UNCLASSIFIED

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

UNCLASSIFIED

NYO-5237

INSTRUMENTATION

UNITED STATES ATOMIC ENERGY COMMISSION

THE ROLE OF PRIMARY BETA RADIATION
IN AREA RADIATION DOSE RATES; PLANT
SIX [URANIUM ORE REFINERY] DIGEST AREA

By
R. F. Nagel

Photostat Price \$ 3.30

Microfilm Price \$ 2.40

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

November 17, 1950

[Mallinckrodt Chemical Works, St. Louis]

Technical Information Service Extension, Oak Ridge, Tenn.

This document is
PUBLICLY RELEASABLE

Hugh Kinsler
Authorizing Official

Date: 1-25-11

17-1

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

THE ROLE OF PRIMARY BETA RADIATION IN AREA RADIATION DOSE RATES; PLANT SIX [URANIUM ORE REFINERY] DIGEST AREA

By R. F. Nagel

Abstract

A survey was made of the Digest Area to analyse the possibility of reducing personnel radiation exposure by better housekeeping in the area. The results of two independent experiments show that better housekeeping would contribute little to the reduction of personnel exposure, the limiting case being an 18.6% reduction in the total exposure.

Introduction

A survey has been made to determine if "apparent beta" radiation, as read in the open window of the film badge, is primary beta from surface contamination which could be reduced by more thorough cleaning of the plant areas. This radiation, reported in the past as beta, is not necessarily pure beta, hence the reference to "apparent beta." The term which will be used for the remainder of this report is the more comprehensive term of "total window density" which will take into consideration any radiation which will produce an increase in window density.

The total window density of a film badge is due to four component types of radiation, two of which are identical except for their origin. They are as follows:

1. Hard Gamma (above 80 kev)
2. Soft Gamma (below 80 kev)
3. Beta produced by scatter from hard gamma (secondary electrons)
4. Beta from surface contamination (primary beta)

For any given hard gamma source and geometry, the soft gamma and beta produced by scatter (items 2 and 3) are proportional to the hard gamma present and therefore can be reduced only by reducing the hard gamma in a given area. Beta from surface contamination (item 4) can obviously be reduced by cleaning the area and removing the surface contamination. The problem then resolves itself into one of a quantitative analysis of item 4 as compared to items 1, 2, and 3 to determine whether or not the film badge readings for the area can be reduced by reducing the primary beta radiation from surface contamination.

Experimental Data

I. Meter readings and film badge exposures were taken at various points throughout the digest area while under normal operating conditions. The area was then shut down and thoroughly cleaned by scrubbing all exposed surfaces with soap and water in order to remove as much of the surface contamination as practical. As soon as the area was back to normal operation, a duplicate set of meter readings and film badge exposures were taken. This was done on the basis that the total beta radiation in the area would be reduced if an area clean-up reduced the surface contamination. Data are recorded in Tables 3 and 4.

II. A. A number of magnetron magnets with a field strength of 4800 gauss were used in separating the beta radiation from the gamma. This was done by placing the open window of the film badge behind the 4800 gauss field. A like set of badges was then placed behind phantom magnet yokes, with no magnetic field, in order to duplicate the geometry of the first set. The phantom magnets would then receive all of the four items of radiation mentioned above while the true magnets would cause the beta radiation to be deflected from the open window leaving only the gamma components.

The effectiveness of the magnetic field was tested by placing both a magnet and a phantom assembly over a Uranium slug and exposing the film for 24 hours. The films were then developed and found to show a 98 percent reduction of the beta radiation by the magnetic field. A previous experiment had shown that a 2500 gauss magnetic field would reduce the window density from beta particles of equilibrium Uranium by 89 percent. A view of the magnet yoke and collimator assemblies is shown in Fig. 1.

B. Two sets of film standards were then prepared using a Radium source. One set was exposed with the magnets in place, the other with the phantom yokes. The curves obtained from this experiment are shown in Fig. 2.

C. Two additional sets of film standards were then prepared using a Radium source. Both sets were exposed in plain film badges without a magnet or phantom yoke. One set, however, was exposed with a $\frac{7}{32}$ lucite shield around the Radium source, in order to eliminate any beta particles which might originate at the Radium source. The curves obtained from this experiment are shown in Fig. 3.

D. Three sets of film badges, one set with magnets, one set with phantoms, and one set of plain badges, were then placed in the digest area. Densities are recorded in Table 1.

