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BY JW Jordan DATE 2-27-81

September 29, 1948

REPORT OF

MEASUREMENT OF RADIATION THROUGH HANFORD SHIELD

PRODUCTION TEST NO. 105-213-P

Prepared By: G. H. Whipple, Jr.

Health Instrument Divisions

General Electric Company

Hanford Works

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-3-

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REPORT OF
MEASUREMENT OF RADIATION THROUGH HANFORD SHIELD
PRODUCTION TEST NO. 103-213-P

ABSTRACT

The intensities of radiations transmitted through a Hanford Pile Shield have been measured with the results tabulated below:

<u>Radiation</u>	<u>True Value Probably is</u>	
	<u>Greater Than</u>	<u>and Less Than</u>
Gamma	0.05	0.5 mr/hr
Slow Neutron	0.1	5.0 nv
Fast Neutron	0.01	0.5 mrep/hr

-3-

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EW-11123

REPORT OF

MEASUREMENT OF RADIATION THROUGH HANFORD SHIELD

PRODUCTION TEST NO. 105-213-P

- I. Problem. The object of this experiment was to measure the intensities of slow neutron, fast neutron and gamma radiations which are transmitted through the shield of a Hanford pile.
- II. Equipment. In addition to the 100-B pile itself, the equipment consisted of the following:
 - A. Shield box to exclude scattered radiation from that section of the pile shield over which measurements were taken.
 - B. Fast neutron and gamma meter.
 - C. Slow neutron meter.

The shield box was composed of paraffin, cadmium and lead as shown in Fig. 1, and enclosed a space two feet square on the top surface of the pile shield and about twenty inches high. Provision was made for flushing the shield box with air from a compressed air line. Two modifications of the shield box were made as shown in Figs. 2 and 3.

The fast neutron and gamma meter was of the "Chang and Eng" type. It consists of two cylindrical ionization chambers and a vibrating reed electrometer. The chambers are 15.9 cm long and 8.9 cm in diameter. One was filled with argon to a pressure of 116 psi (gauge). The pressures in the chambers were adjusted until both demonstrated the same sensitivity to gamma radiation. The argon chamber was calibrated in a known gamma field. Fast neutron measurements were obtained by measuring the difference between the currents through the two chambers and converting this figure into milli-rep with the calculated conversion factor.

The slow neutron meter consisted of a standard Hanford Works BF_3 counter and cadmium shell. The counter was calibrated in the pile in Building 3745.

III. Experimental. A sizeable area of the top of the pile shield was surveyed with X-ray film. The spot over which the shield box was constructed, and a considerable area around, showed no gamma ray spots. The box was placed midway between two near-to-far face seams, and a considerable distance from charge-to-discharge face seams. It was therefore in an optimum position to avoid radiation transmitted through the steel webs in the biological shield. (See Figs. 4 and 5).

The first measurements were made with the shield box constructed as shown in Fig. 2. The cadmium lining was to exclude all slow neutrons from the interior of the box. Readings were taken of the slow neutrons produced by successively thicker layers of paraffin placed between the pile shield and the BF_3 counter tube. This arrangement was simulated in the laboratory as shown in Fig. 3. The radium-beryllium source used for the experiment gave 6.7×10^5 neutrons per second total flux. The results of the two sets of measurements are given in Table 1.

When these measurements were completed the cadmium lining in the shield box was removed and the box was completed as shown in Fig. 1. Measurements of slow neutron, fast neutron and gamma fluxes were made on three days over a period of about two weeks. The pile was shut down during this period and measurements were made at this time also. In order to check the adequacy of the shielding box, measurements were made with an additional two inches of paraffin on the top and discharge face side of the box as shown in Fig. 6. The results are given in Tables II and III.

It was thought that air contamination present on top of the pile might produce enough gamma radiation to affect the gamma and fast neutron readings. To test this, compressed air was fed into the shield box through an opening in a wood envelope, not shown in the drawings, which was placed between the cadmium sheet and the lead. No change was observed when air was forced into the shield and out through the cracks and cable holes.

Measurements taken when the pile was shut down showed that the level of all radiations was below the limit detectable by the instruments.

