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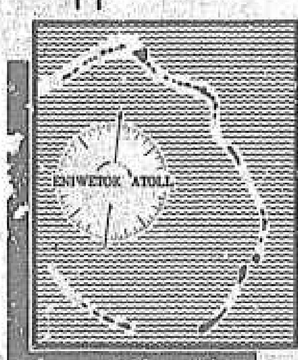
Operation IVY

PACIFIC PROVING GROUNDS

November 1952

Project 5.1

GAMMA RADIATION AS A FUNCTION OF DISTANCE



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No. 71 of 230 copies, Series B

~~Report to the Test Director~~

(6) GAMMA RADIATION AS A FUNCTION OF DISTANCE

(9)

(10) By

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ABSTRACT

Film measurements of gamma-ray exposure vs distance were made on both Mike and King. The results show that gamma radiation from large yield devices cannot be scaled directly from measurements of nominal-size devices, and that the effect of the shock wave and the cloud rise must be taken into consideration. For the 550 KT King shot, the gamma-ray exposures were about 1.5 to 1.7 times those expected by scaling directly from a nominal device. For the 10 MT Mike shot, measured values were 30 to 80 times those expected from scaling.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to George Littlejohn for processing the film and to Theodore Blechar and William de Alva for their assistance in the design and assembly of the drop-gadgets.

1. INTRODUCTION

Gamma radiation as a function of distance was measured using film on both the Mike and the King shots of Operation Ivy. The purpose of these measurements was to determine the manner in which the gamma-radiation exposure would vary with yield or energy release. Malik[1] had predicted that the effect of the shock wave and cloud rise from these large-yield devices would result in much larger exposures than would be expected by simply scaling from a nominal device.

2. METHODS AND PROCEDURE

The fall-out from the Mike device was expected to be excessively large and to produce a greater exposure than the prompt gamma, particularly at large distances. Consequently, an attempt was made to measure the gamma radiation during specific time intervals by using "drop-gadgets." Previous gamma vs time measurements[1] have shown that the largest percentage of the total exposure from about 1 msec to 0.2 sec is due to neutron capture in the nitrogen of the air. From about 0.2 to 60 sec, the exposure is largely due to fission-product gamma rays. Hence, the drop-gadgets were designed to expose films to total times of 0.2 and 60 sec in order to be able to differentiate the contribution of each component to the total exposure.

Several drop-gadgets had been tested on Tumbler-Snapper,[2] and since the "thermal" gadget had been most successful, it was decided to use this device. The thermal gadget, Fig. 1, consisted of a 6-ft aluminum tube containing a wooden insert and four film packets sealed in waterproof plastic jackets. A 10-in. focal-length lens focused the thermal radiation from the fireball through a pyrex window onto a nylon string which, when melted, released the first film; the position of this film allowed an exposure of 0.2 sec during free fall to ground level. When the string melted, a microswitch tied to the string connected a battery to an Amperite delay relay. The relay closed in 60 sec, melting a 1-amp fuse wire holding the second film. A third film was placed at the bottom of the tube, approximately 5 ft below ground level, to measure any exposure the dropped films might receive after they had fallen. The fourth film was placed about 1 ft above ground level to measure the total gamma-ray exposure including that due to fall-out and neutron-induced activity. The gadgets were distributed as close to 100-yd intervals as terrain would permit, 1000 to 6400 yd from ground zero. There was one large gap in the distribution, from 3000 to 4100 yd, where no land was available.

Since the King device was to be detonated some 1500 ft above the ground, it was not expected that the fall-out activity would affect the results appreciably. Consequently, the aluminum and wood badges employed on previous tests[2] were used. These badges were distributed at 100-yd intervals, 700 to 4000 yd from ground zero.

