MASTER

Energy Dependence of Metallic-Encapsulated
Thermoluminescent Dosimeters

Annual Report

G. G. Simons
Kansas State University
Department of Nuclear Engineering
Manhattan, Kansas

June 1980

Prepared for

The U.S. Department of Energy

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Abstract

The gamma-ray energy responses of encapsulated ^7LiF and $\text{CaF}_2\text{:Mn}$ thermoluminescent dosimeters were measured and compared to calculated values. This study was performed in order to improve the accuracy of gamma-ray heating measurements made in polyenergetic gamma-ray fields such as Argonne National Laboratory's Zero Power Reactors. Equations used in the development of the TERC/III computer code and code input parameters are specified. A section on TLD precision is also included. Comparisons between calculations and experiments are reported for a gamma-ray energy range of 0.122 to 1.33 MeV and encasement media with a range of atomic numbers from 13 to 82.

I. Introduction

Thermoluminescent dosimeters are receiving international attention for measuring the gamma-ray energy deposition in various regions of critical assemblies such as the Argonne National Laboratory (ANL) Zero Power Reactors (ZPRs). This interest was largely generated by the successful demonstration of the technique by scientists within the ANL Applied Physics (AP) Division (1-4). Intercomparison of the results obtainable, and procedures used, by the experts in the field provides the opportunity for exchanging information between the United States and foreign nations. Moreover, careful examination of the procedures used will enhance the understanding of the subject. Data reported in this report may allow measurement of more accurate gamma-ray heating data through identification and resolution of systematic errors.

One area of immediate interest in the interpretation of TLD excitation was the subject of this study -- the gamma-ray energy response of encapsulated TLDs. A method devised by Burlin (5) served as the basis for the TLD Energy Response Code (TERC) computer code written for the analyses of gamma-ray heating experiments at ANL (6). The latest version, TERC/III, was used in this investigation to calculate the energy response of encased TLDs. These calculations were performed as a function of the TLD and encasement materials, TLD size, and gamma-ray energy.

2.0. IONIZATION THEORY

Theory appropriate to describe the relationship between the experimentally determinable quantity -- the absorbed dose in the TLD, and the desired quantity -- the absorbed dose in the material surrounding the TLD, must account for interactions which occur inside the TLD. This theory, referred to as solid-state ionization theory, makes allowances for the sum of contributions from electrons produced in the surrounding medium which excite the TLD and those electrons produced inside the TLD. These two gamma ray induced electron sources result in a total TLD absorbed dose which is determined indirectly through the measurement of the TL. The fraction of the total dose stemming from both media -- the surrounding material and the TLD, must be calculated since an experimental technique has not been developed for measuring the individual components.

Solid state ionization theory is based upon a gamma-ray energy T_Y dependent parameter, the theoretically derived dose ratio

$$f(T_Y) = \frac{E_D}{E_M} \quad (1)$$

where E_D is the absorbed dose in the TLD and E_M is the absorbed dose in the surrounding medium. If $f(T_Y)$ is known and E_D evaluated from the TL emitted by the TLD following irradiation, the desired quantity -- the absorbed dose in the surrounding medium, is determined using the equation

$$E_M = \frac{E_D}{f(T_Y)} \quad (2)$$

The general expression developed for calculating $f(T_Y)$ is (7)

$$f(T_Y) = F_M(T_Y) \int_0^T N_M(T_Y, T_0) dT_0 \left(\frac{1}{T_0} \int_0^{T_0} \frac{S_{coll_D}(T)}{S_{coll_M}(T)} dT \right) +$$

$$+ F_D(T_Y) \frac{\left[\frac{\mu_{en}(T_Y)}{\rho} \right]_D}{\left[\frac{\mu_{en}(T_Y)}{\rho} \right]_M} \quad (3)$$

This equation is easily understood when rewritten as

$$f(T_Y) = F_M(T_Y) f_s(T_Y) + F_D(T_Y) f_l(T_Y) \quad (4)$$

where

$f_s(T_Y)$ = f ratio assuming small cavity theory

$f_l(T_Y)$ = f ratio assuming large cavity theory

$F_M(T_Y)$ = primary electron attenuation factor in the TLD

$F_D(T_Y)$ = buildup factor for primary electrons generated in the TLD.

If $\beta(T_Y)$ is defined as the attenuation coefficient for electrons of energy T_Y , $F_M(T_Y)$ becomes

$$F_M(T_Y) = \int_0^g e^{-\beta(T_Y)x} dx / \int_0^g dx$$

$$= \frac{1 - \exp[-\beta(T_Y)g]}{\beta(T_Y)g} \quad (5)$$

and

$$F_D(T_Y) = 1 - F_M(T_Y) \quad (6)$$

g is defined as the mean chord length of the TLD

$$g = \frac{4V_D}{S} \quad (g/cm^2) \quad (7)$$

where V is the volume, ρ the density and S is the surface area of the TLD. For all of the calculations reported, the Katz and Penfold (8) expression

$$\beta(T_Y) = - \frac{\ln 0.01}{R(T_Y)} \quad (8)$$

was used to estimate $\beta(T_Y)$ where the range of the primary electron $R(T_Y)$ of maximum energy T_Y was calculated using

$$R(T_Y) = \begin{cases} 0.412 T_Y^n & \text{for } 0.01 \leq T_Y \leq 3 \text{ MeV} \\ 0.530 T_Y - 0.106 & \text{for } 3.0 < T_Y \leq 20 \text{ MeV} \end{cases} \quad (9)$$

and

$$n = 1.265 - 0.0954 \ln T_Y.$$

The large-cavity term $f_L(T_Y)$ in Eq. 3 is derived by assuming that the TLD is much larger than the range of the primary electrons. Therefore, the energy absorbed in the TLD is only a function of the properties of the TLD material. Similarly, the energy absorbed in the surrounding material is a function of the properties of the material. For a gamma-ray source, the energy absorbed is a function of the mass-energy absorption coefficient in either case. Hence, the energy absorbed in the TLD per unit mass can be related to the energy absorbed per unit mass in the surrounding medium, by the ratio of the mass energy absorption coefficients,

$$\frac{E_D}{E_M} = f_L(T_Y) = \frac{(\mu_{en}/\rho)_D}{(\mu_{en}/\rho)_M} \quad (10)$$

Evaluation of the small cavity term $f_S(T_Y)$ requires calculating the electron spectrum $N_M(T_Y, T_O)$ and the mass stopping powers $S_{coll}(T)$. Spectrum calculations (7) included both Compton and pair production interactions. For Compton scattered gamma rays, number of electrons scattered into (T_O, dT_O) per unit of gamma-ray flux is given by the Klein-Nishina cross section (9)

$$\frac{d\sigma}{dT_O}(T_Y) = \pi r_o^2 \frac{m_o c^2}{T_Y} \left\{ 2 + \left(\frac{T_O}{T_Y - T_O} \right)^2 \left[\left(\frac{m_o c^2}{T_Y} \right)^2 + (T_Y - T_O) \left(\frac{T_O - 2m_o c^2}{T_Y T_O} \right) \right] \right\} \quad (11)$$

The fraction of energy lost via the Compton scattering process and given to electrons in (T_o, dT_o) is

$$N_{CE}(T_Y, T_o) dT_o = \frac{dT_o \frac{d\sigma}{dT_o} (T_Y) T_o}{\int_0^{T_Y} dT_o \frac{d\sigma}{dT_o} (T_Y) T_o} \quad (12)$$

The positron energy distribution from the pair production process is given by (10)

$$\begin{aligned} \frac{d\sigma}{dT_+} = & \frac{\phi}{T_Y} \frac{p_+ p_-}{3} \left\{ -\frac{4}{3} - 2E_+ E_- \frac{p_+^2 + p_-^2}{p_+^2 p_-^2} + m_o^2 c^4 \left(\frac{E_+ \epsilon_-}{p_-^3} + \frac{E_- \epsilon_+}{p_+^3} - \frac{\epsilon_+ \epsilon_-}{p_+ p_-} \right) \right. \\ & + L \left[\frac{T_Y^3}{3 p_+ p_-} (E_+^2 E_-^2 + p_+^2 p_-^2) - \frac{8}{3} \frac{E_+ E_-}{p_+ p_-} - T_Y \frac{m_o^2 c^4}{2 p_+ p_-} \left(\frac{E_+ E_- - p_-^2}{p_-^3} \epsilon_- \right. \right. \\ & \left. \left. + \frac{E_+ E_- - p_+^2}{p_+^3} \epsilon_+ + \frac{2 T_Y E_+ E_-}{p_+ p_-} \right) \right] \right\} \end{aligned} \quad (13)$$

where E_+ = the total energy of the positive electron,

E_- = the total energy of the negative electron,

$p_{\pm}$ = the momentum of the positive/negative electron multiplied by c ,

$$\epsilon_{\pm} = 2 \ln \frac{E_{\pm} + p_{\pm}}{m_o c^2}$$

$$L = \frac{2 \ln E_+ E_- + p_+ p_- + m_o^2 c^4}{T_Y m_o c^2}$$

$m_o c^2$ = rest mass of electron

and $\phi = \frac{Z^2}{137} r_o^2$. This equation is useful for both positive and negative electrons and produces a symmetric distribution. The asymmetry introduced by the coulombic attraction or repulsion of the nucleus was not accounted for, nor was the effect of screening.

When the quantity $\gamma = 100 \frac{T_Y mc^2}{E_+ E_- Z^{1/3}}$ is less than 15, the following equation, which does include screening, was used:

$$\frac{d\sigma}{dT_+} = 4 \pi \frac{1}{T_Y^3} (E_+^2 + E_-^2 + \frac{2}{3} E_+ E_-) \left[\ln \frac{2E_+ E_-}{T_Y m_o c^2} - \frac{1}{2} - C(\gamma) \right] \quad (14)$$

The function $C(\gamma)$ was found by second order polynomial interpolation within a table of values. The values and interpolation curves are shown in Fig. 2.1.

Collision mass stopping powers were calculated using the equation (11)

$$S_{coll} = \frac{2\pi N_a r_o^2 m_o c^2}{\beta^2} \frac{Z}{A} \left\{ \ln \left(\frac{\tau^t (\tau+2)}{2 (I/m_o c^2)^2} \right) + F - \delta \right\} \quad (15)$$

where N_a = Avogadro's number (6.022×10^{23} electrons/mole),

r_o^2 = radius of first Bohr orbit, (7.9403×10^{-26} cm²),

$m_o c^2$ = rest mass energy of electron, (0.510976 MeV),

τ = kinetic energy of electron in units of $m_o c^2$,

$\beta = [\tau(\tau+2)]^{1/2}/(\tau+1)$,

Z = atomic number of medium,

A = atomic weight of medium,

$F = 1 - \beta^2 + [\tau^2/8 - (2\tau+1) \ln 2]/(\tau+1)^2$,

δ = density effect correction,

I = ionization potential of medium (eV).

δ is given by (12)

$$\delta = \begin{cases} 0 & , x < x_o \\ 4.606x + C + a(x_1 - x)^m, & , x_o \leq x < x_1 \\ 4.606x + C & , x \leq x_1 \end{cases}$$

where

$$x = (\log_{10} e) \frac{1}{2} \ln [\beta^2/(1-\beta^2)] = 0.21715 \ln [\beta^2/(1-\beta^2)].$$

The parameters C , a , x_1 , x_2 , m , Z , A , and I are input to the TERC/III code (see Section 3.0) for each encasement material.

Dose ratios were calculated using the TERC/III computer code (written by the principal investigator) for each encasement material investigated (see Appendices A and B). The energy dependence of $f(T_Y)$ is shown in Figs. 2.2 and 2.3 for the $1 \times 1 \times 6$ mm ^7LiF and $\text{CaF}_2:\text{Mn}$ TLDs. As shown, $f(T_Y)$ varies rapidly over the gamma-ray energy range under investigation -- 0.122 to 1.33 MeV. Moreover, as expected, the closer the encasement material and TLD atomic number, the nearer $f(T_Y)$ is to unity. For the matched dosimeter case, i.e., a LiF TLD encased in LiF the dose ratio is exactly equal to one.

Fig. 2.1. $C(\gamma)$ vs γ for Pair Production Screening Correction

Fig. 2.2. Dose ratio $f(T_\gamma)$ for ^7LiF encased TLDs calculated using the TERC/III computer code.

Fig. 2.3. Dose ratio $f(T_\gamma)$ for CaF₂:Mn encased TLDs calculated using the TERC/III computer code.

3.0 TERC/III INPUT PARAMETERS

3.1 Mean Chord Length

Correction for the attenuation of the encasement material electrons requires knowledge of the TLDs volume, surface area, and density. Since both the ^7LiF and $\text{CaF}_2\text{:Mn}$ TLDs used in this investigation were $1 \times 1 \times 6$ mm, their volumes and surface areas were equal to 0.006 cm^3 and 0.26 cm^2 respectively. Using a density of 2.63 g/cm^3 for ^7LiF , the mean chord length is 0.243 g/cm^2 . Likewise, for $\text{CaF}_2\text{:Mn}$, with a density of 3.04 g/cm^3 , the mean chord length is greater than ^7LiF by the ratio of the densities, i.e., equal to 0.2806 g/cm^2 . The TERC/III computer code accepts only the mean chord length. Hence these must be calculated a priori using Eq. (7).

3.2 Collision Mass Stopping Power Ratios

Collision mass stopping power ratios, calculated using Eq. (15), required knowledge of the parameters listed in Tables 3.1 and 3.2. The ionization potential is subject to large errors, however, the final values of mass stopping powers is reasonably insensitive to variations in this parameter.

3.3 Mass Energy Absorption Coefficients

Selection of the mass energy absorption coefficients would have a significant impact on the final values of dose ratios. Coefficients used in this study were taken from the Storm and Israel compilation (13).

Table 3.1. Partial Compilation of Input Parameter used to Calculate the Dose Ratio $[f(T_Y)]$ using TERC/III for $1 \times 1 \times 6$ mm ^7LiF and CaF_2 TLDs.

Material	$\langle Z/A \rangle^a$	Density ρ (g/cm ³)	Mean Chord ^b Length, g (g/cm ²)	Ionization ^c Potential, I (eV)	Density effect Parameters				
					c	a	m	x_0	x_1
^7LiF	0.4616	2.63	0.2430	86.5	-3.07	0.456	2.76	-0.07	2.0
CaF_2	0.4867	3.04	0.2806	158	-4.50	0.100	3.40	0.08	3.0

^aCalculated using the equation: $\langle Z/A \rangle = \sum_j \epsilon_j (Z_j/A_j)$.

For ^7LiF : $\epsilon_1 = 0.269$, $Z_1 = 3$, $A_1 = 7$, $\epsilon_2 = 0.731$, $Z_2 = 9$, and $A_2 = 18.9984$

For CaF_2 : $\epsilon_1 = 0.513$, $Z_1 = 20$, $A_1 = 40.08$, $\epsilon_2 = 0.487$, $Z_2 = 9$, and $A_2 = 18.9984$

^b $g = 4V\rho/s$ (g/cm²)

^c $\ln I = (Z/A)^{-1} \sum_j \epsilon_j (Z_j/A_j) \ln I_j$

Table 3.2. Partial Compilation of Input Parameters Used
to Calculate the Dose Ratio $[f(T_Y)]$ Using
TERC/III for Each Encasement Material

Material	Atomic Number Z	Atomic Weight A	Ionization Potential I (eV)	Density Effect Parameters				
				c	a	m	X_0	X_1
Lead	82	207.2	826.	-6.21	0.355	2.64	0.4	3.0
Tantalum	73	180.9	701	-6.03	0.028	3.91	0.30	4.0
Tin	50	118.7	517	-6.28	0.404	2.52	0.20	3.0
Zirconium	40	91.22	420	-5.39	0.250	2.80	0.20	3.0
Copper	29	63.57	323	-4.43	0.109	3.39	0.20	3.0
Iron	26	55.84	273	-4.62	0.127	3.29	0.10	3.0
Stainless Steel	25.23 ^{a'}	54.98 ^{b'}	273 ^{c'}	-4.62	0.127	3.29	0.10	3.0
Aluminum	13	27	164	-4.21	0.091	3.51	0.05	3.0

$$a'_Z = \sum_j E_j Z_j \quad \text{where } E_j \equiv \text{fraction by weight of the } j\text{th element}$$

$$b'_A = \sum_j E_j A_j$$

$$c'_{\ln I} = (Z/A)^{-1} \sum_j E_j (Z_j/A_j) \ln I_j$$

4.0 EXPERIMENTAL EQUIPMENT AND DEVICES

4.1 Data Acquisition Equipment

Described in detail in Ref. (15).

4.2 Annealing and Handling Equipment

Described in detail in Ref. (15).

4.3 TLDs

Described in detail in Ref. (15).

4.4 Gamma-ray Sources

The six gamma-ray sources, listed in Table 4.1, were purchased from Isotope Products Laboratories. Each source was individually encapsulated in a special capsule as shown in Fig. 4.1. Source material was made as small as possible in order to approximate a point source. The capsule was designed to provide for radial symmetry and minimum attenuation of the primary gamma rays by the encapsulation material.

4.5 Encasement Materials

Encasement materials used to experimentally evaluate relative values of f for this study are listed in Table 4.2. As shown in this table, each sleeve had a desired nominal thickness of 0.7 g/cm^2 .

Table 4.1. Gamma-ray sources purchased for use in the TLD energy response study.

