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GAMMA ENERGY ANALYSIS OF THE RMA LINE AND RECUPLEX

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GAMMA ENERGY ANALYSIS OF THE RMA LINE AND RECUPLEX

By:

C. L. BROWN

FINISHED PRODUCTS TECHNOLOGY
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GAMMA ENERGY ANALYSIS OF THE RMA LINE AND RECUPLEX

I. INTRODUCTION

Knowledge has developed steadily over the past 18 months toward defining the characteristics of the gamma and neutron radiation associated with plutonium and its compounds. Laboratory measurements have been made on plutonium samples taken from the RMA Line[1, 2, 3, 4], film badge studies have been made in plutonium processing areas[9], and calculations have been made predicting dose rates and shielding requirements at higher plutonium exposure levels.[5, 6, 7, 8] As these studies continue, and more precise data is accumulated, it will be possible to (1) more accurately evaluate the radiation received by operating personnel, and (2) more accurately (and economically) specify shielding for facilities designed for processing high exposure plutonium.

This report gives the results of a gamma energy analysis of the RMA Line and Recuplex obtained with a laboratory model gamma spectrometer.

II. SUMMARY

Measurements have been made in the 234-5 Building which have defined the general gamma energy spectrum emitted by the plutonium processing hoods on the RMA Line and in Recuplex. The data obtained from this study has helped resolve the discrepancy between laboratory data and film badge data, and has provided additional information to help in prediction of the gamma radiation levels to be expected from plutonium irradiated to 2000 MWD/T (NPR) and 10,000 MWD/T (PRTR).

From a correlation of this study with laboratory measurements, theoretical calculations, and film badge data, the following observations are made:

1. The gamma energy spectrum on the RMA Line is essentially the same as the spectrum predicted from theoretical calculations and laboratory measurements. There are eight major gamma energy groups (or peaks) emitted from plutonium and its compounds:

17 KEV (Pu)	380 KEV (Pu)
60 KEV (Pu)	500 KEV (Ru)
100 KEV (Pu)	750 KEV (Zr)
200 KEV (Pu)	1.3 MEV (Na)

The 17, 60, 100, 200, and 380 KEV energies were prevalent at all locations on the RMA Line and in Recuplex; the 500 KEV (Ru) was found to be significant only in the R & B Hood in Recuplex; the 750 KEV (Zr) was found at nearly all locations in low percentage; and the 1.3 MEV (Na^{22}), although not detected at any location, may be present in low percentage in Tasks II and III. (Spectrometer sensitivity is low for 1.3 MEV.)

2. The quantity of each gamma energy emitted from the 23 processing locations that were measured ranged as follows:

Gamma Energy (KEV)	Number of Locations	Range of Amount (%)
17 + 60	10	80 - 94
	13	43 - 79
100	20	2 - 8
	3	10 - 20
200	21	1 - 5
	2	8 & 12
380	9	2 - 6
	14	10 - 31
750	18	0 - 4
	2	9 & 18
	3	20 - 24

3. The age, amount, and degree of dispersion of plutonium in the various hoods appear to be the main variables influencing energy distribution. The relative importance of these variables on the level of each gamma energy is estimated to be as follows:

Energy (KEV)	Pu Mass	Pu Age	Pu Dispersion
17	1	1	2
60	1	2	1
100	1	0	1
200	1	2	0
380	2	0	0
500	2	0	0
750	2	0	0

0 Relatively no effect
1 Small effect
2 Large effect

4. The gamma spectrometer data does not confirm film badge exposure information. The comparison is as follows:

	Average Dose Rate Distribution	
	17 KEV + 60 KEV	100 KEV and Over
Gamma Spectrometer Data (Table I)	70%	30%
Film Badge Date (Table IV)	28%	72%

It is assumed that the recent gamma spectrometer data is more nearly correct. Body shielding of the film badge and film density calibration problems may account for the discrepancy.

5. Shielding with ¼" X-Ray lead glass (1/16" lead equivalent) will reduce the major gamma energies as follows (theoretical factors are shown for comparison):

	% of Gamma Flux "Stopped" by ¼" X-Ray Glass	
KEV	Gamma Spectrometer Data (Table I, Part 3)	Calculated (e^{-ut})
17 + 60 + 100	>95%	>95%
200	70%	82%
380	39%	35%
750	20%	15%

6. Based on the data from this study, it is estimated that shielding the RMA Line and Recuplex with ¼" X-Ray glass (or equivalent) would reduce the dose rate at each location by at least 80%, and at some locations, over 90% (650 MWD/T plutonium); 1-3/16" lead glass, by 95% or more.

III. DISCUSSION

1. Purpose of Study

The amount of gamma shielding that will be required on equipment designed for processing high exposure plutonium will depend greatly on the effective gamma energies to be shielded. For example, if the majority of the gamma photons from the plutonium are above 200 KEV, more shielding would be required than if the majority were below 200 KEV.

Two studies made in 1958 gave opposing data. Laboratory analysis of the gamma from plutonium and its compounds indicated that most of the gamma was below 200 KEV. Film badge measurements made directly on the RMA Line, on the other hand, indicated that the majority of gamma was

above 100 KEV (radium-gamma). Even though it was believed that the laboratory data was more nearly correct, the film badge data carried more weight as a shielding basis, because the measurements were made directly on the plutonium processing equipment; also, there was no assurance that the gamma spectrum from the plutonium samples in the laboratory were representative of the actual gamma field around the processing equipment.

To help resolve this problem, it was decided to obtain gamma energy measurements directly on the RMA Line equipment, using a laboratory model gamma spectrometer.(10) These measurements were, therefore, taken during the three week period of April 27, 1959 through May 15, 1959. A gamma spectrometer was borrowed from the Analytical Laboratory Operation, Hanford Laboratories Operation, and was operated by an HLO chemist.

2. Measurements

a. Gamma Spectrometer Scans

Gamma energy measurements were made with a mobile, single channel gamma spectrometer from the 300 Area. To obtain a low background and to make the gamma detector directional, the photo tube and crystal were encased in a cylinder of lead 1" thick. Lead collimators were then inserted into the open end of the lead cylinder in front of the crystal to obtain an optimum degree of sensitivity and wide field coverage. Three sizes of collimator openings were used: ½", 1", and 1½". Most of the gamma scans were made with the 1" collimator at a distance of about 48" from the processing hood. At this distance, the sensing crystal "sees" a circle area (or hood area) about five feet in diameter. Other scans were taken closer to the hoods using the smaller collimator.

Three set-ups were necessary to cover the gamma energy range from 0 to 2 MEV. In general, these set-ups were as follows: for 17 KEV, thin crystal, normal settings; for 50 KEV to 1.0 MEV, 2" crystal, normal settings; for 50 KEV to 2.0 MEV, 2" crystal, decrease gain by a factor of two.

To determine the exact location of the gamma peaks on the recorder chart, an Am^{241} standard and a cesium^{137} standard were used with each scan; Am^{241} gives a 60 KEV peak and Cs^{137} gives a 0.66 MEV peak. A gamma background was also taken at nearly all locations. The general procedure for taking a complete gamma scan was thus as follows:

(1) Set up photo tube and select a collimator such that the dose rate at the crystal is 1 - 4 mr/hr.

(2) Cover the photo tube with a 2" lead brick and take the background scan.

(3) Place the Cs^{137} standard in front of the photo tube and locate the 0.66 MEV peak.

(4) Scan from 900 KEV down to 50 KEV.

(5) Place a ¼" X-Ray glass plate over photo tube and repeat scan.

(6) Repeat with other absorbers, if necessary.

(7) Change gain setting and scan (without absorber) from 1.5 MEV down to 0.9 MEV.

(8) Repeat with absorber, if necessary.

(9) Change crystals and place Am^{241} standard in front of photo tube to locate 60 KEV peak.

(10) Scan for 17 KEV.

A complete scan, taken as above, requires about 1½ hours.

b. GM Measurements

For comparison purposes and to obtain gross gamma flux measurements at each processing location, a standard Geiger-Mueller (GM) counter was used in conjunction with the spectrometer. The Geiger tube was shielded on three sides by ¼" of lead in order to reduce the background and to make the measurements directional. The field of view of the GM tube was thus about 80 degrees.

The gamma counting range of the GM instrument is 100,000 c/m as measured at three sensitivities on one scale: 0 - 1000 c/m, 0 - 10,000 c/m, and 0 - 100,000 c/m. When the gamma spectrometer measurements were made, three measurements were also made on the GM as follows: 1) with no absorber, 2) with an 80 mil aluminum absorber (which stops nearly all 17 KEV), and 3) with a ¼" X-Ray glass absorber.

The efficiency of the GM counter is low at energies much below 500 KEV. For the major plutonium and fission product gamma energies, these efficiencies are approximately as follows:

KEV	GM EFFICIENCY
17	50%
60	90%
100	83%
200	48%
380	63%
500	83%
750	100%
1.3 MEV	100%

A calibration of the GM to dose rate was made by R. E. Slater, Radiation Monitoring Unit, Processing Operation, using a C.P. and a standard plutonium gamma source. It is estimated that 5000 c/m on the GM is equivalent to about one mr/hr.

IV. RESULTS AND CONCLUSIONS

Twenty-three locations on the RMA Line and in Recuplex were scanned with the spectrometer. The energy range covered was 0 to 1.0 MEV and, in some cases, 0 to 2.0 MEV. The results of these scans are shown in Figures 1 - 25.