The film types, as well as calibration and development procedures, were identical to those used on previous tests.[2]

3. RESULTS

The gamma-ray exposures measured on the Mike shot are given in Table I. The stations located from 1000 to 3000 yd from ground zero were destroyed; these stations were installed for the eventuality that the device would not go as anticipated. As previously mentioned, there was a gap in the distribution from 3000 to 4100 yd. Hence, the measurements cover only a range of 4200 to 6400 yd. The films were recovered about eight days after the shot. Most of the pyrex windows had been shattered and the aluminum tubing was filled with sand and debris. In addition, a few of the stations were filled with water and some of the films were moist in spite of the waterproof jackets.

Only nine of the films designed to drop in 0.2 sec were found in the bottom of the aluminum tubes. One of these recorded about the same exposure as the film initially placed at the bottom of the tube; so it can be assumed that this film probably fell before the shot. The results obtained from the remaining eight films are summarized in Table II. The limits placed on the exposures were obtained only from the variation in density found on the films. It is not certain that any of the gadgets operated as designed; this will be discussed in the next section. Hence, the actual accuracy of the dropped-film results is much lower than that indicated in the table because of the uncertainty in drop time.

Only two of the films designed to drop in 60 sec were found at the bottom of the aluminum tubes. These showed slightly higher exposures than the other dropped films at the same location.

Gamma-radiation exposures as a function of distance for the King shot are given in Table III and plotted in Fig. 2. All film badges located from 700 to 1700 yd from ground zero were destroyed; the remainder were recovered the day after the shot. The distances given in the table are the slant ranges or the distance from the detector to the actual point of detonation. The radiation level of the activity in the soil at the time of recovery was about 10 mr/hr at the closest station. Regardless of whether this was due to induced sodium activity of 14.8-hr half-life or to fission-product activity, the contribution to the total exposure on the film was much less than 1 per cent.

4. DISCUSSION OF RESULTS

4.1 Mike Shot

The exposures measured on the eight films that dropped are plotted in Fig. 3 in terms of rd^2 vs d, together with the integrated total exposures from the gamma vs time data obtained by Malik at 2300 and 4000 meters.[3] These points fall roughly along a straight line. Since the gamma vs time points are a measure of the total prompt gamma radiation, it appears that the film also measured the entire prompt gamma radiation. Assuming this to be so, the films could not have been dropped in the designed time of 0.2 sec. The fact that more than half the strings attached to the films designed to drop in 0.2 sec were still intact supports the conclusion that the fireball failed to melt any of the strings and the films were dropped by some other mechanism. The failure of the fireball to melt the strings was at first quite perplexing. But evidence now exists[4,5,6] that the brightness of the fireball was very low and that the radiation appeared in the red region of the spectrum and appeared late. Apparently the brightness of the fireball was too low to melt the strings. The shock arrival time at 4000 meters was about 2.5 sec, so the focusing lenses were probably moved out of alignment or destroyed at this time.

The gamma vs time curves show that about 95 per cent of the prompt gamma radiation came after the shock arrival time, over the interval from 2.5 to 20 sec at 4000 meters. If the films did record most of the prompt gamma-radiation exposure, then they could not have been dropped by the shock wave.

The exposures on the dropped films range from about 140 r at 4500 yd to 2 r at 6000 yd. The total exposure, including fall-out, averaged about 6000 r. Thus, it appears that the films fell after the prompt gamma had been emitted, approximately 20 sec, and before the fall-out became significant, approximately 10 min. There was a water wave that swept over the islands during this time interval which might have dropped these films. Also, motion pictures show that there was a considerable amount of debris flying about during this interval. The actual way in which the strings were severed might have been by sharp fragments produced when the pyrex window shattered.

Malik's computed gamma vs distance curve for Mike is shown in Fig. 3, together with the curve obtained by scaling Ranger F (for an air density of 1.15 g/l) up to 10 MT. In his calculation, Malik had taken into consideration the effect of the shock wave on the amount of air between the source and the detectors, the effect of the rising cloud, and the contribution of the n, γ and fission-product components to the total exposure at various distances from the source. For a detailed account of these calculations, see ref. 1. The experimental results are in fair agreement with Malik's theory, and indicate there is from 30 to 80 times more exposure from a 10 MT device than one would expect simply by scaling from a nominal device.

