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Page 1

Z PLANT RADIATION STUDY  
INTERIM REPORT #5 - PART II  
DATA ON GAMMA SHIELDING OF SPECIAL PLUTONIUM SAMPLES

by

H. A. Moulthrop  
Radiological Development  
Facilities Engineering  
Chemical Processing Department

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E. Doud  
Radiological Development

Z PLANT RADIATION STUDY  
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INTRODUCTION

The calculation of shielding thicknesses for plutonium is complicated by the many different energies represented in the gamma radiation emitted during decay of the plutonium isotopes. Dose rate predictions are also frequently confused by gamma from varying content of fission product impurities in the plutonium, as well as by other gamma radiation induced through alpha and neutron particle absorption within the source material or its environment.

After assumptions are made for these many factors the radiation data for shielding determination is still frequently inadequate because of wide variations in dose rates resulting from self-absorption. The degree of self-shielding is in turn dependent on nature of the plutonium compound, degree of compactness, weight, and over-all geometrical distribution of the source material.

By preparing a variety of plutonium samples representing combinations of these varying factors, actual dose rates and gamma spectra, as obtained from them, can then be extrapolated for application to specific situations.

SUMMARY

The effectiveness of lead, lead glass, steel, safety glass, and plexiglas for shielding gamma radiation from a number of plutonium samples including powders, solution, and the metal are evaluated. The data is presented in nine self-explanatory appendices. The data is summarized graphically in Appendix I which applies to NPR gamma dose rates. Specific applications of the data is discussed in Part I of this report. The basic data, as presented in Appendices II - IX, should be of value for general shielding usage.

DISCUSSION

Special plutonium samples were prepared in various physical forms. Powders were prepared as oxides, oxalates, and fluoride. Aqueous solutions were prepared as nitrates and ingots of plutonium were prepared for shielding study of the metal.

By including three series of these samples in the study, it was possible to vary the content of potential fission products such as ruthenium-rhodium and zirconium-niobium between them so as to permit evaluation of this important variable. Since fluorine has a high alpha-n cross-section, inclusion of a plutonium fluoride sample

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among the several prepared, provided the possibility for studying the separate effect of gamma radiation emitted when alpha particles and neutrons are absorbed with the source material.

The gamma spectrum of each of these samples was determined with a 256-channel gamma analyzer. These spectra were further studied for attenuation of each major energy group using increasing thicknesses of common shielding materials. A study for gamma dose rate reduction was made with varying shields using conventional dose rate survey meters.

As a means of deriving shielding data having practical significance, the sample data was extrapolated to permit its application to a possible process situation. Relationships of dose rate and shield thickness with distance, weight, and compound are described graphically in Appendix I. Evaluation of this data and discussion of the factors used is included in Part I of this report. Data, as presented in Appendices II - IX, defines the relative shielding requirements of the major energies found in plutonium. Unshielded and shielded dose rate differences for the other significant variables are also presented for general reference.

The data, as developed in this study of special plutonium samples, is presented in eight appendices. Content of the appendix tables have, for the most part, been made self-explanatory through inclusion of source data references and appropriate notes. An index of the appendices included in the Table of Contents may be of assistance in referring to specific information.

*Almer Moulthrop*  
Radiological Development  
Facilities Engineering  
Chemical Processing Department

HA Moulthrop

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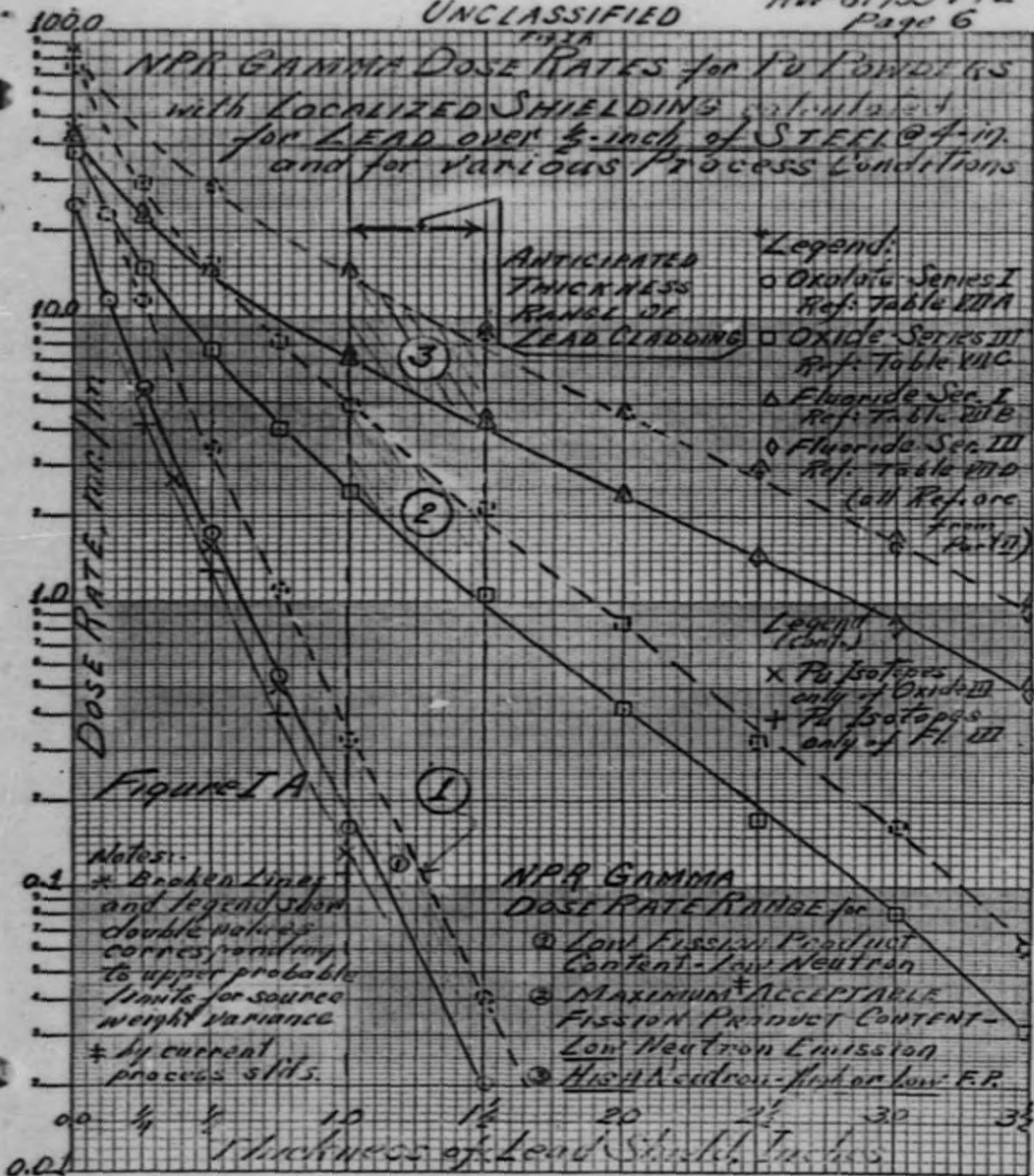
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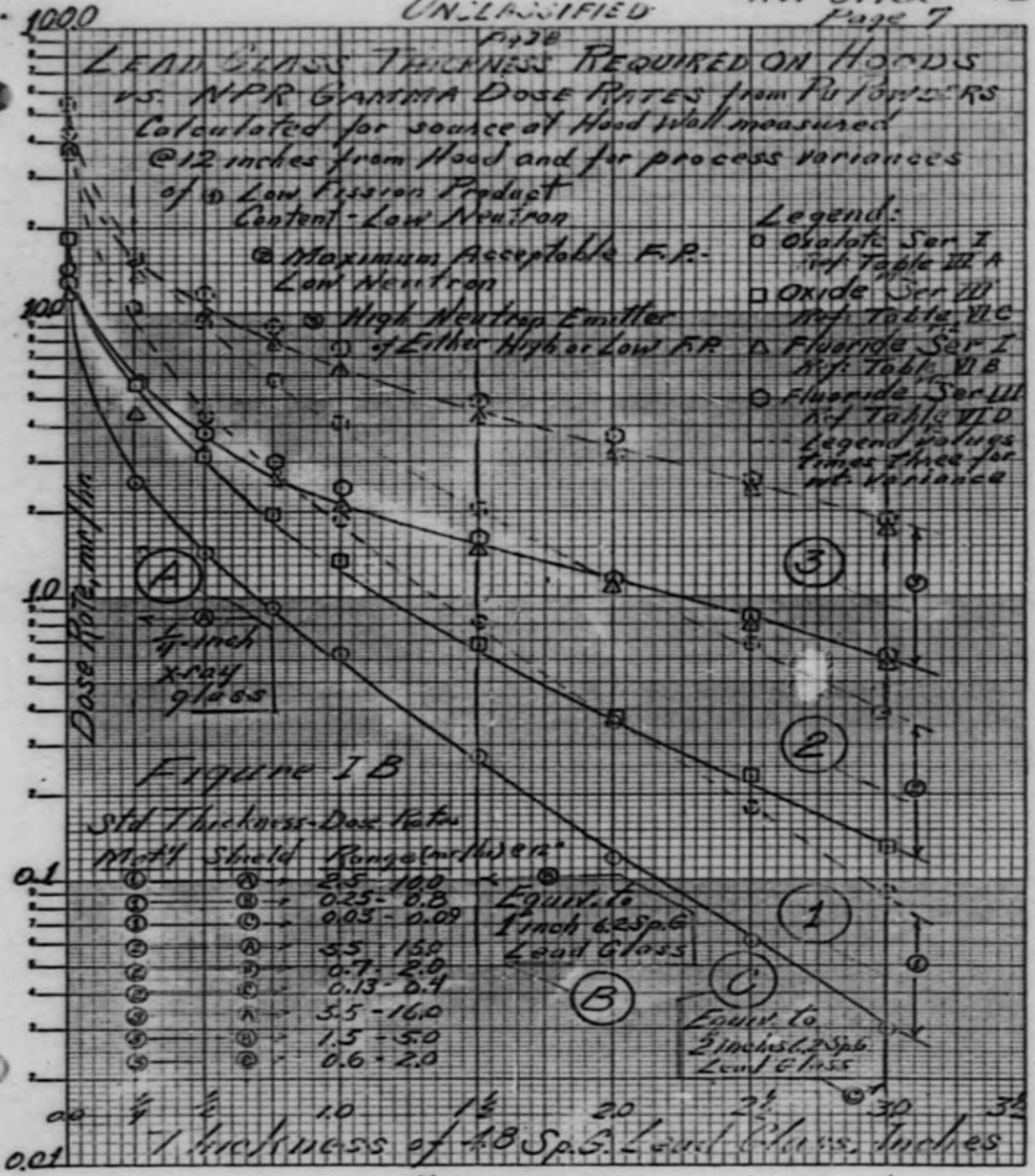
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APPENDIX I

Relationship Between NPR Gamma Dose Rates in  
mr/hour of Samples and Shielding Requirements  
in Inches for Metallic Lead and Lead Glass  
(4.8 Sp. Gr.) Plus Comparison for Lead of Gamma  
Dose Rate Attenuation Vs. Percentage Transmission  
of Gamma Photon with Energies of 0.38, 0.75, 1.27,  
and 2.1 Mev.

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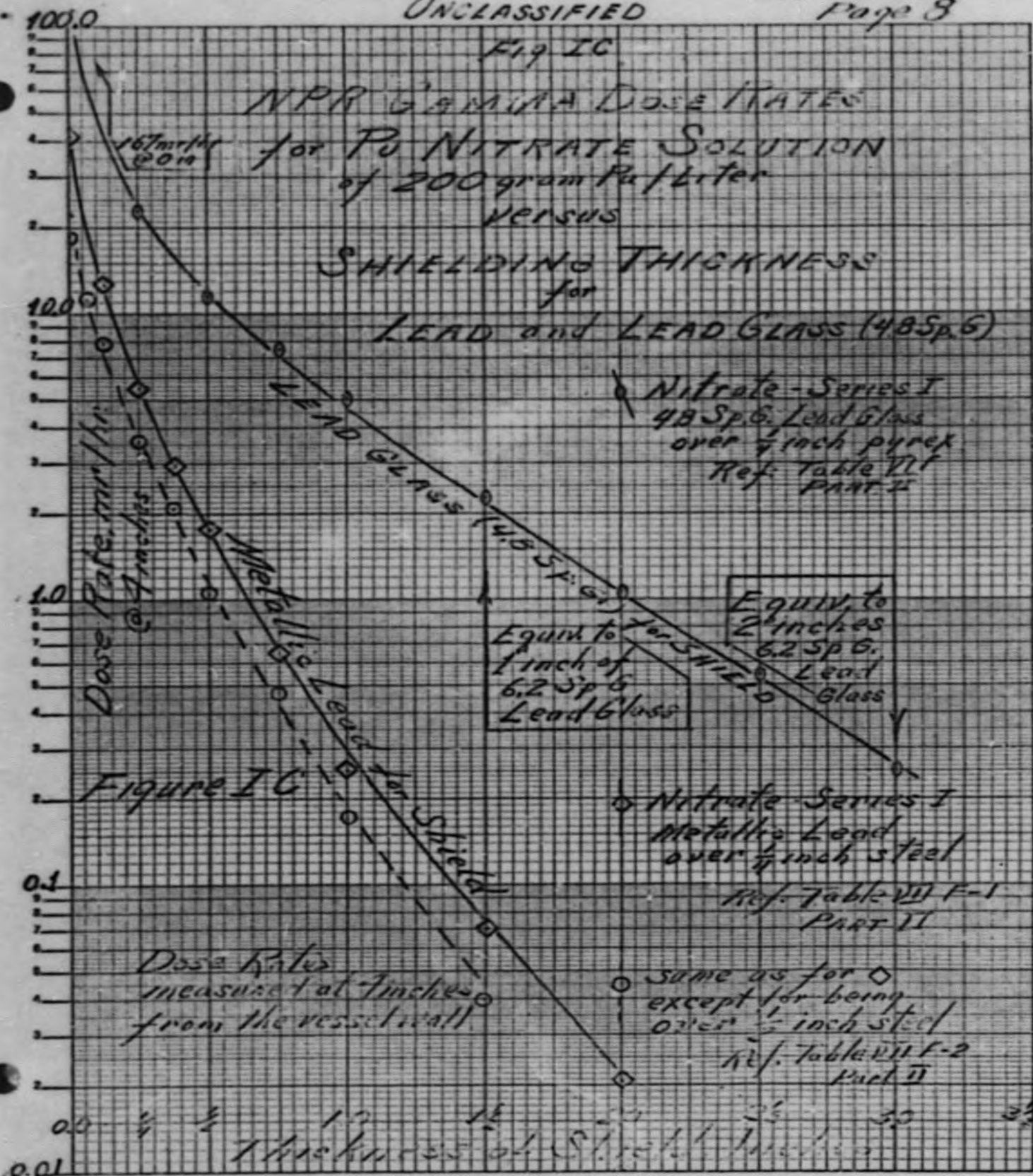




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Fig 1C

NPR GAMMA DOSE RATES  
for  $Pu$  NITRATE SOLUTION  
of 200 gram Pu/liter  
VERSUS  
SHIELDING THICKNESS  
for  
LEAD and LEAD GLASS (48 Sp.G)



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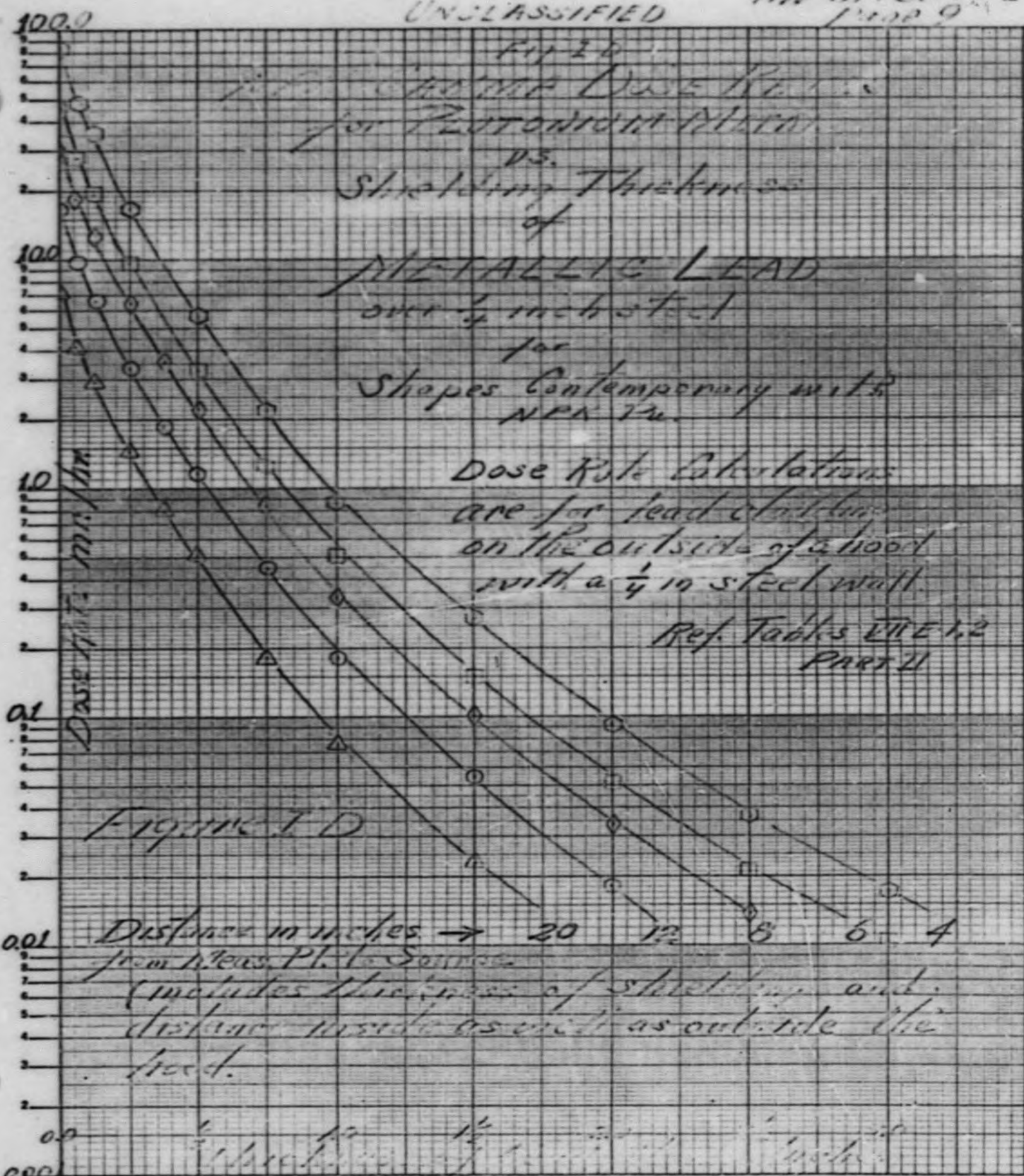


FIGURE I.D  
 Dose Rate vs. Distance  
 for **METALLIC LEAD**  
 over 1/4 inch steel  
 for  
 Shapes Contemporary with  
 NRC 74.

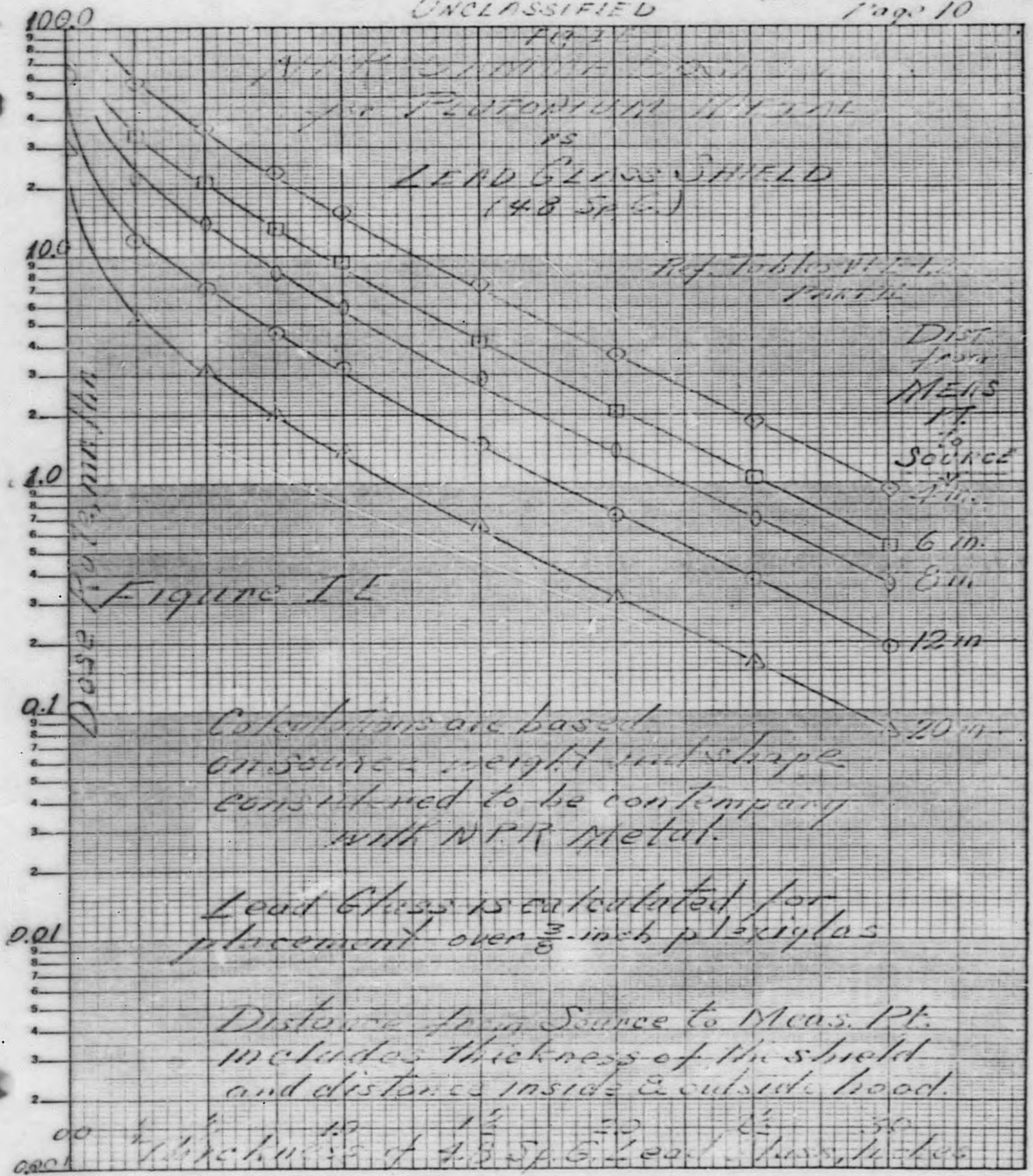
Dose Rate Calculations  
 are for lead shielding  
 on the outside of a hood  
 with a 1/4 in steel wall.

Ref. Tables VII E 1.2  
 Part II

FIGURE I.D

Distance in inches → 20 12 8 6 4  
 from Neus. Pl. to Source  
 (includes thickness of shielding and  
 distance inside as well as outside the  
 hood.)