Nuclide	Half-life	Gamma-ray Energy (MeV)	Activity (mCi)	Calibration Date
Co-57	270 day	0.122, 0.136	5.26 ± 0.53	7/18/79
Ce-141	32.5 day	0.145 ^a	6.40 ± 0.64	7/18/79
Hg-203	47 day	0.279	5.15 ± 0.52	7/18/79
Sn-113	115 day	0.393 ^b	5.86 ± 0.59	8/01/79
Cs-137	30 yr	0.662	5.27 ± 0.21	8/01/79
Co-60	5.3 yr	1.173, 1.333	5.06 ± 0.23	8/01/79

^aCe-141 36.0 keV x-ray plus trace amount of Ce-139 165.8 γ -ray and 33.4 keV x-ray.

^bIn-KB1 24.0, 24.2, and 27.3 keV x-ray.

X-rays were not included in the analysis since all encasements, except aluminum, effectively removed these x-rays.

Table 4.2. Encasement materials used during measurement of the energy response of encased ^7LiF and CaF_2 TLDs.

Material	Quantity	Atomic Number	Density (g/cm^3)	Hole Diameter (cm)	Wall Thickness (g/cm^2)
Lead	10	82	11.34	0.151	0.734
Tantalum	10	73	16.60	0.151	0.696
Tin	10	50	7.30	0.151	0.608
Zirconium	10	40	6.50	0.151	0.541
Copper	10	29	8.94	0.163	0.694
Iron	10	26	7.87	0.151	0.656
Stainless Steel	10	--	7.80	0.151	0.693
Aluminum	10	13	2.70	0.151	0.514
LiF	10	--	2.63	0.151	0.483

Fig. 4.1. Gamma-ray Source Capsule for the TLD Energy Response Study.

5.0 PRECISION OF TLD RESPONSE

The precision of the energy response data was determined using standard statistical procedures. An intercomparison of the precision obtained is presented based upon using two precision improvement techniques -- precision subset selection from a single batch and individual sensitivity evaluation for TLDs from a single batch. These form the bases for the intra-batch sensitivity selection procedure which was initiated at Argonne National Laboratory (14). Those concepts are reviewed and applied to evaluate the precision of the subject research data.

Measurement of absorbed doses having precision better than 3% is difficult when TLDs are used as the radiation sensitive device. Since TLDs are relative devices, they must be calibrated before the relationship between TL emission and absorbed dose is known for any given TLD. However, each time a TLD is irradiated, readout, annealed, and handled throughout the course of the calibration procedure, its sensitivity to gamma radiation changes. It is virtually impossible to calibrate a single TLD. This fact has forced most users of TLDs to use the group approach and work with a set or group of TLDs which have similar sensitivities. Absolute dose measurements are obtained by determining the TL as a function of absorbed dose for a subgroup of TLDs picked from the parent group. The calibration subgroup of TLDs are not used in future experimental investigations. Instead the absorbed doses for the unknown radiation field are determined using other TLDs selected from the group. Therefore, an interesting condition exists -- the TL versus absorbed dose relationship is not really known for the TLD used to measure absolute absorbed doses. The precision and accuracy

of TLD derived data are only as good as the spread in the individual sensitivity of the TLDs within the group.

5.1 Batch Grouping

The easiest and most common procedure for selecting a group of TLDs with similar sensitivity is batch grouping. A batch is defined as TLDs fabricated at the same time from a single composition. The number of TLDs obtained per batch should be adequate for performing the measurement of the unknown absorbed doses plus TLDs to be used for calibration and measurement of the precision per batch. The number of TLDs required for calibration depends upon the absorbed dose range. Precision per batch is obtained by exposing the statistical subgroup to a given dose and calculating the mean and standard deviation of the TLD response. This procedure assumes that all irradiations are performed using new TLDs. Reuse of TLDs add complexity in determining the errors associated with sensitivity shifts per use.

Energy response data, obtained during this study, were measured using new TLDs. One batch each of 1000 ^7LiF and $\text{CaF}_2\text{:Mn}$ TLDs were purchased. Approximately 150 per batch were reserved for calibration purposes. The remainder were used to measure the energy response data. Since the experimental procedure was not restricted just to batch grouping a statistical subset was not required. However, the mean and standard deviation obtained (the procedure is explained later) for each batch was nominally 4.8% and 6.3% for ^7LiF and $\text{CaF}_2\text{:Mn}$ TLDs, respectively. Procedures used for improving the precision for each type of TLD were precision subset grouping and individual sensitivity selection.

5.2 Precision Subset Selection

Intra-batch grouping, to obtain precision subsets per batch of TLDs, involved measuring the relative sensitivity of each TLD. Sensitivity was measured by first annealing, and then irradiating sets of nominally 202 TLDs at one time. Each bare TLD was placed on the styrofoam-pad irradiation device at a radius of 20 cm. A nominal 3 mCi ^{137}Cs source was centered on the circle of the elevated pad and the TLDs exposed for 8 hrs in a dark room. Following irradiation the TLDs were removed from the pad, stored in the dark for exactly 24 hrs and then readout using a 2 min/TLD read cycle. An example sensitivity data set for ^7LiF is shown in Fig. 5.1.

Each precision subset was analyzed by assuming an ideal trial set. That is, the TL response values for each set were independent of each other and were measured under identical conditions. Using the Sort and Dose (SAD) computer code, the mean value, $\bar{C}$, per precision subset of N TLDs was calculated using the expression

$$\bar{C} = \frac{1}{N} \sum_{i=1}^N C_i$$

where C_i was the nanocoulomb reading for the i^{th} TLD. The sample standard deviation, S, was estimated using

$$S^2 = \frac{1}{N-1} \sum_{i=1}^N (C_i - \bar{C})^2.$$

Calculated means and standard deviations for each subset of nominally 202 TLDs are listed in column seven of Tables 5.1 and 5.2.

A preliminary test of the parent distribution of the C_i values has been initiated. The experimental frequency distribution F_i was compared to the normalized Gaussian distribution $P(C, \bar{C}, S)$

$$P(C, \bar{C}, S) = N \Delta z P(z, 0, 1)$$

where

$$z = \frac{|C - \bar{C}|}{S}$$

$$\Delta z = \frac{\Delta C}{S}$$

and

$$P(z; 0, 1) = \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{1}{2} \left(\frac{C_i - \bar{C}}{S}\right)^2\right]$$

Example comparisons for ^7LiF and $\text{CaF}_2\text{:Mn}$ TLDs are shown in Figs. 5.2 and 5.3. Further work is needed to characterize the frequency of the TLD responses.

Following the statistical analysis of each data set, a precision subset was established. In the precision subset, all TLD responses which were within $\pm 5\%$ of the subset mean were retained. TLDs whose responses exceeded this band were eliminated. Results of this study are shown in Tables 5.1 and 5.2. For ^7LiF TLDs, 29% were removed from the sets; while 22% of the $\text{CaF}_2\text{:Mn}$ TLDs had responses exceeding the 5% limit. The standard deviation, for these new commercial grade TLDs, was decreased from 4.8% and 6.3% to 2.7% for ^7LiF and $\text{CaF}_2\text{:Mn}$ TLDs, respectively.

5.3 Individual Sensitivity

Further improvement in the precision of the TLD energy response data was made by applying individual sensitivity corrections.

Fig. 5.1. Sensitivity Data Measured for ^7LiF TLDs Exposed to a 3 mCi ^{137}Cs Gamma-Ray Source.

Fig. 5.2. Frequency response of 1x1x6 mm ^7LiF TLDs from a subset of 202 dosimeters.

Fig. 5.3. Frequency response of CaF₂:Mn TLDs from a subset of 204 dosimeters.

Table 5.1. Summary of sensitivity selection results for the 1x1x6 mm ^7LiF TLDs exposed to a nominal 3 mCi ^{137}Cs .

Sort Number	Number of TLDs				TLD Response, C_i (nc)			
	Total, N	5% Above $\bar{C}$	Within $\pm 5\%$	5% Below $\bar{C}$	Before Sorting			Precision Subset
					Maximum	$\bar{C} \pm S$	Minimum	$\bar{C} \pm S$
1	203	41	133	29	2.167	1.951 ± 0.103	1.677	1.943 ± 0.048
2	204	36	145	23	2.185	1.912 ± 0.094	1.637	1.905 ± 0.052
3	202	38	151	13	2.180	1.939 ± 0.086	1.695	1.919 ± 0.049
4	202	34	146	22	2.145	1.867 ± 0.088	1.646	1.857 ± 0.049
	$\Sigma 811$	149	575	87	Av. 2.169 ± 0.018	1.917 ± 0.037	1.664 ± 0.027	1.906 ± 0.036

Table 5.2. Summary of sensitivity selection results for the 1x1x6 mm CaF_2Mn TLDs.

Sort Number	Total N	TLD Response, C_1 (nc)						
		Number of TLDs			Before Sorting			Precision Subset
		Above 5%	Within $\pm 5\%$	Below 5%	Maximum	$\bar{C} \pm S$	Minimum	$\bar{C} \pm S$
1	204	19	162	23	3.645	3.150 ± 0.161	2.119	3.164 ± 0.088
2	204	7	169	28	3.481	3.218 ± 0.134	2.757	3.248 ± 0.088
3	206	6	152	48	3.390	2.904 ± 0.154	2.028	2.960 ± 0.079
4	204	16	156	32	3.954	2.918 ± 0.150	2.558	2.935 ± 0.076
		48	639	131	Av. 3.618 ± 0.248	3.048 ± 0.160	2.366 ± 0.349	3.077 ± 0.153

6.0 RESULTS^a6.1 Experimental Data

The TL emitted from encapsulated $\text{CaF}_2\text{:Mn}$ and high sensitivity ^7LiF TLDs was measured following irradiation with gamma rays. A range of atomic numbers from 13 to 82, for the media surrounding each type of TLD, was investigated using the encasement materials described in Section 4.0. Gamma-ray energies studied were 0.122, 0.136; 0.145, 0.279, 0.393, 0.662, and 1.173, 1.333 MeV. Characteristics of the gamma-ray sources were presented in Section 4.0. Since this study was based upon the relative response of encapsulated TLDs, each reported value was normalized to the appropriate TL for an iron encased TLD.

Each dosimeter, used in this study, consisted of a cylindrical sleeve which housed a 1 x 1 x 6 mm TLD. These dosimeters were nominally 3.2 mm in Dia. x 12.7 mm long. In order to reduce the standard deviation associated with each final energy response result, ten similar TLDs were individually encased in identical sleeve materials. These sets of dosimeters, containing eight encasement materials and one type of TLD, were simultaneously irradiated using a single gamma-ray source. Raw TL data, recorded from each TLD, were processed to obtain the average TL per group of ten TLDs. These group averaged values were then normalized relative to the mean value of the iron encased TLD. The experimental results are listed in Tables 6.1 and 6.2 for ^7LiF and $\text{CaF}_2\text{:Mn}$ TLDs processed using this direct procedure. These data represent the results obtained using groups of TLDs from a precision subset (see Section 5.0). Their relative TL, measured during the individual sensitivity evaluation, was within $\pm 6\%$ of the average

^a Edited material from Ref. (15) is included for completeness.

TL for the original group of 200 new TLDs.

An alternate data reduction technique, based upon the sensitivity of the individual TLDs, was also used to process these data. This involved using the sensitivity factor measured during the intra-batch sensitivity selection experiments (see Section 5.0). A correction factor was applied to each TL value recorded following irradiation of the encased TLDs which had different individual sensitivities to gamma radiation. Within the errors of the sensitivity data, the sensitivity of all the TLDs were forced to be equal to the average value of the corresponding precision subset. After applying the sensitivity correction, the data were averaged and normalized to the iron encasement result. Relative energy response results are listed in Tables 6.3 and 6.4 for the two types of TLDs corrected for individual sensitivity.

6.2 Comparisons Between Experiment and Calculation

Comparisons between the calculated (C) energy responses of an encapsulated TLDs and the measured (E) responses were completed for all combinations of TLD type, gamma-ray energy, and encasement material. Direct C/E calculations were obtained using (15)

$$C = \frac{E_{Di}^{calc}}{E_{Dj}^{calc}} = \frac{\left(\frac{\mu_{en}(T_Y)}{\rho} \right)_{Mi} f_i(T_Y)}{\left(\frac{\mu_{en}(T)}{\rho} \right)_{Mj} f_j(T_Y)}$$

and

$$E = \frac{E_{Di}^{exp}}{E_{Dj}^{exp}}$$

Calculated values of C were based upon the dose ratio and mass energy absorption coefficients generated using the TERC/III code. Specific

numbers are listed in Tables 6.5 and 6.6 for both types of TLDs investigated. Iron sleeves were chosen as the reference in order to provide C results directly comparable to the normalized experimental data. Common C quantities for each type of sleeve material, gamma-ray energy and TLD type were used to calculate the C/E results listed in Tables 6.7-6.10. Different E values were used since they were extracted from the previously discussed experimental results for encased TLDs with and without correction for individual sensitivity.

Table 6.1. TLD Analyzer Output Normalized to Iron Encased
⁷LiF TLD's from a Precision Subset

Sleeve Material	Z	Normalized TLD Readout $\pm \sigma_{\bar{x}}$					
		Gamma-ray Energy (MeV)					
		0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.333 (100%)
Lead	82	0.486 $\pm$ 0.010	0.508 $\pm$ 0.008	1.559 $\pm$ 0.018	1.657 $\pm$ 0.025	1.613 $\pm$ 0.029	1.354 $\pm$ 0.020
Tantalum	73	0.520 $\pm$ 0.016	0.612 $\pm$ 0.021	1.485 $\pm$ 0.024	1.487 $\pm$ 0.025	1.396 $\pm$ 0.023	1.245 $\pm$ 0.023
Tin	50	1.041 $\pm$ 0.013	1.156 $\pm$ 0.020	1.259 $\pm$ 0.016	1.185 $\pm$ 0.012	1.077 $\pm$ 0.015	1.086 $\pm$ 0.020
Zirconium	40	1.168 $\pm$ 0.014	1.182 $\pm$ 0.014	1.128 $\pm$ 0.017	1.091 $\pm$ 0.017	1.058 $\pm$ 0.013	1.051 $\pm$ 0.012
Copper	29	0.955 $\pm$ 0.020	1.001 $\pm$ 0.014	1.037 $\pm$ 0.015	0.985 $\pm$ 0.012	0.976 $\pm$ 0.010	0.997 $\pm$ 0.012
Iron	26	1.000 $\pm$ 0.010	1.000 $\pm$ 0.015	1.000 $\pm$ 0.014	1.000 $\pm$ 0.009	1.000 $\pm$ 0.013	1.000 $\pm$ 0.013
Stainless	--	0.992 $\pm$ 0.014	0.971 $\pm$ 0.016	1.007 $\pm$ 0.012	1.002 $\pm$ 0.012	1.005 $\pm$ 0.015	0.994 $\pm$ 0.014
Aluminum	13	0.922 $\pm$ 0.012	0.987 $\pm$ 0.014	0.970 $\pm$ 0.019	0.997 $\pm$ 0.012	0.981 $\pm$ 0.013	0.974 $\pm$ 0.015

Table 6.2. TLD Analyzer Output Normalized to Iron Encased
CaF₂:Mn TLD's from a Precision Subset

Sleeve Material	Z	Normalized TLD Readout $\pm \frac{\sigma}{x}$					
		Gamma-ray Energy (MeV)					
		0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.333 (100%)
Lead	82	0.401±0.008	0.523±0.008	1.262±0.018	1.526±0.024	1.464±0.021	1.380±0.019
Tantalum	73	0.492±0.019	0.660±0.012	1.204±0.021	1.412±0.016	1.319±0.015	1.306±0.025
Tin	50	0.999±0.015	1.088±0.013	1.103±0.014	1.149±0.021	1.074±0.016	1.133±0.012
Zirconium	40	1.002±0.019	0.989±0.022	1.016±0.016	1.082±0.019	1.062±0.014	1.048±0.017
Copper	29	0.977±0.016	0.952±0.007	0.987±0.015	1.002±0.015	0.986±0.010	1.072±0.017
Iron	26	1.000±0.018	1.000±0.010	1.000±0.015	1.000±0.017	1.000±0.013	1.000±0.016
Stainless	--	1.002±0.015	0.995±0.012	0.982±0.014	1.006±0.015	1.009±0.012	1.002±0.014
Aluminum	13	1.022±0.015	1.482±0.017	0.987±0.012	1.184±0.019	1.001±0.011	1.003±0.016

Table 6.3. TLD Analyzer Output Normalized to Iron Encased 1x1x6 mm
⁷LiF TLD's Corrected for Individual Sensitivity

