FALLOUT PROTECTION FACTORS FOR RECTANGULAR BUILDINGS

by

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Signatures have been redacted for privacy

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INTRODUCTION

As a result of the development of nuclear fission devices with their potential for hazard to the population, however remote; it is now necessary to provide protection against radiation, blast, and the other effects of nuclear devices. To meet these additional requirements the United States Office of Civil Defense has designated areas in buildings throughout the nation as shelter areas.

One basis for the selection of a shelter is the protection the shelter provides against fallout radiation. The amount of protection can be determined by methods established by the Office of Civil Defense.

The purpose of this investigation was to test by experimental analysis the validity of one of the analytical methods recommended by the Office of Civil Defense. To do this a model of a building was tested for the amount of protection provided by the shelter area.

LITERATURE REVIEW

From a civil defense standpoint, buildings are rated on the basis of the protection provided for the inhabitants from the effects of nuclear weapons. Since 1945, volumes of literature have been published on civil defense against nuclear weapons. Several of these publications discuss both nuclear weapons and civil defense procedures and recommendations. Examples of these are Glasstone (2), Prentiss (3), Suggs (6), and Severud and Merrill (4).

The Office of Civil Defense has many publications including manuals, pamphlets, and technical reports dealing with all aspects of civil defense. One of these is Shelter Design and Analysis (7). In this manual a method of analysis is presented for determining the protection factor of any structure. The effectiveness of a structure against fallout radiation is given by the value of the protection factor. This factor is a ratio of the radiation dosage received in the shelter to that received by a detector located three feet above an infinite plane of radiation on which there are no structures.

Gamma rays incident upon a barrier may interact in several ways, photoelectric effect, Compton effect, pair production, and others. Of these only photoelectric effect and Compton effect are considered to be important in the analysis because of the energy range and the materials considered. If the photon interacts with the barrier by the photoelectric effect or the Compton effect, it is termed absorbed or scattered radiation respectively. A photon which is scattered by the air is termed skyshine radiation. If the photon passes directly through the barrier, it is termed direct radiation.

The geometrical nature of a structure is expressed in terms of solid angle fractions. These solid angle fractions are the solid angles subtended at the detector by selected segments of the structure, expressed as a percentage of the solid angle of a spherical shell at the same distance from the detector. The dosage received by the detector integrated over the volume of the solid angle fraction is termed the directional response or geometry factor. Values of the geometry factor can be found as a function of the solid angle fraction and the height of the detector above the ground from graphs in Shelter Design and Analysis (7).

Barrier factor is the ratio of the emergent radiation from a barrier to the incident radiation upon the barrier. It can be calculated for the appropriate material by

$$\text{Barrier factor} = e^{-\mu t} \qquad (1)$$

where μ is the linear attenuation coefficient of the barrier and t is the thickness of the barrier. Values of the barrier factor as a function of mass thickness (weight per unit area) of the barrier can be found in graphs in Shelter Design and Analysis (7).

The product of the geometry factor and the barrier factor is the reduction factor. The reciprocal of the sum of the reduction factors for the entire structure is termed the protection factor.

In Shelter Design and Analysis (7) various cases of structures are discussed with the appropriate means for the calculation of the protection factor. The use of graphs and charts greatly simplifies the calculations.

Since the energy and the intensity of the fallout radiation possible is dependent upon the time, location, and the nature of the weapon, an assumed spectrum for 1.12 hours after detonation was used in the calculation of the correction factors.

Several studies have been conducted on the effectiveness of structures in shielding against gamma radiation. Eisenhauer (1) cites two of these studies and compares their results to those by analytical methods. These studies involve tests on full-size structures as well as models.

An experiment on a square concrete block house was conducted at the Army Chemical Center in Edgewood, Maryland. The results of these experiments were compared with the calculated values with agreement of about 20 percent for cobalt-60 radiation and 40 percent for cesium-137 radiation. In these experiments the geometry factors for the block house were close to unity and provided a test for barrier factors only.

Another experimental check on the calculation of protection factors was conducted by Technical Operation, Inc. In this study a 6-story building was modeled in steel. This model was used to test calculations on geometry relationships between the source field and a structure. A comparison of some of the results is shown in Table 1.

Another source of information on the calculation of protection factors and the validity of the civil defense methods is found in Spencer (5). This publication gives the basic formulas and methods used to obtain the graphs for the manual on protection factors.

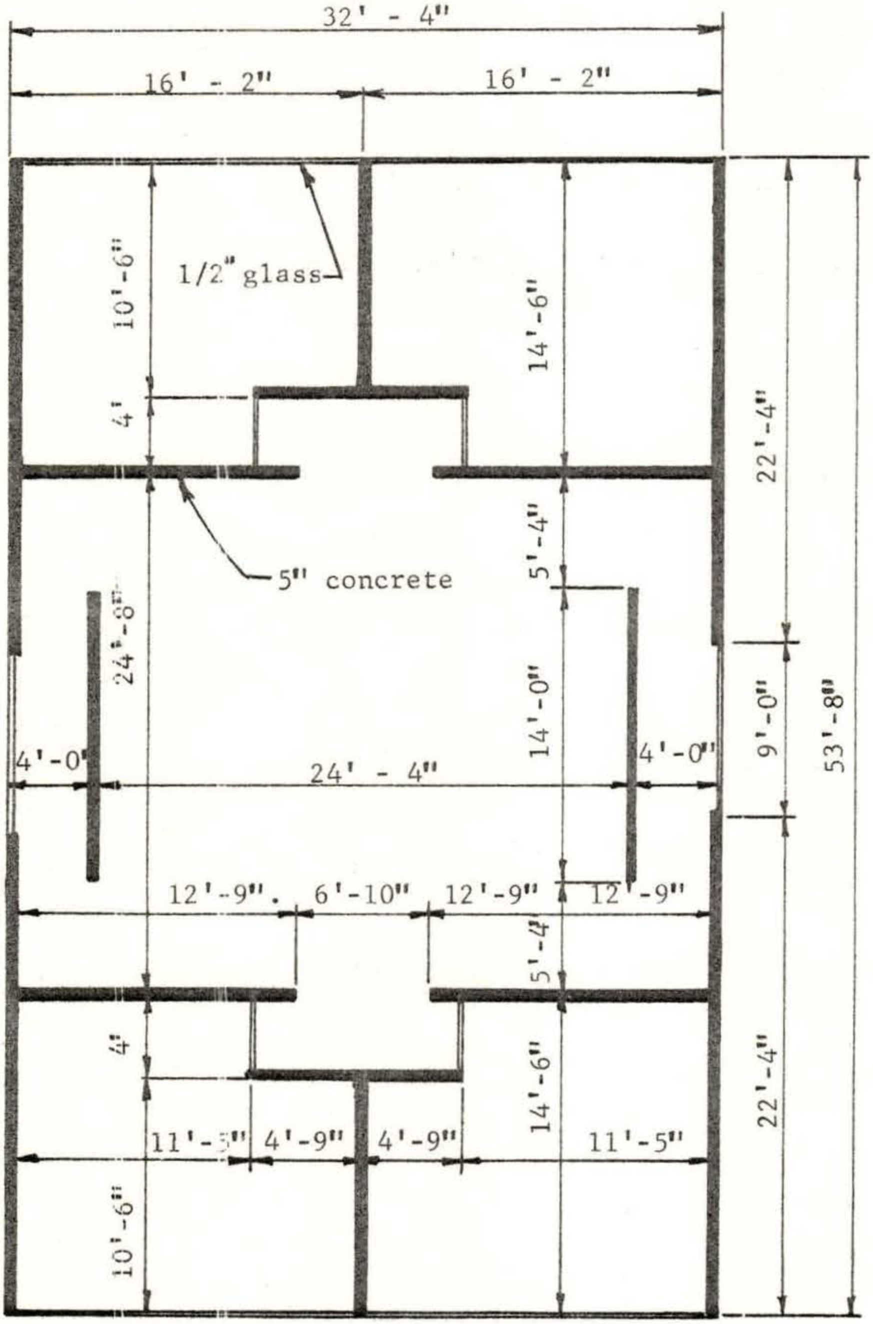
The investigation discussed in this thesis was based on a model study of a structure in which geometry and barrier effects are interrelated. The structure selected for the analysis is a modified section of a one-story

Table 1. Reduction factors in multistory steel model

Detector height above floor	H = 3 ft.		H = 6 ft.		H = 9 ft.	
Story	Exp.	Calc.	Exp.	Calc.	Exp.	Calc.
1	0.36	0.38	0.36	0.38	0.35	0.35
2	0.19	0.26	0.24	0.28	0.27	0.28
3	0.12	0.194	0.19	0.22	0.22	0.22
4	0.096	0.154	0.15	0.176	0.18	0.179
5	0.068	0.124	0.12	0.146	0.16	0.145
6	0.054	0.102	0.11	0.119	0.14	0.117

school building which is used as an example in Shelter Design in New Buildings (7).

The school is arranged with classrooms on the exterior walls and a shelter in the central hall area. The materials of construction were assumed to be those commonly used in this type of structure, with no provision made for fallout protection. The structure which was investigated is shown in Figure 1.



Scale: 1" = 9'

Figure 1. Prototype floor plan

MODEL ANALYSIS

A basic structure, as shown in Figure 1, was assumed as the prototype shelter to be analyzed. The basic parameters were determined and are shown in Figure 2.

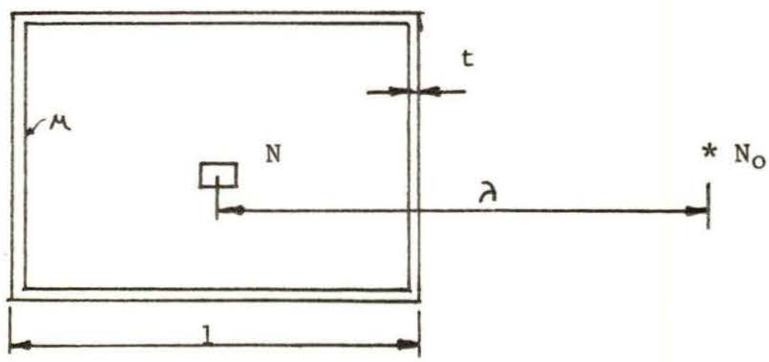


Figure 2. Parameters of prototype structure for model analysis

These parameters are defined as follows:

N_o = Counts emitted by gamma source (unitless)

N = Counts received by detector (unitless)

t = Thickness of wall (cm)

l = Length of structure (cm)

μ = Linear attenuation coefficient of the wall material (cm^{-1})

λ = Distance from the source to the detector (cm)

The counts received by the detector can be expressed as a function of the other variables.

$$N = f(N_o, l, t, \mu, \lambda) \quad (2)$$

The number of variables can be reduced by using a set of dimensionless variables. According to the Buckingham Pi Theorem, the number of dimensionless π terms necessary is the number of variables less the number of dimensions, which in this case is five. If N, N_o, μt, t/1, $\lambda/1$ are the 5 π terms, then

$$N_p = f(N_{op}, \lambda_p/1_p, \mu_p t_p, t_p/1_p) \tag{3}$$

$$N_m = f(N_{cm}, \lambda_m/1_m, \mu_m t_m, t_m/1_m) \tag{4}$$

If

$$N_{om} = N_{op} \tag{5}$$

$$\lambda_m/1_m = \lambda_p/1_p \tag{6}$$

$$t_m/1_m = t_p/1_p \tag{7}$$

$$\mu_m t_m = \mu_p t_p \tag{8}$$

then

$$N_m = N_p \tag{9}$$

and

$$N_m/N_{om} = N_p/N_{op} \tag{10}$$

The relationship between the model and the prototype can be determined if we let

$$1_p = n1_m \tag{11}$$

$$t_p = nt_m \tag{12}$$

where n is the length scale between model and prototype. For equation 8 to be satisfied

$$\mu_m t_m = \mu_p n t_m \tag{13}$$

$$\frac{\mu_m}{\mu_p} = n \tag{14}$$

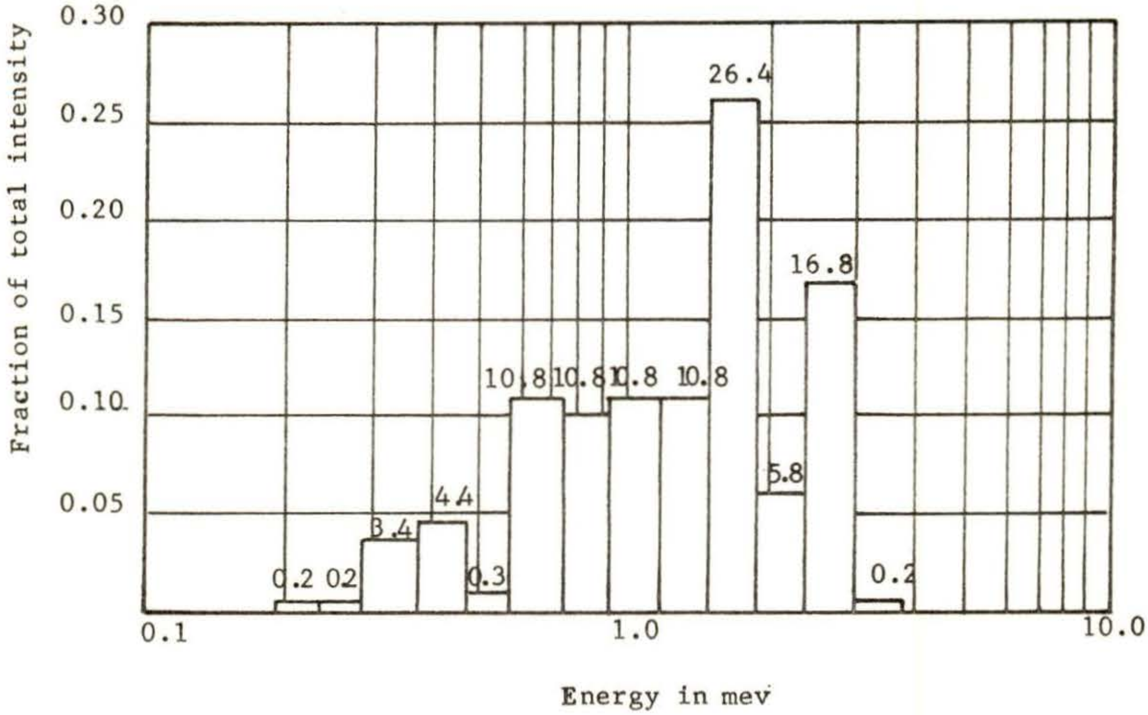


Figure 3. Spectrum of fallout radiation at 1.12 hours

In order to select the materials for the model, it was necessary to have the attenuation coefficients of the model and prototype materials be in a ratio of n. An average attenuation coefficient was calculated for various thicknesses of building materials using the assumed spectrum of fallout radiation at 1.12 hours shown in Figure 3. The results for 5 inches of concrete are shown in Table 2.

Possible model materials and gamma radiation sources were determined from preliminary calculations, and the best selection was lead modeling for concrete and copper modeling for glass with a 0.66 mev cesium-137 source. The attenuation coefficient for lead at 0.66 mev is 1.17 cm^{-1}, and thus n for the lead and concrete was

Table 2. Attenuation coefficient for concrete, t = 5 inches

Energy mev	% of each energy	μ cm^{-1}	μt	$e^{-\mu t}$	$\frac{I}{I_o}$ x 100
3.40	0.2	0.0795	1.01	0.365	0.073
2.55	16.8	0.0958	1.22	0.296	4.973
2.10	5.8	0.1045	1.33	0.266	1.543
1.70	26.4	0.1113	1.41	0.244	6.442
1.27	10.8	0.1330	1.69	0.184	1.987
1.02	10.8	0.149	1.89	0.150	1.620
0.85	10.0	0.162	2.06	0.127	1.270
0.64	10.8	0.184	2.34	0.096	1.037
0.50	0.3	0.204	2.59	0.075	0.023
0.42	4.4	0.220	2.79	0.061	0.268
0.32	3.4	0.247	3.12	0.044	0.150
0.26	0.2	0.270	3.43	0.032	0.006
0.22	0.2	0.283	3.59	0.028	0.006

$$e^{-\mu t} = 0.194 = \Sigma \frac{I}{I_o}$$

$$\mu t = 1.64$$

$$\mu = 0.130 \text{ cm}^{-1} \text{ for 5 inches of concrete}$$

$$n = \frac{1.17}{0.13} = 9$$

Since the facilities for conducting this experiment were limited in size, the length scale needed to be greater than 9 to model the prototype. To increase the magnitude of the length scale the source spectrum was degraded by placing materials of various thicknesses around the source. The spectrum with 1 inch of lead, shown in Figure 4, resulted in a value of 1.75 cm^{-1} for the attenuation coefficient (see Table 3), which gives n equal to 13.6. A length scale of 13.5 is also obtained when 0.375 inches of lead models for 5 inches of concrete.

