeV. The tables are organized as follows:

Table B.1. $(r_o/T_o)\, D_{\overline{\infty}}^{Al}(z/r_o) = (r_o/T_o)\, D_{-}^{Al}(z/r_o)$ for protons.
Units: dimensionless.

Table B.2. $(r_o/T_o)\, D_{\overline{\infty}}^{H_2O}(z/r_o) = (r_o/T_o)\, D_{-}^{H_2O}(z/r_o)$ for protons.
Units: dimensionless.

Table B.3. $(r_o/T_o)\, D_{\overline{\infty}}^{Si}(z/r_o) = (r_o/T_o)\, D_{-}^{Si}(z/r_o)$ for protons.
Units: dimensionless.

Table B.4. $(r_o/T_o)\, D_{\overline{\infty}}^{SiO_2}(z/r_o) = (r_o/T_o)\, D_{-}^{SiO_2}(z/r_o)$ for protons.
Units: dimensionless.

Table B.5. $(r_o/T_o)\, D_{\overline{\infty}}^{Al}(z/r_o)$ for electrons. Units: dimensionless.

Table B.6. $(r_o/T_o)\, D_{-}^{Al}(z/r_o)$ for electrons. Units: dimensionless.

Table B.7. $(r_o/T_o)\ D_{\bar{\infty}}^{H_2O}(z/r_o)$ for electrons. Units: dimensionless.

Table B.8. $(r_o/T_o)\ D_{-}^{H_2O}(z/r_o)$ for electrons. Units: dimensionless.

Table B.9. $(r_o/T_o)\ D_{\bar{\infty}}^{Si}(z/r_o)$ for electrons. Units: dimensionless.

Table B.10. $(r_o/T_o)\ D_{-}^{Si}(z/r_o)$ for electrons. Units: dimensionless.

Table B.11. $(r_o/T_o)\ D_{\bar{\infty}}^{SiO_2}(z/r_o)$ for electrons. Units: dimensionless.

Table B.12. $(r_o/T_o)\ D_{-}^{SiO_2}(z/r_o)$ for electrons. Units: dimensionless.

Table B.13. $(1/T_o)\ D_{\bar{\infty}}^{Al}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.14. $(1/T_o)\ D_{-}^{Al}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.15. $(1/T_o)\ D_{\bar{\infty}}^{H_2O}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.16. $(1/T_o)\ D_{-}^{H_2O}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.17. $(1/T_o)\ D_{\bar{\infty}}^{Si}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.18. $(1/T_o)\ D_{-}^{Si}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.19. $(1/T_o)\ D_{\bar{\infty}}^{SiO_2}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.20. $(1/T_o)\ D_{-}^{SiO_2}(z/T_o)$ for bremstrahlung. Units: cm^2/g.

Table B.1. $(r_o/T_o)\, D_{-\infty}^{A\ell}(z/r_o) = (r_o/T_o)\, D_{-}^{A\ell}(z/r_o)$ for protons. Units: dimensionless.

z/ro	To= 2	3	4	5	6	8	10	15	20	30	40	50	60	80
0.0	1.290	1.237	1.200	1.172	1.153	1.141	1.151	1.139	1.133	1.126	1.124	1.124	1.125	1.130
0.02	1.319	1.268	1.233	1.206	1.187	1.171	1.178	1.169	1.163	1.156	1.153	1.153	1.154	1.158
0.04	1.340	1.290	1.257	1.231	1.212	1.194	1.198	1.192	1.185	1.178	1.176	1.175	1.176	1.179
0.06	1.354	1.306	1.274	1.249	1.231	1.212	1.213	1.209	1.202	1.195	1.192	1.191	1.192	1.195
0.08	1.364	1.318	1.287	1.262	1.245	1.225	1.225	1.221	1.214	1.208	1.205	1.204	1.204	1.206
0.10	1.371	1.326	1.296	1.273	1.255	1.236	1.233	1.231	1.224	1.217	1.214	1.213	1.213	1.215
0.12	1.375	1.332	1.303	1.280	1.264	1.244	1.239	1.238	1.231	1.225	1.221	1.220	1.220	1.221
0.14	1.378	1.336	1.308	1.286	1.271	1.251	1.245	1.244	1.237	1.231	1.227	1.226	1.226	1.227
0.16	1.380	1.338	1.312	1.291	1.276	1.257	1.248	1.248	1.242	1.235	1.232	1.230	1.230	1.231
0.18	1.379	1.339	1.314	1.294	1.280	1.261	1.251	1.251	1.245	1.238	1.235	1.233	1.233	1.233
0.20	1.377	1.338	1.314	1.295	1.281	1.263	1.252	1.252	1.246	1.240	1.236	1.235	1.234	1.234
0.22	1.374	1.336	1.313	1.295	1.282	1.264	1.252	1.252	1.246	1.240	1.236	1.235	1.234	1.233
0.24	1.369	1.332	1.310	1.293	1.280	1.263	1.250	1.250	1.244	1.238	1.235	1.233	1.232	1.232
0.26	1.362	1.326	1.306	1.290	1.278	1.261	1.248	1.247	1.241	1.236	1.233	1.231	1.229	1.229
0.28	1.355	1.320	1.300	1.285	1.274	1.258	1.244	1.243	1.238	1.232	1.229	1.227	1.226	1.225
0.30	1.346	1.313	1.294	1.279	1.269	1.254	1.239	1.238	1.233	1.227	1.224	1.222	1.221	1.220
0.32	1.337	1.304	1.286	1.272	1.263	1.249	1.234	1.231	1.227	1.222	1.219	1.217	1.215	1.214
0.34	1.326	1.294	1.277	1.264	1.255	1.242	1.227	1.224	1.219	1.215	1.212	1.210	1.208	1.207
0.36	1.314	1.283	1.267	1.255	1.247	1.234	1.220	1.215	1.211	1.207	1.204	1.202	1.200	1.198
0.38	1.301	1.271	1.255	1.245	1.237	1.226	1.211	1.205	1.202	1.198	1.195	1.193	1.191	1.189
0.40	1.287	1.257	1.243	1.233	1.226	1.216	1.201	1.194	1.192	1.188	1.185	1.183	1.181	1.179
0.42	1.272	1.243	1.230	1.220	1.214	1.205	1.191	1.183	1.181	1.176	1.174	1.172	1.170	1.168
0.44	1.256	1.227	1.215	1.207	1.201	1.193	1.179	1.170	1.168	1.164	1.162	1.160	1.158	1.156
0.46	1.238	1.211	1.199	1.192	1.187	1.179	1.166	1.156	1.155	1.151	1.149	1.147	1.145	1.143
0.48	1.220	1.193	1.183	1.175	1.171	1.165	1.152	1.141	1.141	1.137	1.134	1.133	1.131	1.128
0.50	1.201	1.175	1.165	1.158	1.155	1.149	1.137	1.125	1.125	1.122	1.119	1.118	1.116	1.113
0.52	1.180	1.155	1.146	1.140	1.137	1.133	1.121	1.108	1.108	1.105	1.103	1.101	1.100	1.097
0.54	1.159	1.134	1.125	1.120	1.118	1.115	1.104	1.090	1.091	1.088	1.086	1.084	1.082	1.080
0.56	1.136	1.112	1.104	1.100	1.098	1.095	1.086	1.071	1.072	1.069	1.067	1.066	1.064	1.061
0.58	1.112	1.089	1.081	1.078	1.076	1.075	1.066	1.052	1.052	1.049	1.048	1.046	1.045	1.042
0.60	1.087	1.064	1.057	1.054	1.054	1.053	1.045	1.031	1.030	1.028	1.027	1.025	1.024	1.021
0.62	1.061	1.038	1.032	1.030	1.030	1.030	1.023	1.008	1.008	1.006	1.005	1.003	1.002	0.999
0.64	1.033	1.012	1.006	1.004	1.004	1.006	0.999	0.985	0.984	0.983	0.981	0.980	0.979	0.976
0.66	1.004	0.983	0.978	0.976	0.977	0.980	0.974	0.961	0.958	0.958	0.957	0.955	0.954	0.951
0.68	0.974	0.953	0.948	0.947	0.949	0.952	0.947	0.935	0.932	0.932	0.930	0.929	0.928	0.925
0.70	0.942	0.922	0.917	0.917	0.919	0.923	0.919	0.907	0.903	0.904	0.903	0.902	0.901	0.898
0.72	0.908	0.889	0.885	0.885	0.887	0.892	0.889	0.878	0.874	0.874	0.874	0.873	0.872	0.869
0.74	0.873	0.855	0.851	0.851	0.854	0.859	0.857	0.848	0.843	0.843	0.843	0.842	0.841	0.838
0.76	0.837	0.819	0.815	0.816	0.818	0.825	0.823	0.816	0.810	0.811	0.810	0.809	0.808	0.806
0.78	0.798	0.781	0.777	0.778	0.781	0.788	0.787	0.781	0.776	0.776	0.775	0.775	0.774	0.771
0.80	0.756	0.740	0.737	0.737	0.741	0.748	0.748	0.744	0.738	0.738	0.738	0.737	0.736	0.734
0.82	0.712	0.696	0.693	0.694	0.697	0.705	0.706	0.703	0.699	0.697	0.697	0.697	0.696	0.694
0.84	0.665	0.650	0.647	0.648	0.651	0.659	0.661	0.660	0.656	0.653	0.654	0.654	0.653	0.651
0.86	0.615	0.602	0.599	0.600	0.603	0.611	0.613	0.613	0.611	0.607	0.608	0.608	0.608	0.606
0.88	0.563	0.550	0.547	0.548	0.551	0.559	0.562	0.564	0.562	0.559	0.559	0.559	0.559	0.558
0.90	0.506	0.494	0.492	0.492	0.495	0.502	0.505	0.509	0.509	0.506	0.506	0.506	0.506	0.505
0.92	0.442	0.432	0.429	0.430	0.432	0.439	0.442	0.447	0.448	0.446	0.445	0.445	0.445	0.444
0.94	0.369	0.360	0.358	0.358	0.360	0.366	0.369	0.374	0.376	0.377	0.375	0.375	0.375	0.374
0.96	0.283	0.276	0.274	0.275	0.276	0.280	0.283	0.287	0.290	0.292	0.292	0.291	0.291	0.290
0.98	0.180	0.175	0.174	0.174	0.175	0.177	0.179	0.182	0.185	0.188	0.190	0.190	0.189	0.188
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.1. $(r_o/T_o)\, D_{\infty}^{A\ell}(z/r_o) = (r_o/T_o)\, D_{-}^{A\ell}(z/r_o)$ for protons. Units: dimensionless. (Continued)

z/r_o	T_o=100	150	200	300	400	500	600	800	1000	1500	2000	3000	4000	5000
0.0	1.137	1.155	1.175	1.216	1.255	1.289	1.325	1.389	1.445	1.557	1.642	1.760	1.839	1.896
0.02	1.164	1.180	1.198	1.235	1.271	1.301	1.333	1.391	1.441	1.542	1.619	1.727	1.798	1.850
0.04	1.184	1.199	1.215	1.248	1.281	1.309	1.337	1.390	1.436	1.527	1.597	1.695	1.760	1.807
0.06	1.199	1.212	1.227	1.257	1.287	1.313	1.338	1.386	1.428	1.511	1.574	1.664	1.724	1.767
0.08	1.210	1.222	1.235	1.263	1.290	1.315	1.337	1.380	1.418	1.494	1.552	1.633	1.689	1.729
0.10	1.218	1.229	1.241	1.266	1.290	1.314	1.333	1.373	1.408	1.477	1.529	1.604	1.654	1.691
0.12	1.224	1.234	1.245	1.268	1.290	1.311	1.329	1.365	1.396	1.459	1.507	1.574	1.620	1.654
0.14	1.229	1.238	1.248	1.268	1.288	1.307	1.323	1.356	1.384	1.441	1.484	1.545	1.587	1.617
0.16	1.233	1.240	1.249	1.267	1.285	1.302	1.317	1.345	1.371	1.422	1.460	1.515	1.553	1.580
0.18	1.235	1.241	1.249	1.265	1.281	1.296	1.309	1.335	1.357	1.402	1.437	1.486	1.519	1.544
0.20	1.235	1.241	1.248	1.262	1.276	1.289	1.301	1.323	1.343	1.383	1.413	1.456	1.486	1.508
0.22	1.234	1.239	1.245	1.257	1.269	1.281	1.291	1.310	1.328	1.363	1.389	1.427	1.453	1.472
0.24	1.232	1.236	1.241	1.251	1.262	1.272	1.281	1.297	1.312	1.342	1.365	1.397	1.420	1.437
0.26	1.229	1.232	1.236	1.245	1.253	1.262	1.270	1.283	1.296	1.321	1.340	1.368	1.387	1.401
0.28	1.225	1.227	1.230	1.237	1.244	1.252	1.258	1.269	1.279	1.300	1.316	1.339	1.354	1.366
0.30	1.219	1.221	1.223	1.229	1.234	1.240	1.246	1.254	1.262	1.278	1.291	1.309	1.322	1.332
0.32	1.213	1.214	1.215	1.219	1.224	1.228	1.232	1.238	1.244	1.257	1.266	1.280	1.289	1.297
0.34	1.206	1.205	1.207	1.209	1.212	1.215	1.218	1.222	1.226	1.234	1.241	1.250	1.257	1.262
0.36	1.197	1.196	1.197	1.198	1.199	1.201	1.203	1.205	1.207	1.212	1.215	1.220	1.225	1.228
0.38	1.188	1.186	1.186	1.186	1.186	1.186	1.187	1.187	1.187	1.189	1.189	1.191	1.192	1.194
0.40	1.178	1.175	1.175	1.173	1.172	1.171	1.171	1.169	1.167	1.165	1.163	1.161	1.160	1.160
0.42	1.166	1.163	1.162	1.159	1.157	1.155	1.154	1.150	1.147	1.141	1.137	1.131	1.128	1.126
0.44	1.154	1.150	1.148	1.145	1.141	1.138	1.136	1.130	1.126	1.117	1.111	1.101	1.095	1.092
0.46	1.141	1.137	1.134	1.129	1.125	1.121	1.118	1.111	1.104	1.092	1.084	1.071	1.063	1.058
0.48	1.126	1.122	1.118	1.113	1.107	1.102	1.098	1.090	1.082	1.068	1.056	1.041	1.031	1.024
0.50	1.111	1.106	1.102	1.095	1.089	1.083	1.078	1.068	1.059	1.042	1.029	1.011	0.998	0.990
0.52	1.094	1.089	1.085	1.077	1.070	1.063	1.058	1.046	1.036	1.016	1.001	0.980	0.966	0.956
0.54	1.077	1.071	1.067	1.058	1.050	1.043	1.036	1.024	1.012	0.990	0.973	0.949	0.933	0.922
0.56	1.059	1.053	1.047	1.038	1.029	1.021	1.014	1.000	0.987	0.963	0.945	0.918	0.901	0.888
0.58	1.039	1.033	1.027	1.017	1.007	0.998	0.990	0.976	0.962	0.936	0.916	0.887	0.868	0.855
0.60	1.018	1.012	1.005	0.995	0.984	0.975	0.966	0.951	0.936	0.908	0.886	0.856	0.835	0.821
0.62	0.996	0.989	0.983	0.972	0.961	0.951	0.942	0.925	0.910	0.879	0.857	0.824	0.803	0.787
0.64	0.973	0.966	0.959	0.947	0.936	0.925	0.916	0.898	0.882	0.850	0.826	0.793	0.770	0.753
0.66	0.948	0.941	0.934	0.922	0.910	0.899	0.889	0.870	0.854	0.821	0.796	0.760	0.736	0.719
0.68	0.922	0.915	0.908	0.895	0.883	0.871	0.861	0.842	0.825	0.790	0.764	0.728	0.703	0.685
0.70	0.895	0.887	0.880	0.867	0.854	0.842	0.832	0.812	0.795	0.759	0.733	0.695	0.669	0.651
0.72	0.866	0.858	0.851	0.838	0.825	0.812	0.801	0.781	0.763	0.727	0.700	0.661	0.635	0.616
0.74	0.835	0.828	0.820	0.807	0.793	0.781	0.770	0.749	0.731	0.695	0.667	0.628	0.601	0.581
0.76	0.803	0.796	0.788	0.774	0.761	0.748	0.737	0.716	0.698	0.661	0.633	0.593	0.566	0.547
0.78	0.769	0.761	0.754	0.740	0.727	0.714	0.702	0.682	0.663	0.626	0.598	0.558	0.531	0.511
0.80	0.732	0.724	0.717	0.703	0.690	0.677	0.666	0.645	0.627	0.590	0.562	0.522	0.495	0.475
0.82	0.692	0.685	0.677	0.664	0.651	0.638	0.627	0.606	0.588	0.552	0.524	0.485	0.458	0.439
0.84	0.649	0.642	0.635	0.622	0.609	0.597	0.586	0.565	0.548	0.512	0.486	0.447	0.421	0.402
0.86	0.604	0.597	0.590	0.578	0.565	0.553	0.543	0.523	0.506	0.471	0.445	0.408	0.383	0.364
0.88	0.556	0.550	0.543	0.531	0.519	0.508	0.497	0.478	0.462	0.429	0.404	0.368	0.344	0.326
0.90	0.503	0.497	0.491	0.480	0.469	0.458	0.448	0.430	0.415	0.383	0.360	0.326	0.303	0.286
0.92	0.443	0.438	0.432	0.422	0.412	0.402	0.393	0.376	0.362	0.334	0.312	0.281	0.260	0.245
0.94	0.373	0.369	0.364	0.355	0.346	0.338	0.330	0.315	0.303	0.278	0.259	0.232	0.213	0.200
0.96	0.289	0.286	0.283	0.275	0.268	0.261	0.255	0.243	0.233	0.213	0.197	0.176	0.161	0.150
0.98	0.188	0.186	0.183	0.178	0.174	0.169	0.165	0.157	0.150	0.136	0.125	0.111	0.100	0.093
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.2. $(r_o/T_o)\, D_{-\infty}^{H_2O}(z/r_o) = (r_o/T_o)\, D_{-}^{H_2O}(z/r_o)$ for protons. Units: dimensionless.

z/r_o	T_o= 2	3	4	5	6	8	10	15	20	30	40	50	60	80
0.0	1.952	1.826	1.751	1.698	1.660	1.613	1.594	1.553	1.529	1.503	1.490	1.483	1.479	1.478
0.02	2.009	1.881	1.805	1.752	1.713	1.663	1.640	1.599	1.574	1.546	1.532	1.524	1.519	1.516
0.04	2.052	1.923	1.846	1.793	1.755	1.703	1.676	1.634	1.608	1.579	1.564	1.555	1.550	1.546
0.06	2.085	1.955	1.878	1.825	1.786	1.734	1.704	1.661	1.634	1.604	1.588	1.579	1.573	1.568
0.08	2.110	1.980	1.903	1.850	1.811	1.758	1.726	1.683	1.655	1.624	1.607	1.597	1.591	1.585
0.10	2.130	2.000	1.923	1.870	1.832	1.778	1.744	1.700	1.672	1.640	1.622	1.612	1.605	1.598
0.12	2.146	2.016	1.939	1.886	1.848	1.795	1.759	1.714	1.685	1.653	1.635	1.623	1.616	1.608
0.14	2.159	2.029	1.952	1.900	1.862	1.809	1.772	1.726	1.697	1.663	1.645	1.633	1.626	1.617
0.16	2.170	2.040	1.964	1.911	1.874	1.822	1.783	1.736	1.706	1.672	1.653	1.641	1.633	1.623
0.18	2.179	2.048	1.973	1.921	1.884	1.832	1.791	1.744	1.713	1.679	1.660	1.647	1.639	1.628
0.20	2.184	2.054	1.979	1.927	1.891	1.839	1.798	1.749	1.719	1.684	1.664	1.651	1.642	1.631
0.22	2.186	2.057	1.982	1.931	1.895	1.844	1.802	1.752	1.721	1.686	1.666	1.653	1.644	1.632
0.24	2.186	2.058	1.983	1.933	1.897	1.847	1.804	1.754	1.722	1.687	1.666	1.653	1.644	1.631
0.26	2.184	2.056	1.983	1.932	1.897	1.848	1.805	1.753	1.722	1.686	1.665	1.651	1.642	1.629
0.28	2.180	2.053	1.980	1.930	1.896	1.847	1.804	1.751	1.720	1.684	1.663	1.649	1.639	1.625
0.30	2.174	2.048	1.976	1.927	1.892	1.844	1.801	1.748	1.716	1.680	1.658	1.644	1.634	1.620
0.32	2.166	2.041	1.969	1.921	1.887	1.840	1.797	1.742	1.711	1.674	1.653	1.638	1.628	1.614
0.34	2.156	2.032	1.961	1.913	1.880	1.834	1.791	1.736	1.704	1.667	1.646	1.631	1.620	1.606
0.36	2.144	2.021	1.951	1.904	1.872	1.826	1.784	1.727	1.696	1.659	1.637	1.622	1.611	1.596
0.38	2.131	2.008	1.940	1.893	1.861	1.817	1.775	1.718	1.686	1.649	1.627	1.612	1.601	1.586
0.40	2.115	1.994	1.926	1.880	1.849	1.806	1.764	1.706	1.675	1.638	1.616	1.601	1.589	1.574
0.42	2.098	1.978	1.911	1.866	1.835	1.793	1.752	1.693	1.662	1.625	1.603	1.588	1.576	1.560
0.44	2.078	1.960	1.894	1.850	1.820	1.778	1.738	1.679	1.648	1.611	1.589	1.573	1.562	1.546
0.46	2.057	1.940	1.875	1.832	1.802	1.762	1.723	1.663	1.632	1.595	1.573	1.558	1.546	1.530
0.48	2.034	1.918	1.855	1.812	1.783	1.744	1.706	1.646	1.615	1.578	1.556	1.540	1.529	1.512
0.50	2.009	1.895	1.832	1.791	1.763	1.724	1.687	1.627	1.597	1.559	1.537	1.522	1.510	1.493
0.52	1.982	1.870	1.808	1.768	1.740	1.703	1.666	1.607	1.576	1.539	1.517	1.502	1.490	1.473
0.54	1.953	1.842	1.782	1.743	1.716	1.680	1.644	1.585	1.554	1.518	1.496	1.480	1.469	1.451
0.56	1.922	1.813	1.754	1.716	1.690	1.655	1.620	1.561	1.531	1.495	1.473	1.457	1.446	1.428
0.58	1.889	1.782	1.724	1.687	1.661	1.628	1.594	1.536	1.506	1.470	1.448	1.433	1.421	1.404
0.60	1.854	1.749	1.693	1.656	1.631	1.599	1.566	1.509	1.479	1.443	1.422	1.406	1.395	1.377
0.62	1.816	1.713	1.658	1.623	1.599	1.568	1.536	1.481	1.450	1.415	1.394	1.378	1.367	1.350
0.64	1.776	1.676	1.622	1.588	1.565	1.535	1.505	1.450	1.420	1.385	1.364	1.349	1.337	1.320
0.66	1.734	1.635	1.584	1.550	1.528	1.499	1.470	1.417	1.387	1.353	1.332	1.317	1.306	1.289
0.68	1.689	1.593	1.542	1.510	1.489	1.462	1.434	1.383	1.352	1.319	1.298	1.283	1.272	1.255
0.70	1.641	1.548	1.499	1.468	1.448	1.421	1.395	1.346	1.315	1.283	1.262	1.248	1.237	1.220
0.72	1.590	1.500	1.453	1.423	1.403	1.378	1.353	1.307	1.276	1.244	1.224	1.210	1.199	1.182
0.74	1.536	1.449	1.404	1.375	1.357	1.333	1.309	1.265	1.235	1.203	1.184	1.170	1.159	1.143
0.76	1.480	1.396	1.352	1.324	1.307	1.285	1.262	1.220	1.191	1.160	1.141	1.127	1.117	1.101
0.78	1.419	1.338	1.296	1.270	1.253	1.233	1.211	1.172	1.144	1.114	1.095	1.082	1.072	1.056
0.80	1.353	1.276	1.236	1.211	1.195	1.176	1.156	1.120	1.093	1.063	1.045	1.033	1.023	1.007
0.82	1.281	1.208	1.170	1.147	1.132	1.115	1.096	1.063	1.038	1.008	0.991	0.979	0.969	0.954
0.84	1.205	1.136	1.100	1.078	1.065	1.048	1.031	1.001	0.978	0.949	0.933	0.921	0.912	0.898
0.86	1.123	1.059	1.026	1.005	0.993	0.978	0.963	0.935	0.915	0.887	0.871	0.860	0.852	0.838
0.88	1.037	0.977	0.947	0.928	0.916	0.903	0.889	0.864	0.847	0.821	0.806	0.795	0.787	0.774
0.90	0.941	0.887	0.859	0.842	0.831	0.820	0.807	0.786	0.771	0.748	0.733	0.723	0.715	0.704
0.92	0.832	0.784	0.759	0.744	0.735	0.724	0.714	0.696	0.683	0.664	0.650	0.641	0.634	0.623
0.94	0.704	0.664	0.643	0.630	0.622	0.613	0.604	0.590	0.580	0.565	0.553	0.544	0.538	0.528
0.96	0.550	0.518	0.502	0.491	0.485	0.478	0.472	0.461	0.454	0.443	0.434	0.428	0.422	0.414
0.98	0.361	0.340	0.329	0.322	0.318	0.313	0.309	0.302	0.298	0.292	0.288	0.284	0.280	0.274
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.2. $(r_o/T_o)\, D_{-\infty}^{H_2O}(z/r_o) = (r_o/T_o)\, D_{-}^{H_2O}(z/r_o)$ for protons. Units: dimensionless. (Continued)