Table I shows a summary of the overall data in Figures 1 - 25. The first part of Table I shows the percentage distribution of the major gamma energy groups (or peaks) and the second part shows the ratio of each energy to the 380 KEV peak. These latter ratios simplify analyzing the data because the effect of the varying field intensity is eliminated; also, the 380 KEV peak (due primarily to Pu^{239}) is relatively stable compared to the other peaks, and is therefore a fairly good index for comparing data.

Table II gives the present field dose rate at each of the locations studied and the dose rate expected if shielded with ¼" X-Ray glass or equivalent (taken from Figures 1 - 25). Also given is the present neutron dose rate at each location. The unshielded gamma dose rate measurements were obtained by RMU personnel using a C.P.

Table III gives a series of GM measurements taken on the RMA Line and in Recuplex prior to the current gamma scan measurements. This information is presented as supplementary to other data in this report.

Table IV lists the gamma dose received by 40 RMA Line and Recuplex operators between December 15, 1958 and March 9, 1959, and was obtained from film badge exposure records in HLO. This information is also given as supplementary data for analyzing the overall shielding and exposure problem.

The following observations are based on the results of this study:

IV. RESULTS AND CONCLUSIONS (Continued)

1. Gamma Energy Spectrum

The spectrometer data obtained from plutonium processing areas confirms previous theoretical and laboratory data.[7] Essentially, there are eight major gamma energy groups (or peaks), and these include 34 primary gamma energies. Briefly, these groups are as follows:

Major Energy Group or Peak (KEV)	Range of Energies in Group (KEV)	Contributing Isotopes
17	14 - 26	Pu^{238}, Pu^{239}, Pu^{240}, Am^{241}
60	37 - 65	Pu^{238}, Pu^{239}, Am^{241}, U^{237}
100	99 - 145	Pu^{238}, Pu^{239}, Pu^{241}, Am^{241}
200	150 - 208	Pu^{238}, Pu^{239}, U^{237}
380	268 - 420	Pu^{239}, U^{237}
500	500 - 620	Ru^{103}, Ru^{106}, Rh^{106}
750	750	Zr^{95}
1.3 MEV	1.3 MEV	Na^{22} (F^{19} α, n Na^{22})

2. Location of Major Gamma Energies

The 17, 60, 100, 200, and 380 KEV peaks were found at all plutonium processing locations.

The 500 KEV peak (Ru) was detected at only one location, the R & B Hood in Recuplex. At all other locations, the 500 KEV was less than 1% of the total gamma radiation.

The 750 KEV peak (Zr) was found in low quantity at several locations where fairly large quantities of plutonium were in process. Certain individual pieces of plutonium metal showed fairly high amounts. The highest 750 KEV concentration was in the R & B Hood in Recuplex.

The 1.3 MEV peak (F^{19} α, n Na^{22}) was not detected on the RMA Line (at Hood 9-A in particular). It should be pointed out, however, that the gamma spectrometer used may have a low sensitivity for 1.3 MEV photons, so the limit of detectability is probably a few percent. A plutonium fluoride sample 18 months old was measured on the spectrometer and showed 4% not including the 17 KEV (see Figure 25).

3. Distribution of Gamma Energies

From Table I, a general picture of the gamma energy distribution on the RMA Line is as follows:

Gamma Energy (KEV)	Number of Locations	Range of Amount (%)
17 + 60	10	80 - 94
	13	43 - 79
100	20	2 - 8
	3	10 - 20
200	21	1 - 5
	2	8 & 12
380	9	2 - 6
	14	10 - 31
750	19	0 - 4
	2	9 & 18
	3	20 - 24

4. Cause of Variance in Gamma Energy Distribution

It is observed in Table I that the relative amounts of gamma photons at the various gamma energies vary as the amount, age, and/or surface area of the plutonium. In general, these variances appear to occur as follows:

KEV	Amount of Pu Present	Pu Age	Degree of Dispersion (i.e., Scattered PuO_2 or PuF_4)
17	1	1	2
60	1	2	1
100	1	0	1
200	1	2	0
380	2	0	0
500	2 *	0	0
750	2 *	0	0

0 - Relatively no effect
1 - Small effect
2 - Large effect

* It should also be noted that the amount of 500 KEV (ruthenium) and 750 KEV (zirconium) present in many areas is influenced by the DF at Purex and Redox.

5. Gamma Energy Data Compared to Film Badge Data

The distribution of gamma as recorded on personnel film badges at several locations on the RMA Line is shown in Table IV. A summary of these data is as follows:

Location	No. of Operators in Group	Average Distribution of Dose (%)			Average Two-Week Dose per Operator (58 Day Period)
		17 KEV	60 KEV	Radium-Gamma (> 100 KEV)	
Hood 5, PR Can Unloading, General I, II, III Work	7	23	10	67	548 mr
Hoods 7, 9-A, Tasks III, IV	20	15	13	72	609 mr
Task V	12	8	17	75	671 mr
Briquetting	2	7	16	77	633 mr
Recuplex	12	23	10	67	623 mr

6. Comparison of Gamma Spectrometer Data to Personnel Film Badge Data

The average gamma spectrometer data (paragraph 3) and film badge data (paragraph 5) compare as follows:

	Average Breakdown	
	17 KEV + 60 KEV	100 KEV and Over
Film Badge Data	28%	72%
Gamma Spectrometer Data	70%	30%

It is now presumed that the gamma spectrometer data is more nearly correct. There are two possible explanations as to why the film badge data is distorted:

a. Not all of the 17 and 60 KEV is "seen" by the film badge. Radiation coming from behind the operator (i.e., when he turns his back on the major gamma field) would be attenuated by his body such that only the harder gamma would reach the badge.

b. The film density of the over 60 KEV fraction (radium-gamma) may be bias high due to the calibration curve of the film (i.e., film density vs gamma energy vs dose).

This would tend to indicate that gamma energy distribution as indicated by the film badges is bias. However, whether the actual dose measured by the badge is high, low, or nearly correct cannot be estimated accurately at this time. This problem will be pursued further by PRO, Finished Products.

7. Attenuation of Gamma Flux by ¼" X-Ray Glass

The attenuation of the major photon energies by ¼" X-Ray glass as measured on the RMA Line (averaged from Table I) are compared below to the attenuation predicted by calculation (i.e., e^{-ut}, neglecting build-up).

	% of Gamma Flux "Stopped" by ¼" X-Ray Glass	
KEV	Gamma Spectrometer Data (Table I, Part 3)	Calculated (e^{-ut})
17 + 60 + 100	>95%	>95%
200	70%	82%
380	39%	35%
750	20%	15%

By applying these factors to the gamma distributions in paragraph 4, it is estimated that ¼" X-Ray glass (or equivalent) will give an overall reduction in gamma flux of at least 80% and, in some cases, over 90%. To achieve this reduction, gloves must be excluded from the field, since a glove alone can have a dose rate of about 20 mr/hr (as several do in Hood 9-A), due mainly to 17, 60, and 100 KEV from PuO_2 dust on the surface.

8. Reduction in Dose Rate by ¼" X-Ray Glass

Table II shows the application of attenuation factors for ¼" X-Ray glass to the actual dose rates on the RMA Line. Briefly, these results show the following:

Locations	Dose Rate After Shielding
RMA Line (except Hood 9-A)	L 1 mr/hr @ 3"
Hood 9-A	1 - 3 mr/hr @ 3"
Recuplex - SE Hood	0.4 - 2.0 mr/hr @ 3"
S & C Hood	L 1 mr/hr @ 3"
RB Hood	2 - 7 mr/hr @ 3"

(Neutron doses are excluded)

It should be noted that in order to apply the reductions in gamma flux (γ/sec/cm^2) to dose rate (mr/hr) estimates, correction factors must be used to account for the relative differences in biological effectiveness of the different gamma energies. These factors are as follows:(11)

Energy KEV	Effectiveness Factor Use in Changing Gamma Flux to Dose Rate (60 KEV = 1)
17	7.6
60	1.0
100	1.3
200	3.2
380	6.7
500	9.2
750	12.8
1300	19.4

V. ACKNOWLEDGEMENTS

The writer wishes to acknowledge the assistance of H. E. Palmer, Analytical Laboratory, HLO, who spent three weeks obtaining the gamma energy data on the RMA Line, and to R. E. Slater and H. A. Moulthrop for their most helpful consultation and assistance.