4.2 King Shot

In Fig. 4, rd^2 vs d is plotted for the King shot. For purposes of comparison, the Ranger F test has been scaled up to 550 KT (for an air density of 1.124 g/l) and is plotted on the same graph. Again it is evident that there is much more exposure from a large device than would be expected by simply scaling from a nominal device, in this case about 55 per cent larger at 3000 yd for a 0.55 MT device. For this particular size device, Malik has shown[1] how the increased exposures may be largely accounted for by shock-wave effects.

REFERENCES

1. J. S. Malik, Summary of Information on Gamma Radiation from Atomic Weapons, Los Alamos Scientific Laboratory Report LA-1620, January 1954.

2. E. Storm, Gamma Radiation Exposure as a Function of Distance, Tumbler-Snapper Project 15.2 Report, WT-549, July 1952.

3. J. S. Malik, Gamma Radiation vs Time, Ivy Project 5.1, 5.2 Report, WT-634, February 1954.

4. C. A. Beck, Low-Resolution Spectroscopy - Color Temperature, Ivy Project 8.4 Report, WT-604, February 1955.

5. Mike Shot Cursory Report, J-14928 (not available).

6. Personal communication from Harold Stewart.

Table I - GAMMA-RADIATION EXPOSURE (r), MIKE

Distance, yd	5 ft below ground surface	Designed to drop after 0.2 sec	Designed to drop after 60 sec	1 ft above ground surface
4200	75	7100	7000	7300
4300	7	5600	6400	7200
4400	4	6000	6800	6700
4500	6	146	6300	6600
4600	0.2	6500	6100	6600
4700	75	4200	4200	4200
4800	4	155	170	3600
5100	30	55	6000	6000
5200	6000*	6000	6000	6000
5400	4	6300	6300	6300
5500	3.0	21	6000	6300
5600	2	6300	6000	6000
5700	2.1	6.2	5500	5500
5800	4.6	4.3**	5600	5600
5800	1.2	5800	5800	6000
5900	37	51	6400	6400
5900	1.2	3.4	5000	5000
6000	0.9	3.2	5.3	5800
6100	1.2	6000	6000	6000
6300	13	285	4200	4300
6400	1.9	4500	4500	4500

*Probably not below ground level.

**Probably fell before shot.

Table II - SUMMARY OF FILMS THAT DROPPED, MIKE

Distance, yd	Average r*	Average rd^2 ($\times 10^7$)*
4500	140 ± 20	280 ± 40
4800	150 ± 30	350 ± 70
5100	25 ± 3	65 ± 8
5500	18 ± 1	54.5 ± 3
5700	4.1 ± 0.2	13.3 ± 0.6
5900	2.2 ± 0.4	8.9 ± 2
5900	14 ± 11	49.0 ± 39**
6000	2.3 ± 0.3	8.1 ± 1

*The limits are derived only from the density variation on the films. The accuracy is considerably lower, as discussed in the text.

**This point was not plotted in Fig. 3 because the films showed extreme variations in density and were probably heavily contaminated.

Table III - GAMMA-RADIATION EXPOSURE VS DISTANCE, KING

Slant distance, yd	Exposure, r	rd^2 (x 10^7)
2020	2400	980
2120	1650	740
2220	1100	540
2320	750	400
2420	560	330
2510	400	250
2610	280	192
2710	200	147
2810	160	126
2910	105	89
3010	77	70
3100	58	56
3200	42	43
3300	34	37
3400	24	28
3500	17	21
3600	14	18.2
3700	10.5	14.4
3800	6.2	9.0
3900	6.4	9.7
4000	4.6	7.4
4100	3.3	5.6
4200	2.3	4.1