z/ro	To=100	150	200	300	400	500	600	800	1000	1500	2000	3000	4000	5000
0.0	1.481	1.496	1.517	1.561	1.607	1.651	1.693	1.769	1.835	1.969	2.068	2.204	2.292	2.353
0.02	1.518	1.530	1.548	1.587	1.628	1.667	1.705	1.773	1.832	1.953	2.042	2.165	2.244	2.299
0.04	1.546	1.556	1.571	1.606	1.642	1.677	1.711	1.773	1.826	1.934	2.015	2.127	2.199	2.249
0.06	1.567	1.574	1.587	1.618	1.650	1.682	1.713	1.769	1.817	1.915	1.989	2.090	2.156	2.201
0.08	1.583	1.588	1.599	1.627	1.655	1.684	1.712	1.763	1.806	1.895	1.962	2.053	2.114	2.155
0.10	1.595	1.599	1.608	1.632	1.658	1.683	1.708	1.754	1.794	1.874	1.934	2.017	2.072	2.110
0.12	1.605	1.607	1.614	1.635	1.657	1.681	1.703	1.744	1.780	1.852	1.907	1.982	2.031	2.066
0.14	1.613	1.613	1.618	1.636	1.656	1.676	1.696	1.733	1.765	1.830	1.878	1.946	1.990	2.021
0.16	1.619	1.617	1.621	1.636	1.653	1.671	1.689	1.721	1.749	1.807	1.850	1.910	1.949	1.976
0.18	1.623	1.620	1.622	1.634	1.649	1.664	1.680	1.708	1.733	1.783	1.821	1.874	1.908	1.932
0.20	1.625	1.620	1.622	1.631	1.643	1.656	1.669	1.694	1.715	1.759	1.792	1.838	1.868	1.889
0.22	1.625	1.619	1.619	1.626	1.635	1.646	1.658	1.678	1.697	1.734	1.762	1.802	1.827	1.845
0.24	1.624	1.616	1.615	1.619	1.627	1.635	1.645	1.662	1.677	1.709	1.732	1.765	1.787	1.802
0.26	1.621	1.612	1.610	1.611	1.617	1.624	1.631	1.645	1.658	1.683	1.702	1.729	1.747	1.759
0.28	1.617	1.607	1.603	1.603	1.606	1.611	1.616	1.627	1.637	1.656	1.672	1.693	1.707	1.717
0.30	1.611	1.600	1.595	1.592	1.594	1.597	1.601	1.608	1.615	1.630	1.641	1.656	1.667	1.674
0.32	1.604	1.592	1.586	1.581	1.581	1.582	1.584	1.589	1.593	1.602	1.610	1.620	1.627	1.631
0.34	1.596	1.582	1.575	1.569	1.566	1.566	1.566	1.568	1.570	1.575	1.578	1.583	1.587	1.589
0.36	1.586	1.571	1.564	1.555	1.551	1.549	1.548	1.547	1.547	1.546	1.546	1.547	1.547	1.546
0.38	1.575	1.559	1.551	1.540	1.535	1.531	1.528	1.525	1.522	1.517	1.514	1.510	1.507	1.504
0.40	1.563	1.546	1.536	1.525	1.517	1.512	1.508	1.502	1.497	1.488	1.482	1.473	1.467	1.462
0.42	1.549	1.532	1.521	1.508	1.498	1.492	1.487	1.478	1.472	1.458	1.449	1.436	1.427	1.420
0.44	1.534	1.516	1.505	1.489	1.479	1.471	1.465	1.454	1.445	1.428	1.416	1.398	1.386	1.378
0.46	1.518	1.499	1.487	1.470	1.458	1.449	1.441	1.429	1.418	1.397	1.382	1.361	1.346	1.336
0.48	1.500	1.481	1.467	1.450	1.436	1.426	1.417	1.402	1.390	1.366	1.348	1.323	1.306	1.294
0.50	1.481	1.461	1.447	1.428	1.414	1.402	1.392	1.375	1.361	1.334	1.314	1.285	1.266	1.252
0.52	1.461	1.440	1.425	1.405	1.390	1.377	1.366	1.347	1.332	1.301	1.279	1.247	1.225	1.210
0.54	1.439	1.418	1.403	1.381	1.365	1.351	1.339	1.319	1.302	1.268	1.243	1.208	1.185	1.168
0.56	1.416	1.394	1.378	1.356	1.338	1.323	1.311	1.289	1.270	1.234	1.207	1.170	1.144	1.126
0.58	1.391	1.369	1.353	1.329	1.311	1.295	1.282	1.258	1.238	1.200	1.171	1.131	1.103	1.083
0.60	1.365	1.342	1.325	1.301	1.282	1.265	1.251	1.226	1.206	1.165	1.134	1.091	1.062	1.041
0.62	1.337	1.314	1.297	1.272	1.252	1.234	1.220	1.194	1.172	1.129	1.097	1.052	1.021	0.999
0.64	1.307	1.284	1.267	1.241	1.220	1.202	1.187	1.160	1.137	1.092	1.059	1.012	0.980	0.956
0.66	1.276	1.252	1.235	1.208	1.187	1.169	1.153	1.125	1.101	1.054	1.020	0.971	0.938	0.914
0.68	1.242	1.219	1.201	1.174	1.152	1.134	1.117	1.088	1.064	1.016	0.980	0.930	0.896	0.871
0.70	1.207	1.184	1.166	1.139	1.116	1.097	1.080	1.050	1.026	0.976	0.940	0.888	0.853	0.828
0.72	1.170	1.146	1.128	1.101	1.078	1.059	1.042	1.011	0.986	0.936	0.899	0.846	0.810	0.784
0.74	1.130	1.107	1.089	1.061	1.038	1.019	1.001	0.971	0.945	0.894	0.857	0.803	0.767	0.741
0.76	1.089	1.065	1.048	1.020	0.997	0.977	0.959	0.929	0.903	0.852	0.814	0.760	0.724	0.697
0.78	1.044	1.021	1.003	0.976	0.953	0.933	0.915	0.885	0.859	0.807	0.769	0.716	0.679	0.652
0.80	0.995	0.973	0.956	0.928	0.906	0.886	0.868	0.838	0.812	0.761	0.723	0.670	0.634	0.607
0.82	0.943	0.921	0.904	0.877	0.855	0.836	0.818	0.788	0.763	0.713	0.675	0.623	0.587	0.561
0.84	0.887	0.866	0.849	0.823	0.801	0.782	0.766	0.736	0.711	0.662	0.626	0.575	0.540	0.514
0.86	0.827	0.807	0.791	0.766	0.745	0.726	0.710	0.682	0.657	0.610	0.575	0.525	0.491	0.466
0.88	0.764	0.745	0.730	0.705	0.685	0.667	0.652	0.624	0.601	0.555	0.522	0.474	0.442	0.418
0.90	0.694	0.676	0.662	0.639	0.620	0.603	0.588	0.562	0.540	0.497	0.466	0.421	0.390	0.368
0.92	0.614	0.598	0.585	0.564	0.546	0.531	0.517	0.493	0.473	0.434	0.404	0.363	0.335	0.315
0.94	0.521	0.506	0.495	0.476	0.461	0.447	0.435	0.414	0.396	0.362	0.336	0.300	0.275	0.257
0.96	0.408	0.396	0.386	0.371	0.359	0.348	0.338	0.321	0.306	0.278	0.257	0.228	0.208	0.193
0.98	0.269	0.260	0.254	0.243	0.234	0.227	0.220	0.208	0.198	0.178	0.164	0.144	0.130	0.120
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.3. $(r_o/T_o)\, D_{-\infty}^{Si}(z/r_o) = (r_o/T_o)\, D_{-}^{Si}(z/r_o)$ for protons. Units: dimensionless.

z/r_o	T_o= 2	3	4	5	6	8	10	15	20	30	40	50	60	80
0.0	1.309	1.258	1.222	1.194	1.175	1.165	1.177	1.165	1.160	1.154	1.152	1.153	1.155	1.160
0.02	1.339	1.289	1.255	1.228	1.209	1.195	1.204	1.196	1.190	1.184	1.182	1.183	1.184	1.189
0.04	1.359	1.311	1.279	1.253	1.235	1.218	1.224	1.219	1.213	1.207	1.205	1.205	1.206	1.210
0.06	1.374	1.327	1.296	1.271	1.253	1.236	1.239	1.236	1.230	1.224	1.222	1.222	1.222	1.226
0.08	1.384	1.339	1.309	1.285	1.268	1.249	1.250	1.249	1.243	1.237	1.234	1.234	1.234	1.237
0.10	1.390	1.347	1.318	1.295	1.278	1.260	1.259	1.258	1.252	1.246	1.244	1.243	1.244	1.246
0.12	1.394	1.352	1.325	1.303	1.287	1.268	1.265	1.266	1.260	1.254	1.251	1.251	1.251	1.253
0.14	1.397	1.356	1.330	1.309	1.293	1.275	1.270	1.271	1.266	1.260	1.257	1.257	1.256	1.258
0.16	1.398	1.358	1.333	1.313	1.299	1.280	1.273	1.276	1.270	1.264	1.262	1.261	1.261	1.262
0.18	1.398	1.359	1.335	1.316	1.302	1.284	1.276	1.278	1.273	1.267	1.265	1.264	1.264	1.264
0.20	1.396	1.358	1.335	1.317	1.304	1.286	1.277	1.279	1.274	1.269	1.266	1.265	1.265	1.265
0.22	1.392	1.355	1.333	1.316	1.304	1.287	1.276	1.279	1.274	1.269	1.266	1.265	1.264	1.265
0.24	1.386	1.351	1.330	1.314	1.302	1.286	1.274	1.277	1.272	1.267	1.264	1.263	1.263	1.263
0.26	1.380	1.346	1.326	1.311	1.300	1.284	1.271	1.273	1.269	1.264	1.262	1.261	1.260	1.260
0.28	1.372	1.339	1.320	1.306	1.295	1.281	1.267	1.269	1.265	1.260	1.258	1.257	1.256	1.255
0.30	1.363	1.331	1.313	1.300	1.290	1.276	1.263	1.263	1.260	1.255	1.253	1.252	1.251	1.250
0.32	1.353	1.322	1.305	1.293	1.284	1.271	1.257	1.257	1.253	1.249	1.247	1.246	1.245	1.244
0.34	1.342	1.312	1.296	1.284	1.276	1.264	1.250	1.249	1.246	1.242	1.240	1.239	1.238	1.237
0.36	1.330	1.300	1.285	1.275	1.267	1.256	1.242	1.240	1.237	1.234	1.232	1.230	1.229	1.228
0.38	1.317	1.288	1.274	1.264	1.257	1.247	1.233	1.229	1.228	1.224	1.222	1.221	1.220	1.219
0.40	1.302	1.274	1.261	1.252	1.246	1.237	1.223	1.218	1.217	1.214	1.212	1.211	1.210	1.208
0.42	1.287	1.259	1.247	1.239	1.233	1.225	1.212	1.206	1.206	1.203	1.201	1.199	1.198	1.197
0.44	1.270	1.244	1.232	1.225	1.220	1.213	1.200	1.193	1.193	1.190	1.188	1.187	1.186	1.184
0.46	1.253	1.227	1.216	1.209	1.205	1.199	1.187	1.179	1.179	1.177	1.175	1.174	1.172	1.171
0.48	1.234	1.209	1.199	1.193	1.190	1.184	1.172	1.163	1.164	1.162	1.160	1.159	1.158	1.156
0.50	1.214	1.190	1.181	1.175	1.173	1.168	1.157	1.147	1.148	1.146	1.145	1.143	1.142	1.140
0.52	1.193	1.170	1.161	1.156	1.154	1.151	1.141	1.129	1.131	1.129	1.128	1.127	1.126	1.124
0.54	1.172	1.148	1.141	1.137	1.135	1.133	1.123	1.111	1.113	1.111	1.110	1.109	1.108	1.106
0.56	1.148	1.126	1.119	1.115	1.114	1.113	1.104	1.092	1.093	1.092	1.091	1.090	1.089	1.087
0.58	1.124	1.102	1.095	1.093	1.092	1.092	1.084	1.071	1.073	1.072	1.071	1.070	1.069	1.067
0.60	1.099	1.077	1.071	1.069	1.069	1.070	1.063	1.049	1.051	1.050	1.050	1.049	1.048	1.045
0.62	1.072	1.051	1.045	1.044	1.045	1.046	1.040	1.027	1.027	1.028	1.027	1.026	1.025	1.023
0.64	1.044	1.023	1.019	1.017	1.019	1.021	1.016	1.003	1.003	1.003	1.003	1.002	1.001	0.999
0.66	1.014	0.995	0.990	0.990	0.991	0.995	0.990	0.978	0.977	0.978	0.978	0.977	0.976	0.974
0.68	0.984	0.964	0.960	0.960	0.962	0.966	0.962	0.951	0.949	0.951	0.951	0.950	0.949	0.947
0.70	0.951	0.932	0.929	0.929	0.932	0.937	0.933	0.923	0.920	0.922	0.922	0.922	0.921	0.919
0.72	0.917	0.899	0.896	0.896	0.899	0.905	0.903	0.894	0.890	0.892	0.892	0.892	0.891	0.889
0.74	0.882	0.864	0.861	0.862	0.865	0.872	0.870	0.862	0.858	0.860	0.861	0.860	0.860	0.858
0.76	0.845	0.828	0.825	0.826	0.829	0.836	0.836	0.829	0.825	0.827	0.827	0.827	0.826	0.825
0.78	0.805	0.789	0.786	0.787	0.791	0.799	0.799	0.794	0.789	0.791	0.792	0.791	0.791	0.789
0.80	0.763	0.748	0.745	0.746	0.750	0.758	0.759	0.756	0.751	0.752	0.753	0.753	0.753	0.751
0.82	0.718	0.703	0.701	0.702	0.706	0.715	0.716	0.715	0.711	0.710	0.711	0.712	0.711	0.710
0.84	0.670	0.657	0.654	0.656	0.659	0.668	0.670	0.670	0.667	0.665	0.667	0.668	0.667	0.666
0.86	0.620	0.607	0.605	0.606	0.610	0.619	0.621	0.623	0.621	0.618	0.620	0.621	0.621	0.619
0.88	0.567	0.555	0.553	0.554	0.558	0.566	0.569	0.572	0.572	0.569	0.570	0.571	0.571	0.570
0.90	0.509	0.499	0.496	0.498	0.501	0.509	0.512	0.516	0.517	0.515	0.515	0.516	0.516	0.515
0.92	0.445	0.435	0.433	0.434	0.437	0.444	0.448	0.453	0.455	0.454	0.453	0.454	0.454	0.454
0.94	0.371	0.363	0.361	0.362	0.364	0.370	0.373	0.379	0.382	0.383	0.382	0.382	0.382	0.382
0.96	0.284	0.278	0.277	0.277	0.279	0.283	0.286	0.291	0.294	0.297	0.296	0.296	0.296	0.296
0.98	0.181	0.176	0.175	0.175	0.176	0.179	0.181	0.184	0.187	0.191	0.193	0.193	0.193	0.192
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.3. $(r_o/T_o)\, D_{\bar{\infty}}^{Si}(z/r_o) = (r_o/T_o)\, D_{-}^{Si}(z/r_o)$ for protons. Units: dimensionless. (Continued)

z/r_o	T_o=100	150	200	300	400	500	600	800	1000	1500	2000	3000	4000	5000
0.0	1.167	1.186	1.207	1.249	1.290	1.329	1.362	1.430	1.489	1.607	1.696	1.821	1.904	1.963
0.02	1.194	1.212	1.231	1.269	1.306	1.341	1.371	1.432	1.485	1.592	1.672	1.786	1.861	1.915
0.04	1.215	1.231	1.248	1.283	1.316	1.348	1.376	1.430	1.478	1.576	1.649	1.752	1.821	1.870
0.06	1.230	1.245	1.260	1.292	1.322	1.351	1.378	1.426	1.470	1.559	1.626	1.720	1.784	1.829
0.08	1.242	1.254	1.269	1.297	1.325	1.352	1.377	1.420	1.460	1.541	1.602	1.688	1.747	1.789
0.10	1.250	1.262	1.274	1.301	1.326	1.350	1.373	1.413	1.449	1.523	1.579	1.657	1.711	1.750
0.12	1.256	1.267	1.278	1.302	1.325	1.347	1.369	1.404	1.437	1.504	1.555	1.627	1.676	1.711
0.14	1.261	1.270	1.281	1.302	1.323	1.343	1.363	1.394	1.424	1.485	1.531	1.596	1.641	1.673
0.16	1.264	1.273	1.282	1.301	1.320	1.338	1.355	1.384	1.411	1.465	1.507	1.565	1.605	1.635
0.18	1.266	1.274	1.282	1.299	1.316	1.332	1.347	1.373	1.397	1.445	1.482	1.535	1.570	1.597
0.20	1.267	1.274	1.281	1.296	1.310	1.325	1.338	1.361	1.382	1.425	1.457	1.504	1.536	1.559
0.22	1.266	1.272	1.278	1.291	1.304	1.316	1.328	1.348	1.366	1.404	1.432	1.473	1.501	1.522
0.24	1.264	1.268	1.274	1.285	1.296	1.307	1.317	1.334	1.350	1.383	1.407	1.443	1.467	1.486
0.26	1.260	1.264	1.269	1.278	1.288	1.297	1.306	1.320	1.333	1.361	1.382	1.412	1.433	1.449
0.28	1.256	1.259	1.263	1.270	1.278	1.286	1.293	1.305	1.316	1.339	1.356	1.382	1.399	1.413
0.30	1.250	1.252	1.255	1.262	1.268	1.274	1.280	1.289	1.298	1.317	1.331	1.351	1.365	1.376
0.32	1.244	1.245	1.247	1.252	1.257	1.261	1.266	1.273	1.280	1.294	1.305	1.321	1.332	1.340
0.34	1.236	1.237	1.238	1.241	1.245	1.248	1.251	1.257	1.261	1.271	1.278	1.290	1.298	1.304
0.36	1.227	1.227	1.228	1.230	1.232	1.234	1.236	1.239	1.241	1.247	1.252	1.259	1.264	1.269
0.38	1.218	1.217	1.217	1.217	1.218	1.219	1.220	1.221	1.221	1.223	1.225	1.228	1.231	1.233
0.40	1.207	1.205	1.205	1.204	1.203	1.203	1.203	1.202	1.200	1.199	1.198	1.197	1.197	1.198
0.42	1.195	1.193	1.192	1.190	1.188	1.186	1.185	1.183	1.179	1.174	1.171	1.166	1.164	1.162
0.44	1.183	1.180	1.178	1.175	1.172	1.169	1.167	1.163	1.158	1.149	1.144	1.135	1.130	1.127
0.46	1.169	1.166	1.163	1.159	1.155	1.151	1.148	1.142	1.135	1.124	1.116	1.104	1.097	1.092
0.48	1.154	1.150	1.148	1.142	1.137	1.132	1.128	1.120	1.113	1.098	1.088	1.073	1.063	1.057
0.50	1.138	1.134	1.131	1.124	1.118	1.113	1.108	1.098	1.089	1.072	1.059	1.042	1.030	1.021
0.52	1.122	1.117	1.113	1.106	1.099	1.092	1.086	1.075	1.065	1.045	1.031	1.010	0.996	0.986
0.54	1.104	1.099	1.094	1.086	1.078	1.071	1.064	1.052	1.041	1.018	1.002	0.978	0.963	0.951
0.56	1.085	1.079	1.074	1.065	1.056	1.048	1.041	1.027	1.015	0.990	0.972	0.946	0.929	0.916
0.58	1.064	1.059	1.053	1.044	1.034	1.025	1.017	1.002	0.989	0.962	0.942	0.914	0.895	0.881
0.60	1.043	1.037	1.031	1.021	1.010	1.001	0.992	0.976	0.963	0.933	0.912	0.882	0.861	0.846
0.62	1.020	1.014	1.008	0.997	0.986	0.976	0.967	0.950	0.935	0.904	0.881	0.849	0.827	0.811
0.64	0.996	0.990	0.984	0.972	0.961	0.950	0.940	0.922	0.907	0.874	0.850	0.816	0.793	0.776
0.66	0.971	0.965	0.958	0.946	0.934	0.923	0.912	0.894	0.877	0.844	0.818	0.783	0.759	0.741
0.68	0.945	0.938	0.931	0.918	0.906	0.894	0.884	0.864	0.847	0.812	0.786	0.749	0.724	0.706
0.70	0.916	0.909	0.902	0.890	0.877	0.865	0.854	0.834	0.816	0.780	0.753	0.715	0.689	0.670
0.72	0.887	0.880	0.872	0.859	0.846	0.834	0.823	0.802	0.784	0.748	0.720	0.681	0.654	0.635
0.74	0.855	0.848	0.841	0.828	0.814	0.802	0.790	0.769	0.751	0.714	0.686	0.646	0.619	0.599
0.76	0.822	0.815	0.808	0.794	0.781	0.768	0.757	0.735	0.717	0.679	0.651	0.610	0.583	0.563
0.78	0.787	0.780	0.773	0.759	0.745	0.733	0.721	0.700	0.681	0.644	0.615	0.574	0.547	0.526
0.80	0.749	0.742	0.735	0.721	0.708	0.695	0.683	0.662	0.643	0.606	0.578	0.537	0.509	0.489
0.82	0.708	0.701	0.694	0.681	0.667	0.655	0.643	0.622	0.604	0.567	0.539	0.499	0.472	0.451
0.84	0.664	0.658	0.651	0.638	0.625	0.612	0.601	0.580	0.562	0.526	0.499	0.460	0.433	0.413
0.86	0.617	0.611	0.605	0.592	0.580	0.568	0.557	0.537	0.519	0.484	0.458	0.420	0.394	0.374
0.88	0.568	0.563	0.556	0.544	0.532	0.521	0.510	0.491	0.474	0.440	0.415	0.379	0.354	0.335
0.90	0.514	0.509	0.503	0.491	0.480	0.469	0.459	0.441	0.426	0.394	0.370	0.336	0.312	0.294
0.92	0.453	0.448	0.443	0.432	0.422	0.412	0.403	0.386	0.372	0.343	0.321	0.289	0.267	0.252
0.94	0.381	0.377	0.373	0.364	0.355	0.346	0.338	0.323	0.311	0.285	0.266	0.238	0.219	0.205
0.96	0.296	0.293	0.289	0.282	0.275	0.268	0.261	0.249	0.239	0.218	0.203	0.180	0.165	0.154
0.98	0.191	0.190	0.187	0.182	0.178	0.173	0.169	0.161	0.154	0.139	0.129	0.113	0.103	0.095
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.4. $(r_o/T_o)\, D_{\bar{\infty}}^{SiO_2}(z/r_o) = (r_o/T_o)\, D_{-}^{SiO_2}(z/r_o)$ for protons. Units: dimensionless.

z/r_o	T_o= 2	3	4	5	6	8	10	15	20	30	40	50	60	80
0.0	1.409	1.345	1.302	1.269	1.247	1.228	1.235	1.218	1.209	1.199	1.196	1.194	1.195	1.199
0.02	1.443	1.380	1.338	1.306	1.284	1.262	1.265	1.251	1.242	1.231	1.227	1.225	1.226	1.229
0.04	1.467	1.406	1.365	1.334	1.312	1.288	1.288	1.276	1.266	1.256	1.251	1.249	1.249	1.251
0.06	1.483	1.424	1.385	1.354	1.333	1.308	1.305	1.295	1.285	1.274	1.269	1.267	1.266	1.268
0.08	1.496	1.438	1.399	1.370	1.349	1.323	1.318	1.309	1.299	1.288	1.283	1.280	1.279	1.280
0.10	1.504	1.447	1.410	1.382	1.361	1.335	1.328	1.320	1.309	1.299	1.293	1.290	1.289	1.290
0.12	1.510	1.454	1.418	1.391	1.371	1.345	1.336	1.328	1.318	1.307	1.301	1.299	1.297	1.297
0.14	1.514	1.460	1.425	1.398	1.379	1.354	1.342	1.335	1.325	1.314	1.308	1.305	1.303	1.303
0.16	1.516	1.463	1.430	1.404	1.385	1.360	1.347	1.340	1.330	1.319	1.313	1.310	1.308	1.307
0.18	1.517	1.465	1.433	1.408	1.390	1.365	1.351	1.344	1.333	1.323	1.317	1.314	1.311	1.310
0.20	1.516	1.465	1.434	1.410	1.392	1.368	1.352	1.346	1.335	1.325	1.319	1.316	1.313	1.311
0.22	1.512	1.463	1.433	1.410	1.393	1.370	1.353	1.346	1.336	1.325	1.319	1.316	1.313	1.311
0.24	1.508	1.459	1.430	1.408	1.392	1.369	1.352	1.344	1.335	1.324	1.318	1.314	1.312	1.309
0.26	1.502	1.454	1.426	1.405	1.390	1.368	1.349	1.342	1.332	1.322	1.316	1.312	1.309	1.307
0.28	1.494	1.448	1.421	1.401	1.386	1.365	1.346	1.338	1.328	1.318	1.312	1.308	1.306	1.303
0.30	1.486	1.440	1.415	1.395	1.381	1.361	1.342	1.333	1.324	1.314	1.308	1.304	1.301	1.298
0.32	1.476	1.432	1.407	1.388	1.375	1.356	1.337	1.326	1.318	1.308	1.302	1.298	1.295	1.291
0.34	1.465	1.421	1.398	1.380	1.368	1.349	1.330	1.319	1.311	1.301	1.295	1.291	1.288	1.284
0.36	1.452	1.410	1.387	1.370	1.359	1.342	1.322	1.310	1.302	1.293	1.287	1.283	1.280	1.276
0.38	1.439	1.397	1.375	1.360	1.349	1.333	1.313	1.300	1.293	1.283	1.278	1.273	1.270	1.266
0.40	1.424	1.383	1.363	1.348	1.337	1.322	1.303	1.289	1.282	1.273	1.267	1.263	1.260	1.255
0.42	1.408	1.368	1.348	1.334	1.325	1.311	1.292	1.277	1.271	1.261	1.256	1.252	1.248	1.244
0.44	1.391	1.352	1.333	1.320	1.311	1.298	1.280	1.264	1.258	1.249	1.243	1.239	1.236	1.231
0.46	1.372	1.335	1.316	1.304	1.296	1.284	1.267	1.249	1.244	1.235	1.229	1.225	1.222	1.217
0.48	1.353	1.316	1.299	1.287	1.280	1.269	1.252	1.234	1.229	1.220	1.215	1.211	1.208	1.203
0.50	1.332	1.296	1.280	1.269	1.262	1.252	1.236	1.217	1.213	1.204	1.199	1.195	1.192	1.187
0.52	1.310	1.275	1.259	1.250	1.243	1.235	1.219	1.200	1.195	1.187	1.182	1.178	1.175	1.170
0.54	1.287	1.252	1.238	1.229	1.223	1.215	1.201	1.181	1.177	1.168	1.164	1.160	1.156	1.151
0.56	1.262	1.229	1.215	1.207	1.202	1.195	1.182	1.161	1.157	1.149	1.144	1.140	1.137	1.132
0.58	1.236	1.204	1.191	1.183	1.179	1.173	1.161	1.140	1.135	1.128	1.123	1.120	1.117	1.111
0.60	1.209	1.177	1.165	1.158	1.155	1.150	1.138	1.117	1.113	1.106	1.101	1.098	1.095	1.090
0.62	1.181	1.150	1.138	1.132	1.129	1.125	1.115	1.094	1.089	1.083	1.078	1.075	1.072	1.066
0.64	1.151	1.120	1.109	1.104	1.102	1.099	1.089	1.069	1.064	1.058	1.054	1.050	1.047	1.042
0.66	1.119	1.090	1.079	1.074	1.073	1.071	1.062	1.043	1.037	1.031	1.027	1.024	1.021	1.016
0.68	1.086	1.057	1.047	1.043	1.042	1.042	1.034	1.016	1.009	1.004	1.000	0.997	0.994	0.989
0.70	1.051	1.023	1.014	1.010	1.010	1.010	1.003	0.986	0.979	0.974	0.970	0.967	0.965	0.960
0.72	1.015	0.988	0.979	0.976	0.976	0.977	0.971	0.955	0.947	0.943	0.939	0.936	0.934	0.929
0.74	0.976	0.950	0.942	0.939	0.939	0.942	0.937	0.923	0.914	0.910	0.907	0.904	0.901	0.896
0.76	0.936	0.911	0.903	0.901	0.901	0.904	0.900	0.888	0.879	0.875	0.872	0.869	0.867	0.862
0.78	0.893	0.869	0.862	0.860	0.861	0.864	0.861	0.851	0.842	0.838	0.835	0.832	0.830	0.826
0.80	0.848	0.825	0.817	0.816	0.817	0.822	0.819	0.811	0.802	0.798	0.795	0.793	0.791	0.786
0.82	0.799	0.777	0.770	0.769	0.770	0.775	0.774	0.767	0.760	0.754	0.752	0.750	0.748	0.744
0.84	0.747	0.726	0.720	0.718	0.720	0.725	0.725	0.720	0.714	0.707	0.706	0.704	0.702	0.698
0.86	0.692	0.673	0.667	0.665	0.667	0.673	0.673	0.670	0.665	0.658	0.657	0.655	0.653	0.650
0.88	0.634	0.616	0.610	0.609	0.611	0.617	0.618	0.617	0.613	0.606	0.605	0.603	0.602	0.599
0.90	0.570	0.554	0.549	0.548	0.550	0.555	0.557	0.557	0.555	0.550	0.547	0.546	0.545	0.542
0.92	0.499	0.485	0.480	0.479	0.481	0.486	0.488	0.490	0.490	0.486	0.483	0.481	0.480	0.478
0.94	0.418	0.406	0.402	0.401	0.402	0.406	0.408	0.411	0.412	0.410	0.407	0.406	0.405	0.403
0.96	0.321	0.312	0.309	0.308	0.308	0.312	0.313	0.317	0.319	0.319	0.317	0.316	0.315	0.313
0.98	0.205	0.199	0.197	0.196	0.197	0.198	0.199	0.202	0.204	0.207	0.207	0.207	0.206	0.204
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.4. $(r_o/T_o)\, D_{-\infty}^{SiO_2}(z/r_o) = (r_o/T_o)\, D_{-}^{SiO_2}(z/r_o)$ for protons. Units: dimensionless. (Continued)