$$n = \frac{1.75}{0.13} = 13.5$$

$$n = \frac{5.0}{0.375} = 13.5$$

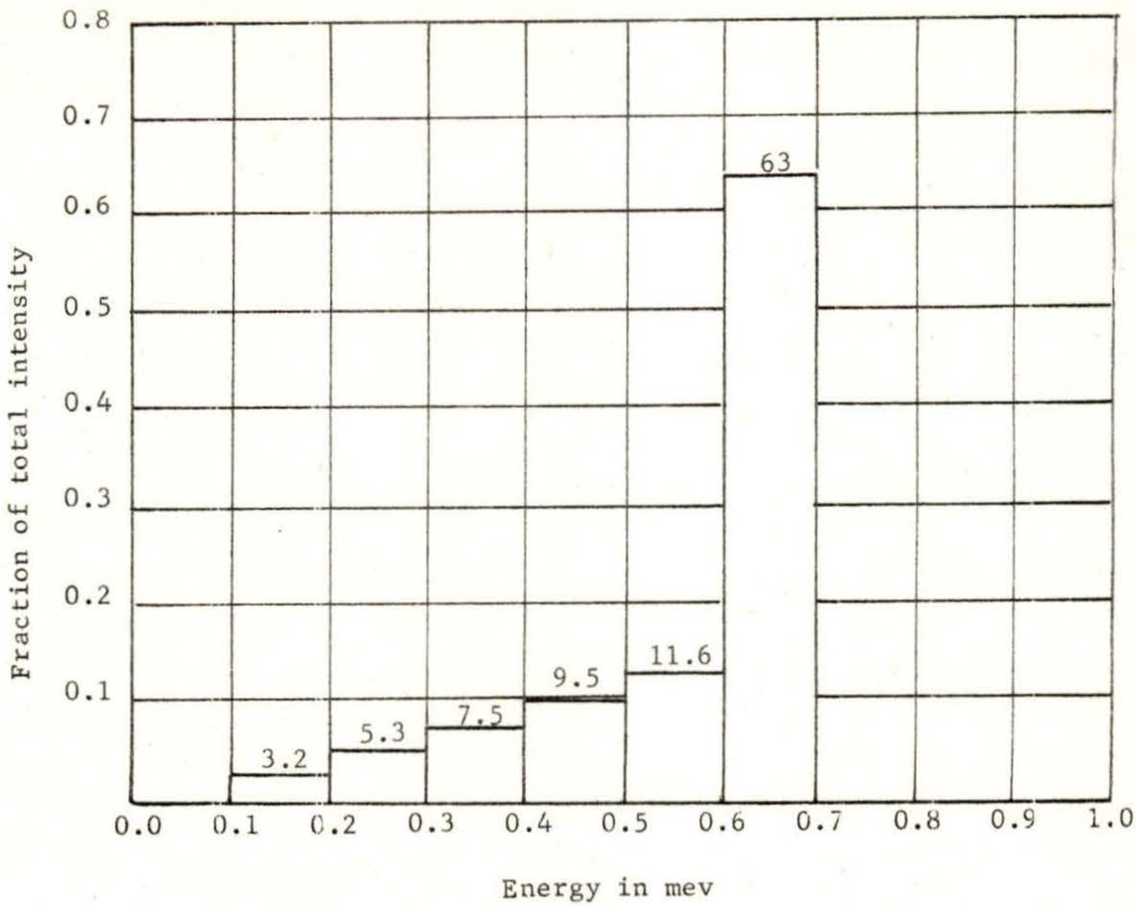


Figure 4. Assumed gamma ray energy spectrum of model source

Table 3. Attenuation coefficient for lead, t = 0.375 inches

Energy mev	% of each energy	μ cm^{-1}	μt	$e^{-\mu t}$	$\frac{I}{I_o} \times 100$
0.66	63.0	1.17	1.11	0.0330	14.238
0.55	11.6	1.47	1.40	0.247	2.865
0.45	9.5	2.00	1.90	0.150	1.433
0.35	7.5	3.21	3.06	0.047	0.350
0.35	5.3	7.10	6.78	0.001	0.006
0.15	3.2	20.87	19.89	0.000	0.000

$e^{-\mu t} = 0.1889 = \sum \frac{I}{I_o}$

$\mu t = 1.665$

$\mu = 1.750$ for 0.375 inches of lead

The glass windows in the prototype were modeled in the same manner. Using the degraded spectrum, copper was the most suitable material from the standpoint of cost and availability to replace the glass. The length scale between 0.0432 inches of copper and 0.5 inches of glass was 11.6. The linear attenuation coefficients for copper and glass were 0.735 cm^{-1} and 0.063 cm^{-1} respectively.

$$n = \frac{0.735}{0.630} = 11.6$$

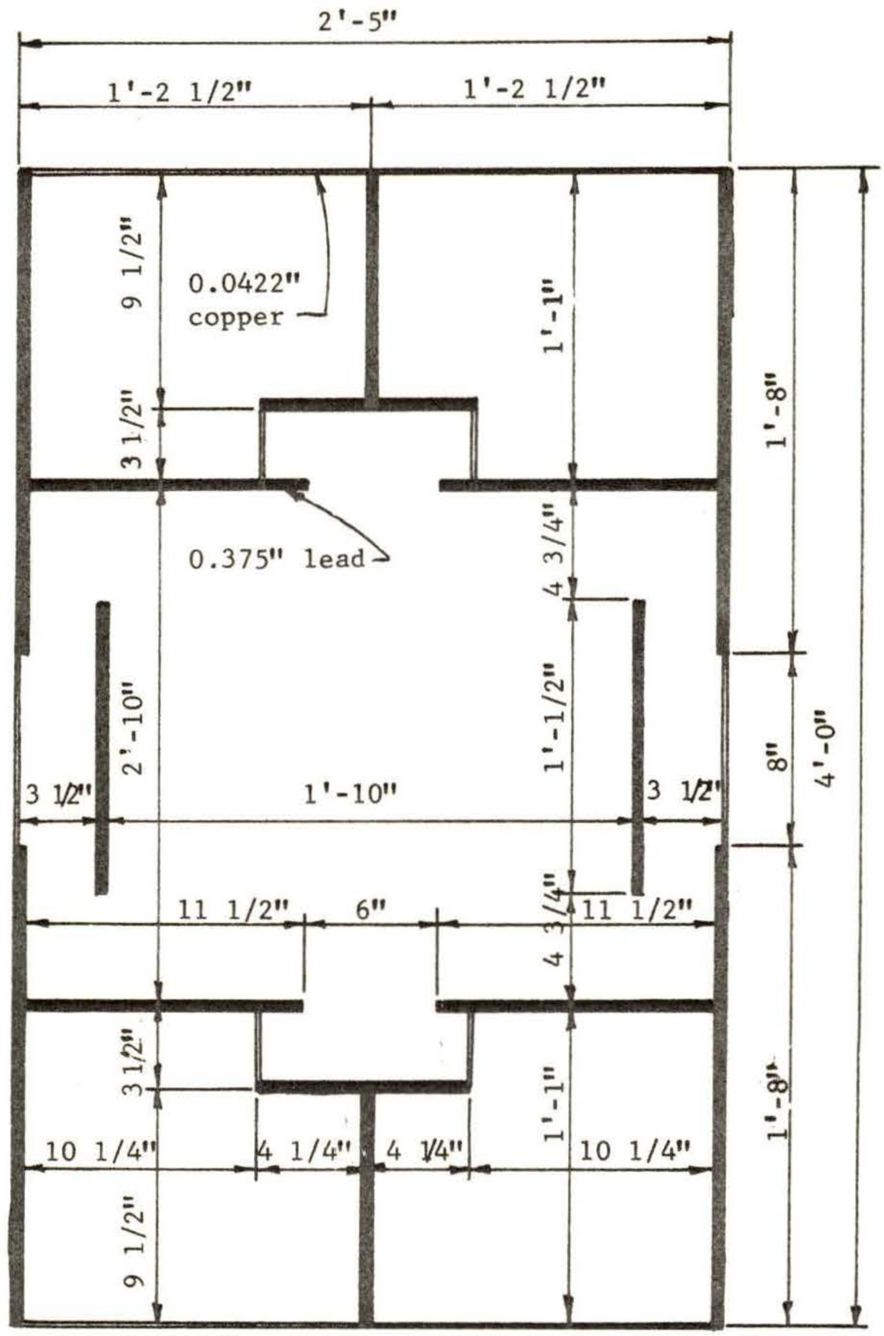
$$n = \frac{0.50}{0.0432} = 11.8$$

A length scale closer to 13.5 was impossible to obtain with available materials. To correct for the differences in length scales, the length scale for the two sets of materials were weighed by the area fraction of each with the resulting value of n equal to 13.4. On this basis the model as shown in Figure 5 was constructed.

Eisenhauer (1) recommends that in model studies of this kind, the room dimension of the model be at leat 10 times the wall thickness. Also the barrier factor for equal weights per unit area of the materials be the same. Since in this model analysis the model room dimension to wall thickness are

$$\frac{\text{room length}}{\text{wall thickness}} = \frac{9.5}{0.375} = 25.2$$

and the attenuation for the model and prototype materials are the same, both of these criteria are satisfied.



Scale: 1" = 8"

Figure 5. Model floor plan

EQUIPMENT AND MATERIALS

Radiation Source

A cesium-137 source rated as 84 millicuries on July 7, 1969 was utilized in this investigation. The source belongs to the Department of Nuclear Engineering at Iowa State University and is numbered Cs-5315. The source is a cylinder, 3/4 inches in diameter and 3 inches long with the activity concentrated in the unnumbered end.

To degrade the energy spectrum of the 0.66 mev gamma emitted, the cylindrical source was placed in a lead capsule shown in Figure 6. The capsule measuring 6 inches in length and 3 inches in diameter was constructed of lead sheet. The capsule provided approximately 1 inch of lead around the source.

Model Materials

The model was constructed of 1/8 and 3/16 inch lead sheet to form 3/8 inch pieces, 0.0216 inch copper sheet doubled to obtain 0.0432 inches, and 1/2 inch angle iron which served as a framework to support the roof. The lead and copper pieces were soldered together and attached to the framework as shown in Figure 7. The model was built on a base of concrete block and plywood.

The copper, lead, angle iron, and plywood were purchased at the Iowa State University Central Stores, and the concrete block was available in the laboratory.

Apparatus

The apparatus for positioning the source around the model was constructed of 1/2 inch steel pipe, available in the laboratory. The central rod rotated to allow the angular placement of the source. The horizontal arm from which the source was suspended was 5 feet long and provided for the radial positioning of the source. The angular position was measured by a needle on a dial marked with 5^{o} divisions, the needle rotating with the central rod. The radial position was measured by marked intervals of 1 inch on the horizontal arm. The apparatus is shown in Figure 8.

Detector and Equipment

The detector used for this study was a Harshaw Integral Line Scintillation Detector, type 12SS12/E, No. DU 209. The crystal was NaI(Tl), 3 inches by 3 inches. It was operated at 806 volts for the spectra analysis and 850 volts for the counting data.

The equipment used for the spectra measurement was a Victoreen Instrument Co. Multi-Channel Analyzer, model PIP 400; a Fluke High Voltage Power Supply, model 412B; and a Victoreen Instrument Co. Pre-amplifier, model DS-J. For the counting data a Nuclear Chicago Ultrascaler and High Voltage Power Supply, model 192A and Nuclear Chicago Pre-amplifier, model DS-5 were used.

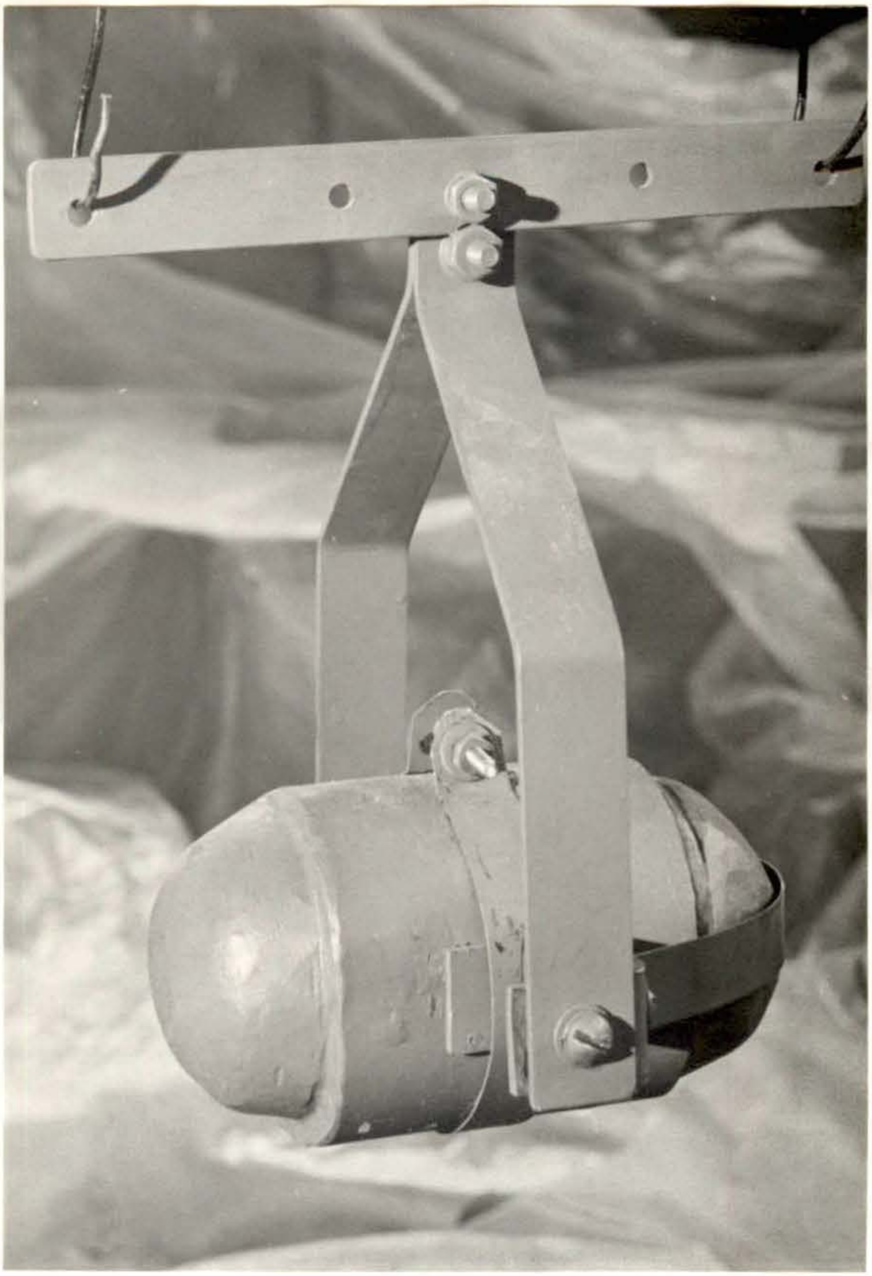


Figure 6. Lead capsule

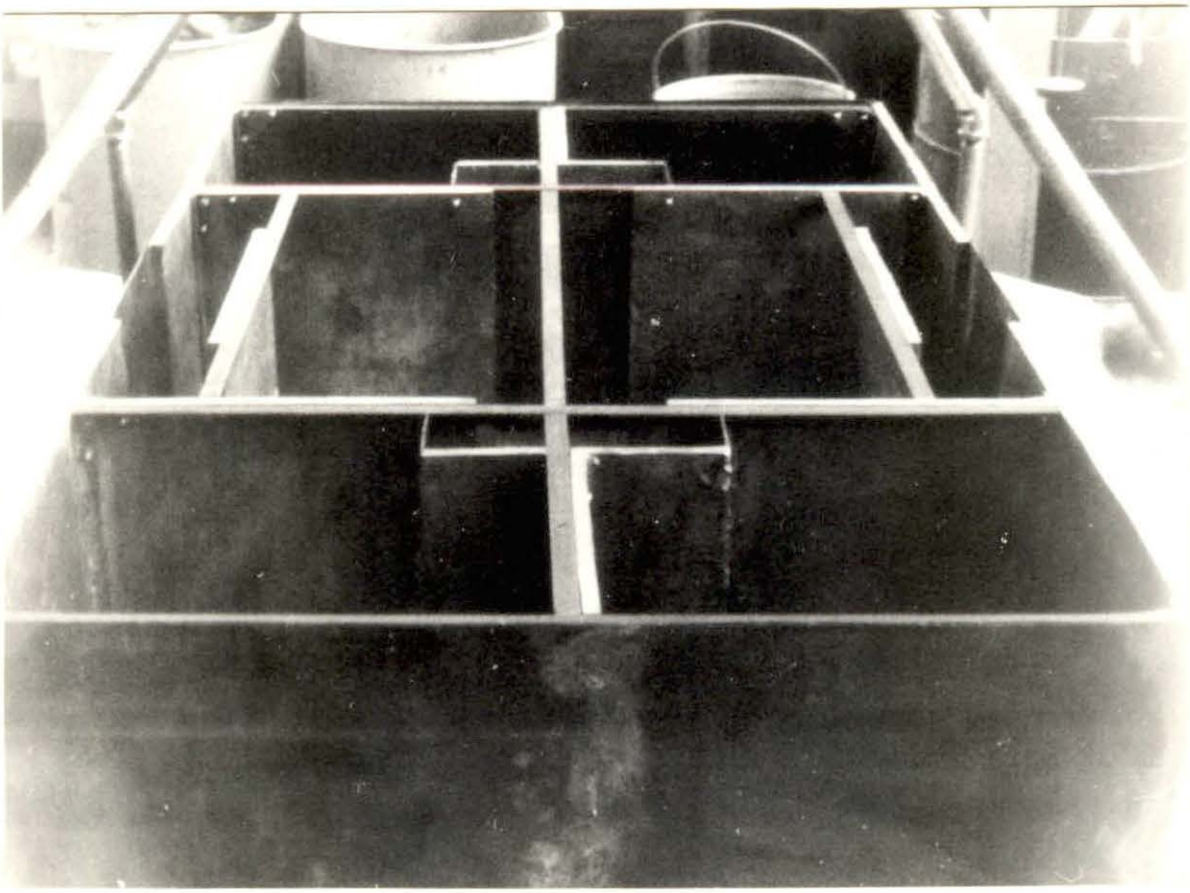


Figure 7. Model without roof

Figure 8. Positioning apparatus and model

PROCEDURE

The procedure consisted of two parts. The first part included a spectrum analysis of the gamma ray energy from the cesium-137 source in the lead capsule, and analysis of the spectra due to the capsuled source through various walls of the model. The second part was the experimentation to determine the protection factor of the model shelter area.

Spectra Analysis

The spectra from the capsule were measured by placing the cesium-137 source in the lead capsule 2 feet from the detector. The detector and capsule were on columns of concrete block in the center of the room to eliminate scattering from adjacent objects. This was repeated for a cesium-137 source without the lead capsule.

The detector was placed in the central room of the model in a horizontal position to measure the spectra through the various wall combinations. The detector was aligned with the source and located 2 feet from the lead capsule containing the source.

Protection Factor

For the protection factor data the source was placed at various positions around the model, and the detector placed vertically in the center of the model. The height from the base to the center of the crystal was 2.5 inches. This height corresponded to a detector height of 3 feet above the floor in the prototype. Readings were taken at each horizontal position on the supporting arm and at angular positions of 10 degree intervals.

