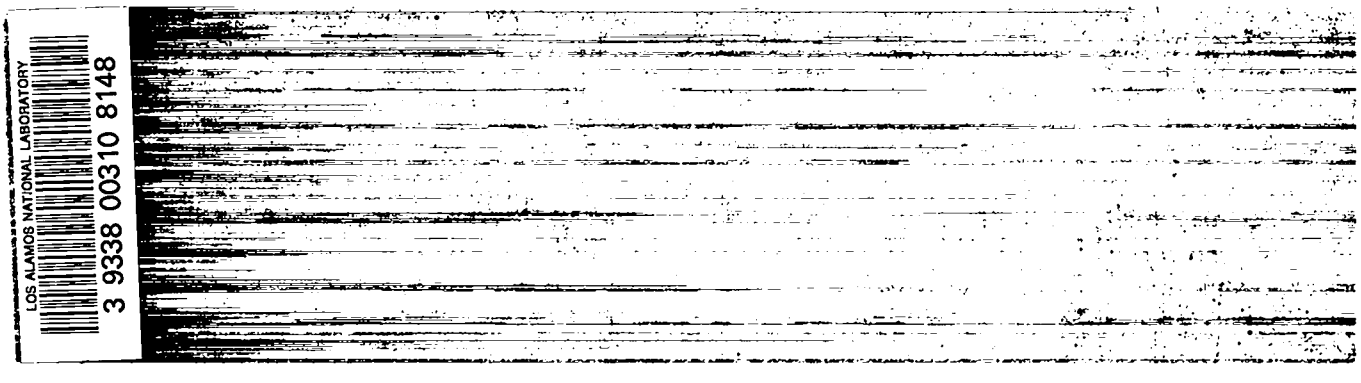
LOS ALAMOS SCIENTIFIC LABORATORY

OF THE

UNIVERSITY OF CALIFORNIA

CONTRACT W-7405-ENG. 36 WITH

U. S. ATOMIC ENERGY COMMISSION



c. 17

LOS ALAMOS SCIENTIFIC LABORATORY

of the

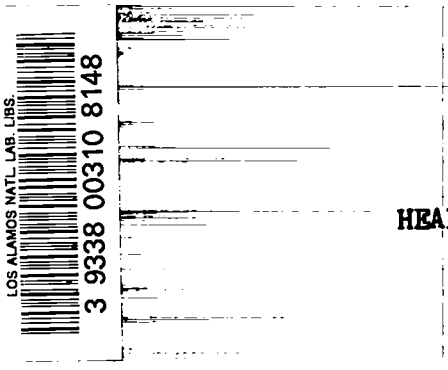
UNIVERSITY OF CALIFORNIA

Report written:
March 16, 1953

LA-1574

SURFACE DOSE RATE FROM MASSIVE PLUTONIUM

by
P. R. Schiavone
W. R. Kennedy
T. N. White



HEALTH AND BIOLOGY

ABSTRACT

Surface dose rates from massive pieces of plutonium were measured with an extrapolation chamber under conditions likely to be met in current working practice. The dose rate through 9 to 11 mils of latex plus 30 to 35 mils of neoprene compound was found to be 490 mrep/hr with a standard deviation of 7.2%. Over-all accuracy is probably within 20%.

Taking into account possible variations in the work-place setup, a value of 900 mrep/hr is suggested as a reasonable estimate of surface dose rate for monitoring purposes.

Measurements through about 11 mg/cm^2 of cellophane gave a dose rate of 2.16 rep/hr. This value is probably accurate to within 20%.

By correlating results with spectrum determinations from other sources, an estimate of the contribution to the surface dose was made for each spectral component.

ACKNOWLEDGMENT

The authors are grateful to S. Shlaer, H. Israel, R. Baker, E. Bemis and J. Anderson for expediting various phases of the work.

1. Introduction

The present work on surface dose rates was performed to re-evaluate the surface dose rate from plutonium.[1] Because of the nature and restricted availability of the material, much of the experimental work was performed at the place where work on plutonium was being carried out. Emphasis was placed on measurements which would give dose rates encountered by the hands of personnel under actual working conditions.

2. Equipment

The extrapolation chamber was originally constructed by Hoffman and adapted by Shlaer and Pettengill. It consisted essentially of two parallel circular plates, one of which could be accurately spaced from the other by means of three micrometer screws.