z/r_o	T_o=100	150	200	300	400	500	600	800	1000	1500	2000	3000	4000	5000
0.0	1.205	1.223	1.243	1.285	1.326	1.365	1.398	1.466	1.526	1.645	1.734	1.861	1.944	2.003
0.02	1.234	1.250	1.268	1.305	1.342	1.377	1.408	1.469	1.522	1.630	1.711	1.825	1.901	1.954
0.04	1.255	1.269	1.286	1.320	1.353	1.385	1.413	1.467	1.516	1.613	1.687	1.791	1.861	1.910
0.06	1.271	1.284	1.299	1.329	1.359	1.389	1.415	1.464	1.507	1.597	1.664	1.759	1.822	1.867
0.08	1.283	1.294	1.308	1.335	1.363	1.389	1.414	1.457	1.498	1.579	1.640	1.726	1.785	1.827
0.10	1.292	1.302	1.314	1.339	1.364	1.388	1.411	1.450	1.487	1.561	1.616	1.695	1.749	1.787
0.12	1.299	1.308	1.318	1.341	1.363	1.385	1.406	1.441	1.474	1.542	1.592	1.663	1.713	1.748
0.14	1.304	1.312	1.321	1.341	1.361	1.381	1.400	1.431	1.462	1.522	1.568	1.632	1.677	1.709
0.16	1.308	1.315	1.323	1.340	1.358	1.376	1.393	1.421	1.448	1.502	1.543	1.601	1.641	1.670
0.18	1.311	1.316	1.323	1.339	1.354	1.370	1.385	1.410	1.433	1.482	1.518	1.570	1.605	1.632
0.20	1.311	1.316	1.321	1.335	1.349	1.363	1.376	1.398	1.418	1.461	1.493	1.539	1.570	1.594
0.22	1.311	1.314	1.319	1.330	1.342	1.354	1.366	1.384	1.402	1.440	1.468	1.507	1.535	1.556
0.24	1.309	1.311	1.315	1.324	1.334	1.345	1.355	1.371	1.386	1.418	1.442	1.476	1.501	1.519
0.26	1.306	1.307	1.310	1.318	1.326	1.334	1.343	1.356	1.369	1.396	1.416	1.445	1.466	1.481
0.28	1.301	1.302	1.304	1.310	1.316	1.323	1.330	1.341	1.351	1.374	1.390	1.414	1.431	1.444
0.30	1.296	1.295	1.297	1.301	1.306	1.311	1.317	1.325	1.333	1.351	1.364	1.383	1.397	1.407
0.32	1.289	1.288	1.288	1.291	1.295	1.298	1.302	1.309	1.314	1.328	1.338	1.352	1.363	1.371
0.34	1.282	1.279	1.279	1.280	1.282	1.285	1.288	1.292	1.295	1.304	1.311	1.321	1.328	1.334
0.36	1.273	1.270	1.269	1.269	1.269	1.270	1.272	1.274	1.275	1.280	1.284	1.290	1.294	1.298
0.38	1.263	1.259	1.258	1.256	1.255	1.255	1.255	1.256	1.255	1.256	1.257	1.258	1.260	1.262
0.40	1.252	1.248	1.246	1.243	1.240	1.239	1.238	1.236	1.234	1.231	1.229	1.227	1.226	1.225
0.42	1.241	1.235	1.233	1.228	1.225	1.222	1.220	1.217	1.212	1.206	1.201	1.195	1.191	1.189
0.44	1.228	1.222	1.218	1.213	1.208	1.205	1.201	1.196	1.190	1.180	1.173	1.164	1.157	1.153
0.46	1.214	1.207	1.203	1.196	1.191	1.186	1.182	1.175	1.167	1.154	1.145	1.132	1.123	1.118
0.48	1.199	1.192	1.187	1.179	1.172	1.167	1.162	1.153	1.144	1.128	1.116	1.100	1.089	1.082
0.50	1.183	1.175	1.170	1.161	1.153	1.147	1.141	1.130	1.120	1.101	1.087	1.068	1.055	1.046
0.52	1.165	1.158	1.152	1.142	1.133	1.126	1.119	1.107	1.096	1.074	1.058	1.035	1.021	1.010
0.54	1.147	1.139	1.132	1.122	1.112	1.104	1.096	1.083	1.071	1.046	1.028	1.003	0.986	0.975
0.56	1.128	1.119	1.112	1.101	1.090	1.081	1.073	1.058	1.045	1.018	0.998	0.970	0.952	0.939
0.58	1.107	1.098	1.091	1.078	1.067	1.057	1.048	1.032	1.018	0.989	0.967	0.938	0.917	0.903
0.60	1.085	1.076	1.068	1.055	1.043	1.033	1.023	1.006	0.991	0.959	0.937	0.905	0.883	0.867
0.62	1.062	1.052	1.044	1.031	1.018	1.007	0.997	0.978	0.962	0.929	0.905	0.871	0.848	0.832
0.64	1.037	1.028	1.019	1.005	0.992	0.980	0.969	0.950	0.933	0.899	0.873	0.837	0.813	0.796
0.66	1.011	1.002	0.993	0.978	0.965	0.952	0.941	0.921	0.903	0.868	0.841	0.803	0.778	0.760
0.68	0.984	0.974	0.965	0.950	0.936	0.923	0.911	0.891	0.872	0.836	0.808	0.769	0.743	0.724
0.70	0.955	0.945	0.936	0.920	0.906	0.893	0.881	0.859	0.841	0.803	0.774	0.734	0.707	0.687
0.72	0.924	0.914	0.905	0.889	0.874	0.861	0.849	0.827	0.808	0.769	0.740	0.699	0.671	0.651
0.74	0.892	0.882	0.873	0.857	0.842	0.828	0.816	0.793	0.774	0.735	0.705	0.663	0.635	0.614
0.76	0.858	0.848	0.839	0.822	0.807	0.793	0.781	0.758	0.739	0.699	0.669	0.627	0.598	0.577
0.78	0.821	0.812	0.802	0.786	0.771	0.757	0.745	0.722	0.702	0.663	0.633	0.590	0.561	0.540
0.80	0.782	0.772	0.763	0.747	0.732	0.718	0.706	0.683	0.663	0.624	0.594	0.552	0.523	0.502
0.82	0.740	0.730	0.721	0.705	0.691	0.677	0.665	0.642	0.623	0.584	0.555	0.513	0.484	0.464
0.84	0.694	0.685	0.676	0.661	0.647	0.633	0.621	0.599	0.580	0.542	0.514	0.473	0.445	0.424
0.86	0.646	0.638	0.629	0.614	0.600	0.587	0.575	0.554	0.536	0.499	0.471	0.432	0.405	0.385
0.88	0.595	0.587	0.579	0.565	0.551	0.539	0.528	0.507	0.489	0.454	0.427	0.390	0.364	0.344
0.90	0.539	0.531	0.524	0.510	0.498	0.486	0.475	0.456	0.439	0.406	0.381	0.345	0.321	0.303
0.92	0.475	0.468	0.462	0.449	0.438	0.427	0.417	0.399	0.384	0.353	0.330	0.298	0.275	0.259
0.94	0.401	0.395	0.389	0.378	0.369	0.359	0.350	0.335	0.321	0.294	0.274	0.245	0.226	0.211
0.96	0.312	0.307	0.302	0.294	0.286	0.278	0.271	0.258	0.247	0.226	0.209	0.186	0.170	0.158
0.98	0.203	0.200	0.196	0.191	0.186	0.180	0.175	0.167	0.159	0.144	0.133	0.117	0.106	0.098
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.5. $(r_o/T_o)\, D_{-\infty}^{A\ell}(z/r_o)$ for electrons. Units: dimensionless.

z/r_o	T_o=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	1.722	1.771	1.892	2.019	2.082	2.055	2.041	1.961	1.898
0.025	1.779	1.817	1.910	2.009	2.062	2.044	2.028	1.959	1.887
0.050	1.809	1.838	1.909	1.986	2.028	2.014	1.994	1.936	1.859
0.075	1.814	1.837	1.892	1.951	1.983	1.969	1.944	1.894	1.816
0.100	1.801	1.819	1.861	1.906	1.928	1.913	1.881	1.839	1.764
0.125	1.774	1.787	1.820	1.854	1.868	1.849	1.812	1.775	1.704
0.150	1.736	1.746	1.771	1.796	1.803	1.783	1.739	1.707	1.641
0.175	1.691	1.698	1.717	1.735	1.737	1.716	1.669	1.640	1.578
0.200	1.642	1.647	1.659	1.670	1.670	1.651	1.602	1.575	1.516
0.225	1.589	1.591	1.597	1.603	1.603	1.588	1.540	1.513	1.457
0.250	1.531	1.531	1.532	1.534	1.535	1.525	1.479	1.454	1.399
0.275	1.468	1.467	1.464	1.463	1.467	1.462	1.421	1.395	1.343
0.300	1.401	1.398	1.392	1.390	1.396	1.398	1.363	1.338	1.288
0.325	1.327	1.324	1.317	1.315	1.325	1.331	1.304	1.281	1.234
0.350	1.247	1.245	1.239	1.238	1.251	1.262	1.244	1.224	1.181
0.375	1.163	1.161	1.158	1.159	1.176	1.190	1.183	1.167	1.128
0.400	1.075	1.074	1.074	1.079	1.098	1.116	1.120	1.109	1.075
0.425	0.985	0.985	0.988	0.996	1.020	1.041	1.056	1.049	1.021
0.450	0.892	0.893	0.900	0.912	0.939	0.964	0.989	0.988	0.965
0.475	0.796	0.799	0.809	0.826	0.857	0.885	0.921	0.925	0.908
0.500	0.699	0.703	0.717	0.738	0.775	0.806	0.850	0.859	0.849
0.525	0.604	0.609	0.625	0.649	0.691	0.727	0.778	0.792	0.789
0.550	0.514	0.520	0.536	0.562	0.609	0.649	0.705	0.724	0.728
0.575	0.433	0.438	0.453	0.478	0.528	0.572	0.632	0.656	0.667
0.600	0.361	0.364	0.376	0.398	0.449	0.496	0.558	0.587	0.606
0.625	0.297	0.299	0.306	0.325	0.375	0.424	0.486	0.520	0.547
0.650	0.240	0.240	0.244	0.258	0.305	0.354	0.414	0.453	0.490
0.675	0.189	0.188	0.189	0.199	0.243	0.289	0.346	0.388	0.435
0.700	0.144	0.142	0.141	0.149	0.187	0.228	0.281	0.326	0.381
0.725	0.103	0.102	0.101	0.107	0.138	0.173	0.222	0.268	0.328
0.750	0.068	0.067	0.068	0.074	0.098	0.125	0.169	0.214	0.277
0.775	0.041	0.041	0.043	0.048	0.066	0.086	0.124	0.164	0.227
0.800	0.024	0.024	0.025	0.029	0.041	0.056	0.088	0.121	0.177
0.825	0.013	0.013	0.014	0.017	0.024	0.035	0.059	0.086	0.133
0.850	0.006	0.007	0.007	0.009	0.013	0.020	0.038	0.057	0.096
0.875	0.003	0.003	0.003	0.004	0.007	0.010	0.022	0.036	0.066
0.900	0.001	0.001	0.001	0.002	0.003	0.005	0.011	0.020	0.041
0.925	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.010	0.022
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.010
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.6. $(r_0/T_0)\, D_-^{A\ell}(z/r_0)$ for electrons. Units: dimensionless.

z/r_0	T_0=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	1.122	1.164	1.272	1.399	1.510	1.538	1.573	1.565	1.561
0.025	1.148	1.185	1.280	1.392	1.492	1.520	1.558	1.554	1.544
0.050	1.160	1.193	1.277	1.375	1.465	1.492	1.529	1.528	1.516
0.075	1.162	1.190	1.263	1.350	1.431	1.456	1.489	1.491	1.478
0.100	1.155	1.179	1.242	1.318	1.390	1.414	1.442	1.446	1.434
0.125	1.139	1.160	1.214	1.280	1.345	1.367	1.389	1.395	1.384
0.150	1.118	1.135	1.182	1.238	1.297	1.317	1.335	1.342	1.333
0.175	1.091	1.106	1.145	1.194	1.247	1.267	1.281	1.289	1.281
0.200	1.060	1.073	1.106	1.148	1.197	1.218	1.230	1.238	1.231
0.225	1.026	1.036	1.064	1.100	1.147	1.168	1.180	1.188	1.182
0.250	0.988	0.996	1.019	1.051	1.095	1.119	1.132	1.139	1.133
0.275	0.946	0.953	0.973	1.001	1.044	1.069	1.084	1.092	1.086
0.300	0.901	0.907	0.924	0.950	0.991	1.018	1.037	1.044	1.039
0.325	0.853	0.858	0.873	0.897	0.938	0.966	0.989	0.997	0.993
0.350	0.800	0.805	0.820	0.843	0.884	0.913	0.941	0.950	0.947
0.375	0.746	0.751	0.766	0.789	0.828	0.859	0.892	0.902	0.901
0.400	0.689	0.695	0.710	0.733	0.772	0.803	0.841	0.854	0.855
0.425	0.632	0.637	0.653	0.676	0.715	0.747	0.790	0.805	0.809
0.450	0.573	0.578	0.594	0.618	0.657	0.690	0.737	0.755	0.762
0.475	0.513	0.518	0.534	0.558	0.599	0.632	0.684	0.704	0.714
0.500	0.451	0.457	0.473	0.498	0.539	0.575	0.629	0.652	0.666
0.525	0.391	0.396	0.412	0.437	0.480	0.517	0.573	0.598	0.616
0.550	0.334	0.339	0.354	0.377	0.422	0.460	0.517	0.545	0.567
0.575	0.281	0.286	0.298	0.320	0.364	0.404	0.461	0.491	0.517
0.600	0.234	0.237	0.247	0.266	0.310	0.350	0.405	0.438	0.469
0.625	0.191	0.193	0.201	0.217	0.258	0.298	0.351	0.385	0.421
0.650	0.152	0.154	0.159	0.172	0.210	0.248	0.299	0.334	0.375
0.675	0.118	0.119	0.122	0.133	0.167	0.201	0.248	0.285	0.330
0.700	0.088	0.089	0.091	0.100	0.128	0.158	0.201	0.237	0.287
0.725	0.064	0.064	0.065	0.071	0.094	0.120	0.158	0.193	0.245
0.750	0.044	0.044	0.044	0.049	0.066	0.087	0.120	0.153	0.205
0.775	0.029	0.028	0.028	0.031	0.044	0.059	0.087	0.117	0.166
0.800	0.018	0.017	0.017	0.019	0.027	0.039	0.061	0.086	0.128
0.825	0.010	0.010	0.009	0.010	0.016	0.024	0.041	0.060	0.096
0.850	0.005	0.005	0.005	0.005	0.009	0.014	0.026	0.040	0.069
0.875	0.002	0.002	0.002	0.002	0.004	0.007	0.015	0.025	0.046
0.900	0.001	0.001	0.001	0.001	0.002	0.003	0.008	0.014	0.028
0.925	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.006	0.015
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.006
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.7. $(r_o/T_o)\, D_{-\infty}^{H_2O}(z/r_o)$ for electrons. Units: dimensionless.

z/r_o	T_o=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	2.296	2.345	2.466	2.590	2.645	2.605	2.559	2.444	2.349
0.025	2.372	2.405	2.489	2.577	2.618	2.590	2.543	2.443	2.337
0.050	2.410	2.433	2.488	2.546	2.574	2.552	2.500	2.414	2.303
0.075	2.418	2.432	2.465	2.501	2.516	2.496	2.438	2.363	2.252
0.100	2.402	2.409	2.426	2.443	2.447	2.426	2.360	2.295	2.188
0.125	2.366	2.368	2.372	2.376	2.370	2.346	2.274	2.217	2.115
0.150	2.316	2.314	2.309	2.302	2.288	2.263	2.184	2.134	2.038
0.175	2.257	2.252	2.238	2.222	2.204	2.179	2.097	2.051	1.960
0.200	2.192	2.184	2.163	2.140	2.119	2.098	2.014	1.971	1.885
0.225	2.121	2.110	2.083	2.054	2.034	2.018	1.936	1.895	1.812
0.250	2.044	2.031	1.998	1.965	1.948	1.938	1.861	1.821	1.741
0.275	1.960	1.945	1.909	1.874	1.861	1.858	1.788	1.749	1.672
0.300	1.870	1.854	1.816	1.780	1.772	1.776	1.715	1.677	1.604
0.325	1.771	1.756	1.718	1.684	1.681	1.692	1.642	1.607	1.538
0.350	1.666	1.651	1.616	1.585	1.587	1.604	1.566	1.535	1.472
0.375	1.553	1.540	1.510	1.484	1.491	1.512	1.490	1.464	1.407
0.400	1.436	1.426	1.401	1.381	1.393	1.418	1.411	1.391	1.341
0.425	1.316	1.307	1.289	1.276	1.293	1.322	1.329	1.316	1.274
0.450	1.192	1.186	1.173	1.168	1.191	1.224	1.246	1.240	1.205
0.475	1.064	1.061	1.055	1.057	1.087	1.124	1.159	1.160	1.134
0.500	0.934	0.934	0.934	0.944	0.982	1.024	1.070	1.078	1.061
0.525	0.807	0.808	0.814	0.831	0.877	0.923	0.979	0.994	0.985
0.550	0.688	0.690	0.699	0.719	0.771	0.823	0.887	0.909	0.909
0.575	0.579	0.581	0.590	0.611	0.668	0.725	0.795	0.823	0.833
0.600	0.483	0.484	0.490	0.509	0.569	0.629	0.702	0.737	0.757
0.625	0.397	0.396	0.399	0.415	0.474	0.537	0.611	0.652	0.684
0.650	0.321	0.319	0.317	0.329	0.386	0.449	0.521	0.568	0.612
0.675	0.253	0.250	0.246	0.254	0.307	0.365	0.435	0.487	0.543
0.700	0.193	0.189	0.184	0.190	0.235	0.289	0.353	0.409	0.476
0.725	0.138	0.135	0.132	0.137	0.174	0.219	0.279	0.336	0.410
0.750	0.091	0.090	0.089	0.094	0.124	0.158	0.212	0.268	0.346
0.775	0.055	0.055	0.056	0.062	0.083	0.108	0.156	0.206	0.283
0.800	0.032	0.032	0.033	0.038	0.052	0.071	0.110	0.152	0.221
0.825	0.017	0.017	0.019	0.022	0.031	0.044	0.075	0.108	0.167
0.850	0.008	0.009	0.009	0.011	0.017	0.025	0.047	0.072	0.121
0.875	0.004	0.004	0.004	0.005	0.008	0.013	0.028	0.045	0.082
0.900	0.001	0.001	0.002	0.002	0.004	0.006	0.014	0.025	0.052
0.925	0.000	0.000	0.000	0.001	0.001	0.002	0.006	0.012	0.028
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.004	0.012
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.8. $(r_0/T_0)\, D_-^{H_2O}(z/r_0)$ for electrons. Units: dimensionless.

z/r_0	T_0=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	1.497	1.543	1.660	1.798	1.921	1.950	1.973	1.950	1.932
0.025	1.531	1.570	1.670	1.789	1.898	1.928	1.955	1.938	1.913
0.050	1.549	1.582	1.666	1.768	1.864	1.894	1.919	1.908	1.880
0.075	1.552	1.579	1.649	1.735	1.821	1.849	1.871	1.864	1.835
0.100	1.542	1.564	1.622	1.694	1.769	1.797	1.813	1.809	1.782
0.125	1.523	1.540	1.586	1.646	1.712	1.738	1.748	1.747	1.722
0.150	1.494	1.508	1.544	1.592	1.651	1.676	1.681	1.681	1.659
0.175	1.459	1.469	1.496	1.535	1.589	1.614	1.614	1.616	1.596
0.200	1.419	1.426	1.445	1.476	1.525	1.551	1.551	1.553	1.534
0.225	1.373	1.377	1.391	1.415	1.461	1.489	1.489	1.491	1.474
0.250	1.322	1.325	1.333	1.352	1.396	1.426	1.429	1.431	1.415
0.275	1.267	1.268	1.272	1.287	1.330	1.363	1.369	1.372	1.356
0.300	1.207	1.206	1.209	1.221	1.263	1.298	1.310	1.313	1.299
0.325	1.142	1.141	1.142	1.153	1.195	1.232	1.250	1.254	1.242
0.350	1.072	1.072	1.073	1.084	1.126	1.164	1.189	1.195	1.185
0.375	0.999	0.999	1.002	1.014	1.056	1.095	1.127	1.136	1.128
0.400	0.924	0.925	0.929	0.942	0.984	1.025	1.064	1.075	1.072
0.425	0.847	0.849	0.854	0.869	0.912	0.953	0.999	1.014	1.014
0.450	0.769	0.771	0.778	0.794	0.838	0.880	0.933	0.952	0.956
0.475	0.688	0.691	0.700	0.718	0.763	0.807	0.865	0.888	0.897
0.500	0.606	0.609	0.620	0.640	0.688	0.733	0.796	0.822	0.836
0.525	0.525	0.529	0.540	0.562	0.612	0.660	0.725	0.755	0.774
0.550	0.448	0.452	0.463	0.485	0.538	0.587	0.654	0.688	0.712
0.575	0.378	0.381	0.391	0.412	0.465	0.516	0.584	0.620	0.651
0.600	0.315	0.316	0.324	0.342	0.395	0.446	0.513	0.553	0.590
0.625	0.257	0.258	0.262	0.279	0.328	0.379	0.445	0.487	0.530
0.650	0.205	0.205	0.208	0.221	0.268	0.316	0.378	0.422	0.472
0.675	0.159	0.158	0.160	0.171	0.212	0.256	0.314	0.360	0.416
0.700	0.119	0.118	0.119	0.128	0.163	0.201	0.255	0.300	0.362
0.725	0.086	0.085	0.085	0.092	0.120	0.153	0.200	0.245	0.309
0.750	0.059	0.058	0.058	0.063	0.084	0.110	0.152	0.194	0.258
0.775	0.039	0.038	0.037	0.040	0.056	0.076	0.111	0.148	0.210
0.800	0.024	0.023	0.022	0.024	0.035	0.050	0.078	0.109	0.163
0.825	0.014	0.013	0.013	0.014	0.021	0.031	0.052	0.077	0.122
0.850	0.007	0.007	0.006	0.007	0.011	0.018	0.033	0.051	0.087
0.875	0.003	0.003	0.003	0.003	0.006	0.009	0.019	0.032	0.059
0.900	0.001	0.001	0.001	0.001	0.002	0.004	0.010	0.018	0.037
0.925	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.008	0.020
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.008
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.9. $(r_0/T_0)\ D_{\bar{\infty}}^{Si}(z/r_0)$ for electrons. Units: dimensionless.

z/r_0	T_0=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	1.761	1.808	1.921	2.031	2.047	1.969	1.857	1.680	1.474
0.025	1.818	1.854	1.942	2.029	2.047	1.989	1.897	1.752	1.570
0.050	1.847	1.875	1.944	2.012	2.029	1.985	1.907	1.788	1.628
0.075	1.852	1.874	1.928	1.982	1.996	1.960	1.891	1.796	1.654
0.100	1.839	1.856	1.898	1.941	1.951	1.920	1.856	1.779	1.655
0.125	1.811	1.825	1.858	1.891	1.897	1.868	1.807	1.746	1.635
0.150	1.772	1.783	1.809	1.834	1.837	1.809	1.749	1.700	1.601
0.175	1.727	1.735	1.754	1.773	1.773	1.748	1.689	1.648	1.560
0.200	1.677	1.682	1.695	1.708	1.708	1.686	1.629	1.593	1.515
0.225	1.622	1.625	1.633	1.641	1.641	1.624	1.569	1.537	1.467
0.250	1.563	1.564	1.567	1.570	1.572	1.561	1.510	1.480	1.416
0.275	1.499	1.498	1.497	1.497	1.502	1.496	1.451	1.421	1.364
0.300	1.430	1.428	1.424	1.422	1.430	1.430	1.391	1.363	1.311
0.325	1.355	1.352	1.347	1.345	1.356	1.361	1.331	1.305	1.258
0.350	1.273	1.271	1.267	1.267	1.280	1.290	1.270	1.247	1.205
0.375	1.187	1.186	1.184	1.186	1.203	1.217	1.208	1.190	1.151
0.400	1.098	1.097	1.098	1.104	1.124	1.141	1.144	1.131	1.097
0.425	1.005	1.006	1.010	1.019	1.043	1.064	1.079	1.072	1.042
0.450	0.910	0.912	0.919	0.933	0.961	0.985	1.012	1.011	0.986
0.475	0.812	0.816	0.827	0.844	0.877	0.905	0.942	0.947	0.928
0.500	0.713	0.718	0.732	0.754	0.792	0.825	0.871	0.881	0.869
0.525	0.616	0.622	0.638	0.664	0.707	0.743	0.797	0.813	0.809
0.550	0.525	0.530	0.548	0.574	0.622	0.663	0.722	0.743	0.747
0.575	0.442	0.447	0.462	0.488	0.539	0.584	0.646	0.672	0.686
0.600	0.368	0.372	0.384	0.407	0.458	0.507	0.571	0.602	0.625
0.625	0.303	0.304	0.312	0.331	0.382	0.432	0.496	0.532	0.565
0.650	0.245	0.245	0.248	0.263	0.311	0.361	0.423	0.464	0.506
0.675	0.193	0.192	0.192	0.203	0.247	0.294	0.353	0.397	0.449
0.700	0.147	0.145	0.144	0.151	0.189	0.232	0.287	0.334	0.394
0.725	0.105	0.104	0.103	0.109	0.140	0.175	0.226	0.274	0.340
0.750	0.069	0.069	0.069	0.075	0.098	0.126	0.172	0.219	0.286
0.775	0.042	0.042	0.043	0.048	0.065	0.086	0.126	0.168	0.234
0.800	0.024	0.024	0.026	0.029	0.041	0.056	0.089	0.124	0.183
0.825	0.013	0.013	0.014	0.016	0.024	0.034	0.059	0.088	0.139
0.850	0.006	0.007	0.007	0.008	0.013	0.019	0.038	0.059	0.101
0.875	0.003	0.003	0.003	0.004	0.006	0.010	0.022	0.037	0.069
0.900	0.001	0.001	0.001	0.001	0.002	0.004	0.011	0.021	0.044
0.925	0.000	0.000	0.000	0.000	0.001	0.001	0.005	0.010	0.024
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.010
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.10. $(r_0/T_0)\ D_-^{Si}(z/r_0)$ for electrons. Units: dimensionless.

