31

AD

AD664758

NDL-TR-94

# EXPOSURE-RATE DEPENDENCE OF SELECTED GAMMA DOSIMETERS

Thomas W. Crimmins
Nancy N. Gibson
Armand M. Pelletier
John R. Jacobson

JANUARY 1968





US ARMY
## NUCLEAR DEFENSE LABORATORY
EDGEWOOD ARSENAL, MARYLAND



25

NDL-TR-94

# EXPOSURE-RATE DEPENDENCE OF SELECTED GAMMA DOSIMETERS

Thomas W. Crimmins
Nancy N. Gibson
Armand M. Pelletier
John R. Jacobson

January 1968



US ARMY
NUCLEAR DEFENSE LABORATORY
Edgewood Arsenal, Maryland

# ABSTRACT

This experiment studied the effects of exposure rate on the response of the following gamma dosimeters: silver-activated metaphosphate glass plates and rods, lithium fluoride and manganese-activated calcium fluoride microthermoluminescent dosimeters, and cobalt-activated borosilicate glass plates. The experiment was conducted at the flash x-ray facility of the Ion Physics Corporation of Burlington, Massachusetts. Data were obtained in the exposure range of approximately 1,500 to 45,000 R at exposure rates from $5.2 \times 10^{10}$ R $s^{-1}$ to $2.2 \times 10^{11}$ R $s^{-1}$.

The results of this experiment indicate that no differences exist in the relative responses of the various dosimeters that may be attributed to exposure rate or to an interaction between exposure and exposure rate. No absolute exposure measurements were made; therefore, data were analyzed on a relative basis.

CONTENTS

BLANK PAGE

## EXPOSURE-RATE DEPENDENCE OF SELECTED GAMMA DOSIMETERS

### 1. BACKGROUND

The US Army Nuclear Defense Laboratory (USANDL) has made radiation measurements at nuclear weapon tests and weapon simulation tests for many years. The extremely high exposure rates encountered at these facilities require determination of dosimeter response as a function of exposure rate.

This experiment studied the effect of exposure rate on the response of the following gamma dosimeters: silver-activated metaphosphate ($AgPO_3$) glass rods and plates, cobalt-activated borosilicate (Co) glass plates, lithium fluoride (LiF) and manganese-activated calcium fluoride ($CaF_2$) microthermoluminescent dosimeters (μTLD). Exposure rate dependence had been studied previously and none has been observed at rates of less than $10^{10}$ R $s^{-1}$ (References 1 through 6). However, only a limited amount of work has been done above this level (Reference 5). The highest expected exposure rate in this experiment was $4 \times 10^{11}$ R $s^{-1}$.

### 2. THEORY

The physical phenomenon resulting from the interaction of ionizing radiation with a dosimeter material is not sufficiently understood for a detailed quantitative discussion. A simple model is summarized below. When a radiation field interacts with matter, some fraction of the radiant energy is given up to the material. This energy excites the electrons, raising them to higher energy levels by either the photoelectric effect, Compton scattering, or pair production. The energy of the incident radiation determines which process is predominant. The number of electrons excited and the levels to which they are raised depend upon the dosimeter material, the energy, amount, and type of incident radiation, and possibly the rate at which the radiation is delivered. A portion of the excited electrons will undergo transitions to the ground state immediately while the remainder will be trapped and bound to some metastable state. The change produced in the dosimeter material by the rearrangement of the electrons is then used as a measure of the exposure.

Donnert et al. (Reference 7) conclude from a theoretical mathematical treatment:

"Any dose rate effect in a dosimetry system is, at least in principle, a dose dependent phenomenon. This does, however, not necessarily imply that this phenomenon is of observable magnitude."

In other words, the response of a dosimeter is a function of exposure, exposure rate, and an interaction term containing both exposure, exposure rate and possibly other factors.

## 3. EXPERIMENTAL PROCEDURE

### 3.1 Experimental Facility.

This experiment used Ion Physics Corporation's (Burlington, Mass.) flash x-ray machine. A 3.6 MV pulsed power supply charges the unit's 3-meter coaxial capacitor. Electrons discharged from the capacitor strike a tantalum target to produce a bremsstrahlung with an average energy of 1.2 MeV and a maximum intensity of $8 \times 10^3$ R at the tube surface. Radiation intensity is monitored with an external fast scintillator and photodiode. The monitoring unit signal is fed to an oscilloscope and photographed. This provides a radiation intensity profile of each pulse (Figure 3.1).

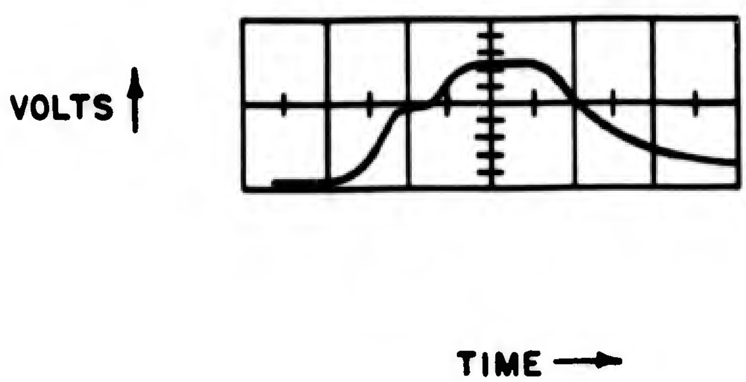


Figure 3.1 A typical radiation intensity profile.

3.2 Dosimetry.

A complete description of all the dosimeters, their readout systems and calibration techniques, is contained in Reference 8. One notable characteristic is the response of the dosimeters as a function of energy. The dosimeters in this experiment exhibit an overresponse to photons in the low energy region (< 200 keV) when compared to $^{60}Co$ radiation (1.25 MeV). All the dosimeters, with the exception of the LiF TLD's, are normally placed in energy discrimination shields to correct for this overresponse. These shields are designed to provide the dosimeters with nearly unit energy responses relative to $^{60}Co$ radiation from approximately 70 keV to a few MeV. The LiF μTLD's have a nearly tissue equivalent response and therefore are not shielded.

3.3 Experimental Design.

Four each of the various dosimeters were placed in polystyrene packets and arranged as shown in Figure 3.2, and then mounted on a circular aluminum faceplate (Figure 3.3) whose quadrants (A,B,C,D) were 1,12,20 and 29 mm respectively from the x-ray tube face. To minimize the distance between the dosimeter packets and the x-ray tube face, the dosimeters were exposed unshielded. The aluminum faceplate was mounted on an optical bench and centered on the x-ray tube face (Figures 3.4 and 3.5).

