LA-1228

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LOS ALAMOS SCIENTIFIC LABORATORY

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GAMMA RADIATION EXPOSURE

AS A

FUNCTION OF DISTANCE

OPERATION RANGER

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4 April 1951 LA-1228

Washington Document Room	1 thru 4
J R. Oppenheimer	5
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Abstract

Gamma radiation exposures as a function of distance were measured for Ranger tests A, B_1, E, B_2, and F. The films used in this experiment covered an exposure range of 0.1 to 3,000 r, and were calibrated with a betatron operating at an effective energy of 3.0 mev.

With the exception of test A, the ratios of the gamma radiation exposure at fixed distances gave calculated bomb yields which agreed to within 5% of the fireball measurements. On test A, a 30% lower yield was measured by this method. The 400 r slant range increased from 700 yards from the 1 KT tests to 1470 yards on the 22 KT test. The apparent mean free path of the gamma radiation was found to be about 400 yards. The neutron induced activity in the film and badge contributed 3 to 5% of the total exposure found on the film, while the neutron induced activity in the soil contributed $\ll$ 1% of the total exposure.

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Table of Contents

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I. Introduction

A. Purpose

The purpose of this project was to measure the gamma radiation during and immediately following an atomic bomb detonation as a function of distance, in order to determine the lethal range of gamma radiation from small atom bombs and to evaluate the accuracy with which this data can be used to determine the bomb yield.

B. History

The gamma radiation exposure as a function of distance was successfully measured by means of film at Bikini by Dr. Dessauer[1], and at Sandstone by Dr. Scoville[2]. The prompt gamma radiation level of 400 roentgens, which is often considered as the LD50, was found to be 1400 yards at Bikini for test Able, and at Sandstone 1500 yards for test X-Ray, 1600 yards for test Yoke, and 1350 yards for test Zebra.

When Ranger was first proposed, Dr. E. Teller suggested that gamma radiation measurements as a function of distance be made with film. This project was assigned to the Rad-Safety Group by Dr. W. Ogle, and was to be carried out during all five air burst detonations.

C. Plan of Operation

In order to measure properly gamma radiation as a function of distance, it was necessary to evaluate several factors which

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affected the interpretation of the film. The important factors investigated were temperature, energy dependence, air density, angle of incidence of radiation, and neutron induced activity.

During the discussion of the project outlined above, the question arose as to what fraction of the gamma radiation reached the film before the blast. This was investigated by means of mouse-trap gadgets[3].

II. Equipment and Procedures

A. Film Calibration

The three types of film used and their ranges are as follow:

Type	Range
Dupont 552 (Sensitive)	0.1 - 10 r
Dupont 552 (Insensitive)	1 - 40 r
Dupont Defender Adlux	20 - 3,000 r

The three films were packaged in a light-proof paper jacket and a 1/8" lead clip placed over each unit. They were then sealed in a water-proof plastic jacket and placed between wooden blocks which were held together by an aluminum box. The boxes were attached by means of bolts to four-foot angle iron stakes which were driven about three and a half feet into the ground. The wood and aluminum served to protect the films from the heat and blast effects

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of the bomb. To insure the security of the badges, wire was wrapped around the outside of the aluminum cans. Fig. 1 shows the film, badge, and manner in which the unit was mounted to the stake.

X-ray units and a betatron were used to calibrate the film, and by adding filtration an effective energy range of 1.0 to 10.0 mev was covered. The calibration procedure and the response of the films are fully described in reports LA-1107 and LA-1220. From the difference in density under the lead filter, placed over the film, and the unshielded portion of the film, the effective energy of the prompt gamma radiation from the bombs was found to be about 3.0 mev. Consequently, the films were interpreted from calibration curves made with the betatron operating at an effective energy of 3.0 mev. Net density versus roentgens for the three films is shown in Fig. 2.