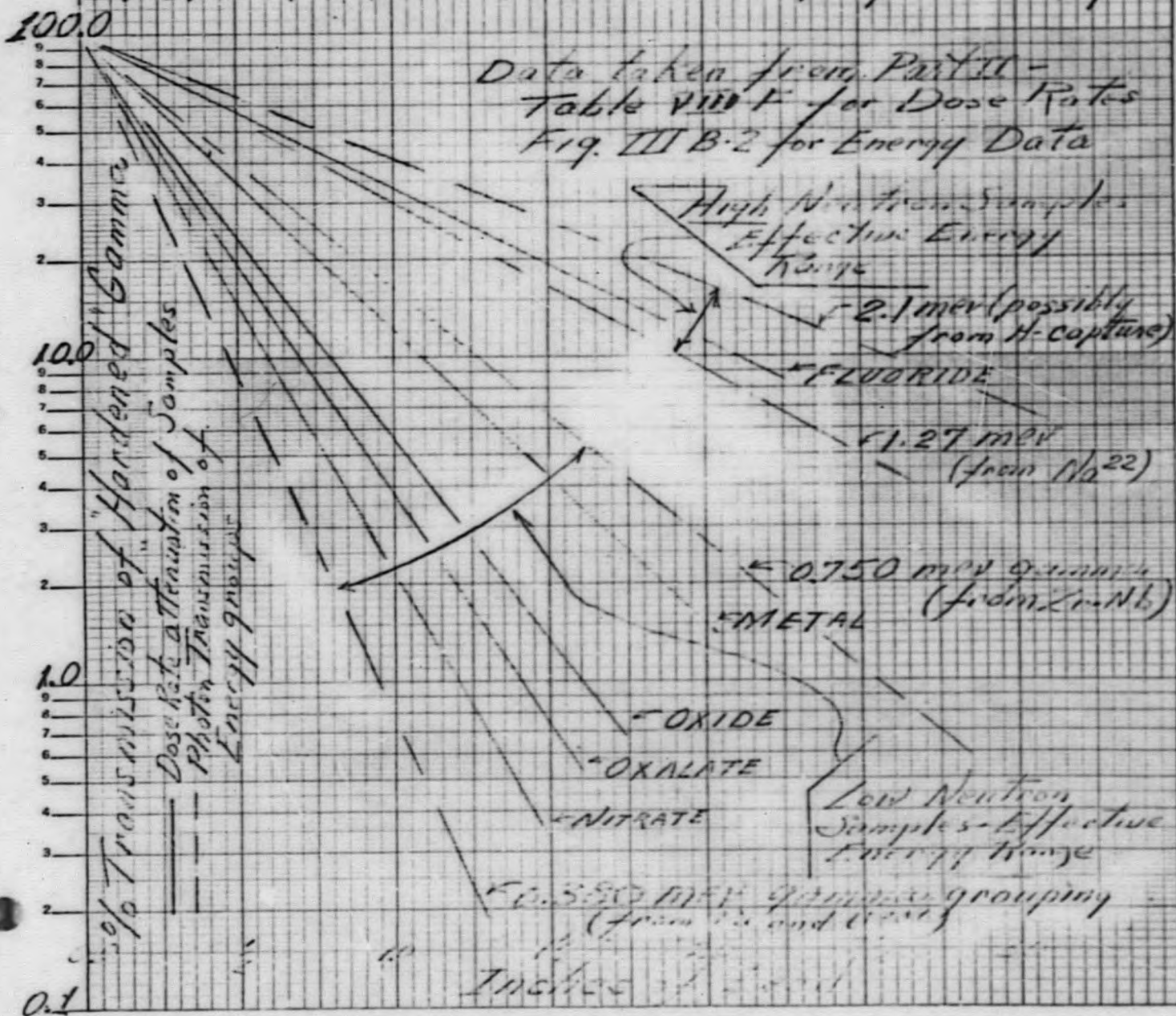
Shielding Thicknesses: 1/2", 1/4", 1/8", 1/16", 1/32"





# Figure - I F ATTENUATION COMPARISON IN LEAD

for  
Measured Gamma Dose Rates of Samples  
vs.  
Percent Photon Transmission by Energy



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APPENDIX II

Determination of Gamma Spectrum  
and  
Computation of Percentage  
Dose Rates by Energy Grouping

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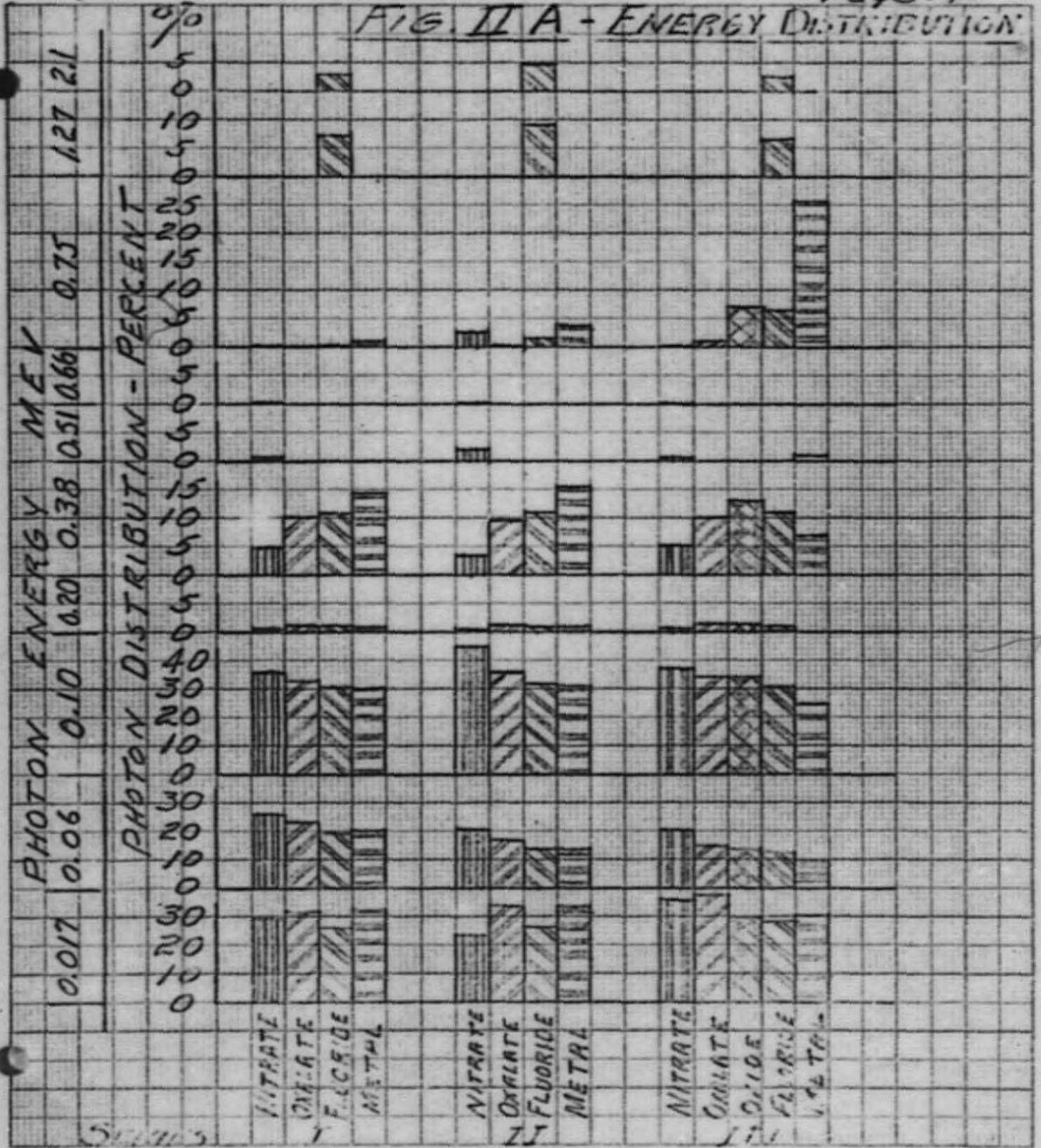
TABLE II A

Unshielded Energy Distribution of Study Samples  
Summary of Spectrum Observation with a 256 Channel Gamma Analyzer

Energy MEV	Percent of Photons										Millions Photons Per Min.	Spl. Wt. Kg. Pu	Millions Photons Per Min. Per Kg.	Remarks
	0.017	0.060	0.10	0.20	0.38	0.51	0.66	0.75	1.27	2.1				
<u>Series I</u>														
Pu Nitrate	29.6	28.0	36.0	1.4	4.6	0.3	0.1	0.1	0	0	12.5	0.200	62.5	Acid Soln
Pu Oxalate	31.8	22.7	33.4	2.1	9.9	0	0	0.1	0	0	13.2	0.558	23.7	
Pu Oxide														Not Run
Pu Fluoride	25.9	19.2	31.6	1.9	10.7	0	0	0.6	7.3	2.8	17.8	0.387	45.9	
Pu Metal	32.7	19.9	30.5	1.9	14.2	0	0	0.9	0	0	14.1	1.003	14.1	Button
Pu Metal	31.5	20.7	32.2	2.0	12.9	0	0	0.8	0	0	14.0	0.996	14.1	Casting
Pu Metal	35.0	17.9	29.9	2.0	14.5	0	0	0.8	0	0	11.7	0.660	17.8	Puri.Btn.
<u>Series II</u>														
Pu Nitrate	23.6	21.4	45.0	1.1	3.6	2.0	0.8	2.5	0	0	14.0	0.223	62.7	Acid Soln
Pu Oxalate	34.3	16.8	36.5	2.4	9.5	0	0	0.4	0	0	13.7	0.290	47.2	
Pu Oxide														Not Run
Pu Fluoride	26.4	13.8	32.2	2.0	10.9	0	0	1.7	8.6	4.5	17.4	0.542	32.1	
Pu Metal	33.9	13.6	31.6	2.0	15.1	0	0	3.8	0	0	13.3	1.493	8.9	Button
Pu Slag	44.0	38.5	15.1	1.0	1.3	0	0	0	0	0	0.4	-	-	
<u>Series III</u>														
Pu Nitrate	35.8	20.0	37.5	1.3	5.0	0.1	0.1	0.3	0	0	12.0	0.141	85.1	Acid Soln
Pu Oxalate	37.6	15.3	34.1	2.3	9.8	0	0	0.9	0	0	14.4	0.363	39.6	
Pu Oxide	29.8	14.0	34.1	2.1	12.8	0	0	7.3	0	0	16.4	0.435	37.8	
Pu Fluoride	28.0	12.7	30.7	1.9	11.0	0	0	6.6	6.6	2.6	18.2	0.353	51.6	
Pu Metal	30.2	10.3	25.1	0.6	7.1	1.0	0	25.7	0	0	15.6	0.773	20.1	Button

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FIG. II A - ENERGY DISTRIBUTION





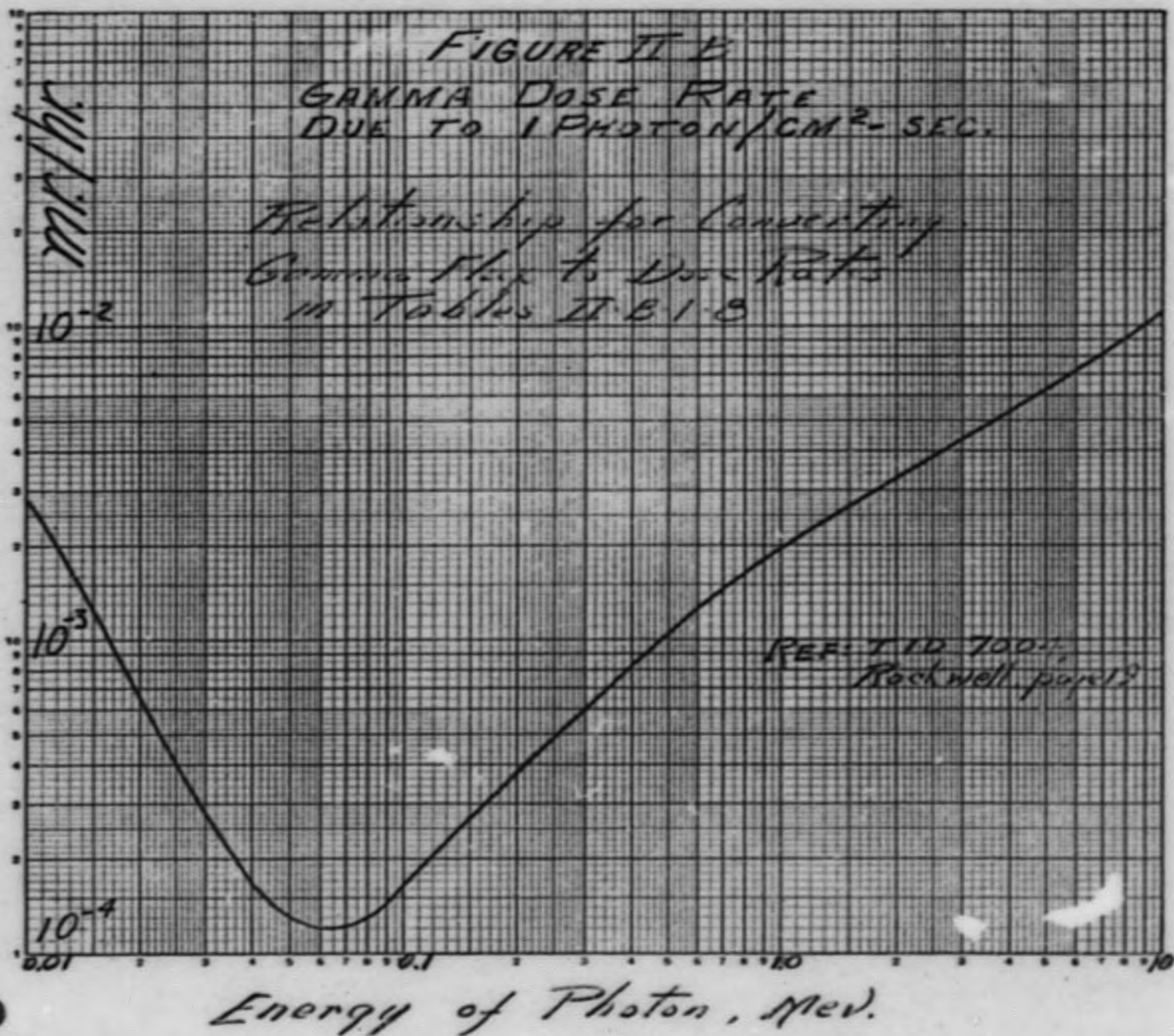


TABLE II B-1

Percent of Dose Rate Contributed by Each  
Energy for Oxalate Sample Series I - Unshielded

Column No.	1	2	3	4
Data Source	Table II A	Fig. IIB	Col 1 x Col 2 $\times 10^{-4}$	Col 3/ Col 3 Total
Gamma Energy in MEV	Percent of Photon	(Mr/hr/ Photon /cm <sup>2</sup> -sec.) $\times 10^4$	Relative Dose Rate	Relative % of Dose Rate
.017	31.8	9.6	305.3	65.1
.060	22.7	1.2	27.2	5.8
.100	33.4	1.5	50.1	10.7
.200	2.1	3.6	7.6	1.6
.380	9.9	7.8	77.2	16.5
.750	0.1 (0.6)	15.0	1.5 (9.0)	0.3
1.3	0.0	24.0		
2.1	0.0	34.0		
Total			468.9 (477.9)	100.0



TABLE II B-2

Percent of Dose Rate Contributed by Each  
Energy for Fluoride Sample Series I - Unshielded

Column No.	1	2	3	4
Data Source	Table IIA	Fig. IIB	Col 1 x Col 2	Col 3/ Col 3 Total
<u>Gamma Energy in MEV</u>	<u>Percent of Photons</u>	(Mr/hour / Phcton / cm <sup>2</sup> -sec) x 10 <sup>4</sup>	<u>Relative Dose Rate</u>	<u>Relative % of Dose Rate</u>
.017	25.9	9.6	248.6	36.1
.060	19.2	1.2	23.0	3.3
.100	31.6	1.5	47.4	6.9
.200	1.9	3.6	6.8	1.0
.380	10.7	7.8	83.4	12.1
.750	0.6	15.0	9.0	1.3
1.3	7.3	24.0	175.2	25.4
2.1	2.8	34.0	95.2	13.8
		Total	688.6	99.9

TABLE II B-3

Percent of Dose Rate Contributed by Each Energy  
For Oxide Sample Series III Unshielded

Column No.	1	2	3	4
Data Source	Table II A	Fig. II B	Col 1 x Col 2	Col 3 / Col 3 Total
Gamma Energy in MEV	Percent of Photons	(Mr/hour / Photon / cm <sup>2</sup> -sec) x 10 <sup>-4</sup>	Relative Dose Rate	Relative % of Dose Rate
.017	29.8	9.6	286.1	50.1
.060	14.0	1.2	16.8	2.9
.100	34.1	1.5	51.2	9.0
.200	2.1	3.6	7.6	1.3
.380	12.8	7.8	99.8	17.4
.750	7.3	15.0	109.5	19.2
1.3	0.0	24.0	0.0	0.0
2.1	0.0	34.0	0.0	0.0
		Total	571.0	99.9

TABLE II B-4Percent of Dose Rate Contributed by Each Energy  
For Fluoride Sample - Series III Unshielded

Column No.	1	2	3	4
Data Source	Table II A	Fig. II B	Col 1 x Col 2	Col 3 / Col 3 Total
Gamma Energy in MEV	Percent of Photons	(Mr/hour / Photon / cm <sup>2</sup> -sec) x 10 <sup>-4</sup>	Relative Dose Rate	Relative % of Dose Rate
.017	28.0	9.6	268.8	35.0
.060	12.7	1.2	15.2	2.0
.100	30.7	1.5	46.1	6.0
.200	1.9	3.6	6.8	0.9
.380	11.0	7.8	85.8	11.2
.750	6.6	15.0	99.0	12.9
1.3	6.6	24.0	158.4	20.6
2.1	2.6	34.0	88.4	11.5
		Total	768.5	100.1

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TABLE II B-5

Percent of Dose Rate Contributed by Each Energy  
Nitrate Sample - Series I

Column No.	1	2	3	4
Data Source	Table II A	Fig. II B	Col 1 x Col 2	Col 3 / Col 3 Total
Gamma Energy in MEV	Photons Observed	(Mr/hour/ 1 Photon /cm <sup>2</sup> -sec) x 10 <sup>4</sup>	Mr/hour /Photon /cm <sup>2</sup> -sec for sample	% Total Dose Rate
0.017	29.6	9.6	284.0	67.94
0.060	28.0	1.2	33.6	8.03
.100	36.0	1.5	54.0	12.91
.200	1.4	3.6	5.0	1.20
.350	4.6	7.8	35.9	8.59
.500	0.3	10.0	3.0	0.94
.660	0.1	11.8	1.2	0.29
.750	0.1	15.0	1.5	0.36
1.27	0.0	24.0		
2.1	0.0	34.0		
		Total	418.2	100.26

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TABLE II B-6

% of Dose Rate Contributed by Each Energy For  
Plutonium Sample - Series I - Unshielded  
Representing Low Fission Product Content  
(Zirconium Only)

Column No.	1	2	3	4
Data Source	Table IIA	Fig. IIB	Col 1 x Col 2	Col 3 / Col 3 Total
<u>Gamma Energy in MEV</u>	<u>Percent of Photons</u>	(Mr/hour/ Photon/ cm <sup>2</sup> -sec) <u>x 10<sup>4</sup></u>	<u>Relative Dose Rate</u>	<u>Relative % of Dose Rate</u>
.017	32.7	9.6	313.9	61.0
.060	19.9	1.2	23.9	4.6
.100	30.5	1.5	45.81	8.9
.200	1.9	3.6	6.81	1.3
.380	14.2	7.8	110.8	21.5
.750	0.9	15.0	13.5	2.6
1.3	0.0	24.0	0.0	
2.1	0.0	34.0	0.0	
		Total	514.7	99.9

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TABLE II B-7

% of Dose Rate Contributed by Each Energy  
For Plutonium Sample - Series II - Unshielded  
Representing Medium Fission Products Content  
(Zirconium Only)

Column No.	1	2	3	4
Data Source	Table IIA	Fig. IIB	Col 1 x Col 2	Col 3 / Col 3 Total
Gamma Energy in MEV	<u>Percent of Photons</u>	(Mr/hour/ Photon/ cm <sup>2</sup> -sec) <u>x 10<sup>4</sup></u>	<u>Relative Dose Rate</u>	<u>Relative % of Dose Rate</u>
.017	33.9	9.6	325.4	56.8
.060	13.6	1.2	16.3	2.8
.100	31.6	1.5	47.4	8.3
.200	2.0	3.6	7.2	1.7
.380	15.1	7.8	117.8	20.6
.750	3.8	15.0	57.0	10.0
1.3	0.0	24.0	0.0	
2.1	0.0	34.0	0.0	
		Total	571.1	100.2

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TABLE II B-8

% of Dose Rate Contributed by Each  
Energy for Plutonium Sample - Series III  
Unshielded Representing High Fission Pro-  
duct Content

Column No.	1	2	3	4
Data Source	Table IIA	Fig. IIB	Col 1 x Col 2	Col 3 / Col 3 Total
Gamma Energy in MEV	Percent of Photons	(Mr/hour/ Photon/ cm <sup>2</sup> -sec) x 10 <sup>4</sup>	Relative Dose Rate	Relative % of Dose Rate
.017	30.2	9.6	289.9	36.6
.060	10.3	1.2	12.4	1.6
.100	25.1	1.5	37.6	4.7
.200	0.6	3.6	2.2	0.2
.380	7.1	7.8	55.4	7.0
.510	1.0	10.0	10.0	1.3
.750	25.7	15.0	385.5	48.6
1.3	0.0	24.0		
2.1	0.0	34.0		
		Total	793.0	100.0

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APPENDIX III

Attenuation of Dose Rates For  
Energy Grouping by Various  
Gamma Shielding Materials

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TABLE III A-1

Observed Analyzer Energy Distribution With Shielding  
of Lead Glass 4.8 Sp. Gr.

Shield Thickness In Inches	Millions of								
	Photons Per Minute As Shown			For Each Gamma Energy in Mev					
	<u>.017</u>	<u>.060</u>	<u>**077</u>	<u>.100</u>	<u>.200</u>	<u>.380</u>	<u>.750</u>	<u>1.27</u>	<u>2.1</u>
0	0.82	1.89		3.89	0.60	3.32	1.81	1.57	1.32
$\frac{1}{4}$	0.01	0.029	0.21		0.20	2.55	1.80	1.85	1.45
$\frac{1}{2}$			0.17		0.067	1.66	1.51	1.62	
$\frac{3}{4}$					0.031	1.13	1.29	1.47	1.1
1			0.13		*0.027	0.63	0.95	1.20	0.96
$1\frac{1}{2}$					*0.027	0.31	0.61	0.95	0.65
2					0.019	0.108	0.40	0.66	0.65
$2\frac{1}{2}$								0.46	
3					*0.018	0.05	0.19		
$3\frac{1}{2}$								0.26	0.26

\* See Fig. III A-1 change of slope - not explained - possibly background interference.

\*\* Attributed to x-ray from lead in the shield.

FIG. IIIA-1  
LEAD GLASS  
4.8 SP. GR.

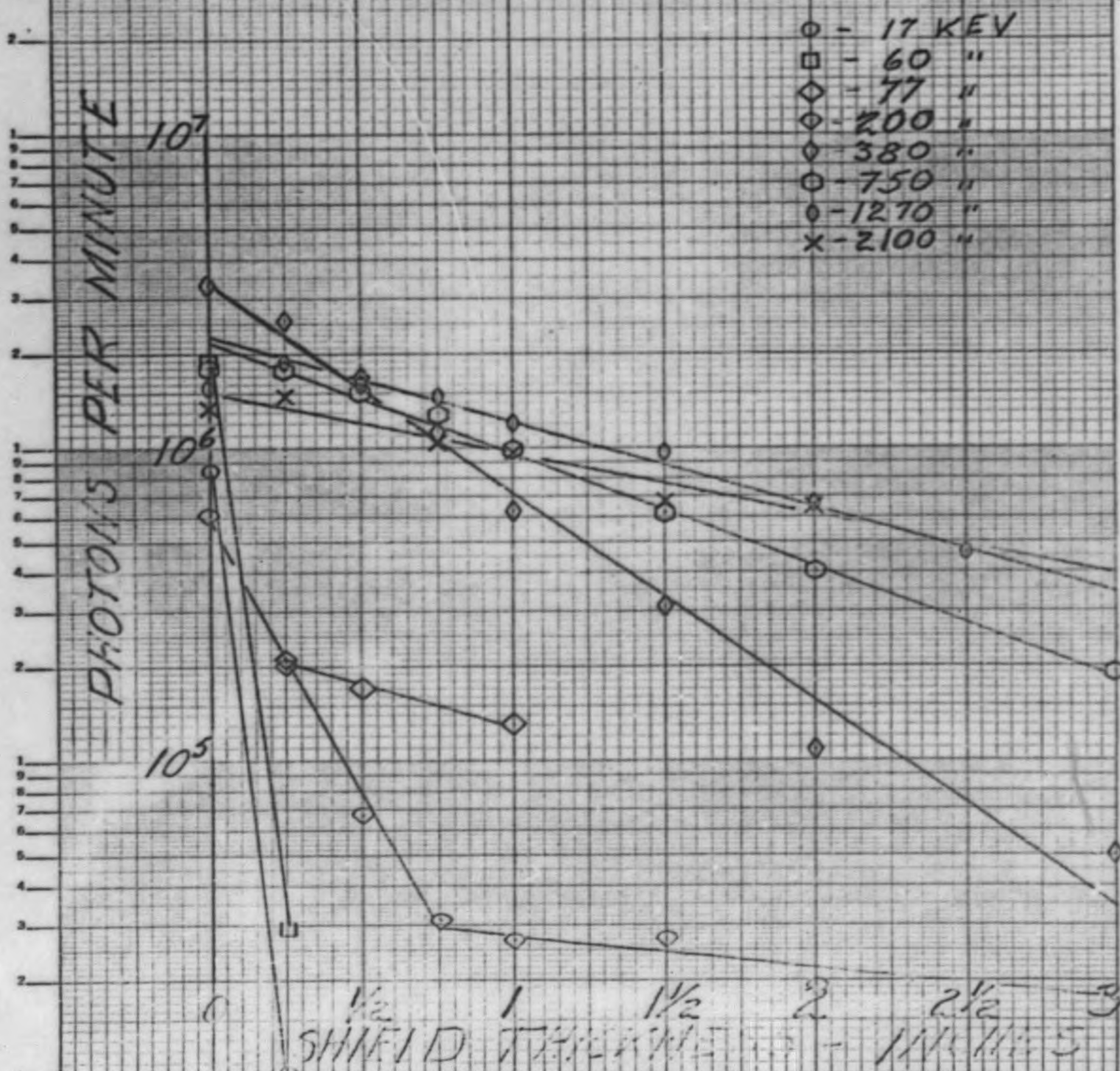


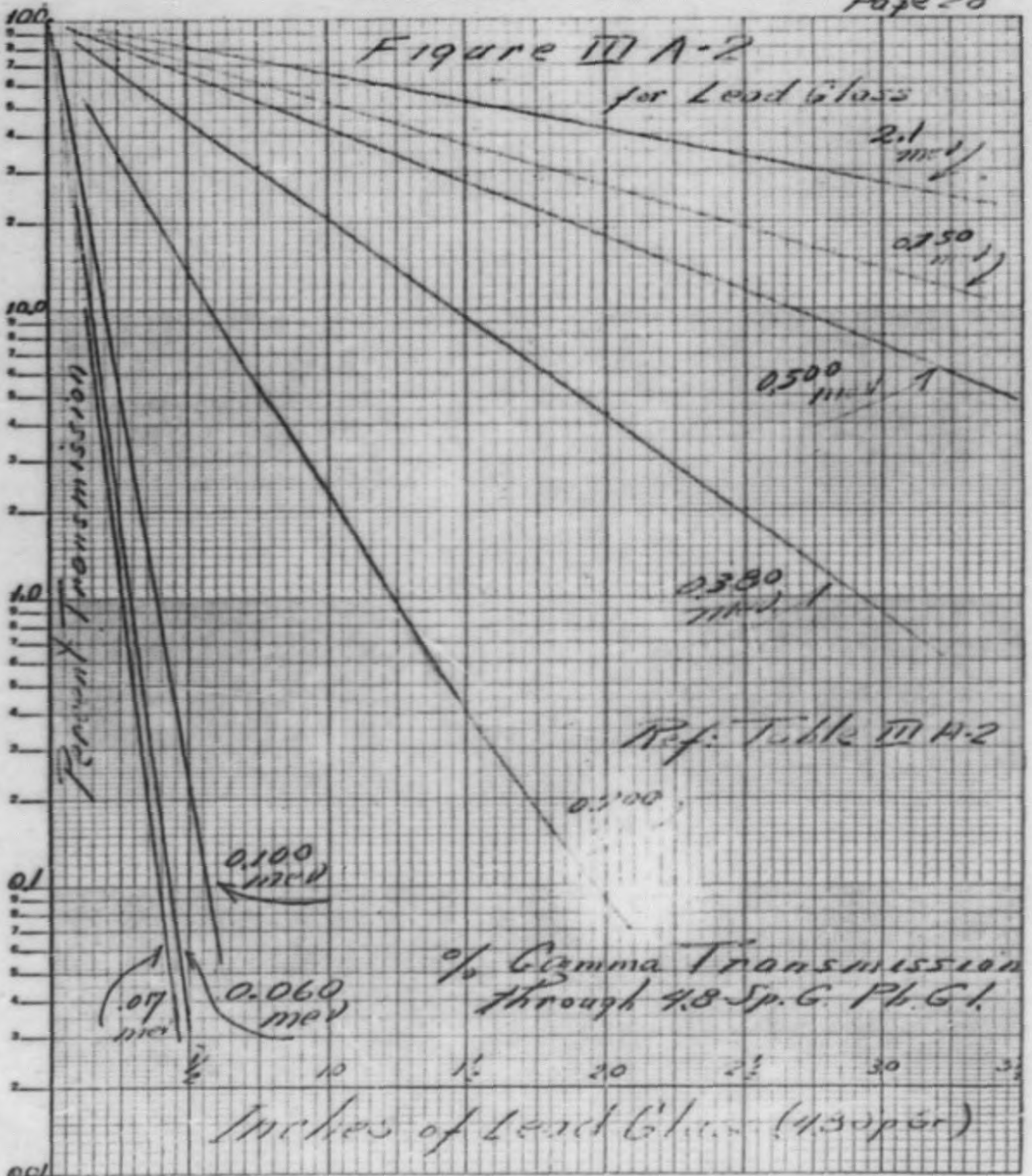
TABLE III A-2  
Data Taken From Fig. III A-2

Gamma Energy Mev	Percent Transmission of Gamma Radiation Through Lead Glass (4.8 Sp. Gr.) for Thickness of Shield in Inches As Shown									
	$\frac{1}{8}$ %	$\frac{1}{4}$ %	$\frac{3}{4}$ %	1 %	1 $\frac{1}{2}$ %	2 %	2 $\frac{1}{2}$ %	3 %	3 $\frac{1}{2}$ %	4 %
.017	1.3	0.0								
.060	1.5	0.0								
*.100	5.4	0.0								
.200	33.0	14.0	5.4	2.2	0.4	0.09	0.0			
.380	69.0	47.0	31.0	21.0	9.4	4.3	2.0	0.9		
** .500	75.0	60.0	45.0	35.0	20.0	1.2	8.0	5.0		
.750	81.0	66.0	52.0	45.0	29.0	19.0	12.8	8.0	5.4	3.5
1.27	87.0	74.0	61.0	52.0	38.0	27.0	20.0	14.0		
2.1	90.0	80.0	73.0	64.0	52.0	44.0	35.0	28.0		

\* Includes 0.077 mev.