z/r₀	T₀=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	1.149	1.191	1.299	1.423	1.522	1.533	1.529	1.478	1.438
0.025	1.173	1.211	1.305	1.413	1.496	1.504	1.500	1.454	1.391
0.050	1.186	1.218	1.300	1.394	1.467	1.473	1.469	1.429	1.356
0.075	1.187	1.215	1.286	1.368	1.433	1.440	1.436	1.402	1.329
0.100	1.179	1.203	1.265	1.337	1.396	1.404	1.400	1.374	1.307
0.125	1.164	1.184	1.238	1.301	1.356	1.366	1.363	1.343	1.287
0.150	1.142	1.159	1.205	1.260	1.313	1.326	1.324	1.310	1.266
0.175	1.115	1.129	1.169	1.217	1.268	1.283	1.284	1.275	1.242
0.200	1.083	1.096	1.129	1.172	1.221	1.239	1.241	1.236	1.213
0.225	1.048	1.059	1.087	1.125	1.172	1.192	1.198	1.196	1.180
0.250	1.009	1.018	1.042	1.076	1.121	1.143	1.152	1.154	1.142
0.275	0.966	0.974	0.995	1.025	1.068	1.093	1.106	1.110	1.101
0.300	0.920	0.927	0.945	0.973	1.015	1.041	1.058	1.064	1.058
0.325	0.871	0.876	0.893	0.919	0.960	0.987	1.009	1.017	1.013
0.350	0.817	0.823	0.839	0.864	0.904	0.932	0.960	0.969	0.966
0.375	0.762	0.767	0.783	0.807	0.847	0.876	0.909	0.919	0.918
0.400	0.704	0.710	0.726	0.750	0.789	0.820	0.857	0.869	0.869
0.425	0.645	0.651	0.667	0.691	0.730	0.762	0.805	0.818	0.821
0.450	0.585	0.591	0.607	0.631	0.671	0.703	0.751	0.767	0.771
0.475	0.524	0.529	0.545	0.570	0.610	0.645	0.696	0.715	0.722
0.500	0.461	0.467	0.483	0.508	0.550	0.586	0.640	0.662	0.674
0.525	0.399	0.405	0.421	0.446	0.489	0.527	0.584	0.609	0.625
0.550	0.341	0.346	0.361	0.385	0.430	0.469	0.527	0.555	0.577
0.575	0.287	0.291	0.304	0.327	0.372	0.412	0.470	0.502	0.530
0.600	0.239	0.242	0.252	0.272	0.316	0.356	0.414	0.448	0.482
0.625	0.195	0.197	0.205	0.221	0.263	0.303	0.358	0.395	0.435
0.650	0.155	0.157	0.162	0.176	0.214	0.252	0.304	0.342	0.388
0.675	0.120	0.121	0.125	0.136	0.169	0.204	0.252	0.291	0.341
0.700	0.090	0.090	0.093	0.101	0.130	0.160	0.204	0.242	0.296
0.725	0.065	0.065	0.066	0.072	0.095	0.120	0.160	0.196	0.252
0.750	0.045	0.044	0.045	0.049	0.066	0.086	0.120	0.154	0.209
0.775	0.029	0.029	0.028	0.030	0.043	0.058	0.087	0.117	0.169
0.800	0.018	0.017	0.017	0.018	0.026	0.037	0.060	0.086	0.131
0.825	0.010	0.010	0.009	0.010	0.015	0.022	0.040	0.061	0.098
0.850	0.005	0.005	0.005	0.005	0.008	0.012	0.025	0.041	0.071
0.875	0.003	0.002	0.002	0.002	0.003	0.006	0.014	0.025	0.048
0.900	0.001	0.001	0.001	0.001	0.001	0.003	0.007	0.014	0.030
0.925	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.007	0.016
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.007
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.11. $(r_0/T_0)\, D_{-\infty}^{SiO_2}(z/r_0)$ for electrons. Units: dimensionless.

z/r_0	T_0=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	1.833	1.880	1.992	2.102	2.130	2.069	1.993	1.855	1.704
0.025	1.893	1.928	2.012	2.097	2.121	2.076	2.011	1.894	1.757
0.050	1.923	1.949	2.013	2.077	2.096	2.060	2.001	1.905	1.779
0.075	1.929	1.949	1.996	2.044	2.056	2.026	1.970	1.890	1.775
0.100	1.915	1.930	1.965	2.000	2.006	1.978	1.922	1.857	1.752
0.125	1.886	1.897	1.923	1.948	1.948	1.920	1.863	1.810	1.713
0.150	1.846	1.854	1.872	1.889	1.884	1.856	1.798	1.754	1.666
0.175	1.799	1.803	1.815	1.825	1.818	1.791	1.732	1.695	1.614
0.200	1.747	1.749	1.754	1.758	1.750	1.727	1.668	1.635	1.561
0.225	1.690	1.690	1.690	1.689	1.681	1.663	1.606	1.575	1.508
0.250	1.628	1.626	1.621	1.616	1.611	1.598	1.545	1.515	1.455
0.275	1.562	1.558	1.549	1.541	1.539	1.533	1.484	1.455	1.401
0.300	1.490	1.485	1.474	1.464	1.466	1.465	1.424	1.396	1.347
0.325	1.411	1.406	1.394	1.385	1.391	1.395	1.363	1.337	1.293
0.350	1.327	1.322	1.311	1.304	1.313	1.323	1.301	1.278	1.238
0.375	1.237	1.233	1.225	1.222	1.234	1.248	1.237	1.219	1.183
0.400	1.144	1.141	1.137	1.137	1.154	1.171	1.172	1.160	1.127
0.425	1.047	1.046	1.046	1.050	1.071	1.092	1.106	1.099	1.070
0.450	0.948	0.949	0.952	0.961	0.987	1.012	1.037	1.036	1.012
0.475	0.847	0.849	0.856	0.870	0.901	0.930	0.966	0.971	0.953
0.500	0.743	0.747	0.758	0.777	0.814	0.847	0.892	0.903	0.892
0.525	0.642	0.647	0.661	0.684	0.727	0.764	0.817	0.833	0.830
0.550	0.547	0.552	0.567	0.592	0.640	0.682	0.741	0.762	0.768
0.575	0.461	0.465	0.479	0.504	0.554	0.601	0.664	0.691	0.705
0.600	0.384	0.387	0.398	0.420	0.472	0.522	0.587	0.619	0.643
0.625	0.316	0.317	0.324	0.342	0.394	0.445	0.511	0.548	0.582
0.650	0.255	0.255	0.258	0.272	0.321	0.372	0.436	0.478	0.523
0.675	0.201	0.200	0.200	0.210	0.255	0.304	0.364	0.411	0.465
0.700	0.153	0.151	0.149	0.157	0.196	0.240	0.297	0.346	0.408
0.725	0.109	0.108	0.107	0.113	0.145	0.182	0.234	0.285	0.353
0.750	0.072	0.072	0.072	0.078	0.103	0.132	0.179	0.228	0.299
0.775	0.044	0.044	0.045	0.050	0.069	0.090	0.132	0.177	0.245
0.800	0.025	0.026	0.027	0.031	0.043	0.059	0.094	0.131	0.193
0.825	0.014	0.014	0.015	0.017	0.026	0.037	0.064	0.094	0.148
0.850	0.007	0.007	0.008	0.009	0.014	0.021	0.041	0.064	0.108
0.875	0.003	0.003	0.003	0.004	0.007	0.011	0.024	0.040	0.075
0.900	0.001	0.001	0.001	0.002	0.003	0.005	0.013	0.023	0.048
0.925	0.000	0.000	0.000	0.000	0.001	0.002	0.006	0.011	0.027
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.004	0.012
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.12. $(r_o/T_o)\, D_-^{SiO_2}(z/r_o)$ for electrons. Units: dimensionless.

z/r_o	T_o=0.1	0.2	0.5	1.0	2.0	3.0	5.0	7.0	10.0
0.0	1.195	1.237	1.342	1.464	1.566	1.583	1.595	1.564	1.525
0.025	1.221	1.258	1.350	1.456	1.542	1.556	1.566	1.537	1.493
0.050	1.234	1.266	1.346	1.439	1.513	1.524	1.533	1.508	1.462
0.075	1.236	1.263	1.333	1.413	1.478	1.489	1.497	1.476	1.432
0.100	1.228	1.251	1.311	1.380	1.439	1.451	1.458	1.441	1.401
0.125	1.212	1.232	1.282	1.342	1.396	1.410	1.415	1.405	1.368
0.150	1.189	1.206	1.248	1.300	1.351	1.366	1.371	1.365	1.334
0.175	1.161	1.175	1.210	1.254	1.303	1.320	1.325	1.323	1.298
0.200	1.129	1.140	1.169	1.207	1.253	1.272	1.278	1.279	1.259
0.225	1.092	1.101	1.125	1.158	1.202	1.223	1.230	1.233	1.218
0.250	1.052	1.059	1.079	1.108	1.149	1.172	1.181	1.185	1.175
0.275	1.007	1.013	1.030	1.055	1.095	1.119	1.131	1.137	1.130
0.300	0.959	0.964	0.979	1.001	1.040	1.066	1.081	1.088	1.085
0.325	0.907	0.912	0.925	0.946	0.984	1.011	1.031	1.039	1.038
0.350	0.852	0.856	0.869	0.890	0.927	0.955	0.981	0.990	0.991
0.375	0.794	0.798	0.811	0.832	0.869	0.898	0.930	0.940	0.943
0.400	0.734	0.738	0.752	0.773	0.811	0.841	0.878	0.891	0.895
0.425	0.673	0.677	0.691	0.713	0.751	0.782	0.825	0.840	0.846
0.450	0.610	0.615	0.629	0.651	0.690	0.723	0.771	0.789	0.796
0.475	0.546	0.551	0.566	0.588	0.628	0.664	0.716	0.737	0.747
0.500	0.481	0.486	0.501	0.524	0.567	0.603	0.659	0.683	0.697
0.525	0.416	0.422	0.437	0.461	0.504	0.543	0.601	0.628	0.647
0.550	0.355	0.360	0.374	0.398	0.443	0.484	0.543	0.573	0.597
0.575	0.300	0.304	0.316	0.338	0.383	0.425	0.484	0.517	0.547
0.600	0.249	0.252	0.262	0.281	0.325	0.368	0.426	0.462	0.498
0.625	0.204	0.205	0.212	0.229	0.271	0.313	0.369	0.407	0.449
0.650	0.162	0.163	0.168	0.182	0.221	0.260	0.314	0.353	0.401
0.675	0.126	0.126	0.129	0.141	0.175	0.211	0.261	0.301	0.354
0.700	0.094	0.094	0.096	0.105	0.134	0.166	0.212	0.252	0.308
0.725	0.068	0.068	0.069	0.075	0.099	0.126	0.167	0.206	0.264
0.750	0.047	0.046	0.047	0.051	0.069	0.091	0.127	0.163	0.221
0.775	0.031	0.030	0.030	0.032	0.046	0.062	0.093	0.126	0.180
0.800	0.019	0.018	0.018	0.019	0.028	0.041	0.065	0.093	0.141
0.825	0.011	0.010	0.010	0.011	0.017	0.025	0.044	0.066	0.107
0.850	0.006	0.005	0.005	0.005	0.009	0.014	0.028	0.045	0.077
0.875	0.003	0.002	0.002	0.002	0.004	0.007	0.016	0.028	0.053
0.900	0.001	0.001	0.001	0.001	0.002	0.003	0.008	0.016	0.033
0.925	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.008	0.018
0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.008
0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table B.13. $(1/T_0)\, D_{\infty}^{Al}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T_0 ($g/cm^2/MeV$)	T_0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	5.74E-02	2.97E-02	1.71E-02	8.39E-03	3.55E-03	2.20E-03	1.63E-03	1.39E-03	1.61E-03	1.90E-03
1.5E-03	5.89E-02	3.07E-02	1.78E-02	8.75E-03	3.71E-03	2.27E-03	1.69E-03	1.43E-03	1.63E-03	2.03E-03
2.0E-03	5.99E-02	3.10E-02	1.84E-02	9.04E-03	3.83E-03	2.33E-03	1.73E-03	1.47E-03	1.64E-03	2.08E-03
3.0E-03	6.14E-02	3.40E-02	1.93E-02	9.49E-03	4.05E-03	2.43E-03	1.80E-03	1.53E-03	1.66E-03	2.09E-03
4.0E-03	6.25E-02	3.76E-02	2.01E-02	9.96E-03	4.21E-03	2.51E-03	1.85E-03	1.58E-03	1.72E-03	2.10E-03
5.0E-03	6.45E-02	4.08E-02	2.08E-02	1.02E-02	4.36E-03	2.58E-03	1.89E-03	1.62E-03	1.81E-03	2.11E-03
6.0E-03	6.70E-02	4.34E-02	2.13E-02	1.05E-02	4.47E-03	2.64E-03	1.93E-03	1.66E-03	1.90E-03	2.12E-03
8.0E-03	7.12E-02	4.73E-02	2.23E-02	1.09E-02	4.67E-03	2.74E-03	2.00E-03	1.73E-03	2.04E-03	2.18E-03
1.0E-02	7.32E-02	4.95E-02	2.28E-02	1.13E-02	4.81E-03	2.83E-03	2.05E-03	1.78E-03	2.12E-03	2.27E-03
1.5E-02	6.95E-02	5.04E-02	2.37E-02	1.17E-02	5.05E-03	3.00E-03	2.15E-03	1.90E-03	2.22E-03	2.57E-03
2.0E-02	6.05E-02	4.78E-02	2.42E-02	1.20E-02	5.20E-03	3.12E-03	2.22E-03	2.00E-03	2.31E-03	2.85E-03
3.0E-02	4.44E-02	3.94E-02	2.44E-02	1.24E-02	5.38E-03	3.26E-03	2.32E-03	2.17E-03	2.53E-03	3.28E-03
4.0E-02	3.36E-02	3.14E-02	2.41E-02	1.28E-02	5.46E-03	3.33E-03	2.39E-03	2.30E-03	2.74E-03	3.61E-03
5.0E-02	2.64E-02	2.53E-02	2.29E-02	1.29E-02	5.50E-03	3.36E-03	2.44E-03	2.39E-03	2.92E-03	3.86E-03
6.0E-02	2.15E-02	2.07E-02	2.10E-02	1.27E-02	5.51E-03	3.38E-03	2.47E-03	2.47E-03	3.07E-03	4.08E-03
8.0E-02	1.54E-02	1.47E-02	1.60E-02	1.15E-02	5.49E-03	3.39E-03	2.53E-03	2.59E-03	3.28E-03	4.42E-03
1.0E-01	1.20E-02	1.11E-02	1.17E-02	9.68E-03	5.39E-03	3.41E-03	2.57E-03	2.68E-03	3.40E-03	4.68E-03
1.5E-01	7.44E-03	6.62E-03	5.97E-03	6.00E-03	4.58E-03	3.24E-03	2.59E-03	2.79E-03	3.55E-03	5.04E-03
2.0E-01	5.29E-03	4.64E-03	3.87E-03	3.90E-03	3.45E-03	2.80E-03	2.44E-03	2.77E-03	3.64E-03	5.15E-03
3.0E-01	3.30E-03	2.87E-03	2.33E-03	2.04E-03	1.91E-03	1.85E-03	1.89E-03	2.54E-03	3.54E-03	4.98E-03
4.0E-01	2.39E-03	2.10E-03	1.70E-03	1.35E-03	1.24E-03	1.27E-03	1.45E-03	2.20E-03	3.20E-03	4.56E-03
5.0E-01	1.87E-03	1.66E-03	1.35E-03	1.05E-03	9.26E-04	9.51E-04	1.18E-03	1.93E-03	2.86E-03	4.05E-03
6.0E-01	1.53E-03	1.38E-03	1.13E-03	8.85E-04	7.53E-04	7.69E-04	1.01E-03	1.75E-03	2.60E-03	3.60E-03
8.0E-01	1.11E-03	1.03E-03	8.58E-04	7.03E-04	5.69E-04	6.13E-04	8.29E-04	1.51E-03	2.19E-03	2.93E-03
1.0E+00	8.45E-04	8.21E-04	6.96E-04	5.92E-04	4.74E-04	5.44E-04	7.49E-04	1.36E-03	1.92E-03	2.43E-03
1.5E+00	5.06E-04	5.50E-04	4.77E-04	4.17E-04	3.57E-04	4.22E-04	6.26E-04	1.07E-03	1.43E-03	1.52E-03
2.0E+00	3.35E-04	4.07E-04	3.62E-04	3.20E-04	2.95E-04	3.51E-04	5.37E-04	8.80E-04	1.09E-03	
3.0E+00	1.77E-04	2.57E-04	2.42E-04	2.16E-04	2.20E-04	2.73E-04	4.13E-04	6.25E-04	6.31E-04	
4.0E+00	1.10E-04	1.83E-04	1.79E-04	1.64E-04	1.77E-04	2.27E-04	3.30E-04	4.49E-04		
5.0E+00	7.58E-05	1.40E-04	1.42E-04	1.32E-04	1.49E-04	1.94E-04	2.72E-04	3.19E-04		
6.0E+00	5.55E-05	1.11E-04	1.17E-04	1.11E-04	1.29E-04	1.69E-04	2.30E-04			
8.0E+00	3.22E-05	7.85E-05	8.55E-05	8.38E-05	1.03E-04	1.30E-04	1.65E-04			
1.0E+01	1.98E-05	5.98E-05	6.68E-05	6.76E-05	8.59E-05	1.05E-04	1.19E-04			
1.5E+01	6.67E-06	3.53E-05	4.23E-05	4.53E-05	5.96E-05	6.54E-05	4.74E-05			
2.0E+01	2.64E-06	2.28E-05	2.99E-05	3.36E-05	4.33E-05	4.04E-05				
3.0E+01	5.92E-07	1.07E-05	1.73E-05	2.11E-05	2.35E-05	1.37E-05				
4.0E+01	2.01E-07	5.97E-06	1.10E-05	1.43E-05	1.30E-05					
5.0E+01	9.35E-08	3.88E-06	7.50E-06	1.01E-05	7.22E-06					
6.0E+01	5.44E-08	2.74E-06	5.29E-06	7.26E-06	4.07E-06					
8.0E+01	3.00E-08	1.43E-06	2.86E-06	3.92E-06						
1.0E+02	1.66E-08	6.75E-07	1.67E-06	2.20E-06						
1.5E+02	3.75E-09	8.77E-08	5.44E-07	5.81E-07						
2.0E+02	8.53E-10	4.34E-08	2.15E-07							
3.0E+02	4.35E-11	2.34E-08								
4.0E+02	2.23E-12	1.48E-09								
5.0E+02	1.15E-13	9.34E-11								
6.0E+02	5.87E-15									
8.0E+02	1.54E-17									
1.0E+03	4.05E-20									
1.5E+03	1.43E-26									

Table B.14. $(1/T_0)\, D_-^{Al}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T_0 ($g/cm^2/MeV$)	T_0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	7.67E-03	3.64E-03	1.97E-03	1.16E-03	5.29E-04	4.09E-04	3.00E-04	1.33E-04	9.75E-05	2.57E-04
1.5E-03	9.92E-03	5.23E-03	2.62E-03	1.50E-03	6.71E-04	5.00E-04	3.60E-04	1.73E-04	1.42E-04	4.14E-04
2.0E-03	1.19E-02	6.53E-03	3.18E-03	1.80E-03	7.97E-04	5.66E-04	4.07E-04	2.08E-04	1.84E-04	5.34E-04
3.0E-03	1.53E-02	8.61E-03	4.15E-03	2.30E-03	1.01E-03	6.65E-04	4.75E-04	2.68E-04	2.61E-04	6.72E-04
4.0E-03	1.81E-02	1.03E-02	5.00E-03	2.73E-03	1.18E-03	7.43E-04	5.28E-04	3.21E-04	3.41E-04	7.30E-04
5.0E-03	2.16E-02	1.17E-02	5.75E-03	3.07E-03	1.32E-03	8.08E-04	5.69E-04	3.69E-04	4.28E-04	7.54E-04
6.0E-03	2.52E-02	1.30E-02	6.45E-03	3.38E-03	1.45E-03	8.67E-04	6.06E-04	4.15E-04	5.15E-04	7.70E-04
8.0E-03	3.20E-02	1.53E-02	7.65E-03	3.89E-03	1.66E-03	9.74E-04	6.68E-04	4.99E-04	6.69E-04	8.13E-04
1.0E-02	3.76E-02	1.73E-02	8.64E-03	4.30E-03	1.82E-03	1.07E-03	7.22E-04	5.78E-04	7.82E-04	8.94E-04
1.5E-02	4.41E-02	2.11E-02	1.04E-02	5.03E-03	2.13E-03	1.26E-03	8.39E-04	7.48E-04	9.60E-04	1.22E-03
2.0E-02	4.37E-02	2.38E-02	1.14E-02	5.52E-03	2.34E-03	1.41E-03	9.42E-04	8.85E-04	1.09E-03	1.58E-03
3.0E-02	3.71E-02	2.57E-02	1.28E-02	6.21E-03	2.62E-03	1.63E-03	1.12E-03	1.10E-03	1.35E-03	2.12E-03
4.0E-02	3.03E-02	2.48E-02	1.38E-02	6.77E-03	2.80E-03	1.75E-03	1.26E-03	1.26E-03	1.60E-03	2.49E-03
5.0E-02	2.50E-02	2.25E-02	1.41E-02	7.18E-03	2.95E-03	1.85E-03	1.36E-03	1.39E-03	1.81E-03	2.80E-03
6.0E-02	2.10E-02	1.97E-02	1.38E-02	7.39E-03	3.05E-03	1.92E-03	1.44E-03	1.50E-03	1.99E-03	3.07E-03
8.0E-02	1.54E-02	1.42E-02	1.19E-02	7.27E-03	3.23E-03	2.04E-03	1.55E-03	1.69E-03	2.28E-03	3.54E-03
1.0E-01	1.20E-02	1.04E-02	9.57E-03	6.67E-03	3.33E-03	2.13E-03	1.64E-03	1.83E-03	2.49E-03	3.88E-03
1.5E-01	7.44E-03	5.93E-03	5.67E-03	4.86E-03	3.15E-03	2.19E-03	1.78E-03	2.06E-03	2.80E-03	4.32E-03
2.0E-01	5.29E-03	4.24E-03	3.84E-03	3.47E-03	2.60E-03	2.02E-03	1.77E-03	2.15E-03	2.97E-03	4.50E-03
3.0E-01	3.29E-03	2.81E-03	2.29E-03	1.96E-03	1.64E-03	1.50E-03	1.49E-03	2.09E-03	3.02E-03	4.49E-03
4.0E-01	2.37E-03	2.10E-03	1.65E-03	1.33E-03	1.12E-03	1.10E-03	1.21E-03	1.87E-03	2.80E-03	4.14E-03
5.0E-01	1.85E-03	1.66E-03	1.32E-03	1.03E-03	8.54E-04	8.33E-04	9.90E-04	1.66E-03	2.53E-03	3.71E-03
6.0E-01	1.52E-03	1.38E-03	1.10E-03	8.61E-04	6.91E-04	6.70E-04	8.48E-04	1.49E-03	2.29E-03	3.31E-03
8.0E-01	1.10E-03	1.03E-03	8.45E-04	6.69E-04	5.12E-04	5.18E-04	6.88E-04	1.28E-03	1.95E-03	2.71E-03
1.0E+00	8.45E-04	8.21E-04	6.84E-04	5.54E-04	4.18E-04	4.49E-04	6.16E-04	1.15E-03	1.70E-03	2.26E-03
1.5E+00	5.06E-04	5.36E-04	4.59E-04	3.83E-04	3.04E-04	3.42E-04	5.05E-04	9.16E-04	1.27E-03	1.49E-03
2.0E+00	3.35E-04	3.92E-04	3.42E-04	2.90E-04	2.46E-04	2.82E-04	4.29E-04	7.52E-04	9.85E-04	
3.0E+00	1.76E-04	2.49E-04	2.24E-04	1.93E-04	1.79E-04	2.16E-04	3.32E-04	5.34E-04	6.09E-04	
4.0E+00	1.09E-04	1.78E-04	1.65E-04	1.43E-04	1.41E-04	1.76E-04	2.67E-04	3.90E-04		
5.0E+00	7.52E-05	1.36E-04	1.30E-04	1.14E-04	1.18E-04	1.51E-04	2.21E-04	2.87E-04		
6.0E+00	5.50E-05	1.09E-04	1.07E-04	9.40E-05	1.02E-04	1.31E-04	1.84E-04			
8.0E+00	3.21E-05	7.65E-05	7.83E-05	7.00E-05	7.97E-05	1.03E-04	1.32E-04			
1.0E+01	1.98E-05	5.80E-05	6.09E-05	5.56E-05	6.57E-05	8.22E-05	9.56E-05			
1.5E+01	6.67E-06	3.39E-05	3.76E-05	3.63E-05	4.45E-05	4.94E-05	4.41E-05			
2.0E+01	2.64E-06	2.17E-05	2.59E-05	2.65E-05	3.20E-05	3.06E-05				
3.0E+01	5.92E-07	1.01E-05	1.45E-05	1.64E-05	1.73E-05	1.24E-05				
4.0E+01	2.01E-07	5.76E-06	9.20E-06	1.10E-05	9.70E-06					
5.0E+01	9.35E-08	3.77E-06	6.25E-06	7.74E-06	5.59E-06					
6.0E+01	5.44E-08	2.68E-06	4.43E-06	5.56E-06	3.27E-06					
8.0E+01	3.00E-08	1.37E-06	2.44E-06	3.01E-06						
1.0E+02	1.66E-08	6.27E-07	1.43E-06	1.69E-06						
1.5E+02	3.75E-09	8.37E-08	4.43E-07	4.50E-07						
2.0E+02	8.53E-10	4.30E-08	1.55E-07							
3.0E+02	4.35E-11	2.34E-08								
4.0E+02	2.23E-12	1.48E-09								
5.0E+02	1.15E-13	9.34E-11								
6.0E+02	5.87E-15									
8.0E+02	1.54E-17									
1.0E+03	4.05E-20									
1.5E+03	1.43E-26									