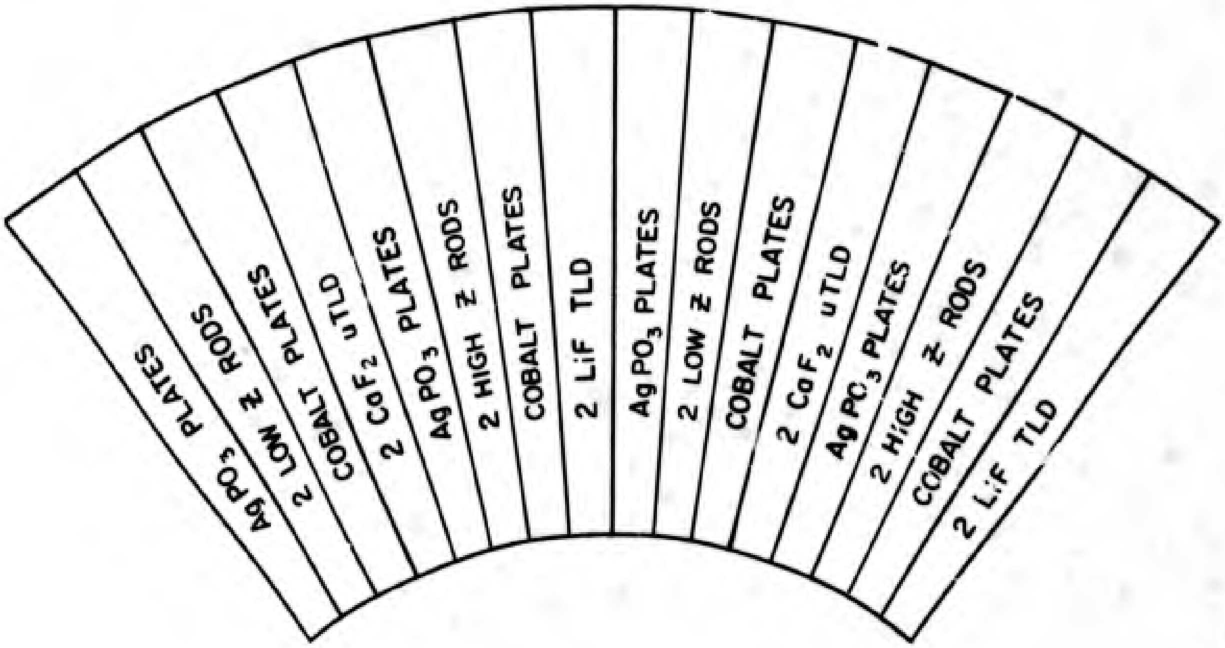


Figure 3.2 A schematic of a dosimeter packet.

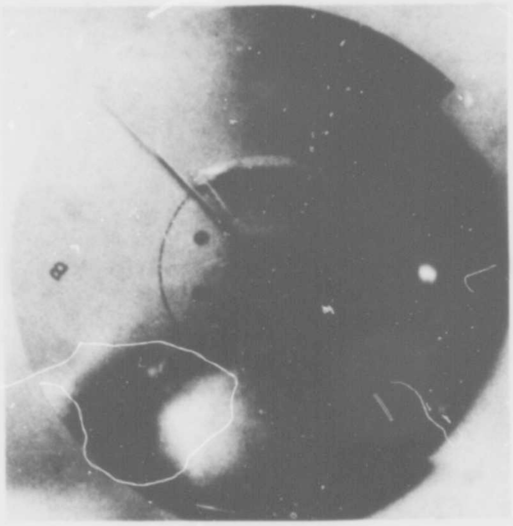

Figure 3.3 Aluminum faceplate with dosimeter packet placed on station A.

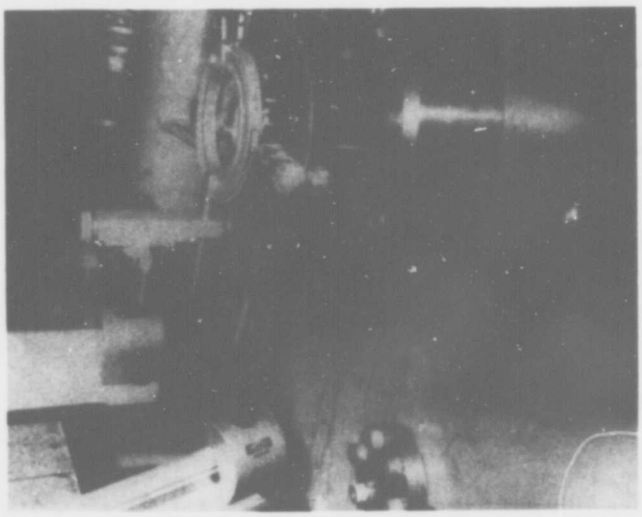

Figure 3.4 Side view of the experimental faceplate in position for exposure.

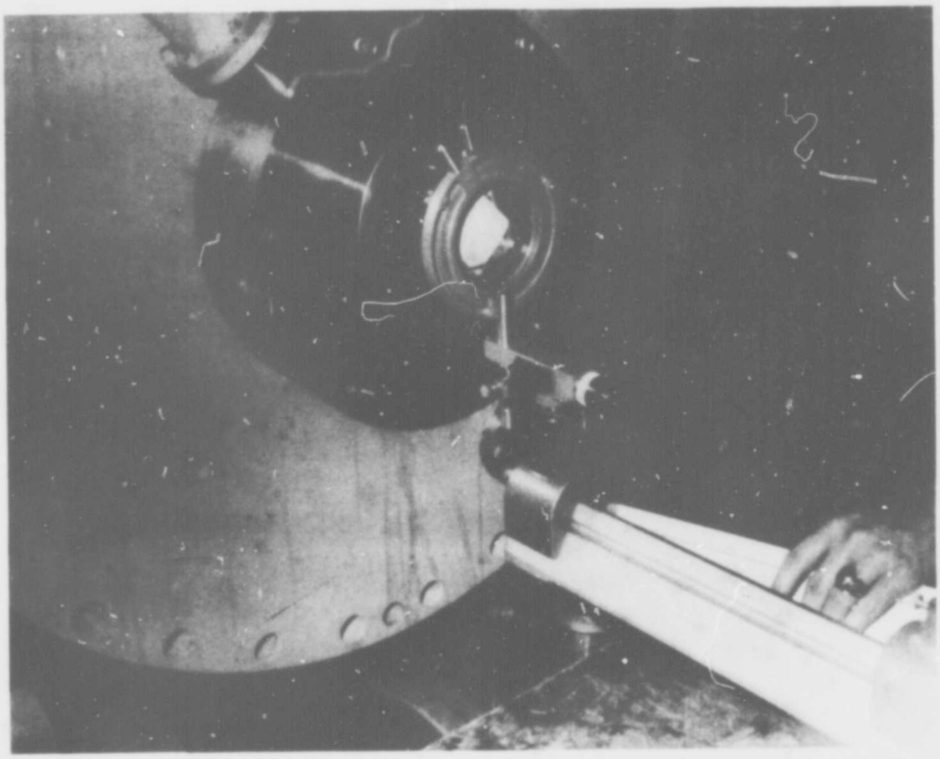

Figure 3.5 Experimental faceplate in position for exposure.

Based on predictions of the source output, the expected exposure rates at the dosimeter packet on each quadrant were: $4.0 \times 10^{11}$ R $s^{-1}$ (A), $2.0 \times 10^{11}$ R $s^{-1}$ (B), $1.0 \times 10^{11}$ R $s^{-1}$ (C), and $0.5 \times 10^{11}$ R $s^{-1}$ (D). The total exposure received by each packet was dependent upon the distance at which it was exposed and the number of pulses it received. Exposure rates for each packet were calculated by dividing the average observed LiF TLD exposure by the pulse width [$2.0 \times 10^{-8}$ s (FWHM)].

### 3.4 Data Analysis.

The amount of radiation received by each dosimeter is proportional to the total integrated area under the radiation intensity profiles. A normalized exposure is obtained by dividing the average observed exposure by the total integrated areas of the radiation intensity profiles. For each dosimeter type exposed to the same exposure rate, the normalized exposures should be equal. A variation relative to the total exposure would indicate an interaction effect of exposure and exposure rate.