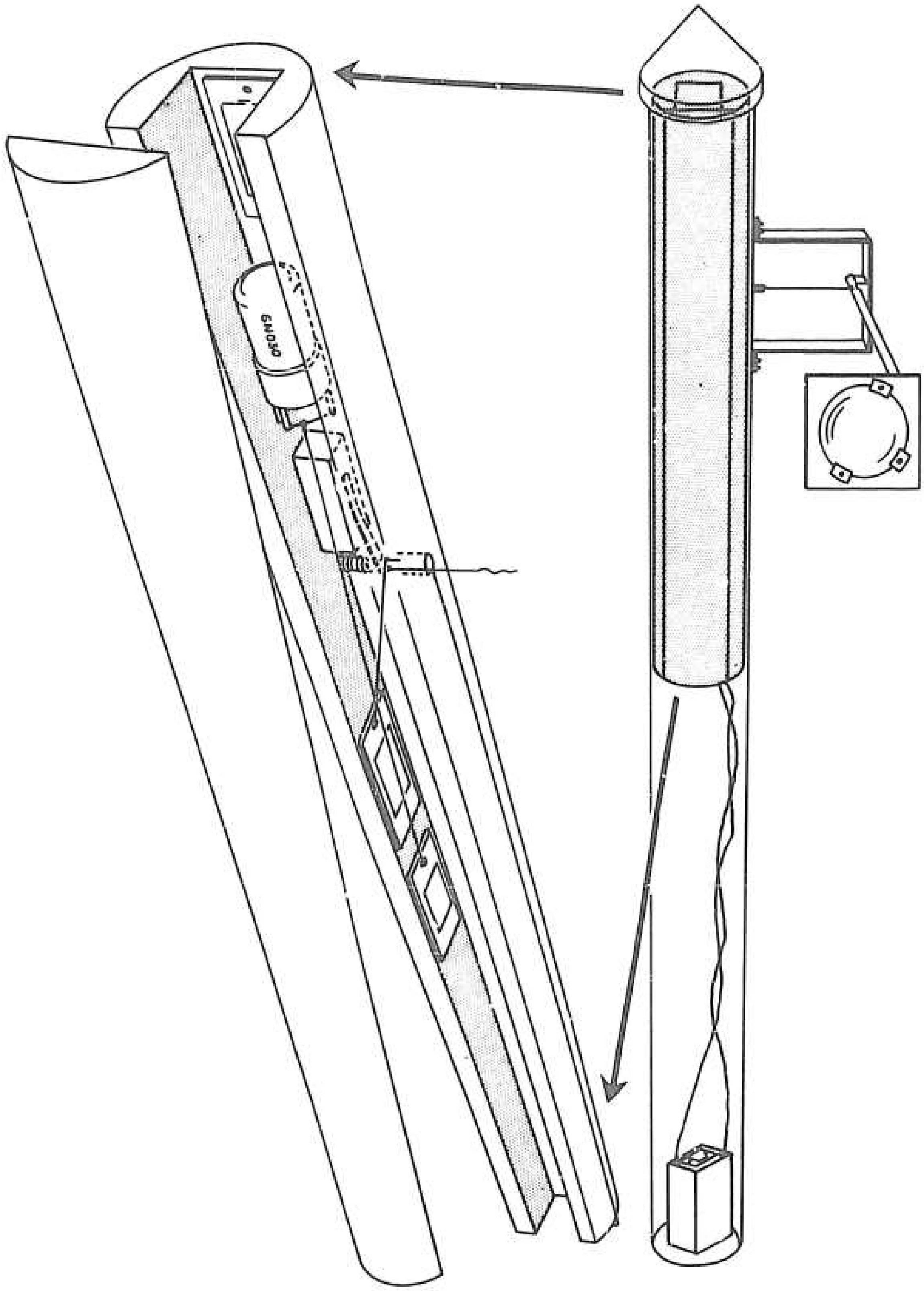

Fig. 1 Thermal drop-gadget.