Table B.15. $(1/T_0)\, D_{\infty}^{H_2O}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T_0 ($g/cm^2/MeV$)	T_0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	1.33E-02	6.66E-03	3.74E-03	1.80E-03	8.47E-04	6.59E-04	8.09E-04	1.11E-03	1.50E-03	1.85E-03
1.5E-03	1.37E-02	6.92E-03	3.88E-03	1.88E-03	8.78E-04	6.76E-04	8.25E-04	1.12E-03	1.53E-03	1.95E-03
2.0E-03	1.40E-02	6.97E-03	4.02E-03	1.95E-03	9.06E-04	6.90E-04	8.37E-04	1.14E-03	1.54E-03	2.00E-03
3.0E-03	1.44E-02	7.69E-03	4.24E-03	2.05E-03	9.50E-04	7.13E-04	8.56E-04	1.18E-03	1.56E-03	2.04E-03
4.0E-03	1.48E-02	8.54E-03	4.43E-03	2.13E-03	9.89E-04	7.32E-04	8.71E-04	1.21E-03	1.62E-03	2.06E-03
5.0E-03	1.53E-02	9.34E-03	4.58E-03	2.21E-03	1.02E-03	7.50E-04	8.84E-04	1.24E-03	1.71E-03	2.08E-03
6.0E-03	1.59E-02	9.97E-03	4.71E-03	2.27E-03	1.04E-03	7.64E-04	8.96E-04	1.27E-03	1.79E-03	2.11E-03
8.0E-03	1.70E-02	1.09E-02	4.90E-03	2.36E-03	1.08E-03	7.90E-04	9.16E-04	1.32E-03	1.93E-03	2.18E-03
1.0E-02	1.75E-02	1.15E-02	5.05E-03	2.43E-03	1.10E-03	8.11E-04	9.33E-04	1.37E-03	2.00E-03	2.27E-03
1.5E-02	1.66E-02	1.17E-02	5.24E-03	2.53E-03	1.16E-03	8.55E-04	9.70E-04	1.47E-03	2.08E-03	2.53E-03
2.0E-02	1.44E-02	1.10E-02	5.32E-03	2.58E-03	1.20E-03	8.89E-04	1.00E-03	1.55E-03	2.16E-03	2.78E-03
3.0E-02	1.04E-02	8.90E-03	5.35E-03	2.66E-03	1.24E-03	9.35E-04	1.05E-03	1.69E-03	2.38E-03	3.21E-03
4.0E-02	7.77E-03	7.01E-03	5.28E-03	2.74E-03	1.26E-03	9.61E-04	1.09E-03	1.80E-03	2.60E-03	3.57E-03
5.0E-02	6.03E-03	5.55E-03	5.00E-03	2.76E-03	1.27E-03	9.76E-04	1.13E-03	1.89E-03	2.76E-03	3.85E-03
6.0E-02	4.85E-03	4.49E-03	4.55E-03	2.72E-03	1.27E-03	9.80E-04	1.15E-03	1.96E-03	2.90E-03	4.07E-03
8.0E-02	3.42E-03	3.11E-03	3.41E-03	2.43E-03	1.25E-03	9.90E-04	1.19E-03	2.08E-03	3.11E-03	4.41E-03
1.0E-01	2.61E-03	2.31E-03	2.44E-03	2.03E-03	1.22E-03	1.00E-03	1.21E-03	2.17E-03	3.25E-03	4.66E-03
1.5E-01	1.57E-03	1.33E-03	1.20E-03	1.22E-03	1.05E-03	9.64E-04	1.24E-03	2.28E-03	3.45E-03	5.05E-03
2.0E-01	1.10E-03	9.08E-04	7.46E-04	7.83E-04	8.18E-04	8.73E-04	1.20E-03	2.28E-03	3.52E-03	5.19E-03
3.0E-01	6.70E-04	5.47E-04	4.31E-04	4.11E-04	5.02E-04	6.65E-04	1.06E-03	2.17E-03	3.47E-03	5.04E-03
4.0E-01	4.78E-04	3.93E-04	3.12E-04	2.75E-04	3.56E-04	5.28E-04	9.24E-04	2.01E-03	3.24E-03	4.63E-03
5.0E-01	3.70E-04	3.09E-04	2.49E-04	2.16E-04	2.87E-04	4.47E-04	8.28E-04	1.86E-03	2.95E-03	4.18E-03
6.0E-01	2.99E-04	2.54E-04	2.11E-04	1.84E-04	2.48E-04	3.98E-04	7.59E-04	1.73E-03	2.70E-03	3.76E-03
8.0E-01	2.13E-04	1.88E-04	1.63E-04	1.50E-04	2.05E-04	3.49E-04	6.74E-04	1.52E-03	2.30E-03	3.05E-03
1.0E+00	1.62E-04	1.49E-04	1.33E-04	1.30E-04	1.82E-04	3.21E-04	6.24E-04	1.36E-03	2.02E-03	2.50E-03
1.5E+00	9.51E-05	9.88E-05	9.13E-05	9.68E-05	1.51E-04	2.71E-04	5.38E-04	1.09E-03	1.50E-03	1.63E-03
2.0E+00	6.26E-05	7.28E-05	6.96E-05	7.80E-05	1.33E-04	2.37E-04	4.72E-04	9.00E-04	1.15E-03	
3.0E+00	3.26E-05	4.58E-05	4.74E-05	5.69E-05	1.08E-04	1.95E-04	3.70E-04	6.40E-04	6.86E-04	
4.0E+00	2.01E-05	3.25E-05	3.60E-05	4.54E-05	9.32E-05	1.68E-04	3.00E-04	4.63E-04		
5.0E+00	1.38E-05	2.47E-05	2.91E-05	3.84E-05	8.22E-05	1.46E-04	2.49E-04	3.36E-04		
6.0E+00	1.01E-05	1.98E-05	2.43E-05	3.35E-05	7.39E-05	1.27E-04	2.11E-04			
8.0E+00	5.82E-06	1.40E-05	1.83E-05	2.72E-05	6.17E-05	1.00E-04	1.53E-04			
1.0E+01	3.56E-06	1.06E-05	1.46E-05	2.30E-05	5.29E-05	8.16E-05	1.11E-04			
1.5E+01	1.20E-06	6.32E-06	9.57E-06	1.69E-05	3.80E-05	5.22E-05	4.74E-05			
2.0E+01	4.71E-07	4.09E-06	6.97E-06	1.33E-05	2.81E-05	3.33E-05				
3.0E+01	1.05E-07	1.94E-06	4.26E-06	8.82E-06	1.56E-05	1.22E-05				
4.0E+01	3.55E-08	1.09E-06	2.86E-06	6.16E-06	8.85E-06					
5.0E+01	1.65E-08	7.14E-07	2.02E-06	4.42E-06	5.09E-06					
6.0E+01	9.59E-09	5.05E-07	1.48E-06	3.23E-06	2.97E-06					
8.0E+01	5.28E-09	2.67E-07	8.42E-07	1.80E-06						
1.0E+02	2.90E-09	1.28E-07	5.10E-07	1.05E-06						
1.5E+02	6.54E-10	1.72E-08	1.70E-07	3.19E-07						
2.0E+02	1.47E-10	8.49E-09	6.63E-08							
3.0E+02	7.42E-12	4.41E-09								
4.0E+02	3.75E-13	2.73E-10								
5.0E+02	1.89E-14	1.69E-11								
6.0E+02	9.59E-16									
8.0E+02	2.44E-18									
1.0E+03	6.23E-21									
1.5E+03	2.05E-27									

Table B.16. $(1/T_0)\, D_-^{H_2O}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T_0 ($g/cm^2/MeV$)	T_0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	1.87E-03	8.67E-04	4.69E-04	2.74E-04	1.24E-04	9.62E-05	7.52E-05	5.12E-05	6.36E-05	2.43E-04
1.5E-03	2.39E-03	1.25E-03	6.24E-04	3.53E-04	1.56E-04	1.18E-04	9.27E-05	6.99E-05	9.51E-05	3.85E-04
2.0E-03	2.86E-03	1.56E-03	7.53E-04	4.19E-04	1.83E-04	1.34E-04	1.07E-04	8.82E-05	1.27E-04	4.92E-04
3.0E-03	3.67E-03	2.04E-03	9.75E-04	5.30E-04	2.30E-04	1.59E-04	1.30E-04	1.24E-04	1.97E-04	6.17E-04
4.0E-03	4.32E-03	2.42E-03	1.17E-03	6.21E-04	2.69E-04	1.77E-04	1.48E-04	1.59E-04	2.76E-04	6.79E-04
5.0E-03	5.13E-03	2.76E-03	1.33E-03	6.98E-04	3.01E-04	1.95E-04	1.64E-04	1.93E-04	3.62E-04	7.10E-04
6.0E-03	5.99E-03	3.05E-03	1.49E-03	7.65E-04	3.29E-04	2.10E-04	1.78E-04	2.27E-04	4.47E-04	7.32E-04
8.0E-03	7.63E-03	3.56E-03	1.76E-03	8.75E-04	3.76E-04	2.38E-04	2.05E-04	2.92E-04	6.00E-04	7.88E-04
1.0E-02	8.94E-03	4.00E-03	1.97E-03	9.59E-04	4.14E-04	2.64E-04	2.29E-04	3.55E-04	7.09E-04	8.73E-04
1.5E-02	1.05E-02	4.88E-03	2.35E-03	1.12E-03	4.84E-04	3.19E-04	2.84E-04	4.96E-04	8.72E-04	1.19E-03
2.0E-02	1.03E-02	5.45E-03	2.56E-03	1.21E-03	5.33E-04	3.66E-04	3.37E-04	6.15E-04	9.94E-04	1.54E-03
3.0E-02	8.69E-03	5.83E-03	2.83E-03	1.35E-03	5.98E-04	4.35E-04	4.35E-04	8.02E-04	1.25E-03	2.07E-03
4.0E-02	6.99E-03	5.56E-03	3.02E-03	1.46E-03	6.41E-04	4.84E-04	5.17E-04	9.48E-04	1.49E-03	2.45E-03
5.0E-02	5.70E-03	4.98E-03	3.07E-03	1.54E-03	6.73E-04	5.17E-04	5.81E-04	1.07E-03	1.72E-03	2.76E-03
6.0E-02	4.72E-03	4.28E-03	2.97E-03	1.58E-03	6.99E-04	5.45E-04	6.32E-04	1.17E-03	1.90E-03	3.04E-03
8.0E-02	3.42E-03	3.01E-03	2.50E-03	1.53E-03	7.36E-04	5.86E-04	7.10E-04	1.34E-03	2.19E-03	3.52E-03
1.0E-01	2.61E-03	2.15E-03	1.97E-03	1.38E-03	7.57E-04	6.21E-04	7.68E-04	1.49E-03	2.41E-03	3.88E-03
1.5E-01	1.57E-03	1.17E-03	1.11E-03	9.87E-04	7.27E-04	6.64E-04	8.64E-04	1.74E-03	2.77E-03	4.36E-03
2.0E-01	1.10E-03	8.22E-04	7.35E-04	6.93E-04	6.20E-04	6.48E-04	9.04E-04	1.86E-03	2.96E-03	4.59E-03
3.0E-01	6.67E-04	5.34E-04	4.29E-04	3.90E-04	4.26E-04	5.43E-04	8.81E-04	1.85E-03	3.05E-03	4.62E-03
4.0E-01	4.72E-04	3.93E-04	3.06E-04	2.66E-04	3.18E-04	4.51E-04	7.91E-04	1.74E-03	2.89E-03	4.29E-03
5.0E-01	3.65E-04	3.09E-04	2.44E-04	2.09E-04	2.59E-04	3.86E-04	7.07E-04	1.62E-03	2.66E-03	3.86E-03
6.0E-01	2.96E-04	2.54E-04	2.05E-04	1.78E-04	2.23E-04	3.42E-04	6.50E-04	1.50E-03	2.43E-03	3.45E-03
8.0E-01	2.12E-04	1.88E-04	1.57E-04	1.42E-04	1.80E-04	2.95E-04	5.80E-04	1.33E-03	2.09E-03	2.83E-03
1.0E+00	1.62E-04	1.49E-04	1.28E-04	1.20E-04	1.57E-04	2.69E-04	5.35E-04	1.20E-03	1.83E-03	2.35E-03
1.5E+00	9.51E-05	9.61E-05	8.66E-05	8.78E-05	1.28E-04	2.26E-04	4.54E-04	9.61E-04	1.37E-03	1.58E-03
2.0E+00	6.26E-05	7.00E-05	6.52E-05	6.94E-05	1.11E-04	1.99E-04	3.96E-04	7.93E-04	1.06E-03	
3.0E+00	3.25E-05	4.42E-05	4.36E-05	4.99E-05	9.00E-05	1.62E-04	3.12E-04	5.66E-04	6.66E-04	
4.0E+00	1.99E-05	3.16E-05	3.28E-05	3.97E-05	7.67E-05	1.37E-04	2.54E-04	4.15E-04		
5.0E+00	1.37E-05	2.42E-05	2.65E-05	3.33E-05	6.74E-05	1.20E-04	2.12E-04	3.09E-04		
6.0E+00	1.00E-05	1.94E-05	2.23E-05	2.89E-05	6.04E-05	1.05E-04	1.79E-04			
8.0E+00	5.79E-06	1.36E-05	1.67E-05	2.30E-05	5.01E-05	8.39E-05	1.30E-04			
1.0E+01	3.55E-06	1.03E-05	1.34E-05	1.93E-05	4.28E-05	6.83E-05	9.46E-05			
1.5E+01	1.19E-06	6.06E-06	8.61E-06	1.38E-05	3.04E-05	4.23E-05	4.48E-05			
2.0E+01	4.71E-07	3.90E-06	6.13E-06	1.07E-05	2.23E-05	2.70E-05				
3.0E+01	1.05E-07	1.85E-06	3.62E-06	7.09E-06	1.25E-05	1.15E-05				
4.0E+01	3.55E-08	1.06E-06	2.40E-06	4.98E-06	7.16E-06					
5.0E+01	1.65E-08	6.96E-07	1.69E-06	3.60E-06	4.21E-06					
6.0E+01	9.59E-09	4.95E-07	1.25E-06	2.65E-06	2.53E-06					
8.0E+01	5.28E-09	2.55E-07	7.27E-07	1.49E-06						
1.0E+02	2.90E-09	1.19E-07	4.45E-07	8.74E-07						
1.5E+02	6.54E-10	1.65E-08	1.45E-07	2.57E-07						
2.0E+02	1.47E-10	8.41E-09	5.16E-08							
3.0E+02	7.42E-12	4.41E-09								
4.0E+02	3.75E-13	2.73E-10								
5.0E+02	1.89E-14	1.69E-11								
6.0E+02	9.59E-16									
8.0E+02	2.44E-18									
1.0E+03	6.23E-21									
1.5E+03	2.05E-27									

Table B.17. $(1/T_0)\, D_{-\infty}^{Si}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T_0 ($g/cm^2/MeV$)	T_0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	7.15E-02	3.74E-02	2.17E-02	1.07E-02	4.54E-03	2.77E-03	1.99E-03	1.58E-03	1.76E-03	2.05E-03
1.5E-03	7.33E-02	3.86E-02	2.25E-02	1.12E-02	4.73E-03	2.87E-03	2.06E-03	1.63E-03	1.78E-03	2.20E-03
2.0E-03	7.46E-02	3.90E-02	2.33E-02	1.16E-02	4.90E-03	2.95E-03	2.11E-03	1.67E-03	1.79E-03	2.26E-03
3.0E-03	7.65E-02	4.27E-02	2.45E-02	1.21E-02	5.17E-03	3.07E-03	2.20E-03	1.74E-03	1.81E-03	2.28E-03
4.0E-03	7.78E-02	4.72E-02	2.55E-02	1.27E-02	5.39E-03	3.18E-03	2.26E-03	1.80E-03	1.88E-03	2.27E-03
5.0E-03	8.02E-02	5.12E-02	2.63E-02	1.31E-02	5.57E-03	3.26E-03	2.32E-03	1.86E-03	1.98E-03	2.27E-03
6.0E-03	8.36E-02	5.45E-02	2.70E-02	1.34E-02	5.71E-03	3.34E-03	2.37E-03	1.90E-03	2.07E-03	2.28E-03
8.0E-03	8.86E-02	5.92E-02	2.81E-02	1.39E-02	5.95E-03	3.48E-03	2.45E-03	1.98E-03	2.22E-03	2.34E-03
1.0E-02	9.10E-02	6.19E-02	2.89E-02	1.44E-02	6.13E-03	3.59E-03	2.50E-03	2.04E-03	2.31E-03	2.44E-03
1.5E-02	8.61E-02	6.30E-02	3.01E-02	1.49E-02	6.45E-03	3.80E-03	2.63E-03	2.17E-03	2.42E-03	2.77E-03
2.0E-02	7.53E-02	5.98E-02	3.05E-02	1.53E-02	6.65E-03	3.95E-03	2.72E-03	2.29E-03	2.53E-03	3.07E-03
3.0E-02	5.54E-02	4.95E-02	3.08E-02	1.59E-02	6.87E-03	4.14E-03	2.85E-03	2.47E-03	2.77E-03	3.54E-03
4.0E-02	4.20E-02	3.96E-02	3.05E-02	1.63E-02	6.99E-03	4.22E-03	2.93E-03	2.62E-03	2.99E-03	3.88E-03
5.0E-02	3.31E-02	3.20E-02	2.91E-02	1.64E-02	7.04E-03	4.26E-03	2.99E-03	2.73E-03	3.18E-03	4.15E-03
6.0E-02	2.70E-02	2.63E-02	2.66E-02	1.63E-02	7.06E-03	4.28E-03	3.03E-03	2.82E-03	3.34E-03	4.38E-03
8.0E-02	1.95E-02	1.87E-02	2.03E-02	1.47E-02	7.04E-03	4.31E-03	3.10E-03	2.95E-03	3.58E-03	4.76E-03
1.0E-01	1.52E-02	1.42E-02	1.49E-02	1.24E-02	6.90E-03	4.33E-03	3.15E-03	3.04E-03	3.71E-03	5.03E-03
1.5E-01	9.51E-03	8.53E-03	7.72E-03	7.74E-03	5.88E-03	4.13E-03	3.18E-03	3.15E-03	3.85E-03	5.40E-03
2.0E-01	6.77E-03	6.00E-03	5.03E-03	5.05E-03	4.43E-03	3.55E-03	2.97E-03	3.12E-03	3.95E-03	5.51E-03
3.0E-01	4.25E-03	3.74E-03	3.05E-03	2.66E-03	2.46E-03	2.33E-03	2.27E-03	2.84E-03	3.82E-03	5.32E-03
4.0E-01	3.09E-03	2.71E-03	2.23E-03	1.77E-03	1.58E-03	1.59E-03	1.71E-03	2.43E-03	3.43E-03	4.86E-03
5.0E-01	2.42E-03	2.15E-03	1.77E-03	1.37E-03	1.18E-03	1.18E-03	1.37E-03	2.12E-03	3.06E-03	4.31E-03
6.0E-01	1.98E-03	1.79E-03	1.48E-03	1.16E-03	9.58E-04	9.39E-04	1.16E-03	1.90E-03	2.76E-03	3.83E-03
8.0E-01	1.43E-03	1.34E-03	1.12E-03	9.17E-04	7.20E-04	7.41E-04	9.42E-04	1.63E-03	2.33E-03	3.12E-03
1.0E+00	1.10E-03	1.08E-03	9.12E-04	7.71E-04	5.98E-04	6.54E-04	8.48E-04	1.46E-03	2.04E-03	2.59E-03
1.5E+00	6.58E-04	7.20E-04	6.25E-04	5.43E-04	4.46E-04	5.02E-04	7.03E-04	1.15E-03	1.53E-03	1.61E-03
2.0E+00	4.37E-04	5.33E-04	4.75E-04	4.15E-04	3.66E-04	4.13E-04	6.00E-04	9.46E-04	1.16E-03	
3.0E+00	2.30E-04	3.37E-04	3.17E-04	2.80E-04	2.70E-04	3.18E-04	4.59E-04	6.71E-04	6.64E-04	
4.0E+00	1.43E-04	2.40E-04	2.36E-04	2.11E-04	2.15E-04	2.64E-04	3.65E-04	4.80E-04		
5.0E+00	9.92E-05	1.83E-04	1.86E-04	1.70E-04	1.80E-04	2.25E-04	3.02E-04	3.39E-04		
6.0E+00	7.26E-05	1.47E-04	1.53E-04	1.42E-04	1.56E-04	1.94E-04	2.53E-04			
8.0E+00	4.21E-05	1.03E-04	1.12E-04	1.07E-04	1.24E-04	1.50E-04	1.83E-04			
1.0E+01	2.58E-05	7.85E-05	8.75E-05	8.62E-05	1.03E-04	1.21E-04	1.31E-04			
1.5E+01	8.69E-06	4.65E-05	5.53E-05	5.75E-05	7.10E-05	7.48E-05	5.13E-05			
2.0E+01	3.45E-06	2.99E-05	3.90E-05	4.25E-05	5.14E-05	4.58E-05				
3.0E+01	7.74E-07	1.40E-05	2.25E-05	2.65E-05	2.78E-05	1.53E-05				
4.0E+01	2.62E-07	7.87E-06	1.44E-05	1.80E-05	1.53E-05					
5.0E+01	1.22E-07	5.11E-06	9.75E-06	1.26E-05	8.46E-06					
6.0E+01	7.12E-08	3.60E-06	6.86E-06	9.05E-06	4.73E-06					
8.0E+01	3.93E-08	1.89E-06	3.70E-06	4.87E-06						
1.0E+02	2.16E-08	8.90E-07	2.16E-06	2.73E-06						
1.5E+02	4.90E-09	1.16E-07	7.00E-07	7.11E-07						
2.0E+02	1.11E-09	5.72E-08	2.77E-07							
3.0E+02	5.67E-11	3.10E-08								
4.0E+02	2.90E-12	1.95E-09								
5.0E+02	1.48E-13	1.23E-10								
6.0E+02	7.61E-15									
8.0E+02	1.99E-17									
1.0E+03	5.22E-20									
1.5E+03	1.83E-26									

Table B.18. $(1/T_0)\ D_-^{>1}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T_0 ($g/cm^2/MeV$)	T_0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	9.51E-03	4.51E-03	2.44E-03	1.43E-03	6.62E-04	5.14E-04	3.77E-04	1.65E-04	1.14E-04	2.82E-04
1.5E-03	1.23E-02	6.56E-03	3.27E-03	1.88E-03	8.42E-04	6.29E-04	4.53E-04	2.14E-04	1.67E-04	4.57E-04
2.0E-03	1.48E-02	8.19E-03	3.97E-03	2.26E-03	9.98E-04	7.14E-04	5.12E-04	2.56E-04	2.12E-04	5.91E-04
3.0E-03	1.90E-02	1.08E-02	5.17E-03	2.90E-03	1.27E-03	8.40E-04	5.98E-04	3.27E-04	2.97E-04	7.42E-04
4.0E-03	2.25E-02	1.28E-02	6.24E-03	3.42E-03	1.49E-03	9.39E-04	6.63E-04	3.89E-04	3.85E-04	8.04E-04
5.0E-03	2.68E-02	1.46E-02	7.19E-03	3.87E-03	1.67E-03	1.02E-03	7.16E-04	4.46E-04	4.79E-04	8.26E-04
6.0E-03	3.13E-02	1.62E-02	8.07E-03	4.26E-03	1.83E-03	1.10E-03	7.61E-04	4.98E-04	5.72E-04	8.38E-04
8.0E-03	3.98E-02	1.90E-02	9.57E-03	4.91E-03	2.10E-03	1.23E-03	8.39E-04	5.95E-04	7.37E-04	8.80E-04
1.0E-02	4.66E-02	2.15E-02	1.09E-02	5.41E-03	2.31E-03	1.35E-03	9.06E-04	6.84E-04	8.60E-04	9.64E-04
1.5E-02	5.48E-02	2.65E-02	1.31E-02	6.35E-03	2.71E-03	1.61E-03	1.05E-03	8.75E-04	1.05E-03	1.31E-03
2.0E-02	5.44E-02	3.00E-02	1.44E-02	6.99E-03	2.98E-03	1.79E-03	1.18E-03	1.03E-03	1.20E-03	1.70E-03
3.0E-02	4.63E-02	3.23E-02	1.62E-02	7.90E-03	3.34E-03	2.06E-03	1.40E-03	1.26E-03	1.48E-03	2.28E-03
4.0E-02	3.80E-02	3.10E-02	1.75E-02	8.61E-03	3.58E-03	2.23E-03	1.55E-03	1.44E-03	1.75E-03	2.69E-03
5.0E-02	3.14E-02	2.79E-02	1.79E-02	9.15E-03	3.76E-03	2.35E-03	1.67E-03	1.59E-03	1.97E-03	3.01E-03
6.0E-02	2.64E-02	2.45E-02	1.76E-02	9.40E-03	3.91E-03	2.44E-03	1.77E-03	1.71E-03	2.17E-03	3.29E-03
8.0E-02	1.95E-02	1.81E-02	1.52E-02	9.30E-03	4.14E-03	2.59E-03	1.90E-03	1.91E-03	2.48E-03	3.79E-03
1.0E-01	1.52E-02	1.34E-02	1.22E-02	8.55E-03	4.27E-03	2.70E-03	2.01E-03	2.07E-03	2.70E-03	4.15E-03
1.5E-01	9.51E-03	7.81E-03	7.33E-03	6.27E-03	4.04E-03	2.76E-03	2.18E-03	2.31E-03	3.02E-03	4.62E-03
2.0E-01	6.77E-03	5.54E-03	4.98E-03	4.50E-03	3.34E-03	2.56E-03	2.16E-03	2.41E-03	3.19E-03	4.81E-03
3.0E-01	4.23E-03	3.60E-03	2.98E-03	2.57E-03	2.10E-03	1.88E-03	1.78E-03	2.32E-03	3.23E-03	4.79E-03
4.0E-01	3.06E-03	2.71E-03	2.15E-03	1.74E-03	1.45E-03	1.36E-03	1.42E-03	2.05E-03	2.99E-03	4.39E-03
5.0E-01	2.39E-03	2.15E-03	1.72E-03	1.34E-03	1.09E-03	1.03E-03	1.15E-03	1.80E-03	2.68E-03	3.93E-03
6.0E-01	1.96E-03	1.79E-03	1.44E-03	1.13E-03	8.81E-04	8.19E-04	9.72E-04	1.61E-03	2.42E-03	3.50E-03
8.0E-01	1.43E-03	1.34E-03	1.10E-03	8.73E-04	6.49E-04	6.26E-04	7.77E-04	1.37E-03	2.05E-03	2.87E-03
1.0E+00	1.10E-03	1.08E-03	8.95E-04	7.21E-04	5.27E-04	5.38E-04	6.91E-04	1.23E-03	1.79E-03	2.39E-03
1.5E+00	6.58E-04	7.07E-04	6.01E-04	4.97E-04	3.80E-04	4.04E-04	5.60E-04	9.75E-04	1.34E-03	1.59E-03
2.0E+00	4.37E-04	5.15E-04	4.48E-04	3.76E-04	3.05E-04	3.29E-04	4.73E-04	8.00E-04	1.04E-03	
3.0E+00	2.30E-04	3.26E-04	2.93E-04	2.49E-04	2.19E-04	2.49E-04	3.64E-04	5.67E-04	6.39E-04	
4.0E+00	1.43E-04	2.33E-04	2.16E-04	1.85E-04	1.72E-04	2.03E-04	2.92E-04	4.13E-04		
5.0E+00	9.84E-05	1.78E-04	1.70E-04	1.47E-04	1.42E-04	1.72E-04	2.42E-04	3.04E-04		
6.0E+00	7.20E-05	1.43E-04	1.40E-04	1.21E-04	1.22E-04	1.50E-04	2.01E-04			
8.0E+00	4.20E-05	1.01E-04	1.02E-04	8.97E-05	9.51E-05	1.17E-04	1.44E-04			
1.0E+01	2.57E-05	7.63E-05	7.98E-05	7.09E-05	7.80E-05	9.32E-05	1.04E-04			
1.5E+01	8.69E-06	4.47E-05	4.92E-05	4.60E-05	5.25E-05	5.56E-05	4.73E-05			
2.0E+01	3.45E-06	2.86E-05	3.39E-05	3.35E-05	3.74E-05	3.42E-05				
3.0E+01	7.74E-07	1.33E-05	1.90E-05	2.05E-05	2.03E-05	1.38E-05				
4.0E+01	2.62E-07	7.57E-06	1.20E-05	1.37E-05	1.13E-05					
5.0E+01	1.22E-07	4.98E-06	8.11E-06	9.59E-06	6.46E-06					
6.0E+01	7.12E-08	3.53E-06	5.75E-06	6.90E-06	3.77E-06					
8.0E+01	3.93E-08	1.81E-06	3.15E-06	3.71E-06						
1.0E+02	2.16E-08	8.28E-07	1.84E-06	2.08E-06						
1.5E+02	4.90E-09	1.10E-07	5.68E-07	5.46E-07						
2.0E+02	1.11E-09	5.67E-08	2.00E-07							
3.0E+02	5.67E-11	3.10E-08								
4.0E+02	2.90E-12	1.95E-09								
5.0E+02	1.48E-13	1.23E-10								
6.0E+02	7.61E-15									
8.0E+02	1.99E-17									
1.0E+03	5.22E-20									
1.5E+03	1.83E-26									