Tochilin and Goldstein have shown that the LiF TLD exhibits no exposure rate effects at rates up to $2.0 \times 10^{11}$ R $s^{-1}$ (Reference 5); therefore experimental results of this dosimeter were used as a standard. The ratio of measured exposure to the LiF TLD exposure was calculated for each dosimeter type in each packet. The ratios vary for the different types of dosimeters because each type is characterized by a different energy response when exposed unshielded. However, for any one dosimeter type, a variation of the ratio relative to the exposure rate would indicate an exposure rate effect. The analysis requires the assumption that the radiation energy spectrum is the same at every station. This assumption is reasonable for the experimental distances from the tube face.

A Student's t-test (95 percent confidence level) was used to test the hypothesis that the exposures relative to LiF TLD are the same for each type of dosimeter, regardless of exposure rate.

## 4. RESULTS

Table 4.1 lists the average observed exposure for each type of dosimeter. The total area under the radiation intensity profile integrals, the LiF TLD measured exposures, and the exposure rates for each dosimeter packet are presented in Table 4.2. Table 4.3 lists the normalized responses of the dosimeters contained in each packet. Table 4.4 contains the response relative to LiF TLD for each type of dosimeter. The results of the Student's t-test of the data in Table 4.3 are presented in Table 4.5. Table 4.5 presents a statistical comparison of the responses at the exposure rates in column 1 to the response at the highest exposure rate in column 2, e.g., the response of the cobalt plates at $1.2 \times 10^{11}$ R $s^{-1}$ is equivalent to their response at $2.2 \times 10^{11}$ R $s^{-1}$.

The relative response of each dosimeter type as a function of the total radiation received (represented by the radiation intensity profile integrals) is presented graphically for the four exposure rates in Figures 4.1 through 4.4. The response relative to LiF TLD for each dosimeter type is shown as a function of exposure rate in Figure 4.5.

TABLE 4.1 AVERAGE OBSERVED EXPOSURE

| Packet Number and Quadrant | LiF TLD | | Cobalt Plates | | $AgPO_3$ Low-Z Rods | | $CaF_2$ μTLD | | $AgPO_3$ High-Z Rods | | $AgPO_3$ Plates | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exposure | Std Dev | Expo-sure | Std Dev | Expo-sure | Std Dev | Expo-sure | Std Dev | Expo-sure | Std Dev | Expo-sure | Std Dev |
| | $10^4$ R | pct | $10^4$ R | pct | $10^4$ R | pct | $10^4$ R | pct | $10^4$ R | pct | $10^4$ R | pct |
| 1A | 0.94 | ±22 | 1.20 | ±3 | 1.60 | ±24 | 1.20 | ±42 | 1.50 | ±15 | 1.20 | ±15 |
| 2A | 2.10 | ±32 | 2.90 | ±12 | 3.40 | ±19 | 2.20 | ±17 | 4.40 | ±33 | 3.20 | ±6 |
| 3A | 1.60 | ±12 | 2.10 | ±8 | 2.20 | ±26 | 2.00 | ±27 | 3.00 | ±13 | 2.70 | ±6 |
| 4A | 0.14 | ±18 | a | b | 0.16 | ±26 | 0.14 | ±10 | 0.15 | ±22 | a | b |
| 5A | 3.10 | ±14 | 4.60 | ±5 | 4.20 | ±21 | 4.50 | ±30 | 5.60 | ±17 | 5.60 | ±7 |
| 6A | 4.70 | ±34 | 7.60 | ±8 | 7.20 | ±23 | 9.00 | ±25 | 8.20 | ±11 | 7.90 | ±8 |
| 1B | 0.96 | ±13 | 1.10 | ±11 | 1.30 | ±3 | 0.96 | ±25 | 1.50 | ±9 | 1.50 | ±3 |
| 2B | 1.00 | ±17 | 1.10 | ±8 | 1.50 | ±2 | 0.91 | ±11 | 1.60 | ±14 | 1.50 | ±10 |
| 3B | 0.96 | ±28 | 1.50 | ±12 | 1.60 | ±9 | 1.40 | ±19 | 1.90 | ±4 | 1.80 | ±2 |
| 4B | 1.40 | ±11 | 2.00 | ±1 | 2.60 | ±50 | 1.80 | ±20 | 2.60 | ±8 | 2.70 | ±11 |
| 5B | 2.90 | ±9 | 4.20 | ±3 | 4.20 | ±13 | 3.90 | ±20 | 4.50 | ±8 | 5.10 | ±1 |
| 6B | 0.28 | ±23 | a | b,c | 3.70 | ±8 | 0.24 | ±5 | 0.37 | d | 0.99 | ±2 |
| 1C | 0.95 | ±12 | 1.20 | ±16 | 1.40 | ±8 | 0.31 | ±12 | 1.60 | ±4 | 1.40 | ±3 |
| 2C | 0.49 | ±5 | 0.72 | ±5 | 0.79 | ±3 | 0.59 | ±2 | 0.78 | ±10 | 0.74 | ±6 |
| 3C | 0.86 | ±12 | 1.20 | ±5 | 0.17 | ±36 | 1.10 | ±18 | 1.40 | ±11 | 1.60 | ±21 |
| 4C | 1.50 | ±14 | 2.20 | ±18 | 3.40 | ±57 | 1.60 | ±42 | 2.60 | ±2 | 2.90 | ±9 |
| 5C | 1.90 | ±14 | 3.20 | ±4 | 3.00 | ±43 | 1.70 | ±5 | 3.40 | ±18 | 3.80 | ±6 |
| 1D | 0.72 | ±9 | 0.90 | ±12 | 1.10 | ±11 | 0.58 | ±16 | 1.20 | ±7 | 1.10 | ±19 |
| 2D | 0.85 | ±12 | 0.95 | ±9 | 1.00 | ±18 | 0.72 | ±18 | 1.10 | ±12 | 1.10 | ±10 |
| 3D | 0.46 | ±18 | 0.52 | ±16 | 0.62 | ±14 | 0.37 | ±8 | 0.71 | ±11 | 0.69 | ±15 |
| 4D | 0.48 | ±21 | 0.51 | ±6 | 0.55 | ±13 | 0.27 | ±4 | 0.69 | ±7 | 0.72 | ±14 |
| 5D | 0.88 | ±11 | 1.20 | ±1 | 1.40 | ±25 | 0.87 | ±11 | 1.40 | ±19 | 1.30 | ±4 |
| 6D | 1.40 | ±8 | 2.00 | ±10 | 2.40 | ±18 | 1.80 | ±2 | 2.50 | ±16 | 2.40 | ±8 |

[a] Below sensitivity of dosimeter.
[b] Not applicable.
[c] Only one reading exceeded lower sensitivity of dosimeter.
[d] Identical readings for all dosimeters.