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TABLE I

SUMMARY OF GAMMA SCAN DATA

(Taken from Figures 1 - 25)

		Hood No.															
	KEV	3	5	7	L	9-A ** C	T	14DC	16BS	17	200A	200C	200BR	22BD	24 SS*	24 GV*	27R
% Gamma Flux in each gamma group	17	50	40	33	65	67	60	48	60	30	44	46	40	40	0	45	38
	60	44	15	45	15	14	14	34	8	62	50	32	13	23	39	45	8
	100	3	4	7	7	4	6	8	6	2	2	8	11	10	34	6	20
	200	2	2	2	3	2	1	4	2	1	1	3	3	4	10	1	5
	380	2	10	10	10	10	19	6	20	5	2	10	31	20	17	3	27
	500	ND*	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	750	-	28	4	ND	2	ND	ND	4	ND	1	1	2	3	ND	ND	2
	1.3MEV	-	-	-	-	ND	-	-	ND	-	-	-	-	-	-	-	-
Ratio of each gamma energy to 380 KEV	17	25	4.0	3.2	24	6.2	3.2	7.9	3.0	5.5	18	4.8	1.3	2.0	0	15	1.4
	60	22	1.5	4.4	1.5	1.3	0.7	5.5	0.4	12	20	3.3	0.4	1.2	2.3	15	0.3
	100	1.3	0.4	0.4	0.7	0.4	0.3	1.4	0.3	0.4	0.7	0.8	0.4	0.5	2.0	2.1	0.8
	200	0.9	0.2	0.2	0.3	0.2	0.1	0.7	0.1	0.2	0.4	0.3	0.1	0.2	0.6	0.4	0.2
	380	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	500		0.1														
	750		2.8	0.4		0.2			0.2			0.2	0.1	0.1			0.1
% Reduction of each gamma group with ¼" X-Ray Glass	17) 60) 100)	99	95		>95	>95	93	96	>95	98	>95	-	>95	>95	98		>95
	200	82	42		70	69	66	82	75	75	77	-	74	82	68		69
	380	30	28		48	36	43	55	41	39	44	-	46	42	29		30
	500		-														
	750		29	-	-				17		-	-	15	28			14

* ND = Not Detected
SS = Scan taken through 3/4" steel.
GV = Scan taken through glove.

** L - Lower
C - Center
T - Top

TABLE I (Continued)

	KEV	Hood No. HC22	HC24C 2'	HC24C GS*	HC24C GV*	Recuplex S & E 1(11')	S & E 1a(b")	S & E #2	S & C #3	S & C #4	R & B #5	R & B #6	PuO_2 in Glass Bottle	PuF_4 in 1/8" Wall Al Tube
% Gamma flux in each gamma group	17	40	3	12	61	42	49	49	27	31	39	28	-	-
	60	2	59	54	29	27	13	21	62	55	18	15	43	56
	100	7	19	19	5	7	9	7	3	4	4	5	18	5
	200	2	3	4	1	12	14	4	3	4	5	8	5	10
	380	25	16	11	4	9	12	10	5	6	9	13	31	25
	500	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	13	ND	ND
	750	24	ND	ND	ND	3	4	9	1	1	20	18	3	ND
	1.3								ND				-	4
Ratio of each gamma energy to 380 KEV	17	1.6	0.2	1.1	16.0	4.5	4.1	5.2	5.2	5.1	4.3	2.2	-	-
	60	0.1	3.6	5.0	7.7	2.9	1.1	2.2	12	9.6	1.9	1.1	1.4	2.2
	100	0.3	1.1	1.8	1.4	1.2	1.2	0.7	0.7	0.6	0.4	0.4	0.6	0.2
	200	0.1	0.2	0.3	0.3	0.7	0.8	0.4	0.5	0.7	0.6	0.6	0.2	0.4
	380	1	1	1	1	1	1	1	1	1	1	1	1	1
	500										0.5	1	-	-
	750	0.9				0.3	0.3	0.9	0.7	0.1	2.2	1.4	0.1	-
	1.3MEV												-	0.14
% Reduction of each gamma group with 1/4" X-Ray Glass	17													
	60	>95	98	>95	>95	>95			>95	>95	>95	>95		97
	100													89
	200	51	54	72	52	85			71	62	65	80		79
	380	49	40	54	33	41			33	28	27	48		30
	500										25	61		
	750	12				25					20	24		

* GS - Scan taken through safety glass.
GV - Scan taken through glove.

TABLE II

SUMMARY OF DOSE RATES AND DOSE RATE REDUCTIONS WITH X-RAY GLASS

(Taken from Figures 1 - 25)

Hood No.	Present Gamma Dose Rate @ 3"* (mr/hr)	% Reduction With ¼" X-Ray Glass		Net Dose Rate With ¼" X-Ray Glass (mr/hr)	Present Neutron Dose Rate @ 6"* (mrem/hr)
		Measured by Gamma Scan (%)	Measured by GM (%)		
3	3 - 6	98	91	0.1	1 - 2
5	3 - 7	71	86	0.2	0.6 - 1
7	6 - 7	-	71	0.2	4
9A Lower	18 - 30	93	95	1 - 2	14 - 40
9A Center		92	93	1 - 2	
9A Top		89	93	2 - 3	
14 DC	4	95	92	0.2	2
16 BS	3	83	88	0.5	2
17	5	96	92	0.4	-
200 A	3	97	97	0.1	0.7
200 C	5	-	97	0.2	0.4 - 1.0
200 BR	3	80	92	0.6	0.4
22 BD	2	85	91	0.2	0.8
24 (3/16" steel)	1	82	99	0.2	0.2
(Glove)	1	-	99		
27 R	2	78	89	0.4	-
HC 22	2	65	62	0.7	0.4

TABLE II (Continued)

Hood No.	Present Gamma Dose Rate @ 3"* (mr/hr)	% Reduction With ¼" X-Ray Glass		Net Dose Rate With ¼" X-Ray Glass (mr/hr)	Present Neutron Dose Rate @ 6"* (mrem/hr)
		Measured by Gamma Scan (%)	Measured by GM (%)		
HC 24 C 2' Glove Glass	1 - 2	88 89 97	- 73 93	0.2	0.4
RECUPLEX SE	10 - 28	91 -	95 96	0.4 - 2.0	0.6
Dissolver	1 - 4	95 93	84 80	0.2	1.3
R & B	8 - 23	71 72	91 91	2 - 7	0.4

* Measured by Radiation Monitoring, Finished Products.

TABLE III

ADDITIONAL GM MEASUREMENTS SHOWING % 17 KEV IN THE FIELD

AND % REDUCTION OF TOTAL GAMMA WITH ¼" X-RAY GLASS

(Not included in Figures 1 - 25)

NOTE: 5000 c/m = 1 mr/hr (approximately)

LOCATION		NO ABSORBER (c/m)	80 mil Al ABSORBER		¼" X-RAY GLASS ABSORBER	
			c/m	CALCULATED % 17 KEV	c/m	CALCULATED % REDUCTION
RMA LINE						
Hood 5, 36"	(a)	36,000	-	-	2,600	93
	(b)	45,000	18,000	60	3,000	93
Hood 2, 36" (Glassed)	(a)	28,000			600	98
Hood 7, West End	(a)	23,000			2,500	89
Hood 9-A						
South Lower Section	(a)	55,000			4,300	92
South Center Section	(a)	50,000			4,500	91
Drum Filter	(a)	78,000			3,500	96
	(b)	45,000	15,000	67	3,000	93
Reactor	(b)	78,000	38,000	51	6,500	92
Hood 13 A, B, C, 72"	(a)	8,000			800	90
Hood 14 DC, 36"	(a)	25,000			1,300	95
	(b)	22,000	6,000	73	1,200	95
Hood 16 BS	(a)	9,000	2,000	78	1,000	89
	(b)	22,000	10,000	55	3,500	84
Hood 17, 48"	(a)	38,000			900	98
Freezer	(a)	900			300	-
Hood 200-A	(a)	68,000			1,500	98

TABLE III (Continued)

LOCATION		NO ABSORBER (c/m)	80 mil Al ABSORBER c/m	80 mil Al ABSORBER CALCULATED % 17 KEV	¼" X-RAY GLASS ABSORBER c/m	¼" X-RAY GLASS ABSORBER CALCULATED % REDUCTION
Hood 200 BR						
Thru ¼" Pb, 0"	(a)	400			-	-
Thru Glass, 0"	(a)	18,000			700	96
Thru Glass, 0"	(b)	17,000	17,000	0	3,800	78
Thru Glove, 0"	(b)	40,000	20,000	50	2,500	94
Glass + Glove, 6"	(b)	17,000	9,700	43	2,000	88
Hood 22 BD, 6"	(a)	20,000			2,000	90
Hood 27 (1 Ball, 9 Plugs)	(a)	20,000			2,000	90
Hood 27 C	(a)	3,500			400	89
RECUPLEX						
S & E Hood						
West End, 24"	(a)	50,000			2,000	96
West End, 10"	(b)	90,000	29,000	68	2,500	97
West End, 36"	(b)	38,000	13,000	66	1,300	97
West End, Plexiglas, 0"	(b)	54,000	17,000	69	1,800	97
West End, Glove, 0"	(b)	43,000	19,000	56	1,500	97
West End, Top, 24"	(a)	10,000			800	92
East End	(a)	95,000			2,000	98
Dissolver Hood						
West End, 24"	(a)	23,000			400	98
East End, 24"	(a)	7,500			400	95
R & B Hood						
South End, 24"	(a)	100,000			4,500	95
North End, 24"	(a)	50,000			8,000	84
Hood 227						
South End, 24"	(a)	30,000			600	98
North End, 24"	(a)	50,000			6,500	87

TABLE III (Continued)

LOCATION	NO ABSORBER (c/m)	80 mil Al ABSORBER		¼" X-RAY GLASS ABSORBER	
		c/m	CALCULATED % 17 KEV	c/m	CALCULATED % REDUCTION
Hood 41, 24" (a)	26,000			2,500	90
PuF_4 Sample (18 months old), 6"	100,000			10,000	90

(a) Taken April 23, 1959.

(b) Taken April 24, 1959.