The lower plate was a disc of polystyrene with a layer of aquadag on the surface. A circular line enscribed through the aquadag layer into the polystyrene defined the collecting area; the remaining area acted as the guard plate. The upper plate consisted of an aquadag-coated nylon screen cemented to a brass ring. The ring fitted snugly around a brass collar so that the nylon was forced against the bottom side of an aluminum spacer. Specimens to be tested were placed on the top side of the aluminum spacer. The top assembly was mounted in a brass cylinder which slid within a larger brass cylinder. The lower plate was attached to the larger cylinder.

The equipment was later modified to include a thermocouple unit in the guard ring portion of the polystyrene plate. In addition, all

switches and all but one of the resistors were removed and the remaining resistor was mounted in a cylinder of polystyrene to eliminate collection of ions at points other than the chamber proper.

A vibrating reed electrometer was used in conjunction with the extrapolation chamber to measure the voltage developed by the ionization current across a calibrated resistor.

Proper functioning and calibration of the equipment was checked by measurements on a disc of natural uranium, the dose rate from which was measured independently by another installation.[2]

3. Procedure

The plutonium to be measured was pulled into a neoprene-compound dry-box glove, a flat section of latex (surgeon's) glove was tied over it, and it was then placed in the extrapolation chamber. Voltage measurements (normal and reversed polarity) were made at 0.01" increments between 0.02" and 0.10". A check series of measurements was made at a later date at smaller spacings (0.008" minimum). The number of spacings was later reduced when it was evident that proper extrapolation would result.

A plot of voltage versus spacing was made and the slope of this curve determined.

Assuming 1 esu/cm^3 of air under standard conditions approximately equals 1 rep, then the surface dose rate in rep/hr is

$$\frac{\text{Volts} \times 3 \times 10^9 \text{ esu/coulomb} \times 3.6 \times 10^3 \text{ sec/hr}}{\text{ohms} \times \text{inch spacing} \times 2.54 \text{ cm/in.} \times \text{collecting area in cm}^2} \times \frac{29.92}{P} \times \frac{273 + T}{273}$$

where P = atmospheric pressure in inches of Hg
T = temperature in degrees Centigrade

In addition to the measurements with the rubber absorbers, measurements were made through copper and lead absorbers (added to the neoprene and latex) of 0.005" and 0.031" thickness, respectively, and through about 0.003" of cellophane only. An aluminum filter of 0.010" thickness was interposed between the metal absorbers and the chamber to stop photoelectrons ejected from the absorbers.

4. Results

A series of measurements was made using 9 to 11 mils of latex (surgeon's glove) and 30 to 35 mils of neoprene compound (dry-box glove). These measurements averaged 490 mrep/hr with a standard deviation of 7.2% and a maximum deviation of 11%. To check the variability of the results, a series of measurements was made using layers of neoprene compound alone, and micrometer measurements of thickness were correlated with weight per square centimeter determinations. These measurements are plotted in Figs. 1 and 2.

Figure 1 shows that the dose rate is quite sensitive to glove thickness in the region of interest (less than 140 mg/cm^2). Figure 2 shows the correlation between weight per unit area and thickness in mils for 10 specimens of neoprene compound obtained from six different gloves. In several cases the correlation was not good, indicating possible differences in neoprene-compound composition. In addition, micrometer measurements were made over several regions of the dry-box gloves. A typical set of such measurements for a new neoprene-compound glove (30 gauge nominal) is shown on page 8.