TABLE 4.2 EXPOSURE, EXPOSURE RATE, AND PULSE INFORMATION

| Packet Number and Quadrant | Pulses | Total Radiation Intensity Integrals | Total LiF Exposure | Exposure per Pulse | Exposure Rate | Average Quadrant Exposure Rate |
|---|---|---|---|---|---|---|
| | No. | | $10^4$ R | $10^3$ R | $10^{11}$ R $s^{-1}$ | $10^{11}$ R $s^{-1}$ |
| 1A | 1-2 | 1662 | 0.94 | 4.70 | 2.40 | 2.2[redacted] ±12%[c] |
| 2A | 3-6[a] | 2892 | 2.10 | 5.20 | 2.60 | |
| 3A | 7-10 | 3433 | 1.60 | 4.00 | 2.00 | |
| 4A | 11[b] | 402 | 0.14 | 1.40 | 0.70 | |
| 5A | 12-19 | 6584 | 3.10 | 3.90 | 2.00 | |
| 6A | 20-31[a] | 9978 | 4.70 | 3.90 | 2.00 | |
| 1B | 1-3 | 2501 | 0.96 | 3.20 | 1.60 | 1.2[redacted] ±28% |
| 2B | 4-6 | 2053 | 0.10 | 3.40 | 1.70 | |
| 3B | 7-11[b] | 3835 | 0.96 | 1.90 | 0.95 | |
| 4B | 12-17 | 4930 | 1.40 | 2.30 | 1.20 | |
| 5B | 18-29 | 9948 | 2.90 | 2.40 | 1.20 | |
| 6B | 30-31[a] | 1684 | 0.28 | 1.40 | 0.70 | |
| 1C | 1-4 | 3349 | 0.95 | 2.40 | 1.20 | 1.0[redacted] ±18% |
| 2C | 5-6[a] | 1205 | 0.49 | 2.50 | 1.30 | |
| 3C | 7-11[b] | 3835 | 0.86 | 1.70 | 0.90 | |
| 4C | 12-19 | 6584 | 1.50 | 1.80 | 0.90 | |
| 5C | 20-31[a] | 9978 | 1.90 | 1.60 | 0.80 | |
| 1D | 1-6[a] | 4554 | 0.72 | 1.20 | 0.60 | 0.52[redacted] ±18% |
| 2D | 1-6[a] | 4554 | 0.85 | 1.40 | 0.70 | |
| 3D | 7-11[b] | 3835 | 0.46 | 0.93 | 0.47 | |
| 4D | 7-11[b] | 3835 | 0.48 | 0.95 | 0.48 | |
| 5D | 12-20 | 7426 | 0.88 | 0.97 | 0.49 | |
| 6D | 12-27 | 13206 | 1.40 | 0.89 | 0.40 | |

[a] Pulses 6 and 31 were normal, but no radiation intensity profiles were obtained. The average intensity was assumed for these pulses.

[b] Pulse 11 was premature discharging at 3 MV instead of the normal 3.6 MV. Due to this premature discharge no radiation intensity profile was obtained. Since the radiation intensity is approximately proportional to the $4^{th}$ power of the charging voltage an intensity of $(3/3.6)^4$ times the average intensity was used. It should be noted that this calculation does not take into account any spectral change which results from the lower energy electrons.

[c] Pulse 11 was excluded from this calculation.

TABLE 4.3 DOSIMETER RESPONSE PER UNIT AREA UNDER THE RADIATION INTENSITY PROFILE

| Packet Number and Quadrant | LiF TLD | | | Cobalt Plates | | | $AgPO_3$ Low-Z Rods | | | $CaF_2$ μTLD | | | $AgPO_3$ High -Z Rods | | | $AgPO_3$ Plates | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Response | Avg | Std Dev | Response | Avg | Std Dev | Response | Avg | Std Dev | Response | Avg | Std Dev | Response | Avg | Std Dev | Response | Avg | Std Dev |
| | R/Unit Area | | pct | R/Unit Area | | pct | R/Unit Area | | pct | R/Unit Area | | pct | R/Unit Area | | pct | R/Unit Area | | pct |
| 1A | 5.7 | 5.1 | ±23 | 6.9 | 7.5 | ±17 | 9.3 | 7.5 | ±32 | 7.2 | 6.7 | ±26 | 9.1 | 9.0 | ±38 | 7.3 | 8.6 | ±16 |
| 2A | 7.2 | | | 9.9 | | | 11.7 | | | 7.6 | | | 15.4 | | | 11.1 | | |
| 3A | 4.6 | | | 6.1 | | | 6.5 | | | 5.8 | | | 8.7 | | | 7.9 | | |
| 4A | 3.5 | | | a | | | 4.0 | | | 3.5 | | | 3.7 | | | a | | |
| 5A | 4.8 | | | 7.0 | | | 6.4 | | | 6.8 | | | 8.5 | | | 8.6 | | |
| 6A | 4.7 | | | 7.6 | | | 7.2 | | | 9.0 | | | 8.2 | | | 8.0 | | |
| 1B | 3.8 | 3.1 | ±33 | 4.4 | 4.4 | ±11 | 5.2 | 4.7 | ±32 | 3.8 | 3.5 | ±27 | 6.0 | 5.0 | ±32 | 6.0 | 5.7 | ±14 |
| 2B | 4.9 | | | 5.3 | | | 7.2 | | | 4.4 | | | 7.5 | | | 7.2 | | |
| 3B | 2.5 | | | 3.9 | | | 4.3 | | | 3.6 | | | 4.8 | | | 4.7 | | |
| 4B | 2.8 | | | 4.1 | | | 5.3 | | | 3.7 | | | 5.2 | | | 5.4 | | |
| 5B | 2.9 | | | 4.2 | | | 4.2 | | | 3.9 | | | 4.5 | | | 5.1 | | |
| 6B | 1.7 | | | a | | | 2.2 | | | 1.4 | | | 2.2 | | | 5.9 | | |
| 1C | 2.8 | 2.6 | ±29 | 3.6 | 3.8 | ±28 | 4.1 | 4.7 | ±25 | 2.4 | 2.9 | ±37 | 4.7 | 4.4 | ±25 | 4.2 | 4.5 | ±18 |
| 2C | 4.1 | | | 6.0 | | | 6.6 | | | 4.9 | | | 6.4 | | | 6.1 | | |
| 3C | 2.2 | | | 3.1 | | | 4.5 | | | 2.9 | | | 3.6 | | | 4.1 | | |
| 4C | 2.2 | | | 3.3 | | | 5.2 | | | 2.4 | | | 3.9 | | | 4.4 | | |
| 5C | 1.9 | | | 3.2 | | | 3.0 | | | 1.8 | | | 3.4 | | | 3.8 | | |
| 1D | 1.6 | 1.4 | ±20 | 2.0 | 1.7 | ±18 | 2.3 | 1.9 | ±17 | 1.3 | 1.2 | ±24 | 2.5 | 2.0 | ±14 | 2.4 | 2.0 | ±14 |
| 2D | 1.9 | | | 2.1 | | | 2.3 | | | 1.6 | | | 2.3 | | | 2.4 | | |
| 3D | 1.2 | | | 1.4 | | | 1.6 | | | .96 | | | 1.8 | | | 1.8 | | |
| 4D | 1.2 | | | 1.3 | | | 1.4 | | | .70 | | | 1.8 | | | 1.9 | | |
| 5D | 1.2 | | | 1.6 | | | 1.9 | | | 1.2 | | | 1.9 | | | 1.7 | | |
| 6D | 1.1 | | | 1.5 | | | 1.8 | | | 1.4 | | | 1.9 | | | 1.8 | | |

[a] Exposure below lower sensitivity level of dosimeter.