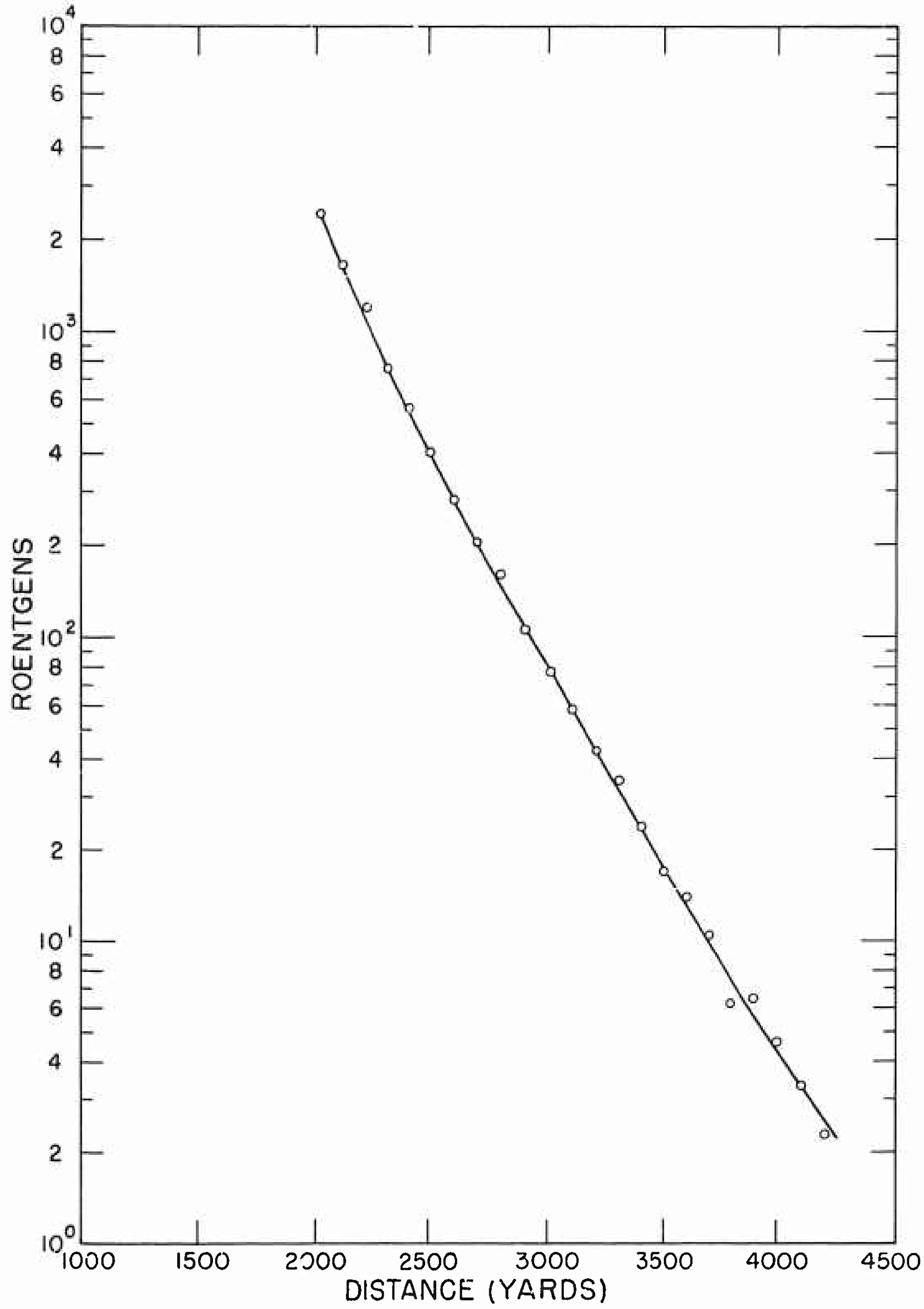

Fig. 2 Gamma-radiation exposure vs distance, King.