Occasional groups of excessively variable data which correlated with large control rod movement were disregarded.

TABLE I. PARAFFIN-MODERATED BF_3 DATA

Laboratory Measurements 325 mv Ra-Be Neutrons				Pile Measurements		
Paraffin Thickness	Cd Shield for BF_3	Counts per minute	Cadmium Difference	Counts per minute	Cadmium Difference	Fast Neutron Flux
0	on	---	---	37 ± 5	---	---
0	off	---	---	31 ± 3	-6 ± 6	---
2 inches	on	16 ± 2	---	28 ± 2	---	---
2 inches	off	80 ± 5	64 ± 5	38 ± 3	10 ± 4	51 n/sec/cm^2
4 inches	on	13 ± 3	---	23 ± 2	---	---
4 inches	off	81 ± 8	68 ± 9	47 ± 2	24 ± 3	115
6 inches	on	9 ± 2	---	19 ± 2	---	---
6 inches	off	62 ± 5	53 ± 5	54 ± 3	35 ± 4	214

- * Calculated at the surface of the paraffin moderator facing the Ra-Be source, see Fig. 6.

TABLE II FAST NEUTRON AND GAMMA DATA

<u>Radiation</u>	<u>Resistor (ohms)</u>	<u>Voltage (volts)</u>	<u>Current (amperes)</u>	<u>Dose</u>	<u>Remarks</u>
Gamma	1.08×10^9	0.021	1.95×10^{-11}	19.1 mr/hr	Calibration
Gamma	1.08×10^9	0.082	7.6×10^{-11}	75.7 mr/hr	Calibration
Gamma	1.06×10^{11}	0.029 ± 0.010	2.7×10^{-13}	0.27 mr/hr	
Gamma	1.06×10^{11}	0.033 ± 0.010	3.1×10^{-13}	0.31 mr/hr	
Gamma	1.06×10^{11}	0.036 ± 0.010	3.4×10^{-13}	0.33 mr/hr	
Gamma	1.06×10^{11}	0.033 ± 0.010	3.1×10^{-13}	0.31 mr/hr	Extra Paraffin
Neutron	1.06×10^{11}	0.007 ± 0.003	6.6×10^{-14}	0.033 mrep/hr*	
Neutron	1.06×10^{11}	0.006 ± 0.003	5.7×10^{-14}	0.027 mrep/hr	Extra Paraffin

* Conversion of current values into mrep/hr is taken from "Calculations for use with Fast Neutron Meter", by G. C. Gamertfelder, July 21, 1944.

$$R_n = 0.39 R_g$$

where R_n is the current for 2.5 mrep/hr of neutrons

R_g is the current for 12.5 mr/hr of gamma

From the gamma calibration above

$$R_g = 1.3 \times 10^{-11} \text{ amperes}$$

$$R_n = 5.0 \times 10^{-12} \text{ amperes}$$

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TABLE III SLOW NEUTRON DATA

The first two rows were taken with the shield box as shown in Fig. 1, the second two rows with an extra two inches of paraffin as shown in Fig. 3.

<u>Cd Shield for BF₃</u>	<u>Counts per minute</u>	<u>Cadmium Difference</u>	<u>Slow Neutron Flux * (nv)</u>
on	17 ± 1	—	—
off	30 ± 2	13 ± 2	1.8
on	5 ± 1	—	—
off	13 ± 1	8 ± 2	1.1

* Calibration of the BF₃ tube used in this experiment in the calibration pile in Building 3745 at four flux densities gave a straight line with a slope of

$$F = 0.14 D,$$

where F is the density in slow neutrons, nv, and

D is the cadmium difference in counts per minute

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IV. Discussion

A. Gamma measurements. The gamma ray calibration is direct and the results were consistent throughout the experiment. The efficiency of the shield box in reducing gamma radiation from the surroundings, chiefly from the vertical rods, is open to some question. Survey along the near-to-far median line of the shield box with a C.P. meter gave a reading of 15 mr/hr. If it is assumed that this came from the vertical rods, and that all of it passed vertically through the top of the shield box where the thickness of lead is only six inches, and if it is further assumed that the radiation is 2 Mev gamma, the stray radiation would contribute about 0.003 mr/hr inside the shield box, an amount entirely insignificant in this experiment. Any such estimates take no account of the radiation entering through cracks between lead bricks.