Sleeve Material	Z	Normalized Sensitivity Corrected TLD Readout $\pm \sigma_x$					
		Gamma-ray Energy (MeV)					
		0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.333 (100%)
Lead	82	0.484 $\pm$ 0.009	0.504 $\pm$ 0.008	1.543 $\pm$ 0.027	1.634 $\pm$ 0.020	1.604 $\pm$ 0.020	1.337 $\pm$ 0.018
Tantalum	73	0.521 $\pm$ 0.008	0.606 $\pm$ 0.016	1.472 $\pm$ 0.026	1.474 $\pm$ 0.022	1.391 $\pm$ 0.016	1.231 $\pm$ 0.015
Tin	50	1.042 $\pm$ 0.016	1.155 $\pm$ 0.014	1.251 $\pm$ 0.022	1.178 $\pm$ 0.012	1.076 $\pm$ 0.014	1.078 $\pm$ 0.016
Zirconium	40	1.171 $\pm$ 0.014	1.186 $\pm$ 0.013	1.122 $\pm$ 0.023	1.093 $\pm$ 0.013	1.063 $\pm$ 0.012	1.047 $\pm$ 0.015
Copper	29	0.978 $\pm$ 0.013	0.999 $\pm$ 0.012	1.032 $\pm$ 0.018	0.993 $\pm$ 0.010	0.976 $\pm$ 0.013	0.991 $\pm$ 0.013
Iron	26	1.000 $\pm$ 0.014	1.000 $\pm$ 0.010	1.000 $\pm$ 0.022	1.000 $\pm$ 0.012	1.000 $\pm$ 0.012	1.000 $\pm$ 0.013
Stainless	--	0.990 $\pm$ 0.014	0.967 $\pm$ 0.011	1.001 $\pm$ 0.018	1.001 $\pm$ 0.017	1.008 $\pm$ 0.011	0.992 $\pm$ 0.013
Aluminum	13	0.924 $\pm$ 0.012	0.985 $\pm$ 0.010	0.966 $\pm$ 0.018	0.993 $\pm$ 0.012	0.982 $\pm$ 0.011	0.970 $\pm$ 0.013

Table 6.4. TLD Analyzer Output Normalized to Iron Encased 1x1x6 mm
CaF₂:Mn TLD's Corrected for Individual Sensitivity

Sleeve Material	Z	Normalized Sensitivity Corrected TLD Readout $\pm \sigma_x$					
		Gamma-ray Energy (MeV)					
		0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.333 (100%)
Lead	82	0.408 $\pm$ 0.005	0.521 $\pm$ 0.008	1.255 $\pm$ 0.010	1.508 $\pm$ 0.011	1.450 $\pm$ 0.011	1.376 $\pm$ 0.014
Tantalum	73	0.488 $\pm$ 0.006	0.658 $\pm$ 0.010	1.193 $\pm$ 0.011	1.399 $\pm$ 0.014	1.309 $\pm$ 0.012	1.297 $\pm$ 0.016
Tin	50	0.995 $\pm$ 0.009	1.086 $\pm$ 0.018	1.095 $\pm$ 0.007	1.142 $\pm$ 0.016	1.065 $\pm$ 0.012	1.127 $\pm$ 0.013
Zirconium	40	1.000 $\pm$ 0.007	1.300 $\pm$ 0.007	1.015 $\pm$ 0.008	1.084 $\pm$ 0.009	1.065 $\pm$ 0.011	1.051 $\pm$ 0.010
Copper	29	0.974 $\pm$ 0.006	0.949 $\pm$ 0.007	0.981 $\pm$ 0.008	0.998 $\pm$ 0.009	0.983 $\pm$ 0.014	1.068 $\pm$ 0.011
Iron	26	1.000 $\pm$ 0.008	1.000 $\pm$ 0.005	1.000 $\pm$ 0.006	1.000 $\pm$ 0.007	1.000 $\pm$ 0.009	1.000 $\pm$ 0.012
Stainless	--	1.001 $\pm$ 0.010	0.994 $\pm$ 0.004	0.978 $\pm$ 0.007	1.006 $\pm$ 0.009	1.008 $\pm$ 0.010	1.002 $\pm$ 0.011
Aluminum	13	1.020 $\pm$ 0.008	1.488 $\pm$ 0.009	1.009 $\pm$ 0.013	1.192 $\pm$ 0.011	0.999 $\pm$ 0.013	1.001 $\pm$ 0.010

Table 6.5. Mass energy absorption coefficients and resulting dose ratios calculated using TERC/III for 1x1x6 mm ^7LiF TLDs encased in various materials.

Nuclide	Gamma-ray Energy, T_γ (MeV)	Mass Energy Absorption Coefficient $(\mu_{\text{en}}(T_\gamma)/\rho)_M$ (cm^2/g)		Calculated Dose Ratio $f(T_\gamma)$
Encasement Material (M) of Lead, $Z = 82$				
Co-57	0.122	1.7480	0.04597	
	0.136	1.4373	0.05479	
Ce-141	0.145	1.2483	0.06002	
Hg-203	0.279	0.3359	0.1902	
Sn-113	0.393	0.1518	0.3425	
Cs-137	0.662	0.06444	0.6929	
Co-60	1.173	0.03423	1.0931	
	1.333	0.03099	1.1589	
Encasement Material (M) of Tantalum, $Z = 73$				
Co-57	0.122	1.6679	0.04552	
	0.136	1.3077	0.05504	
Ce-141	0.145	1.0892	0.06069	
Hg-203	0.279	0.2634	0.2071	
Sn-113	0.393	0.1176	0.3810	
Cs-137	0.662	0.05263	0.7508	
Co-60	1.173	0.03040	1.1179	
	1.333	0.02803	1.1712	
Encasement Material (M) of Tin, $Z = 50$				
Co-57	0.122	0.8543	0.06036	
	0.136	0.6313	0.07563	
Ce-141	0.145	0.4955	0.08485	
Hg-203	0.279	0.1079	0.3450	
Sn-113	0.393	0.05413	0.6111	
Cs-137	0.662	0.03295	0.9619	
Co-60	1.173	0.02485	1.1705	
	1.333	0.02376	1.1938	
Encasement Material (M) of Zirconium, $Z = 40$				
Co-57	0.122	0.4985	0.08318	
	0.136	0.3655	0.1061	
Ce-141	0.145	0.2846	0.1200	
Hg-203	0.279	0.06761	0.4790	
Sn-113	0.393	0.04010	0.7565	
Cs-137	0.662	0.02950	1.0135	
Co-60	1.173	0.02456	1.1365	
	1.333	0.02372	1.1501	

Table 6.5 - continued

Nuclide	Gamma-ray Energy, T_γ (MeV)	Mass Energy Absorption Coefficient $(\mu_{en}(T_\gamma)/\rho)_M$ (cm^2/g)		Calculated Dose Ratio $f(T_\gamma)$
Encasement Material (M) of Copper, Z = 29				
Co-57	0.122	0.2092	0.1604	
	0.136	0.1547	0.2065	
Ce-141	0.145	0.1214	0.2346	
Hg-203	0.279	0.04061	0.0707	
Sn-113	0.393	0.03159	0.9063	
Cs-137	0.662	0.02793	1.0281	
Co-60	1.173	0.02481	1.0885	
	1.333	0.02407	1.0964	
Encasement Material (M) of Iron, Z = 26				
Co-57	0.122	0.1557	0.2031	
	0.136	0.1164	0.2604	
Ce-141	0.145	0.09245	0.2953	
Hg-203	0.279	0.03655	0.7653	
Sn-113	0.393	0.03055	0.9254	
Cs-137	0.662	0.02808	1.0115	
Co-60	1.173	0.02523	1.0570	
	1.333	0.02452	1.0626	
Encasement Material (M) of Stainless Steel				
Co-57	0.122	0.1526	0.2068	
	0.136	0.1142	0.2651	
Ce-141	0.145	0.09075	0.3005	
Hg-203	0.279	0.03628	0.7710	
Sn-113	0.393	0.03055	0.9270	
Cs-137	0.662	0.02805	1.0158	
Co-60	1.173	0.02529	1.0614	
	1.333	0.02457	1.0679	
Encasement Material (M) of Aluminum, Z = 13				
Co-57	0.122	0.03305	0.7011	
	0.136	0.03036	0.7704	
Ce-141	0.145	0.02873	0.8125	
Hg-203	0.279	0.02785	0.9506	
Sn-113	0.393	0.02855	0.9655	
Cs-137	0.662	0.02821	0.9791	
Co-60	1.173	0.02597	0.9924	
	1.333	0.02520	0.9958	
Encasement Material (M) of LiF				
Co-57	0.122	0.02241	1.0000	
	0.136	0.02274	1.0000	
Ce-141	0.145	0.02295	1.0000	
Hg-203	0.279	0.02621	1.0000	
Sn-113	0.393	0.02729	1.0000	
Cs-137	0.662	0.02708	1.0000	
Co-60	1.173	0.02494	1.0000	
	1.333	0.02424	1.0000	

Table 6.6. Mass energy absorption coefficients and resulting dose ratios calculated using TERC/III for 1x1x6 mm CaF_2 TLDs encased in various materials.

Nuclide	Gamma-ray Energy, T_γ (MeV)	Mass Energy	Calculated Dose Ratio $f(T_\gamma)$
		Absorption Coefficient $(\mu_{\text{en}}(T_\gamma)/\rho)_M$ (cm^2/g)	
Encasement material (M) of lead, Z = 82			
Co-57	0.122	1.7480	0.05622
	0.136	1.4373	0.06160
Ce-141	0.145	1.2483	0.06489
Hg-203	0.279	0.3359	0.1824
Sn-113	0.393	0.1518	0.3278
Cs-137	0.662	0.06444	0.6694
Co-60	1.173	0.03423	1.080
	1.333	0.03099	1.145
Encasement Material (M) of Tantalum, Z = 73			
Co-57	0.122	1.6679	0.05709
	0.136	1.3077	0.0638
Ce-141	0.145	1.0892	0.06792
Hg-203	0.279	0.2634	0.2033
Sn-113	0.393	0.1176	0.3721
Cs-137	0.662	0.05263	0.7372
Co-60	1.173	0.03040	1.108
	1.333	0.02803	1.163
Encasement Material (M) of Tin, Z = 50			
Co-57	0.122	0.8543	0.08955
	0.136	0.6313	0.1024
Ce-141	0.145	0.4955	0.1102
Hg-203	0.279	0.1079	0.3624
Sn-113	0.393	0.05413	0.6267
Cs-137	0.662	0.03295	0.9739
Co-60	1.173	0.02485	1.179
	1.333	0.02376	1.202
Encasement Material (M) of Zirconium, Z = 40			
Co-57	0.122	0.4985	0.1373
	0.136	0.3655	0.1572
Ce-141	0.145	0.2846	0.1693
Hg-203	0.279	0.06761	0.5163
Sn-113	0.393	0.04010	0.7881
Cs-137	0.662	0.02950	1.035
Co-60	1.173	0.02456	1.149
	1.333	0.02372	1.162

Nuclide	Gamma-ray Energy, T_γ (MeV)	Mass Energy Absorption Coefficient $(\mu_{en}(T_\gamma)/\rho)_M$ (cm ² /g)		Calculated Dose Ratio $f(T_\gamma)$
Encasement Material (M) of Copper, Z = 29				
Co-57	0.122	0.2092	0.2949	
	0.136	0.1547	0.3339	
Ce-141	0.145	0.1214	0.3577	
Hg-203	0.279	0.04061	0.7780	
Sn-113	0.393	0.03159	0.9545	
Cs-137	0.662	0.02793	1.0568	
Co-60	1.173	0.02481	1.1060	
	1.333	0.02407	1.1123	
Encasement Material (M) of Iron, Z = 26				
Co-57	0.122	0.1557	0.3840	
	0.136	0.1164	0.4300	
Ce-141	0.145	0.09245	0.4581	
Hg-203	0.279	0.03655	0.8457	
Sn-113	0.393	0.03055	0.9771	
Cs-137	0.662	0.02808	1.042	
Co-60	1.173	0.02523	1.075	
	1.333	0.02452	1.079	
Encasement Material (M) of Stainless Steel				
Co-57	0.122	0.1526	0.3914	
	0.136	0.1142	0.4379	
Ce-141	0.145	0.09075	0.4663	
Hg-203	0.279	0.03628	0.8520	
Sn-113	0.393	0.03055	0.9784	
Cs-137	0.662	0.02805	1.046	
Co-60	1.173	0.02529	1.080	
	1.333	0.02457	1.084	
Encasement Material (M) of Aluminum, Z = 13				
Co-57	0.122	0.03305	1.557	
	0.136	0.03036	1.424	
Ce-141	0.145	0.02873	1.343	
Hg-203	0.279	0.02785	1.061	
Sn-113	0.393	0.02856	1.025	
Cs-137	0.662	0.02821	1.014	
Co-60	1.173	0.02597	1.015	
	1.333	0.02520	1.017	
Encasement Material (M) of LiF				
Co-57	0.122	0.02241	2.3554	
	0.136	0.02274	1.9471	
Ce-141	0.145	0.02295	1.6986	
Hg-203	0.279	0.02621	1.1182	
Sn-113	0.393	0.02729	1.0619	
Cs-137	0.662	0.02708	1.0383	
Co-60	1.173	0.02494	1.0266	
	1.333	0.02424	1.0248	

Table 6.7. Comparisons of Dose Ratios Using Encased ^7LiF TLD's from a Precision Subset But Not Corrected for Sensitivity

Sleeve Material	Z	Wall Thickness (g/cm ²)	(C/E) $\pm \sigma_{\bar{x}}$					
			Gamma-ray Energy (MeV)					
			0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.133 (100%)
Lead	82	0.734	5.245 $\pm$ 0.102	5.408 $\pm$ 0.085	1.467 $\pm$ 0.017	1.110 $\pm$ 0.017	0.975 $\pm$ 0.018	1.020 $\pm$ 0.015
Tantalum	73	0.696	4.618 $\pm$ 0.137	3.963 $\pm$ 0.138	1.314 $\pm$ 0.021	1.066 $\pm$ 0.015	0.998 $\pm$ 0.017	1.019 $\pm$ 0.019
Tin	50	0.608	1.561 $\pm$ 0.019	1.333 $\pm$ 0.023	1.058 $\pm$ 0.013	0.987 $\pm$ 0.010	1.037 $\pm$ 0.014	1.004 $\pm$ 0.018
Zirconium	40	0.514	1.120 $\pm$ 0.014	1.059 $\pm$ 0.013	1.027 $\pm$ 0.016	0.984 $\pm$ 0.015	0.995 $\pm$ 0.012	0.996 $\pm$ 0.011
Copper	29	0.694	1.111 $\pm$ 0.023	1.042 $\pm$ 0.015	0.990 $\pm$ 0.014	1.028 $\pm$ 0.013	1.037 $\pm$ 0.010	1.017 $\pm$ 0.012
Iron	26	0.656	1.000 $\pm$ 0.010	1.000 $\pm$ 0.015	1.000 $\pm$ 0.014	1.000 $\pm$ 0.009	1.000 $\pm$ 0.013	1.000 $\pm$ 0.013
Stainless	--	0.693	1.006 $\pm$ 0.014	1.029 $\pm$ 0.017	0.994 $\pm$ 0.012	0.999 $\pm$ 0.012	0.999 $\pm$ 0.015	1.014 $\pm$ 0.015
Aluminum	13	0.514	0.800 $\pm$ 0.011	0.866 $\pm$ 0.013	0.976 $\pm$ 0.019	0.978 $\pm$ 0.012	0.992 $\pm$ 0.014	0.991 $\pm$ 0.015

Table 6.8. Comparison of Dose Ratios Using Encapsulated $\text{CaF}_2\text{:Mn}$ TLD's
from a Precision Subset But Not Corrected for Sensitivity

Sleeve Material	Z	Wall Thickness (g/cm ²)	(C/E) $\pm \sigma_{\bar{x}}$					
			Gamma-ray Energy (MeV)					
			0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.133 (100%)
Lead	82	0.734	4.128 $\pm$ 0.080	3.661 $\pm$ 0.059	1.571 $\pm$ 0.023	1.093 $\pm$ 0.017	1.007 $\pm$ 0.014	0.968 $\pm$ 0.013
Tantalum	73	0.696	3.251 $\pm$ 0.124	2.648 $\pm$ 0.048	1.438 $\pm$ 0.025	1.038 $\pm$ 0.022	1.005 $\pm$ 0.011	0.947 $\pm$ 0.018
Tin	50	0.608	1.282 $\pm$ 0.020	1.186 $\pm$ 0.015	1.146 $\pm$ 0.014	0.989 $\pm$ 0.018	1.022 $\pm$ 0.015	0.953 $\pm$ 0.014
Zirconium	40	0.514	1.143 $\pm$ 0.021	1.150 $\pm$ 0.025	1.111 $\pm$ 0.017	0.979 $\pm$ 0.017	0.983 $\pm$ 0.013	0.993 $\pm$ 0.017
Copper	29	0.694	1.056 $\pm$ 0.018	1.077 $\pm$ 0.010	1.036 $\pm$ 0.015	1.009 $\pm$ 0.015	1.024 $\pm$ 0.011	0.944 $\pm$ 0.015
Iron	26	0.656	1.000 $\pm$ 0.018	1.000 $\pm$ 0.009	1.000 $\pm$ 0.015	1.000 $\pm$ 0.017	1.000 $\pm$ 0.013	1.000 $\pm$ 0.016
Stainless	--	0.693	0.997 $\pm$ 0.015	1.005 $\pm$ 0.012	1.018 $\pm$ 0.014	0.995 $\pm$ 0.014	0.994 $\pm$ 0.012	1.004 $\pm$ 0.014
Aluminum	13	0.514	0.842 $\pm$ 0.012	0.911 $\pm$ 0.016	0.969 $\pm$ 0.012	0.821 $\pm$ 0.013	0.976 $\pm$ 0.011	0.968 $\pm$ 0.015

Table 6.9. Comparisons of Dose Ratios Using Encased ^7LiF TLD's Where the E Values Were Corrected for the Sensitivity of Individual TLD's

Sleeve Material	Z	Wall Thickness (g/cm ²)	(C/E) $\pm \sigma_x$					
			Gamma-ray Energy (MeV)					
			0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.133 (100%)
Lead	82	0.734	5.273 $\pm$ 0.093	5.453 $\pm$ 0.090	1.483 $\pm$ 0.026	1.126 $\pm$ 0.014	0.981 $\pm$ 0.012	1.033 $\pm$ 0.014
Tantalum	73	0.696	4.606 $\pm$ 0.067	4.000 $\pm$ 0.105	1.326 $\pm$ 0.024	1.075 $\pm$ 0.016	1.001 $\pm$ 0.014	1.030 $\pm$ 0.012
Tin	50	0.608	1.561 $\pm$ 0.024	1.334 $\pm$ 0.017	1.065 $\pm$ 0.018	0.994 $\pm$ 0.010	1.039 $\pm$ 0.014	1.012 $\pm$ 0.015
Zirconium	40	0.514	1.117 $\pm$ 0.013	1.055 $\pm$ 0.012	1.032 $\pm$ 0.021	0.982 $\pm$ 0.012	0.991 $\pm$ 0.011	1.000 $\pm$ 0.014
Copper	29	0.694	1.085 $\pm$ 0.015	1.045 $\pm$ 0.012	0.995 $\pm$ 0.017	1.020 $\pm$ 0.010	1.037 $\pm$ 0.014	1.023 $\pm$ 0.014
Iron	26	0.656	1.000 $\pm$ 0.014	1.000 $\pm$ 0.010	1.000 $\pm$ 0.022	1.000 $\pm$ 0.012	1.000 $\pm$ 0.012	1.000 $\pm$ 0.013
Stainless	--	0.693	1.008 $\pm$ 0.015	1.033 $\pm$ 0.012	0.999 $\pm$ 0.018	1.001 $\pm$ 0.017	0.996 $\pm$ 0.011	1.016 $\pm$ 0.014
Aluminum	13	0.514	0.798 $\pm$ 0.010	0.868 $\pm$ 0.009	0.980 $\pm$ 0.018	0.982 $\pm$ 0.012	0.991 $\pm$ 0.011	0.996 $\pm$ 0.014

Table 6.10. Comparison of Dose Ratios Using Encased $\text{CaF}_2\text{:Mn}$ TLD's Where the E Values Were Corrected for the Sensitivity of Individual TLD's.