TABLE 4.4 DOSIMETER RESPONSE RELATIVE TO LiF

| Packet Number and Quadrant | Cobalt Plates | | | $AgPO_3$ Low-Z Rods | | | $CaF_2$ μTLD | | | $AgPO_3$ High-Z Rods | | | $AgPO_3$ Plates | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Response | Avg | Std Dev | Response | Avg | Std Dev | Response | Avg | Std Dev | Response | Avg | Std Dev | Response | Avg | Std Dev |
| | | | pct | | | pct | | | pct | | | pct | | | pct |
| 1A | 1.2 | 1.4 | ±9 | 1.6 | 1.4 | ±12 | 1.3 | 1.3 | ±23 | 1.6 | 1.7 | ±19 | 1.3 | 1.6 | ±11 |
| 2A | 1.4 | | | 1.6 | | | 1.1 | | | 2.1 | | | 1.5 | | |
| 3A | 1.3 | | | 1.4 | | | 1.3 | | | 1.9 | | | 1.7 | | |
| 4A | a | | | 1.2 | | | 1.0 | | | 1.1 | | | a | | |
| 5A | 1.5 | | | 1.3 | | | 1.4 | | | 1.8 | | | 1.8 | | |
| 6A | 1.6 | | | 1.5 | | | 1.9 | | | 1.7 | | | 1.7 | | |
| 1B | 1.2 | 1.4 | ±18 | 1.4 | 1.6 | ±12 | 1.0 | 1.1 | ±20 | 1.6 | 1.6 | ±12 | 1.6 | 2.0 | ±34 |
| 2B | 1.1 | | | 1.5 | | | 0.90 | | | 1.5 | | | 1.5 | | |
| 3B | 1.5 | | | 1.7 | | | 1.5 | | | 1.9 | | | 1.9 | | |
| 4B | 1.5 | | | 1.9 | | | 1.3 | | | 1.9 | | | 1.9 | | |
| 5B | 1.4 | | | 1.4 | | | 1.3 | | | 1.5 | | | 1.7 | | |
| 6B | 1.9 | | | a | | | 0.86 | | | 1.3 | | | 3.5 | | |
| 1C | 1.3 | 1.5 | ±10 | 1.5 | 1.8 | ±18 | 0.86 | 1.1 | ±15 | 1.7 | 1.7 | ±5 | 1.5 | 1.8 | ±13 |
| 2C | 1.5 | | | 1.6 | | | 1.2 | | | 1.6 | | | 1.5 | | |
| 3C | 1.4 | | | 2.0 | | | 1.3 | | | 1.6 | | | 1.8 | | |
| 4C | 1.5 | | | 2.3 | | | 1.1 | | | 1.7 | | | 2.0 | | |
| 5C | 1.7 | | | 1.6 | | | 0.94 | | | 1.8 | | | 2.1 | | |
| 1D | 1.3 | 1.2 | ±8 | 1.5 | 1.4 | ±18 | 0.81 | 0.88 | ±24 | 1.6 | 1.5 | ±10 | 1.5 | 1.5 | ±8 |
| 2D | 1.1 | | | 1.2 | | | 0.85 | | | 1.3 | | | 1.3 | | |
| 3D | 1.2 | | | 1.1 | | | 0.80 | | | 1.5 | | | 1.5 | | |
| 4D | 1.1 | | | 1.1 | | | 0.57 | | | 1.4 | | | 1.5 | | |
| 5D | 1.3 | | | 1.6 | | | 0.99 | | | 1.6 | | | 1.5 | | |
| 6D | 1.4 | | | 1.7 | | | 1.3 | | | 1.7 | | | 1.7 | | |
| | Average | 1.4 | ±6 | | 1.6 | ±11 | | 1.1 | ±14 | | 1.6 | ±4 | | 1.7 | ±11 |

[a] Exposure below lower sensitivity level of dosimeter.

TABLE 4.5 RESULTS OF STUDENT'S T-TEST OF DOSIMETER RESPONSE RELATIVE TO LiF TLD

| Exposure Rate | Highest Exposure Rate | Results of Comparison of Relative Responses[a] | | | | |
|---|---|---|---|---|---|---|
| | | Cobalt Glass Plates | Low Z $AgPO_3$ Glass Rods | $CaF_2$ μTLD | High Z $AgPO_3$ Glass | $AgPO_3$ Glass Plates |
| $R\ s^{-1}$ | $R\ s^{-1}$ | | | | | |
| $1.2 \times 10^{11}$ | $2.2 \times 10^{11}$ | Equivalent | Equivalent | Equivalent | Equivalent | Equivalent |
| $9.9 \times 10^{10}$ | $2.2 \times 10^{11}$ | Equivalent | Equivalent | Equivalent | Equivalent | Equivalent |
| $5.3 \times 10^{10}$ | $2.2 \times 10^{11}$ | Equivalent | Equivalent | Less[b] | Equivalent | Equivalent |

[a] Relationship of relative response at exposure rate in column 1 to relative response at highest exposure rate in column 2. Test was conducted at a 95% confidence level.
[b] Equivalent at a 98% confidence level.

## 5. DISCUSSION

The variations of the observed exposures in Table 4.1 are large, although the precision of the dosimetry is better than 10 percent. The magnitude of the variations may be due to the geometry of the experiment. Each value in Table 4.1 is an average of four measurements from dosimeters in different locations in the packet (Figure 3.2). Although the aluminum faceplate was precisely centered on the tube face, the beam of radiation may not have been. Therefore, some dosimeters of each type were fully within the beam while others may not have been. Since the beam is positionally reproducible within ±5 percent, the off-center effect should be consistent for every pulse (Reference 9).

It was anticipated that the exposure measurements of the different dosimeter types would not agree very well since the dosimeters were exposed without shields and consequently energy responses would differ. This was indeed the case; however, the relative magnitudes of the measurements from different dosimeter types agreed well with the unshielded responses cited in Reference 8.