\*\* Extrapolated Values





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TABLE III B-1

Observed Analyzer Energy Distribution With  
Shielding of Metallic Lead

Thickness in Inches	Millions of Photons Per Minute							
	Shield For Each Gamma Energy in Mev As Shown							
	<u>.017</u>	<u>.060</u>	<u>.100</u>	<u>.200</u>	<u>.380</u>	<u>.750</u>	<u>1.270</u>	<u>2.100</u>
0	0.82	1.9	3.9	0.60	3.3	1.8	1.6	1.3
1/16	0	0	.3	-	-	-	-	-
1/4	0	0	0	0.03	1.1	1.3	1.5	1.1
1/2	0	0	0	0.03	0.30	0.76	1.15	0.95
3/4	0	0	0	0.027	0.10	0.46	-	-
1	0	0	0	0.026	0.053	0.30	0.60	0.50
1 1/2	0	0	0	0.024	0.038	0.11	0.28	0.30
2	0	0	0	0.019	0.036	0.053	0.16	0.22

Includes .077 Mev Lead X-ray.

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FIG. 111 B-1

LEAD

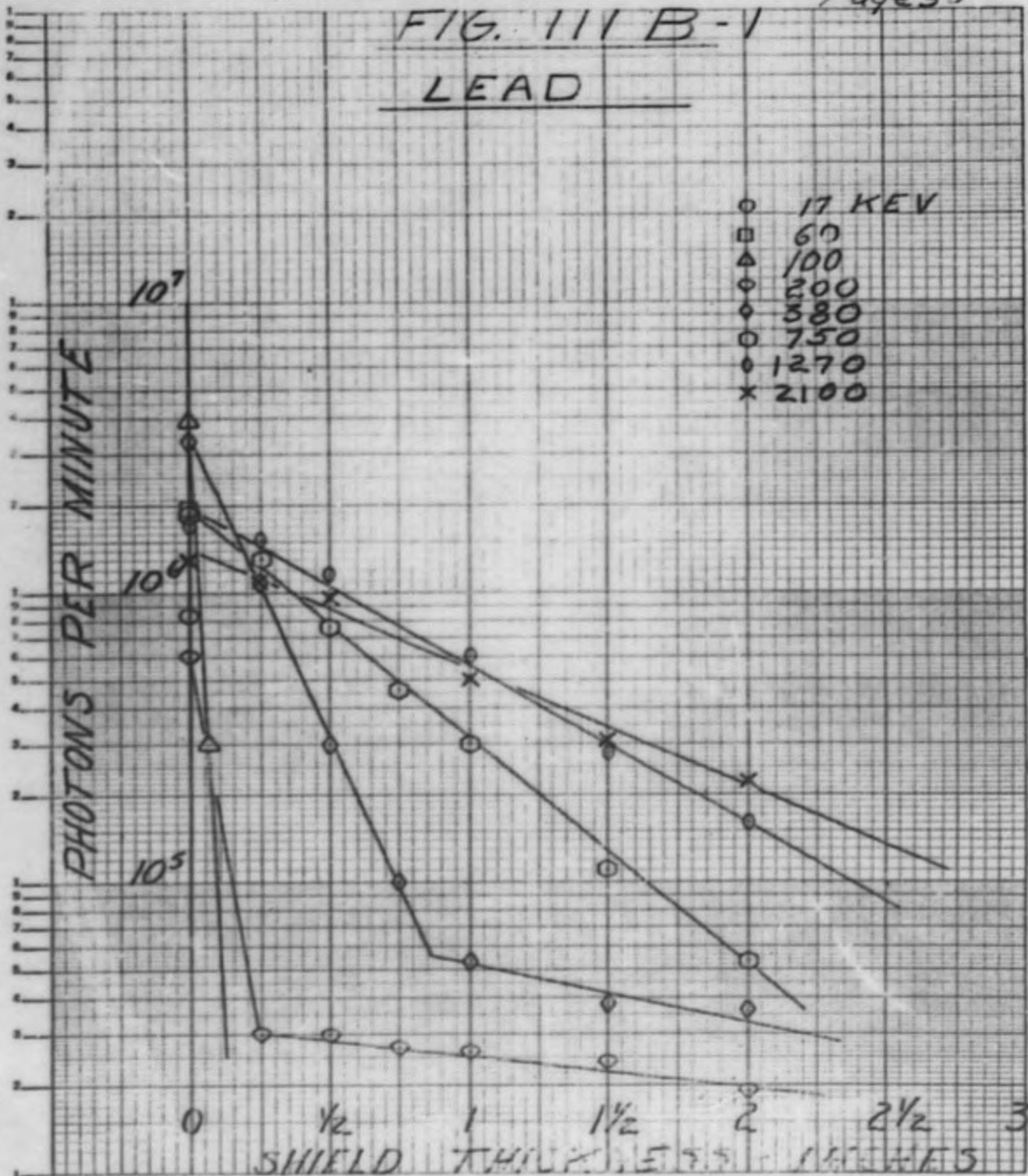




TABLE III B-2

Data Taken From Fig. III B-2

Gamma Energy MeV	Percent Transmission of Gamma Radiation Through Metallic Lead For Thickness of Shield in Inches as Shown												
	$\frac{1}{16}$ $\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{4}$	$\frac{1}{4}$ $\frac{1}{2}$	$\frac{3}{8}$ $\frac{1}{2}$	$\frac{1}{2}$ $\frac{3}{4}$	$\frac{3}{4}$ $1$	$1$ $1\frac{1}{2}$	$1\frac{1}{2}$ $2$	$2$ $2\frac{1}{2}$	$2\frac{1}{2}$ $3$	$3$ $3\frac{1}{2}$	$3\frac{1}{2}$ $4$	$4$ $4\frac{1}{2}$
.017	0.0												
.060	0.0												
*.100	35.0	10.0	1.0	0.08	0.01	0.00							
.200	47.0	25.0	5.0	1.0	0.22	0.01	0.00						
.380	70.0	56.0	30.0	16.0	9.5	3.0	0.8	0.08	0.01	0.0			
** .500	80	70	50	35	25	15	10	4	2	0.8	0.35		
.750	85.0	78.0	62.0	48.0	39.0	23.0	15.0	6.8	2.7	1.1	0.50	0.17	0.08
1.27	88.0	85.0	72.0	60.0	52.0	38.0	28.0	16.0	7.6	4.6	2.5	1.4	0.8
2.1	92.0	87.0	76.0	68.0	60.0	48.0	38.0	25.0	15.0	10.0	6.0	3.8	2.3

\* Includes .077 mev lead x-ray.

\*\* Extrapolated Values.

Figure III B-2

Percent Gamma Transmission  
through  
Metallic Lead

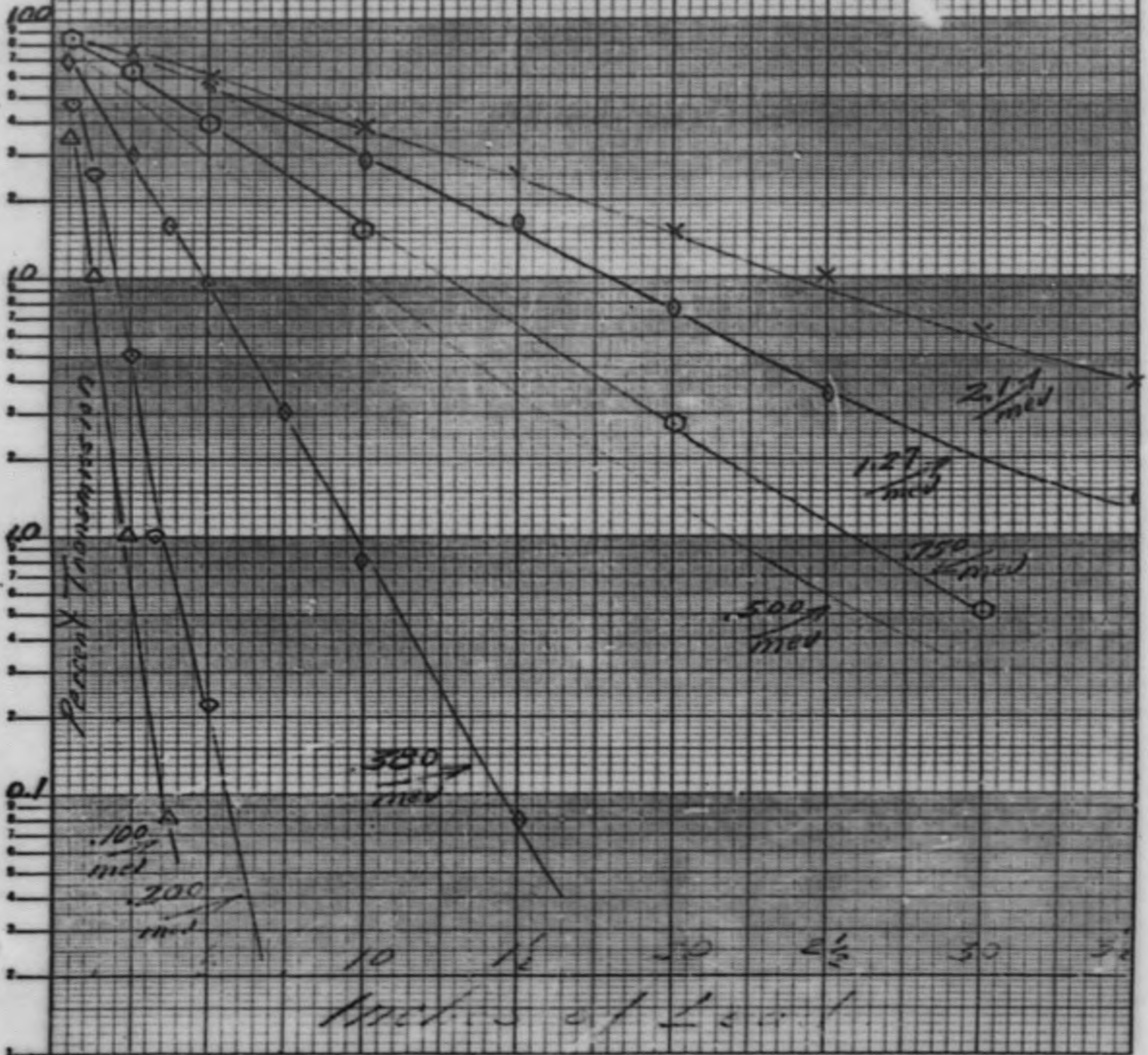


TABLE III C-1

Observed Analyzer Energy Distribution With Shielding  
of Steel or Iron

Shield Thickness In Inches	Millions of Photons Per Minute For Each Gamma Energy in MEV as Shown					
	<u>.017</u>	<u>0.60</u>	<u>.100</u>	<u>.200</u>	<u>.380</u>	<u>.750</u>
0	2.4	1.51	1.89	0.60	3.32	1.81
1/8	0	0	0.88	-	-	-
1/4	0	0	0.45	0.52	2.66	1.51
3/8	0	0	0.31	-	-	-
1/2	0	0	-	0.31	1.94	1.23
5/8	0	0	0.04	-	-	-
1	0	0	-	0.12	0.92	0.65
2	0	0	-	0.027	0.29	0.21
2 1/4	0	0	-	0.018	0.08	0.12



FIG. III C-1

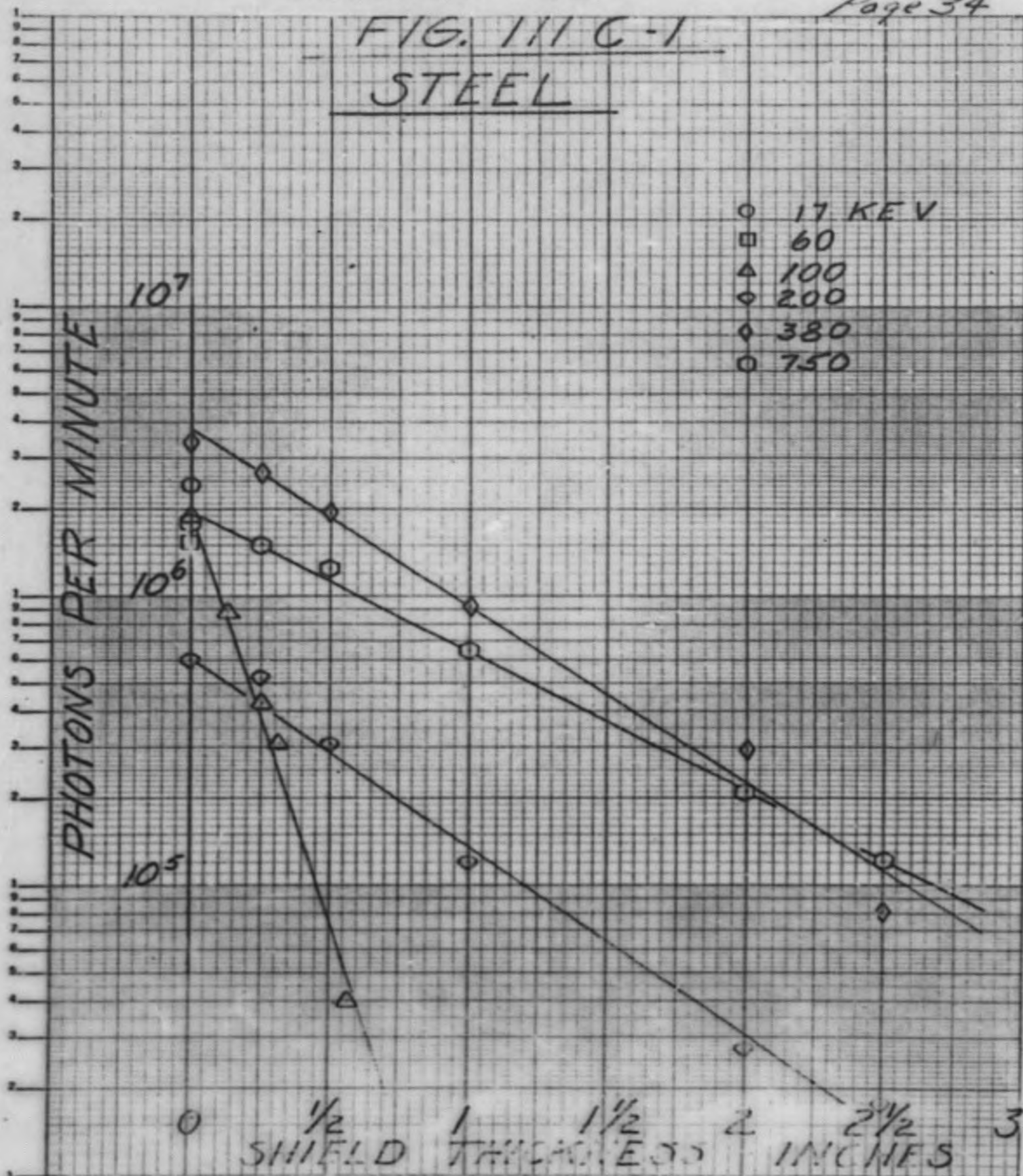
STEEL

TABLE III C-2

Data Taken From Fig. III C-2

Gamma Energy In Mev	Percent Transmission of Gamma Radiation Through Steel or Iron for Thickness of Shield in Inches									
	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{4}$ $\frac{1}{4}$	$\frac{3}{8}$ $\frac{3}{8}$	$\frac{1}{2}$ $\frac{1}{2}$	$\frac{3}{4}$ $\frac{3}{4}$	$1$ $\frac{1}{2}$	$1\frac{1}{2}$ $\frac{1}{2}$	$2$ $\frac{1}{2}$	$2\frac{1}{2}$ $\frac{1}{2}$	$3$ $\frac{1}{2}$
.017	0									
.060	0									
.100	45	20	9.0	3.5	0.8	0.2	0.0			
.200	82	67	55	45	32	22	10	5.0	2.3	1.0
.380	82	68	58	47.0	34	24	12	6.0	4.0	1.5
.750	85	74	66	56	43	33	19	11	6.2	3.5
1.27	90	79	68	61	46	36	21	13	7.5	4.5
2.1	90	80	70	64	51	42	26	17	11	7.0

Figure MC-2  
Percent Gamma Rays  
through  
Iron or Steel

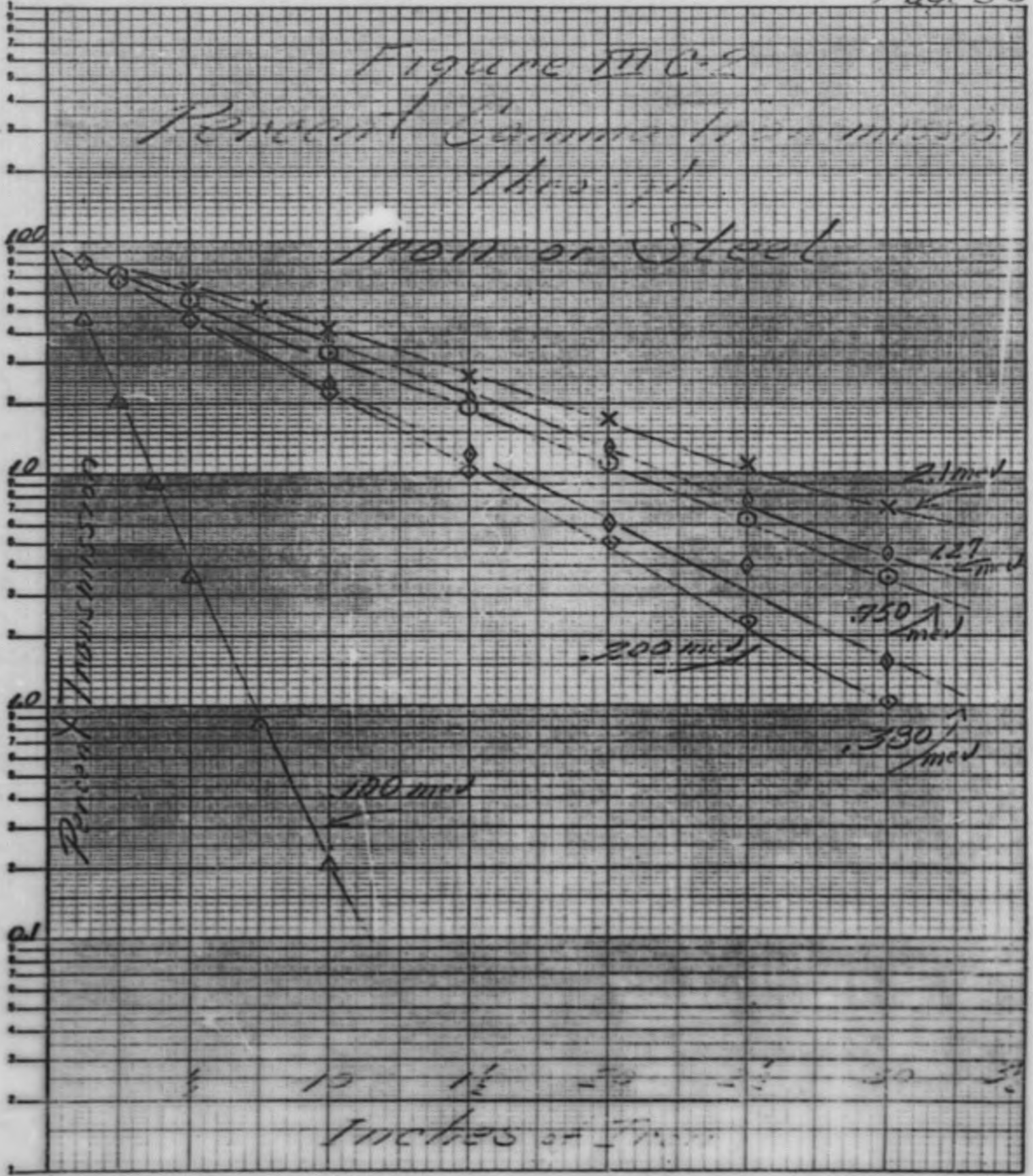




TABLE III D-1

Observed Analyzer Energy Distribution With  
Shielding of Safety Glass

Shield Thickness Inches	Millions of Photons Per Minute for Each Gamma Energy in Mev as Shown					
	<u>.017</u>	<u>.060</u>	<u>.100</u>	<u>.200</u>	<u>.380</u>	<u>.750</u>
0	0.817	1.89	3.89	0.603	3.32	1.81
1/4	*0.10	1.62	3.53	0.618	3.19	1.77
1/2	*0.094	1.19	2.89	-	-	-
1	*0.047	0.65	2.11	0.421	2.33	1.28
2	*0.014	0.20	0.95	-	-	-
2 1/4	-	0.10	0.70	0.19	1.18	0.78

\* Read as 26 KEV - source not determined.