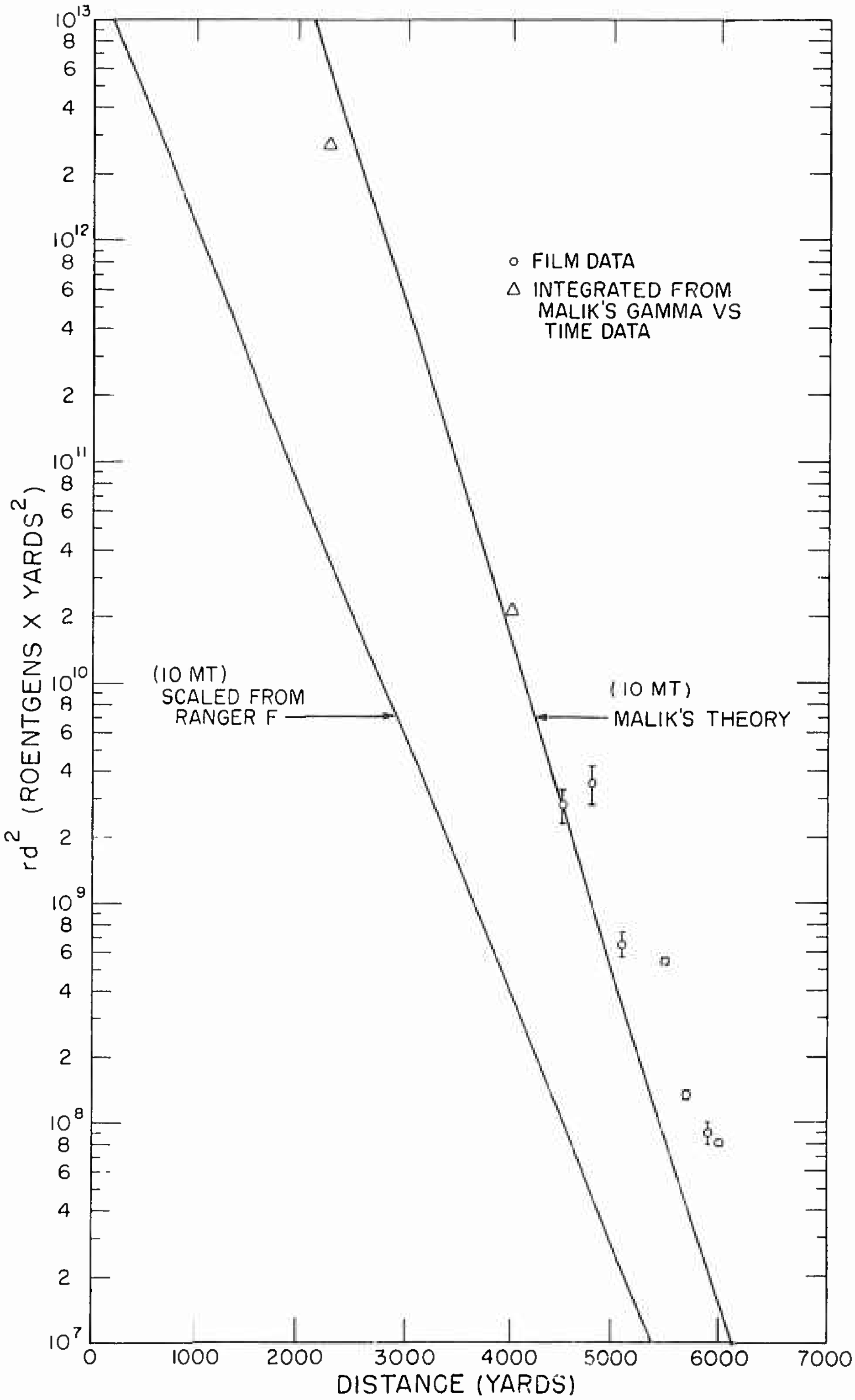

Fig. 3 Gamma radiation times distance squared as a function of distance, Mike.