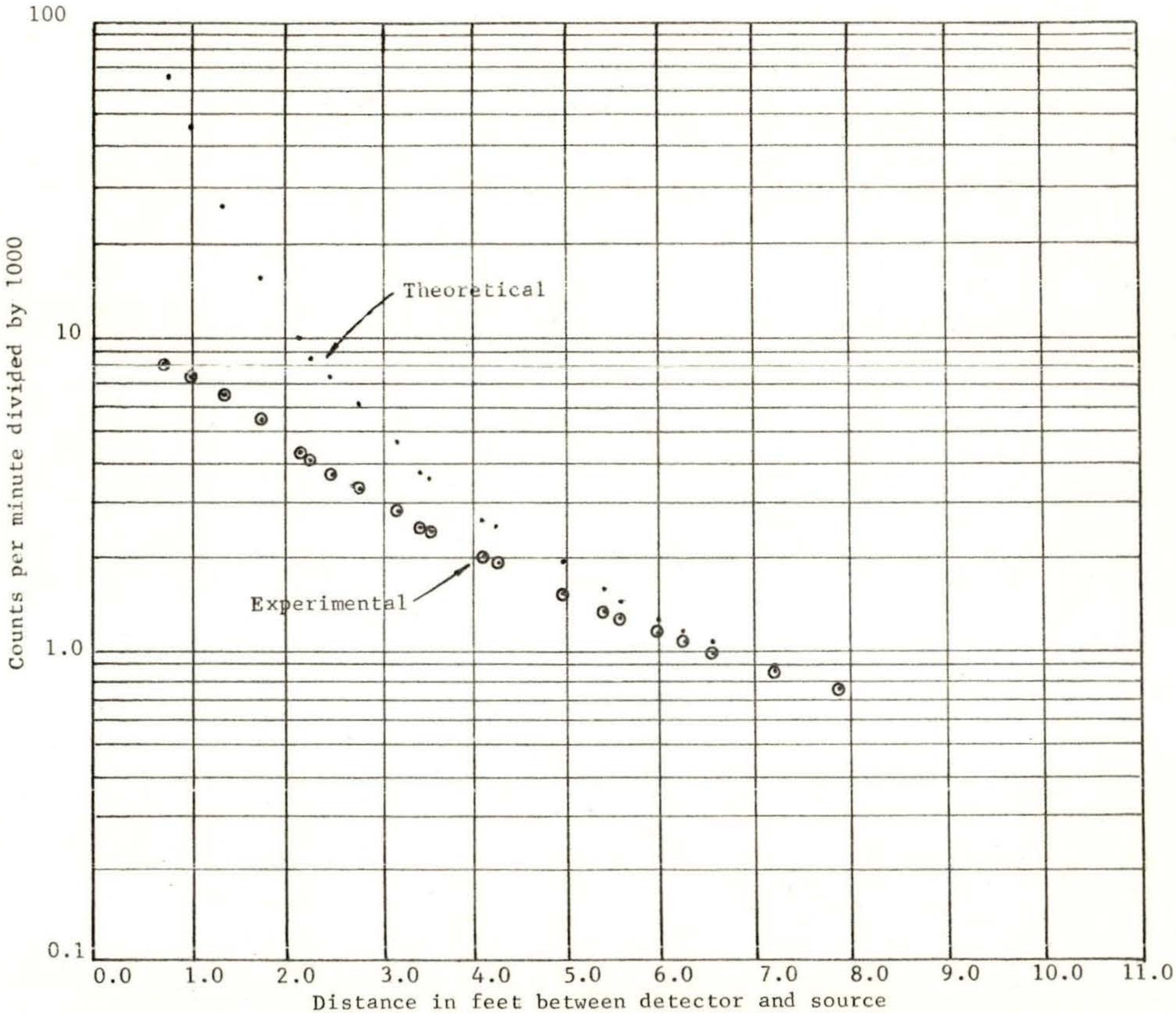
At each horizontal and angular position three one-minute readings were taken and recorded. After completion of one rotation, the source was moved to a new horizontal position and the procedure repeated. Intervals of 6 inches were used horizontally.

To stimulate the fallout on the roof, the roof was divided into squares and the source placed in each square. At each position three sets of one-minute readings were taken.

After two complete sets of readings were taken with the model, the model was removed and the procedure repeated to obtain two sets of data without the model. Background readings were taken frequently.

It was necessary to correct for the dead time effect in the equipment. A set of readings was taken with the source suspended from the ceiling and the source placed directly below. The counts versus distance for 10 inches to 8 feet were plotted as shown in Figure 9. A theoretical curve of counts versus distance was also plotted. The ratio of the theoretical counts to the observed counts versus the observed counts was plotted as shown in Figure 10. The counts observed from the model experiment were corrected by the factors given in the graph.

Figure 9. Experimental and theoretical counting rate versus distance between source and detector


Theoretical
Experimental
Counts per minute divided by 1000
100
10
1.0
0.1
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Distance in feet between detector and source

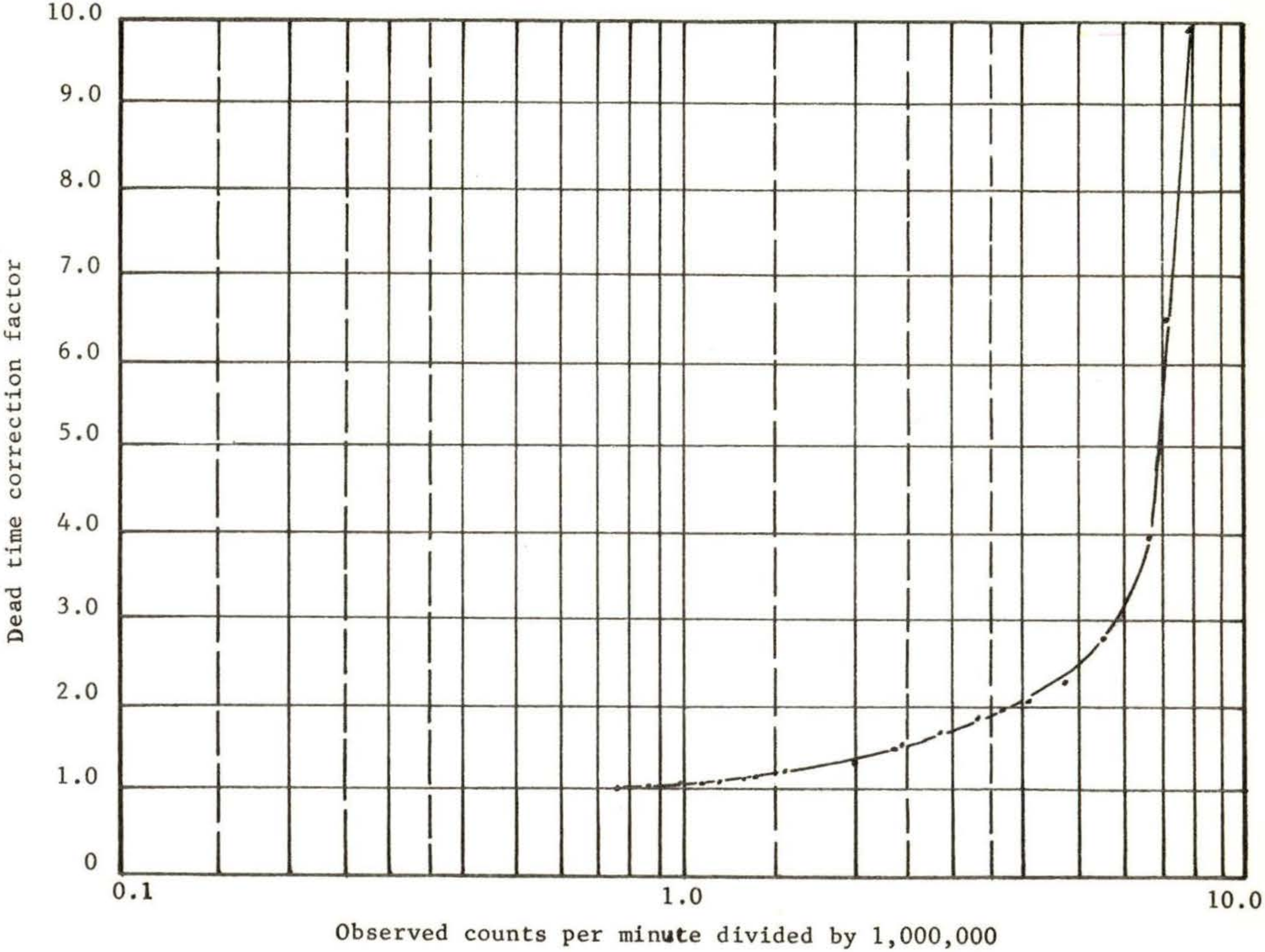


Figure 10. Dead time correction factors versus observed counts

ERROR ANALYSIS

The readings taken with the model study were corrected for background, dead time and area to obtain the necessary information for the protection factor. There were two cases dependent upon the size of the count readings, less than 800,000 counts per minute or more than 800,000 counts per minute.

C_a = Average of three counts

B = Background

F_a = Area correction factor

F_d = Dead time correction factor

C(BD) = Counts corrected for background and dead time

C(BDA) = Counts corrected for background, dead time and area

S_a = Standard deviation of area correction factor

S_b = Standard deviation of background count

S_c = Standard deviation of count received by detector

S_f = Standard deviation of dead time correction factor

The formulas for the corrected counts are as follows:

Case 1. C 800,000 counts per minute

$$C(BDA) = (C_a - B) \times F_a \tag{15}$$

$$C(BD) = C_a - B \tag{16}$$

Case 2. C 800,000 counts per minute

$$C(BDA) = (C_a - B) \times F_a \times F_d \tag{17}$$

$$C(BD) = (C_a - B) \times F_d \tag{18}$$

The standard deviations for the two cases can be calculated from the contributions to the total variance by each contributing random error factor. (Strictly speaking only estimates of the standard deviations are available. To simplify terminology these estimates will be called standard deviations.) The formulas for the variances are:

$$S_{C(BDA)_1}^{\ 2} = S_a^{\ 2}\ (C_a-B)^2 + S_b^{\ 2}\ (F_a)^2 + S_c^{\ 2}\ (F_a)^2 \qquad (19)$$

$$S_{C(BD)_1}^{\ 2} = S_b^{\ 2}\ (-1)^2 + S_c^{\ 2}\ (1)^2 \qquad (20)$$

$$S_{C(BDA)_2}^{\ 2} = S_a^{\ 2}\ (F_d\ (C_a-B)\ )^2 + S_b^{\ 2}\ (F_aF_d)^{\ 2} + S_c^{\ 2}\ (F_aF_d)^2$$

$$+ S_f^{\ 2}\ (F_a\ (C_a-B)\ )^2 \qquad (21)$$

$$S_{C(BD)_2}^{\ 2} = S_b^{\ 2}\ (F_d\ )^2 + S_c^{\ 2}\ (F_d)^2 + S_f^{\ 2}\ (C_a-B)^2 \qquad (22)$$

A sample calculation for readings taken at the radial position of 31 inches and 5^{o} in sample 1 is shown as follows:

$$F_a = \frac{\pi(\ (R + 3)^2 + (R - 3)^2)}{30 \times 22.5} \qquad (23)$$

where R is the radial position and 22.5 square inches is the smallest area division of the readings.

$$F_a = 12\pi R/81$$

$$= 1.44$$

The square of the standard deviation of F_a is

$$S_a^{\ 2} = S_r^{\ 2}\ (12\pi/81)^2 \qquad (24)$$

where S_r is the standard deviation of R. Since the measurement of R was accurate to 1/8 inch,

$$S_a^{\ 2} = (0.125)^2\ (0.465)^2$$

$$S_a = 0.0582$$

The standard deviation of the counts was assumed to be the square root of the counting rate.

$$S_b = \sqrt{B} \qquad (25)$$

$$= \sqrt{8200}$$

$$= 91$$

$$S_c^2 = S_{c1}^2 \ (1/3)^2 + S_{c2}^2 \ (1/3)^2 + S_{c3}^2 \ (1/3)^2 \qquad (26)$$

If $S_{c1} = S_{c2} = S_{c3}$ approximately and

$$S_{c1} = \sqrt{C_1} \qquad (27)$$

$$= \sqrt{2,231,000}$$

$$= 1,460$$

$$S_c^2 = 3/9 \ (1,460)^2$$

$$S_c = 842$$

The standard deviation of the correction factor for dead time is a assumed to be the accuracy with which the graph could be read.

$$S_f = 0.01$$

For this example $F_d = 1.64$.

The standard deviation for C(BD) and C(BDA) is calculated below.

$$S_{C(BD)}^2 = (0.01)^2 \ (2,232,000 - 8,000)^2 + (842)^2 (1.64)^2$$

$$S_{C(BD)} = 22,300$$

$$S_{C(BDA)}^2 = (0.0582)^2 \ (1.64)(2,232,000 - 8,000)^2 + (91)^2 \ (1.44)(1.64)^2 + (842)^2 \ (1.44)(1.64)^2 + (0.01)^2 \ (1.44)(2,232,000 - 8,000)^2$$

$$S_{C(BDA)} = 37,000$$

ANALYTICAL CALCULATIONS

The protection factor for the prototype structure can be determined using the Office of Civil Defense publication Shelter Design and Analysis (7). The ground contribution is obtained by dividing the structure into angle segments of similar construction materials and idealizing the resultant sections. The roof is divided into rectangular idealized sections to determine the roof contribution to the shelter.

In the case of the assumed structure shown in Figure 1, there are only two types of exterior materials, glass and concrete. The idealized buildings are shown in Figure 11. In Figure 12 a quadrant of the structure has been divided into azimuths. Due to the different interior partitions, four types of wall combinations need to be analyzed:

1. Concrete exterior wall with no interior partition
2. Concrete exterior wall with concrete partition
3. Glass exterior wall with concrete partition
4. Glass exterior wall with glass and concrete partitions

The ground contribution is calculated for the four cases and each case is weighted to determine the total contribution.

The formulas for the ground contribution are

$$G_g = [G_s(\omega_u) + G_s(\omega_1)]\, E(e)\, S_w(x_e) + [G_d(H,\omega_1) + G_a(\omega_1)][1 - S_w(x_e)] \quad (28)$$

$$C_g = G_g\, B_d(x_e)\, B_i(x_i) \quad (29)$$

where

$$\omega = \omega(e, f) \quad (30)$$

$$e = W/L \quad (31)$$

$$f = 2Z/L \tag{32}$$

Values of the terms can be found from the graphs and are

$x_e(\text{glass}) = 7$ psf $= x_i(\text{glass})$

$x_e(\text{concrete}) = 60$ psf $= x_i(\text{concrete})$

$S_w(60) = 0.64$

$S_w(7) = 0.15$

$e = 0.595$

$f_u = 0.323$

$f_1 = 0.111$

$\omega_u = 0.63$

$\omega_1 = 0.88$

$E(0.595) = 1.375$

$G_d(H,\omega_1) = 0.42$

$G_s(\omega_u) = 0.32$

$G_s(\omega_1) = 0.13$

$G_a(\omega_u) = 0.078$

$B_e(3.60) = 0.26$

$B_e(3.7) = 0.84$

$B_i(0) = 1.0$

$B_i(60) = 0.26$

$B_i(67) = 0.23$

The ground contribution for each exterior case is then

$$\begin{aligned} G_g(\text{glass}) &= [G_s(.63) + G_s(.88)]\, E(.595)\, S_w(7) \\ &\quad + [G_d(3,.88) + G_a(.63)]\, [1 - S_w(7)] \\ &= (.32 + .13)(1.375)(.15) + (.42 + .078)(1 - .15) \\ &= 0.517 \end{aligned}$$