FIG. N1 D-1  
SAFETY GLASS

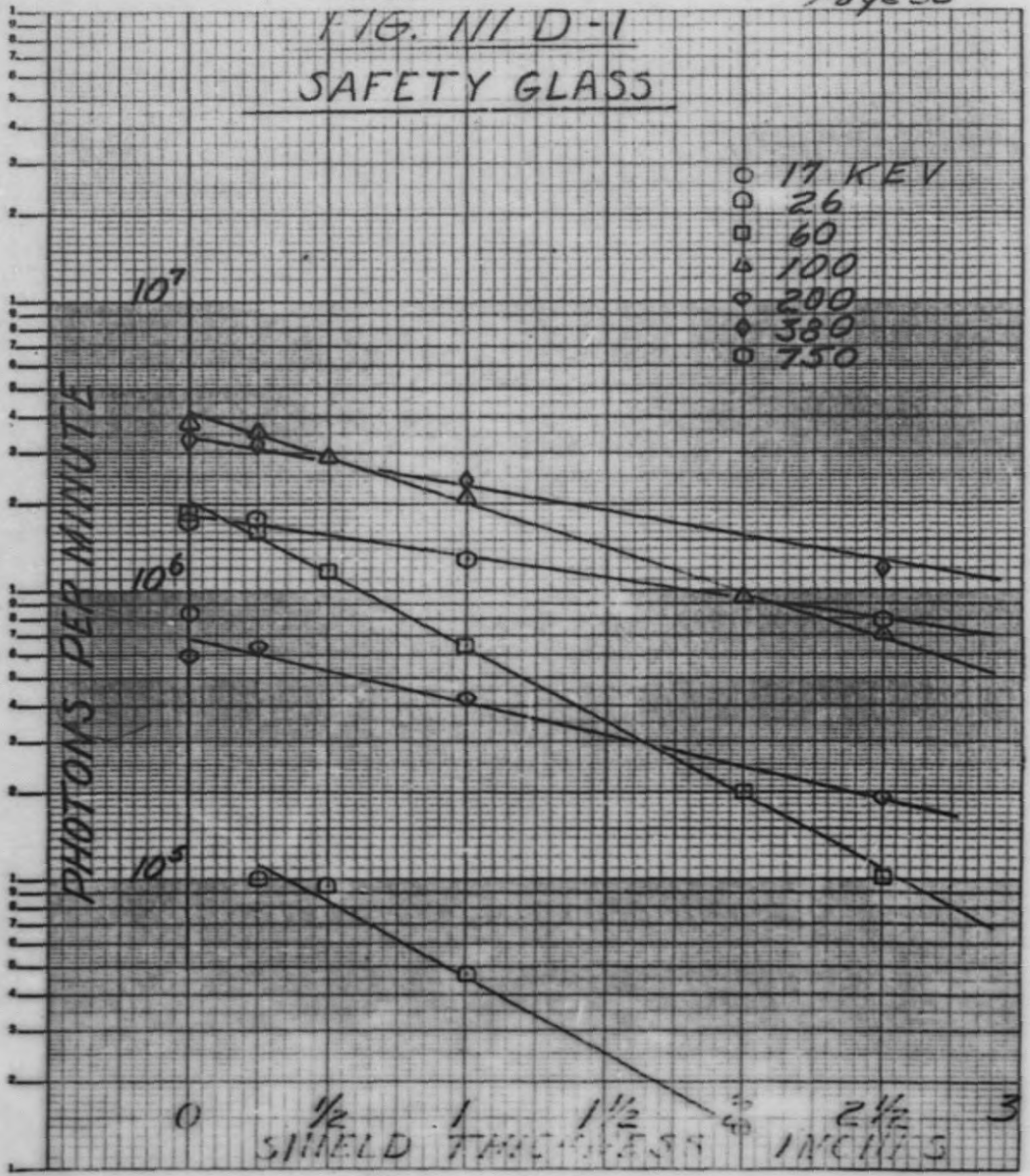


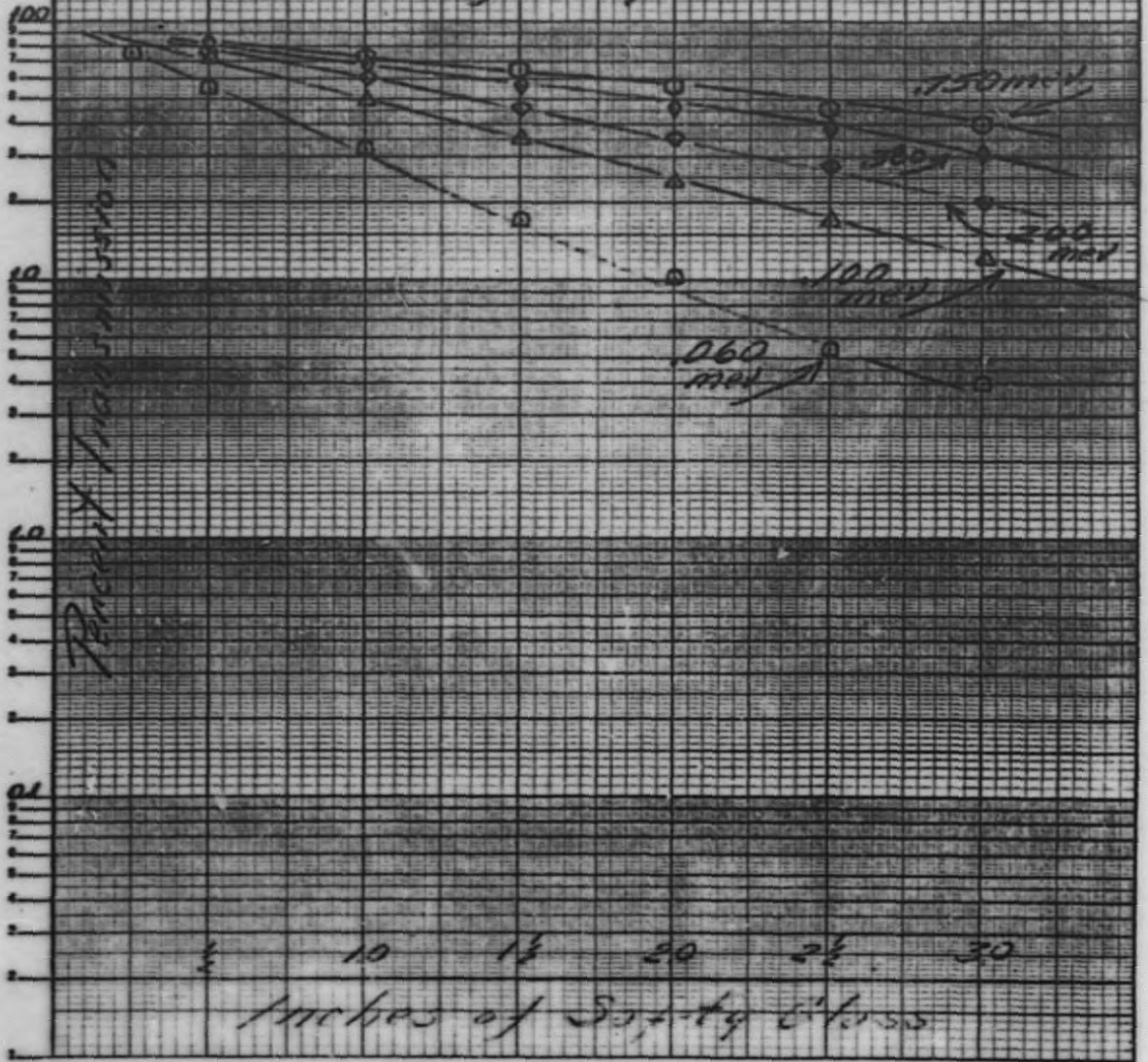
TABLE III D-2

Percent Transmission of Gamma Radiation  
Through Safety Glass - Data Taken From  
Fig. III D-2

Gamma Energy In Mev	For Thickness of Shield in Inches							
	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
.017	13							
.060	75	55	42	32	17	10	5.4	4.0
.100	84	70	58	49	35	24	17	12
.200	88	76	67	60	46	35	27	20
.380	90	84	75	68	56	46	38	30
.750	94	87	80	75	64	54	46	40



Figure III E 2  
Percent Gamma Transmission  
through  
Safety Glass



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TABLE III E-1

Observed Analyzer Energy Distribution With  
Shielding of Lucite or Plexiglas

Shield Thickness In <u>Inches</u>	Millions of Photons Per Minute in Mev as Shown					
	<u>.017</u>	<u>.060</u>	<u>.100</u>	<u>.200</u>	<u>.380</u>	<u>.750</u>
0	2.4	1.51	1.90	0.603	3.32	1.81
3/8	1.12	1.32	1.42	0.573	3.14	1.59
1-1/8	0.287	0.98	1.19	-	-	-
1-1/2	0.14	0.89	1.08	0.32	1.84	1.02
2-1/4	0.035	0.68	0.89	-	-	-
4-1/2	0.004	0.29	0.38	0.21	1.40	0.87
7-1/2	-	0.10	0.047	-	-	-

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FIG. III E-1

LUCITE or PLEXIGLAS

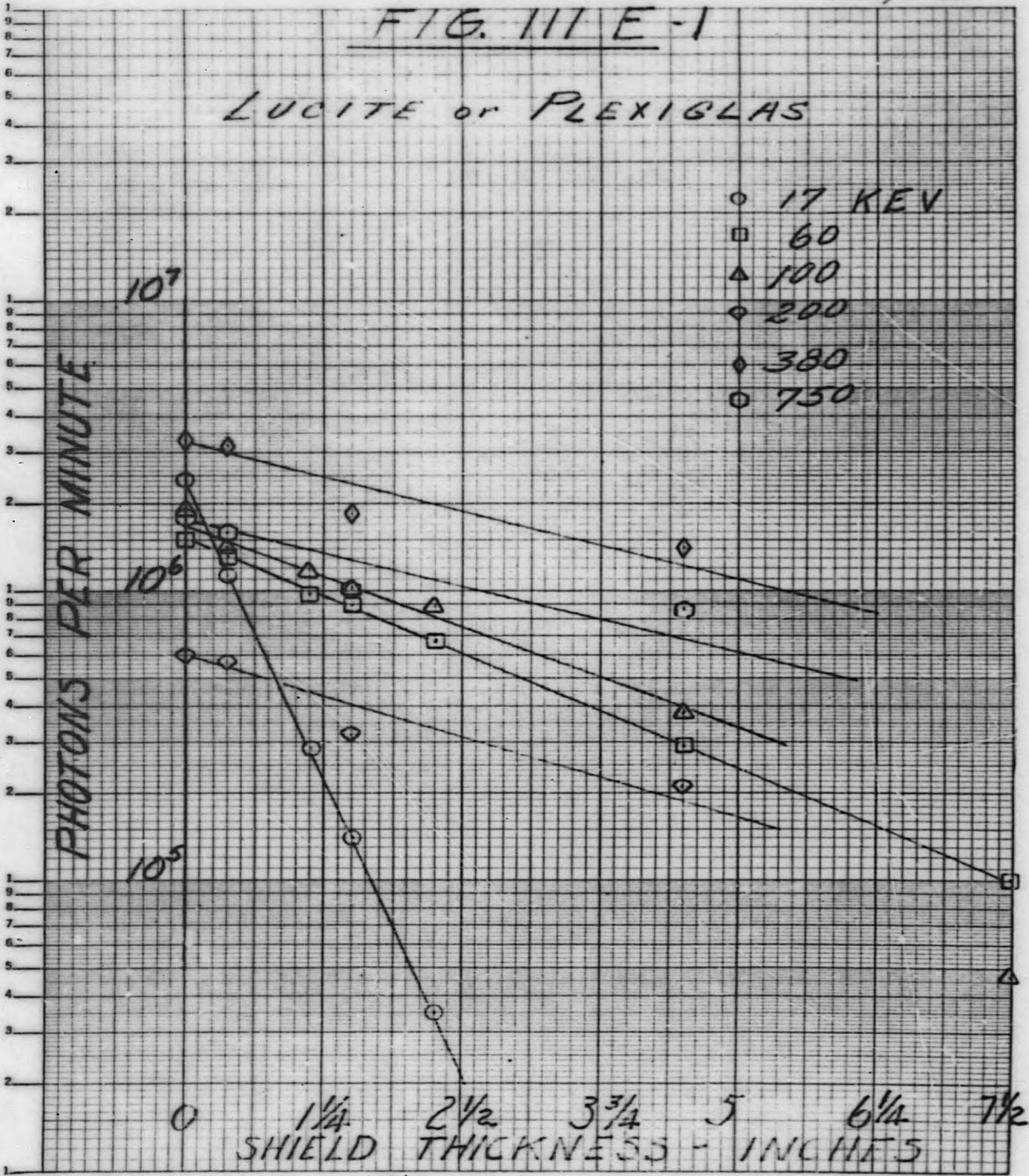




TABLE III E-2

Data Taken From Fig. III-E-2 - Percent Transmission of  
Gamma Radiation Through Lucite or Plexiglas

Gamma Energy In Mev	$\frac{1}{4}$ %	$\frac{3}{8}$ %	$\frac{1}{2}$ %	$\frac{3}{4}$ %	$\frac{1}{2}$ %	$\frac{1\frac{1}{2}}$ %	$\frac{2}{2}$ %	$\frac{2\frac{1}{2}}$ %	$\frac{3}{2}$ %	$\frac{4}{2}$ %	$\frac{5}{2}$ %	$\frac{6}{2}$ %
.017	64	50	40	25	15	6.0	2.2	0.8	0.1	0.0		
.060	90	85	81	74	68	57	47	38	33	23	16	11
.100	90	86	82	76	71	60	52	44	38	27	20	15
.200	96	91	87	81	76	67	59	52	45	35	27	21
.380	98	94	90	86	78	72	64	57	51	42	32	26
.750	98	94	90	86	80	74	66	60	54	47	35	29
1.3	~100	~100										
2.1	~100	~100										

Figure TAF-2

Percent Gamma Transmission  
through  
Lucite or Plexiglas

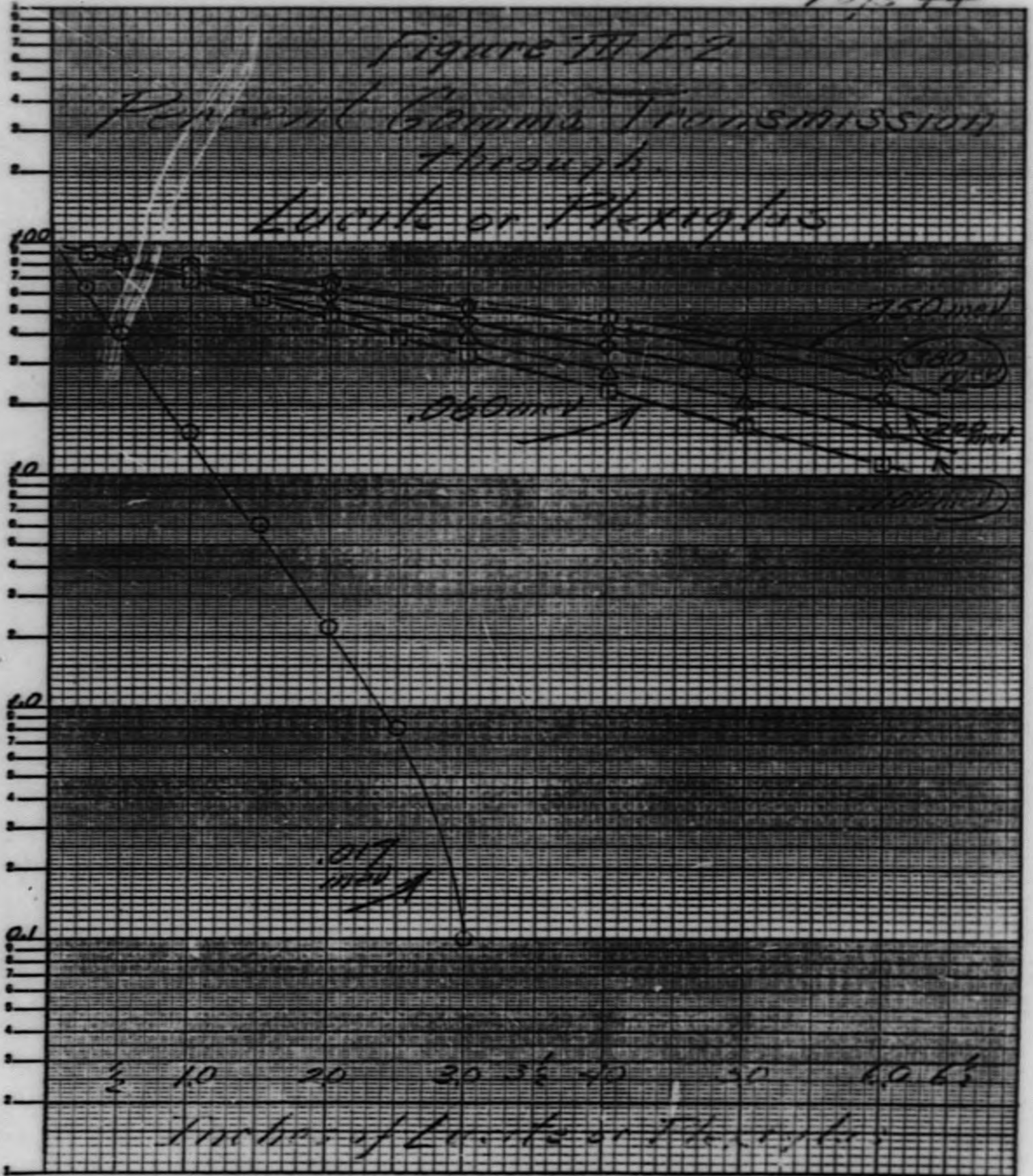


TABLE III F-1

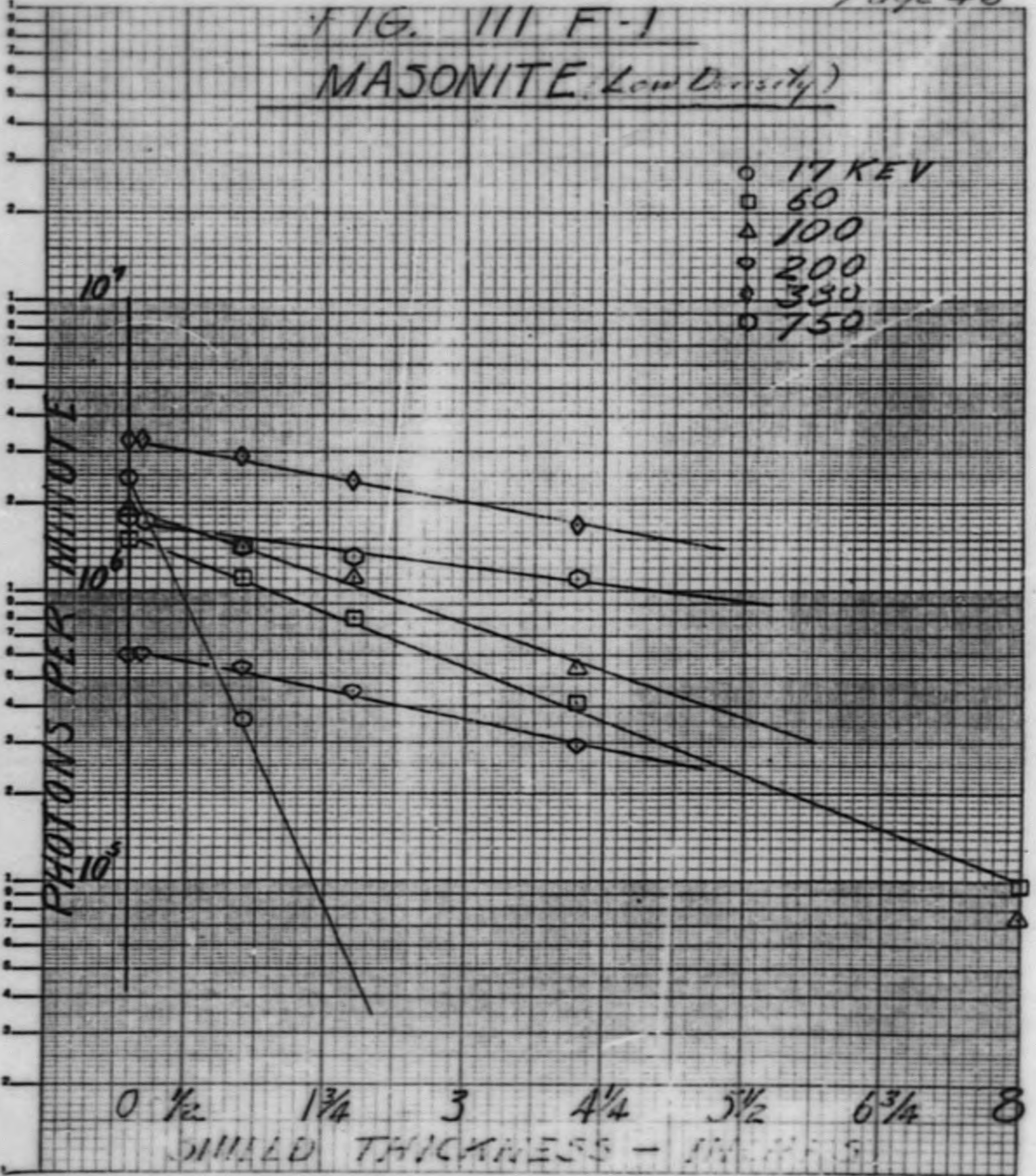
Observed Analyzer Energy Distribution With  
Shielding Using Masonite

Shield Thickness In Inches	Millions of Photons Per Minute For Each Photon Energy In Mev As Shown					
	<u>.017</u>	<u>.060</u>	<u>.100</u>	<u>.200</u>	<u>.380</u>	<u>.750</u>
0	2.4	1.5	1.9	0.60	3.3	1.8
1/8	-	-	-	0.61	3.3	1.7
1	0.36	1.1	1.4	0.54	2.9	1.4
2	-	0.80	1.1	0.45	2.4	1.3
4	-	0.41	0.54	0.29	1.7	1.1
8	-	0.097	0.074	-	-	-
	% of Initial Photons Transmitted					
0	100	100	100	100	100	100
1/8				100	100	94.4
1	15.0	73.3	73.7	90.0	87.9	77.8
2		53.3	57.9	75.0	72.7	72.2
4		27.3	28.4	48.3	51.5	61.1
8		6.4	3.9			



FIG. III F-1

MAJONITE (Low Density)



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TABLE III F-2

Percent Transmission of Gamma Radiation Through  
Masonite - Data Taken From Fig. III F-2 For  
Thickness of Shielding in Inches as Shown

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>10</u>	<u>12</u>
.017	15	2.5	0.3							
.060	70	50	36	26	19	14	11	7.2	3.6	1.9
.100	75	55	42	30	24	18	14	10	5.4	3.0
.200	82	68	56	47	42	34	30	24	17	12
.380	85	72	60	52	45	38	34	28	20	15
.500	} 88	77	66							
.600										
.750	90	80	70	60	55	49	44	38	30	23

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Figure III F-2  
GAMMA ATTENUATION  
in  
MASONITE  
(Low Density)

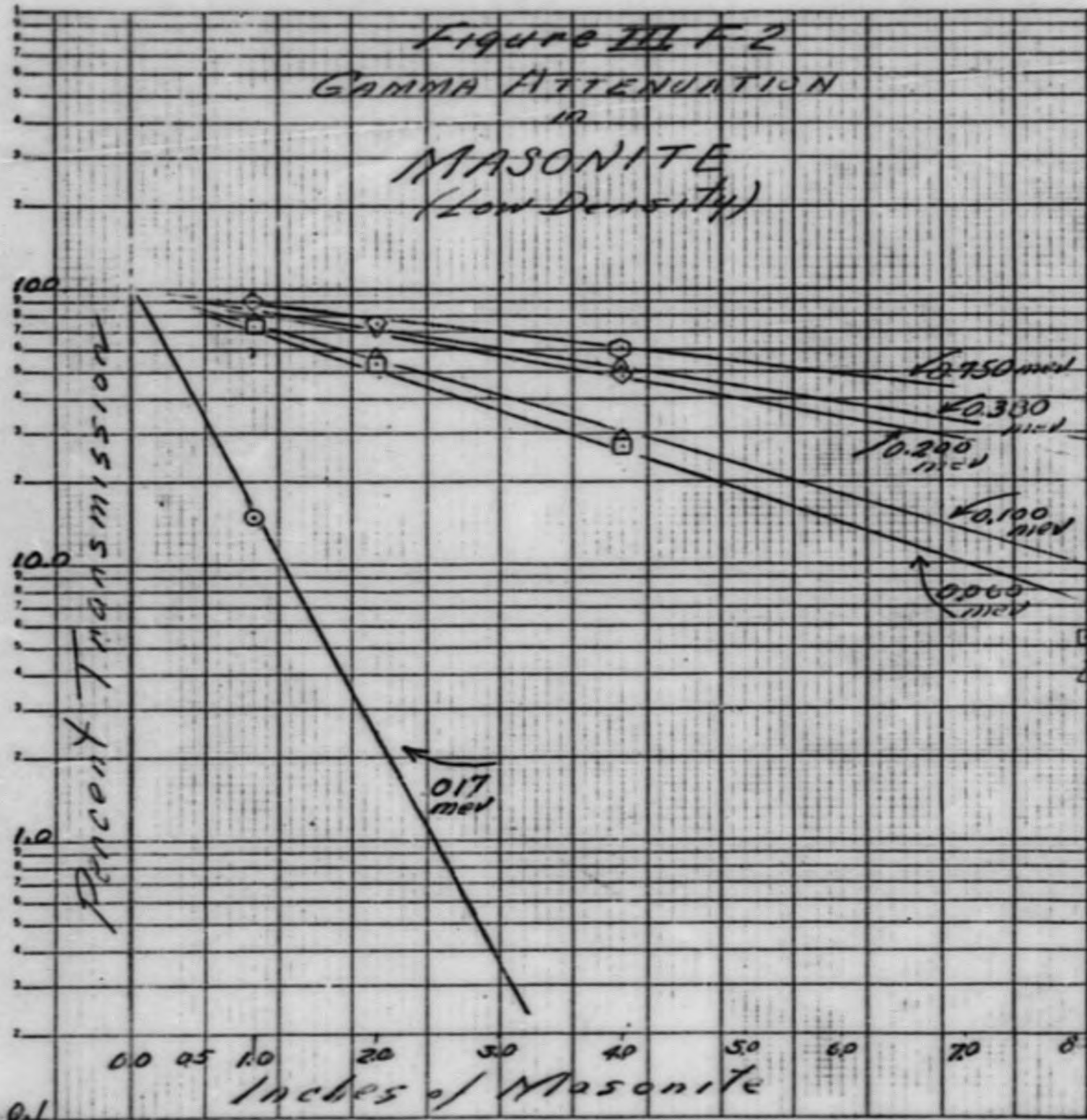




TABLE III G-1Observed Analyzer Energy Distribution With  
Shielding Using PVC Sheeting

Shield Thickness In Inches	Photons Per Minute $\times 10^{-6}$ For Each Photon Energy In Mev As Shown				
	<u>.017</u>	<u>.060</u>	<u>.100</u>	<u>.200</u>	<u>.380</u> <u>.750</u>
0	2.4	1.5	1.9	0.38	2.6
0.040	1.25	1.4	1.8		
0.080	0.66	1.4	2.0	0.39	2.5
0.20	0.15	1.3	1.9		

TABLE III -G-2

Data Taken from Fig. III G-2

Gamma Energy MEV	Percent Transmission for Gamma Radiation Through PVC Shielding in Inches as Shown		
	<u>0.04</u>	<u>0.08</u>	<u>0.20</u>
.017	52.1	27.5	6.3
.060	93.3		86.7
.100			~100.0

Nearly 100% Transmission for Higher Energies.