E. All films were developed at one time in order to eliminate developing errors.

Discussions

The curves obtained from the Radium standards as given in Fig. 2 show that the shield densities are the same for both sets of film, indicating that the hard gamma was the same for both sets of film. The window densities of the magnet exposures are noted to be less than the shield densities of the same film. This is due, not to an attenuation of the gamma reaching the open window, but rather to an intensification produced by the cadmium shield in the badge. The mechanics of this intensification will not be discussed in this report since it is proportional to the amount of hard gamma present and therefore will not enter into the calculations.

The important fact to be noted from the curves of Fig. 2, however, is the increased density in the phantom window readings. It is postulated that this increase is due to secondary electrons, produced by the hard gamma from the Radium source, reaching the open window of the phantom film. An analysis of the curves of Fig. 3 will verify this conclusion; it will be noted that the window and shield density curves of both the shielded and the unshielded Radium exposures are identical, thus indicating that the increased window densities of the phantom magnet films (Fig. 2) are not due to primary beta particles from the Radium source.

Since it has been established for the standard films that the window density over and above that due to hard gamma is due to secondary

electrons, it is now possible to draw another conclusion. It will be noted that all three curves of Fig. 2 are parallel, indicating that the secondary beta is proportional to the hard gamma. This conclusion should remain essentially correct even though such factors as scatter geometry will have some small effect for various plant areas. From this it is possible to say that the secondary electrons in a given area will be proportional to the hard gamma in that area and their amount may be determined from the curves given in Fig. 2.

An analysis of the digest area film badges was then made as shown in Table 1. The window densities (column 4) were first corrected for their hard gamma components and the resultant figure recorded in column 5. This was done by referring the shield densities (column 3) to the shield density curve of Fig. 2 and obtaining a resultant window density from the magnet window density curve. This density was then subtracted from the total window density leaving only the density due to the following:

Type film holder	Remaining components
Magnet	Soft Gamma*
Phantom	Soft Gamma,* Primary and Secondary Beta
Open	Soft Gamma,* Primary and Secondary Beta

*Soft Gamma over and above that obtained from a Radium calibration.

From these data it may be seen that the phantom film reads higher than the magnet film by an amount due to the beta radiation received by the phantom film. The difference, however, is only relative, since the shielding of the pole faces and the collimator prevent all of the beta from reaching the film and therefore introduce a geometry factor. In order to convert the relative reading to an absolute value the geometry factor must be determined by reference to the open badge which receives practically all of the beta radiation present.

The ratio of the open badge to the phantom badge, as given in column 6, is the geometry factor. Column 7 then, is this factor applied to the column 5 figures converting them to absolute values. The total beta radiation is the increase in geometry-corrected density of the phantom badge over the geometry-corrected density of the magnet badge. This difference is recorded in column 8.

5

Table 1 —Digest Area Film Density Calculations

1	2	3	4	5	6	7	8	9	10
Film Position	Type Film Holder	Sh. Den.	Win. Den.	Hard Gamma Corr.	Geom. Factor	Factor Applied	Total Beta	Secondary Beta	Primary Beta
A	Magnet	0.21	0.19	0.00		0.00			
A	Phantom	0.21	0.22	0.03	2.7	0.08	0.08	0.11	-0.03
A	Open	0.22	0.28	0.08					
B	Magnet	0.24	0.21	-0.01					
B	Phantom	0.23	0.27	0.05	6.8	0.34	0.34	0.125	0.215
B	Open	0.27	0.59	0.34					
C	Magnet	0.22	0.21	0.01		0.029			
C	Phantom	0.21	0.255	0.065	2.9	0.19	0.161	0.12	0.041
C	Open	0.25	0.42	0.19					
D	Magnet	0.135	0.135	0.01		0.04			
D	Phantom	0.13	0.17	0.05	4.0	0.20	0.16	0.09	0.07
D	Open	0.19	0.37	0.20					
E	Magnet	0.22	0.21	0.01		0.03			
E	Phantom	0.21	0.23	0.04	3.0	0.12	0.09	0.11	-0.02
E	Open	0.23	0.34	0.12					
F	Magnet	0.18	0.16	-0.005					
F	Phantom	0.17	0.18	0.025	4.0	0.10	0.10	0.10	0.00
F	Open	0.21	0.29	0.10					
G	Magnet	0.20	0.19	0.005		0.012			
G	Phantom	0.23	0.27	0.05	2.3	0.115	0.103	0.115	-0.012
G	Open	0.235	0.335	0.115					