B. Slow neutron measurements. The slow neutron measurements are subject to two uncertainties. The first is the rather puzzling decrease in the slow neutron flux produced by the addition of the extra paraffin as shown in Table III. The second is the difference between the calibration and measurement procedures. The BF₃ tube was calibrated in the standard manner in holes in the calibration pile where the tube is immersed in the slow neutron field. In the shield box, however, the slow neutrons can be thought of as diffusing from the floor of the box only.

C. Fast neutron measurements. There are two fundamental weaknesses to the fast neutron measurements made with the moderated BF₃. The first is the energy error inherent in going from Ra-Be neutrons to neutrons escaping through the pile shield. The second weakness is the geometry error. The laboratory measurements involved a point source while the pile shield presented an essentially infinite plane to the detector. In view of these difficulties it is not believed that the divergence between the two sets of fast neutron measurements is significant.

The fast neutron measurements obtained from the methane argon chambers are believed to be valid within the limitations of this type of instrument.

V. Conclusion. The following table summarizes the data obtained in the experiment.

TABLE IV. SUMMARY OF EXPERIMENTAL DATA

Radiation	Experimental Value	True value probably is		
		greater than	and	less than
Gamma	0.3 mr/hr	0.05 mr/hr		0.5 mr/hr
Slow neutron	1.0 nv	0.1 nv		5.0 nv
Fast neutron	0.03 mrep/hr	0.01 mrep/hr		0.3 mrep/hr

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-9-

VI. Acknowledgments. This experiment was conducted in collaboration with the Technical Division, "P" Division and H.I. Operations Division. Without the assistance of these divisions and the advice of Dr. B. T. Feld, Massachusetts Institute of Technology, the experiment could hardly have been carried off in the limited time available.

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Physics Group Head
Health Instrument Divisions

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-9-

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-10-

Health & Biology Research Laboratory

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SCALE: 1/4" = 2"

CHARGING FACE

FIG. 1 SHIELD BOX -- ELEVATION SECTION

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FIG. 2. SHIELD BOX ARRANGEMENT FOR MODERATED BF_3 MEASUREMENTS

FIG. 3 SHIELD BOX WITH EXTRA PARAFFIN

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-12-

SCALE: 1/4" = 1'

FIG. 4 POSITION OF SHIELD BOX IN PILE — PLAN VIEW

SCALE: 1/4" = 1'

FIG. 5 POSITION OF SHIELD BOX ON PILE — ELEVATION SECTION

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SCALE: 1/4" = 2"

ELEVATION

PLAN

FIG. 6 LABORATORY ARRANGEMENT FOR MODERATING NF_3

IV. Discussion

A. Gamma measurements. The gamma ray calibration is direct and the results were consistent throughout the experiment. The efficiency of the shield box in reducing gamma radiation from the surroundings, chiefly from the vertical rods, is open to some question. Survey along the near-to-far median line of the shield box with a C.P. meter gave a reading of 15 mr/hr. If it is assumed that this came from the vertical rods, and that all of it passed vertically through the top of the shield box where the thickness of lead is only six inches, and if it is further assumed that the radiation is 2 Mev gamma, the stray radiation would contribute about 0.008 mr/hr inside the shield box, an amount entirely insignificant in this experiment. Any such estimates take no account of the radiation entering through cracks between lead bricks.

B. Slow neutron measurements. The slow neutron measurements are subject to two uncertainties. The first is the rather puzzling decrease in the slow neutron flux produced by the addition of the extra paraffin as shown in Table III. The second is the difference between the calibration and measurement procedures. The BF₃ tube was calibrated in the standard manner in holes in the calibration pile where the tube is immersed in the slow neutron field. In the shield box, however, the slow neutrons can be thought of as diffusing from the floor of the box only.

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Slow neutron	1.0 nv	0.1 nv	5.0 nv
Fast neutron	0.03 mrep/hr	0.01 mrep/hr	0.3 mrep/hr

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