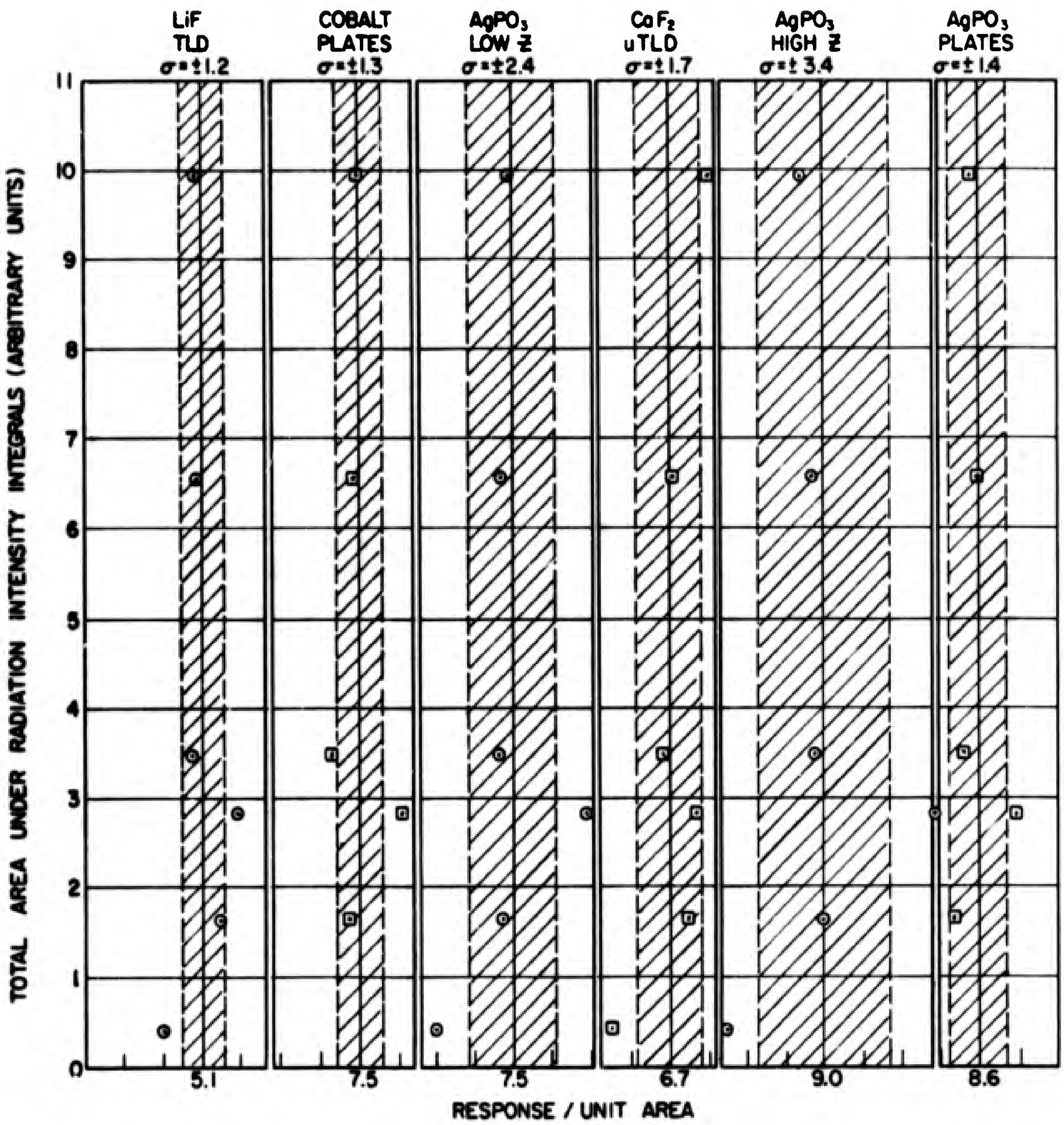


Figure 4.1 Dosimeter response per unit area at an exposure rate of $2.2 \times 10^{11}$ R $s^{-1}$.

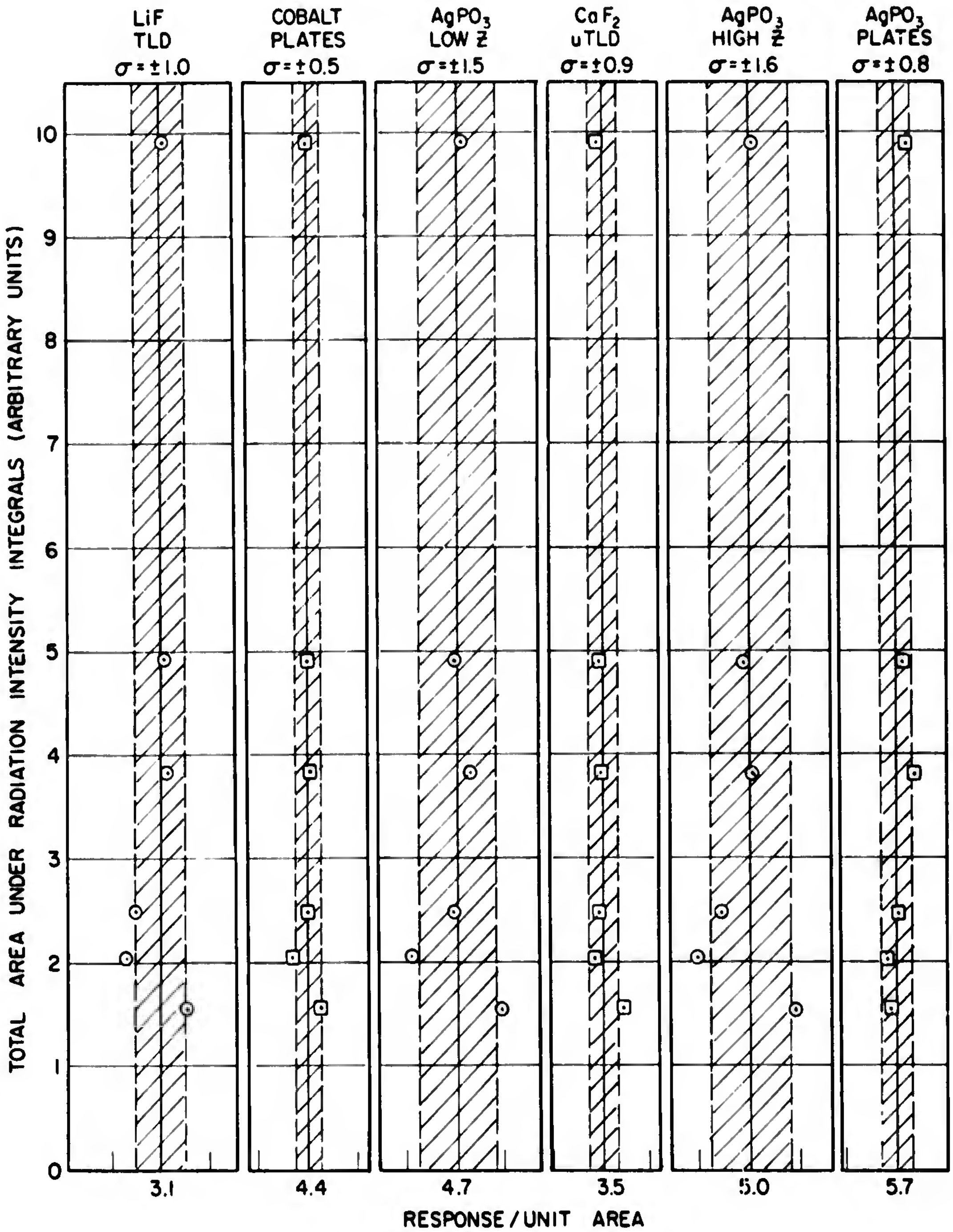


Figure 4.2 Dosimeter response per unit area at an exposure rate of $1.2\times10^{11}$ R $s^{-1}$.