Table 1 — (Cont'd)

6

- Column 1 —Position in digest area.
Column 2 —Type Film Holder.
Column 3 —Transmission density of shielded portion of film.
Column 4 —Transmission density of open portion (window) of film.
Column 5 —Column 4 window density minus hard gamma window taken from Fig. 2 for shield density given in Column 3.
Column 6 —Geometry factor equals Column 5 open density divided by Column 5 phantom density.
Column 7 —Product of Column 5 and Column 6.
Column 8 —Column 7 phantom density minus Column 7 magnet density.
Column 9 —Taken from Fig. 2 for Column 3 shield densities.
Column 10 —Column 8 minus Column 9.

177

It now remains to divide the column 8 figure for the total beta into its two component parts, primary and secondary beta. It was previously concluded that one could expect an amount of secondary beta proportional to the hard gamma in a given area.

From the Radium calibration curves given in Fig. 2 it is possible to determine the amount of secondary beta associated with any given amount of hard gamma. Since it has been shown that the Radium calibrated film badges receive no primary beta, the numerical difference between the window densities of the magnet film and the phantom film, for any given shield density, is the density produced by the secondary electrons associated with the given shield density.

The secondary beta (as determined from the hard gamma open badge shield density) was recorded in column 9 and then subtracted from the total beta as given in column 8. The remaining primary beta density was recorded in column 10.

A statistical analysis of these results (Table 2) shows the average of the density value of the primary beta to be between -0.032 and 0.048 with a 90% limit of error. From the beta calibration curve (Fig. 4) these densities represent an exposure range of from minus 93 to a positive 140 millirep beta. The average primary beta will be taken as 24 millirep, confidence limits from -93 to $+140$ millirep with a 90% limit of error.

The average total radiation exposure (beta and gamma) as interpreted from the open badges was found to be 750 millirep. The average primary beta radiation in the digest area, then, is 3.2% confidence limits from -12.4 to 18.6 percent, of the total radiation in the area, within 90% confidence limits.

The before and after clean-up data, Tables 3 and 4, show the following percentage total beta reduction.

Conditions	Beta Radiation, percent of total radiation	
	By Film Badge	By Meter
Before clean-up	28%	9.5%
After clean-up	26%	8.3%

The significance of these figures lies in the reduction in the percentage figures after cleaning.

Summary

The results of the two independent experiments conducted in the digest area are tabulated below.

Experiment I

Method of detection	Reduction in percentage of beta radiation after cleaning
Film Badge	0.2%
Survey Meter	1.2%

Experiment II

The primary beta radiation determined to the 0.9 confidence limit is 3.2%, confidence limits from -12.4 to 18.6 percent, of the total radiation in the area.

The foregoing experiments indicate that the radiation in the digest area from surface contamination contributes at most 18.6 percent of the total radiation in the area and probably only about 0.3%. This low percentage indicates that a general clean-up would not significantly reduce the digest operators exposure.

It should be recognized that the data presented here are representative of the area and not of the workers. Film badges worn by workers show greater window densities for equivalent shield densities. Workmen are often engaged in activities such that their film badge "sees" a primary beta source (viz., man-hole inspection, work in sumps, etc.), and the workman receives beta radiation which he would not receive were he merely standing in the area.

Since all but the primary beta radiation will remain proportional to the hard gamma radiation it is further concluded that reduction of the hard gamma through shielding would be the only effective way to reduce the film badge exposure from "background" in the digest area.

Table 2—Statistical Analysis of Results of Primary Beta from Table 1

(From Table 1)

Position Primary Beta

A	-0.03
B	0.215
C	0.041
D	0.07
E	-0.02
F	0.00
G	-0.012

$$\bar{X} \text{ (mean)} = 0.038$$

$$X_n \text{ (value furthest from mean)} = 0.215$$

$$S \text{ (standard deviation)} = \sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + (X_n - \bar{X})^2}{n-1}}$$

$$S = 0.086$$

$$T = \frac{X_n - \bar{X}}{S} = \frac{0.215 - 0.038}{0.086} = 2.06$$

From the table of T, a value of T as large as or larger than 2.020 could occur by chance only one time in twenty. Point B will then be dropped from the calculations.