TABLE IV

FILM BADGE EXPOSURE RECORDS OF 40 PROCESS OPERATORS

Period: December 15, 1958 through March 9, 1959
(58 Working Days)

The data below was taken from film badge exposure records of 234-5 Building personnel, compiled by the Exposure Evaluation Operation, Hanford Laboratories Operation.

A. Operators unloading PR Cans at Hood 5, and working in and around Tasks I, II, and III.

OPERATOR	TOTAL X-RAY (mr)	TOTAL 60 KEV (mr)	TOTAL >100 KEV (mr)
1	65	57	266
2	52	34	217
3	310	117	467
4	162	59	360
5	115	55	556
6	114	47	388
7	69	21	301
Average	127	56	365
	23%	10%	67%

B. Operators working Hood 7-A and 9-A, and Tasks III and IV.

1	30	74	391
2	111	83	474
3	126	84	489
4	107	89	489
5	180	85	544
6	53	60	496
7	82	94	512
8	65	57	391
9	75	67	369
10	103	103	490
11	121	69	296
12	62	114	457
13	162	99	495
14	68	50	317
15	105	73	406

TABLE IV (Continued)

OPERATOR	TOTAL X-RAY (mr)	TOTAL 60 KEV (mr)	TOTAL >100 KEV (mr)
16	123	66	518
17	53	84	490
18	73	51	257
19	86	83	430
20	102	71	385
Average	94	78	437
	15%	13%	72%
C. Task V Operators			
1	47	166	653
2	51	155	500
3	53	131	550
4	97	111	611
5	65	98	523
6	43	83	385
7	83	119	621
8	59	83	451
9	23	76	387
10	41	117	491
11	33	106	444
12	19	142	447
Average	51	115	505
	8%	17%	75%
D. Briquetting Operators			
1	29	127	583
2	56	71	398
Average	43	99	491
	7%	16%	77%

TABLE IV (Continued)

E. Recuplex Operators

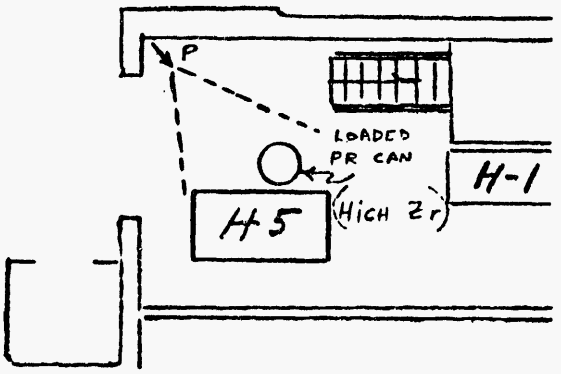
OPERATOR	TOTAL X-RAY (mr)	TOTAL 60 KEV (mr)	TOTAL >100 KEV (mr)
1	157	78	557
2	181	76	261
3	118	65	382
4	143	60	515
5	164	52	276
6	126	71	401
7	238	122	498
8	219	56	381
9	177	75	622
10	83	31	420
11	54	37	183
12	86	21	484
Average	146	62	415
	23%	10%	67%

F. Recuplex Operator working at the chemical addition hood (upstairs).

57	41	234
17%	12%	71%

FIGURE 1

GAMMA SCAN OF HOOD 5
(PR Can Unloading Station)



Radiation Level of Hood 5

Gamma Dose Rate @ 3": 3 - 7 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.6 - 1 mrem/hr

A. GM Measurements at point P

No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
13,000 c/m	6000 c/m (54% 17 KEV)	1800 c/m (86% Reduction)

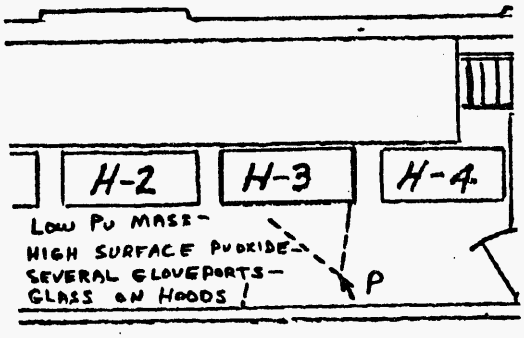
B. Spectrometer Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	2.0×10^7	40	4.0	)	
60	7.4×10^6	15	1.5	) 4.8×10^5	95
100	1.8×10^6	4	0.4	)	
200	6.5×10^5	2	0.2	4.9×10^5	42
380	5.0×10^6	10	1.0	3.6×10^6	28
500	6.7×10^5	1	0.1	ND	-
750	1.4×10^7	28	2.8	9.9×10^6	29
Total	49.7×10^6			14.5×10^6	71% (Net)

	¼" X-Ray Glass Absorber		1-3/16" High Density Glass Absorber	
KEV	Photons/t	% Reduction	Photons/t	% Reduction
17	)		)	
60	) L 4.8×10^5	> 95	) > 5.5×10^5	> 95
100	)		)	
200	L 1.3×10^5	> 80	)	
380	2.3×10^6	46	L 4×10^5	92
500	ND	-	ND	-
750	9.2×10^6	34	3.8×10^6	73
	12.1×10^6	76% (Net)	4.8×10^6	90% (Net)

FIGURE 2

GAMMA SCAN OF HOOD 3
(Old Task I)



Radiation Level of Hood 3

Gamma Dose Rate @ 3": 3 - 6 mr/hr (C.P.)

Neutron Dose Rate @ 6": 1 - 2 mrem/hr

A. GM Measurements at point P

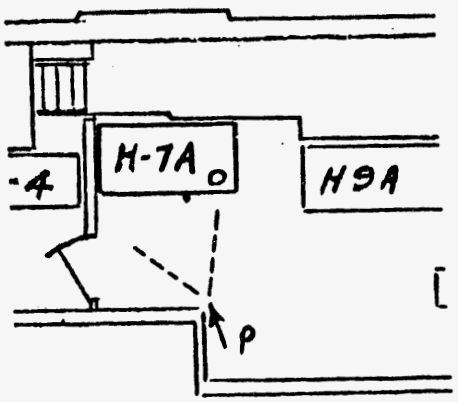
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
7500 c/m	4500 c/m (60% 17 KEV)	700 c/m (91% Reduction)

B. Spectrometer Scan at point P

	No Absorber			¼" X-Ray Glass	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	10.6×10^6	50	25	)	
60	9.3×10^6	44	22	)L 1×10^5	99
100	5.5×10^5	3	1.3	)	
200	3.7×10^5	2	0.9	6.7×10^4	82
380	4.2×10^5	2	1.0	2.9×10^5	30
500	ND				
750	ND				
Total	21.2×10^6			4.6×10^5	98% (Net)

FIGURE 3

GAMMA SCAN OF HOOD 7
(Feed and Filtrate)



Radiation Level of Hood 7

Gamma Dose Rate @ 3": 6 - 7 mr/hr (C.P.)

Neutron Dose Rate @ 6" = 4 mrem/hr
(probably from Hood 9-A)

A. GM Measurements at point P

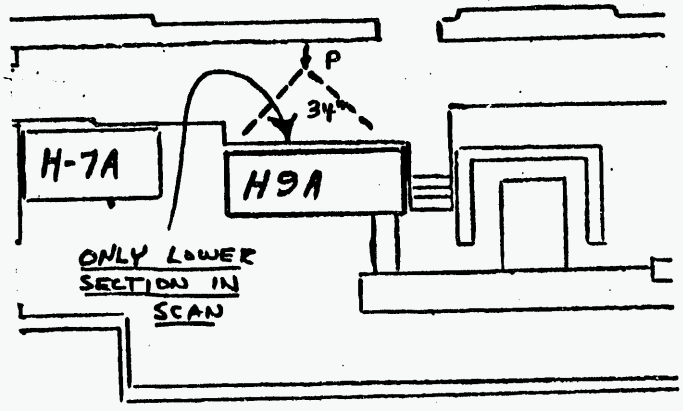
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
14,000 c/m	7800 c/m (44% 17 KEV)	4000 c/m (71% Reduction)

B. Spectrometer Scan at point P

	No Absorber		
KEV	Photons/t	%	Ratio to 380 KEV
17	1.1×10^7	33	3.2
60	1.5×10^7	45	4.4
100	1.5×10^6	7	0.4
200	5.2×10^5	2	0.2
380	3.4×10^6	10	1.0
500	ND	-	-
750	1.3×10^6	4	0.4

FIGURE 4

GAMMA SCAN OF LOWER SECTION OF HOOD 9-A
(Filtrate Receivers)



Radiation Level of Hood 9-A - General

Gamma Dose Rate @ 3": 18 - 30 mr/hr (C.P.)