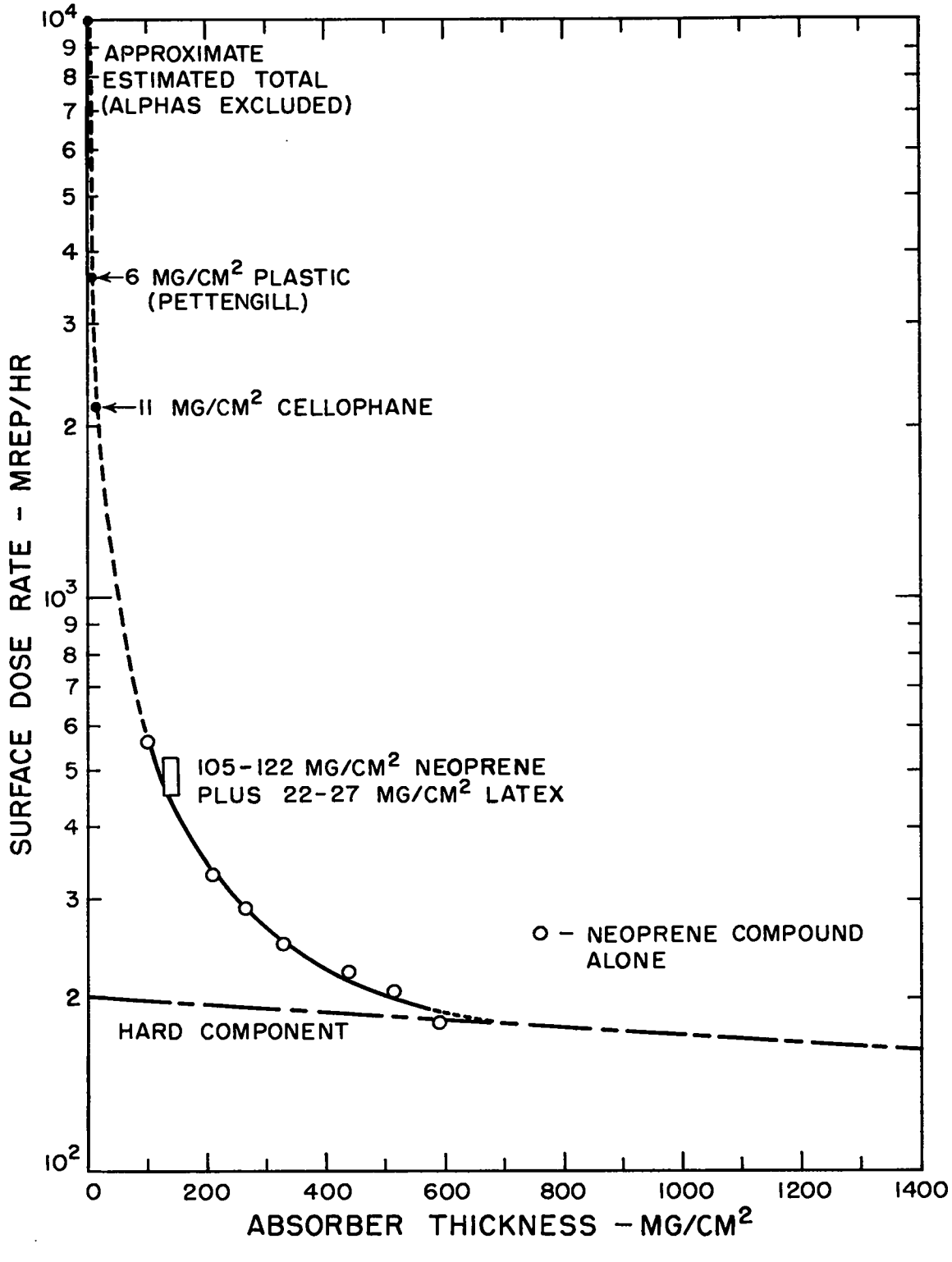


Fig. 1 - The surface dose rate from bulk plutonium as a function of mass per unit area of intervening absorber.