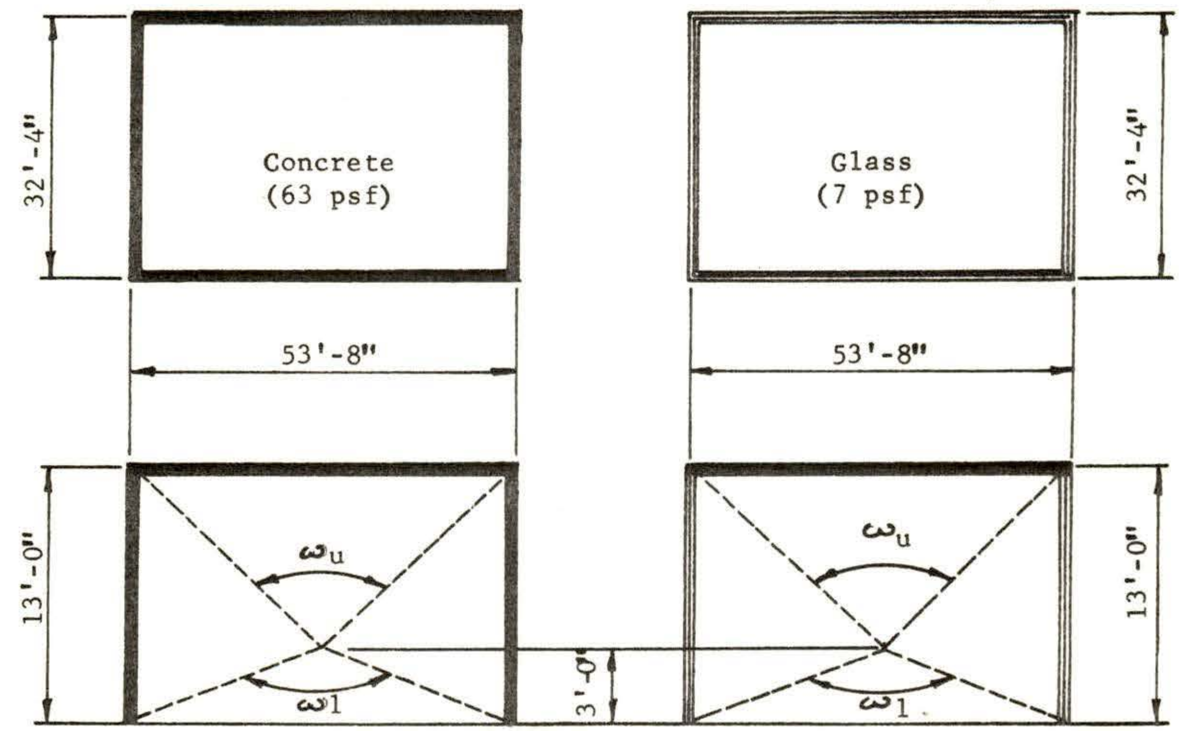


Figure 11. Idealized structures

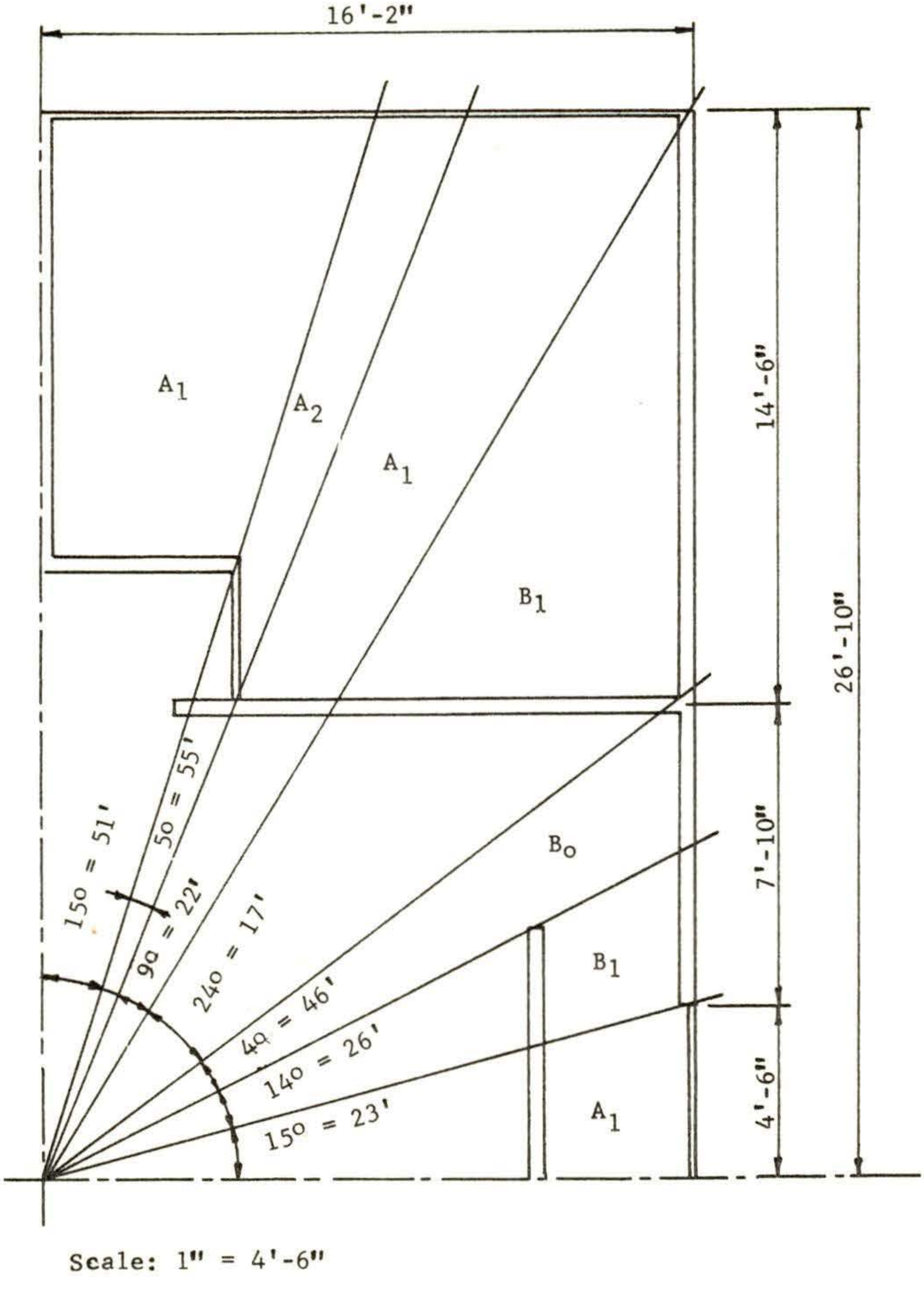
$$G_g(\text{concrete}) = [G_s(.63) + G_s(.88)]\, E(.595)\, S_w(60) + [G_d(3,.88) + G_a(.63)][1 - S_w(60)]$$

$$= (.32 + .13)(1.375)(.64) + (.42 + .078)(1 - .64)$$

$$= 0.576$$

The contribution of the different azimuths is shown in Table 4.

The roof can be divided into sections and each of these sections is corrected by an appropriate factor for the barrier effect of interior partitions. The idealized sections are shown in Figure 13 and the calculations shown in Table 5.



Scale: 1" = 4'-6"

Figure 12. Azimuth divisions of a quadrant of the prototype structure

Table 4. Azimuth contributions

	Angle	%	G_g	B_e	B_i	C_i
A_1	166.4	0.461	0.517	0.84	0.26	0.0520
A_2	23.7	0.066	0.517	0.84	0.23	0.0066
B_1	154.8	0.430	0.576	0.26	0.26	0.0168
B_0	19.1	0.043	0.576	0.26	1.00	0.0064
						C_g = 0.0818

The protection factor for the ground contribution is

$$R_f = C_g = 0.0818$$

$$P_f = \frac{1}{R_f} = \frac{1}{0.0818} = 12.2$$

The protection factor for the roof contribution is

$$R_f = C_o = 0.0458$$

$$P_f = \frac{1}{R_f} = \frac{1}{0.0458} = 21.4$$

The total protection factor is

$$R_f = C_g + C_o = 0.0818 + 0.0458$$

$$= 0.1276$$

$$P_f = \frac{1}{R_f} = \frac{1}{0.1276} = 7.77$$

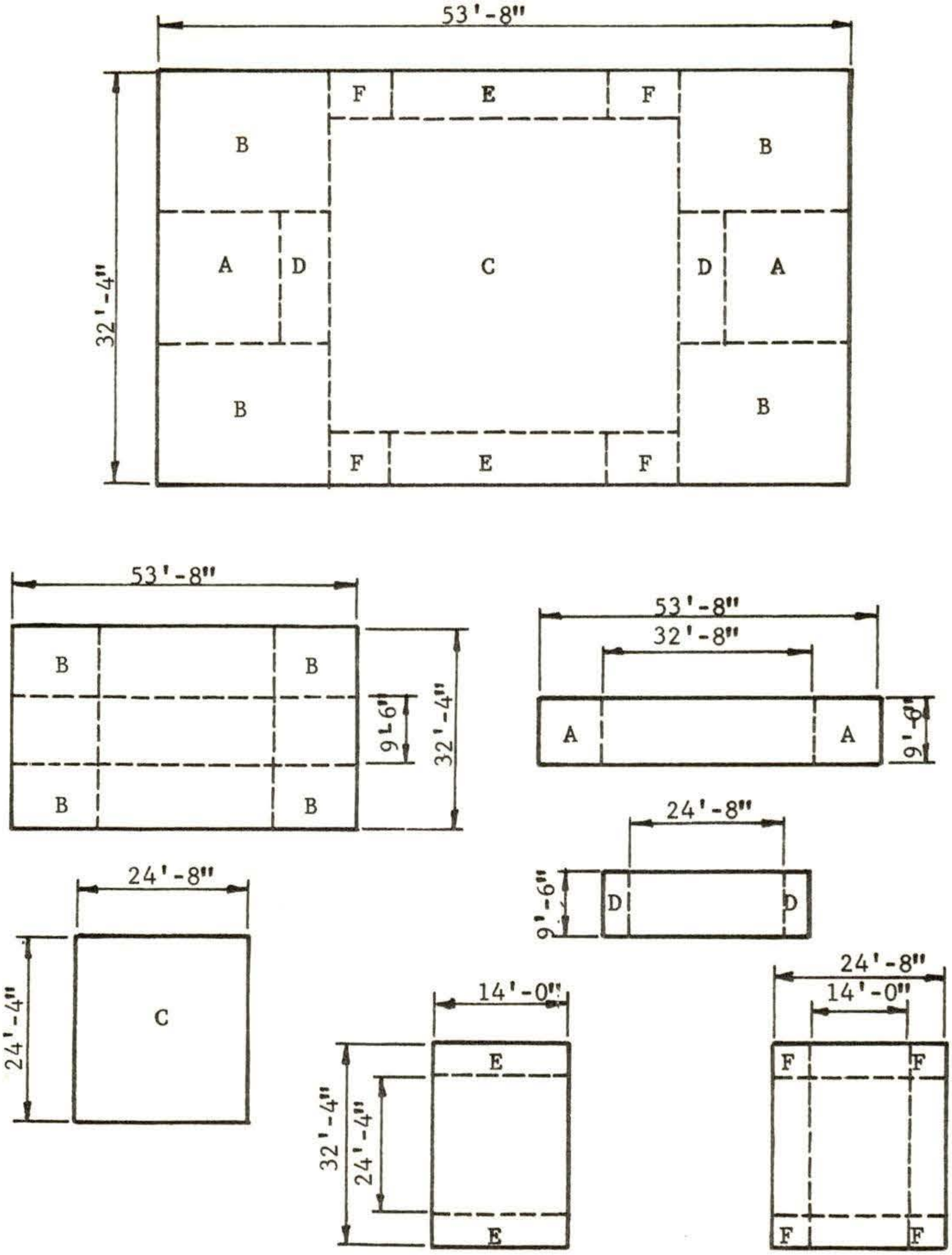


Figure 13. Idealized roof sections of prototype structure

Table 5. Results of the roof contribution to the total protection factor

Roof Section	W ft.	L ft.	Z ft.	e	f	ω	C_o	Actual
A	9.5	53.67	10	0.176	0.370	0.26	0.027	
	9.5	32.33	10	0.288	0.606	0.24	0.026	
						Difference =	0.001	0.00016
B	32.3	53.67	10	0.593	0.370	0.58	0.055	
	24.67	32.3	10	0.780	0.625	0.47	0.047	
	9.5	24.67	10	0.380	0.800	0.23	0.025	
	9.5	53.67	10	0.176	0.370	0.26	0.027	
						Difference =	0.006	0.00096
C	24.3	24.67	10	0.960	0.800	0.41	0.041	0.0410
D	9.5	32.67	10	0.288	0.606	0.24	0.026	
	9.5	24.87	10	0.380	0.800	0.23	0.025	
						Difference =	0.001	0.0010
E	14.0	32.3	10	0.447	0.625	0.32	0.033	
	14.0	24.3	10	0.596	0.834	0.28	0.029	
						Difference =	0.004	0.00064
F	24.67	32.3	10	0.780	0.625	0.47	0.047	
	24.3	24.67	10	0.960	0.800	0.41	0.041	
	14.0	32.3	10	0.447	0.625	0.32	0.033	
	14.0	24.3	10	0.596	0.834	0.28	0.029	
						Difference =	0.002	0.0020
							TOTAL	0.04576

RESULTS AND DISCUSSION

Spectra Analysis

The results from the spectra analysis with the capsule are shown in Figure 14, 15 and 16. To correct for the effect of the scattering in the detector crystal, the measured spectrum was corrected by the following procedure. The spectrum for the cesium-137 source without the lead capsule, shown in Figure 15, was multiplied by the ratio of the peak area of the spectrum from the cesium-137 source with the lead capsule to the peak area of the cesium-137 source without the lead capsule. In the energy range from 0.6 to 0.7 mev the spectrum was assumed to be the same as the spectrum in that range due to the cesium-137 source in the lead capsule.

The resulting spectrum has an average value of 149,580 counts per minute in the energy range of 0.0 to 0.6 mev and 133,380 counts per minute between 0.6 and 0.7 mev. This resultant energy intensity spectrum for the model source had an agreement of 1% with the one shown in Figure 4 from which the model materials were selected.

Figure 17 shows the positions of the source for the spectra analysis through the model. The spectra through the walls of the model are shown in Figure 18, 19, 20 and 21. In comparison to the spectrum from the capsule at the same distance from the detector, these spectra show additional degradation of the energy due to the scattering in the model materials. The intensity and the energy of the resulting spectra differ due to the various combinations of wall types and the location of the walls with respect to the source.