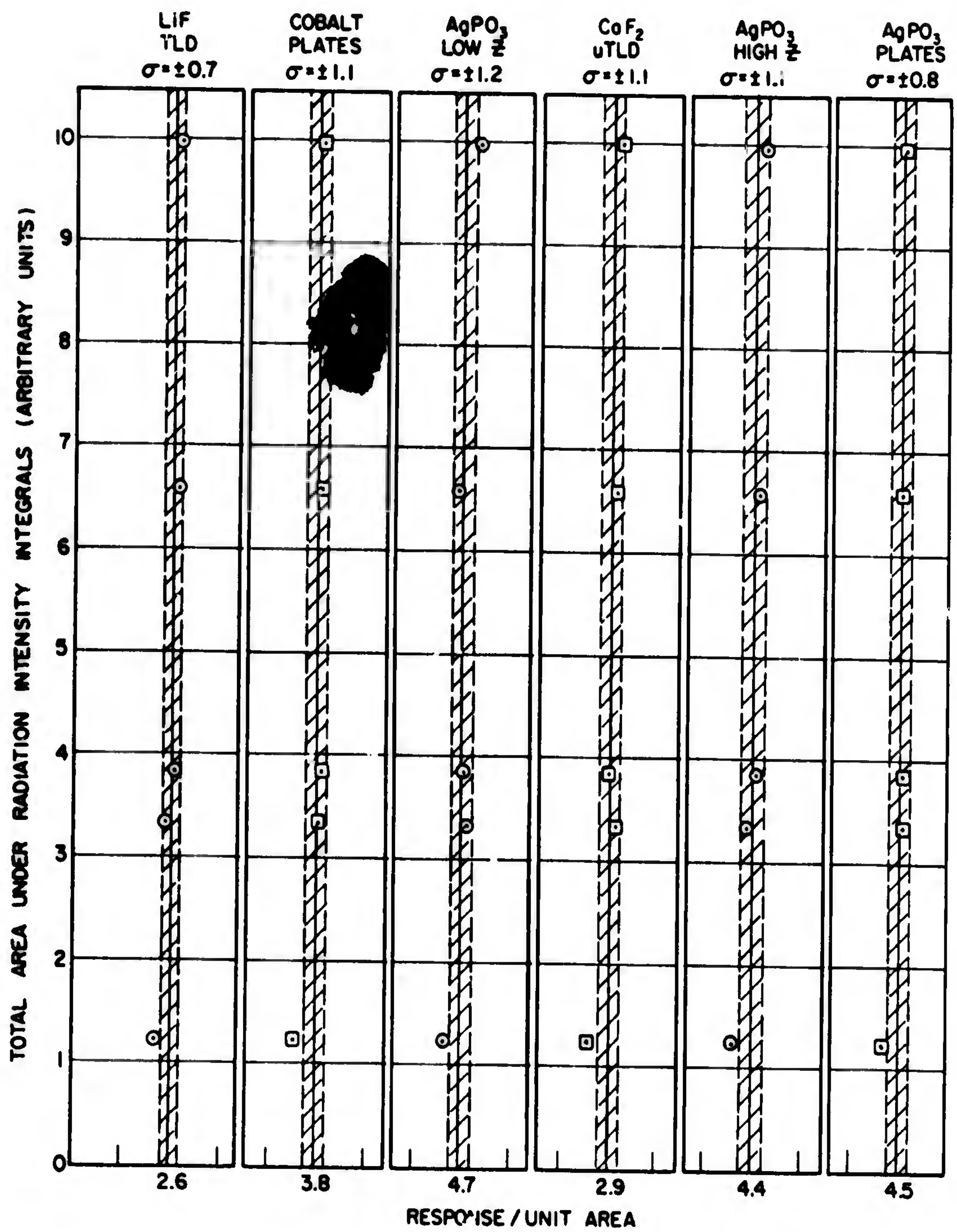


Figure 4.3 Dosimeter response per unit area at an exposure rate of $1.0 \times 10^{11}$ R $s^{-1}$.

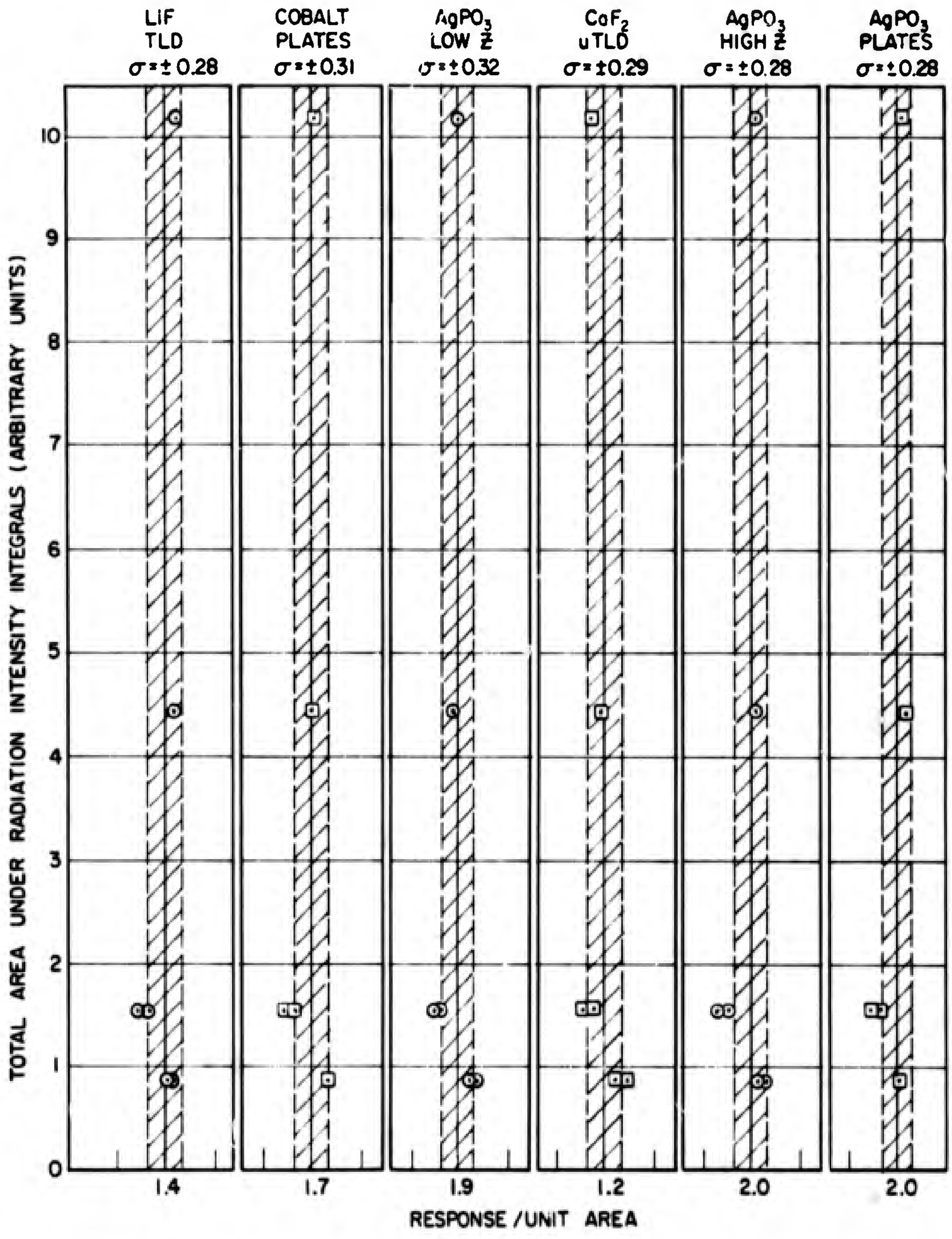


Figure 4.4 Dosimeter response per unit area at an exposure rate of $5.2 \times 10^{10}$ R $s^{-1}$.