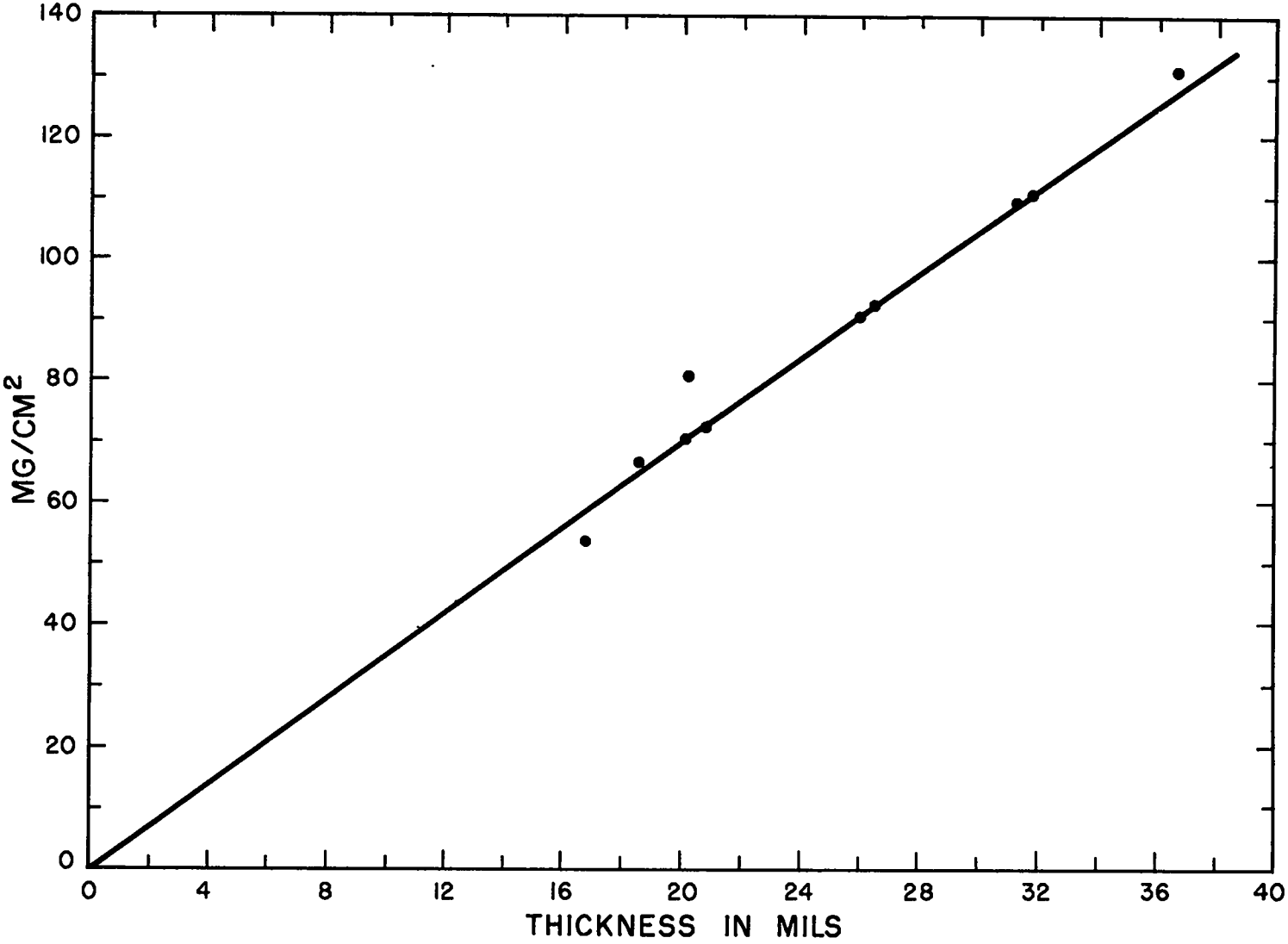


Fig. 2 - Correlation between weight per unit area and thickness in mils for dry-box glove neoprene.

Thickness of Various Regions of a New Neoprene-Compound Glove
(30 Gauge Nominal)

Region	Average Thickness, mils
Palm	46
Back	41
Fingers	38
Finger tips	30
Between fingers	37
Wrist	41
Gauntlet	35

It has been observed that glove finger tips and glove fingers are most susceptible to wear.

Because of the foregoing variations and the fact that gloves as thin as 15 gauge are available as possible replacements, a value of 900 mrep/hr appears reasonable as an over-all estimate of surface dose rate for monitoring purposes.

Reductions to 44% and 21% of the average surface dose rate (490 mrep/hr) were observed with the copper and lead absorbers, respectively. One series of measurements made through about 11 mg/cm^2 of cellophane gave a dose rate of 2160 mrep/hr. After due allowance was taken for the increased thickness of absorber, this value was within 9% of that previously determined by Pettengill.[1]

Spectrometer measurements [3 - 7] and exponential integrals [8] were used to estimate the transmission of various components through the absorbers used in the extrapolation chamber and the results of these

estimates are listed below. The dosage rates are probably correct to within 20% except for the components around 100 kev which may be in error by 50%. The alpha surface dose contribution is not included.