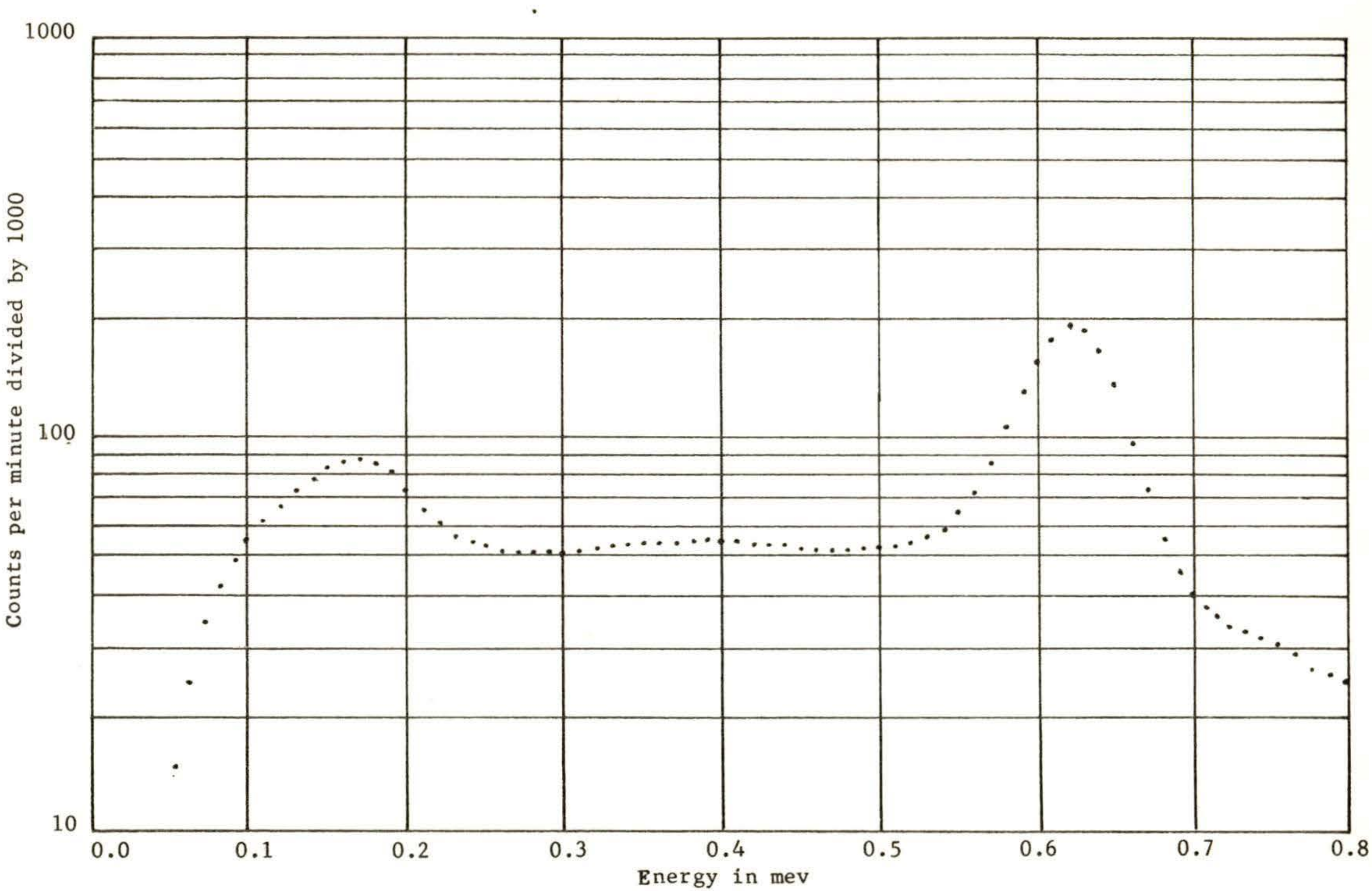


Figure 14. Gamma ray energy spectrum of the cesium source in the lead capsule

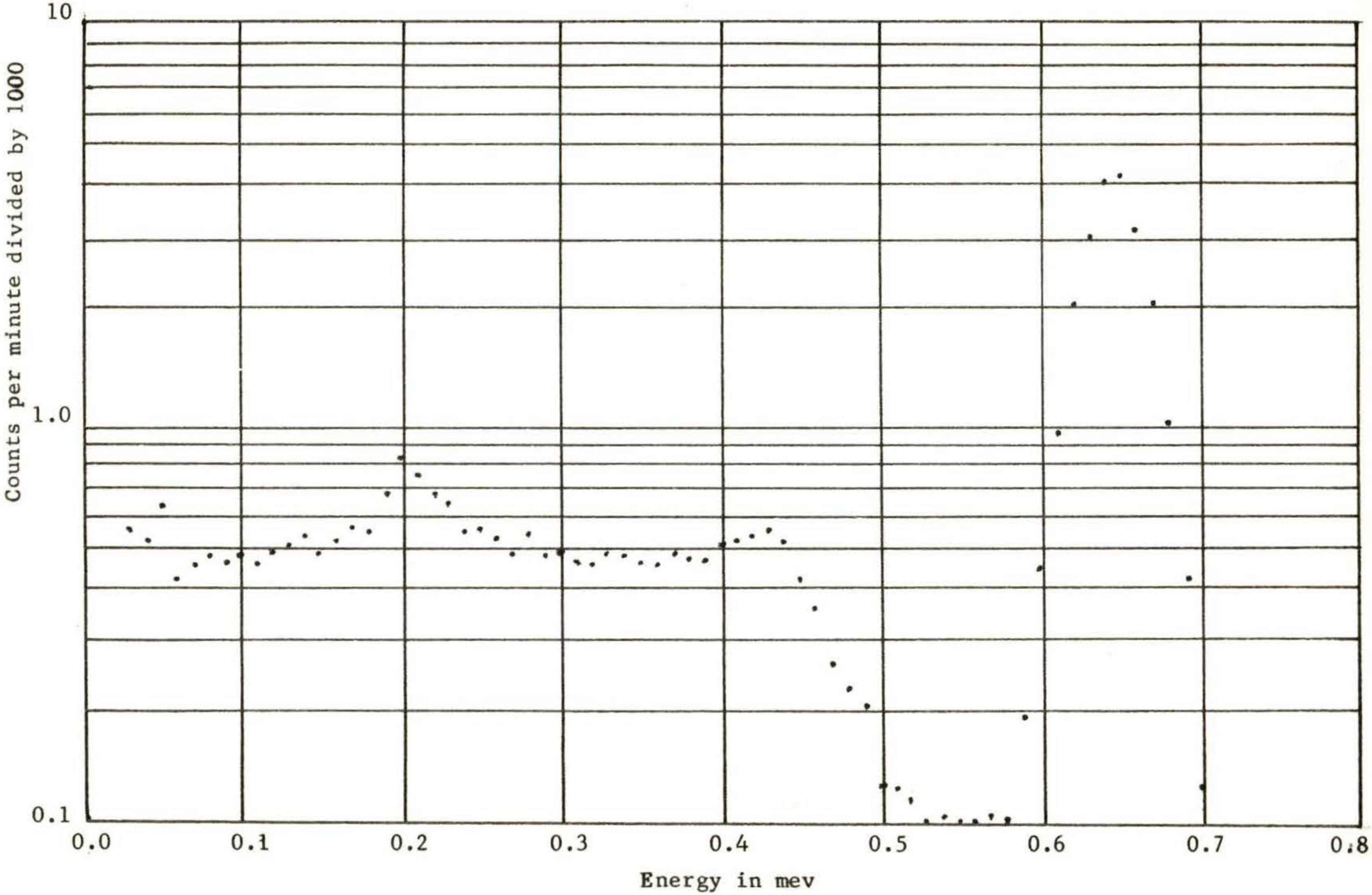


Figure 15. Gamma ray energy spectrum for C_s-137 source in plastic capsule

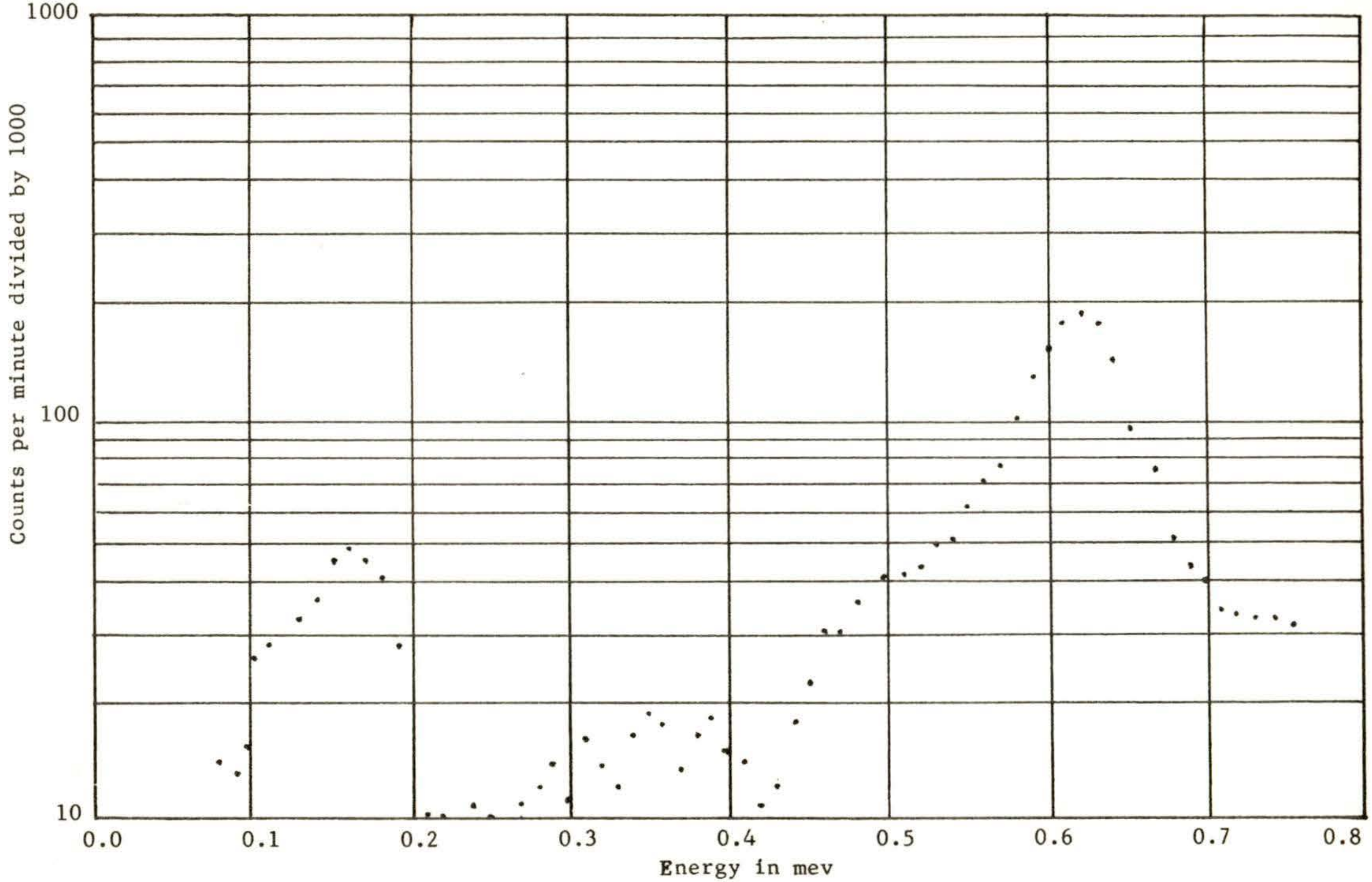


Figure 16. Assumed gamma ray spectrum of the cesium source in the lead capsule

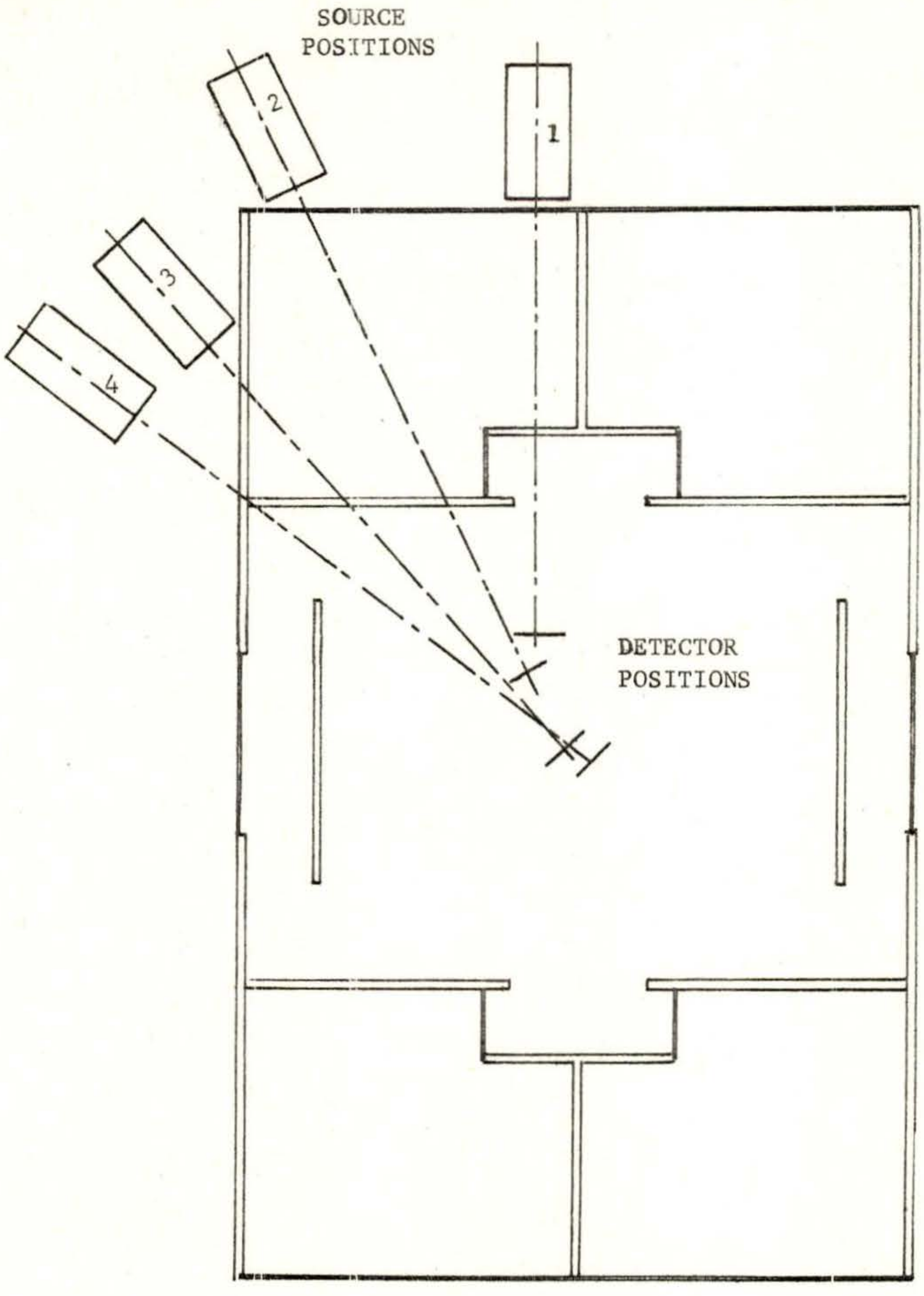


Figure 17. Positions of detector and cesium source in lead capsule for gamma ray energy spectra readings through model

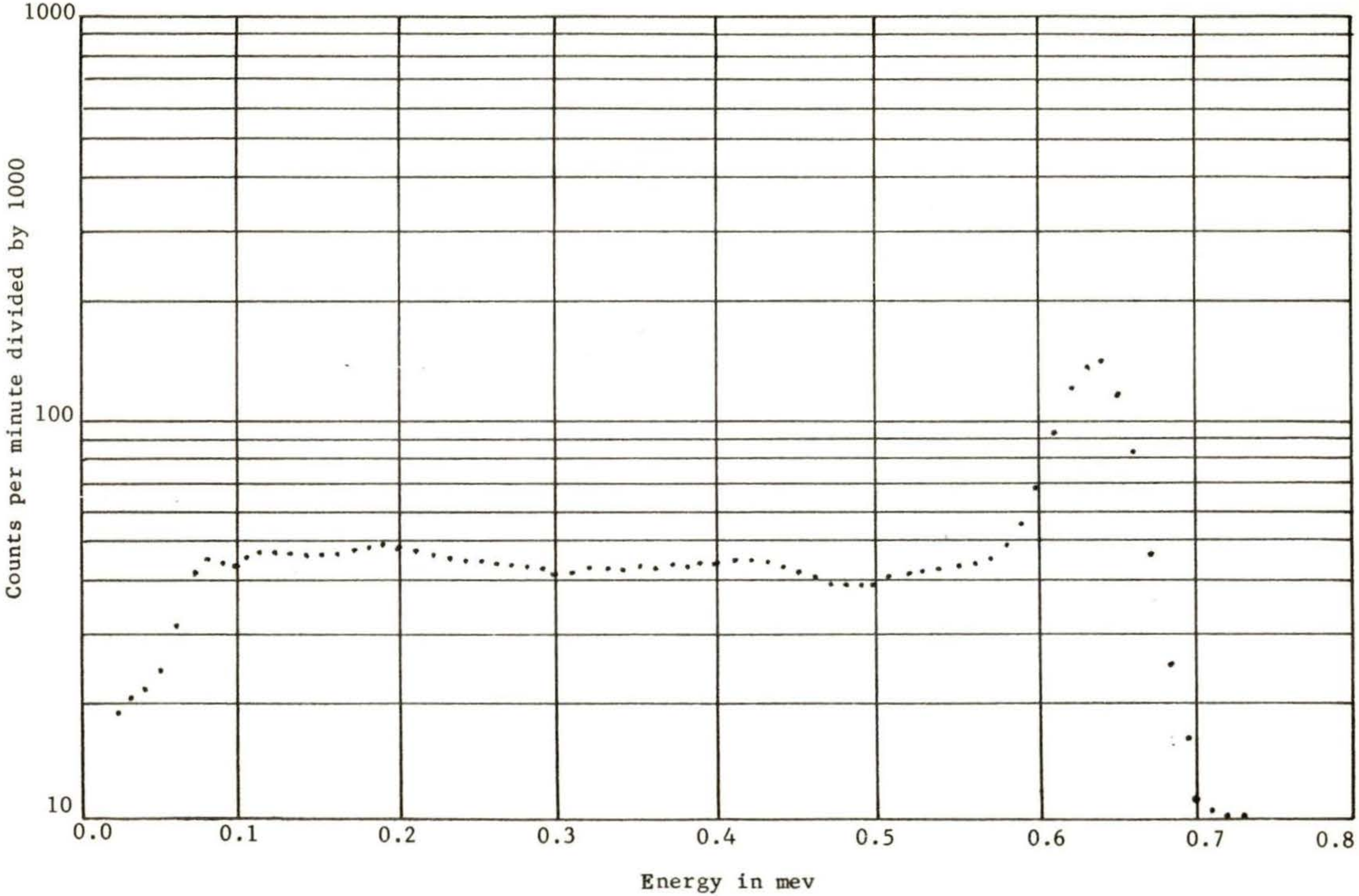


Figure 18. Gamma ray energy spectrum of the cesium source in the lead capsule at position 1 outside the model

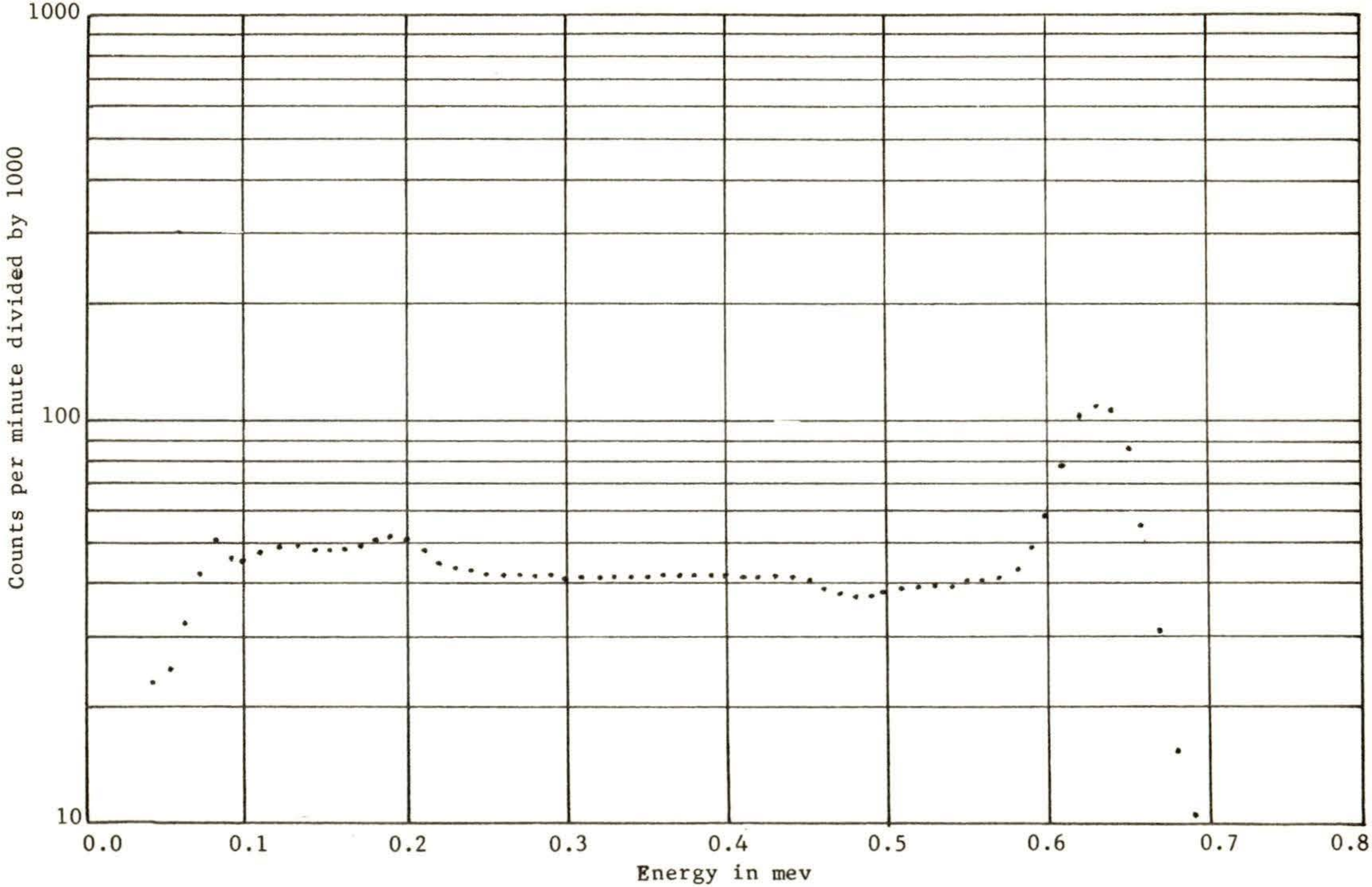


Figure 19. Gamma ray energy spectrum of the cesium source in the lead capsule at position 2 outside the model

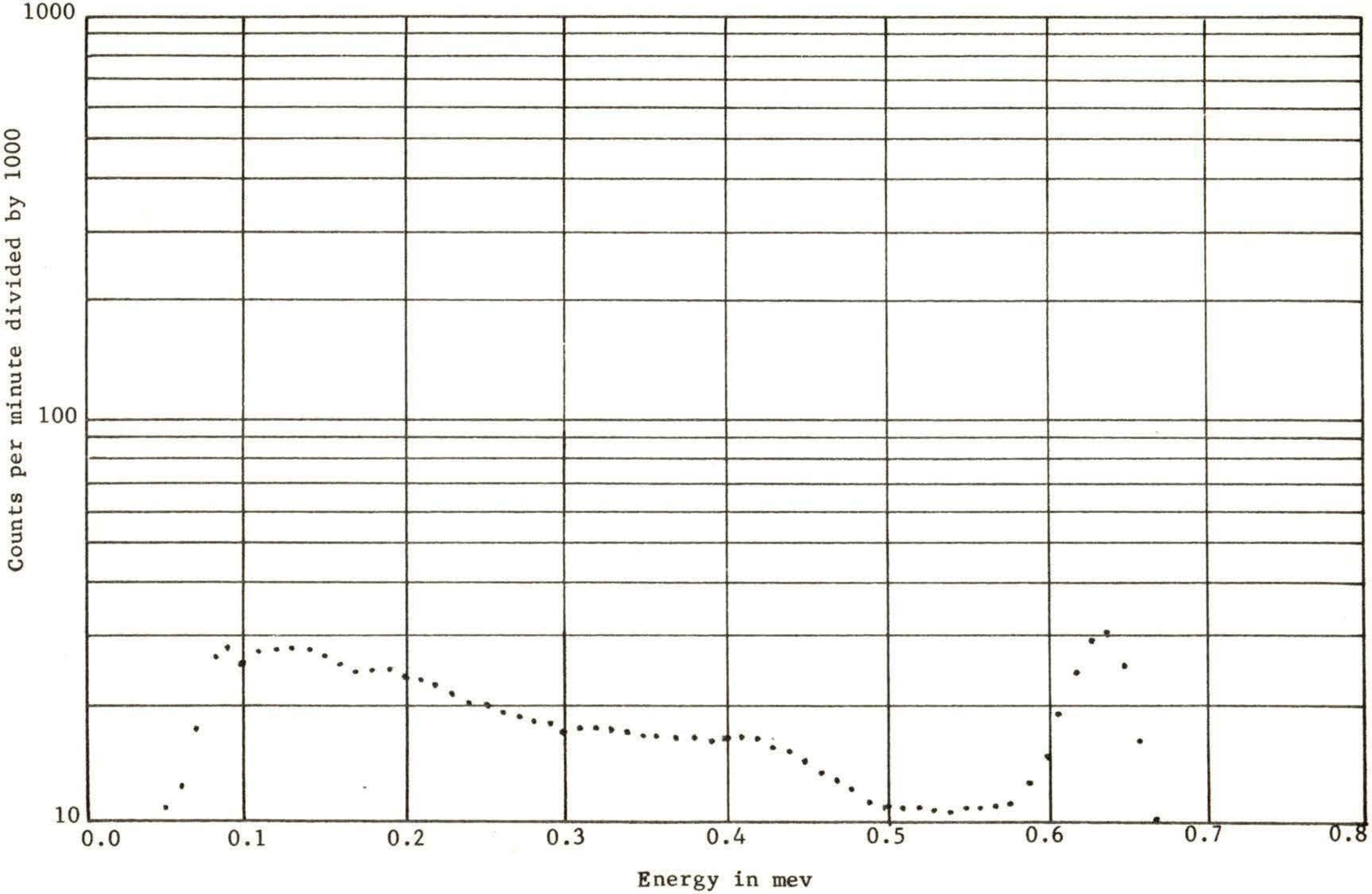


Figure 20. Gamma ray energy spectrum of the cesium source in the lead capsule at position 3 outside the model