Table B.19. $(1/T_0)\, D_{Br}^{SiO_2}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T_0 (g/cm^2/MeV)	T_0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	4.08E-02	2.14E-02	1.24E-02	6.06E-03	2.60E-03	1.66E-03	1.35E-03	1.28E-03	1.56E-03	1.88E-03
1.5E-03	4.20E-02	2.22E-02	1.29E-02	6.33E-03	2.72E-03	1.72E-03	1.39E-03	1.31E-03	1.58E-03	2.00E-03
2.0E-03	4.30E-02	2.23E-02	1.32E-02	6.54E-03	2.81E-03	1.75E-03	1.42E-03	1.34E-03	1.59E-03	2.06E-03
3.0E-03	4.43E-02	2.46E-02	1.40E-02	6.89E-03	2.97E-03	1.82E-03	1.47E-03	1.39E-03	1.61E-03	2.08E-03
4.0E-03	4.53E-02	2.71E-02	1.45E-02	7.18E-03	3.08E-03	1.88E-03	1.50E-03	1.44E-03	1.67E-03	2.07E-03
5.0E-03	4.67E-02	2.95E-02	1.50E-02	7.42E-03	3.19E-03	1.94E-03	1.53E-03	1.48E-03	1.75E-03	2.08E-03
6.0E-03	4.85E-02	3.14E-02	1.55E-02	7.60E-03	3.27E-03	1.98E-03	1.56E-03	1.51E-03	1.84E-03	2.09E-03
8.0E-03	5.16E-02	3.42E-02	1.61E-02	7.91E-03	3.41E-03	2.06E-03	1.61E-03	1.57E-03	1.98E-03	2.15E-03
1.0E-02	5.30E-02	3.58E-02	1.65E-02	8.14E-03	3.50E-03	2.13E-03	1.65E-03	1.62E-03	2.05E-03	2.24E-03
1.5E-02	5.03E-02	3.64E-02	1.72E-02	8.51E-03	3.69E-03	2.24E-03	1.73E-03	1.73E-03	2.15E-03	2.54E-03
2.0E-02	4.38E-02	3.45E-02	1.75E-02	8.71E-03	3.80E-03	2.33E-03	1.78E-03	1.83E-03	2.23E-03	2.82E-03
3.0E-02	3.21E-02	2.85E-02	1.76E-02	9.00E-03	3.93E-03	2.45E-03	1.87E-03	1.99E-03	2.45E-03	3.24E-03
4.0E-02	2.43E-02	2.27E-02	1.74E-02	9.23E-03	3.99E-03	2.50E-03	1.93E-03	2.11E-03	2.67E-03	3.56E-03
5.0E-02	1.91E-02	1.82E-02	1.66E-02	9.32E-03	4.01E-03	2.53E-03	1.97E-03	2.20E-03	2.83E-03	3.82E-03
6.0E-02	1.55E-02	1.50E-02	1.51E-02	9.18E-03	4.02E-03	2.54E-03	2.01E-03	2.27E-03	2.97E-03	4.03E-03
8.0E-02	1.12E-02	1.06E-02	1.15E-02	8.29E-03	4.00E-03	2.56E-03	2.06E-03	2.39E-03	3.17E-03	4.38E-03
1.0E-01	8.61E-03	8.00E-03	8.40E-03	7.01E-03	3.93E-03	2.57E-03	2.09E-03	2.47E-03	3.31E-03	4.64E-03
1.5E-01	5.37E-03	4.77E-03	4.31E-03	4.33E-03	3.34E-03	2.45E-03	2.11E-03	2.59E-03	3.49E-03	5.00E-03
2.0E-01	3.82E-03	3.35E-03	2.79E-03	2.82E-03	2.53E-03	2.13E-03	2.00E-03	2.59E-03	3.55E-03	5.12E-03
3.0E-01	2.39E-03	2.07E-03	1.67E-03	1.48E-03	1.42E-03	1.44E-03	1.59E-03	2.39E-03	3.46E-03	4.96E-03
4.0E-01	1.72E-03	1.51E-03	1.22E-03	9.87E-04	9.36E-04	1.02E-03	1.26E-03	2.11E-03	3.18E-03	4.54E-03
5.0E-01	1.34E-03	1.19E-03	9.75E-04	7.63E-04	7.07E-04	7.75E-04	1.05E-03	1.88E-03	2.86E-03	4.05E-03
6.0E-01	1.10E-03	9.88E-04	8.14E-04	6.46E-04	5.80E-04	6.39E-04	9.14E-04	1.71E-03	2.60E-03	3.61E-03
8.0E-01	7.95E-04	7.39E-04	6.19E-04	5.15E-04	4.44E-04	5.20E-04	7.69E-04	1.49E-03	2.20E-03	2.94E-03
1.0E+00	6.10E-04	5.90E-04	5.02E-04	4.34E-04	3.73E-04	4.66E-04	7.00E-04	1.34E-03	1.93E-03	2.44E-03
1.5E+00	3.63E-04	3.95E-04	3.45E-04	3.08E-04	2.86E-04	3.68E-04	5.90E-04	1.07E-03	1.44E-03	1.53E-03
2.0E+00	2.41E-04	2.93E-04	2.62E-04	2.37E-04	2.39E-04	3.10E-04	5.10E-04	8.75E-04	1.10E-03	
3.0E+00	1.27E-04	1.85E-04	1.76E-04	1.62E-04	1.81E-04	2.45E-04	3.95E-04	6.22E-04	6.42E-04	
4.0E+00	7.89E-05	1.32E-04	1.31E-04	1.23E-04	1.48E-04	2.06E-04	3.16E-04	4.49E-04		
5.0E+00	5.44E-05	1.01E-04	1.04E-04	9.96E-05	1.26E-04	1.76E-04	2.62E-04	3.20E-04		
6.0E+00	3.98E-05	8.04E-05	8.56E-05	8.44E-05	1.09E-04	1.53E-04	2.21E-04			
8.0E+00	2.31E-05	5.65E-05	6.27E-05	6.47E-05	8.86E-05	1.20E-04	1.59E-04			
1.0E+01	1.42E-05	4.31E-05	4.91E-05	5.25E-05	7.43E-05	9.64E-05	1.15E-04			
1.5E+01	4.79E-06	2.55E-05	3.12E-05	3.56E-05	5.20E-05	6.05E-05	4.68E-05			
2.0E+01	1.89E-06	1.64E-05	2.22E-05	2.66E-05	3.79E-05	3.76E-05				
3.0E+01	4.26E-07	7.69E-06	1.29E-05	1.68E-05	2.07E-05	1.30E-05				
4.0E+01	1.44E-07	4.32E-06	8.28E-06	1.10E-05	1.15E-05					
5.0E+01	6.69E-08	2.80E-06	5.69E-06	8.15E-06	6.45E-06					
6.0E+01	3.91E-08	1.98E-06	4.09E-06	5.89E-06	3.67E-06					
8.0E+01	2.16E-08	1.04E-06	2.18E-06	3.21E-06						
1.0E+02	1.19E-08	4.90E-07	1.28E-06	1.81E-06						
1.5E+02	2.68E-09	6.40E-08	4.19E-07	4.87E-07						
2.0E+02	6.06E-10	3.17E-08	1.65E-07							
3.0E+02	3.09E-11	1.70E-08								
4.0E+02	1.57E-12	1.07E-09								
5.0E+02	8.02E-14	6.71E-11								
6.0E+02	4.08E-15									
8.0E+02	1.06E-17									
1.0E+03	2.76E-20									
1.5E+03	9.43E-27									

1.5E+03 9.43E-27

Table B.20. $(1/T_0)\ D_-^{SiO_2}(z/T_0)$ for bremstrahlung. Units: cm^2/g.

z/T0 (g/cm²/MeV)	T0=0.02	0.05	0.10	0.20	0.50	1.00	2.00	5.00	10.00	20.00
1.0E-03	5.65E-03	2.63E-03	1.42E-03	8.34E-04	3.83E-04	2.97E-04	2.20E-04	1.04E-04	8.51E-05	2.54E-04
1.5E-03	7.23E-03	3.78E-03	1.90E-03	1.09E-03	4.86E-04	3.64E-04	2.65E-04	1.38E-04	1.25E-04	4.07E-04
2.0E-03	8.61E-03	4.73E-03	2.30E-03	1.31E-03	5.77E-04	4.13E-04	3.00E-04	1.67E-04	1.63E-04	5.24E-04
3.0E-03	1.11E-02	6.23E-03	3.00E-03	1.66E-03	7.30E-04	4.85E-04	3.52E-04	2.18E-04	2.36E-04	6.59E-04
4.0E-03	1.31E-02	7.44E-03	3.62E-03	1.96E-03	8.55E-04	5.42E-04	3.93E-04	2.63E-04	3.16E-04	7.16E-04
5.0E-03	1.56E-02	8.48E-03	4.16E-03	2.23E-03	9.60E-04	5.91E-04	4.26E-04	3.05E-04	4.01E-04	7.40E-04
6.0E-03	1.82E-02	9.43E-03	4.66E-03	2.44E-03	1.06E-03	6.35E-04	4.54E-04	3.46E-04	4.87E-04	7.55E-04
8.0E-03	2.31E-02	1.10E-02	5.53E-03	2.81E-03	1.20E-03	7.13E-04	5.04E-04	4.23E-04	6.38E-04	8.00E-04
1.0E-02	2.71E-02	1.25E-02	6.25E-03	3.10E-03	1.32E-03	7.84E-04	5.47E-04	4.96E-04	7.48E-04	8.81E-04
1.5E-02	3.19E-02	1.52E-02	7.50E-03	3.63E-03	1.55E-03	9.31E-04	6.43E-04	6.57E-04	9.19E-04	1.20E-03
2.0E-02	3.16E-02	1.72E-02	8.27E-03	3.99E-03	1.70E-03	1.05E-03	7.29E-04	7.87E-04	1.05E-03	1.56E-03
3.0E-02	2.68E-02	1.86E-02	9.29E-03	4.49E-03	1.91E-03	1.21E-03	8.80E-04	9.85E-04	1.30E-03	2.09E-03
4.0E-02	2.20E-02	1.80E-02	9.94E-03	4.89E-03	2.04E-03	1.31E-03	1.00E-03	1.14E-03	1.55E-03	2.46E-03
5.0E-02	1.80E-02	1.63E-02	1.02E-02	5.19E-03	2.15E-03	1.38E-03	1.09E-03	1.26E-03	1.76E-03	2.77E-03
6.0E-02	1.52E-02	1.42E-02	9.94E-03	5.34E-03	2.23E-03	1.44E-03	1.15E-03	1.37E-03	1.94E-03	3.04E-03
8.0E-02	1.12E-02	1.02E-02	8.57E-03	5.25E-03	2.36E-03	1.53E-03	1.26E-03	1.55E-03	2.22E-03	3.50E-03
1.0E-01	8.61E-03	7.54E-03	6.89E-03	4.82E-03	2.43E-03	1.60E-03	1.34E-03	1.69E-03	2.43E-03	3.85E-03
1.5E-01	5.37E-03	4.27E-03	4.08E-03	3.51E-03	2.30E-03	1.66E-03	1.47E-03	1.93E-03	2.76E-03	4.30E-03
2.0E-01	3.82E-03	3.05E-03	2.76E-03	2.51E-03	1.91E-03	1.54E-03	1.47E-03	2.03E-03	2.93E-03	4.49E-03
3.0E-01	2.37E-03	2.02E-03	1.65E-03	1.43E-03	1.22E-03	1.17E-03	1.27E-03	1.98E-03	2.99E-03	4.49E-03
4.0E-01	1.71E-03	1.51E-03	1.19E-03	9.68E-04	8.49E-04	8.73E-04	1.05E-03	1.80E-03	2.80E-03	4.15E-03
5.0E-01	1.33E-03	1.19E-03	9.48E-04	7.49E-04	6.50E-04	6.78E-04	8.91E-04	1.62E-03	2.54E-03	3.72E-03
6.0E-01	1.09E-03	9.88E-04	7.96E-04	6.27E-04	5.31E-04	5.56E-04	7.76E-04	1.48E-03	2.31E-03	3.32E-03
8.0E-01	7.90E-04	7.39E-04	6.09E-04	4.89E-04	3.98E-04	4.39E-04	6.44E-04	1.28E-03	1.97E-03	2.72E-03
1.0E+00	6.08E-04	5.90E-04	4.94E-04	4.06E-04	3.28E-04	3.85E-04	5.81E-04	1.15E-03	1.72E-03	2.27E-03
1.5E+00	3.63E-04	3.85E-04	3.32E-04	2.82E-04	2.43E-04	3.01E-04	4.82E-04	9.19E-04	1.29E-03	1.52E-03
2.0E+00	2.41E-04	2.81E-04	2.47E-04	2.14E-04	2.00E-04	2.52E-04	4.13E-04	7.56E-04	9.97E-04	
3.0E+00	1.26E-04	1.79E-04	1.63E-04	1.44E-04	1.48E-04	1.96E-04	3.22E-04	5.37E-04	6.20E-04	
4.0E+00	7.83E-05	1.28E-04	1.20E-04	1.08E-04	1.19E-04	1.62E-04	2.59E-04	3.93E-04		
5.0E+00	5.40E-05	9.79E-05	9.48E-05	8.64E-05	9.98E-05	1.39E-04	2.15E-04	2.91E-04		
6.0E+00	3.95E-05	7.86E-05	7.82E-05	7.20E-05	8.70E-05	1.22E-04	1.80E-04			
8.0E+00	2.30E-05	5.51E-05	5.74E-05	5.40E-05	6.93E-05	9.55E-05	1.30E-04			
1.0E+01	1.42E-05	4.17E-05	4.48E-05	4.32E-05	5.76E-05	7.68E-05	9.41E-05			
1.5E+01	4.79E-06	2.45E-05	2.78E-05	2.87E-05	3.96E-05	4.65E-05	4.38E-05			
2.0E+01	1.89E-06	1.57E-05	1.92E-05	2.11E-05	2.85E-05	2.91E-05				
3.0E+01	4.26E-07	7.34E-06	1.09E-05	1.32E-05	1.56E-05	1.21E-05				
4.0E+01	1.44E-07	4.17E-06	6.91E-06	8.96E-06	8.79E-06					
5.0E+01	6.69E-08	2.73E-06	4.71E-06	6.32E-06	5.09E-06					
6.0E+01	3.91E-08	1.94E-06	3.36E-06	4.56E-06	3.00E-06					
8.0E+01	2.16E-08	9.97E-07	1.86E-06	2.49E-06						
1.0E+02	1.19E-08	4.57E-07	1.09E-06	1.41E-06						
1.5E+02	2.68E-09	6.11E-08	3.41E-07	3.83E-07						
2.0E+02	6.06E-10	3.13E-08	1.21E-07							
3.0E+02	3.09E-11	1.70E-08								
4.0E+02	1.57E-12	1.07E-09								
5.0E+02	8.02E-14	6.71E-11								
6.0E+02	4.08E-15									
8.0E+02	1.06E-17									
1.0E+03	2.76E-20									
1.5E+03	9.43E-27									

Appendix C. Sample Run

1. Input Data

Below is a listing of the input data for the run producing the results shown in figure 12 of Appendix A. Note that the monoenergetic depth-dose data set is read from unit 9.

```
     1     9     2
    42     2
     0.03000     0.04000     0.05000     0.06000     0.08000     0.10000
     0.15000     0.20000     0.30000     0.40000     0.50000     0.60000
     0.80000     1.00000     1.25000     1.50000     1.75000     2.00000
     2.50000     3.00000     3.50000     4.00000     4.50000     5.00000
     5.50000     6.00000     6.50000     7.00000     7.50000     8.00000
     8.50000     9.00000     9.50000    10.00000    12.50000    15.00000
    17.50000    20.00000    22.50000    25.00000    27.50000    30.00000
     2.000  1000.000     2.000  1000.000   301     0.100     7.000   101
GEOSTAT,35790 KM,INCL=0,PLONG=160W; SP:1AL(95%),TP:NONE,EL:AEI7-HI(79)
     3     0    28 1.00000E 03 3.15360E 07
 0.0000E 00  0.0000E 00  0.0000E 00
 2.6500E 01  2.4500E 10  0.0000E 00
 1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01
 7.0000E-01  8.0000E-01  9.0000E-01  1.0000E 00  1.2500E 00  1.5000E 00
 1.7500E 00  2.0000E 00  2.2500E 00  2.5000E 00  2.7500E 00  3.0000E 00
 3.2500E 00  3.5000E 00  3.7500E 00  4.0000E 00  4.2500E 00  4.5000E 00
 4.7500E 00  5.0000E 00  5.5000E 00  6.0000E 00  6.5000E 00  7.0000E 00
 7.5343E 04  5.7226E 04  3.5768E 04  2.0637E 04  1.2084E 04  7.7592E 03
 5.3738E 03  4.0677E 03  3.3050E 03  2.0840E 03  9.4707E 02  4.4939E 02
 2.2097E 02  1.0413E 02  5.1592E 01  2.6350E 01  1.2667E 01  5.7739E 00
 2.9428E 00  1.8846E 00  1.4374E 00  1.1547E 00  8.4948E-01  6.2276E-01
 4.8761E-01  3.4227E-01  2.1946E-01  1.2189E-02  0.0         0.0
```

2. Output Data

The output listing, the significant portions of which are given below, is mostly self-explanatory. In addition to monitoring the input data, the total flux and the average energy is given, both for the protons and electron incident fluxes:

$$\text{INT SPEC} \equiv \int_{T_{min}}^{T_{max}} \psi_{4\pi}(T_o)\, dT_o$$

$$\text{EAV} \equiv \int_{T_{min}}^{T_{max}} T_o\, \psi_{4\pi}(T_o)\, dT_o \Bigg/ \int_{T_{min}}^{T_{max}} \psi_{4\pi}(T_o)\, dT_o$$