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137450

FIG. III G-1  
PVC PLASTIC  
SHEETING

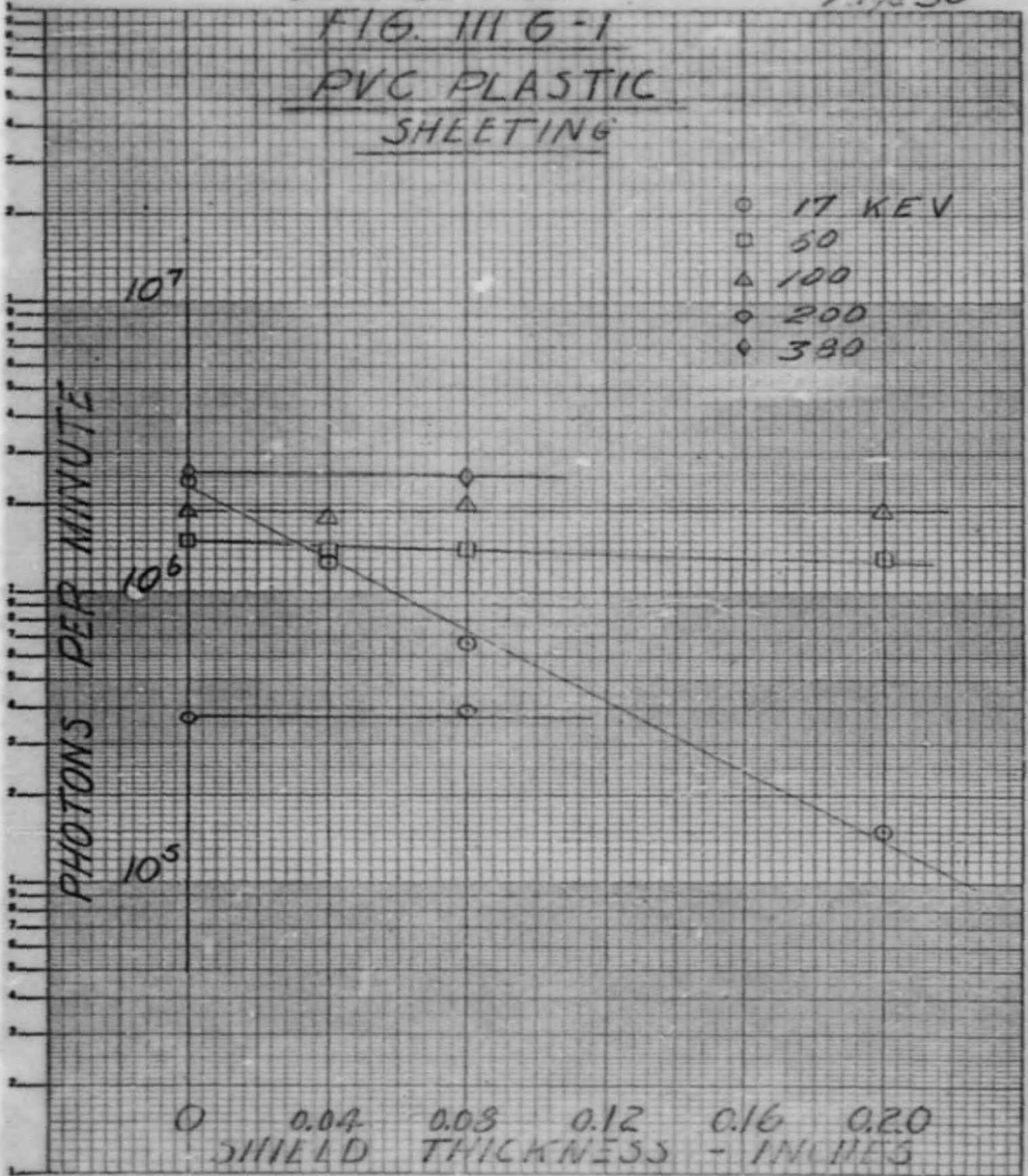
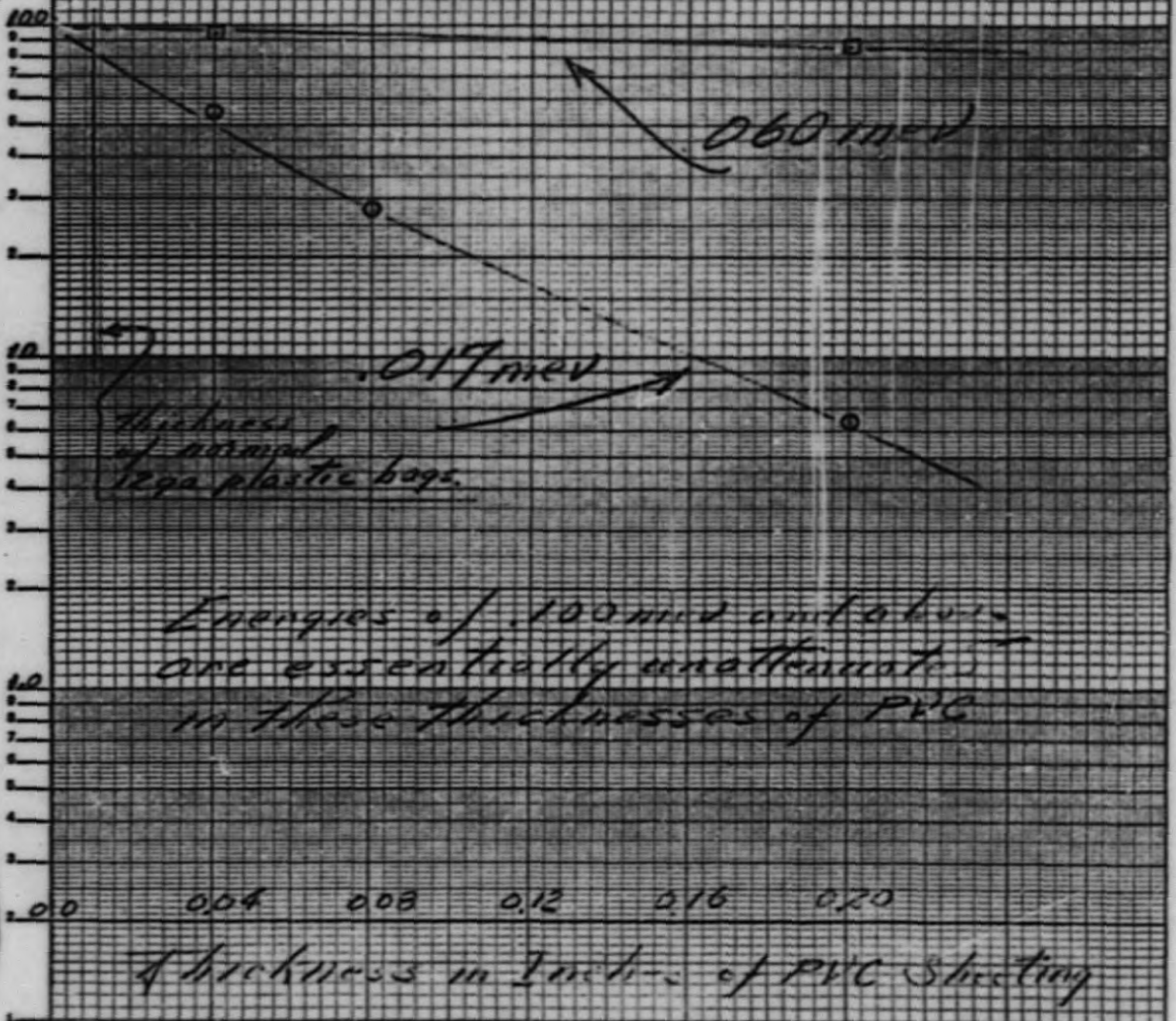


Figure III G-2

Percent Gamma Transmission  
through  
Poly vinyl chloride (PVC) Sheeting





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APPENDIX IV

Calculations of Dose Rates for Specific  
Weights, Distances, and Geometries of  
Plutonium Samples Used as Sources in the  
Determination.

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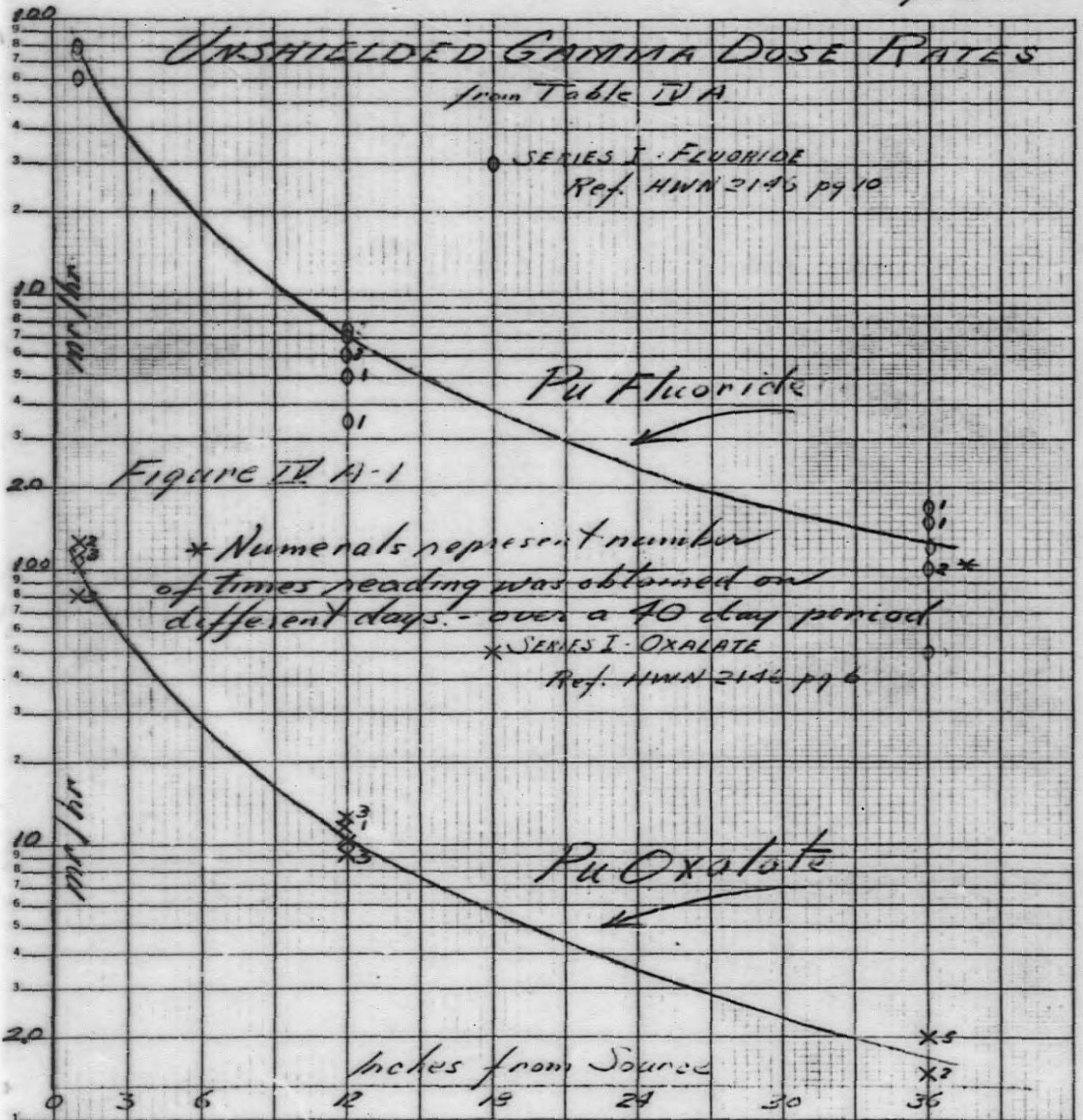
TABLE IV A

Unshielded Gamma Dose Rates From Samples As  
Used in Study

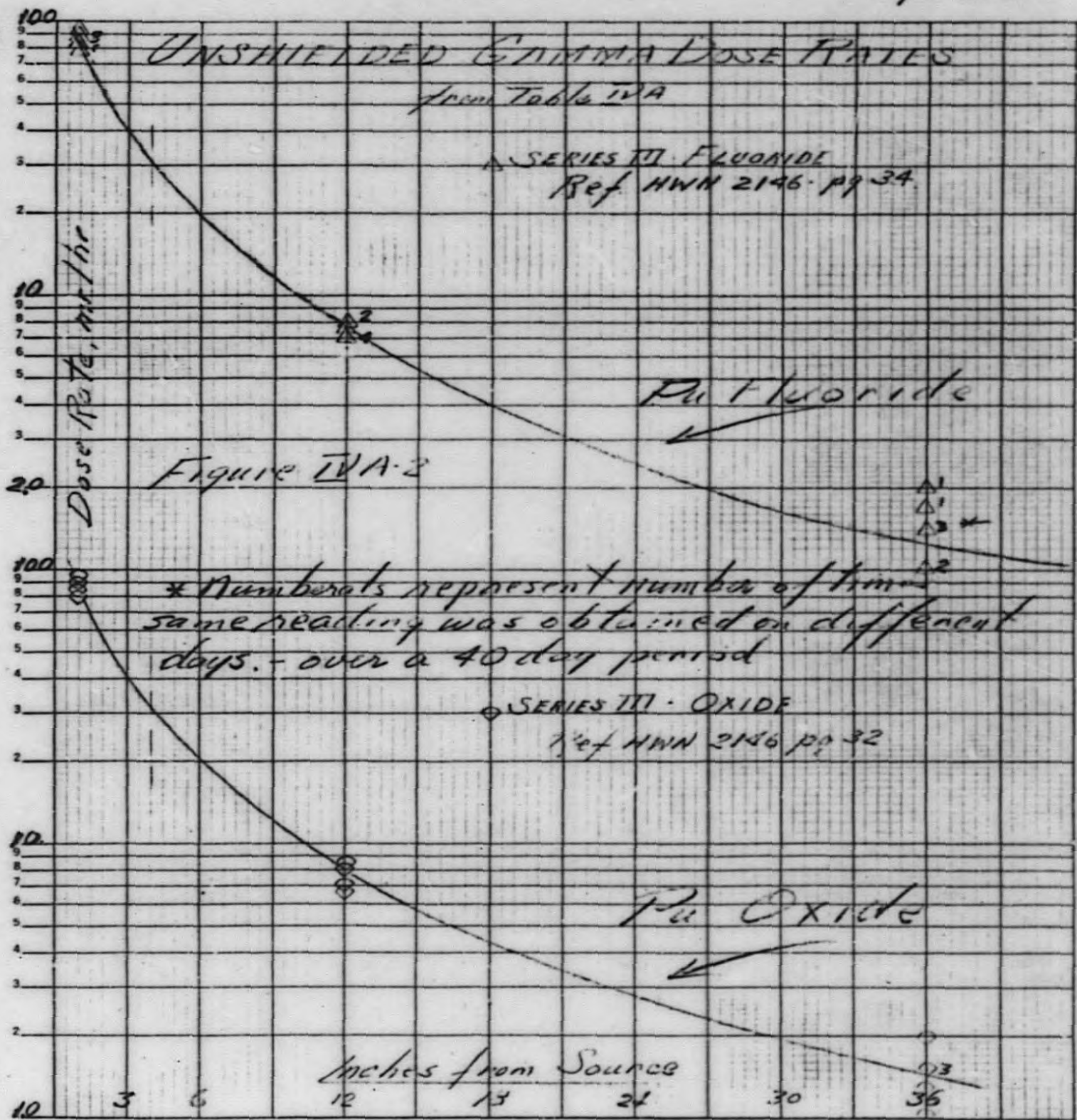
Reference: HWN-2146 - Pages 4 - 39

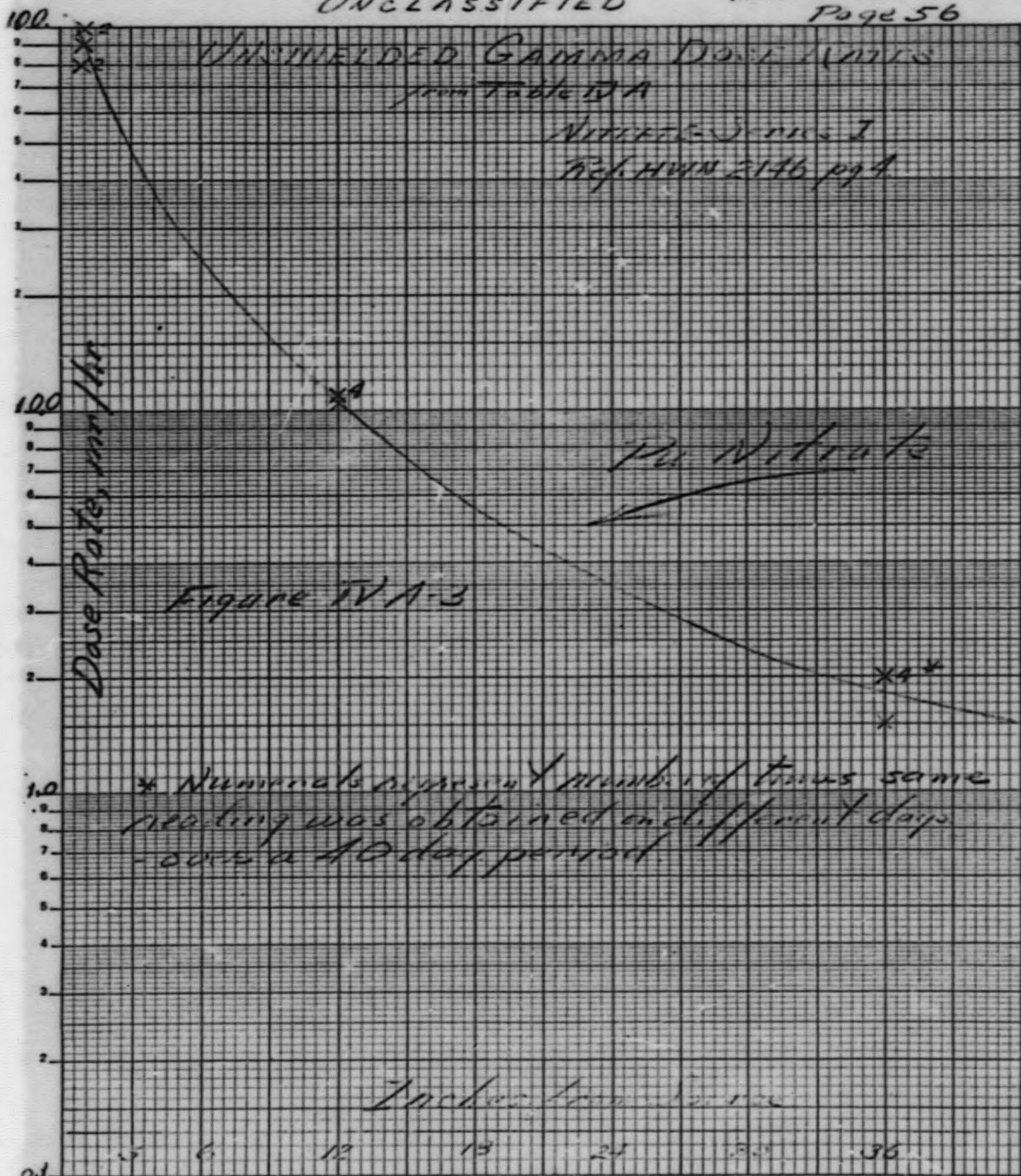
<u>Plutonium Sample</u>		<u>Mr/Hour * Taken with C.P. (W.O.)</u>					
<u>Series I</u>	<u>Gr. of Pu</u>	<u>● 1-Inch</u>		<u>● 1-Foot</u>		<u>● 3-Feet</u>	
		<u>Max.</u>	<u>Min.</u>	<u>Max.</u>	<u>Min.</u>	<u>Max.</u>	<u>Min.</u>
Nitrate	200.0	100	70	11.0	9.0	2.0	1.3
Oxalate	558.1	128	80	12.5	9.0	2.0	1.2
Oxide	330.5	80	50	7.5	5.0	1.7	0.5
Fluoride	387.7	80	59	7.5	3.5	1.7	0.5
Button-129	1003.2	110	70	8.0	5.0	2.0	1.0
<u>Series II</u>							
Nitrate	223.0	120	85	15.0	9.5	2.3	1.0
Oxalate	290.5	73	50	6.0	4.5	2.0	0.5
Oxide	394.7	95	60	8.5	6.0	2.0	0.5
Fluoride	542.5	95	70	8.8	6.5	2.0	1.0
Button-58	1493.4	100	60	7.0	5.5	1.5	0.1
<u>Series III</u>							
Nitrate	141.0	135	110	15.0	13.0	3.0	1.5
Oxalate	363.0	100	85	8.5	7.0	2.8	1.0
Oxide	435.0	95	80	8.5	6.5	2.0	1.0
Fluoride	353.0	95	77	8.0	7.0	2.0	1.0
Button-98	773.1	126	103	7.3	6.5	1.5	1.0

\* Eight readings were taken at intervals over a nine week period. These are recorded in HWN-2146 Pages 4 - 39. The values are plotted on Figures IV A-1-4.











UNCLASSIFIED Gamma Dose Rates  
from Table IV A

Series I (1954)  
Fig. 104-2-10-74

P<sub>2</sub> Metal

Figure IV N 4

Dose Rate, mr/hr

\* Numerals represent number of times  
this reading was obtained on different  
days, over a 40 day period

Inches from Source

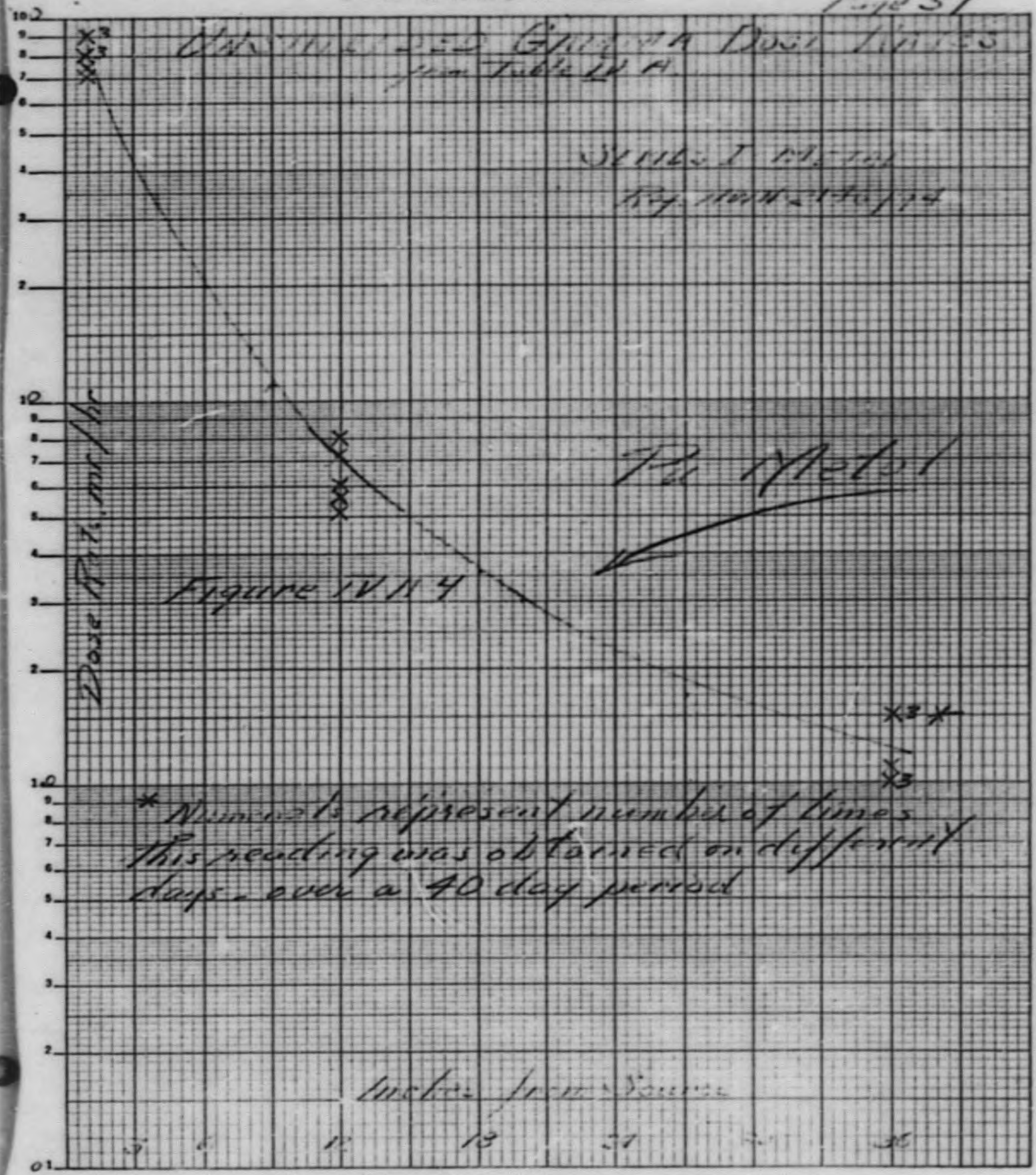




TABLE IV B

Adjustment of Radiation for Sample Weight  
Variance Using 400 Grams as a Common Base