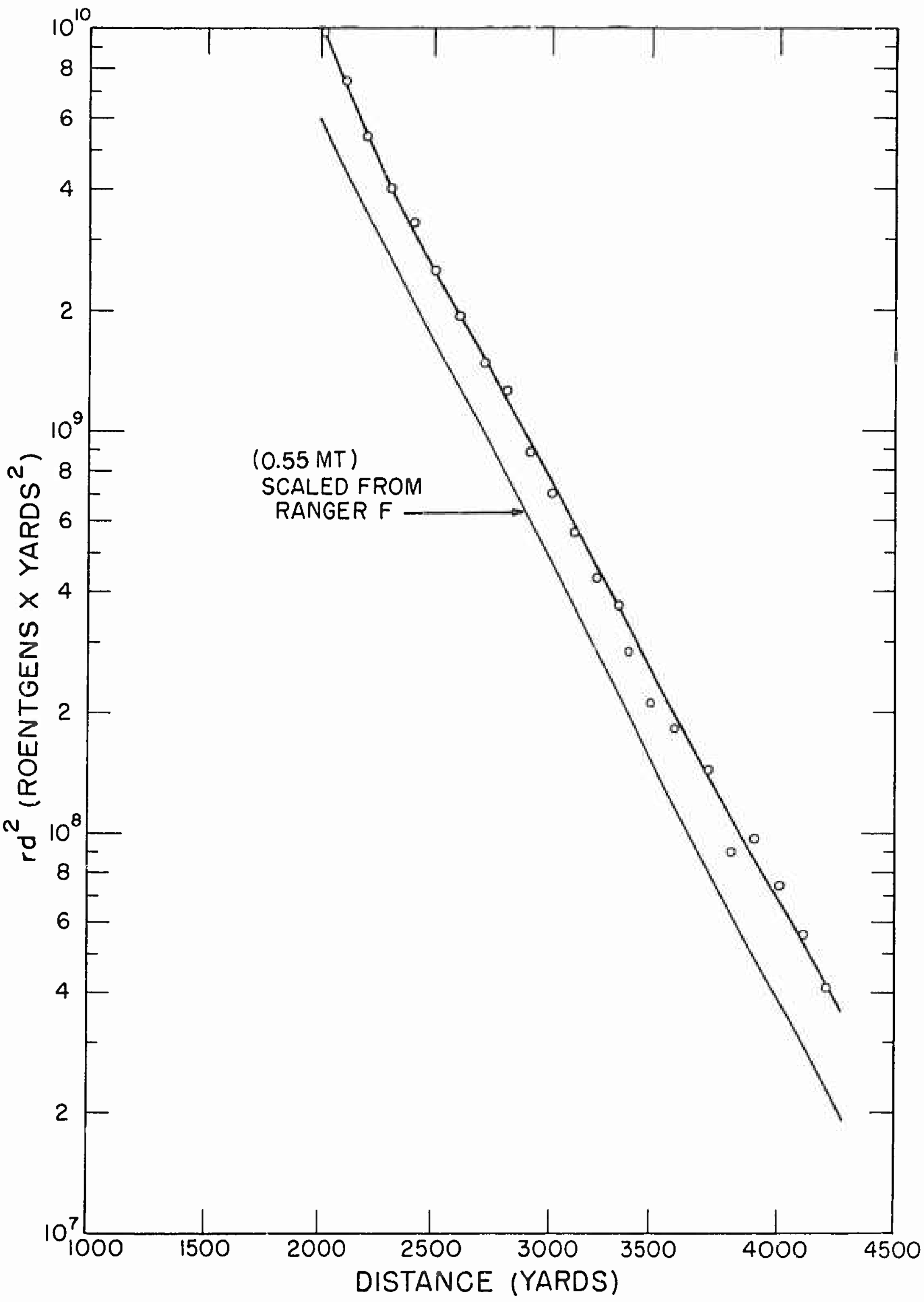

Fig. 4 Gamma radiation times distance squared as a function of distance, King.