TABLE 8.4. Comparison of Maximum Penetration Depth t_{max} with CSDA Range[a] for Electrons of Energy T_o

T_o (MeV)	Z	t_{max} (mg/cm^2)	$\Re_{CSDA}$ (mg/cm^2)	$t_{max}/\Re_{CSDA}$
.05	13 (Al)	5.05	5.71	.88
.10	13 (Al)	15.44	18.64	.83
.15	13 (Al)	31.0	36.4	.85
.05	29 (Cu)	5.42	6.90	.79
.10	29 (Cu)	17.1	22.1	.77
.15	29 (Cu)	34.0	42.8	.79
.05	47 (Ag)	5.04	7.99	.63
.10	47 (Ag)	15.6	25.2	.62
.15	47 (Ag)	30.2	48.4	.62
.05	79 (Au)	4.73	9.88	.48
.10	79 (Au)	14.3	30.3	.47
.15	79 (Au)	27.6	57.5	.48

[a] After Bichsel (1968), based on experimental results of Gubernator and Flammersfeld, and CSDA ranges of Berger and Seltzer (1964). Reproduced with permission from H. Bichsel and Academic Press, Inc.

TABLE 8.5. $t_{max}/\Re_{CSDA}$ as Calculated by Spencer (1959) for a Plane Perpendicular Source of Electrons of Incident Energy T_o[a]

T_o (MeV)	Z = 6 (C)	13 (Al)	29 (Cu)	50 (Sn)	82 (Pb)
0.025	.95	.90	.80	—	—
0.05	.95	$.87_5$	$.77_5$	$.72_5$	—
0.1	.95	$.87_5$	$.77_5$	.70	.60
0.2	.95	$.87_5$	.75	$.67_5$	—
0.4	.95	$.87_5$	.75	$.67_5$	—
0.7	.95	$.87_5$	.75	$.67_5$	.55
1.0	.95	$.87_5$	$.77_5$	$.67_5$	$.57_5$
2	.95	.90	$.77_5$	.70	.60
4	.95	.90	.80	.75	—
10	.95	$.92_5$	.85	.80	—

[a] t_{max} was chosen as the tabulated penetration depth at which the dose first becomes zero. Data are not available where a dash is shown.

TABLE 8.6. Radiation Lengths for Selected Elements[a]

Element	Z	X_o (g/cm^2)
H	1	63.04
He	2	94.39
C	6	43.35
Al	13	24.46
Cu	29	13.04
Sn	50	8.919
Pb	82	6.496
U	92	6.124

[a] After Seltzer and Berger (1985).

TABLE 7-2

Ratio of averaged stopping powers, $\bar{\bar{S}}_{air}^{med}$ for a number of materials relative to air for a series of photon spectra. Data was calculated using equation 7-10. For comparison, $\bar{S}$ water/$\bar{S}$ air, determined using equation 6-45, is entered in the last column.

Spectrum Number*	Description	$\bar{\bar{S}}_{air}^{med}$ for Various Media					$\bar{\bar{S}}_{water}/\bar{\bar{S}}_{air}$
		Carbon	Bakelite	Lucite	Poly-styrene	Water	
1	60 kV_p, HVL—1.6 mm Al	1.022	1.094	1.125	1.137	1.140	1.141
2	100 kV_p, HVL—2.8 mm Al	1.022	1.095	1.126	1.138	1.140	1.141
3	250 kV_p, HVL—2.6 mm Cu	1.021	1.090	1.121	1.132	1.139	1.139
4	270 kV_p primary only, 2.7 mm Cu	1.020	1.089	1.120	1.131	1.138	1.138
5	270 kV_p primary plus scatter	1.022	1.094	1.124	1.136	1.139	1.137
6	400 kV_p, HVL—4 mm Cu	1.019	1.086	1.116	1.127	1.138	1.137
7	Cs-137	1.015	1.075	1.104	1.112	1.133	1.132
8	Co-60, primary only	1.009	1.071	1.099	1.105	1.129	1.128
9	Co-60, primary plus scatter	1.011	1.073	1.101	1.109	1.131	1.129
10	6 MV, Linac	1.000	1.064	1.092	1.098	1.123	1.120
11	8 MV, Linac	.993	1.058	1.085	1.091	1.117	1.114
12	12 MV, Schiff spect.	.976	1.043	1.069	1.073	1.102	1.100
13	18 MV, Schiff spect.	.965	1.033	1.059	1.063	1.092	1.091
14	26 MV, Betatron	.960	1.028	1.053	1.057	1.086	1.083
15	26 MV, Linac	.968	1.035	1.061	1.065	1.094	1.092
16	35 MV, Schiff spect.	.946	1.015	1.039	1.043	1.073	1.073
17	45 MV, Schiff spect.	.940	1.009	1.034	1.037	1.068	1.068