Sample		Ratio Spl Wt/ 400 Gr	Gamma Radiation Unshielded							
			● 1-Inch		● 4-Inches		● 12-Inches		● 36-Inches	
Type	Wt.		Act. Fig. IV A	Adj. to 400 Gr.	Act. Fig. IV A	Adj. to 400 Gr.	Act. Fig. IV A	Adj. to 400 Gr.	Act. Fig. IV A	Adj. to 400 Gr.
Oxalate I	558	0.72	100	72	42	30	10	7.2	1.7	1.2
Fluoride I	388	1.03	80	82	30	31	7.1	7.3	1.3	1.3
Oxide III	435	0.92	85	78	30	27	8.0	7.3	1.4	1.3
Fluoride III	353	1.13	85	96	30	34	7.5	8.4	1.3	1.4

TABLE IV C

Dose Rate at Center of Elongated Source -  
Data of Figs. IV A computed for Samples  
in Row (to Simulate Source in Tube)

Inches, Distance from Center	Inches Distance from Source	<u>Mr/hr Center Reading @ 4" as Read from Figs. IV-A-1-4</u>				
		<u>Nitrate Series I</u>	<u>Oxalate Series I</u>	<u>Oxide Series III</u>	<u>Fluoride Series I</u>	<u>Metal Series I</u>
18	22	4.0	5.0	3.2	2.7	2.6
15	19	5.0	6.1	4.0	3.6	3.4
12	16	6.6	7.0	5.2	4.8	4.6
9	13	9.2	9.5	7.0	6.2	6.2
6	10	13.5	14.0	10.0	9.5	9.6
3	7	21.0	23.0	17.0	16.0	17.0
0	4	37.0	42.0	30.0	30.0	34.0
3	7	21.0	23.0	17.0	16.0	17.0
6	10	13.5	14.0	10.0	9.5	9.6
9	13	9.2	9.5	7.0	6.2	6.2
12	16	6.6	7.0	5.2	4.8	4.6
15	19	5.0	6.1	4.0	3.6	3.4
18	22	4.0	5.0	3.2	2.7	2.6
Full 39" Source Length	mr/hr Total	155.6	171.2	122.8	115.6	120.8
	Ratio to Sample	4.2	4.1	4.1	3.9	3.6

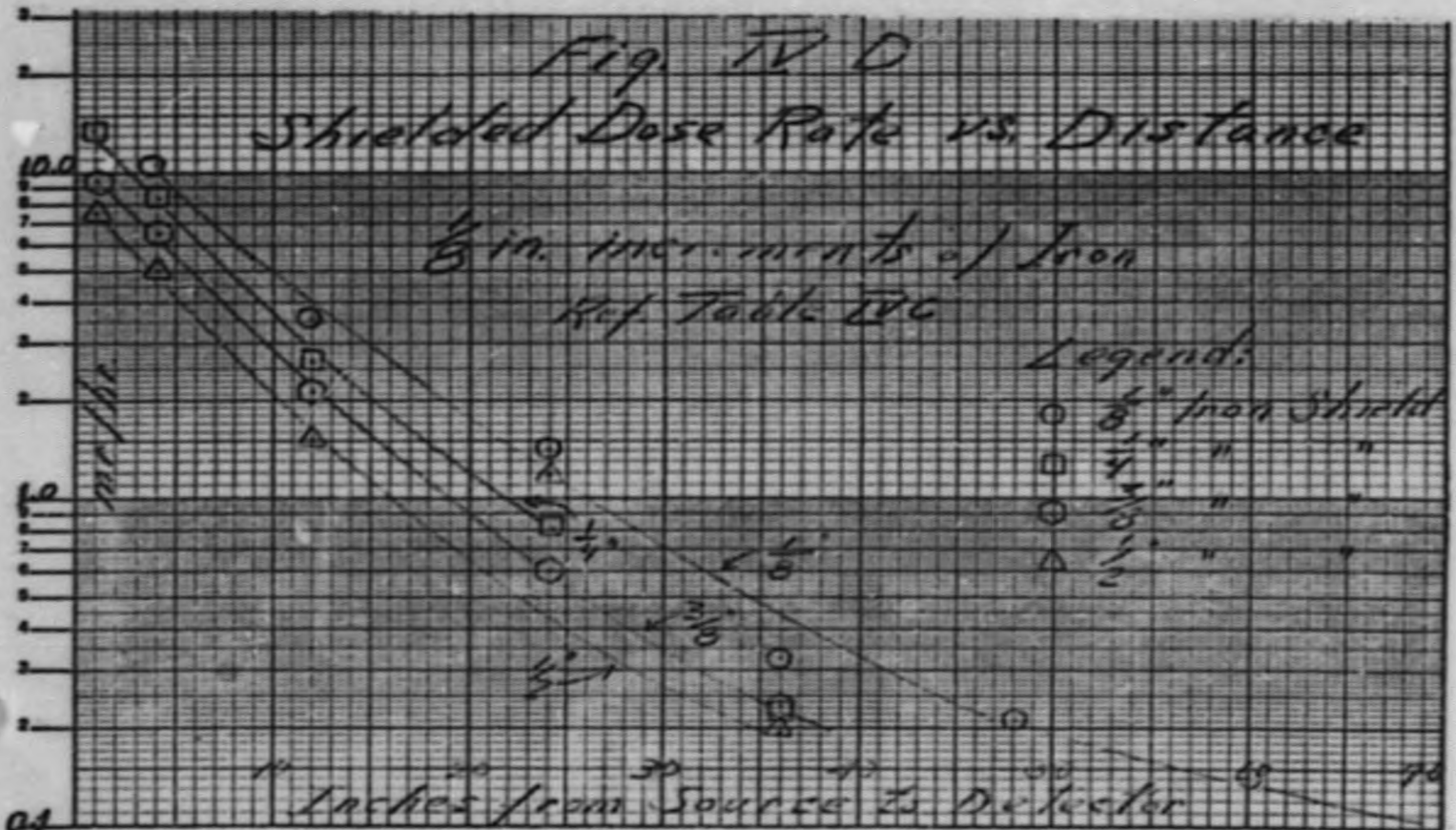
Note: To compensate for shielding effect of adjacent sources, maximum dose rate at center of a tube is considered to be 3" x sample dose/rate.

TABLE IV D

Fall Off of Gamma Dose Rate with  
Distance Through Varying Thick-  
nesses of Iron

Samples: Series I & III Nitrates - Total of 423 Gr. Pu.  
References: H&N-2145 - Page 126

Inches of Iron In Shield	Inches From Source To Detector							
	1	4	12	24	36	48	60	72
1/8		10.5	3.5	1.4	0.32	0.21	0.14	0.10
1/4	13.5	8.2	2.6	0.80	0.22			
3/8	9.5	6.5	2.1	0.60	0.24			
1/2	7.5	5.0	1.5	1.2	0.2			





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APPENDIX V

Determination of Dose Rates per Energy Grouping  
Through Equipment and Hood Walls for Specific  
Operating Conditions and for NPR Material

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TABLE V-A

Low Fission Products - Low Neutron Source Determination of Energy  
Dose Rates at Equipment and Hood Walls Using Oxalate Sample from  
Series I

Col. No.	1	2	3	4	5	6	7	8	9	
Data Source	Table II-B-1 Values	Table IV B 30.0 mr/ hour x Col 1	Col 2 x Col 3	Part I	Col 3 x Col 4	Table III C-2 For $\frac{1}{2}$ - Inch x Col 5	Table IV B 7.2 mr/ hour x Col 1	Col 7 x Col 4	Table III-E-2 3/8" Values x Col 8	
Gamma Energy MEV	Relative Dose Rate	400 Gr Sample Dose Rate Distri. @ 4"	Unshld Equip. Dose Rate @ 4"	NPR Gamma Increase Factors	Unshld NPR Equip. Dose Rates @ 4"	NPR Equip. Dose Rate @ 4" Thru $\frac{1}{2}$ " Stl	400 Gr Unshld NPR Dose Rate @ 12"	400 Gr Unshld NPR $\supset$ pl. Dose Rate @ 12"	Est. Max. NPR Hood Dose Rate @ 12", 3/8" Flexiglas mr/hour	
		<u>mr/hr</u>	<u>mr/hr</u>		<u>mr/hr</u>	<u>mr/hr</u>	<u>mr/hr</u>	<u>mr/hr</u>		
	.017	65.1	19.53	58.59	1.5	87.88	0.00	4.69	7.03	3.51
	.060	5.8	1.74	5.22	7.0	36.54	0.00	0.42	2.94	2.50
	.100	10.7	3.21	9.63	7.0	67.41	2.36	0.77	5.39	4.63
	.200	1.6	0.48	1.44	7.0	10.08	4.54	0.12	0.84	0.76
	.380	16.5	4.95	14.85	2.5	37.12	17.45	1.19	2.98	2.80
	.750	0.3	0.09	0.27	1.0	0.27	0.15	0.02	0.02	0.02
	1.3	0.0								
	2.1	0.0								
Total	100.0	30.0	90.0		239.3	24.50	7.21	119.17	14.22	



TABLE V-B

Low Fission Product - High Neutron Source Determination of  
Energy Dose Rates at Equipment and Hood Walls Using Fluoride  
Samples from Series I

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table II-B-2 Values	Table 31 mr/ hr x Col 1	Col 2 x Col 3	Part I	Col 3 x Col 4	Table III-C-2 Values x Col 5	Table IV B 7.3 mr/hr x Col 1	Col 7 x Col 4	Table III-E-2 Values x Col 8
Gamma Energy MEV	Relative Dose Rate	400 Gr Sample Dose Rate Distri @ 4"	Unshld Equip. Dose Rate @ 4"	NPR Gamma Increase Factors	Unshld NPR Equip Dose Rate @ 4" mr/hr	NPR $\frac{1}{2}$ " Steel Wall Equip. Dose Rate @ 4" mr/hr	400 Gr Sample Dose Rate Dist. @ 12" mr/hr	400 Gr Unshld NPR Dose Rate @ 12" mr/hr	Est. Max. NPR Hood Dose Rate @ 12" 3/8" Flex- iglas mr/hr
	%	mr/hr	mr/hr						
.017	36.1	11.2	33.6	1.5	50.4	0.0	2.63	3.94	1.97
.060	3.3	1.0	3.0	7.0	2.1	0.0	0.24	1.68	1.43
.100	6.9	2.1	6.3	7.0	4.5	0.15	0.50	3.50	3.01
.200	1.0	0.3	0.9	7.0	6.3	2.85	0.07	0.49	0.45
.380	12.1	4.7	14.1	2.5	35.2	16.50	0.88	2.20	2.07
.750	1.3	0.4	1.2	1.0	1.2	0.60	0.09	0.09	0.09
1.3	25.4	7.9	23.7	*1.0	23.7	14.40	1.85	1.85	1.85
2.1	13.8	4.3	12.9	*1.0	12.9	8.25	1.07	1.01	1.01
Total	99.9	30.9	92.4		12.12	42.75	7.27	14.76	11.88

May increase with higher neutron flux.



TABLE V-C

High Fission Product - Low Neutron Source Determination of  
Energy Dose Rates at Equipment and Hood Walls Using Oxide  
Sample from Series III

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table II-B-3 Values/	Table 27 mr/hr x Col 1	Col 2 x 3	Part I	Col 3 x Col 4	Table III-C-2 Values x Col 5	Table IV-B 7.3 mr/ hr x Col 1	Col 7 x Col 4	Table III-E-2 Values x Col 8
Gamma Energy MEV	Relative Dose Rate  %	400 Gr Sample Dose Rate Distri. @ 4" mr/hr	Unshld Equip Dose Rate @ 4" mr/hr	NPR Gamma Increase Factors	Unshld NPR Equip Dose Rate @ 4" mr/hr	NPR $\frac{1}{2}$ " Steel Wall Dose Rate @ 4" mr/hr	400 Gr Sample Dose Rate Distri. @ 12" mr/hr	400 Gr Unshld NPR Dose Rate @ 12" mr/hr	Est. Max. NPR Hood Dose Rate @ 12" 3/8" Flexiglas mr/hr
.017	50.1	13.53	40.59	1.5	60.88	0.0	3.66	5.49	2.74
.060	2.9	0.78	2.34	7.0	16.38	0.0	0.21	1.47	1.25
.100	9.0	2.43	7.29	7.0	51.03	1.78	0.66	4.62	3.97
.200	1.3	0.35	1.05	7.0	7.35	3.31	0.95	6.65	6.05
.380	17.4	4.70	14.10	2.5	35.25	16.57	1.27	3.18	2.98
.750	19.2	5.18	15.54	1.0	15.54	15.54	1.40	1.40	1.32
1.3	0.0								
2.1	0.0								
Total	99.9	26.97	80.91		186.43	37.20	8.15	22.81	18.31

TABLE V-D

High Fission Product - High Neutron Source Determination of  
Energy Dose Rates at Equipment and Hood Walls Using Fluoride  
Sample from Series III

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table II-B-4 Values	Table 34 mr/hr . x Col 1	Col 2 x Col 3	Part I	Col 3 x Col 4	Table III-C-2 Values x Col 5	Table IV-B 8.4 mr/ hr x Col 1	Col 7 x Col 4	Table III-E-2 Values x Col 8
Gamma Energy MEV	Relative Dose Rate %	400 Gr Sample Dose Rate Dist. ④ 4" mr/hr	Unshld Equip Dose Rate ④ 4" mr/hr	NPR Gamma Increase Factors	Unshld NPR Equip Dose Rate ④ 4" mr/hr	NPR 1/2" Steel Wall Equip. Dose Rate ④ 4" mr/hr	400 Gr Sample Dose Rate Dist. ④ 12" mr/hr	400 Gr Unshld NPR Dose Rate ④ 12" mr/hr	Est. Max. NPR Hood Dose Rate ④ 12" 3/8" Flexiglas mr/hr
.017	35.0	11.90	35.70	1.5	53.55	0.0	2.94	4.41	2.20
.060	2.0	0.68	2.04	7.0	14.28	0.0	0.17	1.19	1.01
.100	6.0	2.04	6.12	7.0	42.84	1.50	0.50	3.50	3.01
.200	0.9	0.31	0.93	7.0	6.51	2.92	0.07	0.49	0.45
.380	11.2	3.81	11.43	2.5	28.57	13.43	0.94	2.35	2.21
.750	12.9	4.39	13.17	1.0	13.17	7.38	1.08	1.08	1.01
1.3	20.6	7.00	21.00	1.0	21.00	12.81	1.73	1.73	1.73
2.1	11.5	3.91	11.73	1.0	11.73	7.51	0.97	0.97	0.97
Total	100.1	34.04	102.12		191.65	45.55	8.40	15.73	12.59



TABLE V-E

Gamma Determination of NPR Plutonium Dose Rates Through Hood  
Walls Using Plutonium Samples From Series I

Col No.	1	2	3	4	5	6	7	8
Data Source	Table II-B-6 Values	Fig. IV A-4 35 mr/hr x Col 1	Col 2 x 5	Part I	Col 3 x Col 4	Table III-C-2 x Col 5	Table III-C-2 x Col 5	Table III-E-2 x Col 5
Gamma Energy MEV	Relative Dose Rate %	Dose Rate @ 4" From Hood  mr/hr	Est. Geometry Increase For Max. Gamma  mr/hr	NPR Gamma Increase Factors	Unshld NPR Hood Dose Rate @ 12"  mr/hr	NPR Gamma from Plutonium at 1 Foot from the Hood wall for Hood Wall Shielding as Shown Below.  1/4" Steel      1/2" Steel      3/8" Flexiglas mr/hr      mr/hr      mr/hr		
.017	61.0	21.35	106.75	1.5	160.12	0.0	0.0	180.06
.060	4.6	1.61	8.05	7.0	56.35	0.0	0.0	47.90
.100	8.9	3.11	15.55	7.0	108.85	21.77	3.81	93.61
.200	1.3	0.46	2.30	7.0	16.10	10.79	7.24	14.65
.380	21.5	7.52	37.60	2.5	94.00	46.92	32.43	64.86
.750	2.6	0.91	4.55	1.0	4.55	3.37	2.55	4.28
1.3	0.0							
2.1	0.0							
Total	99.9	34.96	174.80		439.97	82.85	46.03	305.36



TABLE V-F

Determination of NPR Gamma Dose Rates Through Container Walls  
@ 4" Using Nitrate Samples of Series I

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table II-B-5	Fig. 35 x Col 1	Col 2 x 3	Part I	Col 3 x Col 4	Table III-D-2 Values x Col 5	Table III-D-2 x Col 5	Table III-C-2 x Col 5	Table III-C-2 x Col 5
Gamma Energy MEV	Relative Dose Rate %	Dose Rate Dist. by Energy @ 4" <u>mr/hr</u>	Est. Gamma Increase by Wt. & Geometry @ 4" <u>mr/hr</u>	NPR Gamma Increase Factors	Unshld NPR Dose Rate @ 4" <u>mr/hr</u>	Safety Glass $\frac{1}{2}$ " <u>mr/hr</u>	Safety Glass $\frac{1}{4}$ " <u>mr/hr</u>	Steel $\frac{1}{2}$ " <u>mr/hr</u>	Steel $\frac{1}{4}$ " <u>mr/hr</u>
.017	67.94	23.78	71.34	1.5	107.01	13.91		0.0	
.060	8.03	2.81	8.43	7.0	59.01	44.26	32.45	0.0	
.100	12.91	4.52	13.56	7.0	94.92	79.73	66.44	18.98	3.32
.200	1.20	0.42	1.26	7.0	8.82	7.76	6.70	5.91	3.96
.380	8.59	3.01	9.03	2.5	22.57	20.31	18.96	15.35	10.61
.500	0.94	0.33	0.99	1.0	0.99	0.91	0.84	0.70	0.50
.660	0.29	0.10	0.30	1.0	0.30	0.27	0.25	0.21	0.15
.750	0.36	0.12	0.36	1.0	0.36	0.34	0.31	0.27	0.20
1.3									
2.1									
Total	100.26	35.09	105.27		293.98	167.49	125.95	41.42	18.74

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APPENDIX VI

Determination of Dose Rates  
for Each Energy Grouping  
Through Increasing Thick-  
nesses of 4.8 Sp G. Lead  
Glass Over 3/8" Plexiglas  
for NPR Material

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TABLE VI A

NPR Lead Glass (4.8 Sp. Gr.) Shielding Versus NPR Gamma Dose Rates @ 1' From Hood Walls For a Low Fission Product - Low Neutron Source Using Oxalate Samples from Series I.

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table VA Col 9	Values for Percent of Gamma Transmission from Table III-A-2 x Col. 1							
Gamma Energy MEV	Dose Rate @ 1' Thru 3/8" Flexiglas mr/hr	Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness of Lead Glass in Inches.							
		1/4"	1/2"	3/4"	1"	1 1/2"	2"	2 1/2"	3"
.017	3.51	0.05	0.00						
.060	2.50	0.04	0.00						
.100	4.63	0.25	0.00						
.200	0.76	0.25	0.11	0.04	0.02	0.00			
.380	2.80	1.93	1.32	0.87	0.59	0.26	0.12	0.06	0.02
Pu Sub-Total	(14.20)	(2.57)	(1.43)	(0.91)	(0.61)	(0.26)	(0.12)	(0.06)	(0.02)
.750	0.02	0.017	0.015	0.012	0.010	0.008	0.005	0.004	0.00
1.3	0.0								
2.1	0.0								
Total	14.22	2.53	1.44	0.92	0.62	0.27	0.12	0.06	0.03



TABLE VI B

Lead Glass (4.8 Sp Gr) Shielding Versus NFR Gamma Dose Rates at 1'  
from Hood Walls for Low Fission Product - Pu Neutron Source Using  
the Plutonium Fluoride Samples from Series I.

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table V B Col 9	Values for Percent of Gamma Transmission Shown in Table III A-2 x Dose Rate of Col. 1.							
Gamma Energy MEV	Dose Rate @ 12" Thru 3/8" Flexiglas at Hood mr/hour	Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Lead Glass Shield.							
		1/4"	1/2"	3/4"	1"	1 1/2"	2"	2 1/2"	3"
.017	1.97	0.03	0.00						
.060	1.43	0.02	0.00						
.100	3.01	0.16	0.00						
.200	0.45	0.15	0.06	0.02	0.01	0.00			
.380 Pu Sub-Total	2.07 (24.68)	1.43 (1.79)	0.97 (1.03)	0.64 (0.66)	0.43 (0.44)	0.19 (0.19)	0.09 (0.09)	0.04 (0.04)	0.02 (0.02)
.750 Pu + F.P. Sub-Total	0.09 (24.77)	0.07 (1.86)	0.06 (1.09)	0.05 (0.71)	0.04 (0.48)	0.03 (0.22)	0.02 (0.11)	0.02 (.06)	0.01 (0.03)
1.3	1.85	1.61	1.37	1.13	0.96	0.70	0.50	0.37	0.26
2.1	1.01	0.91	0.81	0.74	0.65	0.50	0.44	0.35	0.28
Total	11.88	4.38	3.27	2.57	2.09	1.42	1.05	0.78	0.57

TABLE VI C

Lead Glass (4.8 Sp. Gr.) Shielding Versus NFR Gamma Dose Rates  
at 1 Foot From Hood Walls for a High Fission Product - Low Neutron  
Source Using Oxide Sample from Series III.

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table V C Col 9	Values for Percent of Gamma Transmission as Shown in Table III-A-E x Dose Rate of Col. 1.							
Gamma Energy MEV	Dose Rate @ 12" Thru 3/8" Flexiglas at Hood r/hour	Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Lead Glass Shield.							
		1/4"	1/2"	3/4"	1"	1 1/2"	2"	2 1/2"	3"
		—	—	—	—	—	—	—	—
.017	2.74	0.04	0.00						
.060	1.25	0.02							
.100	3.97	0.21							
.200	6.05	2.00	0.84	0.33	0.13	0.02	0.00	0.00	0.00
.380	2.98	2.06	1.40	0.92	0.62	0.28	0.13	0.06	0.03
Pu Sub-Total	(16.99)	(4.33)	(2.24)	(1.25)	(0.75)	(0.30)	(0.13)	(0.06)	(0.03)
.750	1.32	1.06	0.87	0.69	0.59	0.38	0.25	0.17	0.10
1.3									
2.1									
Total	18.31	5.39	3.11	1.94	1.59	0.68	0.38	0.23	0.13



TABLE VI D

Lead Glass (4.8 Sp. Gr.) Shielding Versus NFR Gamma Dose Rates  
at 1' from Hood Walls for a High Fission Products - High Neutron  
Source Using Fluoride Samples of Series III.

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table V D Col 9	Values For Percent of Gamma Transmission As Shown in Table III-A-2 X Dose Rate of Col 1.							
Gamma Energy MEV	Dose Rate @ 12" Thru 3/8" Plexi- glas at Hd mr/hour	Mr/hour of Gamma Radiation Transmitted Through Indicated Thicknesses in Inches of Lead Glass Shield.							
		<u>1/8"</u>	<u>1/4"</u>	<u>3/4"</u>	<u>1"</u>	<u>1 1/2"</u>	<u>2"</u>	<u>2 1/2"</u>	<u>3"</u>
.017	2.20	0.03	0.00						
.060	1.01	0.02	0.00						
.100	3.01	0.16	0.00						
.200	0.45	0.15	0.06	0.02	0.00				
.380 Pu Sub-Total	2.21 *(.88)	1.52 (1.88)	1.04 (1.10)	0.69 (0.71)	0.46	0.21	0.10	0.04	0.02
.750 Pu+FP Sub-Ttl	1.01 (9.89)	0.82 (2.70)	0.67 (1.77)	0.53 (1.24)	0.45 (0.46)	0.29 (0.50)	0.19 (0.39)	0.13 (0.17)	0.08 (0.10)
1.3	1.73	1.50	1.28	1.05	0.90	0.66	0.47	0.35	0.24
2.1	0.97	0.87	0.78	0.71	0.62	0.48	0.43	0.34	0.28
Total	12.99	5.07	3.83	3.00	2.43	1.64	1.19	0.86	0.62



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TABLE VI-E-1

Lead Glass (4.8 Sp Gr) Shielding Versus NPR Fabrication Dose Rates  
@ 4" from Hood-Wall Using Plutonium Samples from Series I

Col No.	1	2	3	4	5	6	7	8	9
Data Source	Table V E Col 8	Values for Percent of Transmission Shown in Table III-A-2 x Dose Rate of Col 1.							
Gamma Energy MEV	Dose Rate @ 4" Thru 3/8" Flexi- glas at H1	Mr/Hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Lead Glass Shield.							
		<u>1"</u>	<u>1"</u>	<u>3/4"</u>	<u>1"</u>	<u>1 1/2"</u>	<u>2"</u>	<u>2 1/2"</u>	<u>3"</u>
.017	80.06	1.04	0.0						
.060	47.90	0.72	0.0						
.100	93.61	5.05	0.0						
.200	14.65	4.83	2.05	0.79	0.32	0.06	0.01	0.00	
.380 Pu Sub-Total	64.86 (60.58)	44.75 (56.39)	30.48 (32.53)	20.10 (20.89)	13.62 (13.94)	6.10	2.78	1.30	0.60
.750	4.28	3.46	2.82	2.22	1.93	1.24	0.81	0.55	0.34
1.3	0.0								
2.1	0.0								
Total	305.36	59.85	35.35	23.11	15.87	7.40	3.60	1.85	.94

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TABLE VI-E-2

Lead Glass (4.8 Sp Gr) Shielding Versus NFR Dose Rates at Various Distances from Pu Metal Shapes of NFR Contemporary Design

Col No	1	2	3	4	5	6	7	8	9	10	11
Data Source	Fig. IV-A-4	Ratio of Col 1 to 35 mr/hr	Dose Rate Values of Table VI-E-1 for Total Spectrum x % of Col 1								
Distance Between Source and Meas. Point in Inches	Base mr/hour	% of mr/hr @ 4"	NFR Gamma In mr/hour through $\frac{1}{4}$ " of Steel plus Indicated Thickness of Lead in Inches								
			0"	$\frac{1}{4}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	$1\frac{1}{2}$ "	2"	$2\frac{1}{2}$ "	3"
4	35	100	305.36	59.85	35.35	23.11	15.87	7.40	3.60	1.85	0.94
6	20	57	173.8	34.11	20.15	13.17	9.04	4.22	2.05	1.05	0.53
8	13.5	38	115.9	22.74	13.43	8.78	6.03	2.81	1.36	0.70	0.35
12	7.0	20	60.10	11.97	7.07	4.62	3.17	1.48	0.72	0.37	0.19
20	3.0	8.6	30.50	5.14	3.04	1.98	1.36	0.63	0.31	0.16	0.08



TABLE VI-F

Lead Glass (4.8 Sp Gr) Shielding Versus NPR Gamma Dose Rates at 4"  
From  $\frac{1}{4}$ " Glass Container Wall Using Nitrate Sample of Series I.