Position Primary Beta

A	-0.03
C	0.041
D	0.07
E	-0.02
F	0.00
G	-0.012

$$\bar{X} \text{ (mean)} = 0.0081$$

$$R \text{ (range)} = (D - A) = 0.10$$

$$\text{From the table of F, the 90\% limit of error for the mean of six observations} = FR = (0.399) (0.10) = 0.04$$

$$\text{To the 0.9 confidence limit } \bar{X} = 0.008 \pm 0.04$$

The range in values of the primary beta density to the 0.9 confidence limit is then -0.032 to 0.048, with the mean being 0.008.

Table 3—Digest Area Survey Meter Data Percent Beta of Total Radiation

10

Position	North		East		South		West		UP		Down		Avg. All Directions		Average N,E,S,W	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
A	4	14	9	0	11	10	9	17	0	0	10	0	7	7	8	10
B	19	0	19	0	0	10	0	5	0	0	14	0	9	3	9	4
C	7	0	0	0	5	0	4	8	0	0	14	9	5	3	4	2
D	23	4	17	0	0	0	0	6	0	0	39	17	13	5	10	3
E	38	25	0	0	0	0	32	9	9	5	39	26	20	11	17	9
F	8	19	4	12	0	30	19	7	0	6	20	10	9	14	8	17
G	4	0	0	10	16	25	11	12	0	8	28	24	10	13	8	12
H	9	0	0	18	9	29	9	14	9	29	14	17	8	18	7	15
I	18	0	8	0	5	0	11	12	0	0	21	0	11	2	11	3
J	6	23	19	20	4	7	0	0	0	6	0	8	5	11	7	13
K	17	9	5	11	0	17	0	13	0	4	12	17	6	12	5	13
L	12	7	0	0	0	8	20	24	12	20	15	4	10	11	11	10
M	12	20	10	23	6	0	10	15	8	13	17	0	11	12	10	15
N	12	8	12	9	20	12	5	7	7	0	9	0	11	6	12	9
O	7	8	19	4	13	8	23	5	3	3	16	0	14	5	16	6
P	20	0	0	40	29	0	8	27	0	0	22	17	13	14	14	17
Q	8	0	2	4	7	5	8	9	13	0	9	0	8	3	6	5
R	6	5	6	3	5	6	5	3	4	5	10	3	6	4	6	4
S	3	5	5	3	8		0	2	1	2	12	0	5	3	4	2

B-before clean-up (7/14/50)

A-after clean-up (7/18/50)

Area cleaned 7/16/50

Before clean-up After clean-up

Grand Total Average All Direction

9.5%

8.3%

Grand Total Average N,E,S,W

9.1%

9.0%

//

Table 4 —Digest Area Film Badge Data Before and After Clean-up

Film No.	mr gamma		mr beta		mr/hr gamma		mr/hr beta		Total mrep/hr		percent beta	
	B	A	B	A	B	A	B	A	B	A	B	A
G1	135	200	260	230	3.2	3.9	6.2	4.4	9.4	8.3	66%	53%
G3	190	260	320	190	4.5	5.0	7.6	3.7	12.1	8.7	63%	43%
G4	125	30	60	190	3.0	0.6	1.4	3.7	4.4	4.3	32%	86%
G7	440	590	0	0	10.5	11.3	0	0	10.5	11.3	0	0
G8	170	200	0	0	4.0	3.8	0	0	4.8	3.8	0	0
G9	60	135	46	0	1.4	2.6	1.1	0	2.5	2.6	44%	0
G10	460	700	80	0	11.0	13.5	1.9	0	12.9	13.5	15%	0

Before clean-up badges exposed 42 hours.

After clean-up badges exposed 52 hours.

Before clean-up grand total average, 28 percent beta.

After clean-up grand total average, 26 percent beta.

Magnet Yoke Assembly

Phantom Yoke Assembly

Lucite
Collimator

Film Packet
Holder

Film Packets

Fig. 1

17-13
Y-36-4

FIGURE 2

RADIUM GAMMA FILM BADGE CALIBRATION

Film processed 10/9/50

FIGURE 3

RADIUM GAMMA FILM BADGE CALIBRATION

Film processed 10/9/50

FIGURE 4

URANIUM BETA FILM BADGE CALIBRATION

Film processed 10/9/50

17-46