Sample output listing:

```
 IMAX  IUNT
   42     2

SHIELD DEPTH (G/CM2)
    0.03000     0.04000     0.05000     0.06000     0.08000     0.10000
    0.15000     0.20000     0.30000     0.40000     0.50000     0.60000
    0.80000     1.00000     1.25000     1.50000     1.75000     2.00000
    2.50000     3.00000     3.50000     4.00000     4.50000     5.00000
    5.50000     6.00000     6.50000     7.00000     7.50000     8.00000
    8.50000     9.00000     9.50000    10.00000    12.50000    15.00000
   17.50000    20.00000    22.50000    25.00000    27.50000    30.00000

EMINS      EMAXS      EMINP      EMAXP NPTSP      EMINE      EMAXE NPTSE
2.000   1000.000      2.000   1000.000   301      0.100      7.000   101
2.000    999.999      2.000    999.999   301      0.100      7.000   101  ADJUSTED VALUES



GEOSTAT,35790 KM,INCL=0,PLONG=160W; SP:1AL(95%),TP:NONE,EL:AEI7-HI(79)

JSMAX JPMAX JEMAX       EUNIT      TINTER
    3     0    28 1.00000E+03 3.15360E+07

E(MEV)
 0.0          0.0          0.0

SOLAR PROTON SPECTRUM (/ENERGY/CM2)
 2.6500E+01  2.4500E+10  0.0

   INT SPEC     EAV(MEV)
 2.2719E+10     28.50006

E(MEV)
 1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01
 7.0000E-01  8.0000E-01  9.0000E-01  1.0000E+00  1.2500E+00  1.5000E+00
 1.7500E+00  2.0000E+00  2.2500E+00  2.5000E+00  2.7500E+00  3.0000E+00
 3.2500E+00  3.5000E+00  3.7500E+00  4.0000E+00  4.2500E+00  4.5000E+00
 4.7500E+00  5.0000E+00  5.5000E+00  6.0000E+00

ELECTRON SPECTRUM (/ENERGY/CM2/TIME)
 7.5343E+04  5.7226E+04  3.5768E+04  2.0637E+04  1.2084E+04  7.7592E+03
 5.3738E+03  4.0677E+03  3.3050E+03  2.0840E+03  9.4707E+02  4.4939E+02
 2.2097E+02  1.0413E+02  5.1592E+01  2.6350E+01  1.2667E+01  5.7739E+00
 2.9428E+00  1.8846E+00  1.4374E+00  1.1547E+00  8.4948E-01  6.2276E-01
 4.8761E-01  3.4227E-01  2.1946E-01  1.2189E-02

   INT SPEC     EAV(MEV)
 1.9162E+07      0.34290
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DOSE AT TRANSMISSION SURFACE OF FINITE ALUMINUM SLAB SHIELDS

RADS AL

Z(MILS)	Z(MM)	Z(G/CM2)	ELECTRON	BREMS	EL+BR	TRP PROT	SOL PROT	EL+BR+TRP	TOTAL
4.374	0.111	0.030	4.130E+06	2.719E+03	4.133E+06	0.0	3.942E+03	4.133E+06	4.136E+06
5.833	0.148	0.040	3.186E+06	2.470E+03	3.189E+06	0.0	3.638E+03	3.189E+06	3.192E+06
7.291	0.185	0.050	2.534E+06	2.252E+03	2.537E+06	0.0	3.402E+03	2.537E+06	2.540E+06
8.749	0.222	0.060	2.063E+06	2.064E+03	2.065E+06	0.0	3.209E+03	2.065E+06	2.068E+06
11.665	0.296	0.080	1.440E+06	1.759E+03	1.442E+06	0.0	2.907E+03	1.442E+06	1.445E+06
14.581	0.370	0.100	1.059E+06	1.530E+03	1.061E+06	0.0	2.673E+03	1.061E+06	1.064E+06
21.872	0.556	0.150	5.683E+05	1.155E+03	5.695E+05	0.0	2.250E+03	5.695E+05	5.717E+05
29.163	0.741	0.200	3.410E+05	9.277E+02	3.419E+05	0.0	1.958E+03	3.419E+05	3.439E+05
43.744	1.111	0.300	1.393E+05	6.600E+02	1.399E+05	0.0	1.568E+03	1.399E+05	1.415E+05
58.326	1.481	0.400	6.246E+04	5.077E+02	6.296E+04	0.0	1.310E+03	6.296E+04	6.427E+04
72.907	1.852	0.500	3.040E+04	4.125E+02	3.081E+04	0.0	1.123E+03	3.081E+04	3.194E+04
87.489	2.222	0.600	1.546E+04	3.493E+02	1.581E+04	0.0	9.811E+02	1.581E+04	1.679E+04
116.652	2.963	0.800	4.411E+03	2.727E+02	4.683E+03	0.0	7.749E+02	4.683E+03	5.458E+03
145.815	3.704	1.000	1.436E+03	2.279E+02	1.664E+03	0.0	6.329E+02	1.664E+03	2.297E+03
182.269	4.630	1.250	4.360E+02	1.919E+02	6.279E+02	0.0	5.069E+02	6.279E+02	1.135E+03
218.722	5.556	1.500	1.736E+02	1.673E+02	3.409E+02	0.0	4.153E+02	3.409E+02	7.562E+02
255.176	6.481	1.750	8.030E+01	1.492E+02	2.295E+02	0.0	3.473E+02	2.295E+02	5.769E+02
291.630	7.407	2.000	3.669E+01	1.353E+02	1.720E+02	0.0	2.937E+02	1.720E+02	4.657E+02
364.537	9.259	2.500	5.603E+00	1.149E+02	1.205E+02	0.0	2.179E+02	1.205E+02	3.385E+02
437.445	11.111	3.000	3.263E-01	1.005E+02	1.009E+02	0.0	1.673E+02	1.009E+02	2.682E+02
510.352	12.963	3.500	9.898E-04	8.968E+01	8.969E+01	0.0	1.314E+02	8.969E+01	2.210E+02
583.260	14.815	4.000	1.070E-08	8.110E+01	8.110E+01	0.0	1.047E+02	8.110E+01	1.858E+02
656.167	16.667	4.500	0.0	7.405E+01	7.405E+01	0.0	8.459E+01	7.405E+01	1.586E+02
729.074	18.519	5.000	0.0	6.812E+01	6.812E+01	0.0	6.959E+01	6.812E+01	1.377E+02
801.982	20.370	5.500	0.0	6.302E+01	6.302E+01	0.0	5.784E+01	6.302E+01	1.209E+02
874.889	22.222	6.000	0.0	5.855E+01	5.855E+01	0.0	4.804E+01	5.855E+01	1.066E+02
947.797	24.074	6.500	0.0	5.459E+01	5.459E+01	0.0	4.051E+01	5.459E+01	9.510E+01
1020.704	25.926	7.000	0.0	5.104E+01	5.104E+01	0.0	3.438E+01	5.104E+01	8.542E+01
1093.612	27.778	7.500	0.0	4.784E+01	4.784E+01	0.0	2.927E+01	4.784E+01	7.711E+01
1166.519	29.630	8.000	0.0	4.493E+01	4.493E+01	0.0	2.524E+01	4.493E+01	7.017E+01
1239.427	31.481	8.500	0.0	4.227E+01	4.227E+01	0.0	2.187E+01	4.227E+01	6.414E+01
1312.334	33.333	9.000	0.0	3.983E+01	3.983E+01	0.0	1.886E+01	3.983E+01	5.870E+01
1385.241	35.185	9.500	0.0	3.758E+01	3.758E+01	0.0	1.642E+01	3.758E+01	5.400E+01
1458.149	37.037	10.000	0.0	3.550E+01	3.550E+01	0.0	1.425E+01	3.550E+01	4.975E+01
1822.686	46.296	12.500	0.0	2.709E+01	2.709E+01	0.0	7.526E+00	2.709E+01	3.462E+01
2187.223	55.556	15.000	0.0	2.102E+01	2.102E+01	0.0	4.275E+00	2.102E+01	2.530E+01
2551.760	64.815	17.500	0.0	1.648E+01	1.648E+01	0.0	2.527E+00	1.648E+01	1.901E+01
2916.298	74.074	20.000	0.0	1.300E+01	1.300E+01	0.0	1.532E+00	1.300E+01	1.453E+01
3280.835	83.333	22.500	0.0	1.028E+01	1.028E+01	0.0	9.578E-01	1.028E+01	1.124E+01
3645.372	92.593	25.000	0.0	8.137E+00	8.137E+00	0.0	6.197E-01	8.137E+00	8.757E+00
4009.910	101.852	27.500	0.0	6.440E+00	6.440E+00	0.0	3.963E-01	6.440E+00	6.836E+00
4374.445	111.111	30.000	0.0	5.094E+00	5.094E+00	0.0	2.679E-01	5.094E+00	5.362E+00

DOSE IN SEMI-INFINITE ALUMINUM MEDIUM

RADS AL

Z(MILS)	Z(MM)	Z(G/CM2)	ELECTRON	BREMS	EL+BR	TRP PROT	SOL PROT	EL+BR+TRP	TOTAL
4.374	0.111	0.030	6.237E+06	4.284E+03	6.242E+06	0.0	3.942E+03	6.242E+06	6.245E+06
5.833	0.148	0.040	4.796E+06	3.732E+03	4.800E+06	0.0	3.638E+03	4.800E+06	4.804E+06
7.291	0.185	0.050	3.804E+06	3.299E+03	3.808E+06	0.0	3.402E+03	3.808E+06	3.811E+06
8.749	0.222	0.060	3.089E+06	2.947E+03	3.091E+06	0.0	3.209E+03	3.091E+06	3.095E+06
11.665	0.296	0.080	2.147E+06	2.418E+03	2.149E+06	0.0	2.907E+03	2.149E+06	2.152E+06
14.581	0.370	0.100	1.573E+06	2.044E+03	1.575E+06	0.0	2.673E+03	1.575E+06	1.578E+06
21.872	0.556	0.150	8.384E+05	1.471E+03	8.399E+05	0.0	2.250E+03	8.399E+05	8.421E+05
29.163	0.741	0.200	5.009E+05	1.145E+03	5.020E+05	0.0	1.958E+03	5.020E+05	5.040E+05
43.744	1.111	0.300	2.033E+05	7.851E+02	2.041E+05	0.0	1.568E+03	2.041E+05	2.057E+05
58.326	1.481	0.400	9.076E+04	5.938E+02	9.136E+04	0.0	1.310E+03	9.136E+04	9.267E+04
72.907	1.852	0.500	4.403E+04	4.800E+02	4.451E+04	0.0	1.123E+03	4.451E+04	4.563E+04
87.489	2.222	0.600	2.232E+04	4.072E+02	2.273E+04	0.0	9.811E+02	2.273E+04	2.371E+04
116.652	2.963	0.800	6.326E+03	3.214E+02	6.648E+03	0.0	7.749E+02	6.648E+03	7.422E+03
145.815	3.704	1.000	2.042E+03	2.719E+02	2.314E+03	0.0	6.329E+02	2.314E+03	2.947E+03
182.269	4.630	1.250	6.118E+02	2.319E+02	8.436E+02	0.0	5.069E+02	8.436E+02	1.351E+03
218.722	5.556	1.500	2.414E+02	2.041E+02	4.455E+02	0.0	4.153E+02	4.455E+02	8.608E+02
255.176	6.481	1.750	1.117E+02	1.836E+02	2.953E+02	0.0	3.473E+02	2.953E+02	6.426E+02
291.630	7.407	2.000	5.124E+01	1.676E+02	2.188E+02	0.0	2.937E+02	2.188E+02	5.125E+02
364.537	9.259	2.500	7.982E+00	1.439E+02	1.519E+02	0.0	2.179E+02	1.519E+02	3.698E+02
437.445	11.111	3.000	4.826E-01	1.270E+02	1.275E+02	0.0	1.673E+02	1.275E+02	2.948E+02
510.352	12.963	3.500	1.500E-03	1.139E+02	1.139E+02	0.0	1.314E+02	1.139E+02	2.453E+02
583.260	14.815	4.000	1.763E-08	1.033E+02	1.033E+02	0.0	1.047E+02	1.033E+02	2.081E+02
656.167	16.667	4.500	0.0	9.456E+01	9.456E+01	0.0	8.459E+01	9.456E+01	1.792E+02
729.074	18.519	5.000	0.0	8.710E+01	8.710E+01	0.0	6.959E+01	8.710E+01	1.567E+02
801.982	20.370	5.500	0.0	8.064E+01	8.064E+01	0.0	5.784E+01	8.064E+01	1.385E+02
874.889	22.222	6.000	0.0	7.500E+01	7.500E+01	0.0	4.804E+01	7.500E+01	1.230E+02
947.797	24.074	6.500	0.0	7.001E+01	7.001E+01	0.0	4.051E+01	7.001E+01	1.105E+02
1020.704	25.926	7.000	0.0	6.556E+01	6.556E+01	0.0	3.438E+01	6.556E+01	9.993E+01
1093.612	27.778	7.500	0.0	6.155E+01	6.155E+01	0.0	2.927E+01	6.155E+01	9.082E+01
1166.519	29.630	8.000	0.0	5.793E+01	5.793E+01	0.0	2.524E+01	5.793E+01	8.317E+01
1239.427	31.481	8.500	0.0	5.462E+01	5.462E+01	0.0	2.187E+01	5.462E+01	7.649E+01
1312.334	33.333	9.000	0.0	5.159E+01	5.159E+01	0.0	1.886E+01	5.159E+01	7.045E+01
1385.241	35.185	9.500	0.0	4.879E+01	4.879E+01	0.0	1.642E+01	4.879E+01	6.521E+01
1458.149	37.037	10.000	0.0	4.619E+01	4.619E+01	0.0	1.425E+01	4.619E+01	6.044E+01
1822.686	46.296	12.500	0.0	3.548E+01	3.548E+01	0.0	7.526E+00	3.548E+01	4.300E+01
2187.223	55.556	15.000	0.0	2.743E+01	2.743E+01	0.0	4.275E+00	2.743E+01	3.170E+01
2551.760	64.815	17.500	0.0	2.121E+01	2.121E+01	0.0	2.527E+00	2.121E+01	2.373E+01
2916.298	74.074	20.000	0.0	1.638E+01	1.638E+01	0.0	1.532E+00	1.638E+01	1.792E+01
3280.835	83.333	22.500	0.0	1.266E+01	1.266E+01	0.0	9.578E-01	1.266E+01	1.362E+01
3645.372	92.593	25.000	0.0	9.797E+00	9.797E+00	0.0	6.197E-01	9.797E+00	1.042E+01
4009.910	101.852	27.500	0.0	7.600E+00	7.600E+00	0.0	3.963E-01	7.600E+00	7.996E+00
4374.445	111.111	30.000	0.0	5.912E+00	5.912E+00	0.0	2.679E-01	5.912E+00	6.180E+00

1/2 DOSE AT CENTER OF ALUMINUM SPHERES

RADS AL

Z(MILS)	Z(MM)	Z(G/CM2)	ELECTRON	BREMS	EL+BR	TRP PROT	SOL PROT	EL+BR+TRP	TOTAL
4.374	0.111	0.030	1.150E+07	6.162E+03	1.150E+07	0.0	4.994E+03	1.150E+07	1.151E+07
5.833	0.148	0.040	9.510E+06	5.675E+03	9.516E+06	0.0	4.694E+03	9.516E+06	9.521E+06
7.291	0.185	0.050	7.972E+06	5.239E+03	7.977E+06	0.0	4.464E+03	7.977E+06	7.982E+06
8.749	0.222	0.060	6.766E+06	4.852E+03	6.771E+06	0.0	4.264E+03	6.771E+06	6.775E+06
11.665	0.296	0.080	5.019E+06	4.177E+03	5.023E+06	0.0	3.956E+03	5.023E+06	5.027E+06
14.581	0.370	0.100	3.848E+06	3.631E+03	3.852E+06	0.0	3.723E+03	3.852E+06	3.855E+06
21.872	0.556	0.150	2.240E+06	2.714E+03	2.242E+06	0.0	3.280E+03	2.242E+06	2.246E+06
29.163	0.741	0.200	1.471E+06	2.171E+03	1.473E+06	0.0	2.955E+03	1.473E+06	1.476E+06
43.744	1.111	0.300	7.227E+05	1.541E+03	7.243E+05	0.0	2.496E+03	7.243E+05	7.268E+05
58.326	1.481	0.400	3.664E+05	1.170E+03	3.676E+05	0.0	2.175E+03	3.676E+05	3.697E+05
72.907	1.852	0.500	1.975E+05	9.265E+02	1.984E+05	0.0	1.927E+03	1.984E+05	2.003E+05
87.489	2.222	0.600	1.111E+05	7.619E+02	1.118E+05	0.0	1.737E+03	1.118E+05	1.136E+05
116.652	2.963	0.800	3.658E+04	5.709E+02	3.715E+04	0.0	1.448E+03	3.715E+04	3.860E+04
145.815	3.704	1.000	1.293E+04	4.699E+02	1.340E+04	0.0	1.232E+03	1.340E+04	1.463E+04
182.269	4.630	1.250	3.855E+03	3.951E+02	4.250E+03	0.0	1.040E+03	4.250E+03	5.290E+03
218.722	5.556	1.500	1.429E+03	3.456E+02	1.775E+03	0.0	8.824E+02	1.775E+03	2.657E+03
255.176	6.481	1.750	7.022E+02	3.095E+02	1.012E+03	0.0	7.676E+02	1.012E+03	1.779E+03
291.630	7.407	2.000	3.843E+02	2.817E+02	6.660E+02	0.0	6.728E+02	6.660E+02	1.339E+03
364.537	9.259	2.500	9.336E+01	2.422E+02	3.356E+02	0.0	5.214E+02	3.356E+02	8.570E+02
437.445	11.111	3.000	1.130E+01	2.153E+02	2.266E+02	0.0	4.200E+02	2.266E+02	6.465E+02
510.352	12.963	3.500	9.096E-02	1.954E+02	1.955E+02	0.0	3.459E+02	1.955E+02	5.415E+02
583.260	14.815	4.000	1.677E-06	1.799E+02	1.799E+02	0.0	2.897E+02	1.799E+02	4.696E+02
656.167	16.667	4.500	0.0	1.671E+02	1.671E+02	0.0	2.401E+02	1.671E+02	4.073E+02
729.074	18.519	5.000	0.0	1.563E+02	1.563E+02	0.0	1.999E+02	1.563E+02	3.561E+02
801.982	20.370	5.500	0.0	1.469E+02	1.469E+02	0.0	1.768E+02	1.469E+02	3.236E+02
874.889	22.222	6.000	0.0	1.386E+02	1.386E+02	0.0	1.510E+02	1.386E+02	2.896E+02
947.797	24.074	6.500	0.0	1.312E+02	1.312E+02	0.0	1.276E+02	1.312E+02	2.587E+02
1020.704	25.926	7.000	0.0	1.245E+02	1.245E+02	0.0	1.133E+02	1.245E+02	2.378E+02
1093.612	27.778	7.500	0.0	1.186E+02	1.186E+02	0.0	9.724E+01	1.186E+02	2.158E+02
1166.519	29.630	8.000	0.0	1.132E+02	1.132E+02	0.0	8.303E+01	1.132E+02	1.963E+02
1239.427	31.481	8.500	0.0	1.084E+02	1.084E+02	0.0	7.656E+01	1.084E+02	1.850E+02
1312.334	33.333	9.000	0.0	1.040E+02	1.040E+02	0.0	6.740E+01	1.040E+02	1.714E+02
1385.241	35.185	9.500	0.0	1.000E+02	1.000E+02	0.0	5.999E+01	1.000E+02	1.600E+02
1458.149	37.037	10.000	0.0	9.632E+01	9.632E+01	0.0	5.446E+01	9.632E+01	1.508E+02
1822.686	46.296	12.500	0.0	8.142E+01	8.142E+01	0.0	2.981E+01	8.142E+01	1.112E+02
2187.223	55.556	15.000	0.0	6.969E+01	6.969E+01	0.0	1.818E+01	6.969E+01	8.787E+01
2551.760	64.815	17.500	0.0	5.946E+01	5.946E+01	0.0	1.158E+01	5.946E+01	7.104E+01
2916.298	74.074	20.000	0.0	5.022E+01	5.022E+01	0.0	7.526E+00	5.022E+01	5.775E+01
3280.835	83.333	22.500	0.0	4.197E+01	4.197E+01	0.0	4.787E+00	4.197E+01	4.676E+01
3645.372	92.593	25.000	0.0	3.480E+01	3.480E+01	0.0	3.380E+00	3.480E+01	3.818E+01
4009.910	101.852	27.500	0.0	2.872E+01	2.872E+01	0.0	2.258E+00	2.872E+01	3.098E+01
4374.445	111.111	30.000	0.0	1.318E+01	1.318E+01	0.0	4.569E-01	1.318E+01	1.363E+01

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C     SHIELDOSE, 12 FEB 80.                                                    A   10
C        DEVELOPED BY S. M. SELTZER, NATIONAL BUREAU OF STANDARDS.             A   15
C                                                                              A   20
C        IDET = 1, AL DETECTOR                                                 A   30
C               2, H2-O DETECTOR                                               A   40
C               3, SI DETECTOR                                                 A   50
C               4, SI-O2 DETECTOR                                              A   60
C        INCIDENT OMNIDIRECTIONAL FLUX IN /ENERGY/CM2/UNIT TIME                A   70
C        (SOLAR-FLARE FLUX IN /ENERGY/CM2).                                    A   80
C        EUNIT IS CONVERSION FACTOR FROM /ENERGY TO /MEV,                      A   90
C             E.G., EUNIT = 1000 IF FLUX IS /KEV.                              A  100
C        TINTER IS MISSION DURATION IN MULTIPLES OF UNIT TIME.                 A  110
C                                                                              A  120
      DIMENSION  EP(30),RP(30),DP(30,51),ZP(51),ER(80),RE(80),EE(10),          A  130
     1   DE(10,41,2),ZE(41),ZB(60),EB(10),DB(10,60,2),ZM(50),Z(50),            A  140
     2   TPL(301),TP(301),RINP(301),TEL(101),TE(101),RINE(101),SOL(301),       A  150
     3   EPS(101),S(101),SPG(301),G(301),SEG(101),DOSOL(50,2),                 A  160
     4   DOSP(50,2),DIN(60,301),GP(301,50),GE(101,50,2),GB(101,50,2),          A  170
     5   DOSE(50,2,2),DOSB(50,2,2),ZMM(50),ZL(50),GARB(60)                     A  180
      CALL ERRSET (208,256,-1,1)                                               A  190
      ZCON=0.001*2.540005*2.70                                                 A  200
      ZMCON=10.0/2.70                                                          A  210
      RADCON=1.6021892E-08                                                     A  220
      PRINT 10                                                                 A  230
   10 FORMAT ('0 IDET   NUT IPRNT')                                            A  240
      READ 30, IDET,NUT,IPRNT                                                  A  250
      PRINT 30, IDET,NUT,IPRNT                                                 A  260
      IDET1=IDET+1                                                             A  270
      REWIND NUT                                                               A  280
      PRINT 20                                                                 A  290
   20 FORMAT ('0MPMAX LPMAX  KMAX MEMAX LEMAX MBMAX LBMAX')                    A  300
      READ (NUT,30) MPMAX,LPMAX,KMAX,MEMAX,LEMAX,MBMAX,LBMAX                  A  310
      PRINT 30, MPMAX,LPMAX,KMAX,MEMAX,LEMAX,MBMAX,LBMAX                      A  320
   30 FORMAT (12I6)                                                            A  330
      PRINT 40                                                                 A  340
   40 FORMAT ('0PROTON DOSE DATA (ENERGIES INCREASING)')                       A  350
      PRINT 50                                                                 A  360
   50 FORMAT ('0     E(MEV)    R(G/CM2)')                                      A  370
      DO 110 M=1,MPMAX                                                         A  380
      READ (NUT,60) EP(M),RP(M)                                                A  390
      PRINT 60, EP(M),RP(M)                                                    A  400
   60 FORMAT (1P6E12.4)                                                        A  410
      EP(M)=ALOG(EP(M))                                                        A  420
      RP(M)=ALOG(RP(M))                                                        A  430
      DO 70 ID=1,IDET                                                          A  440
      READ (NUT,60) (DP(M,L),L=1,LPMAX)                                        A  450
   70 CONTINUE                                                                 A  460
      GO TO (80,90), IPRNT                                                     A  470
   80 PRINT 60, (DP(M,L),L=1,LPMAX)                                            A  480
   90 IF (IDET1.GT.4) GO TO 110                                                A  490
      DO 100 ID=IDET1,4                                                        A  500
      READ (NUT,60) (GARB(L),L=1,LPMAX)                                        A  510
  100 CONTINUE                                                                 A  520
  110 CONTINUE                                                                 A  530
      ZPFAC=1.0/FLOAT(LPMAX-1)                                                 A  540
      DO 120 L=1,LPMAX                                                         A  550
  120 ZP(L)=FLOAT(L-1)*ZPFAC                                                   A  560
      PRINT 130                                                                A  570
  130 FORMAT ('0ELECTRON DOSE DATA')                                           A  580
      PRINT 140                                                                A  590
  140 FORMAT ('0E(MEV)')                                                       A  600
      READ (NUT,150) (ER(K),K=1,KMAX)                                          A  610
      PRINT 150, (ER(K),K=1,KMAX)                                              A  620
  150 FORMAT (6F12.5)                                                          A  630
      PRINT 160                                                                A  640
  160 FORMAT ('0RANGE(G/CM2)')                                                 A  650
      READ (NUT,60) (RE(K),K=1,KMAX)                                           A  660
      PRINT 60, (RE(K),K=1,KMAX)                                               A  670
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      DO 170 K=1,KMAX                                                    A  680
      ER(K)=ALOG(ER(K))                                                  A  690
  170 RE(K)=ALOG(RE(K))                                                  A  700
      PRINT 180                                                          A  710
  180 FORMAT ('0E(MEV), THEN R0*D/E (ENERGIES INCREASING)')              A  720
      DO 270 M=1,MEMAX                                                   A  730
      READ (NUT,150) EE(M)                                               A  740
      PRINT 150, EE(M)                                                   A  750
      EE(M)=ALOG(EE(M))                                                  A  760
      DO 210 ID=1,IDET                                                   A  770
      DO 200 N=1,2                                                       A  780
      READ (NUT,190) (DE(M,L,N),L=1,LEMAX)                               A  790
  190 FORMAT (1P8E10.3)                                                  A  800
  200 CONTINUE                                                           A  810
  210 CONTINUE                                                           A  820
      GO TO (220,240), IPRNT                                             A  830
  220 DO 230 N=1,2                                                       A  840
      PRINT 190, (DE(M,L,N),L=1,LEMAX)                                   A  850
  230 CONTINUE                                                           A  860
  240 IF (IDET1.GT.4) GO TO 270                                          A  870
      DO 260 ID=IDET1,4                                                  A  880
      DO 250 N=1,2                                                       A  890
      READ (NUT,190) (GARB(L),L=1,LEMAX)                                 A  900
  250 CONTINUE                                                           A  910
  260 CONTINUE                                                           A  920
  270 CONTINUE                                                           A  930
      ZEFAC=1.0/FLOAT(LEMAX-1)                                           A  940
      DO 280 L=1,LEMAX                                                   A  950
  280 ZE(L)=FLOAT(L-1)*ZEFAC                                             A  960
      PRINT 290                                                          A  970
  290 FORMAT ('0BREMSSTRAHLUNG DOSE DATA (ENERGIES INCREASING)')         A  980
      PRINT 300                                                          A  990
  300 FORMAT ('0Z/E (G/CM2 KEV)')                                        A 1000
      READ (NUT,310) (ZB(L),L=1,LBMAX)                                   A 1010
      PRINT 310, (ZB(L),L=1,LBMAX)                                       A 1020
  310 FORMAT (1P8E9.2)                                                   A 1030
      DO 320 L=1,LBMAX                                                   A 1040
  320 ZB(L)=ALOG(1000.0*ZB(L))                                           A 1050
      PRINT 330                                                          A 1060
  330 FORMAT ('0E(MEV), THEN D/E (CM2/G)')                               A 1070
      DO 420 M=1,MBMAX                                                   A 1080
      READ (NUT,150) EB(M),RENORM                                        A 1090
      PRINT 150, EB(M),RENORM                                            A 1100
      EB(M)=ALOG(EB(M))                                                  A 1110
      DO 350 ID=1,IDET                                                   A 1120
      DO 340 N=1,2                                                       A 1130
      READ (NUT,310) (DB(M,L,N),L=1,LBMAX)                               A 1140
  340 CONTINUE                                                           A 1150
  350 CONTINUE                                                           A 1160
      GO TO (360,380), IPRNT                                             A 1170
  360 DO 370 N=1,2                                                       A 1180
      PRINT 310, (DB(M,L,N),L=1,LBMAX)                                   A 1190
  370 CONTINUE                                                           A 1200
  380 DO 390 N=1,2                                                       A 1210
      DO 390 L=1,LBMAX                                                   A 1220
  390 DB(M,L,N)=ALOG(RENORM*DB(M,L,N))                                   A 1230
      IF (IDET1.GT.4) GO TO 420                                          A 1240
      DO 410 ID=IDET1,4                                                  A 1250
      DO 400 N=1,2                                                       A 1260
      READ (NUT,310) (GARB(L),L=1,LBMAX)                                 A 1270
  400 CONTINUE                                                           A 1280
  410 CONTINUE                                                           A 1290
  420 CONTINUE                                                           A 1300
      PRINT 430                                                          A 1310
  430 FORMAT ('0 IMAX  IUNT')                                            A 1320
      READ 30, IMAX,IUNT                                                 A 1330
      PRINT 30, IMAX,IUNT                                                A 1340
      GO TO (440,470,500), IUNT                                          A 1350
  440 PRINT 450                                                          A 1360
  450 FORMAT ('0SHIELD DEPTH (MILS)')                                    A 1370
```

```
      READ 150, (ZM(I),I=1,IMAX)                                          A 1380
      PRINT 150, (ZM(I),I=1,IMAX)                                         A 1390
      DO 460 I=1,IMAX                                                     A 1400
      Z(I)=ZCON*ZM(I)                                                     A 1410
  460 ZMM(I)=Z(I)*ZMCON                                                   A 1420
      GO TO 530                                                           A 1430
  470 PRINT 480                                                           A 1440
  480 FORMAT ('0SHIELD DEPTH (G/CM2)')                                    A 1450
      READ 150, (Z(I),I=1,IMAX)                                           A 1460
      PRINT 150, (Z(I),I=1,IMAX)                                          A 1470
      DO 490 I=1,IMAX                                                     A 1480
      ZM(I)=Z(I)/ZCON                                                     A 1490
  490 ZMM(I)=Z(I)*ZMCON                                                   A 1500
      GO TO 530                                                           A 1510
  500 PRINT 510                                                           A 1520
  510 FORMAT ('0SHIELD DEPTH (MM)')                                       A 1530
      READ 150, (ZMM(I),I=1,IMAX)                                         A 1540
      PRINT 150, (ZMM(I),I=1,IMAX)                                        A 1550
      DO 520 I=1,IMAX                                                     A 1560
      Z(I)=ZMM(I)/ZMCON                                                   A 1570
  520 ZM(I)=Z(I)/ZCON                                                     A 1580
  530 DO 540 I=1,IMAX                                                     A 1590
  540 ZL(I)=ALOG(Z(I))                                                    A 1600
      PRINT 550                                                           A 1610
  550 FORMAT ('0     EMINS      EMAXS      EMINP      EMAXP NPTSP      EMINE   A 1620
     1     EMAXE NPTSE')                                                  A 1630
      READ 560, EMINS,EMAXS,EMINP,EMAXP,NPTSP,EMINE,EMAXE,NPTSE          A 1640
      PRINT 560, EMINS,EMAXS,EMINP,EMAXP,NPTSP,EMINE,EMAXE,NPTSE         A 1650
  560 FORMAT (4F10.3,I6,2F10.3,I6)                                        A 1660
      EMINU=AMIN1(EMINP,EMINS)                                            A 1670
      EMAXU=AMAX1(EMAXP,EMAXS)                                            A 1680
      DEP=ALOG(EMAXU/EMINU)/FLOAT(NPTSP-1)                                A 1690
      NFSTS=ALOG(EMINS/EMINU)/DEP+0.5                                     A 1700
      NFSTS=NFSTS+1                                                       A 1710
      NLSTS=ALOG(EMAXS/EMINU)/DEP+0.5                                     A 1720
      NLSTS=NLSTS+1                                                       A 1730
      NLENS=NLSTS-NFSTS+1                                                 A 1740
      NFSTP=ALOG(EMINP/EMINU)/DEP+0.5                                     A 1750
      NFSTP=NFSTP+1                                                       A 1760
      NLSTP=ALOG(EMAXP/EMINU)/DEP+0.5                                     A 1770
      NLSTP=NLSTP+1                                                       A 1780
      NLENP=NLSTP-NFSTP+1                                                 A 1790
      EMINUL=ALOG(EMINU)                                                  A 1800
      DELP=DEP/3.0                                                        A 1810
      ICALL=1                                                             A 1820
      DO 570 NP=1,NPTSP                                                   A 1830
      TPL(NP)=EMINUL+FLOAT(NP-1)*DEP                                      A 1840
      TP(NP)=EXP(TPL(NP))                                                 A 1850
      CALL SPOL (TPL(NP),EP,RP,MPMAX,ICALL,ANS)                           A 1860
  570 RINP(NP)=EXP(ANS)                                                   A 1870
      PRINT 580, TP(NFSTS),TP(NLSTS),TP(NFSTP),TP(NLSTP),NPTSP,EMINE,EMA  A 1880
     1XE,NPTSE                                                            A 1890
  580 FORMAT (4F10.3,I6,2F10.3,I6,'  ADJUSTED VALUES')                    A 1900
      DO 620 L=1,LPMAX                                                    A 1910
      ICALL=1                                                             A 1920
      DO 610 NP=1,NPTSP                                                   A 1930
      IF (TPL(NP).LT.EP(MPMAX)) GO TO 590                                 A 1940
      DIN(L,NP)=DP(MPMAX,L)                                               A 1950
      GO TO 610                                                           A 1960
  590 IF (TPL(NP).GT.EP(1)) GO TO 600                                     A 1970
      DIN(L,NP)=DP(1,L)                                                   A 1980
      GO TO 610                                                           A 1990
  600 CALL SPOL (TPL(NP),EP,DP(1,L),MPMAX,ICALL,DIN(L,NP))                A 2000
  610 CONTINUE                                                            A 2010
  620 CONTINUE                                                            A 2020
      DO 660 NP=1,NPTSP                                                   A 2030
      ICALL=1                                                             A 2040
      DO 650 I=1,IMAX                                                     A 2050
      ZRIN=Z(I)/RINP(NP)                                                  A 2060
      IF (ZRIN.LT.1.0) GO TO 640                                          A 2070
```