Component Name	Estimated Dose Rate (no absorber), mrep/hr	Remarks
M X-rays plus photo- and conversion electrons	8820	Average photon energy of M radiation of uranium is about 3.3 kev. Intensity reduced to 8% by about 11 mg/cm^2 cellophane. Calculation based on measurement of 2160 mrep/hr through 11 mg/cm^2 cellophane.
L X-rays	1340	This value calculated by setting up three simultaneous equations for transmission of L radiations at 150, 200, and 250 mg/cm^2 of neoprene (see Fig. 1). Comparison with calculations for bulk Pu from argon counter spectrometer measurements with thin deposits on aluminum[3] is shown below:

Line	kev	mrep/hr from neoprene transmission	mrep/hr from spectrometer measurements
ULα	13.6	840	310
ULβ	16.9	430	420
ULγ	20.2	70	40
Total		1340	770

There is no obvious reason for the indicated discrepancies, but it is possible that currently proposed spectrometer measurements with thick sources may resolve the differences.

Intermediate	2 or 3	This component shows lines on the krypton counter spectrometer at 34, 40, 52, and 60 kev.[3]
K X-rays and 127 kev gamma	50	In addition to the K X-rays (about 100 kev), a gamma component at about 127 kev was found by Bunker[9] and more

		recently by others.[10] These two components are listed together since their neoprene absorption coefficients are almost identical.
Hard and general background components*	150	This component was found by Bunker[9] and others[10] to be approximately 380 kev. The origin of this component is still a mystery. About 8 x 10^{-5} photons per alpha are required to produce observed dose rate. K and harder components are approximated by two methods: one graphical (see Fig. 1) and the other by assuming an absorption coefficient of 0.03 cm^2/gm for these components at a neoprene compound thickness of 600 mg/cm^2. Breakdown of K and harder component determined by use of simultaneous equations.
Total	10360	

Under actual working conditions the M X-rays are completely filtered out by the gloves. Transmission of the L spectrum is very sensitive to glove thickness, but transmission of the harder components seems not to be much affected by conditions met in current working practice.

5. Conclusions

The dose rate through 9 to 11 mils of latex (surgeon's glove) plus 30 to 35 mils of neoprene compound (dry-box glove) was found to be 490 mrep/hr with a standard deviation of 7.2% and a maximum deviation of 11%.

The radiation can be classified roughly into two categories -- soft

*General background radiation includes ionization caused by fluorescence of neoprene and wall elements and may apply to more than the hard component.

and hard. The hard radiation contributes about 40% to the dose rate and is not affected by varying working conditions. The soft component is sensitive to glove thicknesses.

Because of possible variations in glove composition, thickness, gauge size, and wear, 900 mrep/hr is considered a reasonable estimate of surface dose rate for monitoring purposes.

Measurements through about 11 mg/cm^2 of cellophane gave a dose rate of 2.16 rep/hr. This value is probably accurate to within 20%.

By correlating extrapolation chamber results with current knowledge of the plutonium radiation spectrum, an estimate of the contribution of each spectral component to the surface dose was made.

6. References

1. G. Pettengill (unpublished work) finds a dose rate of 3.6 rep/hr through 6 mg/cm^2 of plastic.

2. H. D. LeVine, Chief, Instruments Branch, Health and Safety Division, New York Operations Office USAEC, Communication dated Oct. 22, 1952.

3. H. I. Israel, "Soft Radiation From Pu^{239}," Phy. Rev. 88, 682 (1952), and unpublished work.

4. D. West and J. K. Dawson, "Soft Radiations From Pu^{239}," Proc. Phys. Soc. (London) 64A, 586-7 (1951).

5. F. Asaro, "Summary of the Research Progress Meeting of August 16, 1951," UCRL-1458 (declassified).

6. G. Albouy and J. Teillac, Comptes Rend. 232, 326, (1951).

7. D. West, J. K. Dawson, and C. J. Mandleberg, "The Investigation of Soft Radiations from Pu^{239} and U^{233} with a Proportional Counter," A.E.R.E. N/R 902, Apr. 28, 1952.

8. G. Placzek, "The Functions E_n (X)," National Research Council of Canada, Atomic Energy Project, Chalk River, Ont. (1947).

9. M. E. Bunker, unpublished work.

10. M. S. Freedman, F. Wagner, Jr., and D. W. Engelkeimer, "The Beta-Spectra of Pu^{239}, Pu^{240}, and Pu^{241}," Phys. Rev. 88, 1155 (1952).