Sleeve Material	Z	Wall Thickness (g/cm^2)	(C/E) $\pm \sigma_{\bar{x}}$					
			Gamma-ray Energy (MeV)					
			0.136 (11%) 0.122 (87%)	0.145	0.279	0.393	0.662	1.173 (100%) 1.133 (100%)
Lead	82	0.734	4.054 $\pm$ 0.048	3.671 $\pm$ 0.056	1.579 $\pm$ 0.013	1.105 $\pm$ 0.008	1.017 $\pm$ 0.008	0.970 $\pm$ 0.010
Tantalum	73	0.696	3.281 $\pm$ 0.039	2.655 $\pm$ 0.042	1.452 $\pm$ 0.013	1.047 $\pm$ 0.010	1.013 $\pm$ 0.009	0.954 $\pm$ 0.012
Tin	50	0.608	1.287 $\pm$ 0.011	1.188 $\pm$ 0.020	1.155 $\pm$ 0.007	0.995 $\pm$ 0.014	1.030 $\pm$ 0.011	0.958 $\pm$ 0.011
Zirconium	40	0.514	1.138 $\pm$ 0.008	1.105 $\pm$ 0.007	1.113 $\pm$ 0.009	0.977 $\pm$ 0.008	0.980 $\pm$ 0.010	0.990 $\pm$ 0.010
Copper	29	0.694	1.059 $\pm$ 0.007	1.081 $\pm$ 0.008	1.043 $\pm$ 0.008	1.012 $\pm$ 0.010	1.027 $\pm$ 0.016	0.948 $\pm$ 0.010
Iron	26	0.656	1.000 $\pm$ 0.008	1.000 $\pm$ 0.005	1.000 $\pm$ 0.006	1.000 $\pm$ 0.007	1.000 $\pm$ 0.009	1.000 $\pm$ 0.012
Stainless	--	0.693	0.998 $\pm$ 0.010	1.005 $\pm$ 0.004	1.023 $\pm$ 0.007	0.996 $\pm$ 0.009	0.995 $\pm$ 0.010	1.005 $\pm$ 0.010
Aluminum	13	0.514	0.844 $\pm$ 0.007	0.912 $\pm$ 0.004	0.947 $\pm$ 0.012	0.823 $\pm$ 0.008	0.979 $\pm$ 0.013	0.970 $\pm$ 0.010

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APPENDIX A

TERC/III Calculations of Encased 1x1x6 mm
⁷LiF TLDs Without Sleeve Attenuation.

EVALUATION OF $1 \times 1 \times 6 \text{ MM}^7$ LIF AND LEAD
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) FI(LARGE)		D*FS	(1-D)FI	GENERAL RATIO F
1	0.010	2.63413	0.04674	0.0004	0.0467	0.04712
2	0.015	2.44507	0.01762	0.0008	0.0176	0.01844
3	0.020	2.32588	0.00921	0.0014	0.0092	0.01062
4	0.025	2.24550	0.00836	0.0021	0.0084	0.01048
5	0.030	2.18501	0.00705	0.0029	0.0070	0.00998
6	0.035	2.13792	0.00672	0.0039	0.0067	0.01059
7	0.040	2.10065	0.00637	0.0049	0.0064	0.01126
8	0.045	2.06914	0.00641	0.0060	0.0064	0.01242
9	0.050	2.04245	0.00659	0.0072	0.0066	0.01378
10	0.055	2.01947	0.00705	0.0085	0.0070	0.01552
11	0.060	1.99953	0.00772	0.0098	0.0077	0.01753
12	0.065	1.98178	0.00873	0.0113	0.0087	0.01995
13	0.070	1.96595	0.00993	0.0128	0.0099	0.02262
14	0.075	1.95197	0.01121	0.0143	0.0111	0.02543
15	0.080	1.93948	0.01231	0.0159	0.0122	0.02812
16	0.085	1.92728	0.01133	0.0176	0.0112	0.02880
17	0.090	1.91606	0.01063	0.0193	0.0105	0.02981
18	0.095	1.90569	0.01014	0.0211	0.0100	0.03109
19	0.100	1.89609	0.00984	0.0229	0.0097	0.03259
20	0.150	1.83068	0.02027	0.0434	0.0198	0.06317
21	0.200	1.79106	0.03972	0.0672	0.0382	0.10547
22	0.250	1.76366	0.06293	0.0936	0.0596	0.15319
23	0.300	1.74505	0.10264	0.1220	0.0955	0.21747
24	0.350	1.72823	0.13987	0.1518	0.1276	0.27938
25	0.400	1.71696	0.18991	0.1831	0.1697	0.35273
26	0.450	1.70558	0.23574	0.2151	0.2060	0.42112
27	0.500	1.69746	0.28832	0.2481	0.2462	0.49431
28	0.550	1.68871	0.33248	0.2814	0.2771	0.55845
29	0.600	1.68173	0.38160	0.3149	0.3101	0.62507
30	0.650	1.67350	0.41915	0.3480	0.3320	0.68001
31	0.700	1.66645	0.45969	0.3809	0.3546	0.73551
32	0.750	1.66055	0.50264	0.4133	0.3775	0.79086
33	0.800	1.65580	0.54694	0.4453	0.3999	0.84512
34	0.850	1.64962	0.58224	0.4758	0.4143	0.89014
35	0.900	1.64416	0.61902	0.5056	0.4287	0.93424
36	0.950	1.63942	0.65682	0.5344	0.4427	0.97711
37	1.000	1.63527	0.69503	0.5623	0.4561	1.01831
38	1.100	1.62605	0.72930	0.6142	0.4538	1.06801
39	1.200	1.61725	0.76320	0.6616	0.4510	1.11259
40	1.300	1.60945	0.79581	0.7050	0.4472	1.15224
41	1.400	1.60266	0.82604	0.7448	0.4421	1.18697
42	1.500	1.59674	0.85265	0.7813	0.4354	1.21675
43	1.600	1.59123	0.86286	0.8146	0.4211	1.23574
44	1.700	1.58609	0.87177	0.8451	0.4073	1.25235
45	1.800	1.58132	0.87917	0.8730	0.3938	1.26678
46	1.900	1.57691	0.88489	0.8986	0.3807	1.27922

LEAD

A2

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
47	2.000	1.57284	0.88877	0.9222	0.3677	1.28984
48	2.200	1.56478	0.87652	0.9636	0.3368	1.30034
49	2.400	1.55744	0.86241	0.9989	0.3093	1.30816
50	2.600	1.55092	0.84654	1.0293	0.2847	1.31401
51	2.800	1.54505	0.82903	1.0557	0.2626	1.31828
52	3.000	1.53976	0.81005	1.0789	0.2425	1.32133
53	3.500	1.52710	0.75314	1.1280	0.1968	1.32484
54	4.000	1.51565	0.70088	1.1628	0.1632	1.32599
55	4.500	1.50517	0.65066	1.1894	0.1365	1.32589
56	5.000	1.49606	0.61062	1.2104	0.1166	1.32699
57	5.500	1.48756	0.58241	1.2270	0.1020	1.32900
58	6.000	1.48003	0.55688	1.2406	0.0901	1.33066
59	6.500	1.47289	0.53310	1.2515	0.0801	1.33162
60	7.000	1.46643	0.51190	1.2606	0.0718	1.33246
61	7.500	1.46057	0.49312	1.2683	0.0649	1.33323
62	8.000	1.45521	0.47656	1.2749	0.0591	1.33394
63	8.500	1.45005	0.46210	1.2803	0.0541	1.33440
64	9.000	1.44528	0.44961	1.2850	0.0499	1.33484
65	9.500	1.44085	0.43896	1.2890	0.0463	1.33526
66	10.000	1.43913	0.43896	1.2947	0.0441	1.33873

EVALUATION OF 1X1X6 MM² LIF AND TANTALUM
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
1	0.010	2.27202	0.02779	0.0003	0.0278	0.02811
2	0.015	2.15709	0.01353	0.0007	0.0135	0.01425
3	0.020	2.07849	0.01132	0.0013	0.0113	0.01258
4	0.025	2.02364	0.01052	0.0019	0.0105	0.01242
5	0.030	1.98113	0.00921	0.0027	0.0092	0.01187
6	0.035	1.94744	0.00891	0.0035	0.0089	0.01242
7	0.040	1.92085	0.00859	0.0045	0.0086	0.01306
8	0.045	1.89783	0.00874	0.0055	0.0087	0.01424
9	0.050	1.87818	0.00908	0.0066	0.0091	0.01565
10	0.055	1.86115	0.00999	0.0078	0.0099	0.01778
11	0.060	1.84631	0.01079	0.0091	0.0107	0.01983
12	0.065	1.83275	0.00930	0.0104	0.0092	0.01567
13	0.070	1.82049	0.00829	0.0118	0.0082	0.02005
14	0.075	1.80945	0.00765	0.0133	0.0076	0.02086
15	0.080	1.79931	0.00733	0.0148	0.0073	0.02203
16	0.085	1.79017	0.00783	0.0163	0.0078	0.02409
17	0.090	1.78178	0.00842	0.0179	0.0083	0.02627
18	0.095	1.77403	0.00909	0.0196	0.0090	0.02859
19	0.100	1.76689	0.00986	0.0213	0.0097	0.03105
20	0.150	1.71632	0.02398	0.0407	0.0234	0.06409
21	0.200	1.68554	0.04965	0.0633	0.0478	0.11107
22	0.250	1.66401	0.07981	0.0883	0.0756	0.16388
23	0.300	1.65015	0.13268	0.1154	0.1234	0.23877
24	0.350	1.63688	0.18088	0.1438	0.1650	0.30876
25	0.400	1.62873	0.24524	0.1737	0.2191	0.39275
26	0.450	1.61970	0.30279	0.2043	0.2646	0.46889
27	0.500	1.61361	0.36712	0.2359	0.3135	0.54933
28	0.550	1.60643	0.41760	0.2677	0.3480	0.61568
29	0.600	1.60069	0.47226	0.2998	0.3838	0.68358
30	0.650	1.59383	0.51398	0.3315	0.4071	0.73855
31	0.700	1.58809	0.55784	0.3630	0.4303	0.79332
32	0.750	1.58317	0.60290	0.3941	0.4528	0.84690
33	0.800	1.57912	0.64771	0.4246	0.4735	0.89818
34	0.850	1.57367	0.68022	0.4539	0.4840	0.93794
35	0.900	1.56877	0.71328	0.4824	0.4939	0.97633
36	0.950	1.56437	0.74646	0.5099	0.5031	1.01307
37	1.000	1.56043	0.77925	0.5365	0.5113	1.04784
38	1.100	1.55218	0.81157	0.5863	0.5050	1.09131
39	1.200	1.54438	0.84285	0.6318	0.4980	1.12984
40	1.300	1.53735	0.87222	0.6735	0.4901	1.16359
41	1.400	1.53114	0.89871	0.7116	0.4810	1.19263
42	1.500	1.52565	0.92124	0.7465	0.4705	1.21699
43	1.600	1.52043	0.92823	0.7784	0.4530	1.23140
44	1.700	1.51554	0.93388	0.8075	0.4363	1.24375
45	1.800	1.51099	0.93808	0.8341	0.4202	1.25434
46	1.900	1.50675	0.94068	0.8586	0.4047	1.26324

INDEX	GAMMA RAY ENERGY (MEV)	TANTALUM STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.50282	0.94158	0.8811	0.3895	1.27064
48	2.200	1.49541	0.92633	0.9209	0.3559	1.27676
49	2.400	1.48864	0.90939	0.9547	0.3262	1.28089
50	2.600	1.48260	0.89089	0.9840	0.2996	1.28359
51	2.800	1.47715	0.87099	1.0093	0.2758	1.28518
52	3.000	1.47220	0.84987	1.0315	0.2544	1.28592
53	3.500	1.46083	0.78890	1.0791	0.2062	1.28523
54	4.000	1.45044	0.73370	1.1128	0.1708	1.28360
55	4.500	1.44113	0.68164	1.1388	0.1430	1.28178
56	5.000	1.43305	0.64008	1.1594	0.1222	1.28164
57	5.500	1.42551	0.61107	1.1758	0.1070	1.28284
58	6.000	1.41886	0.58419	1.1893	0.0945	1.28381
59	6.500	1.41261	0.55780	1.2003	0.0838	1.28412
60	7.000	1.40699	0.53430	1.2095	0.0750	1.28450
61	7.500	1.40189	0.51344	1.2174	0.0676	1.28495
62	8.000	1.39724	0.49505	1.2241	0.0613	1.28544
63	8.500	1.39276	0.47893	1.2297	0.0561	1.28579
64	9.000	1.38863	0.46495	1.2346	0.0516	1.28618
65	9.500	1.38481	0.45296	1.2389	0.0477	1.28660
66	10.000	1.38351	0.45296	1.2446	0.0455	1.29009

EVALUATION OF 1X1X6 MM² LIF AND TIN
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
1	0.010	1.81867	0.04380	0.0003	0.0438	0.04406
2	0.015	1.77453	0.03586	0.0006	0.0358	0.03644
3	0.020	1.73714	0.03213	0.0011	0.0321	0.03316
4	0.025	1.70908	0.02065	0.0016	0.0206	0.02225
5	0.030	1.68617	0.01175	0.0023	0.0117	0.01401
6	0.035	1.66735	0.00959	0.0030	0.0096	0.01260
7	0.040	1.65254	0.00767	0.0039	0.0076	0.01151
8	0.045	1.63911	0.00720	0.0048	0.0072	0.01195
9	0.050	1.62741	0.00686	0.0058	0.0068	0.01259
10	0.055	1.61713	0.00707	0.0068	0.0070	0.01385
11	0.060	1.60800	0.00742	0.0079	0.0074	0.01530
12	0.065	1.59979	0.00801	0.0091	0.0080	0.01706
13	0.070	1.59235	0.00877	0.0103	0.0087	0.01904
14	0.075	1.58567	0.00975	0.0116	0.0097	0.02130
15	0.080	1.57960	0.01102	0.0130	0.0109	0.02389
16	0.085	1.57394	0.01232	0.0144	0.0122	0.02657
17	0.090	1.56875	0.01392	0.0158	0.0138	0.02957
18	0.095	1.56399	0.01588	0.0173	0.0157	0.03298
19	0.100	1.55970	0.01828	0.0188	0.0181	0.03688
20	0.150	1.52946	0.05532	0.0362	0.0540	0.09026
21	0.200	1.51263	0.12305	0.0568	0.1184	0.17522
22	0.250	1.50057	0.19672	0.0796	0.1863	0.26591
23	0.300	1.49577	0.32044	0.1046	0.2980	0.40261
24	0.350	1.48763	0.41499	0.1307	0.3785	0.50520
25	0.400	1.48412	0.52543	0.1582	0.4694	0.62764
26	0.450	1.47801	0.60679	0.1864	0.5303	0.71667
27	0.500	1.47400	0.68508	0.2155	0.5849	0.80040
28	0.550	1.46830	0.73670	0.2446	0.6140	0.85860
29	0.600	1.46323	0.78660	0.2740	0.6393	0.91332
30	0.650	1.45725	0.82117	0.3031	0.6504	0.95345
31	0.700	1.45203	0.85456	0.3319	0.6592	0.99112
32	0.750	1.44741	0.88607	0.3603	0.6655	1.02579
33	0.800	1.44331	0.91491	0.3881	0.6689	1.05700
34	0.850	1.43863	0.93443	0.4150	0.6649	1.07987
35	0.900	1.43429	0.95312	0.4410	0.6600	1.10107
36	0.950	1.43026	0.97076	0.4662	0.6543	1.12054
37	1.000	1.42650	0.98714	0.4905	0.6477	1.13821
38	1.100	1.41921	1.00077	0.5361	0.6228	1.15882
39	1.200	1.41241	1.01301	0.5778	0.5986	1.17641
40	1.300	1.40616	1.02362	0.6160	0.5752	1.19119
41	1.400	1.40049	1.03234	0.6509	0.5526	1.20344
42	1.500	1.39530	1.03896	0.6827	0.5306	1.21332
43	1.600	1.39065	1.04011	0.7119	0.5076	1.21957
44	1.700	1.38629	1.04022	0.7386	0.4860	1.22461
45	1.800	1.38220	1.03923	0.7630	0.4655	1.22857
46	1.900	1.37836	1.03709	0.7854	0.4461	1.23156