*Spectra 1 and 2 are taken from Yaffe (Y1); 3 and 6 are from Johns, appendix B, (J9); 4 and 5 are taken from Skarsgard, Table 8-1 (S8); 7 is monoenergetic radiation at 0.662 MeV; 8 has two energies at 1.17 and 1.33 MeV; 9 is taken from Bruce, Fig. 13x (B4); 10 is from Bentley et al., Fig. 3, calculated thick target (B8); 11 is taken from Levy et al., Fig. 5 (L3); 12 and 13 are calculated thin target spectra filtered by 2 cm tungsten and 2 cm water; 14 is from Sherman et al. representing an Allis Chalmers betatron (S9); 15 is from Levy et al., Fig. 6, experimental spectrum for Saggittaire (L4); 16 and 17 are calculated thin target spectra plus 2.2 cm tungsten and 10 cm of water representing high energy betatrons.

TABLE 7-3

Ratios of Averaged Restricted Stopping Powers for Water to Air, $\bar{\bar{L}}_{air}^{water}$

$\bar{\bar{L}}_{air}^{water}$ calculated by Nahum (N4) is compared to $\bar{\bar{S}}_{air}^{water}$ calculated using equation 7-10 and given in Table 7-2.

Photon Spectrum*	$\bar{\bar{S}}_{air}^{water}$ (eq. 7-10)	$\bar{\bar{L}}_{air}^{water}$ (Nahum) $\Delta = 10$ keV	% Diff.
8 ^{60}Co	1.130		
9 ^{60}Co plus scatter	1.131	1.135	+.4
10 6 MV	1.123	1.129	+.5
12 12 MV	1.102	1.109†	+.6
13 18 MV	1.092	1.101†	+.8
14 26 MV, betatron	1.087	1.092	+.4
15 26 MV, linac	1.094	1.099	+.5
16 35 MV	1.073	1.076†	+.3

*Spectrum 8 has two energies at 1.17 and 1.33 MeV; 9 is taken from Bruce, Fig. 13x (B4); 10 is from Bentley et al., Fig. 3, calculated thick target (B8); 12 and 13 are calculated thin target spectra filtered by 2 cm tungsten and 2 cm water; 14 is from Sherman et al. representing an Allis Chalmers betatron (S9); 15 is from Levy et al., Fig. 6, experimental spectrum for Saggittaire (L4); 16 is a calculated thin target spectrum plus 2.2 cm tungsten and 10 cm of water representing high energy betatron.

†Interpolated or extrapolated from Nahum's data

TABLE 7-4

Values of $\left(\frac{\bar{\mu}_{ab}}{\rho}\right)^{water}_{med}$ for Carbon, Bakelite, Lucite, and Polystyrene and $\left(\frac{\bar{\mu}_{ab}}{\rho}\right)^{med}_{air}$ for Water, Muscle, and Fat Determined Using Equation 7-12 for Photon Spectra Listed in Table 7-2.