Neutron Dose Rate @ 6": 14 - 40 mrem/hr

A. GM Measurements at point P

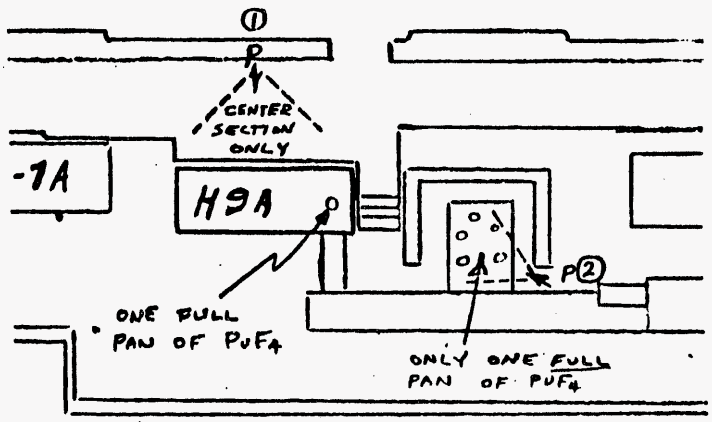
No Absorber	70 mil Al Absorber	¼" X-Ray Glass Absorber
38,000 c/m	9000 c/m (76% 17 KEV)	2000 c/m (95% Reduction)

B. Spectrometer Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	3.0×10^7	65	20	L 2×10^5	>95
60	6.9×10^6	15	1.5		
100	3.2×10^6	7	0.7		
200	1.5×10^6	3	0.3	4.4×10^5	70
380	4.5×10^6	10	1.0	2.8×10^6	48
500	ND				
750	ND				
Total	46.0×10^6			3.4×10^6	93% (Net)

FIGURE 5

GAMMA SCAN OF CENTER SECTION OF HOOD 9-A
(Fluorinator)



Radiation Level of Hood 9-A
General

Gamma Dose Rate @ 3": 18 - 30 mr/hr (C.P.)

Neutron Dose Rate @ 6": 14 - 40 mrem/hr

A. GM Measurements at point P(1)

No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
38,000 c/m	13,000 c/m (66% 17 KEV)	2800 c/m (93% Reduction)

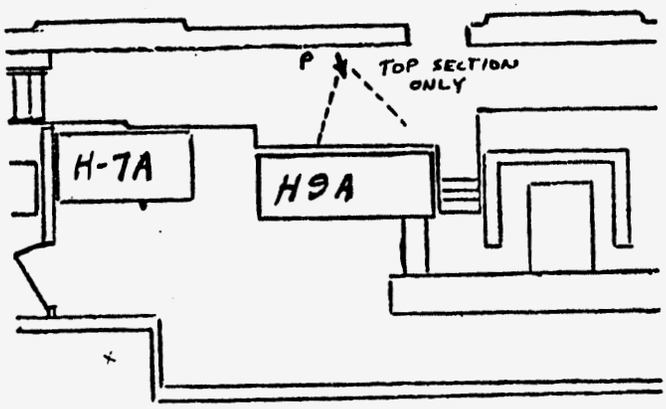
B. Spectrometer Scan at point P(2)

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	4.1×10^7	67	6.2	L 4×10^5	>95
60	8.6×10^6	14	1.3		
100	2.4×10^6	4	0.4		
200	1.4×10^6	2	0.2	3.1×10^5	69
380	6.6×10^6	10	1.0	4.2×10^6	36
500	ND				
750	1.3×10^6	2	0.2	ND	-
1.3	ND				
2.1	ND				
	61.3×10^6			4.9×10^6	92% (Net)

NOTE: P(2) was scanned for 1.3 MEV and none was detected.

FIGURE 6

GAMMA SCAN OF TOP SECTION OF HOOD 9-A
(Precipitation - Calcination)



Radiation Level of Hood 9-A - General

Gamma Dose Rate @ 3": 18 - 30 mr/hr (C.P.)

Neutron Dose Rate @ 6": 14 - 40 mrem/hr

A. GM Measurements at point P

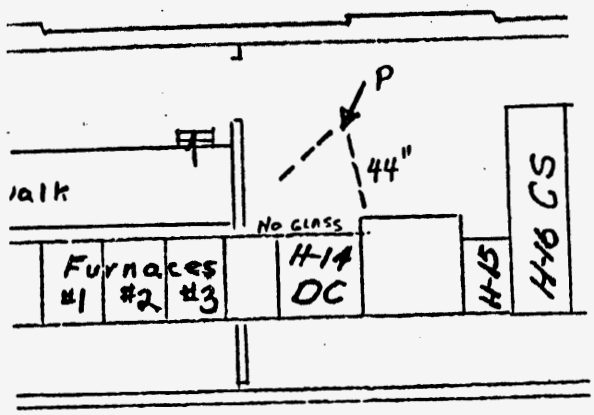
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
40,000 c/m	13,000 c/m (68% 17 KEV)	3000 c/m (93% Reduction)

B. Gamma Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio 380 KEV	Photons/t	% Reduction
17	4.2×10^7	60	3.2	)	
60	9.5×10^6	14	0.7	)L 1×10^5	93
100	4.4×10^6	6	0.3	)	
200	8.9×10^5	1	0.1	3.0×10^5	66
380	1.3×10^7	19	1.0	7.4×10^6	43
500	ND				
750	ND				
Total	69.5×10^6.			8.0×10^6	89% (Net)

FIGURE 7

GAMMA SCAN OF HOOD 14 DC
(Button Breakout)



Radiation Level of Hood 14 DC

Gamma Dose Rate @ 3": 4 mr/hr (C.P.)

Neutron Dose Rate @ 6": 2 mrem/hr

A. GM Measurements at point P

No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
8300 c/m	3500 c/m (58% 17 KEV)	700 c/m (92% Reduction)

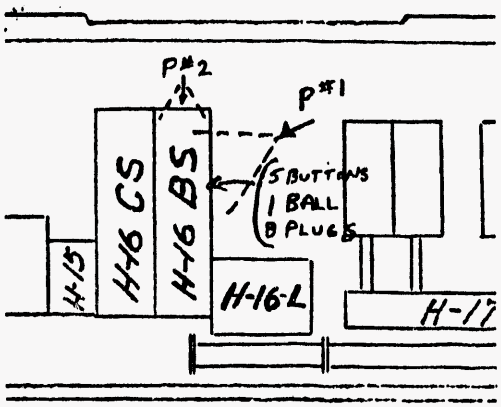
B. Gamma Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	8.7×10^6	48	7.9	3.4×10^5	96
60	6.1×10^6	34	5.5		
100	1.5×10^6	8	1.4		
200	7.4×10^5	4	0.7	1.3×10^5	82
380	1.1×10^6	6	1.0	5.0×10^5	55
500	ND				
750	ND				
Total	18.1×10^6			9.7×10^5	95% (Net)

[redacted]

FIGURE 8

GAMMA SCAN OF HOOD 16 BS
(Metal Storage)



Radiation Level of Hood 16 BS

Gamma Dose Rate @ 3": 3 mr/hr (C.P.)

Neutron Dose Rate @ 6": 2 mrem/hr

A. GM Measurements at point P

	No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
P#1	32,000 c/m	9000 c/m (72% 17 KEV)	3500 c/m (89% Reduction)
P#2	23,000 c/m	13,000 c/m (42% 17 KEV)	3000 c/m (87% Reduction)

B. Gamma Scan at point P#1

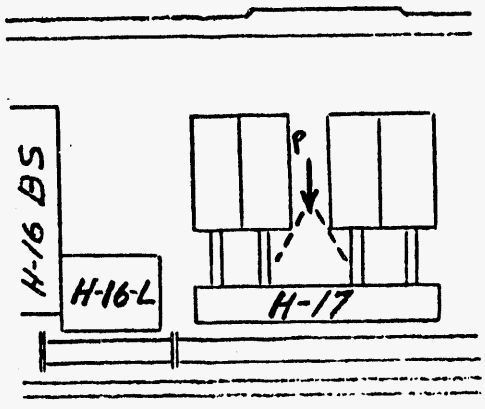
	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	3.3×10^7	60	3.0		
60	4.3×10^6	8	0.4	4.0×10^5	>95
100	3.2×10^6	6	0.3		
200	1.3×10^6	2	0.1	3.3×10^5	75
380	1.1×10^7	20	1.0	6.5×10^6	41
500	ND				
750	2.4×10^6	4	0.2	2.0×10^6	17
1.3	ND				
Total	55.5×10^6			9.2×10^6	83% (Net)

	½" X-Ray Glass Absorber		1-3/16" High Density Glass Absorber	
KEV	Photons/t	% Reduction	Photons/t	% Reduction
60	2×10^5	>95	L 2×10^5	
100				
200	L 1.6×10^5			
380	4.0×10^6	64	1.9×10^5	
500	-			
750	9.0×10^5	62	L 4.2×10^5	
Total	5.3×10^6	90% (Net)	8×10^5	99% (Net)

[redacted]

FIGURE 9

GAMMA SCAN OF HOOD 17
(Casting)



Radiation Level of Hood 17

Gamma Dose Rate @ 3": 5 mr/hr (C.P.)