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630 GP(NP,I)=0.0                                                        A 2080
    GO TO 650                                                           A 2090
640 CALL SPOL (ZRIN,ZP,DIN(1,NP),LPMAX,ICALL,ANS)                       A 2100
    IF (ANS.LT.0.0) GO TO 630                                           A 2110
    GP(NP,I)=TP(NP)*ANS/RINP(NP)                                        A 2120
650 CONTINUE                                                            A 2130
660 CONTINUE                                                            A 2140
    EMINEL=ALOG(EMINE)                                                  A 2150
    DEE=(ALOG(EMAXE)-EMINEL)/FLOAT(NPTSE-1)                             A 2160
    DELE=DEE/3.0                                                        A 2170
    ICALL=1                                                             A 2180
    DO 670 NE=1,NPTSE                                                   A 2190
    TEL(NE)=EMINEL+FLOAT(NE-1)*DEE                                      A 2200
    TE(NE)=EXP(TEL(NE))                                                 A 2210
    CALL SPOL (TEL(NE),ER,RE,KMAX,ICALL,ANS)                            A 2220
670 RINE(NE)=EXP(ANS)                                                   A 2230
    DO 820 N=1,2                                                        A 2240
    DO 710 L=1,LEMAX                                                    A 2250
    ICALL=1                                                             A 2260
    DO 700 NE=1,NPTSE                                                   A 2270
    IF (TEL(NE).LT.EE(MEMAX)) GO TO 680                                 A 2280
    DIN(L,NE)=DE(MEMAX,L,N)                                             A 2290
    GO TO 700                                                           A 2300
680 IF (TEL(NE).GT.EE(1)) GO TO 690                                     A 2310
    DIN(L,NE)=DE(1,L,N)                                                 A 2320
    GO TO 700                                                           A 2330
690 CALL SPOL (TEL(NE),EE,DE(1,L,N),MEMAX,ICALL,DIN(L,NE))              A 2340
700 CONTINUE                                                            A 2350
710 CONTINUE                                                            A 2360
    DO 750 NE=1,NPTSE                                                   A 2370
    ICALL=1                                                             A 2380
    DO 740 I=1,IMAX                                                     A 2390
    ZRIN=Z(I)/RINE(NE)                                                  A 2400
    IF (ZRIN.LT.1.0) GO TO 730                                          A 2410
720 GE(NE,I,N)=0.0                                                      A 2420
    GO TO 740                                                           A 2430
730 CALL SPOL (ZRIN,ZE,DIN(1,NE),LEMAX,ICALL,ANS)                       A 2440
    IF (ANS.LT.0.0) GO TO 720                                           A 2450
    GE(NE,I,N)=TE(NE)*ANS/RINE(NE)                                      A 2460
740 CONTINUE                                                            A 2470
750 CONTINUE                                                            A 2480
    DO 790 L=1,LBMAX                                                    A 2490
    ICALL=1                                                             A 2500
    DO 780 NE=1,NPTSE                                                   A 2510
    IF (TEL(NE).LT.EB(MBMAX)) GO TO 760                                 A 2520
    DIN(L,NE)=DB(MBMAX,L,N)                                             A 2530
    GO TO 780                                                           A 2540
760 IF (TEL(NE).GT.EB(1)) GO TO 770                                     A 2550
    DIN(L,NE)=DB(1,L,N)                                                 A 2560
    GO TO 780                                                           A 2570
770 CALL SPOL (TEL(NE),EB,DB(1,L,N),MBMAX,ICALL,DIN(L,NE))              A 2580
780 CONTINUE                                                            A 2590
790 CONTINUE                                                            A 2600
    DO 810 NE=1,NPTSE                                                   A 2610
    ICALL=1                                                             A 2620
    DO 800 I=1,IMAX                                                     A 2630
    ZBIN=ALOG(Z(I)/TE(NE))                                              A 2640
    CALL SPOL (ZBIN,ZB,DIN(1,NE),LBMAX,ICALL,ANS)                       A 2650
800 GB(NE,I,N)=TE(NE)*EXP(ANS)                                          A 2660
810 CONTINUE                                                            A 2670
820 CONTINUE                                                            A 2680
830 PRINT 840                                                           A 2690
840 FORMAT ('1')                                                        A 2700
    PRINT 850                                                           A 2710
850 FORMAT ('0')                                                        A 2720
    READ (5,860,END=1420)                                               A 2730
    PRINT 860                                                           A 2740
860 FORMAT (72H                                                         A 2750
   1                  )                                                A 2760
    PRINT 870                                                           A 2770
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  870 FORMAT ('0JSMAX JPMAX JEMAX       EUNIT      TINTER')                A 2780
      READ 880, JSMAX,JPMAX,JEMAX,EUNIT,TINTER                            A 2790
      PRINT 880, JSMAX,JPMAX,JEMAX,EUNIT,TINTER                           A 2800
  880 FORMAT (3I6,1P2E12.5)                                               A 2810
      IF (TINTER.LE.0.0) TINTER=1.0                                       A 2820
      DELTAS=RADCON*DELP/4.0                                              A 2830
      DELTAP=TINTER*RADCON*DELP/4.0                                       A 2840
      DELTAE=TINTER*RADCON*DELE/4.0                                       A 2850
      IF (EUNIT.LE.0.0) EUNIT=1.0                                         A 2860
      ISOL=2                                                              A 2870
      IF (JSMAX.LT.3) GO TO 900                                           A 2880
      ISOL=1                                                              A 2890
      PRINT 140                                                           A 2900
      READ 60, (EPS(J),J=1,JSMAX)                                         A 2910
      PRINT 60, (EPS(J),J=1,JSMAX)                                        A 2920
      PRINT 890                                                           A 2930
  890 FORMAT ('0SOLAR PROTON SPECTRUM (/ENERGY/CM2)')                     A 2940
      READ 60, (S(J),J=1,JSMAX)                                           A 2950
      PRINT 60, (S(J),J=1,JSMAX)                                          A 2960
      CALL SPECTR (JSMAX,EPS,S,EUNIT,DELP,NLENS,TP(NFSTS),TPL(NFSTS),SOL  A 2970
     1(NFSTS))                                                            A 2980
  900 ITRP=2                                                              A 2990
      IF (JPMAX.LT.3) GO TO 920                                           A 3000
      ITRP=1                                                              A 3010
      PRINT 140                                                           A 3020
      READ 60, (EPS(J),J=1,JPMAX)                                         A 3030
      PRINT 60, (EPS(J),J=1,JPMAX)                                        A 3040
      PRINT 910                                                           A 3050
  910 FORMAT ('0TRAPPED PROTON SPECTRUM (/ENERGY/CM2/TIME)')              A 3060
      READ 60, (S(J),J=1,JPMAX)                                           A 3070
      PRINT 60, (S(J),J=1,JPMAX)                                          A 3080
      CALL SPECTR (JPMAX,EPS,S,EUNIT,DELP,NLENP,TP(NFSTP),TPL(NFSTP),SPG  A 3090
     1(NFSTP))                                                            A 3100
  920 ILEC=2                                                              A 3110
      IF (JEMAX.LT.3) GO TO 940                                           A 3120
      ILEC=1                                                              A 3130
      PRINT 140                                                           A 3140
      READ 60, (EPS(J),J=1,JEMAX)                                         A 3150
      PRINT 60, (EPS(J),J=1,JEMAX)                                        A 3160
      PRINT 930                                                           A 3170
  930 FORMAT ('0ELECTRON SPECTRUM (/ENERGY/CM2/TIME)')                    A 3180
      READ 60, (S(J),J=1,JEMAX)                                           A 3190
      PRINT 60, (S(J),J=1,JEMAX)                                          A 3200
      CALL SPECTR (JEMAX,EPS,S,EUNIT,DELE,NPTSE,TE,TEL,SEG)               A 3210
  940 GO TO (980,950), ISOL                                               A 3220
  950 DO 960 NP=NFSTS,NLSTS                                               A 3230
  960 SOL(NP)=0.0                                                         A 3240
      DO 970 J=1,2                                                        A 3250
      DO 970 I=1,IMAX                                                     A 3260
  970 DOSOL(I,J)=0.0                                                      A 3270
      GO TO 1010                                                          A 3280
  980 DO 1000 I=1,IMAX                                                    A 3290
      DO 990 NP=NFSTS,NLSTS                                               A 3300
  990 G(NP)=SOL(NP)*GP(NP,I)                                              A 3310
      CALL INT (DELTAS,G(NFSTS),NLENS,DOSOL(I,1))                         A 3320
 1000 CONTINUE                                                            A 3330
      CALL SPHERE (ZL,DOSOL(1,1),IMAX,DOSOL(1,2))                         A 3340
 1010 GO TO (1050,1020), ITRP                                             A 3350
 1020 DO 1030 NP=NFSTP,NLSTP                                              A 3360
 1030 SPG(NP)=0.0                                                         A 3370
      DO 1040 J=1,2                                                       A 3380
      DO 1040 I=1,IMAX                                                    A 3390
 1040 DOSP(I,J)=0.0                                                       A 3400
      GO TO 1080                                                          A 3410
 1050 DO 1070 I=1,IMAX                                                    A 3420
      DO 1060 NP=NFSTP,NLSTP                                              A 3430
 1060 G(NP)=SPG(NP)*GP(NP,I)                                              A 3440
      CALL INT (DELTAP,G(NFSTP),NLENP,DOSP(I,1))                          A 3450
 1070 CONTINUE                                                            A 3460
      CALL SPHERE (ZL,DOSP(1,1),IMAX,DOSP(1,2))                           A 3470
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1080 GO TO (1110,1090), ILEC                                                    A 3480
1090 DO 1100 J=1,2                                                              A 3490
     DO 1100 N=1,2                                                              A 3500
     DO 1100 I=1,IMAX                                                           A 3510
     DOSE(I,N,J)=0.0                                                            A 3520
1100 DOSB(I,N,J)=0.0                                                            A 3530
     GO TO 1160                                                                 A 3540
1110 DO 1150 N=1,2                                                              A 3550
     DO 1130 I=1,IMAX                                                           A 3560
     DO 1120 NE=1,NPTSE                                                         A 3570
     G(NE)=SEG(NE)*GE(NE,I,N)                                                   A 3580
1120 SPG(NE)=SEG(NE)*GB(NE,I,N)                                                 A 3590
     CALL INT (DELTAE,G,NPTSE,DOSE(I,N,1))                                      A 3600
     CALL INT (DELTAE,SPG,NPTSE,DOSB(I,N,1))                                    A 3610
1130 CONTINUE                                                                   A 3620
     GO TO (1150,1140), N                                                       A 3630
1140 CALL SPHERE (ZL,DOSE(1,N,1),IMAX,DOSE(1,N,2))                              A 3640
     CALL SPHERE (ZL,DOSB(1,N,1),IMAX,DOSB(1,N,2))                              A 3650
1150 CONTINUE                                                                   A 3660
1160 J=1                                                                        A 3670
     DO 1340 N=1,2                                                              A 3680
     GO TO (1170,1190), N                                                       A 3690
1170 PRINT 1180                                                                 A 3700
1180 FORMAT ('1DOSE AT TRANSMISSION SURFACE OF FINITE ALUMINUM SLAB SHI         A 3710
    1ELDS')                                                                     A 3720
     GO TO 1210                                                                 A 3730
1190 PRINT 1200                                                                 A 3740
1200 FORMAT ('1DOSE IN SEMI-INFINITE ALUMINUM MEDIUM')                          A 3750
1210 GO TO (1220,1240,1260,1280), IDET                                          A 3760
1220 PRINT 1230                                                                 A 3770
1230 FORMAT ('0RADS AL')                                                        A 3780
     GO TO 1300                                                                 A 3790
1240 PRINT 1250                                                                 A 3800
1250 FORMAT ('0RADS H2O')                                                       A 3810
     GO TO 1300                                                                 A 3820
1260 PRINT 1270                                                                 A 3830
1270 FORMAT ('0RADS SI')                                                        A 3840
     GO TO 1300                                                                 A 3850
1280 PRINT 1290                                                                 A 3860
1290 FORMAT ('0RADS SI-O2')                                                     A 3870
1300 PRINT 1310                                                                 A 3880
1310 FORMAT ('0   Z(MILS)      Z(MM)   Z(G/CM2)   ELECTRON    BREMS            A 3890
    1  EL+BR     TRP PROT   SOL PROT  EL+BR+TRP    TOTAL')                     A 3900
     PRINT 850                                                                  A 3910
     DO 1330 I=1,IMAX                                                           A 3920
     DOSEB=DOSE(I,N,J)+DOSB(I,N,J)                                              A 3930
     DOSEBP=DOSEB+DOSP(I,J)                                                     A 3940
     DOST=DOSEBP+DOSOL(I,J)                                                     A 3950
     PRINT 1320, ZM(I),ZMM(I),Z(I),DOSE(I,N,J),DOSB(I,N,J),DOSEB,DOSP(I        A 3960
    1,J),DOSOL(I,J),DOSEBP,DOST                                                 A 3970
1320 FORMAT (0P3F11.3,1P7E11.3)                                                 A 3980
1330 CONTINUE                                                                   A 3990
1340 CONTINUE                                                                   A 4000
     J=2                                                                        A 4010
     N=2                                                                        A 4020
     PRINT 1350                                                                 A 4030
1350 FORMAT ('11/2 DOSE AT CENTER OF ALUMINUM SPHERES')                         A 4040
     GO TO (1360,1370,1380,1390), IDET                                          A 4050
1360 PRINT 1230                                                                 A 4060
     GO TO 1400                                                                 A 4070
1370 PRINT 1250                                                                 A 4080
     GO TO 1400                                                                 A 4090
1380 PRINT 1270                                                                 A 4100
     GO TO 1400                                                                 A 4110
1390 PRINT 1290                                                                 A 4120
1400 PRINT 1310                                                                 A 4130
     PRINT 850                                                                  A 4140
     DO 1410 I=1,IMAX                                                           A 4150
     DOSEB=DOSE(I,N,J)+DOSB(I,N,J)                                              A 4160
     DOSEBP=DOSEB+DOSP(I,J)                                                     A 4170
```

```
      DOST=DOSEBP+DOSOL(I,J)                                                A 4180
      PRINT 1320, ZM(I),ZMM(I),Z(I),DOSE(I,N,J),DOSB(I,N,J),DOSEB,DOSP(I   A 4190
     1,J),DOSOL(I,J),DOSEBP,DOST                                           A 4200
 1410 CONTINUE                                                              A 4210
      GO TO 830                                                             A 4220
 1420 STOP                                                                  A 4230
      END                                                                   A 4240



C     SUBROUTINE SPECTR (JMAX,EPS,S,EUNIT,DELTA,NPTS,T,TL,SP), 1 NOV 79.    B   10
      SUBROUTINE SPECTR (JMAX,EPS,S,EUNIT,DELTA,NPTS,T,TL,SP)               B   20
      DIMENSION EPS(1),S(1),T(1),TL(1),SP(1),G(301)                         B   30
      IF (EPS(1).GT.0.0) GO TO 20                                           B   40
      ALPHA=S(1)                                                            B   50
      BETA=S(2)                                                             B   60
      IF (BETA.LE.0.0) BETA=1.0                                             B   70
      BETA=BETA/ALPHA                                                       B   80
      DO 10 N=1,NPTS                                                        B   90
      SP(N)=T(N)*BETA*EXP(-T(N)/ALPHA)                                      B  100
   10 G(N)=T(N)*SP(N)                                                       B  110
      GO TO 50                                                              B  120
   20 DO 30 J=1,JMAX                                                        B  130
      EPS(J)=ALOG(EPS(J))                                                   B  140
   30 S(J)=ALOG(EUNIT*S(J))                                                 B  150
      ICALL=1                                                               B  160
      DO 40 N=1,NPTS                                                        B  170
      CALL SPOL (TL(N),EPS,S,JMAX,ICALL,ANS)                                B  180
      SP(N)=T(N)*EXP(ANS)                                                   B  190
   40 G(N)=T(N)*SP(N)                                                       B  200
   50 CALL INT (DELTA,SP,NPTS,SIN)                                          B  210
      CALL INT (DELTA,G,NPTS,EBAR)                                          B  220
      EBAR=EBAR/SIN                                                         B  230
      PRINT 60                                                              B  240
   60 FORMAT ('0   INT SPEC    EAV(MEV)')                                   B  250
      PRINT 70, SIN,EBAR                                                    B  260
   70 FORMAT (1PE12.4,0PF12.5)                                              B  270
      RETURN                                                                B  280
      END                                                                   B  290



C     SUBROUTINE SPOL (S,X,Y,N,IN,T), 15 JAN 71.                            C   10
      SUBROUTINE SPOL (S,X,Y,N,IN,T)                                        C   20
C     CUBIC SPLINE INTERPOLATION WITH PARABOLIC RUNOUT.                     C   30
      DIMENSION  X(1),Y(1),E(101),U(101)                                    C   40
      GO TO (10,50), IN                                                     C   50
   10 IN=2                                                                  C   60
      N1=N-1                                                                C   70
      E(1)=1.0                                                              C   80
      U(1)=0.0                                                              C   90
      B1=X(2)-X(1)                                                          C  100
      C1=(Y(2)-Y(1))/B1                                                     C  110
      DO 20 J=2,N1                                                          C  120
      B2=X(J+1)-X(J)                                                        C  130
      C2=(Y(J+1)-Y(J))/B2                                                   C  140
      B=X(J+1)-X(J-1)                                                       C  150
      D=(C2-C1)/B                                                           C  160
      C=B1/B                                                                C  170
      B1=B2                                                                 C  180
      C1=C2                                                                 C  190
      P=C*E(J-1)+2.0                                                        C  200
      E(J)=(C-1.0)/P                                                        C  210
   20 U(J)=(D-C*U(J-1))/P                                                   C  220
      E(N)=U(N1)/(1.0-E(N1))                                                C  230
      DO 30 KK=1,N1                                                         C  240
      K=N-KK                                                                C  250
   30 E(K)=E(K)*E(K+1)+U(K)                                                 C  260
```

```
      IF (X(1).GT.X(N)) GO TO 40                                        C  270
      IDIR=0                                                            C  280
      MLB=0                                                             C  290
      MUB=N                                                             C  300
      GO TO 50                                                          C  310
   40 IDIR=1                                                            C  320
      MLB=N                                                             C  330
      MUB=0                                                             C  340
   50 IF (S.GE.X(MUB+IDIR)) GO TO 90                                    C  350
      IF (S.LE.X(MLB+1-IDIR)) GO TO 100                                 C  360
      ML=MLB                                                            C  370
      MU=MUB                                                            C  380
      GO TO 70                                                          C  390
   60 IF (IABS(MU-ML).LE.1) GO TO 110                                   C  400
   70 MAV=(ML+MU)/2                                                     C  410
      IF (S.LT.X(MAV)) GO TO 80                                         C  420
      ML=MAV                                                            C  430
      GO TO 60                                                          C  440
   80 MU=MAV                                                            C  450
      GO TO 60                                                          C  460
   90 MU=MUB+2*IDIR                                                     C  470
      GO TO 120                                                         C  480
  100 MU=MLB+2*(1-IDIR)                                                 C  490


C     SUBROUTINE INT(DELTA,G,N,RESULT), (N=1).                          D   10
      SUBROUTINE INT (DELTA,G,N,RESULT)                                 D   20
      DIMENSION G(1)                                                    D   30
      NL1=N-1                                                           D   40
      NL2=N-2                                                           D   50
      IF (FLOAT(N)-2.0*FLOAT(N/2)) 90,90,10                             D   60
   10 IF (N-1) 20,20,30                                                 D   70
   20 SIGMA=0.0                                                         D   80
      GO TO 80                                                          D   90
   30 IF (N-3) 40,40,50                                                 D  100
   40 SIGMA=G(1)+4.0*G(2)+G(3)                                          D  110
      GO TO 80                                                          D  120
   50 SUM4=0.0                                                          D  130
      DO 60 K=2,NL1,2                                                   D  140
   60 SUM4=SUM4+G(K)                                                    D  150
      SUM2=0.0                                                          D  160
      DO 70 K=3,NL2,2                                                   D  170
   70 SUM2=SUM2+G(K)                                                    D  180
      SIGMA=G(1)+4.0*SUM4+2.0*SUM2+G(N)                                 D  190
   80 RESULT=DELTA*SIGMA                                                D  200
      RETURN                                                            D  210
   90 IF (N-2) 100,100,110                                              D  220
  100 SIGMA=1.5*(G(1)+G(2))                                             D  230
      GO TO 80                                                          D  240
  110 IF (N-4) 120,120,130                                              D  250
  120 SIGMA=1.125*(G(1)+3.0*G(2)+3.0*G(3)+G(4))                         D  260
      GO TO 80                                                          D  270
  130 IF (N-6) 140,140,150                                              D  280
  140 SIGMA=G(1)+3.875*G(2)+2.625*G(3)+2.625*G(4)+3.875*G(5)+G(6)       D  290
      GO TO 80                                                          D  300
  150 IF (N-8) 160,160,170                                              D  310
  160 SIGMA=G(1)+3.875*G(2)+2.625*G(3)+2.625*G(4)+3.875*G(5)+2.0*G(6)+4.  D  320
     10*G(7)+G(8)                                                       D  330
      GO TO 80                                                          D  340
  170 SIG6=G(1)+3.875*G(2)+2.625*G(3)+2.625*G(4)+3.875*G(5)+G(6)        D  350
      SUM4=0.0                                                          D  360
      DO 180 K=7,NL1,2                                                  D  370
  180 SUM4=SUM4+G(K)                                                    D  380
      SUM2=0.0                                                          D  390
      DO 190 K=8,NL2,2                                                  D  400
  190 SUM2=SUM2+G(K)                                                    D  410
      SIGMA=SIG6+G(6)+4.0*SUM4+2.0*SUM2+G(N)                            D  420
      GO TO 80                                                          D  430
      END                                                               D  440
```

```
C     SUBROUTINE SPHERE (ZL,DOSE,IMAX,DOSPH), 30 AUG 79                    E   10
      SUBROUTINE SPHERE (ZL,DOSE,IMAX,DOSPH)                               E   20
      DIMENSION  ZL(1),DOSE(1),DOSL(50),DERV(50),DOSPH(1)                  E   30
      DO 10 I=1,IMAX                                                       E   40
      IF (DOSE(I).LE.0.0) GO TO 20                                         E   50
   10 DOSL(I)=ALOG(DOSE(I))                                                E   60
      I=IMAX+1                                                             E   70
   20 IMIX=I-1                                                             E   80
      IF (IMIX.LT.3) GO TO 40                                              E   90
      CALL SPLDRV (ZL,DOSL,DERV,IMIX)                                      E  100
      DO 30 I=1,IMIX                                                       E  110
   30 DOSPH(I)=DOSE(I)*(1.0-DERV(I))                                       E  120
   40 IMIX1=IMIX+1                                                         E  130
      IF (IMIX1.GT.IMAX) RETURN                                            E  140
      DO 50 I=IMIX1,IMAX                                                   E  150
   50 DOSPH(I)=0.0                                                         E  160
      RETURN                                                               E  170
      END                                                                  E  180
```

```
C     SUBROUTINE SPLDRV (X,Y,U,N), 28 AUG 79.                              F   10
      SUBROUTINE SPLDRV (X,Y,U,N)                                          F   20
C     CUBIC SPLINE WITH PARABOLIC RUNOUT.                                  F   30
C        U CONTAINS DERIVATIVES AT KNOTS                                   F   40
      DIMENSION  X(1),Y(1),E(101),U(1)                                     F   50
      N1=N-1                                                               F   60
      E(1)=1.0                                                             F   70
      U(1)=0.0                                                             F   80
      B1=X(2)-X(1)                                                         F   90
      C1=(Y(2)-Y(1))/B1                                                    F  100
      DO 10 J=2,N1                                                         F  110
      B2=X(J+1)-X(J)                                                       F  120
      C2=(Y(J+1)-Y(J))/B2                                                  F  130
      B=X(J+1)-X(J-1)                                                      F  140
      D=(C2-C1)/B                                                          F  150
      C=B1/B                                                               F  160
      B1=B2                                                                F  170
      C1=C2                                                                F  180
      P=C*E(J-1)+2.0                                                       F  190
      E(J)=(C-1.0)/P                                                       F  200
   10 U(J)=(D-C*U(J-1))/P                                                  F  210
      E(N)=U(N1)/(1.0-E(N1))                                               F  220
      DO 20 KK=1,N1                                                        F  230
      K=N-KK                                                               F  240
      E(K)=E(K)*E(K+1)+U(K)                                                F  250
      B2=X(K+1)-X(K)                                                       F  260
      U(K)=(Y(K+1)-Y(K))/B2-B2*(2.0*E(K)+E(K+1))                           F  270
   20 CONTINUE                                                             F  280
      U(N)=(Y(N)-Y(N1))/B2+B2*(2.0*E(N)+E(N1))                             F  290
      RETURN                                                               F  300
      END                                                                  F  310
```

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. TN 1116	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

SHIELDOSE: A Computer Code for Space-Shielding Radiation Dose Calculations

5. Publication Date

May 1980

6. Performing Organization Code

7. AUTHOR(S)

Stephen Seltzer

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, DC 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Office of Naval Research, Arlington, Va. 22217

NASA Goddard Space Flight Center, Greenbelt, Md. 20771

13. Type of Report & Period Covered

Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A computer code, SHIELDOSE, has been developed for the calculation of absorbed dose as a function of depth in aluminum shielding material of spacecraft, given the electron and proton fluences encountered in orbit. Absorbed dose, for small volumes of the detector materials Aℓ, H_2O, Si, and SiO_2, is evaluated in three geometries: (1) in a semi-infinite plane medium, (2) at the transmission surface of a finite-thickness slab, and (3) at the center of a solid sphere. Use of the code is described, and an extensive set of monoenergetic depth-dose data for the various detector materials and geometries is tabulated.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Computer code; depth-dose data; electrons; electron bremsstrahlung; protons; space shielding.

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