Since the detonations occurred in the air, the films, which were placed vertically with respect to the ground, were not perpendicular to the direction of the radiation. It was anticipated that there might be some angular dependence on account of the thick lead filter. To determine the manner in which film density varies with the angle at which the film is facing the beam, exposures were made in which films were rotated through an angle of 90 degrees. The density on the unshielded portion of the film was found to decrease beyond an angle of 30 degrees, and reached a minimum at 90 degrees; that is, when the edge of the film was facing the beam, a correction

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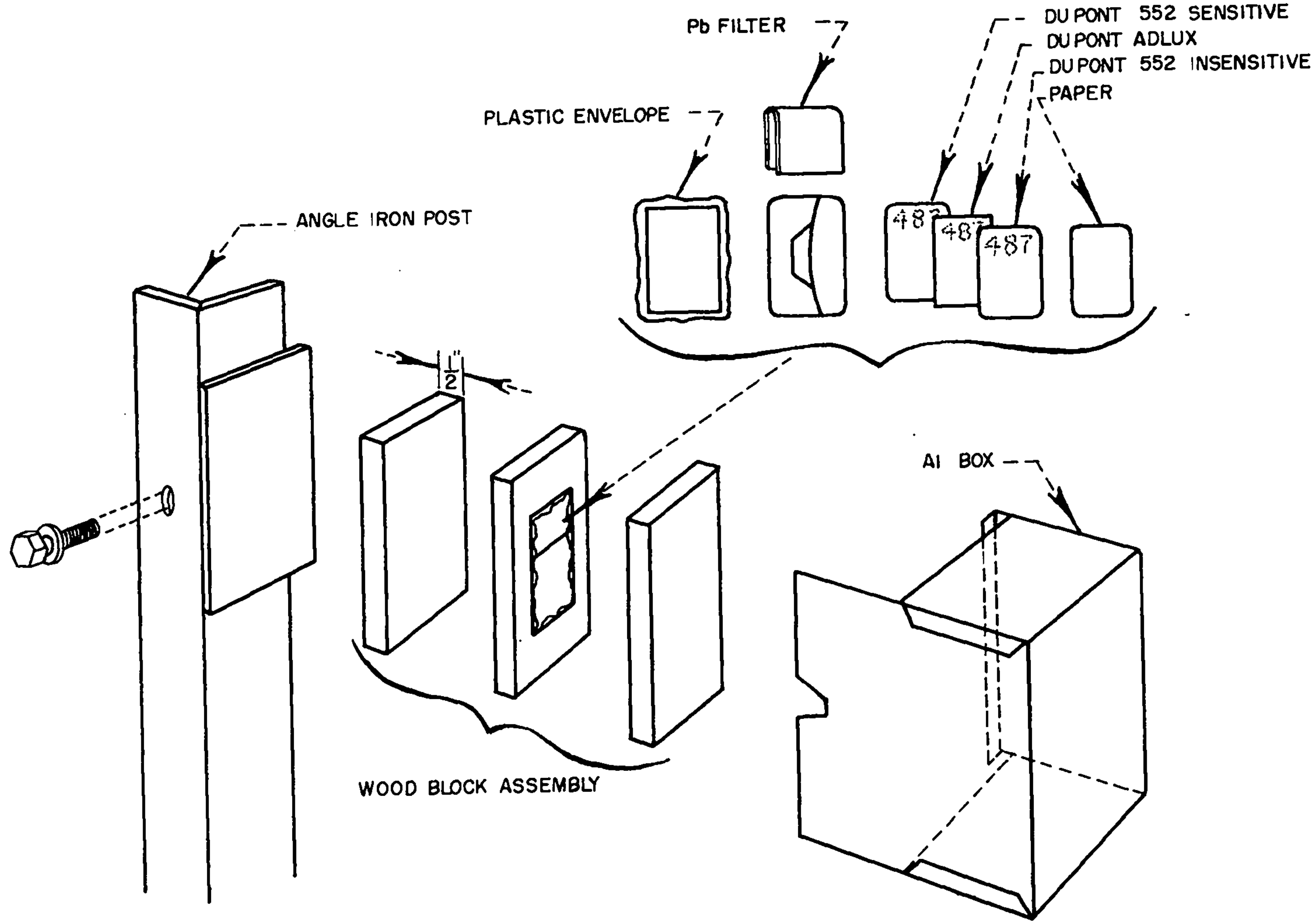