Neutron Dose Rate @ 6": 2 mrem/hr

A. GM Measurements at point P

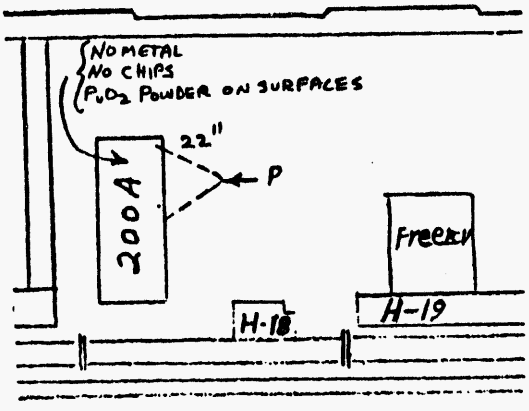
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
8400 c/m	5000 c/m (40% 17 KEV)	700 c/m (92% Reduction)

B. Gamma Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	1.0×10^7	30	5.5		
60	2.1×10^7	62	12	L 3×10^5	98
100	7.2×10^5	2	0.4		
200	4.4×10^5	1	0.2	1.1×10^5	75
380	1.8×10^6	5	1	1.1×10^6	39
500	ND				
750	ND				
Total	34.1×10^6			1.5×10^6	96% (Net)

FIGURE 10

GAMMA SCAN OF HOOD 200-A
(Maintenance and Button Loadout)



Radiation Level of Hood 200-A

Gamma Dose Rate @ 3": 3 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.7 mrem/hr

A. GM Measurements at point P

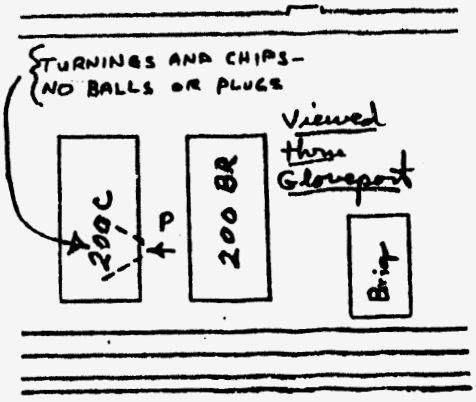
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
33,000 c/m	12,000 c/m (64% 17 KEV)	1100 c/m (97% Reduction)

B. Gamma Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	1.7×10^7	44	18	L 1×10^5	>95
60	1.9×10^7	50	20		
100	6.7×10^5	2	0.7		
200	3.7×10^5	1	0.4	8.7×10^4	77
380	9.3×10^5	2	1	5.2×10^5	44
500	ND				
750	L 4×10^5	1	-	ND	-
Totals	38.4×10^6			1.1×10^6	97% (Net)

FIGURE 11

GAMMA SCAN OF HOOD 200-C
(Machining)



Radiation Level of Hood 200-C

Gamma Dose Rate: 5 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.4 - 1 mrem/hr

A. GM Measurements at point P

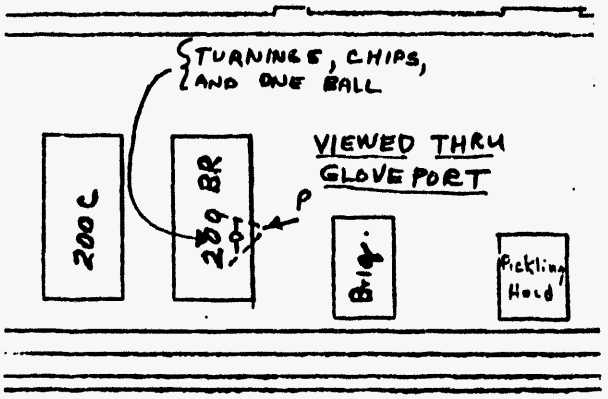
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
35,000 c/m	14,000 c/m (60% 17 KEV)	900 c/m (97% Reduction)

B. Gamma Scan at point P

	No Absorber		
KEV	Photons/t	%	Ratio to 380 KEV
17	1.1×10^7	46	4.8
60	7.6×10^6	32	3.3
100	1.9×10^6	8	0.8
200	7.1×10^5	3	0.3
380	2.3×10^6	10	1.0
500	ND	-	-
750	L 4.0×10^5	1	0.2

FIGURE 12

GAMMA SCAN OF HOOD 200-BR
(Machining)



Radiation Level of Hood 200-BR

Gamma Dose Rate: 3 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.4 mrem/hr

A. GM Measurements at point P

No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
25,000 c/m	12,000 c/m (52% 17 KEV)	2100 c/m (92% Reduction)

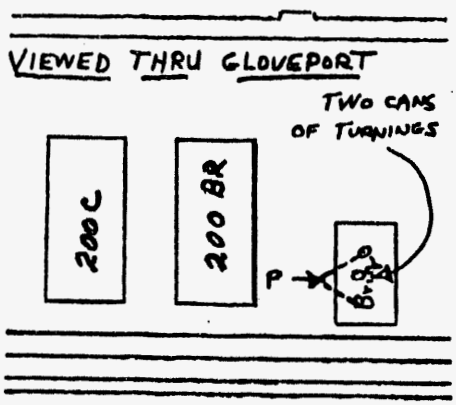
B. Gamma Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	2.1×10^7	40	1.3	)	
60	6.9×10^6	13	0.4	)L 3.6×10^5	> 95
100	5.7×10^6	11	0.4	)	
200	1.8×10^6	3	0.1	4.7×10^5	74
380	1.6×10^7	31	1.0	8.6×10^6	46
500	ND				
750	9.6×10^5	2	0.06	8.2×10^5	15
Totals	52.3×10^6			10.3×10^6	80% (Net)

[redacted]

FIGURE 13

GAMMA SCAN OF HOOD 22-BD
(Briquetting)



Radiation Level of Hood 22-BD

Gamma Dose Rate: 2 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.8 mrem/hr

A. GM Measurements at point P

No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
28,000 c/m	14,000 c/m (50% 17 KEV)	2500 c/m (91% Reduction)

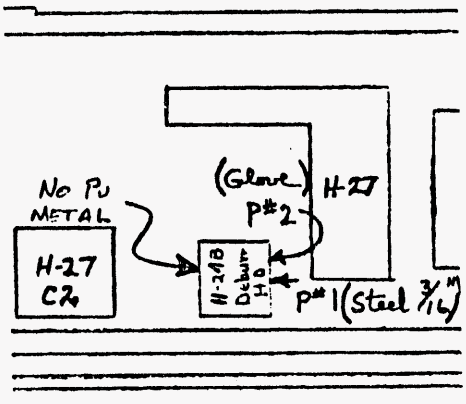
B. Gamma Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	1.7×10^7	40	2.0		
60	1.0×10^7	23	1.2	4.2×10^5	> 95
100	4.4×10^6	10	0.5		
200	1.7×10^6	4	0.2	3.0×10^5	82
380	8.5×10^6	20	1.0	4.9×10^6	42
500	ND				
750	1.2×10^6	3	0.1	8.6×10^5	28
Total	43.1×10^6			6.5×10^6	85% (Net)

[redacted]

FIGURE 14

GAMMA SCAN OF HOOD 24
(Deburring)



Radiation Level of Hood 24

Gamma Dose Rate: 1 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.2 mrem/hr

A. GM Measurements at point P

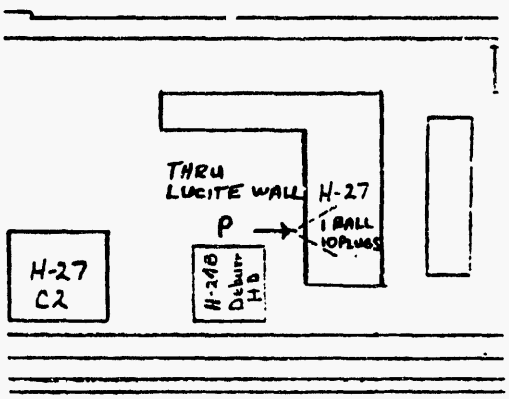
	No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
P#1	1700 c/m	1700 c/m (No 17 KEV)	250 c/m (99% Reduction)
P#2	36,000 c/m	11,000 c/m (69% 17 KEV)	400 c/m (99% Reduction)

B. Gamma Scan at P#1 (STEEL)

	No Absorber			¼" X-Ray Glass Absorber		Gamma Scan at P#2 (GLOVE) No Absorber		
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction	Photons/t	%	Ratio to 380 KEV.
17	-	0	-			1.4×10^7	45	15.0
60	4.8×10^6	39	2.3	9.5×10^4	98	1.4×10^7	45	15.0
100	4.2×10^6	34	2.0			1.9×10^6	6	2.1
200	1.2×10^6	10	0.6	3.8×10^5	68	3.5×10^5	1	0.4
380	2.1×10^6	17	1.0	1.5×10^6	29	9.2×10^5	3	1.0
500	ND					ND		
750	ND					ND		
Total	12.3×10^6			2.2×10^6	82% (Net)			

FIGURE 15

GAMMA SCAN OF HOOD 27-R
(Inspection)



Radiation Level of Hood 27-R

Gamma Dose Rate @ 3": 1.5 mr/hr

Neutron Dose Rate @ 6": 0.2 mrem/hr

A. GM Measurements at point P

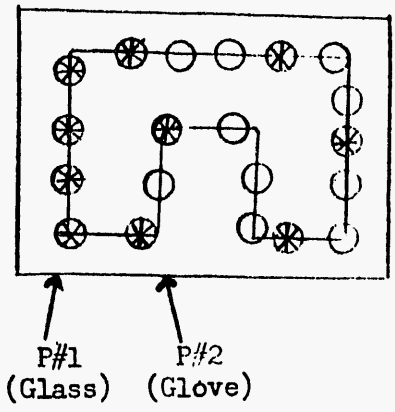
No Absorber	30 mil Al Absorber	¼" X-Ray Glass Absorber
8300 c/m	4000 c/m (52% 17 KEV)	900 c/m (89% Reduction)