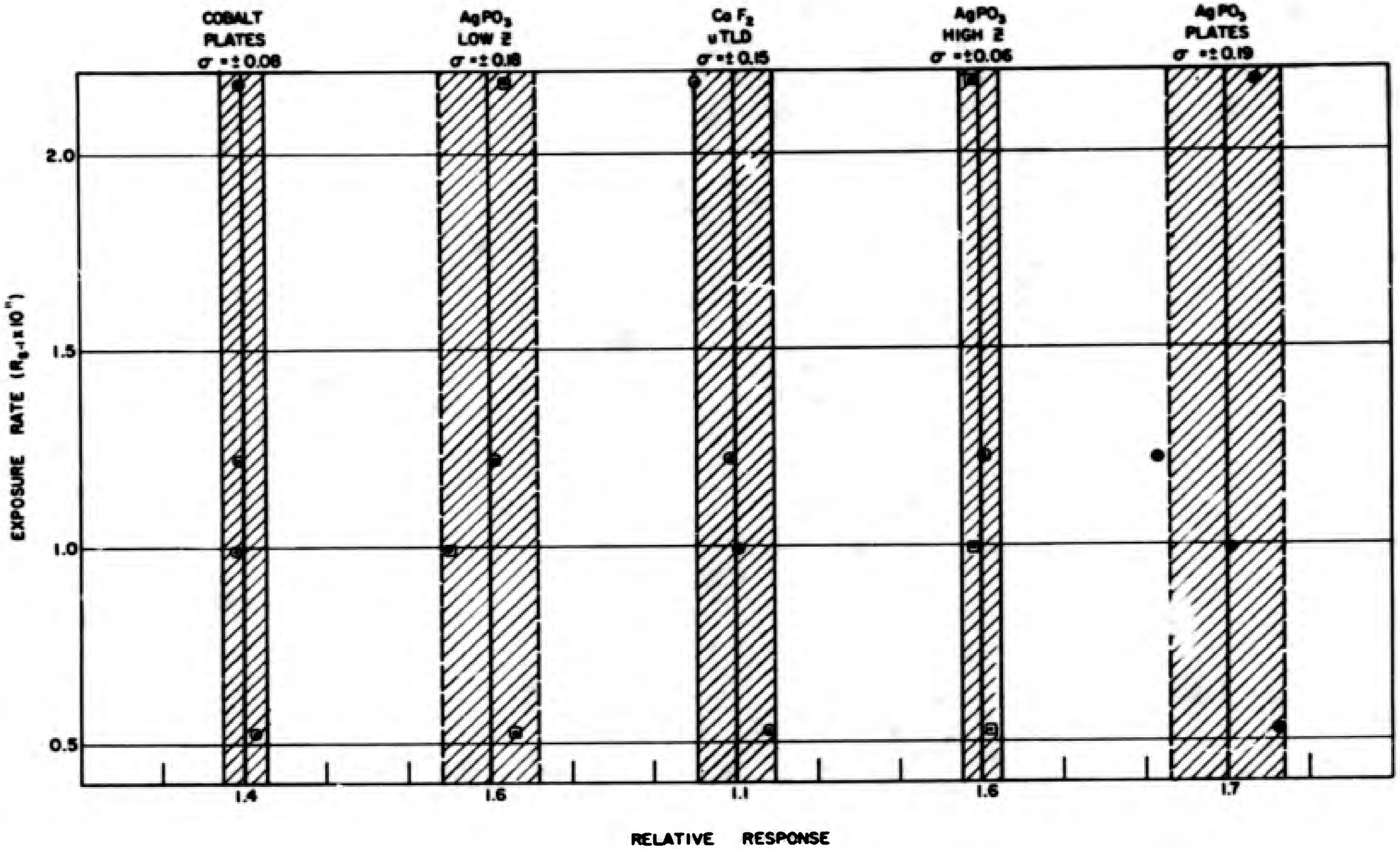


Figure 4.5 Dosimeter response relative to LiF TLD.

The calculated exposures per unit area under the radiation intensity profiles (Table 4.3) exhibit large deviations which are attributed to (1) the 10 percent precision of the dosimetry, (2) the 5 percent error in planimetering the radiation intensity traces, and (3) errors in positioning the dosimeters in the packets and the packets on the aluminum faceplate. Despite the magnitude of the deviations, they are random with respect to the total exposure, i.e., there is no difference in response due to the amount of total exposure at any of the four exposure rates (Figures 4.1 through 4.4).

The responses relative to LiF TLD (Table 4.4 and Figure 4.5) are statistically equivalent (at a 95 percent confidence level) regardless of exposure rate for each dosimeter type. The only exception is the response of the $CaF_2$ μTLD which is less at the lowest exposure rate than at the highest exposure rate. However, these responses are equivalent at a 98 percent confidence level. Therefore, this data contain no convincing evidence of exposure-rate effects between the exposure rates observed.

The $CaF_2$ μTLD's exposed to the lower exposure rates were not read out with the other dosimetry. Due to reader malfunction it was possible to read these dosimeters only after considerable time delay. Therefore, fading is believed responsible for the discrepancies in the $CaF_2$ μTLD relative response data in Table 4.4 and Figure 4.5. An exposure-rate effect would be expected to result in smaller relative responses at higher exposure rates rather than in the larger relative responses observed.

## 6. CONCLUSIONS AND RECOMMENDATIONS

The results of this experiment indicate that no differences exist in the relative responses of the various dosimeters that may be attributed to exposure rate or to an interaction between exposure and exposure rate. No absolute exposure measurements were made, therefore data were analyzed on a relative basis. Data were obtained in the exposure range of approximately 1,500 to 45,000 R at exposure rates from $5.2\times10^{10}$ R $s^{-1}$ to $2.2\times10^{11}$ R $s^{-1}$. Further experimentation is recommended to extend dosimeter response information to exposures and exposure rates above this range.

REFERENCES


1. J. H. Schulman, et al, "Measuring High Doses by Adsorption Changes in Glass," Nucleonics 13, 2, 30 (1955).

2. S. Davidson, S. A. Goldblith, and B. E. Proctor; "Glass Dosimetry," Nucleonics 14, 1, 34 (1956).

3. S. Kondo, "Response of Silver-Activated Phosphate Glass to α, β and γ Rays and Neutrons," Health Physics, 7, 25 (1961).

4. S. I. Taimuty, R. A. Glass, and B. J. Deaver, "High Level Dosimetry of Gamma and Electron Sources," "Proceedings of Second UN Conference on the Peaceful Uses of Atomic Energy," 21, 204 (1958).

5. E. Tochilin and N. Goldstein, Dose Rate and Spectral Measurements from Pulsed X-ray Generators, USNRDL-TR-939 (1965); Unclassified.

6. R. K. Durkee, et al, Energy and Rate Dependence Studies, Progress Report No. 4, Edgerton, Germeshausen & Grier, S-237-R, (1963); Unclassified.

7. H. Donnert, N. Klein, and R. Sasse, "The Response of Selected Gamma Dosimeters to Radiation Delivered at Very High Dose Rates," presented at Army Science Conference, West Point; (June 1964).

8. K. C. Humphreys, et al, A Mobile Gamma Dosimetry Facility, Edgerton, Germeshausen & Grier, Report S-308-R, (1966); Unclassified.

9. K. P. Melia, Ion Physics Corporation, Burlington, Massachusetts, Private Communication.

UNCLASSIFIED
Security Classification

## DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

**1. ORIGINATING ACTIVITY (Corporate author)**

US Army Nuclear Defense Laboratory
Edgewood Arsenal, Maryland 21010

**2a. REPORT SECURITY CLASSIFICATION**

Unclassified

**2b. GROUP**

**3. REPORT TITLE**

EXPOSURE-RATE DEPENDENCE OF SELECTED GAMMA DOSIMETERS

**4. DESCRIPTIVE NOTES (Type of report and inclusive dates)**

**5. AUTHOR(S) (First name, middle initial, last name)**

Thomas W. Crimmins
Nancy N. Gibson
Armand M. Pelletier
John R. Jacobson

**6. REPORT DATE**

January 1968

**7a. TOTAL NO. OF PAGES**

32

**7b. NO. OF REFS**

9

**8a. CONTRACT OR GRANT NO.**

**b. PROJECT NO.**

**c.**

**d.**

**9a. ORIGINATOR'S REPORT NUMBER(S)**

NDL-TR-94

**9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)**

**10. DISTRIBUTION STATEMENT**

This document has been approved for public release and sale; its distribution is unlimited.

**11. SUPPLEMENTARY NOTES**

**12. SPONSORING MILITARY ACTIVITY**

Department of the Army

**13. ABSTRACT**

This experiment studied the effects of exposure rate on the response of the following gamma dosimeters: silver-activated metaphosphate glass plates and rods, lithium fluoride and manganese-activated calcium fluoride microthermoluminescent dosimeters, and cobalt-activated borosilicate glass plates. The experiment was conducted at the flash x-ray facility of the Ion Physics Corporation of Burlington, Massachusetts. Data was obtained in the exposure range of approximately 1,500 to 45,000 R at exposure rates from $5.2 \times 10^{10}$ R $s^{-1}$ to $2.2 \times 10^{11}$ R $s^{-1}$.

The results of this experiment indicate that no differences exist in the relative responses of the various dosimeters that may be attributed to exposure rate or to an interaction between exposure and exposure rate. No absolute exposure measurements were made, therefore data were analyzed on a relative basis.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Dosimeters | | | | | | |
| Gamma Dosimeters | | | | | | |
| Gamma Exposure Rate | | | | | | |