Col No	1	2	3	4	5	7	8	9	10	
Data Source	Table V-F Col 6	Values for Percent Transmission Shown in Table III A-2 x Dose Rate of Col 1								
Gamma Energy MEV	Dose Rate @ 4" Thru $\frac{1}{4}$ " Pyrex Glass mr/hr	Mr/hr of Gamma Radiation Transmitted Through Indicated Thickness In Inches of Lead Glass Shield.								
		$\frac{1}{4}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	1 $\frac{1}{2}$ "	2"	2 $\frac{1}{2}$ "	3"	
.017	13.91	0.18	0.00							
0.00	44.26	0.66	0.00							
.100	79.73	4.30	0.00							
.200	7.76	2.56	1.08	0.42	0.17	0.03	0.01	0.00		
.380	20.31	14.01	9.54	6.30	4.27	1.91	0.87	0.41	0.18	
Pu Sub Total	(165.97)	(21.71)	(10.62)	(6.72)	(4.44)	(1.94)	(0.88)	(0.41)	(0.18)	
.500	0.91	0.60	0.54	0.40	0.32	0.18	0.10	0.07	0.04	
.660	0.27	0.20	0.17	0.13	0.11	0.06	0.03	0.02	0.01	
.750	0.34	0.27	0.22	0.18	0.15	0.10	0.06	0.04	0.02	
1.3										
2.1										
To	167.49	22.78	11.55	7.43	5.02	2.28	1.07	0.54	0.25	



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APPENDIX VII

Determination of NPR Dose Rates for Each  
Energy Grouping Through Increasing Thick-  
nesses of Lead Cladding Over  $\frac{1}{2}$ " or  $\frac{1}{4}$ " Steel  
Walls

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TABLE VII-A

Lead Cladding Thickness Versus NPR Gamma Dose Rates of 4" from Surface of 1/2" Steel Equipment for Low Fission Product - Low Neutron Source Using Oxalate Sample from Series I.

Col No	1	2	3	4	5	6	7	8	9	10	11	12
Data Source	Table V A Col 6	Values for Percent of Gamma Transmission Shown in Table III-B-2 X Dose Rate of Col 1.										
Gamma Energy MEV	Dose Rate Thru 1/2" Steel @ 4" From Unclad Equip. Wall Mr/hr	Mr/hour of NPR Gamma Radiation Transmitted Through Indicated Thickness in inches of Metallic Lead.										
		1/16"	1/8"	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	2"	2 1/2"	3"
.017	0.00	0.00										
.060	0.00	0.00										
.100	2.36	0.83	0.24	0.02	0.00							
.200	4.54	21.3	1.13	0.23	0.04	0.01	0.00					
.380 Pu Sub-Ttl	17.45 (24.35)	12.21 (15.17)	9.77 (11.14)	5.23 (5.48)	2.79 (2.83)	1.66 (1.67)	0.52 (0.52)	0.14 (0.14)	0.01 (0.01)	0.00		
.750	0.15	0.13	0.12	0.09	0.07	0.06	0.03	0.02	0.01	0.00		
1.27	0.00											
2.1	0.00											
Total	24.50	15.28	11.26	5.57	2.90	1.73	0.55	0.16	0.02			



TABLE VII-B

Lead Gladding Thickness Versus NPR Gamma Dose Rates @ 4" from Surface of  
1/2" Steel Equipment For Low Fission Product - High Neutron Source Using  
Fluoride Sample from Series I.

Col No	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Data Source	Table V-B Col 6	Values for Percent of Gamma Radiation Shown in Table III-B-2 X Dose Rate of Col 1.												
Gamma Energy MEV	Dose Rate Through 1/2" Steel @ 4" from Unclad Equip. Wall Mr/hr	Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Metallic Lead												
		1/16"	1/8"	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	2"	2 1/2"	3"	3 1/2"	4"
.017	0.00													
.060	0.00													
.100	0.15	0.05	0.01	0.00										
.200	2.85	1.34	0.71	0.14	0.03	0.01	0.00							
.380	16.50	11.55	6.30	4.95	2.64	1.56	0.49	0.13	0.01	0.00				
Pu Sub-Total	(19.50)	(12.94)	(7.02)	(5.09)	(2.67)	(1.57)	(0.49)	(0.13)	(0.01)					
.750	0.60	0.51	0.47	0.37	0.29	0.23	0.14	0.09	0.04	0.01	0.00			
Pu+FP Sub-Ttl	(20.10)	(13.45)	(7.49)	(5.46)	(2.96)	(1.80)	(0.63)	(0.22)	(0.05)	(0.01)				
1.27	14.40	12.67	12.24	10.36	8.64	7.49	5.47	3.74	2.30	1.09	0.66	0.36	0.20	0.11
2.1	8.25	7.59	7.17	6.27	5.61	4.95	3.96	3.13	2.06	1.23	0.82	0.49	0.31	0.20
		(20.20)	(19.41)	(16.63)	(14.25)	(12.44)	(9.43)	(6.87)	(4.36)	(2.32)				
Total	42.75	33.65	26.90	22.09	17.21	14.24	10.06	7.09	4.41	2.33	1.48	0.85	0.51	0.31



TABLE VII-C

Lead Cladding Thickness Versus NPR Gamma Dose Rates at 4" from Surface  
of  $\frac{1}{2}$ " Steel Equipment for High Fission Product - Low Neutron Source Using  
Oxide Sample from Series III

Col No	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Data Source	Table V-C Col 6	Values for Percent of Gamma Radiation Shown in Table III-B-2 X Dose Rate of Col 1.												
Gamma Energy MEV	Dose Rate Thru $\frac{1}{2}$ " Stl @ 4" From Unclad Equip. Wall Mr/hr	Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Metallic Lead												
		1/16"	1/8"	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	2"	2 1/2"	3"	3 1/2"	4"
.017	0.00	0.00												
.060	0.00	0.00												
.100	1.78	0.62	0.18	0.02	0.00									
.200	3.31	1.55	0.83	0.16	0.03	0.01	0.00							
.380 Pu Sub-Total	16.57 (21.66)	11.60 (13.77)	9.28 (10.29)	4.97 (5.15)	2.65 (2.68)	1.57 (1.58)	0.50 (0.50)	0.13 (0.13)	0.01 (0.01)	0.00				
.750	15.54	13.20	12.12	9.63	7.46	6.06	3.57	2.33	1.05	0.42	0.17	0.08	0.03	0.01
1.27	0.00													
2.1	0.00													
Total	37.20	26.97	22.41	14.78	10.14	7.64	4.07	2.46	1.06	0.42	0.17	0.08	0.03	0.01

TABLE VII-D

Lead Cladding Thickness Versus NPR Gamma Dose Rates at 4" From Surface of  $\frac{1}{8}$ " Steel Equipment For High Fission Product - High Neutron Source Using Fluoride Sample from Series III.

Col No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Data Source	Table V-D Col 6	Values for Percent of Gamma Radiation Shown in Table III-B-2 X Dose Rate of Col 1.													
Gamma Energy MEV	Dose Rate Through $\frac{1}{8}$ " Steel @ 4" From Unclad Equip. Wall	Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Metallic Lead													
	Mr/hr	1/16"	1/8"	$\frac{1}{4}$ "	3/8"	$\frac{1}{2}$ "	3/4"	1"	1 1/4"	2"	2 1/2"	3"	3 1/2"	4"	
.017	0.00	0.00													
.060	0.0	0.0													
.100*	1.50	0.52	0.15	0.01	0.00										
.200	2.92	1.37	0.73	0.15	0.03	0.01	0.0								
.380	13.43	9.40	7.52	4.03	2.15	1.27	0.40	0.11	0.01	0.00					
Pu Sub-Total	(17.85)	(11.29)	(8.40)	(4.19)	(2.18)	(1.28)	(0.40)	(0.11)	(0.01)						
.750	7.38	6.27	5.75	4.57	3.54	2.88	1.69	1.10	0.50	0.20	0.08				
Pu+FP Sub Ttl	(25.23)	(17.56)	(14.15)	(8.76)	(5.72)	(4.16)	(2.09)	(1.21)	(0.51)	(0.20)	(0.08)				
1.27	12.81	11.27	10.89	9.22	7.69	6.66	4.86	3.33	2.04	0.97	0.58	0.32	0.18	0.10	
2.1	7.51	6.91	6.53	5.70	5.10	4.50	3.60	2.85	1.88	1.26	0.75	0.45	0.28	0.17	
	(20.32)	(18.18)	(17.42)	(14.92)	(12.79)	(11.10)	(8.46)	(6.18)	(3.92)	(2.23)	(1.33)	(0.77)	(0.46)	(0.27)	
Total	45.55	35.74	31.57	23.68	18.51	15.32	10.55	7.39	4.43	2.43	1.41	0.77	0.46	0.27	

\* Includes some .077 mev lead x-ray.



TABLE VII E-1

Lead Cladding Thickness Versus NPR Gamma Dose Rates at 4" from Sample Source Through  
1/4" Steel Hood Using Plutonium - Metal Sample from Series I.

Col No	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Data Source	Table V E Col 6	Values for Percent of Gamma Radiation Shown in Table III B-2 I Dose Rate of Col 1.												
Gamma Energy MEV	Dose Rate Thru 1/4" Steel @ 4" From Sample	Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Metallic Lead.												
		1/16"	1/8"	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	2"	2 1/2"	3"	3 1/2"	4"
.017	0.0	0.0												
.060	0.0	0.0												
.100 *	21.77	7.62	2.18	0.22	0.02	0.00								
.200	10.79	5.07	2.70	0.54	0.11	0.02	0.00							
.380 Pu Sub-Total	46.92 (79.48)	32.84 (45.53)	26.28 (31.16)	14.08 (14.84)	7.51 (7.64)	4.46 (4.48)	1.41 (1.41)	0.37 (0.37)	0.04 (0.04)	0.00				
.750	3.37	2.86	2.62	2.09	1.62	1.31	0.77	0.51	0.23	0.09	0.037	0.017		
1.27	0.0													
2.1	0.0													
Total	82.85	48.39	33.78	16.93	9.26	5.79	2.18	0.88	0.27	0.09				



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TABLE VII E-2

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Lead Gladding Versus NPR Dose Rates at Various Distances from Pu Metal Shapes of NPR Contemporary Design Through  $\frac{1}{4}$ " Steel Hood Wall.

Col No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Data Source	Fig. IV-A-4	Ratio Col 1 to 35 mr/hr	Values in Table VII-E-1 for Total Spectrum X Percent in Col 1.											
Distance Between Source & Meas. Pt. in Inches	Base mr/hour	% of Dose Rate @ 4"	NPR Gamma in Mr/hour Through $\frac{1}{4}$ -inch Steel Plus Indicated Thickness of Lead in Inches.											
			None	$\frac{1}{16}$ "	$\frac{1}{8}$ "	$\frac{1}{4}$ "	$\frac{3}{8}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	$1\frac{1}{2}$ "	2"	$2\frac{1}{2}$ "	3"
4"	35	100	82.85	48.39	33.78	16.93	9.26	5.79	2.18	0.88	0.27	0.09	0.037	0.017
6"	20	57	47.22	27.58	19.25	9.65	5.27	3.30	1.24	0.50	0.15	0.05	0.21	0.01
8"	13.5	38	31.48	18.39	12.83	6.43	3.51	2.20	0.83	0.33	0.10	0.034	0.014	
12"	7.0	20	16.57	9.68	6.76	3.38	1.85	1.16	0.44	0.18	0.054	0.018		
20"	3.0	8.6	7.12	4.16	2.90	1.45	0.80	0.50	0.18	0.076	0.023			

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TABLE VII F-1

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Lead Cladding Thickness Versus NPR Gamma Dose Rates at 4" from  
1/4" Steel Container Using Nitrate Sample of Series I.

Col No	1	2	3	4	5	6	7	8	9	10	11	12
Data Source	Table VI Col 8	Values for Percent of Gamma Transmission as Shown in Table III B-2 X Dose Rate of Col 1.										
Gamma Energy MEV	Dose Rate Thru 1/4" Stl @ 4" From Hood	Mr/hour of NPR Gamma Radiation Transmitted Through Indicated Thickness in Inches of Metallic Lead.										
	Mr/hr	1/16"	1/8"	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	2"	2 1/2"	3"
.017	0.0											
.060	0.0											
.100 *	18.98	6.43	1.90	0.19	0.01	0.00						
.200	5.91	2.78	1.48	0.30	0.06	0.01	0.00					
.380	15.35	10.74	8.59	4.61	2.46	1.46	0.46	0.12	0.01	0.00		
Fu Sub-Total	(40.24)	(19.95)	(11.97)	(5.10)	(2.53)	(1.47)	(0.46)	(0.12)	(0.01)			
.500	0.70	0.56	0.49	0.35	0.24	0.17	0.10	0.07	0.03	0.01	0.00	
.660	0.21	0.18	0.14	0.10	0.07	0.05	0.03	0.02	0.01	0.00		
.750	0.27	0.23	0.21	0.17	0.13	0.10	0.06	0.04	0.02	0.01	0.00	
1.27	0.0											
2.1	0.0											
Total	41.15	20.90	12.81	5.62	2.97	1.74	0.65	0.25	0.07	0.02		



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TABLE VII P-2

Lead Cladding Thickness Versus NPR Gamma Dose Rates at 4" From  $\frac{1}{2}$ "  
Container Using Nitrate Sample of Series I.

Col No	1	2	3	4	5	6	7	8	9	10	11
Data Source	Table VI Col 9	Values for Percent of Gamma Transmission As Shown in Table III-B-2 I Dose Rate of Col 2.									
Gamma Energy MEV		Mr/hour of Gamma Radiation Transmitted Through Indicated Thickness in Inches of Metallic Lead.									
		$\frac{1}{16}$ "	$\frac{1}{8}$ "	$\frac{1}{4}$ "	$\frac{3}{8}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	1 $\frac{1}{2}$ "	2"	2 $\frac{1}{2}$ "
.017	0.00										
.060	0.00										
.100	3.32	1.16	0.33	0.03	0.00						
.200	3.96	1.86	0.99	0.20	0.04	0.01					
.380 Pu Sub- Total	10.61 (17.89)	7.42 (10.44)	5.94 (7.26)	3.18 (3.41)	1.70 (1.74)	0.79 (0.79)	0.32 (0.32)	0.08 (0.08)	0.01 (0.01)		
.500	0.50	0.52	0.45	0.32	0.23	0.16	0.09	0.06	0.02	0.01	
.660	0.15										
.750	0.20	0.17	0.15	0.12	0.10	0.08	0.07	0.03	0.01	0.00	
Total	18.74	11.13	7.86	3.53	2.07	1.03	0.48	0.17	0.04	0.01	



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APPENDIX VIII

Dose Rate Shielding Measurements For  
Plutonium Samples Through Varying Thicknesses  
Of Lead Iron And Lead Glass.

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TABLE VIII A

Plutonium Nitrate - Shielding Data  
Lead, Lead Glass, and Iron

Samples: Series I and III Nitrates - Total of 423 Gr. Pu.  
Reference: HW-2145 - Pages 126 - 131.

Inches of Shield	*Lead		**Lead Glass (4.8 Sp Gr)		Iron	
	@4"	@12"	@4"	@12"	@4"	@12"
0	#	#	#	#	#	#
1/8					12.5	3.5
1/4	1.75 *(0.90)	0.40 (0.26)	4.0 **(2.8)	1.2 (0.9)	8.5	2.6
3/8					6.5	2.1
1/2	0.33 (0.24)	0.10 (0.05)	2.4 (1.8)	0.60 (0.55)	5.0	1.55
3/4	0.12 (0.06)	0.03 (0.02)	1.15 (0.80)	0.35 (0.27)	3.7	0.72
1	0.04 (0.03)		0.67 (0.52)	0.21 (0.19)	2.0	0.55
1 1/4			0.39 (0.30)		1.3	0.44
1 1/2			0.24 (0.18)	0.06 (0.06)	0.85	0.30
1-3/4			0.14 (0.12)		0.42	0.19
2			0.09 (0.08)		0.25	0.12

\* - Reading taken through a 1/8" Fe Plate in addition to lead shield with plate between lead and detector for values in parenthesis and behind it in others.

\*\* - Taken through 20 ga. vinyl plastic with the plastic between lead glass and detector for values in parenthesis.

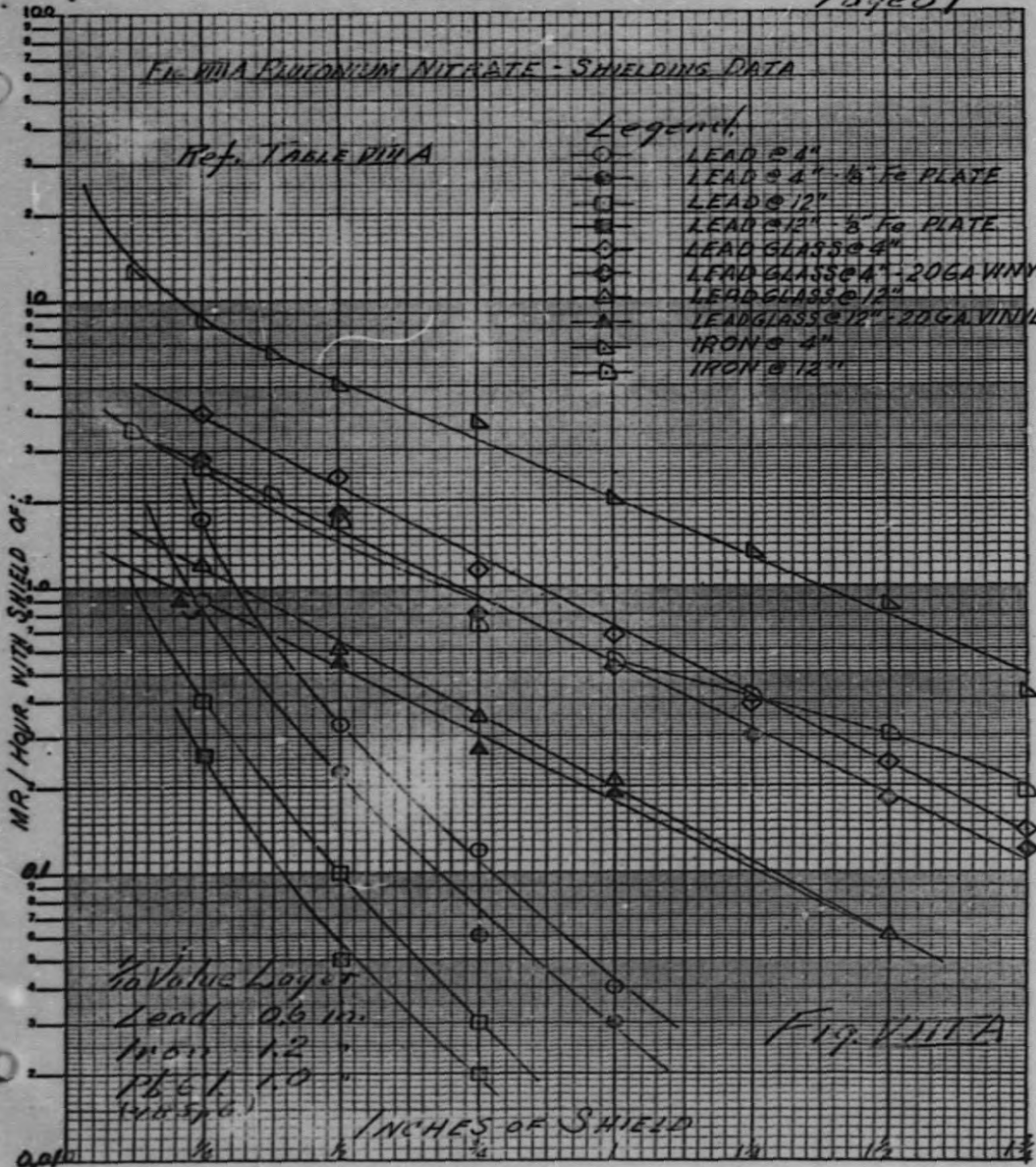
# - Inches Between Instrument Face and Source	0	4	12
Dose Rate in mr/hour Without Shielding	C.P. Window Open   117	38.5	12.5
Other Than Packaging	C.P. Window Closed   95	29.5	9.5

FIG. VIII PLUTONIUM NITRATE - SHIELDING DATA

Ref. TABLE VIII A

Legend

- LEAD @ 4"
- LEAD @ 4" - 1/8" Fe PLATE
- ◊ LEAD @ 12"
- ◐ LEAD @ 12" - 1/8" Fe PLATE
- ◇ LEAD GLASS @ 4"
- ◑ LEAD GLASS @ 4" - 20 GA VINYL
- △ LEAD GLASS @ 12"
- ◒ LEAD GLASS @ 12" - 20 GA VINYL
- ▽ IRON @ 4"
- ◓ IRON @ 12"



1/10 Value Layer  
 Lead 0.6 in.  
 Iron 1.2 "  
 Pb 6.1 1.0 "  
 (1.0576)

FIG. VIII A



TABLE VIII B-1

Plutonium Oxalate Shielding Data

Samples: Series I, II, III - Total of 1211 Grams  
Reference: HWN-2145 - Pages 133-136

Inches of Shield	Mr/Hour With Shield Of					
	** Lead		*** Lead Glass (4.8 Sp Gr)		I r o n	
	④"	⑫"	④"	⑫"	④"	⑫"
0 #						
1/8						4.5
1/4	3.0 (2.1)	0.79 (0.60)	8.2 (6.0)		12.5	3.5
3/8					10.0	2.8
1/2	0.70 (0.55)	0.19	(3.2)		7.4	2.2
3/4	0.24	0.06	(2.0)		5.3	
1	0.10	0.03	(1.2)	(0.4)	4.4	1.0
1½			(0.85)		2.6	
1¾			(0.55)		2.0	
1-3/4			(0.38)		1.2	
2			(0.24)		0.8	0.2

\*\* - Readings taken with .020 inch plastic sheeting between shield and detector for values in parentheses. When plastic sheeting was placed between source and shield instead of between shield and detector, reading was essentially same as with shield only.

# - Inches Between Instrument Face and Source

Dose Rate in mr/hour	C.P. Window Open	0	4	12
(Shielded by packaging only)	C.P. Window Closed	170	67	20
		140	46	14.5



TABLE VIII B-2

Plutonium Nitrate and Oxalate Shielding Data  
For Safety Glass

Samples: Series I - Nitrate and Series I - Oxalate.  
Reference: HWN-2145 - Page 17.

<u>Inches of Shield</u>	<u>Mr/hour through safety glass, as measured @ 3"</u> <u>with survey instrument as indicated</u>			
	<u>T.P.</u>	<u>C.P. W.O.</u>	<u>C.P. W.C.</u>	<u>Sampson</u>
0	55.5	42.0	31.0	Off-scale
$\frac{1}{8}$	17.5	9.0	8.5	13.7
$\frac{1}{4}$	15.5	8.5	8.0	12.8
$\frac{3}{4}$	13.5	7.5	7.0	11.5
1	12.7	7.0	6.5	10.7
$1\frac{1}{4}$	12.0			
$1\frac{1}{2}$	10.5			
$1\frac{3}{4}$	9.0			



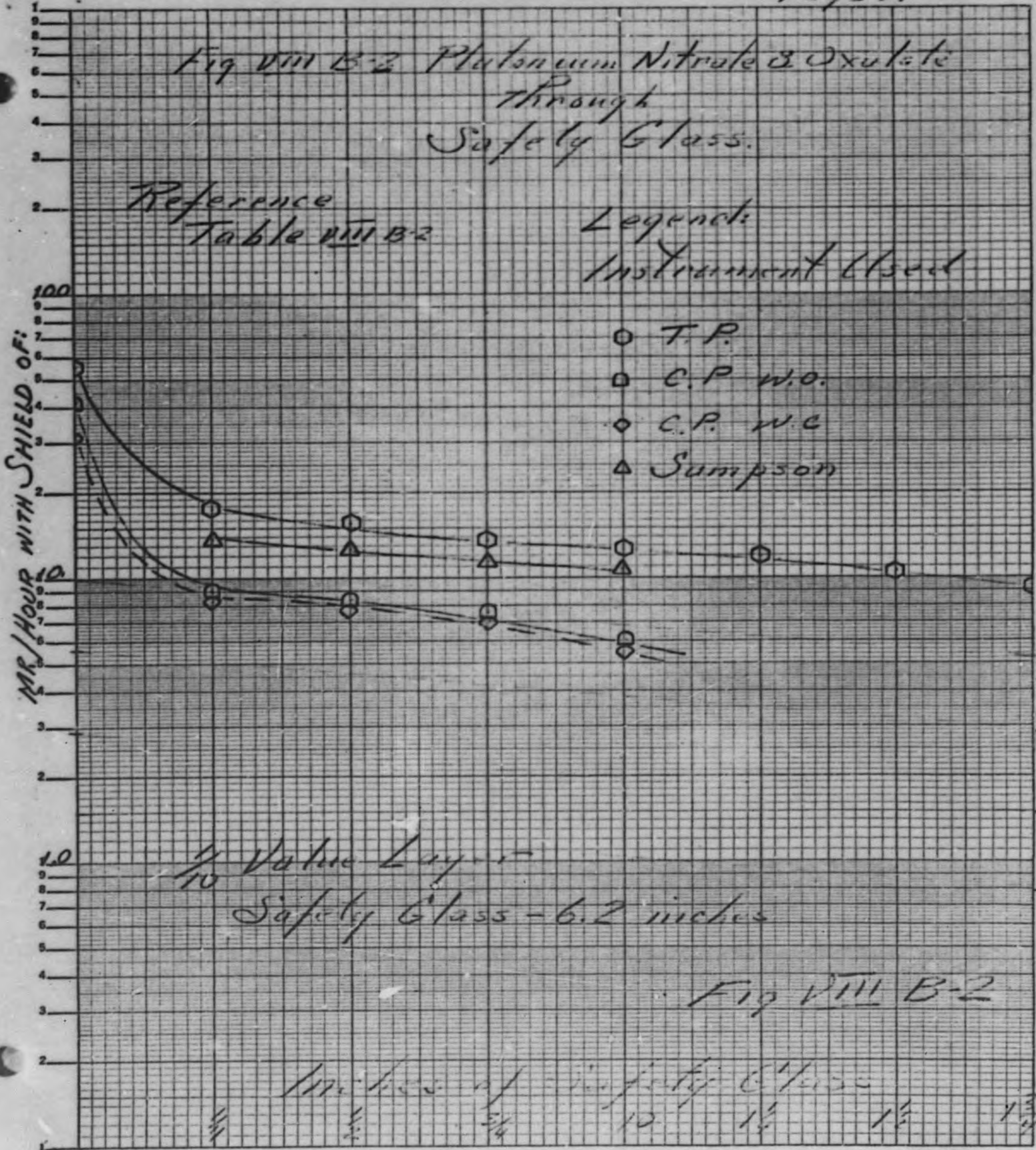
Fig VIII B-2 Plutonium Nitrate & Oxalate  
Through  
Safety Glass.