B. Gamma Scan at point P

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	6.6×10^6	38	1.4		
60	1.4×10^6	8	0.3	$L\ 1 \times 10^5$	> 95
100	3.5×10^6	20	0.8		
200	8.8×10^5	5	0.2	2.7×10^5	69
380	4.6×10^6	27	1.0	3.2×10^6	30
500					
750	3.2×10^5	2	0.1	2.7×10^5	14
Total	17.3×10^6			3.9×10^6	78% (Net)

FIGURE 16

GAMMA SCAN OF HOOD HC-22
(Storage - RMC Line)



Radiation Level of Hood HC-22

Gamma Dose Rate @ 3": 2 mr/hr

Neutron Dose Rate @ 6": ~ 0.3 mrem/hr

A. GM Measurements at point P

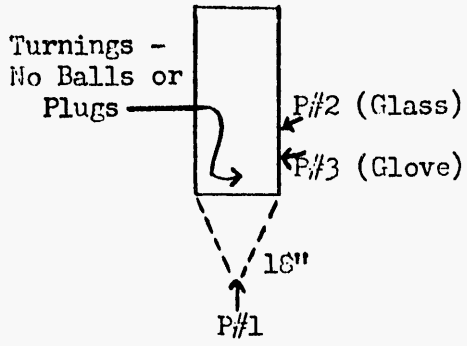
	No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
P#1 (Glass)	5300 c/m	5300 c/m	2800 c/m
P#2 (Glove)	15,000 c/m	8000 c/m (47% 17 KEV)	5300 c/m (77% Reduction)

B. Gamma Scan at P#1

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	2.7×10^7	40	1.6		
60	1.6×10^6	2	0.1	L 2×10^5	>95
100	4.4×10^6	7	0.3		
200	1.2×10^6	2	0.1	5.9×10^5	51
380	1.7×10^7	25	1.0	8.7×10^6	49
500	ND				
750	1.6×10^7	24	0.9	1.4×10^7	12
Total	67.7×10^6			23.5×10^6	65% (Net)

FIGURE 17

GAMMA SCAN OF HOOD HC-24-C
(Machining - HMC Line)



Radiation Level of Hood HC-24-C

Gamma Dose Rate @ 3": 2 mr/hr

Neutron Dose Rate @ 6": 0.3 mrem/hr

A. GM Measurements at point P

	No Absorber	80 mil Al Absorber	½" X-Ray Glass Absorber
	730 c/m	500 c/m	200 c/m
P#1	2200 c/m	2200 c/m	600 c/m
P#2	8300 c/m	2600 c/m	600 c/m
P#3		(69% 17 KEV)	(93% Reduction)

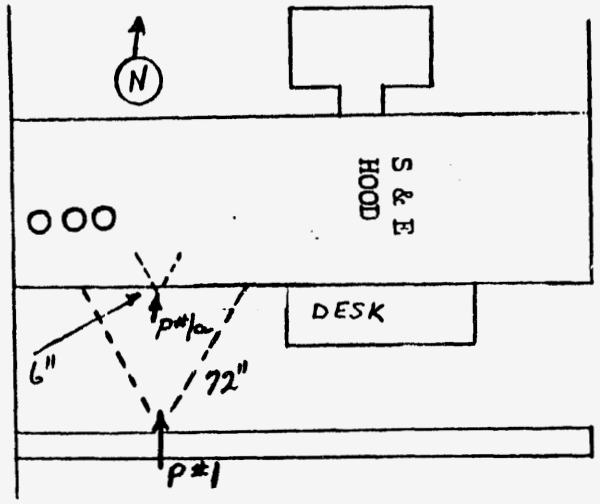
B. Gamma Scan at point P

		No Absorber			½" X-Ray Glass Absorber	
	KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
P#1	17	L 1 x 10^5	3	0.2	)	
	60	2.4 x 10^6	59	3.6	)L 5.4 x 10^4	98
	100	7.7 x 10^5	19	1.1	)	
	200	1.3 x 10^5	3	0.2	6.0 x 10^4	54
	380	6.7 x 10^5	16	1.0	4.0 x 10^5	40
	Total	4.1 x 10^5			0.5 x 10^6	88% (Net)
P#2	17	L 6 x 10^5	12	1.1	)	
	60	2.8 x 10^6	54	5.0	)L 2.5 x 10^5	>95
	100	1.0 x 10^6	19	1.8	)	
	200	1.9 x 10^5	4	0.3	5.3 x 10^4	72
	380	5.6 x 10^5	11	1.0	2.6 x 10^5	54
	Total	5.2 x 10^6			5.5 x 10^5	89% (Net)
P#3	17	1.6 x 10^7	61	16.0	)	
	60	7.7 x 10^6	29	7.7	)L 1.0 x 10^5	>95
	100	1.4 x 10^6	5	1.4	)	
	200	2.7 x 10^5	1	0.3	1.3 x 10^5	52
	380	1.0 x 10^6	4	1.0	6.7 x 10^5	33
	Total	19.5 x 10^6			9 x 10^5	97% (Net)

NOTE: The 500 KEV and 750 KEV energies were not detected in the above scans.

FIGURE 18

GAMMA SCAN OF WEST END OF SOLVENT EXTRACTION HOOD - RECUPLEX



Radiation Level of S & E Hood

Gamma Dose Rate @ 3": 10 - 28 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.6 mrem/hr

A. GM Measurements

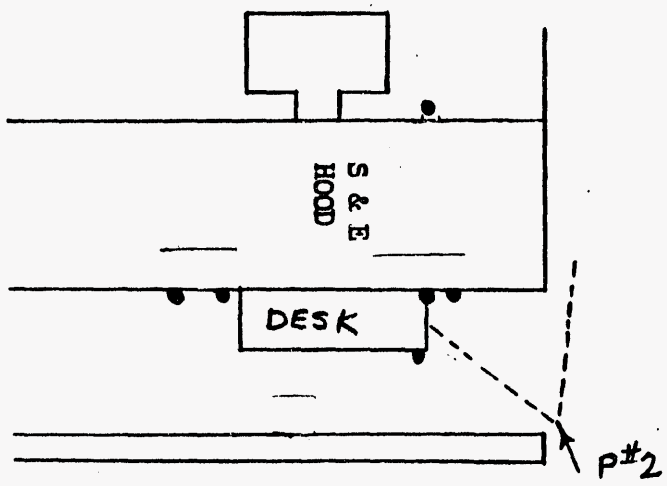
	No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
P#1	21,000 c/m	9000 c/m (57% 17 KEV)	1000 c/m (95% Reduction)
P#1a	24,000 c/m	9000 c/m (63% 17 KEV)	1000 c/m (96% Reduction)

B. Gamma Scans

	P#1 No Absorber			¼" X-Ray Glass Absorber		P#1a No Absorber		
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction	Photons/t	%	Ratio to 380 KEV
17	2.2×10^7	42	4.5			2.3×10^7	49	4.1
60	1.4×10^7	27	2.9	) 1.2×10^5	95	6.0×10^6	13	1.1
100	3.5×10^6	7	0.7			4.2×10^6	9	0.8
200	6.1×10^6	12	1.2	6.8×10^5	85	6.7×10^6	14	1.2
380	4.9×10^6	9	1.0	2.9×10^6	41	5.6×10^6	12	1.0
500	ND					ND		
750	1.6×10^6	3	0.3	1.2×10^6	25	1.9×10^6	4	0.3
Totals	52.1×10^6			4.9×10^6	91% (Net)			

FIGURE 19

GAMMA SCAN OF EAST END OF SOLVENT EXTRACTION HOOD - RECUPLEX



Radiation Level of S & E Hood

Gamma Dose Rate @ 3": 10 - 28 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.6 mrem/hr

A. GM Measurement at P#2

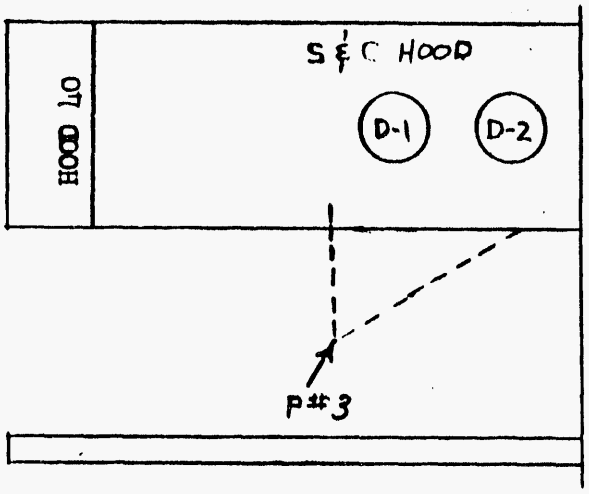
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
8000 c/m	3300 c/m (50% 17 KEV)	400 c/m (95% Reduction)

B. Gamma Scan at P#2

	No Absorber		
KEV	Photons/t	%	Ratio to 380 KEV
17	1.7×10^6	49	5.2
60	7.4×10^5	21	2.2
100	2.4×10^5	7	0.7
200	1.3×10^5	4	0.4
380	3.3×10^5	10	1.0
500	ND		
750	3.0×10^5	9	0.9

FIGURE 20

GAMMA SCAN OF WEST END OF DISSOLVER HOOD - RECUPLEX



Radiation Level of Dissolver Hood

Gamma Dose Rate @ 3": 1 - 4 mr/hr (C.P.)