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.37475	1.03377	0.8060	0.4277	1.23369
48	2.200	1.36834	1.01621	0.8426	0.3904	1.23305
49	2.400	1.36245	0.99750	0.8738	0.3578	1.23156
50	2.600	1.35717	0.97775	0.9007	0.3288	1.22956
51	2.800	1.35237	0.95709	0.9241	0.3031	1.22718
52	3.000	1.34798	0.93567	0.9445	0.2801	1.22456
53	3.500	1.33889	0.87735	0.9890	0.2293	1.21827
54	4.000	1.33027	0.82311	1.0206	0.1916	1.21221
55	4.500	1.32275	0.77083	1.0452	0.1617	1.20695
56	5.000	1.31620	0.72783	1.0649	0.1390	1.20386
57	5.500	1.31020	0.69638	1.0807	0.1220	1.20267
58	6.000	1.30484	0.66723	1.0937	0.1080	1.20168
59	6.500	1.29979	0.63850	1.1044	0.0960	1.20039
60	7.000	1.29522	0.61293	1.1134	0.0860	1.19946
61	7.500	1.29105	0.59026	1.1211	0.0777	1.19881
62	8.000	1.28723	0.57031	1.1277	0.0707	1.19839
63	8.500	1.28354	0.55289	1.1333	0.0647	1.19802
64	9.000	1.28013	0.53785	1.1381	0.0597	1.19780
65	9.500	1.27696	0.52505	1.1424	0.0553	1.19771
66	10.000	1.27659	0.52505	1.1484	0.0527	1.20114

EVALUATION OF 1X1X6 MM² LIF AND ZIRCONIUM
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS (SMALL) FI (LARGE)		D*FS	(1-D)FI	GENERAL RATIO F
1	0.010	1.57538	0.08194	0.0002	0.0819	0.08216
2	0.015	1.56205	0.06798	0.0005	0.0680	0.06848
3	0.020	1.54164	0.01746	0.0009	0.0174	0.01838
4	0.025	1.52484	0.01462	0.0014	0.0146	0.01605
5	0.030	1.51025	0.01100	0.0020	0.0110	0.01302
6	0.035	1.49788	0.01021	0.0027	0.0102	0.01290
7	0.040	1.48834	0.00936	0.0035	0.0093	0.01281
8	0.045	1.47929	0.00933	0.0043	0.0093	0.01361
9	0.050	1.47131	0.00948	0.0052	0.0094	0.01465
10	0.055	1.46424	0.01012	0.0062	0.0101	0.01624
11	0.060	1.45793	0.01104	0.0072	0.0110	0.01817
12	0.065	1.45220	0.01213	0.0083	0.0121	0.02032
13	0.070	1.44701	0.01356	0.0094	0.0135	0.02286
14	0.075	1.44235	0.01544	0.0106	0.0153	0.02589
15	0.080	1.43817	0.01789	0.0118	0.0177	0.02954
16	0.085	1.43421	0.02020	0.0131	0.0200	0.03310
17	0.090	1.43059	0.02307	0.0144	0.0228	0.03724
18	0.095	1.42732	0.02665	0.0158	0.0264	0.04213
19	0.100	1.42446	0.03115	0.0172	0.0308	0.04796
20	0.150	1.40484	0.05700	0.0333	0.0947	0.12800
21	0.200	1.39549	0.21235	0.0524	0.2044	0.25677
22	0.250	1.38823	0.32371	0.0737	0.3065	0.38020
23	0.300	1.38644	0.48778	0.0969	0.4537	0.55061
24	0.350	1.37986	0.59292	0.1212	0.5408	0.66204
25	0.400	1.37654	0.69568	0.1468	0.6251	0.77185
26	0.450	1.37086	0.76714	0.1729	0.6704	0.84328
27	0.500	1.36646	0.82620	0.1997	0.7054	0.90517
28	0.550	1.36113	0.86310	0.2268	0.7193	0.94608
29	0.600	1.35616	0.89660	0.2540	0.7287	0.98266
30	0.650	1.35092	0.91791	0.2809	0.7270	1.00796
31	0.700	1.34620	0.93769	0.3077	0.7234	1.03106
32	0.750	1.34194	0.95568	0.3340	0.7178	1.05182
33	0.800	1.33805	0.97157	0.3598	0.7103	1.07012
34	0.850	1.33401	0.98197	0.3848	0.6987	1.08352
35	0.900	1.33024	0.99169	0.4090	0.6868	1.09579
36	0.950	1.32673	1.00064	0.4325	0.6745	1.10693
37	1.000	1.32344	1.00875	0.4550	0.6619	1.11695
38	1.100	1.31732	1.01474	0.4976	0.6315	1.12903
39	1.200	1.31171	1.01990	0.5366	0.6027	1.13928
40	1.300	1.30657	1.02414	0.5724	0.5755	1.14786
41	1.400	1.30191	1.02737	0.6051	0.5499	1.15496
42	1.500	1.29765	1.02951	0.6350	0.5258	1.16071
43	1.600	1.29390	1.02957	0.6624	0.5025	1.16489
44	1.700	1.29040	1.02883	0.6875	0.4807	1.16819
45	1.800	1.28713	1.02726	0.7105	0.4602	1.17072
46	1.900	1.28406	1.02482	0.7317	0.4408	1.17254

ZIRCONIUM

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) FI(LARGE)		D*FS	(1-D)FI	GENERAL RATIO F
47	2.000	1.28117	1.02150	0.7512	0.4226	1.17375
48	2.200	1.27611	1.00684	0.7858	0.3868	1.17266
49	2.400	1.27149	0.99119	0.8155	0.3555	1.17096
50	2.600	1.26736	0.97464	0.8411	0.3278	1.16891
51	2.800	1.26362	0.95726	0.8634	0.3032	1.16659
52	3.000	1.26020	0.93918	0.8830	0.2811	1.16411
53	3.500	1.25329	0.89008	0.9258	0.2326	1.15837
54	4.000	1.24680	0.84271	0.9566	0.1962	1.15273
55	4.500	1.24120	0.79521	0.9808	0.1668	1.14762
56	5.000	1.23635	0.75533	1.0003	0.1442	1.14451
57	5.500	1.23198	0.72535	1.0162	0.1271	1.14323
58	6.000	1.22810	0.69745	1.0294	0.1128	1.14224
59	6.500	1.22441	0.67017	1.0404	0.1007	1.14110
60	7.000	1.22107	0.64563	1.0497	0.0906	1.14031
61	7.500	1.21804	0.62366	1.0577	0.0821	1.13980
62	8.000	1.21526	0.60414	1.0647	0.0749	1.13953
63	8.500	1.21260	0.58694	1.0707	0.0687	1.13936
64	9.000	1.21013	0.57194	1.0759	0.0634	1.13935
65	9.500	1.20784	0.55905	1.0806	0.0589	1.13947
66	10.000	1.20793	0.55905	1.0867	0.0561	1.14279

EVALUATION OF $1 \times 1 \times 6 \text{ MM}^2$ LIF AND COPPER
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS (SMALL) FL (LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
1	0.010	1.35919	0.03758	0.0002	0.0376	0.03777
2	0.015	1.36277	0.02642	0.0005	0.0264	0.02687
3	0.020	1.35582	0.02228	0.0008	0.0223	0.02309
4	0.025	1.34828	0.02104	0.0013	0.0210	0.02230
5	0.030	1.34050	0.01897	0.0018	0.0189	0.02075
6	0.035	1.33343	0.01864	0.0024	0.0186	0.02103
7	0.040	1.32907	0.01840	0.0031	0.0184	0.02146
8	0.045	1.32382	0.01896	0.0039	0.0189	0.02276
9	0.050	1.31911	0.02004	0.0047	0.0200	0.02463
10	0.055	1.31485	0.02188	0.0055	0.0218	0.02732
11	0.060	1.31104	0.02454	0.0065	0.0244	0.03088
12	0.065	1.30755	0.02725	0.0074	0.0271	0.03453
13	0.070	1.30441	0.03087	0.0085	0.0307	0.03913
14	0.075	1.30164	0.03569	0.0095	0.0354	0.04497
15	0.080	1.29925	0.04206	0.0107	0.0417	0.05238
16	0.085	1.29690	0.04769	0.0118	0.0473	0.05908
17	0.090	1.29481	0.05470	0.0130	0.0542	0.06719
18	0.095	1.29301	0.06352	0.0143	0.0628	0.07710
19	0.100	1.29162	0.07468	0.0156	0.0738	0.08936
20	0.150	1.28347	0.22567	0.0304	0.2203	0.25074
21	0.200	1.28120	0.43036	0.0481	0.4142	0.46230
22	0.250	1.27729	0.57690	0.0678	0.5463	0.61406
23	0.300	1.27457	0.73661	0.0891	0.6851	0.77422
24	0.350	1.26836	0.81119	0.1114	0.7399	0.85134
25	0.400	1.26395	0.87363	0.1348	0.7805	0.91525
26	0.450	1.25884	0.90753	0.1588	0.7931	0.95184
27	0.500	1.25449	0.93393	0.1834	0.7974	0.98079
28	0.550	1.25003	0.94804	0.2083	0.7901	0.99836
29	0.600	1.24572	0.96044	0.2333	0.7806	1.01386
30	0.650	1.24161	0.96901	0.2582	0.7675	1.02571
31	0.700	1.23798	0.97675	0.2830	0.7535	1.03646
32	0.750	1.23468	0.98361	0.3073	0.7388	1.04610
33	0.800	1.23165	0.98953	0.3312	0.7234	1.05464
34	0.850	1.22873	0.99335	0.3544	0.7068	1.06125
35	0.900	1.22601	0.99686	0.3770	0.6903	1.06732
36	0.950	1.22346	1.00004	0.3988	0.6741	1.07286
37	1.000	1.22106	1.00286	0.4198	0.6580	1.07789
38	1.100	1.21667	1.00502	0.4596	0.6254	1.06496
39	1.200	1.21267	1.00672	0.4961	0.5949	1.05097
40	1.300	1.20898	1.00791	0.5296	0.5664	1.09599
41	1.400	1.20564	1.00858	0.5603	0.5398	1.10016
42	1.500	1.20257	1.00868	0.5884	0.5151	1.10355
43	1.600	1.19986	1.00785	0.6143	0.4919	1.10614
44	1.700	1.19733	1.00656	0.6379	0.4703	1.10820
45	1.800	1.19496	1.00479	0.6597	0.4501	1.10977
46	1.900	1.19274	1.00252	0.6797	0.4313	1.11091

COPPER A10

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
47	2.000	1.19066	0.99974	0.6981	0.4136	1.11168
48	2.200	1.18700	0.98994	0.7309	0.3803	1.11129
49	2.400	1.18367	0.97935	0.7591	0.3512	1.11039
50	2.600	1.18070	0.96801	0.7836	0.3256	1.10916
51	2.800	1.17801	0.95596	0.8049	0.3028	1.10769
52	3.000	1.17556	0.94325	0.8237	0.2823	1.10603
53	3.500	1.17073	0.90822	0.8648	0.2373	1.10213
54	4.000	1.16620	0.87266	0.8947	0.2031	1.09787
55	4.500	1.16234	0.83486	0.9185	0.1752	1.09363
56	5.000	1.15901	0.80227	0.9377	0.1532	1.08909
57	5.500	1.15605	0.77736	0.9535	0.1362	1.08971
58	6.000	1.15343	0.75348	0.9668	0.1219	1.08872
59	6.500	1.15099	0.72867	0.9780	0.1095	1.08751
60	7.000	1.14879	0.70623	0.9876	0.0991	1.08668
61	7.500	1.14680	0.68607	0.9959	0.0903	1.08616
62	8.000	1.14499	0.66812	1.0031	0.0828	1.08589
63	8.500	1.14325	0.65232	1.0094	0.0764	1.08578
64	9.000	1.14165	0.63861	1.0150	0.0708	1.08585
65	9.500	1.14017	0.62692	1.0200	0.0661	1.08608
66	10.000	1.14059	0.62692	1.0261	0.0629	1.08903

EVALUATION OF $1 \times 1 \times 6 \text{ MM}^3$ LIF AND IRON
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS (SMALL)	F1 (LARGE)			
1	0.010	1.24898	0.04156	0.0002	0.0416	0.04173
2	0.015	1.26149	0.03168	0.0004	0.0317	0.03210
3	0.020	1.26059	0.02780	0.0008	0.0278	0.02855
4	0.025	1.25724	0.02661	0.0012	0.0266	0.02777
5	0.030	1.25258	0.02458	0.0017	0.0246	0.02624
6	0.035	1.24796	0.02442	0.0023	0.0244	0.02664
7	0.040	1.24610	0.02446	0.0029	0.0244	0.02732
8	0.045	1.24263	0.02543	0.0036	0.0254	0.02898
9	0.050	1.23942	0.02715	0.0044	0.0270	0.03143
10	0.055	1.23648	0.02967	0.0052	0.0295	0.03474
11	0.060	1.23378	0.03331	0.0061	0.0331	0.03922
12	0.065	1.23133	0.03701	0.0070	0.0368	0.04380
13	0.070	1.22913	0.04194	0.0080	0.0417	0.04964
14	0.075	1.22716	0.04851	0.0090	0.0482	0.05715
15	0.080	1.22550	0.05720	0.0101	0.0567	0.06679
16	0.085	1.22386	0.06483	0.0112	0.0642	0.07540
17	0.090	1.22242	0.07433	0.0123	0.0736	0.08589
18	0.095	1.22121	0.08623	0.0135	0.0853	0.09877
19	0.100	1.22033	0.10127	0.0147	0.1001	0.11477
20	0.150	1.21584	0.29354	0.0288	0.2866	0.31540
21	0.200	1.21488	0.51814	0.0456	0.4987	0.54430
22	0.250	1.21196	0.65727	0.0643	0.6224	0.68670
23	0.300	1.20896	0.79316	0.0845	0.7377	0.82223
24	0.350	1.20382	0.85261	0.1057	0.7777	0.88345
25	0.400	1.19997	0.90027	0.1279	0.8043	0.93223
26	0.450	1.19576	0.92609	0.1508	0.8093	0.96010
27	0.500	1.19213	0.94476	0.1743	0.8067	0.98092
28	0.550	1.18859	0.95194	0.1980	0.7933	0.99137
29	0.600	1.18525	0.95854	0.2220	0.7790	1.00100
30	0.650	1.18208	0.96437	0.2458	0.7638	1.00964
31	0.700	1.17917	0.96964	0.2695	0.7480	1.01753
32	0.750	1.17647	0.97434	0.2928	0.7318	1.02466
33	0.800	1.17357	0.97844	0.3157	0.7153	1.03102
34	0.850	1.17155	0.98137	0.3379	0.6983	1.03623
35	0.900	1.16928	0.98401	0.3595	0.6814	1.04098
36	0.950	1.16713	0.98635	0.3804	0.6648	1.04528
37	1.000	1.16510	0.98837	0.4006	0.6485	1.04913
38	1.100	1.16135	0.98883	0.4387	0.6153	1.05399
39	1.200	1.15790	0.98909	0.4737	0.5845	1.05815
40	1.300	1.15471	0.98914	0.5058	0.5558	1.06167
41	1.400	1.15179	0.98897	0.5353	0.5293	1.06464
42	1.500	1.14910	0.98856	0.5623	0.5048	1.06711
43	1.600	1.14669	0.98827	0.5870	0.4823	1.06937
44	1.700	1.14444	0.98754	0.6098	0.4614	1.07114
45	1.800	1.14234	0.98637	0.6306	0.4419	1.07247
46	1.900	1.14036	0.98472	0.6498	0.4236	1.07341

IRON

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.13849	0.98260	0.6675	0.4065	1.07400
48	2.200	1.13519	0.97383	0.6990	0.3742	1.07319
49	2.400	1.13217	0.96450	0.7261	0.3459	1.07203
50	2.600	1.12947	0.95464	0.7496	0.3211	1.07067
51	2.800	1.12702	0.94428	0.7701	0.2991	1.06915
52	3.000	1.12479	0.93347	0.7881	0.2794	1.06752
53	3.500	1.12038	0.90493	0.8276	0.2365	1.06408
54	4.000	1.11622	0.87463	0.8564	0.2036	1.05999
55	4.500	1.11267	0.84044	0.8792	0.1763	1.05556
56	5.000	1.10960	0.81097	0.8977	0.1548	1.05258
57	5.500	1.10685	0.78885	0.9130	0.1382	1.05115
58	6.000	1.10443	0.76719	0.9257	0.1241	1.04986
59	6.500	1.10217	0.74362	0.9365	0.1118	1.04828
60	7.000	1.10014	0.72225	0.9457	0.1014	1.04711
61	7.500	1.09830	0.70303	0.9537	0.0925	1.04628
62	8.000	1.09662	0.68590	0.9607	0.0850	1.04573
63	8.500	1.09501	0.67083	0.9668	0.0785	1.04536
64	9.000	1.09352	0.65775	0.9722	0.0730	1.04519
65	9.500	1.09214	0.64664	0.9770	0.0681	1.04519
66	10.000	1.09268	0.64664	0.9830	0.0649	1.04791