Reference  
Table VIII B-2

Legend:  
Instrument Used

MR/HOUR WITH SHIELD OF:

- T.P.
- ◻ C.P. W.O.
- ◊ C.P. W.C.
- △ Sumpson



1/10 Value Layer  
Safety Glass - 6.2 inches

Fig VIII B-2

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TABLE VIII C

Plutonium Oxide - Shielding Data

Samples: Series I, II, III - Total Pu = 1160 Grams  
Reference: HWN-2145 - Pages 124, 125, 132

Inches of Shield	Mr/hour With Shield Of					
	*L e a d		**Lead Glass		I r o n	
	@4"	@12"	@4"	@12"	@4"	@12"
0	60.0	18.0		5.50		
1/8					14.5	5.7
1/4	5.0 *(3.25)	1.3 (0.85)	12.7 (10.0)	3.25 (2.55)	11.5	4.4
3/8					13.0	3.5
1/2	1.6 (1.05)	0.40 (0.32)	7.5 (6.2)	2.0 (1.7)	11.25	3.0
3/4	0.85 (0.60)	0.18 (0.12)	4.8 (4.0)	3.3 (2.5)	8.0	2.3
1	0.38 (0.29)	0.10 (0.007)	3.3 (2.5)	0.8 (0.8)	5.5	1.6
1 1/8	0.22 (0.18)		2.1		4.0	1.1
1 1/4			1.5		2.6	0.8
1-3/4			1.1		2.15	0.50
2			8.5	6.2	.4	0.37

\* 1/8" iron over lead toward detector for values in parentheses.

\*\* 20 Ga plastic over lead glass towards detector for values in parentheses.

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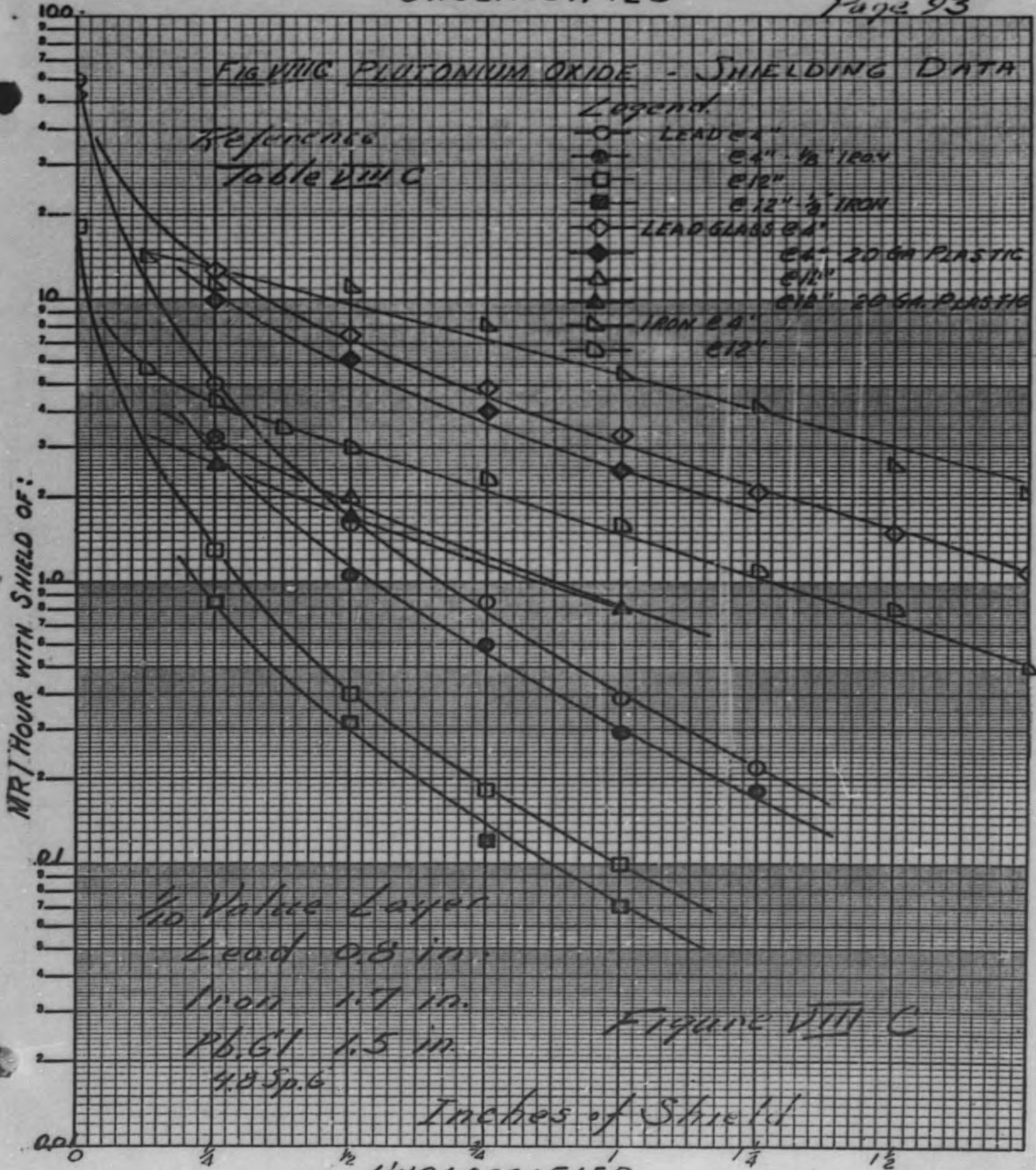


FIG VIII C PLUTONIUM OXIDE - SHIELDING DATA

Reference  
Table VIII C

Legend

- LEAD 2"
- 2" - 1/8" IRON
- 2" IRON
- 2" - 1/2" IRON
- ◇ LEAD GLASS 2"
- ◆ 2" - 20 GA PLASTIC
- △ 2" IRON
- ▽ 2" - 20 GA PLASTIC
- IRON 2"
- 2"



1/10 Value Layer  
 Lead 0.8 in.  
 Iron 1.7 in.  
 Pb, GI 1.5 in.  
 4.8 Sp. G

Figure VIII C

Inches of Shield



TABLE VIII D-1

Plutonium Fluoride Shielding Data

Samples: Series I, II, III - Total of 1283 Grams Pu  
 Reference: HW-2145 - Pages 122-123.

Inches of Shield	Mr/Hour With Shield Of					
	* Lead		**Lead Glass		# Iron	
	@4"	@12"	@4"	@12"	@4"	@12"
0	65	19			65	19
1/8					21.0	8.0
1/4	11.3 (9.7)	3.5 (3.2)	4.0 (12.0)		17.0	6.5
3/8					14.0	3.5
1/2	6.7 (6.25)	2.4 (2.25)	13.0 (11.2)		13.0	4.8
3/4	6.0 (5.7)	1.95 (1.85)	9.0 (8.5)		10.0 13.0 S	4.0
1	4.9 4.7	1.7 (1.7)	7.2 (7.0)		10.6 S	3.2
1 1/8	4.0 (4.0)	1.45	6.0 (6.0)		8.7 S	2.6
1 1/4	3.57	1.35	5.4 (5.4)		7.2 S	2.1
1-3/4			4.0 (4.0)		6.0 S	1.8
2			3.7 (3.7)		5.7 S	1

\* Readings in parentheses taken with 1/8-inch iron between shield and detector.

\*\* Reading in parentheses taken with .020-inch plastic sheeting between shield and detector.

# "S" after dose rate indicates reading is with Sampson.

FIG VIII D-1. PLUTONIUM FLUORIDE -  
SHIELDING DATA

Reference: Table VIII D-1

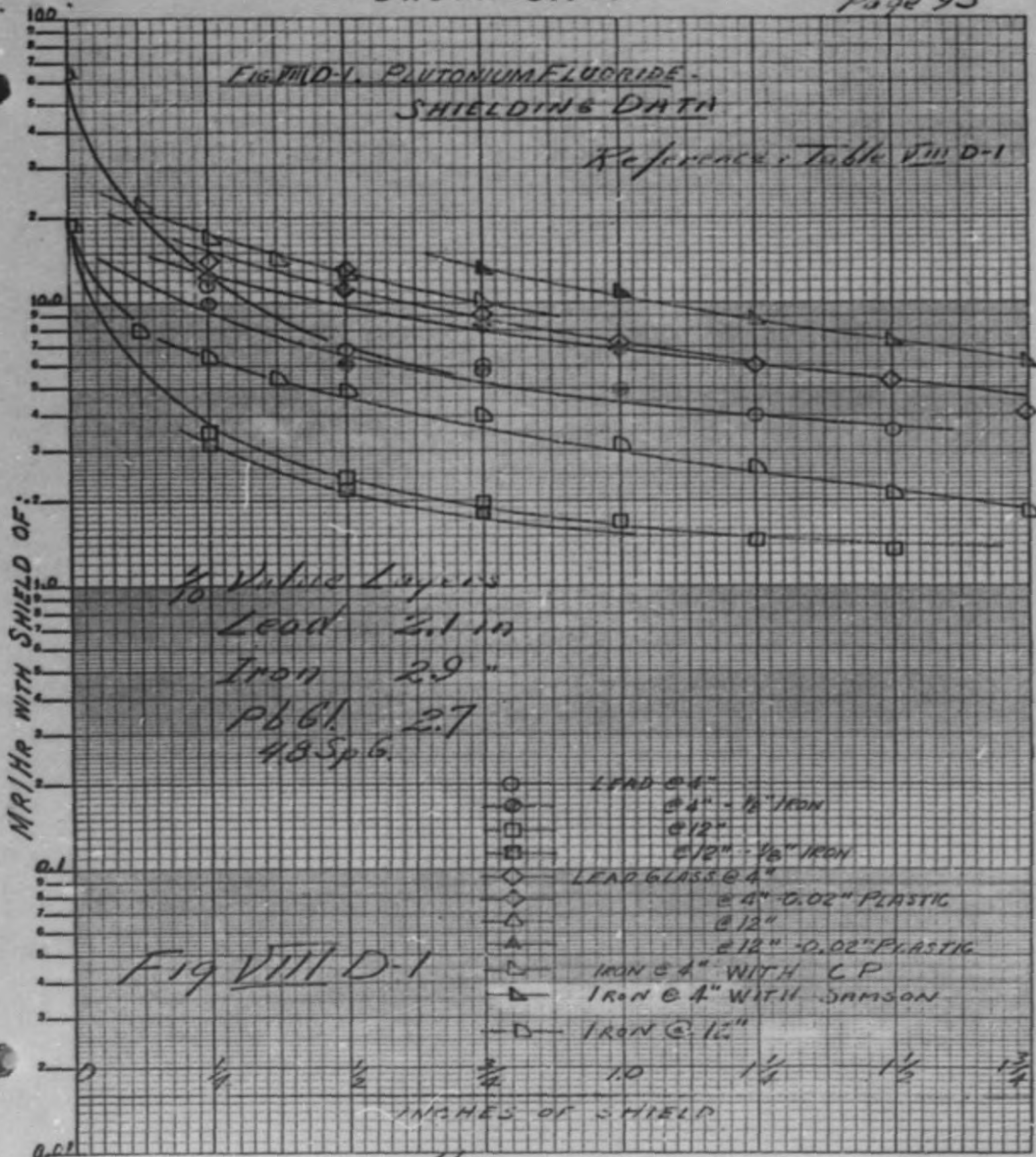


Fig VIII D-1

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TABLE VIII D-2

Plutonium Fluoride - Shielding Data

Samples: Series I, II, III - Total of 1283 Grams Pu  
Reference: HW-2145 - Pages 110-120

Inches of Shield	Mr/Hour With Shield Of						Iron		
	** Lead		** Lead Glass						
	<u>021"</u>	<u>06"</u>	<u>012"</u>	<u>021"</u>	<u>06"</u>	<u>012"</u>	<u>021"</u>	<u>06"</u>	<u>012"</u>
0									
1/8							18		
1/4	9.0 (8.5)	5.2 (4.8)	2.1 (2.0)	16 (14)	8 (7)	4 (3)	13	8.0	3.0
3/8							13	6.0	2.2
1/2	5.5	2.7	1.2	12 (10)	6 (5.5)	3 (3)			
3/4	4.0	1.2					10.4	16	
1	3.2			8.0	4.0 (3.5)	1.75 (1.60)	9.6	4.7	
1 1/4							8.0	5.0	
1 1/2				5.2	3.0	1.3	5.7	3.7	
1-3/4									
2				2.7	2.2			1.5	

\*\* Readings in parentheses taken with .020-inch plastic sheeting between source and detector.

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TABLE VIII E-1

Plutonium Metal - Shielding Data

Samples: B-126, 129, 58 - Total 3162 Gr. Pu  
Reference: HW-2145 - Pages 137-140 Data Taken with C.P.

Inches of Shield	Mr/Hour With Shield Of					
	Lead		**Lead Glass		Iron	
	<u>0.4"</u>	<u>0.12"</u>	<u>0.4"</u>	<u>0.12"</u>	<u>0.4"</u>	<u>0.12"</u>
0	See Table VIII-E-2 for Values Through Lead		24.0	6.2		
1/8					9.0	2.7
1/4			6.0 (4.0)	1.4 (1.0)	7.2	2.0
3/8					5.5	1.8
1/2			3.3 (2.7)	0.72 (0.60)	4.3	1.5
3/4			2.0 (1.6)	0.45 (0.38)	3.7	1.3
1			2.1 (1.0)	0.31 (0.27)	2.2	0.7
1 1/4			0.8 (0.7)	0.18 (0.18)	1.7	0.5
1 1/2			0.55 (0.55)	0.11 (0.11)	1.1	0.4
1-3/4					0.9	0.3
2			0.5	0.2		

\*\* Readings in parentheses taken with .020-inches plastic between source and shield.

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FIGURE-1 PLUTONIUM METAL - SHIELDING DATA

Reference  
Table VIII E-1

- ◇ IRON AT 4 INCHES
- △ IRON AT 12 INCHES
- ▽ LEAD GLASS AT 4 INCHES
- ▲ DO. WITH 0.02" PLASTIC
- ◊ LEAD GLASS AT 12 INCHES
- DO. WITH 0.02" PLASTIC

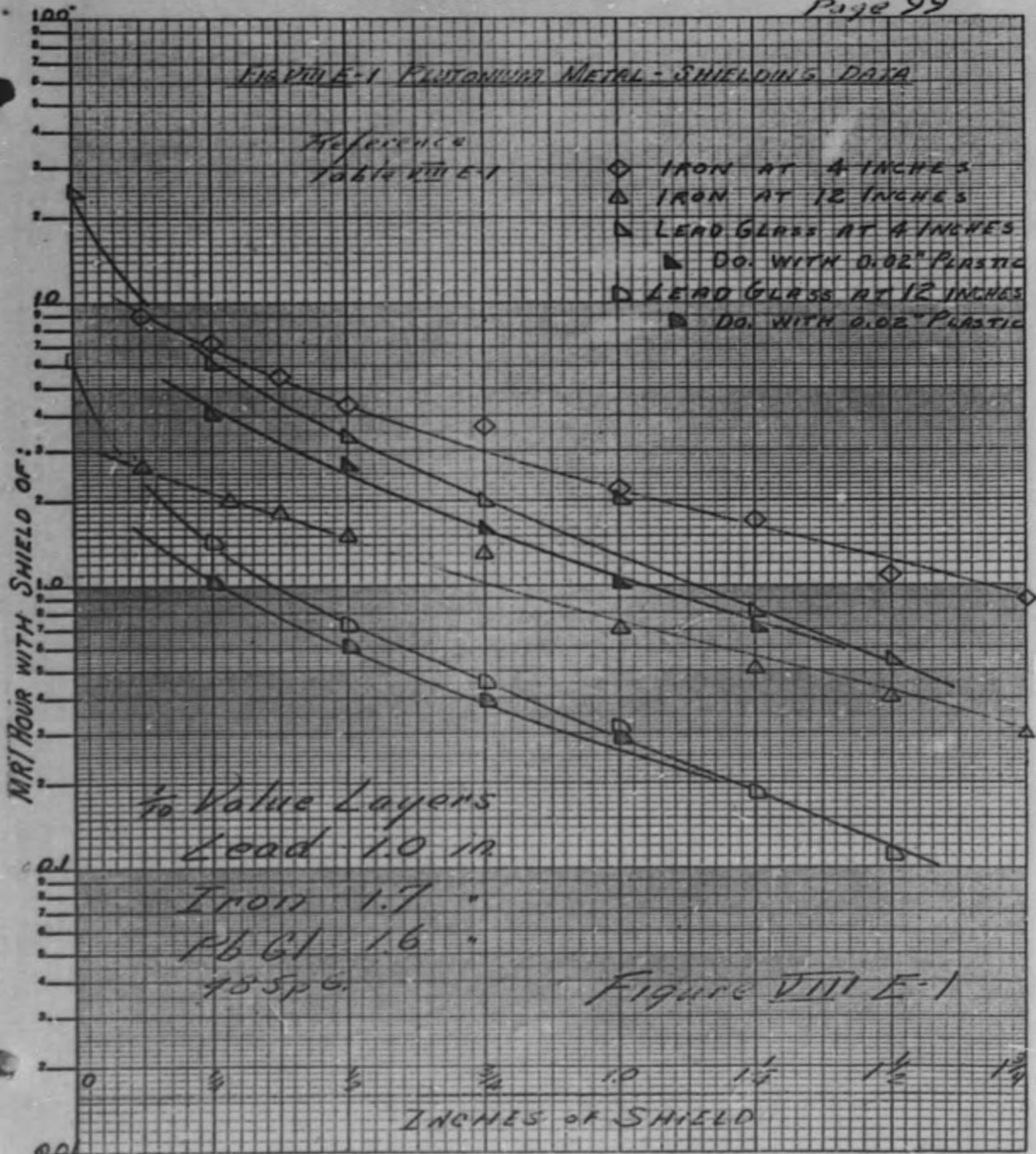


Figure VIII E-1



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TABLE VIII E-2

Plutonium Metal - Shielding Data

Samples: B-129 (Y-18.2 - 129) - Total of 1003 Grams

Reference: HW-2145 - Pages 39 - 39

Mr/hr Taken with a C.P. - TP  
Through a Shield of

Inches of Shield	L e a d		Lead Glass		Lucite		Safety Glass	
	<u>①"</u>	<u>①'</u>	<u>①"</u>	<u>①'</u>	<u>①½"</u>	<u>①'</u>	<u>②½"</u>	<u>①'</u>
0	290	9.0	195	9.2	150	9.0	94	9.5
1/8	31.0	3.0						
1/4	16.5	2.0	21.5	2.5			2.3	3.3
3/8	9.0	1.5			75.0	6.0		
1/2	5.5	1.25	15.0	2.0			19.0	3.0
3/4			7.5	1.5	53.0	4.5	17.3	
1			5.0	1.2			15.5	2.7
1-1/8					44.5	4.0		
1-1/2					32.0	3.5	15.0	2.5

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FIG. VIII-2 PLUTONIUM METAL SHIELDING DATA

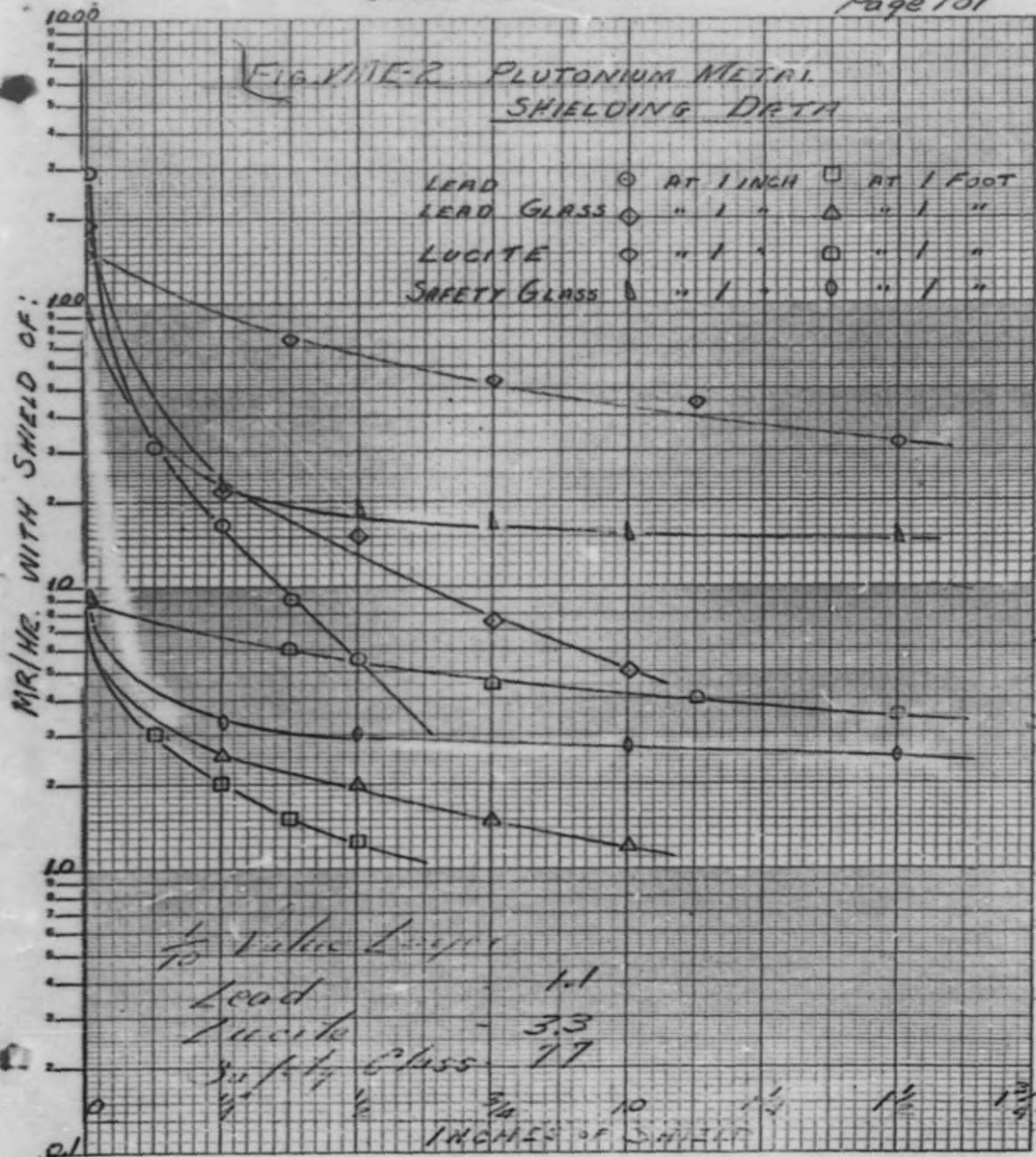


TABLE VIII F

Shielding Effectiveness for Plutonium Compounds & Metal  
Based on Dose Rates As Measured Through Shielding  
Summarized From Figures VIII A-E

Plutonium Material To Be Shielded	Grams of Plutonium In Sample Used	*Mr/hour @4" With Shielding As Shown Below For Samples As Used				Inches of Shielding Required For 10-Fold Reduction In Dose Rate Of *Hardened* Gamma Radiation			
		No Shield	$\frac{1}{4}$ " Lead Glass 4.8 Sp G	$\frac{1}{2}$ " Lead	$\frac{1}{2}$ " Iron	Lead	Lead Glass 4.8 Sp G	Iron	
Nitrate	423	39	2.8	0.9	5.0	0.6	1.0	1.2	
Oxalate	1211	52	6.0	2.1	7.4	0.7	1.3	1.6	
Oxide	1160	60	10.0	3.3	11.5	0.8	1.5	1.7	
Fluoride	1283	65	12.0	9.7	13.0	2.1	2.8	3.0	
Metal	3162	24	4.0	*3.2	4.3	1.1	1.6	1.7	

\* Calculated Value

**END**