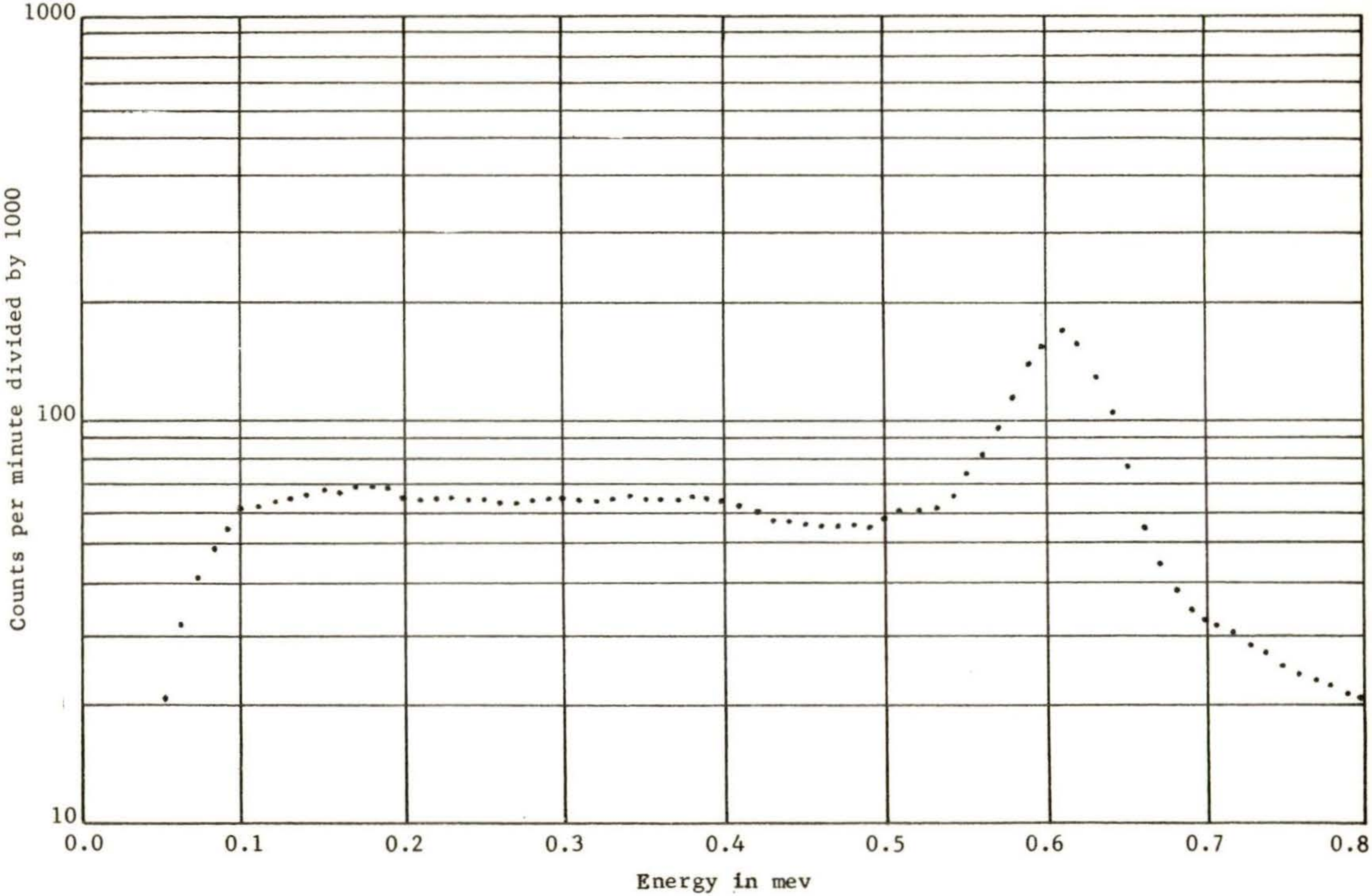
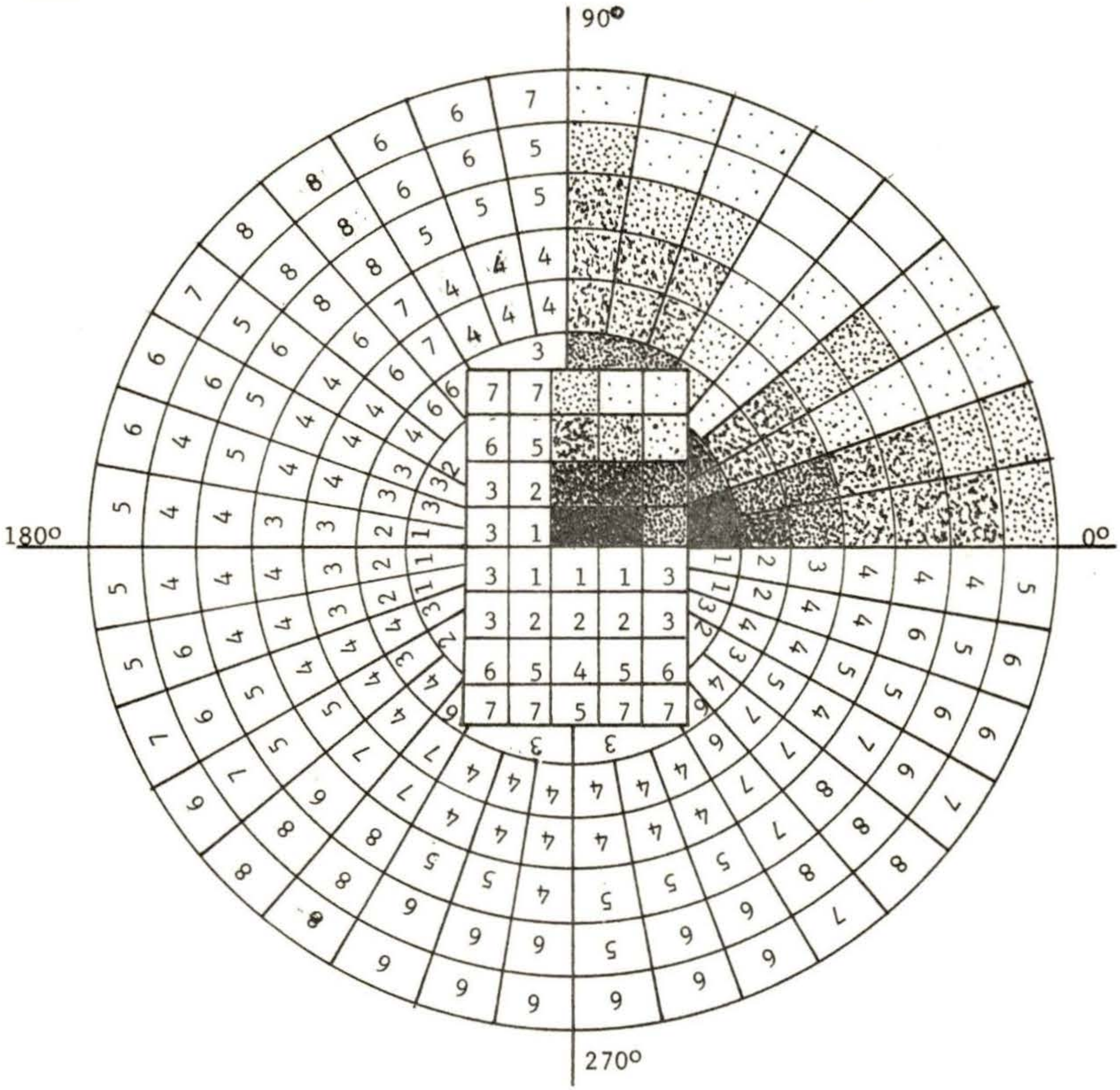


Figure 21. Gamma ray energy spectrum of the cesium source in the lead capsule at position 4 outside the model



KEY

Counts per minute divided by 1000					
1		More than 7000	5		700 - 1000
2		5000 - 7000	6		500 - 700
3		3000 - 5000	7		300 - 500
4		1000 - 3000	8		Less than 300

Figure 22. Counts received by detector as a function of the source location

Protection Factor

As noted previously, the source was placed in a pattern of radial positions at specified radii. These are indicated in Figure 22, with each position of the source designated by an area for which the source is simulating fallout.

The data from the simulated field of fallout are shown in the tables in Appendix B. The tables contain the counting data (C), the counting data corrected for background and dead time C(BD) , and the counting data corrected for background, dead time, and area of fallout C(BDA).

Results of the experimental data and the analytical calculations are shown in Table 6. The total contributions from the radiation on the ground and the roof are broken into the sections which formed the basis of the analytical calculations.

Comparison of the experimental and analytical results shows 16.8 percent difference in the protection factor for the roof only, 8.2 percent difference in the protection factor for the ground contribution only, and 2.06 percent difference in the total protection factor. The division of the roof and ground contributions into sections results in agreement between the experimental and analytical results of 1.16 to 308 percent in the roof contribution by sections and 7.72 to 49.4 percent in the ground contribution by sections.

The lack of agreement between the results for the roof sections is attributed to the size of the divisions on the roof used in the counting procedure. Since the location of the interior partitions affect the contributions, the use of smaller area divisions could possibly improve the agreement with the calculated values.

A graph of the number of counts measured at the detector versus the position of the source with respect to the model is shown in Figure 22. The effect on radiation measurement due to geometry, barriers, and the distance from the detector can be easily seen. In the angle interval from 20 to 30 degrees, it is possible to see the effect of the interior partition at the end of the shelter area stopping in order to form a hallway between the classrooms and the shelter area. The effect of the interior partitions and the increased thickness at the corners is seen in the angle interval of 40 to 60 degrees. The values of the readings due to fallout on the roof show the effect of the interior partition between the classroom area and the shelter area.

The accuracy of the experimental results is dependent upon the random errors in the counting data and the systematic errors in the model analysis. These systematic errors due to the spectra analysis assumptions and the dead time correction method are difficult to estimate accurately. A small change in the assumed spectrum for the model materials has a relatively small effect on the value of the linear attenuation coefficient and the length scale. The errors in the dead time correction factors also cause a relatively small effect in the total protection factor, since the protection factor is a ratio of the two sums corrected by the same dead time method.

The accuracy of the analytical protection factor is discussed by Spencer (6). According to Spencer, plots for the barrier factors are accurate to 5 percent, the scattering factors are accurate to 10 to 15 percent and the solid angle fractions and mass thicknesses are accurate to 10 percent.

Table 6. Experimental and analytical results

	Counts per Minute divided by 1000 Set 1	Counts per Minute divided by 1000 Set 2	Average Contribution %	Calculated Contribution %	Protection Factors Exp.	Protection Factors Calc.
Roof contributions						
A	8,061	8,015	3.48	3.44		
B	19,479	19,570	8.40	2.06		
C	174,743	175,009	75.50	88.00		
D	7,437	7,255	3.20	2.14		
E	13,035	13,357	5.65	1.37		
F	8,650	8,632	3.77	4.30		
Total	231,405 ± 3021	231,838 ± 3040	100.00	100.00	25.0 ± 0.11	21.4
Ground Contributions						
A_1	309,905	310,864	58.6	63.5		
A_2	26,379	25,337	4.9	8.1		
B_1	167,106	163,785	30.9	20.7		
B_0	29,588	28,979	5.6	7.8		
Total	520,433 ± 351	528,905 ± 358	100.0	100.00	11.2 ± 0.004	12.2
Roof and ground contributions						
	752,104 ± 3021	760,594 ± 3040			7.62 ± 0.001	7.77
Contribution with no model						
	5,824,776 ± 9116	5,789,260 ± 9075				

CONCLUSIONS

The results of this investigation tend to support the method of analysis recommended by the Office of Civil Defense. The agreement between the experimental and analytical results for the total protection factor is within 2.06 percent. The differences between the experimental and analytical results for the percentage of contribution of small sections is most likely due to the number and spacing of the positions at which experimental readings were taken. If in the model analysis the positions were selected at smaller intervals, the assumption of an average value of counts for an area would have been more valid.

The agreement between the experimental and analytical results tends to verify the spectral analysis method used to determine the model source spectrum.

Since the results confirm the basic method, the possibilities for further study could include additional model studies to test the validity of analytical methods on structures with unusual material and geometry combinations.

LITERATURE CITED

1. Eisenhauer, Charles. An engineering method for calculating protection afforded by structures against fallout radiation. National Bureau of Standards Monograph 76. 1964.

2. Glasstone, Smauel. The effects of nuclear weapons. Washington, D.C., U.S. Atomic Energy Commission. 1962.

3. Prentiss, Augustin M. Civil defense in modern war. New York, N.Y., McGraw-Hill. c1951.

4. Severud, Fred N. and Anthony F. Merrill. The bomb, survival and you. New York, N.Y., Reinhold Publishing Corp. c1954.

5. Spencer, L. V. Structure shielding against fallout radiation from nuclear weapons. National Bureau of Standards Monograph 42. 1962.

6. Suggs, Robert C. Survival handbook. New York, N.Y., Macmillan Co. c1962.

7. U.S. Department of Defense. Office of Civil Defense. Shelter design and analysis. Vol. 1. Office of Civil Defense Tech. Report 20. 1968.

8. U.S. Department of Defense. Office of Civil Defense. Shelter design in new buildings. Office of Civil Defense Tech. Report 43. 1967.

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APPENDIX

List of Symbols

B	Background counts
B_e	Barrier reduction factor for exterior walls
B_i	Barrier reduction factor through interior partitions
C	Count measured by detector
C(BD)	Counts corrected for background and dead time
C(BDA)	Counts corrected for background, dead time and area of fallout
C_g	Total ground contribution to detector
C_{gi}	Individual ground contribution to detector
C_o	Roof contribution to detector
e	Eccentricity ratio, ratio of width to length of a structure
E	Shape factor applied to scatter geometry
f	Normality ratio
F_a	Area correction factor
F_d	Dead time correction factor
G_a	Directional response for skyshine radiation
G_d	Directional response for direct radiation
G_g	Total geometry reduction factor for ground contribution
G_s	Direction response for scatter radiation
H	Height of detector above the contaminated plane
I	Intensity of radiation incident on a barrier
I_o	Intensity of radiation emergent from a barrier
L	Length of a rectangular structure
n	Length scale

N	Counts received by detector
N_o	Counts emitted by source
P_f	Protection factor
R_f	Reduction factor
S_a	Standard deviation of area correction factor
S_b	Standard deviation of background counts
S_c	Standard deviation of count received by detector
S_f	Standard deviation of dead time correction factor
S_w	Scatter fraction, fraction of wall emergent radiation that has been scattered in the wall
t	Thickness of wall
W	Width of a rectangular structure
x_o	Mass thickness of exterior wall
x_i	Mass thickness of interior wall
Z	Distance from the detector to an overhead plane of contamination
ω	A solid angle fraction at the apex of a pyramid or cone
ω_u	Upper solid angle fraction, defined by a wall segment above the plane of the detector
ω_l	Lower solid angle fraction defined by a segment of wall in elevation below the detector plane
μ	Linear attenuation coefficient
r	Distance between source and detector

Experimental Data

The data taken with and without the model is given in the following tables. The key to the position notation used in the tables is shown in Figure 23.

The readings taken at each position have been corrected for background and dead time C(BD) and for background, dead time, and area C(BDA). The sum of C(BDA) for all positions is the contribution received by the detector due to that segment of the simulated radiation field.