EVALUATION OF 1X1X6 MM² LIF AND STAINLESS STEEL
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
1	0.010	1.26728	0.04247	0.0002	0.0425	0.04264
2	0.015	1.27997	0.03238	0.0004	0.0324	0.03280
3	0.020	1.27905	0.02842	0.0008	0.0284	0.02918
4	0.025	1.27565	0.02721	0.0012	0.0272	0.02839
5	0.030	1.27090	0.02514	0.0017	0.0251	0.02682
6	0.035	1.26619	0.02498	0.0023	0.0249	0.02723
7	0.040	1.26435	0.02503	0.0030	0.0250	0.02793
8	0.045	1.26083	0.02606	0.0037	0.0260	0.02965
9	0.050	1.25758	0.02784	0.0044	0.0277	0.03219
10	0.055	1.25459	0.03040	0.0053	0.0303	0.03556
11	0.060	1.25186	0.03411	0.0062	0.0339	0.04011
12	0.065	1.24938	0.03789	0.0071	0.0377	0.04478
13	0.070	1.24715	0.04292	0.0081	0.0426	0.05074
14	0.075	1.24516	0.04964	0.0091	0.0493	0.05840
15	0.080	1.24348	0.05850	0.0102	0.0580	0.06822
16	0.085	1.24183	0.06629	0.0113	0.0657	0.07701
17	0.090	1.24038	0.07597	0.0125	0.0752	0.08769
18	0.095	1.23916	0.08810	0.0137	0.0871	0.10082
19	0.100	1.23828	0.10341	0.0149	0.1022	0.11710
20	0.150	1.23387	0.29881	0.0292	0.2917	0.32097
21	0.200	1.23296	0.52427	0.0463	0.5046	0.55088
22	0.250	1.22994	0.66316	0.0653	0.6280	0.69323
23	0.300	1.22680	0.79751	0.0858	0.7418	0.82753
24	0.350	1.22156	0.85394	0.1073	0.7789	0.86623
25	0.400	1.21762	0.89973	0.1298	0.8038	0.93362
26	0.450	1.21335	0.92675	0.1530	0.8099	0.96290
27	0.500	1.20963	0.94615	0.1768	0.8078	0.98467
28	0.550	1.20603	0.95319	0.2009	0.7944	0.99532
29	0.600	1.20264	0.95968	0.2252	0.7800	1.00518
30	0.650	1.19941	0.96583	0.2494	0.7650	1.01441
31	0.700	1.19646	0.97122	0.2735	0.7492	1.02270
32	0.750	1.19372	0.97583	0.2971	0.7329	1.03006
33	0.800	1.19117	0.97961	0.3203	0.7162	1.03650
34	0.850	1.18872	0.98142	0.3429	0.6983	1.04122
35	0.900	1.18642	0.98307	0.3648	0.6808	1.04560
36	0.950	1.18424	0.98454	0.3860	0.6636	1.04963
37	1.000	1.18217	0.98582	0.4065	0.6469	1.05333
38	1.100	1.17836	0.98644	0.4451	0.6138	1.05893
39	1.200	1.17487	0.98688	0.4806	0.5831	1.06379
40	1.300	1.17163	0.98713	0.5133	0.5547	1.06795
41	1.400	1.16867	0.98717	0.5431	0.5284	1.07152
42	1.500	1.16593	0.98699	0.5705	0.5040	1.07455
43	1.600	1.16349	0.98699	0.5956	0.4817	1.07735
44	1.700	1.16121	0.98656	0.6187	0.4609	1.07961
45	1.800	1.15907	0.98568	0.6399	0.4415	1.08140
46	1.900	1.15706	0.98434	0.6593	0.4234	1.08276

STEEL

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.15516	0.98252	0.6773	0.4065	1.08374
48	2.200	1.15181	0.97481	0.7093	0.3745	1.08381
49	2.400	1.14875	0.96632	0.7367	0.3466	1.08332
50	2.600	1.14601	0.95706	0.7606	0.3219	1.08246
51	2.800	1.14353	0.94705	0.7814	0.2999	1.08130
52	3.000	1.14126	0.93635	0.7996	0.2803	1.07992
53	3.500	1.13678	0.90559	0.8397	0.2367	1.07636
54	4.000	1.13256	0.87439	0.8689	0.2035	1.07246
55	4.500	1.12896	0.84128	0.8921	0.1765	1.06860
56	5.000	1.12584	0.81255	0.9109	0.1551	1.06602
57	5.500	1.12306	0.79085	0.9263	0.1385	1.06487
58	6.000	1.12060	0.76936	0.9393	0.1245	1.06377
59	6.500	1.11831	0.74502	0.9502	0.1120	1.06220
60	7.000	1.11625	0.72319	0.9596	0.1015	1.06108
61	7.500	1.11438	0.70377	0.9677	0.0926	1.06033
62	8.000	1.11267	0.68669	0.9748	0.0851	1.05989
63	8.500	1.11103	0.67188	0.9810	0.0786	1.05962
64	9.000	1.10952	0.65928	0.9864	0.0731	1.05958
65	9.500	1.10811	0.64884	0.9913	0.0684	1.05971
66	10.000	1.10867	0.64884	0.9974	0.0651	1.06251

EVALUATION OF 1X1X6 MM² LIF AND ALUMINUM
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
1	0.010	1.01902	0.22535	0.0001	0.2253	0.22546
2	0.015	1.04724	0.21264	0.0004	0.2126	0.21292
3	0.020	1.05675	0.20550	0.0006	0.2054	0.20601
4	0.025	1.06014	0.20559	0.0010	0.2054	0.20640
5	0.030	1.05657	0.20652	0.0014	0.2062	0.20767
6	0.035	1.05182	0.20993	0.0019	0.2096	0.21146
7	0.040	1.06652	0.21685	0.0025	0.2163	0.21883
8	0.045	1.06606	0.22648	0.0031	0.2258	0.22893
9	0.050	1.06475	0.24249	0.0038	0.2416	0.24540
10	0.055	1.06343	0.26355	0.0045	0.2624	0.26692
11	0.060	1.06127	0.29259	0.0052	0.2912	0.29638
12	0.065	1.06047	0.31718	0.0060	0.3154	0.32141
13	0.070	1.06010	0.34792	0.0069	0.3457	0.35254
14	0.075	1.05894	0.38571	0.0078	0.3829	0.39064
15	0.080	1.05805	0.43055	0.0087	0.4270	0.43570
16	0.085	1.05807	0.46451	0.0096	0.4603	0.46992
17	0.090	1.05807	0.50232	0.0107	0.4973	0.50791
18	0.095	1.05819	0.54392	0.0117	0.5379	0.54960
19	0.100	1.05814	0.58895	0.0128	0.5818	0.59460
20	0.150	1.06284	0.83128	0.0252	0.8116	0.83677
21	0.200	1.06432	0.91217	0.0400	0.8779	0.91788
22	0.250	1.06403	0.93487	0.0565	0.8853	0.94173
23	0.300	1.06229	0.94930	0.0743	0.8829	0.95720
24	0.350	1.06055	0.95296	0.0931	0.8693	0.96241
25	0.400	1.05894	0.95496	0.1129	0.8531	0.96605
26	0.450	1.05741	0.95376	0.1334	0.8335	0.96684
27	0.500	1.05601	0.95425	0.1544	0.8148	0.96912
28	0.550	1.05475	0.95780	0.1757	0.7982	0.97395
29	0.600	1.05346	0.96033	0.1973	0.7805	0.97777
30	0.650	1.05221	0.96018	0.2188	0.7605	0.97932
31	0.700	1.05102	0.96002	0.2402	0.7406	0.98082
32	0.750	1.04987	0.95984	0.2613	0.7209	0.98225
33	0.800	1.04877	0.95963	0.2820	0.7016	0.98360
34	0.850	1.04770	0.95922	0.3022	0.6825	0.98475
35	0.900	1.04668	0.95891	0.3218	0.6641	0.98590
36	0.950	1.04569	0.95870	0.3409	0.6462	0.98706
37	1.000	1.04474	0.95859	0.3592	0.6290	0.98821
38	1.100	1.04295	0.96036	0.3939	0.5976	0.99156
39	1.200	1.04128	0.96179	0.4260	0.5683	0.99431
40	1.300	1.03971	0.96285	0.4555	0.5411	0.99652
41	1.400	1.03825	0.96352	0.4825	0.5157	0.99825
42	1.500	1.03689	0.96378	0.5074	0.4922	0.99955
43	1.600	1.03564	0.96273	0.5302	0.4699	1.00005
44	1.700	1.03446	0.96163	0.5512	0.4493	1.00043
45	1.800	1.03334	0.96048	0.5704	0.4303	1.00071
46	1.900	1.03229	0.95929	0.5882	0.4127	1.00089

ALUMINUM

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) FI(LARGE)		D*FS	(1-D)FI	GENERAL RATIO F
47	2.000	1.03129	0.95804	0.6047	0.3963	1.00099
48	2.200	1.02949	0.95544	0.6339	0.3671	1.00104
49	2.400	1.02783	0.95265	0.6592	0.3417	1.00087
50	2.600	1.02634	0.94965	0.6811	0.3194	1.00055
51	2.800	1.02498	0.94645	0.7004	0.2997	1.00011
52	3.000	1.02373	0.94306	0.7173	0.2823	0.99958
53	3.500	1.02126	0.93468	0.7544	0.2443	0.99863
54	4.000	1.01890	0.92366	0.7817	0.2150	0.99673
55	4.500	1.01690	0.90694	0.8035	0.1903	0.99383
56	5.000	1.01517	0.89384	0.8213	0.1707	0.99200
57	5.500	1.01363	0.88765	0.8361	0.1555	0.99156
58	6.000	1.01227	0.88006	0.8485	0.1424	0.99088
59	6.500	1.01101	0.85737	0.8590	0.1289	0.98792
60	7.000	1.00989	0.84256	0.8681	0.1183	0.98640
61	7.500	1.00886	0.83540	0.8761	0.1100	0.98603
62	8.000	1.00793	0.83601	0.8830	0.1036	0.98662
63	8.500	1.00711	0.84482	0.8892	0.0989	0.98811
64	9.000	1.00637	0.86267	0.8947	0.0957	0.99043
65	9.500	1.00570	0.89093	0.8997	0.0939	0.99361
66	10.000	1.00634	0.89093	0.9053	0.0894	0.99475

APPENDIX B

TERC/III Calculations of Encased 1x1x6 mm
CaF₂:Mn TLDs Without Sleeve Attenuation.

EVALUATION OF 1X1X6 MM CA₂ AND LEAD
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
1	0.010	2.32330	0.39300	0.0003	0.3930	0.39324
2	0.015	2.19054	0.17222	0.0006	0.1722	0.17281
3	0.020	2.10479	0.09653	0.0011	0.0965	0.09759
4	0.025	2.04640	0.08914	0.0017	0.0891	0.09074
5	0.030	2.00208	0.07743	0.0023	0.0773	0.07968
6	0.035	1.96740	0.07339	0.0031	0.0733	0.07636
7	0.040	1.93998	0.06327	0.0039	0.0681	0.07206
8	0.045	1.91663	0.06623	0.0048	0.0661	0.07089
9	0.050	1.89679	0.06375	0.0058	0.0636	0.06937
10	0.055	1.87968	0.06209	0.0068	0.0619	0.06871
11	0.060	1.86480	0.06017	0.0080	0.0599	0.06787
12	0.065	1.85153	0.06164	0.0091	0.0613	0.07045
13	0.070	1.83969	0.06236	0.0103	0.0620	0.07235
14	0.075	1.82920	0.06157	0.0116	0.0612	0.07279
15	0.080	1.81983	0.05833	0.0129	0.0579	0.07085
16	0.085	1.81069	0.04836	0.0143	0.0480	0.06228
17	0.090	1.80226	0.04060	0.0157	0.0402	0.05596
18	0.095	1.79447	0.03445	0.0172	0.0341	0.05129
19	0.100	1.78725	0.02956	0.0187	0.0293	0.04792
20	0.150	1.73789	0.03176	0.0357	0.0311	0.06678
21	0.200	1.70790	0.04949	0.0555	0.0479	0.10341
22	0.250	1.68737	0.07301	0.0775	0.0697	0.14720
23	0.300	1.67365	0.11344	0.1013	0.1066	0.20791
24	0.350	1.66143	0.15192	0.1264	0.1404	0.26673
25	0.400	1.65343	0.20382	0.1527	0.1850	0.33768
26	0.450	1.64541	0.25201	0.1798	0.2245	0.40425
27	0.500	1.63981	0.30712	0.2077	0.2682	0.47595
28	0.550	1.63377	0.35297	0.2361	0.3020	0.53806
29	0.600	1.62903	0.40396	0.2649	0.3383	0.60319
30	0.650	1.62341	0.44279	0.2937	0.3627	0.65638
31	0.700	1.61867	0.48482	0.3225	0.3882	0.71073
32	0.750	1.61474	0.52949	0.3512	0.4143	0.76554
33	0.800	1.61163	0.57573	0.3797	0.4401	0.81581
34	0.850	1.60755	0.61320	0.4075	0.4578	0.86526
35	0.900	1.60400	0.65223	0.4348	0.4754	0.91021
36	0.950	1.60098	0.69235	0.4615	0.4928	0.95424
37	1.000	1.59836	0.73289	0.4875	0.5094	0.99635
38	1.100	1.59264	0.76896	0.5370	0.5057	1.04666
39	1.200	1.58713	0.80473	0.5831	0.5091	1.09216
40	1.300	1.58226	0.83924	0.6260	0.5072	1.13319
41	1.400	1.57801	0.87137	0.6658	0.5037	1.16953
42	1.500	1.57432	0.89981	0.7028	0.4981	1.20092
43	1.600	1.57089	0.91120	0.7370	0.4837	1.22070
44	1.700	1.56764	0.92130	0.7636	0.4656	1.23819
45	1.800	1.56458	0.92992	0.7978	0.4557	1.25356
46	1.900	1.56173	0.93688	0.8249	0.4420	1.26694

LEAD

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.55907	0.94201	0.8501	0.4284	1.27846
48	2.200	1.55378	0.93150	0.8949	0.3950	1.28990
49	2.400	1.54892	0.91931	0.9337	0.3651	1.29885
50	2.600	1.54460	0.90553	0.9676	0.3383	1.30587
51	2.800	1.54071	0.89027	0.9974	0.3140	1.31132
52	3.000	1.53717	0.87367	1.0237	0.2919	1.31553
53	3.500	1.52871	0.82297	1.0808	0.2412	1.32191
54	4.000	1.52091	0.77742	1.1226	0.2036	1.32617
55	4.500	1.51368	0.73553	1.1554	0.1741	1.32948
56	5.000	1.50733	0.70165	1.1819	0.1515	1.33337
57	5.500	1.50134	0.67583	1.2034	0.1341	1.33752
58	6.000	1.49600	0.65451	1.2214	0.1202	1.34152
59	6.500	1.49089	0.64273	1.2363	0.1098	1.34605
60	7.000	1.48625	0.63097	1.2490	0.1007	1.34972
61	7.500	1.48201	0.61922	1.2599	0.0928	1.35271
62	8.000	1.47811	0.60745	1.2694	0.0858	1.35518
63	8.500	1.47434	0.59563	1.2775	0.0795	1.35705
64	9.000	1.47085	0.58376	1.2847	0.0739	1.35857
65	9.500	1.46760	0.57179	1.2910	0.0683	1.35980
66	10.000	1.46635	0.57179	1.2982	0.0656	1.36376