Neutron Dose Rate @ 6": 1.3 mrem/hr

A. GM Measurements at P#3

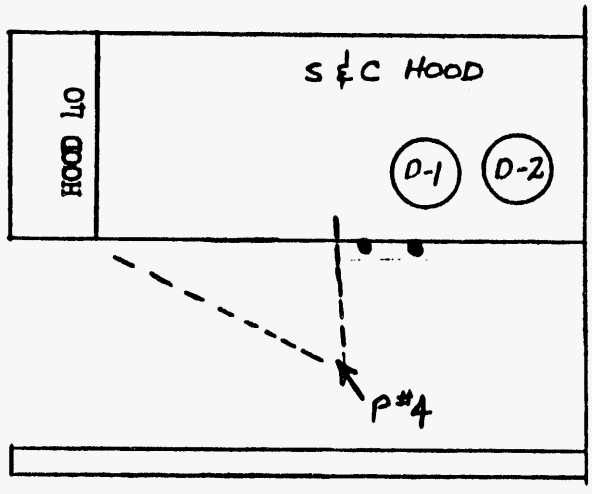
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
3800 c/m	2300 c/m (50% 17 KEV)	600 c/m (84% Reduction)

B. Gamma Scan

	No Absorber			¼" X-Ray Glass Absorber		1-3/16" Hi-Density Glass	
KEV	Photons/t	%	Ratio of 380 KEV	Photons/t	% Reduction	Photons/t	% Reduction
17	7.8×10^6	27	5.2	)		)	
60	1.8×10^7	62	12	)L 1.3×10^5	>95	)L 1.1×10^5	99
100	1.0×10^6	3	0.7	)		)	
200	7.8×10^5	3	0.5	2.3×10^5	71	L 4×10^4	99
380	1.5×10^6	5	1.0	1.0×10^6	33	L 1.2×10^5	90
500	ND						
750	L 1.0×10^5	L 1	-	-	-	-	-
1.3	L 6×10^4	L 1	-	-	-	-	-
Total	29.2×10^6			1.4×10^6	95% (Net)	3×10^5	99% (Net)

FIGURE 21

GAMMA SCAN OF EAST END OF DISSOLVER HOOD - RECUPLEX



Radiation Level of Dissolver Hood

Gamma Dose Rate @ 3": 1 - 4 mr/hr (C.P.)

Neutron Dose Rate @ 6": 1.3 mrem/hr

A. GM Measurement at P#4

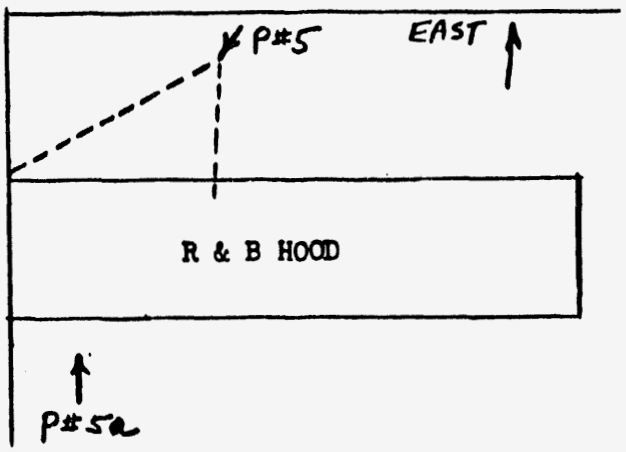
No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
3500 c/m	2800 c/m (20% 17 KEV)	700 c/m (80% Reduction)

B. Gamma Scan at P#4

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	3.8×10^6	31	5.1		
60	6.6×10^6	55	9.6	1.2×10^5	> 95
100	4.3×10^5	4	0.6		
200	4.5×10^5	4	0.7	1.7×10^5	62
380	6.9×10^5	6	1.0	5.0×10^5	28
500	ND				
750	L 1×10^5	L 1	0.1	ND	
Total	12.1×10^6			7.9×10^5	93% (Net)

FIGURE 22

GAMMA SCAN OF NORTH END OF RECEPTION BLENDING HOOD - RECUPLEX



Radiation Level of R & B Hood

Gamma Dose Rate @ 3": 8 - 23 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.4 mrem/hr

A. GM Measurements

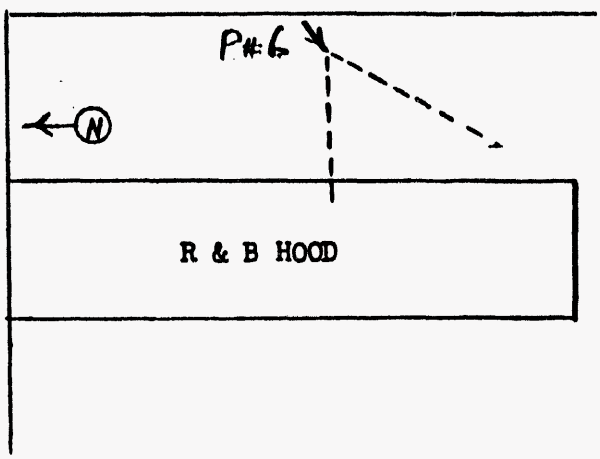
	No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
P#5a	87,000 c/m	52,000 c/m (40% 17 KEV)	22,000 c/m (75% Reduction)
P#5	29,000 c/m	13,000 c/m (55% 17 KEV)	2700 c/m (91% Reduction)

B. Gamma Scan at P#5

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	1.6×10^7	39	4.3		
60	7.2×10^6	18	1.9	2×10^5	>95
100	1.6×10^6	4	0.4		
200	2.2×10^6	5	0.6	7.8×10^5	65
380	3.7×10^6	9	1.0	2.7×10^6	27
500	2.0×10^6	5	0.5	1.5×10^6	25
750	8.0×10^6	20	2.2	6.4×10^6	20
Total	40.7×10^6			11.7×10^6	71% (Net)

FIGURE 23

GAMMA SCAN OF SOUTH END OF RECEPTION BLENDING HOOD - RECUPLEX



Radiation Level of R & B Hood

Gamma Dose Rate @ 3": 8 - 23 mr/hr (C.P.)

Neutron Dose Rate @ 6": 0.4 mrem/hr

A. GM Measurement at P#6

No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
37,000 c/m	15,000 c/m (60% 17 KEV)	3500 c/m (91% Reduction)

B. Gamma Scan at P#6

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	1.7×10^7	28	2.2		
60	8.8×10^6	15	1.1	2.0×10^5	> 95
100	3.0×10^6	5	0.4		
200	4.9×10^6	8	0.6	1.0×10^6	80
380	7.8×10^6	13	1.0	4.1×10^6	48
500	7.5×10^6	13	1.0	2.9×10^6	61
750	1.1×10^7	18	1.4	8.4×10^6	24
Total	60.0×10^6			16.6×10^6	72% (Net)

	½" X-Ray Glass Absorber		1-3/16" Hi-Density Glass Absorber	
KEV	Photons/t	% Reduction	Photons/t	% Reduction
17				
60	2×10^5	> 95	4.3×10^5	> 95
100				
200				
380	1.7×10^6	78	7.8×10^5	90
500	1.9×10^6	75	6.6×10^5	91
750	5.6×10^6	44	3.2×10^6	71
Total	9.4×10^6		5.1×10^6	92 % (Net)

FIGURE 24

GAMMA SCAN OF PLUTONIUM OXIDE SAMPLE CONTAINED IN GLASS BOTTLE

(PuO_2 Age: About two months)

A. GM Measurement

No Absorber	80 mil Al Absorber	¼" X-Ray Glass Absorber
8300 c/m	6500 c/m (22% 17 KEV)	800 c/m (90% Reduction)

B. Gamma Scan

KEV	Photons/t	Ratio to 380 KEV
17	(NOT MEASURED)	
60	9.0×10^6	1.4
100	3.8×10^6	0.6
200	1.0×10^6	0.2
380	6.5×10^6	1.0
500	ND	-
750		0.1

FIGURE 25

GAMMA SCAN OF PLUTONIUM FLUORIDE SAMPLE CONTAINED IN 1/8" WALL Al TUBE

(NIDX 17-11-1)

(PuF_4 Age: 18 Months)

A. GM Measurement

No Absorber	¼" X-Ray Glass Absorber
11,000 c/m	1000 c/m (91% Reduction)

B. Gamma Scan

	No Absorber			¼" X-Ray Glass Absorber	
KEV	Photons/t	%	Ratio to 380 KEV	Photons/t	% Reduction
17	ND				
60	7.4×10^6	56	2.2	L 2×10^5	97
100	7.2×10^5	5	0.2	L 8×10^4	89
200	1.3×10^6	10	0.4	2.7×10^5	79
380	3.3×10^6	25	1.0	2.3×10^6	30
500	ND				
750	ND				
1.3	4.6×10^5	4	0.1	4.6×10^5	0
Total	13.2×10^6			3.9×10^6	70% (Net)

	¼" X-Ray Glass Absorber		1-3/16" Hi-Density Glass Absorber	
KEV	Photons/t	% Reduction	Photons/t	% Reduction
60, 100, 200	2×10^5	>95	2×10^5	>95
380	9.9×10^5	70	1.3×10^5	96
1.3	3.2×10^5	31	1.7×10^5	62
Total	1.5×10^6	89% (Net)	0.5×10^6	96% (Net)

DATE FILMED

10/17/94

END