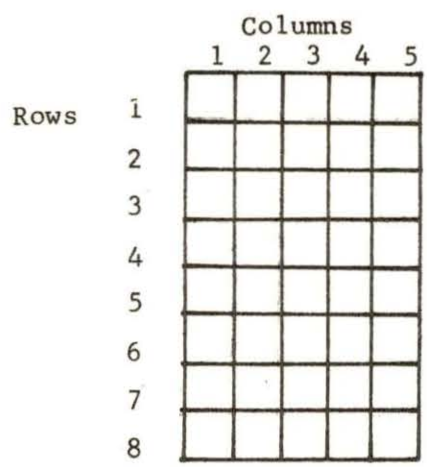

Figure 23. Position notation used in the tables of experimental data for roof

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, RADIAL POSITION = 19 INCHES

ANGLE DEG.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	4375	4372	4372	9715	43.7	9715	71.4
10	4345	4340	4343	9596	43.4	9596	70.7
20	3704	3700	3702	7341	37.0	7341	56.5
30	2480	2482	2482	3806	24.7	3806	33.2
150	3569	3568	3569	6873	35.6	6873	53.6
160	2455	2453	2454	3737	24.5	3737	32.7
170	4200	4201	4196	9120	41.9	9120	67.6
180	4342	4342	4337	9587	43.4	9587	70.7
190	4151	4149	4250	9059	41.8	9059	67.3
200	2857	2859	2855	4699	28.5	4699	39.5
210	3073	3074	3071	5288	30.7	5288	43.4
330	3281	3282	3283	5948	32.8	5948	47.7
340	2450	2445	2452	3725	24.4	3725	32.7
350	4122	4124	4121	8827	41.2	8827	65.8

AVERAGE BACKGROUND = 8.7

SUM OF C(BDA) = 97327 208

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, RADIAL POSITION = 25 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	3113	3114	3114	5409	31.1	6464	48.7
10	3085	3085	3079	5318	30.8	6355	48.1
20	2408	2406	2409	3623	24.0	4329	35.6
30	1847	1845	1848	2455	18.4	2933	26.2
40	1960	1963	1964	2689	19.6	3214	28.1
50	683	681	680	673	0.3	804	3.9
85	2504	2500	2501	3859	25.0	6521	47.8
95	2449	2446	2450	3723	24.4	6292	46.6
130	687	689	688	680	0.3	812	4.0
140	1042	1043	1044	1117	10.4	1335	14.0
150	2515	2533	2512	3902	25.1	4663	37.7
160	1848	1849	1847	2457	18.4	2937	26.2
170	3002	3002	3004	5085	30.0	6077	46.5
180	3122	3119	3119	5429	31.1	6488	48.8
190	3052	3050	3054	5227	30.5	6247	47.4
200	2034	2032	2033	2824	20.3	3375	29.3
210	2054	2053	2053	2861	20.5	3419	29.6
220	1332	1334	1333	1560	13.3	1864	18.3
230	751	750	750	742	0.3	886	4.3
265	2528	2525	2525	3916	25.2	6618	48.3
275	2369	2364	2363	3528	23.6	5963	44.8
310	597	595	596	587	0.3	702	3.4
320	1020	1020	1017	1085	10.1	1297	13.6
330	2335	2336	2338	3464	23.3	4140	34.4
340	1786	1782	1780	2333	17.8	2788	25.2
350	2969	2970	2965	4995	29.6	5969	45.8

AVERAGE BACKGROUND = 8.7

SUM OF C(BDA) = 102505   177

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, RADIAL POSITION = 31 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
5	2239	2237	2236	3236	22.3	4660	37.2
15	2166	2171	2169	3084	21.6	4442	35.9
25	1267	1267	1265	1445	12.6	2081	20.0
35	1641	1640	1637	2087	16.3	3005	26.5
45	700	701	702	692	0.3	997	4.1
55	497	498	499	489	0.3	704	2.9
65	1886	1889	1886	2539	18.8	3656	30.8
75	1790	1788	1787	2342	17.8	3373	29.0
85	1976	1973	1971	2711	19.7	3904	32.4
95	1799	1800	1800	2361	17.9	3400	29.2
105	1785	1784	1783	2335	17.8	3363	29.0
115	1949	1942	1943	2654	19.4	3823	31.9
125	490	490	489	481	0.3	693	2.8
135	551	551	552	543	0.3	782	3.2
145	1071	1074	1075	1160	10.7	1671	16.8
155	1416	1415	1415	1691	14.1	2435	22.5
165	1485	1486	1486	1807	14.8	2602	23.7
175	2196	2191	2193	3137	21.9	4518	36.4
185	2217	2214	2218	3187	22.1	4589	36.8
195	2152	2137	2138	3030	21.4	4363	35.4
205	1232	1230	1233	1384	12.2	1993	19.4
215	1656	1654	1655	2114	16.5	3045	26.7
225	1034	1035	1035	1106	10.3	1593	16.1
235	488	487	486	478	0.3	689	2.8
245	1865	1860	1861	2486	18.5	3581	30.4
255	1655	1653	1652	2111	16.5	3040	26.7
265	1909	1908	1909	2585	19.0	3723	31.2
275	1709	1708	1708	2209	17.0	3182	27.7
285	1773	1772	1776	2318	17.7	3338	28.8
295	1854	1851	1852	2466	18.5	3551	30.2
305	539	541	539	531	0.3	765	3.1
315	505	504	505	496	0.3	715	2.9
325	818	822	817	815	8.1	1174	12.6
335	1469	1468	1468	1778	14.6	2560	23.4
345	1409	1407	1408	1680	14.0	2419	22.4
355	2200	2200	2194	3146	21.9	4531	36.5

AVERAGE BACKGROUND = 8.7
SUM OF C(BDA) = 98974 153

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, RADIAL POSITION = 37 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	1650	1648	1649	2103	16.4	3650	31.0
10	1647	1646	1646	2099	16.4	3641	30.9
20	1198	1196	1199	1329	11.9	2307	22.1
30	912	910	910	947	9.0	1644	16.6
40	854	856	855	866	8.5	1503	15.5
50	377	377	376	368	0.2	639	2.2
60	317	317	317	308	0.2	535	1.8
70	1250	1248	1248	1414	12.4	2454	23.1
80	1082	1081	1082	1172	10.7	2033	19.8
90	1232	1230	1232	1384	12.2	2401	22.7
100	1393	1389	1389	1651	13.8	2864	25.8
110	1154	1150	1152	1268	11.4	2200	21.2
120	1296	1294	1295	1497	12.9	2597	24.0
130	369	369	368	360	0.2	625	2.1
140	675	673	673	665	0.3	1154	3.9
150	1264	1264	1261	1439	12.6	2498	23.3
160	967	967	965	1017	9.6	1765	17.7
170	1650	1646	1646	2101	16.4	3645	31.0
180	1657	1665	1665	2128	16.6	3692	31.3
190	1647	1646	1647	2099	16.4	3642	31.0
200	1150	1148	1149	1263	11.4	2193	21.1
210	1021	1021	1018	1086	10.1	1884	18.7
220	674	673	675	665	0.3	1154	3.9
230	327	327	326	318	0.2	552	1.9
240	362	361	361	353	0.2	612	2.1
250	1248	1249	1249	1414	12.4	2454	23.1
260	1186	1189	1187	1316	11.8	2283	21.9
270	1148	1146	1146	1261	11.4	2187	21.1
280	1340	1343	1345	1575	13.4	2732	24.9
290	1083	1084	1083	1174	10.8	2038	19.9
300	1242	1245	1244	1405	12.4	2438	23.0
310	332	331	332	323	0.2	561	1.9
320	411	410	411	402	0.2	698	2.4
330	1145	1146	1146	1259	11.4	2185	21.1
340	878	676	877	803	8.0	1393	14.7
350	1539	1544	1538	1903	15.3	3303	28.8

AVERAGE BACKGROUND = 8.7

SUM OF C(BDA) = 74175 123

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, RADIAL POSITION = 43 INCHES

ANGLE DEG.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
5	1273	1273	1274	1458	12.7	2925	26.8
15	1239	1239	1243	1401	12.3	2809	26.0
25	681	682	681	673	0.3	1350	4.0
35	872	875	873	893	8.7	1792	18.1
45	355	355	355	347	0.2	696	2.1
55	248	249	250	240	0.2	483	1.5
65	871	870	871	890	8.6	1784	18.1
75	829	830	829	830	8.2	1664	17.2
85	1000	999	1000	1059	9.9	2124	20.8
95	821	821	822	818	8.1	1642	17.0
105	855	854	853	865	8.5	1735	17.7
115	924	921	926	964	9.2	1934	19.2
125	292	292	292	284	0.2	570	1.7
135	289	290	289	282	0.2	565	1.7
145	601	599	600	592	0.3	1187	3.5
155	804	804	803	795	0.3	1595	4.7
165	860	859	860	873	8.5	1752	17.8
175	1268	1268	1268	1449	12.6	2906	26.7
185	1302	1303	1302	1511	13.0	3031	27.4
195	1297	1295	1294	1498	12.9	3004	27.3
205	854	853	853	864	8.5	1733	17.7
215	811	810	810	803	8.0	1611	16.8
225	507	508	508	499	0.3	1002	3.0
235	269	268	268	260	0.2	522	1.6
245	887	887	888	914	8.8	1833	18.4
255	819	819	819	815	8.1	1635	17.0
265	1010	1009	1008	1071	10.0	2148	21.0
275	866	864	866	882	8.6	1769	18.0
285	855	857	856	868	8.5	1741	17.8
295	910	909	908	946	9.0	1897	18.9
305	315	313	313	306	0.2	613	1.8
315	286	287	286	278	0.2	558	1.7
325	483	481	482	474	0.2	951	2.8
335	785	784	784	776	0.3	1556	4.6
345	827	827	829	828	8.2	1660	17.1
355	1269	1269	1269	1451	12.6	2909	26.7

AVERAGE BACKGROUND = 8.2
SUM OF C(BDA) = 59703 100

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, RADIAL POSITION = 49 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	995	993	998	1054	9.9	2403	23.4
10	1009	1008	1008	1070	10.0	2441	23.7
20	761	760	761	752	0.3	1716	4.4
30	563	562	562	554	0.3	1265	3.3
40	497	496	496	488	0.3	1114	2.9
50	209	211	210	202	0.2	461	1.2
60	195	195	195	187	0.2	427	1.2
70	668	668	670	660	0.3	1506	3.9
80	599	596	597	589	0.3	1343	3.5
90	763	762	763	754	0.3	1720	4.4
100	769	770	769	761	0.3	1736	4.5
110	603	602	602	594	0.3	1355	3.5
120	686	686	684	677	0.3	1545	4.0
130	227	227	226	218	0.2	498	1.3
140	296	297	296	288	0.2	658	1.7
150	726	725	724	717	0.3	1636	4.2
160	554	555	553	546	0.3	1245	3.2
170	974	973	973	1026	9.7	2340	22.8
180	1010	1011	1013	1074	10.0	2450	23.7
190	1007	1008	1006	1069	10.0	2437	23.6
200	681	680	681	672	0.3	1533	4.0
210	628	621	627	617	0.3	1408	3.7
220	377	377	377	369	0.2	842	2.2
230	212	213	213	205	0.2	467	1.3
240	238	237	237	229	0.2	523	1.4
250	669	670	671	662	0.3	1509	3.9
260	659	659	659	651	0.3	1485	3.8
270	609	610	609	601	0.3	1371	3.6
280	769	769	769	761	0.3	1736	4.5
290	602	601	602	594	0.3	1354	3.5
300	674	675	676	667	0.3	1521	3.9
310	210	210	210	202	0.2	461	1.2
320	264	279	279	266	0.2	607	1.6
330	669	671	672	663	0.3	1512	3.9
340	529	529	529	521	0.3	1188	3.1
350	944	945	948	992	9.4	2262	22.2

AVERAGE BACKGROUND = 8.2
SUM OF C(BDA) = 50093 59

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, RADIAL POSITION = 55 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
5	824	825	823	822	8.2	2106	21.4
15	809	811	807	801	8.0	2050	21.0
25	447	446	446	438	0.2	1122	2.6
35	555	555	554	546	0.3	1399	3.3
45	266	266	266	257	0.2	659	1.6
55	181	181	182	173	0.2	443	1.1
65	526	525	526	517	0.3	1325	3.1
75	517	515	514	507	0.3	1298	3.0
85	625	626	626	617	0.3	1580	3.7
95	507	506	507	498	0.3	1276	3.0
105	519	519	518	510	0.3	1307	3.0
115	564	566	566	557	0.3	1427	3.3
125	220	220	221	212	0.2	542	1.3
135	197	198	198	189	0.2	486	1.2
145	370	369	370	361	0.2	925	2.2
155	521	520	522	512	0.3	1312	3.1
165	549	550	550	541	0.3	1386	3.2
175	811	813	813	805	8.0	2062	21.1
185	869	864	865	882	8.6	2259	22.6
195	822	820	819	817	8.1	2092	21.3
205	461	461	460	452	0.2	1159	2.7
215	582	582	580	573	0.3	1467	3.4
225	256	256	256	248	0.2	635	1.5
235	189	189	189	180	0.2	462	1.1
245	549	548	548	540	0.3	1382	3.2
255	515	514	512	505	0.3	1294	3.0
265	635	637	637	628	0.3	1608	3.7
275	523	522	522	513	0.3	1315	3.1
285	563	564	562	554	0.3	1420	3.3
295	563	564	562	554	0.3	1419	3.3
305	331	330	330	322	0.2	825	2.0
315	198	198	198	189	0.2	486	1.2
325	331	331	332	323	0.2	827	2.0
335	516	515	514	506	0.3	1297	3.0
345	540	539	539	531	0.3	1360	3.2
355	823	823	823	820	8.2	2101	21.4

AVERAGE BACKGROUND = 8.6

SUM OF C(BDA) = 46128 54

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, ROOF POSITIONS

GRID POS.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
11	323	322	322	314	0.2	483	27.5
12	341	340	342	332	0.2	512	29.1
13	266	265	265	256	0.2	395	22.5
14	348	349	350	340	0.2	524	29.8
15	324	323	323	314	0.2	484	27.6
21	531	531	530	522	0.3	804	45.7
22	803	804	804	795	0.3	1224	69.6
23	2009	2008	2000	2774	20.0	4273	244.8
24	809	809	808	800	8.0	1232	71.1
25	533	533	532	524	0.3	807	45.9
31	2222	2223	2220	3199	22.1	4926	282.0
32	3094	3096	3095	5355	30.9	8246	471.0
33	3447	3442	3441	6481	34.4	9981	569.6
34	3277	3276	3275	5926	32.7	9127	521.0
35	2216	2216	2215	3184	22.1	4904	280.7
41	2612	2611	2607	4112	26.0	6333	362.1
42	4401	4401	4411	9840	44.0	15153	863.7
43	5102	5099	5100	13059	51.0	201111145.4	
44	4344	4347	4347	9609	43.4	14798	843.5
45	2576	2578	2579	4035	25.7	6215	355.4
51	2920	2918	2916	4867	29.1	7496	428.3
52	4350	4371	4382	9694	43.6	14929	850.9
53	5498	5498	5497	15506	54.9	238791359.4	
54	4677	4686	4682	10920	46.8	16817	958.2
55	2727	2726	2688	4332	27.1	6672	381.4
61	2317	2317	2317	3422	23.1	5271	301.6
62	3214	3212	3216	5714	32.1	8801	502.5
63	3708	3709	3704	7358	37.0	11332	646.4
64	3307	3308	3311	6041	33.0	9303	531.0
65	2417	2414	2419	3644	24.1	5612	321.0
71	521	523	521	513	0.3	790	44.9
72	806	805	806	797	0.3	1228	69.8

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, FIRST SAMPLE, ROOF POSITIONS

GRID POS.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
73	2069	2067	2071	2889	20.6	4449	254.8
74	809	808	808	800	8.0	1232	71.1
75	551	550	550	541	0.3	834	47.4
81	325	323	323	315	0.2	485	27.6
82	331	351	351	335	0.2	517	29.4
83	284	283	284	275	0.2	423	24.1
84	362	361	363	353	0.2	545	31.0
85	348	348	349	340	0.2	523	29.8

AVERAGE BACKGROUND = 8.7

SUM OF C(BDA) = 231689 3021

COUNTING DATA (COUNTS PER MINUTE/1000)

NO MODEL, FIRST SAMPLE

ANGLE DEG.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
			RADIAL DISTANCE = 10 INCHES				
0	7935	7923	7908	62735	79.3	370137	3320
90	7958	7943	7935	50065	79.4	295384	2664
180	7772	7771	7727	57954	77.6	341932	3071
270	7786	7823	7824	59632	78.2	351830	3158
			RADIAL DISTANCE = 16 INCHES				
0	7461	7533	7538	51972	75.1	348738	2769
90	7568	7557	7548	53225	75.6	357144	2834
180	7448	7439	7442	49510	74.4	332215	2641
270	7403	7392	7399	48274	74.0	323920	2577
			RADIAL DISTANCE = 22 INCHES				
0	6231	6230	6227	20944	62.1	193527	1238
90	6356	6348	6346	22298	63.3	206037	1306
180	6232	6227	6228	20944	62.1	193526	1238
270	6384	6378	6382	22608	63.6	208898	1322
			RADIAL DISTANCE = 28 INCHES				
0	4842	4847	4842	11620	48.2	120857	788
90	5033	5033	5033	12551	50.1	130538	839
180	4880	4890	4889	11846	48.6	123198	800
270	4754	4754	4759	11191	47.3	116392	765
			RADIAL DISTANCE = 34 INCHES				
0	3763	3766	3766	7472	37.4	106483	661
90	3843	3839	3840	7706	38.2	109819	677
180	3827	3825	3823	7639	38.0	108865	673
270	3629	3627	3625	7026	36.0	100133	631
			RADIAL DISTANCE = 40 INCHES				
0	2982	2986	2981	4991	29.6	83614	560
90	2976	2975	2973	4970	29.5	83258	558
180	3027	3025	3025	5103	30.0	85482	569
270	2862	2868	2865	4675	28.4	78314	535
			RADIAL DISTANCE = 46 INCHES				
0	2377	2373	2372	3511	23.5	67598	488
90	2327	2324	2329	3408	23.0	65616	478
180	2430	2434	2435	3644	24.1	70164	501
270	2257	2259	2256	3243	22.3	62446	462

COUNTING DATA (COUNTS PER MINUTE/1000)

NO MODEL, FIRST SAMPLE

ANGLE DEG.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
			RADIAL DISTANCE = 52 INCHES				
0	1959	1934	1935	2618	19.2	57022	439
90	1875	1875	1877	2480	18.5	54020	423
180	1990	1992	1991	2713	19.7	59090	451
270	1835	1835	1839	2399	18.1	52261	414
			RADIAL DISTANCE = 58 INCHES				
0	1640	1643	1639	2059	16.2	49948	406
90	1563	1562	1564	1916	15.4	46464	386
180	1679	1677	1679	2126	16.5	51557	416
270	1527	1527	1526	1848	15.0	44820	377
			RADIAL DISTANCE = 64 INCHES				
0	1455	1454	1454	1727	14.3	46474	395
90	1302	1301	1298	1476	12.8	39720	351
180	1481	1478	1478	1768	14.6	47573	402
270	1345	1346	1346	1553	13.2	41791	364
			RADIAL DISTANCE = 70 INCHES				
0	1265	1269	1267	1417	12.4	41513	371
90	1226	1225	1222	1343	12.0	39328	358
180	1246	1254	1252	1389	12.3	40674	366
270	1255	1256	1257	1398	12.3	40939	368

AVERAGE BACKGROUND = 25.3
SUM OF C(BDA) = 5789260 9075

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, RADIAL POSITION = 19 INCHES

ANGLE DEG.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	4364	4377	4376	9715	43.7	9715	71.4
10	4334	4317	4315	9517	43.2	9517	70.2
20	3693	3254	3255	6367	34.0	6367	50.3
30	2473	2523	2522	3870	25.0	3870	33.6
150	3560	3494	3495	6683	35.1	6683	52.4
160	2445	2500	2504	3812	24.8	3812	33.3
170	4190	4156	4164	9012	41.7	9012	67.0
180	4332	4473	4476	9933	44.2	9933	72.8
190	4174	4392	4388	9501	43.1	9501	70.1
200	2849	2811	2309	4605	28.2	4605	38.9
210	3064	2220	3214	4633	28.3	4633	39.1
330	3273	3141	3138	5624	31.8	5624	45.6
340	2440	2519	2513	3831	24.8	3831	33.4
350	4114	4183	4184	8973	41.6	8973	66.7