EVALUATION OF 1X1X6 MM CA₂ AND TANTALUM
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
1	0.010	2.01076	0.23366	0.0003	0.2336	0.23338
2	0.015	1.93846	0.13217	0.0006	0.1321	0.13270
3	0.020	1.88610	0.11865	0.0010	0.1186	0.11958
4	0.025	1.84881	0.11215	0.0015	0.1121	0.11357
5	0.030	1.81942	0.10121	0.0021	0.1011	0.10322
6	0.035	1.79589	0.09723	0.0028	0.0971	0.09990
7	0.040	1.77739	0.09211	0.0036	0.0919	0.09552
8	0.045	1.76116	0.09024	0.0044	0.0900	0.09446
9	0.050	1.74722	0.08790	0.0053	0.0876	0.09298
10	0.055	1.73510	0.08794	0.0063	0.0876	0.09395
11	0.060	1.72449	0.08413	0.0074	0.0836	0.09113
12	0.065	1.71480	0.06563	0.0084	0.0653	0.07375
13	0.070	1.70602	0.05207	0.0096	0.0518	0.06137
14	0.075	1.69809	0.04204	0.0108	0.0418	0.05255
15	0.080	1.69080	0.03472	0.0120	0.0345	0.04649
16	0.085	1.68421	0.03345	0.0133	0.0332	0.04649
17	0.090	1.67815	0.03216	0.0146	0.0319	0.04651
18	0.095	1.67255	0.03087	0.0160	0.0306	0.04658
19	0.100	1.66738	0.02963	0.0174	0.0293	0.04674
20	0.150	1.63061	0.03758	0.0335	0.0368	0.07028
21	0.200	1.60813	0.06137	0.0523	0.0599	0.11214
22	0.250	1.59259	0.09259	0.0732	0.0883	0.16152
23	0.300	1.58277	0.14665	0.0958	0.1378	0.23360
24	0.350	1.57352	0.19645	0.1197	0.1815	0.30119
25	0.400	1.56800	0.26320	0.1448	0.2389	0.38369
26	0.450	1.56189	0.32369	0.1706	0.2883	0.45897
27	0.500	1.55787	0.39106	0.1974	0.3415	0.53888
28	0.550	1.55310	0.44333	0.2244	0.3793	0.60370
29	0.600	1.54934	0.49994	0.2520	0.4186	0.67060
30	0.650	1.54488	0.54297	0.2795	0.4447	0.72422
31	0.700	1.54125	0.58835	0.3071	0.4711	0.77820
32	0.750	1.53814	0.63511	0.3346	0.4970	0.83153
33	0.800	1.53559	0.68180	0.3618	0.5212	0.88298
34	0.850	1.53216	0.71638	0.3884	0.5348	0.92318
35	0.900	1.52911	0.75154	0.4145	0.5478	0.96230
36	0.950	1.52641	0.78683	0.4400	0.5600	1.00000
37	1.000	1.52402	0.82170	0.4648	0.5711	1.03590
38	1.100	1.51915	0.85570	0.5122	0.5672	1.07938
39	1.200	1.51451	0.88871	0.5504	0.5622	1.11861
40	1.300	1.51034	0.91982	0.5975	0.5559	1.15344
41	1.400	1.50666	0.94802	0.6357	0.5480	1.18373
42	1.500	1.50340	0.97220	0.6711	0.5382	1.20933
43	1.600	1.50030	0.98022	0.7039	0.5203	1.22422
44	1.700	1.49736	0.98694	0.7341	0.5031	1.23720
45	1.800	1.49458	0.99223	0.7621	0.4863	1.24640
46	1.900	1.49196	0.99595	0.7881	0.4699	1.25795

TANTALUM

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
47	2.000	1.48952	0.99799	0.8122	0.4538	1.26599
48	2.200	1.48486	0.98443	0.8552	0.4174	1.27265
49	2.400	1.48057	0.96939	0.8925	0.3850	1.27753
50	2.600	1.47674	0.95298	0.9251	0.3560	1.28108
51	2.800	1.47326	0.93533	0.9537	0.3299	1.28355
52	3.000	1.47008	0.91662	0.9790	0.3062	1.28519
53	3.500	1.46274	0.86205	1.0341	0.2526	1.28672
54	4.000	1.45591	0.81382	1.0746	0.2132	1.28773
55	4.500	1.44971	0.77056	1.1065	0.1824	1.28894
56	5.000	1.44427	0.73550	1.1324	0.1588	1.29124
57	5.500	1.43915	0.70908	1.1536	0.1407	1.29427
58	6.000	1.43459	0.68662	1.1712	0.1260	1.29728
59	6.500	1.43023	0.67252	1.1860	0.1148	1.30087
60	7.000	1.42638	0.65857	1.1987	0.1051	1.30381
61	7.500	1.42282	0.64475	1.2096	0.0966	1.30622
62	8.000	1.41956	0.63101	1.2191	0.0891	1.30822
63	8.500	1.41642	0.61733	1.2273	0.0824	1.30975
64	9.000	1.41351	0.60368	1.2346	0.0764	1.31101
65	9.500	1.41081	0.59002	1.2410	0.0710	1.31204
66	10.000	1.40990	0.59002	1.2482	0.0677	1.31587

EVALUATION OF 1X1X6 MM CA₂ AND TIN
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) FI(LARGE)		D*FS	(1-D)FI	GENERAL RATIO F
1	0.010	1.61476	0.36828	0.0002	0.3682	0.36844
2	0.015	1.59942	0.35040	0.0005	0.3503	0.35077
3	0.020	1.58062	0.33666	0.0008	0.3365	0.33732
4	0.025	1.56529	0.22014	0.0013	0.2200	0.22124
5	0.030	1.55206	0.12917	0.0018	0.1290	0.13084
6	0.035	1.54085	0.10471	0.0024	0.1045	0.10697
7	0.040	1.53216	0.08219	0.0031	0.0820	0.08512
8	0.045	1.52391	0.07433	0.0038	0.0741	0.07739
9	0.050	1.51664	0.06637	0.0046	0.0662	0.07081
10	0.055	1.51019	0.06228	0.0055	0.0620	0.06755
11	0.060	1.50441	0.05785	0.0064	0.0576	0.06402
12	0.065	1.49918	0.05650	0.0074	0.0562	0.06360
13	0.070	1.49443	0.05505	0.0084	0.0547	0.06313
14	0.075	1.49012	0.05357	0.0095	0.0532	0.06269
15	0.080	1.48620	0.05221	0.0106	0.0518	0.06240
16	0.085	1.48253	0.05262	0.0117	0.0522	0.06391
17	0.090	1.47915	0.05317	0.0129	0.0527	0.06560
18	0.095	1.47604	0.05392	0.0141	0.0534	0.06753
19	0.100	1.47322	0.05494	0.0154	0.0544	0.06975
20	0.150	1.45323	0.08670	0.0298	0.0849	0.11474
21	0.200	1.44196	0.15332	0.0469	0.1483	0.19522
22	0.250	1.43407	0.22822	0.0659	0.2177	0.28364
23	0.300	1.43104	0.35417	0.0866	0.3327	0.41937
24	0.350	1.42589	0.45073	0.1085	0.4164	0.52490
25	0.400	1.42376	0.56392	0.1315	0.5118	0.64332
26	0.450	1.41998	0.64868	0.1551	0.5778	0.73294
27	0.500	1.41755	0.72975	0.1796	0.6373	0.81638
28	0.550	1.41402	0.78209	0.2043	0.6691	0.87341
29	0.600	1.41088	0.83271	0.2294	0.6973	0.92673
30	0.650	1.40724	0.86749	0.2546	0.7106	0.96514
31	0.700	1.40413	0.90129	0.2798	0.7217	1.00147
32	0.750	1.40141	0.93340	0.3048	0.7304	1.03520
33	0.800	1.39902	0.96306	0.3296	0.7361	1.06578
34	0.850	1.39634	0.98411	0.3540	0.7346	1.08861
35	0.900	1.39388	1.00425	0.3778	0.7320	1.10986
36	0.950	1.39163	1.02326	0.4011	0.7283	1.12943
37	1.000	1.38955	1.04092	0.4238	0.7234	1.14725
38	1.100	1.38564	1.05520	0.4672	0.6994	1.16661
39	1.200	1.38206	1.06814	0.5077	0.6757	1.18346
40	1.300	1.37882	1.07948	0.5455	0.6524	1.19790
41	1.400	1.37591	1.08899	0.5805	0.6295	1.21006
42	1.500	1.37326	1.09643	0.6130	0.6070	1.22001
43	1.600	1.37088	1.09838	0.6432	0.5831	1.22622
44	1.700	1.36861	1.09933	0.6710	0.5603	1.23135
45	1.800	1.36645	1.09923	0.6968	0.5387	1.23549
46	1.900	1.36438	1.09803	0.7207	0.5180	1.23872

TIN

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.36242	1.09570	0.7429	0.4983	1.24113
48	2.200	1.35886	1.07996	0.7826	0.4580	1.24059
49	2.400	1.35553	1.06332	0.8171	0.4223	1.23947
50	2.600	1.35251	1.04589	0.8473	0.3907	1.23797
51	2.800	1.34973	1.02779	0.8737	0.3625	1.23619
52	3.000	1.34715	1.00915	0.8971	0.3371	1.23424
53	3.500	1.34175	0.95870	0.9486	0.2809	1.22951
54	4.000	1.33648	0.91299	0.9864	0.2391	1.22556
55	4.500	1.33179	0.87137	1.0165	0.2063	1.22280
56	5.000	1.32764	0.83632	1.0410	0.1806	1.22156
57	5.500	1.32378	0.80809	1.0611	0.1604	1.22144
58	6.000	1.32029	0.78421	1.0779	0.1440	1.22188
59	6.500	1.31697	0.76981	1.0921	0.1315	1.22353
60	7.000	1.31394	0.75549	1.1042	0.1206	1.22479
61	7.500	1.31115	0.74121	1.1147	0.1111	1.22574
62	8.000	1.30857	0.72695	1.1238	0.1026	1.22645
63	8.500	1.30608	0.71266	1.1317	0.0951	1.22686
64	9.000	1.30375	0.69833	1.1387	0.0884	1.22712
65	9.500	1.30158	0.68393	1.1450	0.0823	1.22725
66	10.000	1.30135	0.68393	1.1521	0.0784	1.23054

EVALUATION OF 1X1X6 MM CAF_2 AND ZIRCONIUM
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS (SMALL) F1 (LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
1	0.010	1.40414	0.68892	0.0002	0.6888	0.68900
2	0.015	1.40965	0.66430	0.0004	0.6641	0.66452
3	0.020	1.40433	0.18293	0.0007	0.1828	0.18357
4	0.025	1.39801	0.15585	0.0011	0.1557	0.15686
5	0.030	1.39149	0.12084	0.0016	0.1207	0.12233
6	0.035	1.38550	0.11143	0.0022	0.1113	0.11343
7	0.040	1.38109	0.10033	0.0028	0.1001	0.10292
8	0.045	1.37641	0.09633	0.0035	0.0961	0.09956
9	0.050	1.37218	0.09175	0.0042	0.0915	0.09567
10	0.055	1.36834	0.08910	0.0050	0.0888	0.09377
11	0.060	1.36486	0.08613	0.0058	0.0858	0.09158
12	0.065	1.36167	0.08560	0.0067	0.0852	0.09188
13	0.070	1.35875	0.08512	0.0076	0.0846	0.09228
14	0.075	1.35608	0.08479	0.0086	0.0843	0.09286
15	0.080	1.35367	0.08478	0.0096	0.0842	0.09380
16	0.085	1.35138	0.08625	0.0107	0.0856	0.09624
17	0.090	1.34928	0.08812	0.0118	0.0874	0.09912
18	0.095	1.34736	0.09052	0.0129	0.0897	0.10254
19	0.100	1.34565	0.09360	0.0141	0.0926	0.10668
20	0.150	1.33385	0.15202	0.0274	0.1489	0.17627
21	0.200	1.32810	0.26458	0.0432	0.2560	0.29916
22	0.250	1.32386	0.37554	0.0608	0.3583	0.41912
23	0.300	1.32291	0.53913	0.0801	0.5065	0.58658
24	0.350	1.31916	0.64398	0.1003	0.5950	0.69533
25	0.400	1.31729	0.75094	0.1216	0.6816	0.80324
26	0.450	1.31403	0.82009	0.1436	0.7305	0.87405
27	0.500	1.31149	0.88008	0.1661	0.7686	0.93473
28	0.550	1.30845	0.91629	0.1891	0.7839	0.97296
29	0.600	1.30564	0.94915	0.2123	0.7948	1.00712
30	0.650	1.30272	0.96969	0.2357	0.7943	1.02993
31	0.700	1.30013	0.98897	0.2590	0.7919	1.05096
32	0.750	1.29782	1.00673	0.2823	0.7878	1.07004
33	0.800	1.29575	1.02270	0.3053	0.7817	1.08704
34	0.850	1.29364	1.03418	0.3279	0.7720	1.09995
35	0.900	1.29172	1.04489	0.3501	0.7617	1.11179
36	0.950	1.28956	1.05476	0.3718	0.7507	1.12255
37	1.000	1.28835	1.06370	0.3929	0.7393	1.13222
38	1.100	1.28547	1.06992	0.4334	0.7092	1.14260
39	1.200	1.28294	1.07540	0.4713	0.6803	1.15164
40	1.300	1.28072	1.08003	0.5067	0.6528	1.15942
41	1.400	1.27876	1.08375	0.5396	0.6265	1.16603
42	1.500	1.27699	1.08646	0.5701	0.6015	1.17151
43	1.600	1.27545	1.08724	0.5984	0.5772	1.17554
44	1.700	1.27398	1.08729	0.6246	0.5542	1.17882
45	1.800	1.27258	1.08656	0.6489	0.5325	1.18142
46	1.900	1.27125	1.08504	0.6715	0.5119	1.18340

ZIRCONIUM

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.26998	1.08270	0.6925	0.4924	1.18481
48	2.200	1.26770	1.07000	0.7301	0.4537	1.18386
49	2.400	1.26556	1.05659	0.7629	0.4197	1.18256
50	2.600	1.26362	1.04256	0.7916	0.3895	1.18104
51	2.800	1.26183	1.02798	0.8168	0.3625	1.17936
52	3.000	1.26017	1.01294	0.8392	0.3384	1.17758
53	3.500	1.25676	0.97260	0.8885	0.2850	1.17350
54	4.000	1.25343	0.93473	0.9251	0.2448	1.16996
55	4.500	1.25049	0.89893	0.9545	0.2128	1.16727
56	5.000	1.24789	0.86793	0.9785	0.1874	1.16585
57	5.500	1.24551	0.84170	0.9983	0.1670	1.16537
58	6.000	1.24336	0.81973	1.0151	0.1505	1.16559
59	6.500	1.24129	0.80800	1.0293	0.1380	1.16730
60	7.000	1.23940	0.79580	1.0416	0.1270	1.16859
61	7.500	1.23766	0.78315	1.0522	0.1174	1.16955
62	8.000	1.23606	0.77007	1.0615	0.1087	1.17026
63	8.500	1.23452	0.75655	1.0697	0.1010	1.17071
64	9.000	1.23308	0.74260	1.0770	0.0940	1.17099
65	9.500	1.23173	0.72822	1.0835	0.0876	1.17114
66	10.000	1.23180	0.72822	1.0905	0.0835	1.17405

EVALUATION OF 1X1X6 MM CaF_2 AND COPPER
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) FI(LARGE)		D*FS	(1-D)FI	GENERAL RATIO F
1	0.010	1.20978	0.31594	0.0002	0.3159	0.31605
2	0.015	1.23118	0.25816	0.0004	0.2581	0.25844
3	0.020	1.23634	0.23346	0.0006	0.2333	0.23398
4	0.025	1.23732	0.22430	0.0010	0.2241	0.22513
5	0.030	1.23619	0.20844	0.0014	0.2082	0.20964
6	0.035	1.23443	0.20352	0.0019	0.2032	0.20514
7	0.040	1.23422	0.19717	0.0025	0.1968	0.19927
8	0.045	1.23260	0.19575	0.0031	0.1953	0.19837
9	0.050	1.23095	0.19397	0.0038	0.1934	0.19714
10	0.055	1.22937	0.19265	0.0045	0.1919	0.19643
11	0.060	1.22781	0.19135	0.0052	0.1905	0.19577
12	0.065	1.22640	0.19233	0.0060	0.1914	0.19742
13	0.070	1.22509	0.19380	0.0069	0.1927	0.19960
14	0.075	1.22384	0.19603	0.0078	0.1948	0.20255
15	0.080	1.22272	0.19933	0.0087	0.1979	0.20660
16	0.085	1.22166	0.20360	0.0096	0.2020	0.21164
17	0.090	1.22069	0.20895	0.0106	0.2071	0.21777
18	0.095	1.21982	0.21573	0.0117	0.2137	0.22533
19	0.100	1.21906	0.22438	0.0127	0.2220	0.23477
20	0.150	1.21479	0.35365	0.0249	0.3464	0.37132
21	0.200	1.21369	0.53621	0.0395	0.5188	0.55824
22	0.250	1.21217	0.66928	0.0557	0.6385	0.69423
23	0.300	1.21117	0.81415	0.0733	0.7649	0.83819
24	0.350	1.20841	0.98104	0.0919	0.8140	0.90594
25	0.400	1.20641	0.93763	0.1114	0.8510	0.96245
26	0.450	1.20406	0.97017	0.1315	0.8642	0.99573
27	0.500	1.20204	0.99484	0.1523	0.8688	1.02105
28	0.550	1.19997	1.00646	0.1734	0.8610	1.03442
29	0.600	1.19798	1.01673	0.1948	0.8514	1.04620
30	0.650	1.19615	1.02368	0.2164	0.8385	1.05488
31	0.700	1.19462	1.03016	0.2380	0.8249	1.06293
32	0.750	1.19329	1.03615	0.2596	0.8108	1.07033
33	0.800	1.19210	1.04161	0.2809	0.7962	1.07707
34	0.850	1.19101	1.04616	0.3019	0.7810	1.08288
35	0.900	1.19004	1.05034	0.3226	0.7656	1.08820
36	0.950	1.18916	1.05412	0.3428	0.7503	1.09304
37	1.000	1.18837	1.05749	0.3624	0.7350	1.09741
38	1.100	1.18703	1.05968	0.4002	0.7024	1.10261
39	1.200	1.18592	1.06150	0.4357	0.6715	1.10721
40	1.300	1.18500	1.06292	0.4688	0.6424	1.11122
41	1.400	1.18423	1.06392	0.4997	0.6150	1.11469
42	1.500	1.18355	1.06448	0.5284	0.5893	1.11763
43	1.600	1.18295	1.06430	0.5550	0.5650	1.11997
44	1.700	1.18237	1.06375	0.5797	0.5422	1.12191
45	1.800	1.18182	1.06279	0.6027	0.5208	1.12349
46	1.900	1.18128	1.06143	0.6240	0.5008	1.12474