	$\left(\frac{\bar{\mu}_{ab}}{\rho}\right)^{water}_{med}$				$\left(\frac{\bar{\mu}_{ab}}{\rho}\right)^{med}_{air}$			
(1) Photon Spectrum*	(2) Carbon	(3) Bakelite	(4) Lucite	(5) Polyst.	(6) Water	(7) Muscle	(8) Fat	(9) Bone
1. 60 kV_p	2.399	1.931	1.622	2.518	1.016	1.057	.617	4.873
2. 100 kV_p	2.112	1.758	1.519	2.152	1.026	1.062	.670	4.524
3. 250 kV_p	1.155	1.086	1.056	1.076	1.103	1.098	1.073	1.427
4. 270 kV_p	1.170	1.098	1.065	1.092	1.100	1.097	1.060	1.530
5. 270 kV_p	1.372	1.253	1.181	1.303	1.073	1.085	.924	2.668
6. 400 kV_p	1.129	1.065	1.040	1.050	1.108	1.101	1.095	1.217
7. ^{137}Cs	1.111	1.051	1.029	1.032	1.112	1.102	1.112	1.064
8. ^{60}Co	1.111	1.051	1.029	1.032	1.112	1.103	1.113	1.061
9. ^{60}Co	1.116	1.055	1.032	1.037	1.111	1.102	1.107	1.105
10. 6 MV	1.112	1.053	1.030	1.035	1.111	1.101	1.109	1.066
11. 8 MV	1.114	1.055	1.032	1.038	1.109	1.098	1.104	1.067
12. 12 MV	1.120	1.062	1.039	1.049	1.101	1.090	1.087	1.078
13. 18 MV	1.125	1.068	1.044	1.059	1.095	1.083	1.073	1.087
14. 26 MV	1.129	1.073	1.049	1.067	1.089	1.078	1.061	1.094
15. 26 MV	1.124	1.068	1.044	1.058	1.095	1.084	1.074	1.085
16. 35 MV	1.135	1.081	1.056	1.080	1.081	1.069	1.043	1.102
17. 45 MV	1.137	1.085	1.059	1.085	1.077	1.065	1.035	1.106

*Spectra 1 and 2 are taken from Yaffe (Y1); 3 and 6 are from Johns, appendix B, (J9); 4 and 5 are taken from Skarsgard, Table 8-1 (S8); 7 is monoenergetic radiation at 0.662 MeV; 8 has two energies at 1.17 and 1.33 MeV; 9 is taken from Bruce, Fig. 13x (B4); 10 is from Bentley et al., Fig. 3, calculated thick target (B8); 11 is taken from Levy et al., Fig. 5 (L3); 12 and 13 are calculated thin target spectra filtered by 2 cm tungsten and 2 cm water; 14 is from Sherman et al. representing an Allis Chalmers betatron (S9); 15 is from Levy et al., Fig. 6, experimental spectrum for Saggittaire (L4); 16 and 17 are calculated thin target spectra plus 2.2 cm tungsten and 10 cm of water representing high energy betatrons.

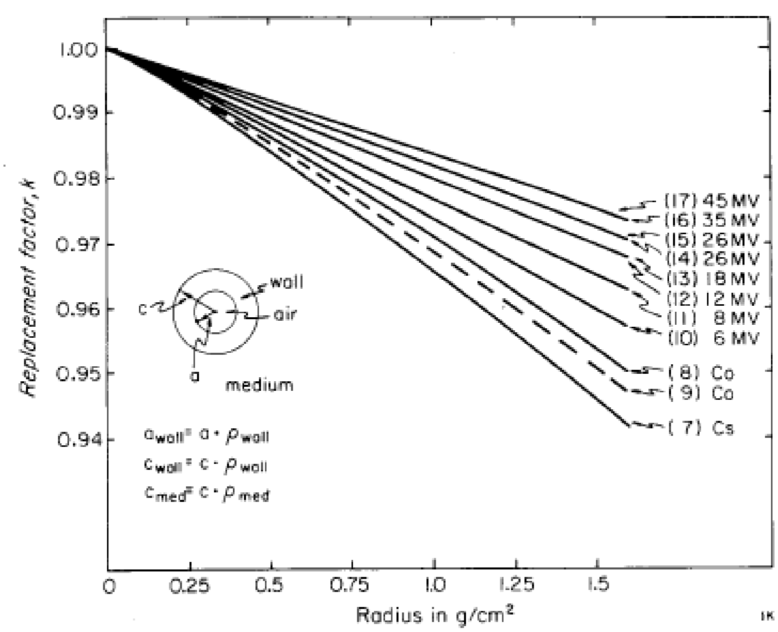

Figure 7-5. Attenuation correction factors as a function of the equivalent radius in cm of water. The insert shows how the three equivalent radii (a_{wall}, c_{wall}, c_{med}) are calculated. The numbers affixed to the graph correspond to the spectra of Table 7-2.