AVERAGE BACKGROUND = 8.0
SUM OF C(BDA) = 96082 207

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, RADIAL POSITION = 25 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	3172	3166	3171	5581	31.6	6670	49.9
10	3128	3132	3122	5453	31.2	6517	49.0
20	2363	2359	2353	3515	23.5	4200	34.8
30	1773	1770	1770	2314	17.6	2766	25.0
40	1323	1320	1319	1541	13.1	1841	18.1
50	671	697	693	679	0.3	812	4.0
85	2419	2417	2414	3646	24.1	6163	45.9
95	2393	2401	2403	3605	23.9	6092	45.6
130	703	700	699	692	0.3	827	4.0
140	1056	1056	1056	1137	10.5	1358	14.2
150	2517	2511	2516	3891	25.1	4650	37.6
160	1838	1838	1835	2436	18.3	2911	26.1
170	3013	3012	3012	5113	30.1	6110	46.7
180	3094	3092	3092	5350	30.9	6393	48.3
190	3022	3024	3023	5144	30.2	6147	46.9
200	2098	2102	2099	2946	20.9	3520	30.3
210	2000	2004	2004	2770	20.0	3310	28.8
220	1360	1354	1358	1599	13.5	1910	18.6
230	704	705	703	696	0.3	832	4.1
265	2494	2490	2482	3826	24.8	6467	47.5
275	2511	2513	2510	3883	25.1	6563	48.0
310	565	585	588	571	0.3	683	3.3
320	1003	1005	1005	1065	10.0	1273	13.4
330	2323	2320	2320	3433	23.1	4103	34.1
340	1812	1785	1780	2350	17.9	2808	25.3
350	3013	3012	3012	5113	30.1	6111	46.7

AVERAGE BACKGROUND = 8.0

SUM OF C(BDA) = 101050   176

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, RADIAL POSITION = 31 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
5	2231	2234	2232	3225	22.3	4644	37.1
15	2167	2165	2165	3080	21.6	4436	35.9
25	1242	1243	1246	1406	12.4	2025	19.6
35	1626	1627	1627	2066	16.2	2975	26.2
45	558	558	557	549	0.3	791	3.2
55	476	477	476	468	0.2	675	2.8
65	1929	1925	1927	2621	19.2	3775	31.6
75	1736	1736	1734	2256	17.3	3248	28.1
85	1939	1941	1939	2646	19.3	3810	31.8
95	1733	1730	1730	2248	17.2	3238	28.1
105	1728	1726	1735	2246	17.2	3234	28.0
115	1875	1878	1874	2516	18.7	3623	30.6
125	544	542	540	534	0.3	769	3.1
135	700	701	700	692	0.3	997	4.1
145	1142	1140	1141	1254	11.3	1806	17.9
155	1422	1420	1418	1700	14.1	2448	22.6
165	1483	1483	1482	1803	14.8	2596	23.7
175	2175	2175	2171	3096	21.7	4459	36.0
185	2217	2220	2217	3192	22.1	4596	36.9
195	2094	2095	2094	2936	20.9	4228	34.6
205	1191	1194	1191	1323	11.9	1905	18.7
215	1629	1630	1629	2070	16.2	2981	26.3
225	916	916	918	956	9.1	1376	14.2
235	467	466	466	458	0.2	660	2.7
245	1755	1751	1752	2284	17.5	3289	28.4
255	1579	1583	1581	1981	15.7	2853	25.4
265	1932	1925	1925	2622	19.2	3775	31.6
275	1718	1718	1715	2225	17.1	3204	27.8
285	1709	1709	1702	2208	17.0	3179	27.6
295	1790	1788	1787	2343	17.8	3375	29.1
305	450	450	450	442	0.2	637	2.6
315	665	664	665	656	0.3	946	3.8
325	895	895	895	926	8.9	1333	13.9
335	1443	1444	1445	1739	14.4	2504	23.0
345	1352	1350	1348	1587	13.4	2285	21.4
355	2208	2203	2205	3163	22.0	4555	36.6

AVERAGE BACKGROUND = 8.0

SUM OF C(BDA) = 97246 151

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, RADIAL POSITION = 37 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	1622	1621	1619	2054	16.1	3565	30.5
10	1617	1621	1617	2050	16.1	3557	30.4
20	1169	1168	1170	1291	11.6	2241	21.5
30	886	888	884	912	8.8	1583	16.1
40	825	821	820	820	8.2	1424	14.9
50	303	304	303	295	0.2	513	1.8
60	348	349	348	340	0.2	591	2.0
70	1286	1287	1284	1480	12.8	2569	23.8
80	1094	1096	1094	1191	10.9	2067	20.1
90	1274	1276	1277	1463	12.7	2538	23.6
100	1359	1359	1357	1600	13.5	2777	25.2
110	1106	1109	1108	1210	11.0	2099	20.4
120	1263	1263	1265	1441	12.6	2501	23.4
130	364	365	365	357	0.2	619	2.1
140	536	541	541	532	0.3	923	3.1
150	1202	1198	1205	1336	11.9	2317	22.1
160	872	871	867	889	8.6	1543	15.8
170	1502	1509	1509	1843	15.0	3197	28.1
180	1652	1651	1648	2106	16.4	3655	31.0
190	1626	1628	1625	2064	16.2	3582	30.6
200	1021	1016	1018	1085	10.1	1882	18.7
210	1050	1045	1043	1123	10.4	1948	19.2
220	706	703	702	696	0.3	1208	4.1
230	374	373	372	365	0.2	634	2.2
240	369	366	365	359	0.2	623	2.1
250	1268	1268	1267	1449	12.6	2514	23.4
260	1180	1178	1175	1303	11.7	2261	21.7
270	1187	1182	1182	1311	11.8	2276	21.8
280	1356	1354	1357	1596	13.5	2770	25.2
290	1098	1096	1099	1196	10.9	2075	20.2
300	1260	1259	1257	1433	12.5	2486	23.3
310	321	321	320	313	0.2	543	1.9
320	454	454	453	446	0.2	773	2.6
330	1140	1138	1140	1252	11.3	2172	21.0
340	851	854	851	863	8.5	1497	15.5
350	1499	1500	1501	1832	14.9	3179	28.0

AVERAGE BACKGROUND = 8.0
SUM OF C(BDA) = 72719 121

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, RADIAL POSITION = 43 INCHES

ANGLE DEG.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
5	1223	1221	1224	1370	12.2	2747	25.6
15	1193	1196	1197	1327	11.9	2661	25.1
25	640	640	641	632	0.3	1268	3.7
35	837	837	839	842	8.3	1689	17.4
45	342	341	341	334	0.2	669	2.0
55	252	251	253	244	0.2	489	1.5
65	854	854	854	865	8.5	1735	17.7
75	841	837	838	843	8.3	1691	17.4
85	996	995	996	1055	9.9	2115	20.8
95	845	847	847	854	8.4	1713	17.5
105	860	859	859	874	8.5	1753	17.8
115	938	937	937	981	9.3	1968	19.5
125	366	365	368	358	0.2	719	2.1
135	281	281	281	273	0.2	548	1.6
145	555	557	557	548	0.3	1100	3.2
155	775	778	777	769	0.3	1542	4.5
165	820	821	818	817	8.1	1638	17.0
175	1227	1232	1234	1384	12.2	2776	25.8
185	1214	1216	1217	1358	12.1	2723	25.5
195	1166	1166	1168	1288	11.6	2584	24.4
205	626	631	628	620	0.3	1244	3.7
215	855	856	860	870	8.5	1744	17.8
225	318	319	321	311	0.2	625	1.9
235	256	257	356	282	0.2	565	1.7
245	865	868	865	883	8.6	1771	18.0
255	799	801	803	793	0.3	1590	4.7
265	985	987	987	1043	9.8	2092	20.6
275	856	856	855	868	8.5	1740	17.7
285	821	822	821	819	8.1	1642	17.0
295	909	905	906	943	9.0	1892	18.9
305	359	358	357	350	0.2	702	2.1
315	302	304	305	296	0.2	593	1.8
325	473	473	474	465	0.2	933	2.8
335	754	754	755	746	0.3	1497	4.4
345	747	749	746	739	0.3	1483	4.3
355	1214	1218	1218	1359	12.1	2725	25.5

AVERAGE BACKGROUND = 8.0

SUM OF C(BDA) = 56984 93

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, RADIAL POSITION = 49 INCHES

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
0	1037	1033	1024	1101	10.2	2511	24.2
10	1043	1041	1043	1117	10.4	2548	24.5
20	760	760	760	751	0.3	1713	4.4
30	580	582	584	573	0.3	1308	3.4
40	486	487	488	479	0.2	1092	2.8
50	202	202	202	193	0.2	441	1.2
60	200	200	200	192	0.2	438	1.2
70	600	599	601	591	0.3	1349	3.5
80	560	560	559	551	0.3	1257	3.3
90	648	643	659	641	0.3	1462	3.8
100	733	733	734	725	0.3	1653	4.3
110	574	573	573	565	0.3	1289	3.3
120	647	647	649	639	0.3	1457	3.8
130	229	229	229	220	0.2	503	1.4
140	358	357	357	349	0.2	795	2.1
150	755	753	753	745	0.3	1699	4.4
160	602	598	597	590	0.3	1347	3.5
170	1008	1008	1001	1066	10.0	2431	23.6
180	1027	1026	1025	1094	10.2	2495	24.1
190	1030	1030	1032	1100	10.2	2509	24.2
200	657	657	655	647	0.3	1477	3.8
210	638	639	639	630	0.3	1437	3.7
220	362	360	361	352	0.2	804	2.1
230	209	209	209	200	0.2	458	1.2
240	248	247	244	238	0.2	543	1.5
250	618	613	614	606	0.3	1383	3.6
260	623	620	619	612	0.3	1396	3.6
270	669	667	670	660	0.3	1506	3.9
280	738	737	738	729	0.3	1663	4.3
290	602	601	602	593	0.3	1353	3.5
300	632	640	641	629	0.3	1434	3.7
310	210	211	211	202	0.2	460	1.2
320	278	279	279	270	0.2	616	1.6
330	710	711	713	703	0.3	1603	4.1
340	571	572	573	563	0.3	1285	3.3
350	986	985	987	1042	9.8	2376	23.1

AVERAGE BACKGROUND = 8.7
SUM OF C(BDA) = 50107 61

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, RADIAL POSITION = 55 INCHES

ANGLE DEG.	C #1	#2	#3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
5	829	816	821	819	8.1	2097	21.4
15	803	803	803	795	0.3	2035	4.7
25	437	450	446	436	0.2	1116	2.6
35	559	559	560	551	0.3	1411	3.3
45	235	236	237	228	0.2	583	1.4
55	170	172	173	163	0.2	417	1.0
65	534	534	534	525	0.3	1345	3.1
75	504	501	503	494	0.3	1265	3.0
85	619	619	621	611	0.3	1565	3.6
95	502	501	503	494	0.3	1264	2.9
105	519	519	520	510	0.3	1308	3.0
115	479	473	474	467	0.2	1195	2.8
125	191	193	192	183	0.2	470	1.2
135	229	228	229	220	0.2	564	1.4
145	346	347	348	338	0.2	867	2.0
155	547	545	545	537	0.3	1375	3.2
165	602	603	603	594	0.3	1521	3.5
175	844	847	847	853	8.4	2186	22.0
185	829	830	831	831	8.2	2128	21.6
195	795	816	815	800	8.0	2048	21.0
205	458	466	464	454	0.2	1163	2.7
215	592	586	588	580	0.3	1486	3.5
225	230	246	247	232	0.2	595	1.4
235	190	190	190	182	0.2	466	1.1
245	550	550	553	543	0.3	1390	3.2
255	514	514	514	505	0.3	1295	3.0
265	642	647	647	637	0.3	1631	3.8
275	554	554	554	546	0.3	1397	3.2
285	534	533	533	525	0.3	1344	3.1
295	575	573	578	567	0.3	1451	3.4
305	379	373	379	368	0.2	943	2.2
315	210	211	211	202	0.2	518	1.3
325	332	339	338	327	0.2	839	2.0
335	541	538	539	531	0.3	1359	3.2
345	583	571	572	567	0.3	1451	3.4
355	833	833	835	835	8.3	2139	21.7

AVERAGE BACKGROUND = 8.7

SUM OF C(BDA) = 46245 50

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, ROOF POSITIONS

GRID POS.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
11	339	338	336	329	0.2	507	28.8
12	341	339	339	331	0.2	510	29.0
13	274	274	273	265	0.2	409	23.2
14	353	351	350	343	0.2	528	30.0
15	312	312	312	303	0.2	467	26.6
21	533	532	533	524	0.3	807	45.9
22	796	795	794	786	0.3	1211	68.8
23	1990	2048	2027	2804	20.1	4319	247.4
24	808	808	809	800	8.0	1232	71.1
25	527	528	529	519	0.3	800	45.5
31	2237	2232	2232	3226	22.3	4969	284.4
32	3107	3116	3104	5396	31.0	8310	474.6
33	3425	3424	3418	6428	34.2	9899	564.9
34	3242	3229	3227	5780	32.3	8901	508.2
35	2263	2261	2261	3293	22.5	5072	290.3
41	2649	2651	2552	4127	26.1	6356	363.4
42	4412	4410	4405	9859	44.0	15183	865.4
43	5158	5160	5154	13384	51.5	20612	1173.8
44	4381	4377	4393	9759	43.8	15029	856.6
45	2569	2571	2575	4022	25.7	6194	354.2
51	2739	2735	2737	4390	27.3	6761	386.4
52	4430	4434	4429	9946	44.3	15318	873.0
53	5442	5442	5441	15197	54.4	23404	1332.4
54	4515	4513	4512	10276	45.1	15826	901.9
55	2798	2792	2797	4533	27.9	6981	399.0
61	2355	2352	2347	3499	23.4	5388	308.3
62	3377	3267	3262	6016	33.0	9265	528.9
63	3705	3699	3694	7332	36.9	11292	644.1
64	3336	3332	3328	6123	33.3	9430	538.2
65	2433	2427	2424	3673	24.2	5657	323.6
71	516	516	517	508	0.3	782	44.5
72	802	803	802	794	0.3	1222	69.5

COUNTING DATA (COUNTS PER MINUTE/1000)

MODEL, SECOND SAMPLE, ROOF POSITIONS

GRID POS.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
73	2058	2060	2058	2871	20.5	4421	253.2
74	810	810	809	802	8.0	1235	71.3
75	546	551	552	541	0.3	833	47.4
81	325	324	324	316	0.2	486	27.7
82	342	354	354	341	0.2	526	29.9
83	296	296	296	287	0.2	443	25.2
84	366	367	365	357	0.2	551	31.3
85	342	341	352	336	0.2	518	29.5

AVERAGE BACKGROUND = 8.6

SUM OF C(BDA) = 231671 3015

COUNTING DATA (COUNTS PER MINUTE/1000)

NC MODEL, SECOND SAMPLE

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
			RADIAL DISTANCE = 10 INCHES				
0	7700	7698	7792	57142	77.4	337140	3028
90	7914	7898	7912	62338	79.2	367796	3299
180	7748	7734	7732	57393	77.5	338618	3041
270	7702	7705	7696	56442	77.1	333012	2992
			RADIAL DISTANCE = 16 INCHES				
0	7467	7477	7471	50553	74.7	339216	2696
90	7545	7545	7548	52971	75.5	355439	2821
180	7473	7473	7478	50651	74.8	339872	2701
270	7433	7427	7433	49079	74.3	329325	2619
			RADIAL DISTANCE = 22 INCHES				
0	6263	6261	6265	21331	62.4	197103	1257
90	6289	6289	6301	21677	62.7	200301	1275
180	6217	6223	6223	20855	62.0	192701	1233
270	6292	6291	6288	21651	62.7	200064	1274
			RADIAL DISTANCE = 28 INCHES				
0	4845	4839	4833	11595	48.2	120593	787
90	4994	4992	4987	12348	49.7	128427	828
180	4898	4887	4888	11871	48.7	123458	802
270	4785	4783	4782	11328	47.6	117818	773
			RADIAL DISTANCE = 34 INCHES				
0	3761	3754	3758	7452	37.4	106197	660
90	3802	3805	3604	7397	37.1	105412	656
180	3783	3789	3790	7534	37.6	107369	666
270	3623	3645	3654	7074	36.[illegible]	100814	635
			RADIAL DISTANCE = 40 INCHES				
0	2987	2996	2986	5009	29.7	83909	562
90	2968	2969	2964	4951	29.4	82939	557
180	3033	3031	3029	5118	30.1	85727	570
270	2833	2832	2837	4589	28.1	76879	528
			RADIAL DISTANCE = 46 INCHES				
0	2407	2406	2410	3586	23.8	69036	495
90	3367	2372	2371	4274	26.8	92289	562
180	2430	2435	2441	3650	24.1	70263	502
270	2274	2274	2272	3282	22.5	63184	466

COUNTING DATA (COUNTS PER MINUTE/1000)

NO MODEL, SECOND SAMPLE

ANGLE DEG.	C #1	C #2	C #3	C(BD)	ST. DEV.	C(BDA)	ST. DEV.
	RADIAL DISTANCE = 52 INCHES						
0	1971	1973	1972	2676	19.5	58285	446
90	1915	1913	1920	2569	18.9	55966	434
180	2010	2015	2015	2759	19.9	60075	456
270	1853	1854	1853	2435	18.3	53040	418
	RADIAL DISTANCE = 58 INCHES						
0	1646	1643	1646	2070	16.2	50209	408
90	1591	1590	1591	1967	15.7	47701	393
180	1683	1685	1686	2138	16.6	51847	418
270	1539	1543	1540	1874	15.2	45450	380
	RADIAL DISTANCE = 64 INCHES						
0	1499	1497	1494	1798	14.7	48371	407
90	1415	1415	1415	1664	13.9	44770	384
180	1508	1509	1508	1817	14.8	48895	410
270	1354	1364	1361	1575	13.4	42391	368
	RADIAL DISTANCE = 70 INCHES						
0	1244	1243	1244	1376	12.2	40316	364
90	1272	1263	1263	1415	12.4	41460	371
180	1298	1296	1298	1471	12.7	43076	380
270	1190	1190	1193	1298	11.7	38022	348

AVERAGE BACKGROUND = 25.2
SUM OF C(BDA) = 5824776 9116