COPPER

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
47	2.000	1.18076	1.05964	0.6438	0.4819	1.12568
48	2.200	1.17979	1.05203	0.6795	0.4461	1.12562
49	2.400	1.17887	1.04396	0.7106	0.4147	1.12528
50	2.600	1.17801	1.03547	0.7379	0.3868	1.12476
51	2.800	1.17721	1.02657	0.7621	0.3620	1.12409
52	3.000	1.17646	1.01733	0.7835	0.3398	1.12330
53	3.500	1.17492	0.99243	0.8306	0.2908	1.12145
54	4.000	1.17339	0.96795	0.8661	0.2535	1.11958
55	4.500	1.17203	0.94376	0.8946	0.2234	1.11799
56	5.000	1.17082	0.92187	0.9180	0.1990	1.11707
57	5.500	1.16972	0.90205	0.9376	0.1790	1.11660
58	6.000	1.16873	0.88559	0.9542	0.1626	1.11675
59	6.500	1.16779	0.87852	0.9684	0.1500	1.11839
60	7.000	1.16693	0.87049	0.9806	0.1390	1.11961
61	7.500	1.16614	0.86152	0.9914	0.1291	1.12049
62	8.000	1.16542	0.85162	1.0009	0.1202	1.12111
63	8.500	1.16472	0.84082	1.0092	0.1122	1.12143
64	9.000	1.16407	0.82915	1.0167	0.1049	1.12168
65	9.500	1.16347	0.81663	1.0235	0.0983	1.12173
66	10.000	1.16365	0.81663	1.0302	0.0937	1.12385

EVALUATION OF 1X16 MM CAP₂ AND IRON
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS (SMALL) F1 (LARGE)		D*FS	(1-D) F1	GENERAL RATIO F
1	0.010	1.11232	0.34940	0.0001	0.3494	0.34949
2	0.015	1.14031	0.30960	0.0003	0.3095	0.30935
3	0.020	1.15009	0.29126	0.0006	0.2911	0.29171
4	0.025	1.15434	0.28366	0.0009	0.2834	0.28437
5	0.030	1.15564	0.27017	0.0014	0.2699	0.27120
6	0.035	1.15579	0.26663	0.0018	0.2662	0.26802
7	0.040	1.15760	0.26222	0.0023	0.2617	0.26403
8	0.045	1.15739	0.26263	0.0029	0.2620	0.26486
9	0.050	1.15692	0.26274	0.0035	0.2619	0.26547
10	0.055	1.15635	0.26121	0.0042	0.2603	0.26447
11	0.060	1.15564	0.25576	0.0049	0.2586	0.26353
12	0.065	1.15503	0.26119	0.0057	0.2599	0.26559
13	0.070	1.15445	0.26332	0.0065	0.2618	0.26833
14	0.075	1.15378	0.26648	0.0073	0.2643	0.27211
15	0.080	1.15312	0.27108	0.0082	0.2692	0.27735
16	0.085	1.15259	0.27678	0.0091	0.2746	0.28370
17	0.090	1.15207	0.28390	0.0100	0.2814	0.29147
18	0.095	1.15158	0.29288	0.0110	0.2901	0.30110
19	0.100	1.15103	0.30428	0.0120	0.3011	0.31313
20	0.150	1.14893	0.46001	0.0236	0.4506	0.47415
21	0.200	1.14878	0.64559	0.0374	0.6246	0.66195
22	0.250	1.14831	0.76252	0.0523	0.7275	0.78025
23	0.300	1.14768	0.87665	0.0695	0.8236	0.89306
24	0.350	1.14612	0.92603	0.0872	0.8556	0.94277
25	0.400	1.14487	0.96623	0.1057	0.8770	0.98272
26	0.450	1.14341	0.99001	0.1249	0.8819	1.00677
27	0.500	1.14210	1.00637	0.1447	0.8739	1.02357
28	0.550	1.14086	1.01060	0.1649	0.8646	1.02942
29	0.600	1.13977	1.01472	0.1854	0.8497	1.03506
30	0.650	1.13876	1.01877	0.2060	0.8345	1.04048
31	0.700	1.13786	1.02266	0.2267	0.8189	1.04561
32	0.750	1.13705	1.02639	0.2473	0.8031	1.05046
33	0.800	1.13631	1.02994	0.2677	0.7873	1.05500
34	0.850	1.13563	1.03355	0.2879	0.7715	1.05942
35	0.900	1.13502	1.03680	0.3076	0.7558	1.06343
36	0.950	1.13447	1.03970	0.3270	0.7400	1.06701
37	1.000	1.13397	1.04221	0.3459	0.7243	1.07020
38	1.100	1.13313	1.04261	0.3820	0.6911	1.07313
39	1.200	1.13245	1.04292	0.4160	0.6598	1.07531
40	1.300	1.13190	1.04313	0.4478	0.6305	1.07825
41	1.400	1.13144	1.04324	0.4774	0.6031	1.08045
42	1.500	1.13102	1.04324	0.5049	0.5775	1.08243
43	1.600	1.13066	1.04362	0.5305	0.5540	1.08445
44	1.700	1.13029	1.04365	0.5542	0.5320	1.08613
45	1.800	1.12992	1.04331	0.5762	0.5113	1.08748
46	1.900	1.12955	1.04259	0.5967	0.4919	1.08852

IRON

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.12919	1.04146	0.6157	0.4736	1.08929
48	2.200	1.12849	1.03491	0.6500	0.4388	1.08881
49	2.400	1.12779	1.02813	0.6798	0.4084	1.08821
50	2.600	1.12713	1.02116	0.7061	0.3815	1.08755
51	2.800	1.12650	1.01403	0.7292	0.3576	1.08684
52	3.000	1.12590	1.00677	0.7498	0.3363	1.08611
53	3.500	1.12466	0.98834	0.7951	0.2898	1.08486
54	4.000	1.12338	0.97014	0.8291	0.2541	1.08324
55	4.500	1.12222	0.95007	0.8566	0.2249	1.08147
56	5.000	1.12113	0.93186	0.8791	0.2012	1.08031
57	5.500	1.12022	0.91539	0.8979	0.1817	1.07957
58	6.000	1.11935	0.90170	0.9139	0.1655	1.07940
59	6.500	1.11853	0.88965	0.9275	0.1531	1.08062
60	7.000	1.11777	0.88025	0.9393	0.1421	1.08145
61	7.500	1.11708	0.88282	0.9497	0.1323	1.08197
62	8.000	1.11643	0.87428	0.9588	0.1234	1.08224
63	8.500	1.11581	0.86467	0.9669	0.1154	1.08228
64	9.000	1.11523	0.85401	0.9741	0.1081	1.08216
65	9.500	1.11468	0.84232	0.9805	0.1014	1.08191
66	10.000	1.11491	0.84232	0.9870	0.0966	1.08365

EVALUATION OF 1X1X6 MM CA₂ AND STAINLESS STEEL
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) FI(LARGE)		D*FS	(1-D)FI	GENERAL RATIO F
1	0.010	1.12862	0.35706	0.0001	0.3570	0.35715
2	0.015	1.15701	0.31638	0.0003	0.3163	0.31663
3	0.020	1.16694	0.29780	0.0006	0.2976	0.29826
4	0.025	1.17124	0.29005	0.0010	0.2898	0.29077
5	0.030	1.17254	0.27631	0.0014	0.2760	0.27735
6	0.035	1.17268	0.27272	0.0018	0.2723	0.27413
7	0.040	1.17455	0.26831	0.0024	0.2678	0.27014
8	0.045	1.17434	0.26905	0.0030	0.2684	0.27133
9	0.050	1.17386	0.26947	0.0036	0.2686	0.27224
10	0.055	1.17328	0.26771	0.0043	0.2667	0.27101
11	0.060	1.17255	0.26600	0.0050	0.2649	0.26987
12	0.065	1.17193	0.26741	0.0058	0.2661	0.27187
13	0.070	1.17134	0.26952	0.0065	0.2680	0.27459
14	0.075	1.17066	0.27256	0.0074	0.2709	0.27835
15	0.080	1.17000	0.27725	0.0083	0.2753	0.28359
16	0.085	1.16946	0.28299	0.0092	0.2808	0.29000
17	0.090	1.16893	0.29017	0.0102	0.2876	0.29784
18	0.095	1.16843	0.29922	0.0112	0.2964	0.30754
19	0.100	1.16793	0.31071	0.0122	0.3075	0.31566
20	0.150	1.16579	0.46826	0.0239	0.4567	0.48258
21	0.200	1.16569	0.65322	0.0379	0.6320	0.66968
22	0.250	1.16520	0.76935	0.0535	0.7340	0.78754
23	0.300	1.16454	0.88146	0.0705	0.8281	0.89860
24	0.350	1.16294	0.92747	0.0885	0.8569	0.94538
25	0.400	1.16167	0.96564	0.1073	0.8765	0.98374
26	0.450	1.16018	0.99072	0.1268	0.8825	1.00923
27	0.500	1.15884	1.00786	0.1468	0.8902	1.02698
28	0.550	1.15758	1.01192	0.1673	0.8657	1.03297
29	0.600	1.15648	1.01592	0.1881	0.8507	1.03878
30	0.650	1.15545	1.02031	0.2090	0.8357	1.04476
31	0.700	1.15453	1.02433	0.2300	0.8202	1.05027
32	0.750	1.15371	1.02795	0.2509	0.8044	1.05530
33	0.800	1.15296	1.03116	0.2717	0.7882	1.05936
34	0.850	1.15227	1.03360	0.2921	0.7716	1.06368
35	0.900	1.15165	1.03581	0.3122	0.7551	1.06721
36	0.950	1.15109	1.03779	0.3318	0.7387	1.07044
37	1.000	1.15058	1.03952	0.3509	0.7225	1.07339
38	1.100	1.14973	1.04008	0.3676	0.6894	1.07705
39	1.200	1.14904	1.04058	0.4221	0.6583	1.08042
40	1.300	1.14848	1.04100	0.4544	0.6292	1.08352
41	1.400	1.14801	1.04134	0.4844	0.6020	1.08635
42	1.500	1.14759	1.04159	0.5123	0.5766	1.08891
43	1.600	1.14722	1.04227	0.5382	0.5533	1.09151
44	1.700	1.14684	1.04261	0.5623	0.5314	1.09372
45	1.800	1.14647	1.04259	0.5846	0.5109	1.09556
46	1.900	1.14610	1.04218	0.6054	0.4917	1.09707

STEEL

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
47	2.000	1.14573	1.04138	0.6247	0.4736	1.09828
48	2.200	1.14502	1.03596	0.6595	0.4393	1.09877
49	2.400	1.14431	1.03008	0.6898	0.4091	1.09894
50	2.600	1.14364	1.02375	0.7164	0.3824	1.09886
51	2.800	1.14200	1.01701	0.7399	0.3587	1.09857
52	3.000	1.14239	1.00588	0.7608	0.3374	1.09813
53	3.500	1.14113	0.98956	0.8067	0.2900	1.09671
54	4.000	1.13983	0.96987	0.8413	0.2540	1.09531
55	4.500	1.13866	0.95101	0.8691	0.2251	1.09424
56	5.000	1.13760	0.93367	0.8920	0.2016	1.09357
57	5.500	1.13663	0.91771	0.9111	0.1821	1.09319
58	6.000	1.13575	0.90425	0.9272	0.1660	1.09325
59	6.500	1.13491	0.89824	0.9411	0.1534	1.09449
60	7.000	1.13414	0.89140	0.9531	0.1423	1.09539
61	7.500	1.13343	0.88374	0.9636	0.1324	1.09602
62	8.000	1.13278	0.87529	0.9728	0.1236	1.09642
63	8.500	1.13214	0.86603	0.9810	0.1156	1.09662
64	9.000	1.13155	0.85600	0.9883	0.1083	1.09667
65	9.500	1.13100	0.84518	0.9949	0.1017	1.09661
66	10.000	1.13124	0.84518	1.0015	0.0969	1.09843

EVALUATION OF 1X1X6 MM CaF_2 AND ALUMINUM
ELECTRON SPECTRUM WEIGHTED MASS STOPPING POWER RATIOS

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS FS(SMALL) F1(LARGE)		D*FS	(1-D)F1	GENERAL RATIO F
1	0.010	0.90865	1.89462	0.0001	1.8944	1.89450
2	0.015	0.94730	2.07797	0.0003	2.0774	2.07764
3	0.020	0.96524	2.15320	0.0005	2.1521	2.15257
4	0.025	0.97442	2.19170	0.0008	2.1899	2.19070
5	0.030	0.97579	2.26951	0.0011	2.2669	2.26800
6	0.035	0.97508	2.29213	0.0015	2.2885	2.29006
7	0.040	0.99070	2.32425	0.0020	2.3196	2.32156
8	0.045	0.99227	2.33865	0.0025	2.3328	2.33525
9	0.050	0.99211	2.34703	0.0030	2.3358	2.34238
10	0.055	0.99167	2.32055	0.0036	2.3121	2.31570
11	0.060	0.98942	2.28168	0.0042	2.2719	2.27617
12	0.065	0.98912	2.23847	0.0049	2.2274	2.22232
13	0.070	0.98856	2.18460	0.0056	2.1723	2.17788
14	0.075	0.98708	2.11858	0.0063	2.1051	2.11140
15	0.080	0.98488	2.04051	0.0070	2.0260	2.03300
16	0.085	0.98479	1.98304	0.0078	1.9674	1.97515
17	0.090	0.98445	1.91865	0.0086	1.9019	1.91051
18	0.095	0.98397	1.84732	0.0094	1.8296	1.83906
19	0.100	0.98274	1.76952	0.0103	1.7510	1.76130
20	0.150	0.98975	1.30270	0.0203	1.2760	1.29628
21	0.200	0.99761	1.13653	0.0324	1.0996	1.13201
22	0.250	1.00206	1.08458	0.0461	1.0347	1.08078
23	0.300	1.00582	1.04923	0.0609	0.9857	1.04660
24	0.350	1.00803	1.03502	0.0767	0.9563	1.03296
25	0.400	1.00947	1.02493	0.0932	0.9303	1.02350
26	0.450	1.01054	1.01960	0.1104	0.9082	1.01861
27	0.500	1.01143	1.01648	0.1281	0.8877	1.01584
28	0.550	1.01225	1.01681	0.1463	0.8699	1.01615
29	0.600	1.01300	1.01661	0.1647	0.8513	1.01602
30	0.650	1.01367	1.01435	0.1834	0.8308	1.01422
31	0.700	1.01425	1.01251	0.2021	0.8108	1.01286
32	0.750	1.01479	1.01111	0.2207	0.7912	1.01191
33	0.800	1.01528	1.01014	0.2392	0.7721	1.01135
34	0.850	1.01575	1.01022	0.2575	0.7541	1.01162
35	0.900	1.01620	1.01036	0.2754	0.7365	1.01194
36	0.950	1.01663	1.01056	0.2930	0.7193	1.01231
37	1.000	1.01705	1.01081	0.3102	0.7025	1.01272
38	1.100	1.01786	1.01259	0.3432	0.6712	1.01437
39	1.200	1.01867	1.01413	0.3742	0.6416	1.01580
40	1.300	1.01947	1.01540	0.4033	0.6137	1.01701
41	1.400	1.02023	1.01640	0.4305	0.5875	1.01802
42	1.500	1.02094	1.01709	0.4558	0.5630	1.01881
43	1.600	1.02157	1.01665	0.4793	0.5397	1.01896
44	1.700	1.02213	1.01627	0.5011	0.5180	1.01914
45	1.800	1.02263	1.01593	0.5215	0.4979	1.01935
46	1.900	1.02307	1.01566	0.5404	0.4792	1.01957

ALUMINUM

INDEX	GAMMA RAY ENERGY (MEV)	STOPPING POWER RATIOS		D*FS	(1-D)F1	GENERAL RATIO F
		FS(SMALL)	F1(LARGE)			
47	2.000	1.02347	1.01544	0.5580	0.4618	1.01982
48	2.200	1.02413	1.01537	0.5899	0.4306	1.02042
49	2.400	1.02467	1.01550	0.6177	0.4033	1.02103
50	2.600	1.02511	1.01583	0.6422	0.3795	1.02164
51	2.800	1.02547	1.01636	0.6638	0.3584	1.02225
52	3.000	1.02576	1.01713	0.6831	0.3393	1.02288
53	3.500	1.02628	1.02134	0.7256	0.2993	1.02483
54	4.000	1.02665	1.02452	0.7577	0.2683	1.02609
55	4.500	1.02690	1.02523	0.7838	0.2427	1.02650
56	5.000	1.02706	1.02708	0.8053	0.2218	1.02707
57	5.500	1.02718	1.03003	0.8233	0.2044	1.02775
58	6.000	1.02726	1.03435	0.8387	0.1899	1.02857
59	6.500	1.02732	1.03369	0.8519	0.1765	1.02841
60	7.000	1.02736	1.03853	0.8634	0.1658	1.02914
61	7.500	1.02739	1.04904	0.8734	0.1572	1.03063
62	8.000	1.02740	1.06561	0.8823	0.1505	1.03280
63	8.500	1.02741	1.08894	0.8903	0.1454	1.03562
64	9.000	1.02741	1.12007	0.8974	0.1418	1.03914
65	9.500	1.02741	1.16053	0.9038	0.1397	1.04343
66	10.000	1.02742	1.16053	0.9096	0.1331	1.04269