Figure 1 Exploded View of Film Assembly

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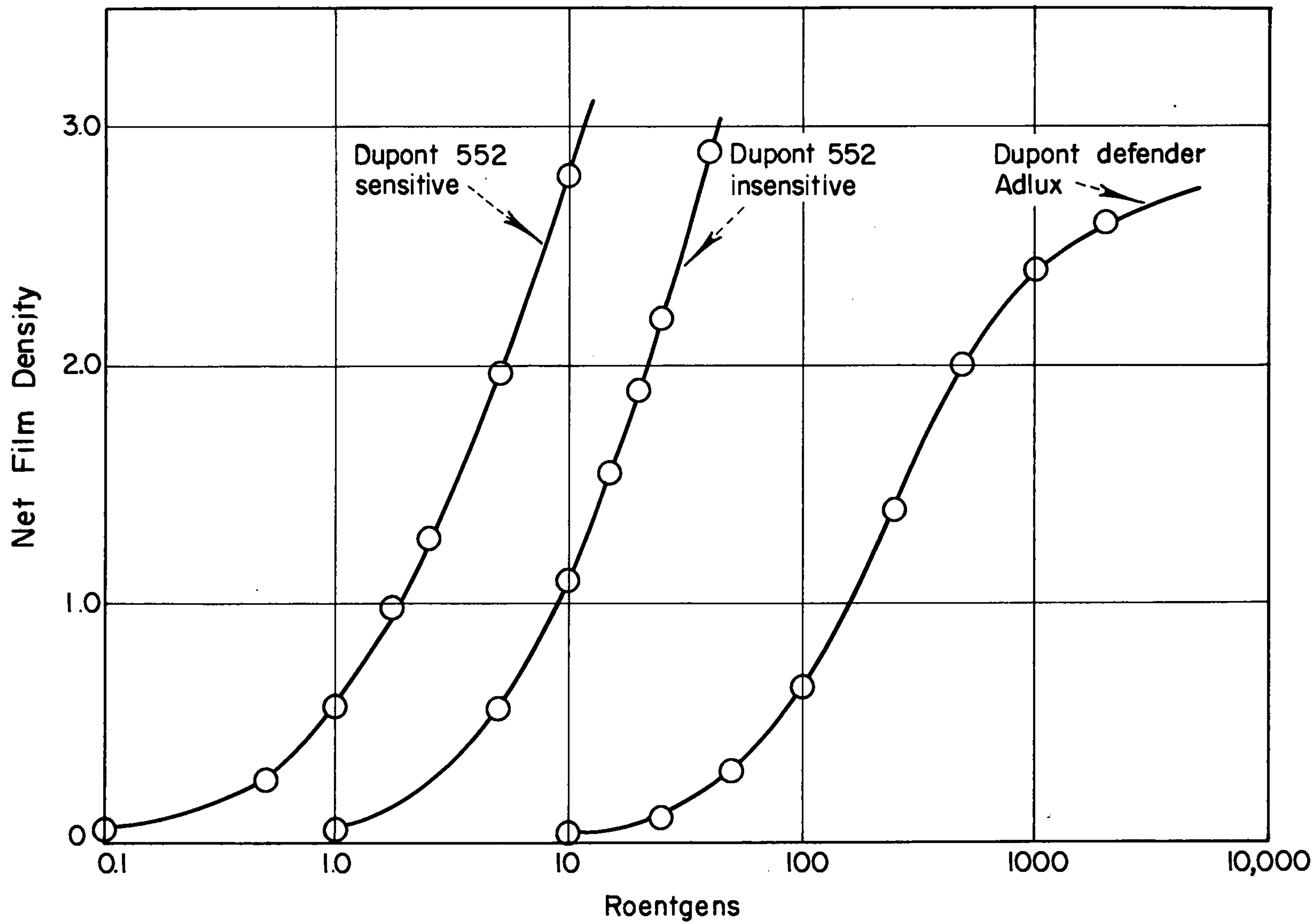

Figure 2

Calibration Curves for Effective Energy of 3.0 Mev.

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factor of 1.5 in the determined exposure was necessary.

Since sub-freezing temperatures were expected at Ranger, a set of films was placed in a refrigerator for a 24-hour period at a temperature of minus 5.5 degrees Centigrade. These films, in the wooden-aluminum badges, were then exposed immediately after removal from the refrigerator. The film was found to be approximately 10% less sensitive when subjected to this temperature.

The development was done under carefully controlled conditions. Eastman rapid x-ray developer was used at a thermostatically controlled temperature of 68 degrees Fahrenheit. The films were mechanically agitated during the five-minute developing period. A set of control films was handled simultaneously with the exposed films in order to obtain a base density, and to serve as a check on development procedures. As an additional check on development procedures, a set of film exposed to radium was developed with the calibrated and test films. Film densities were read on a Weston densitometer.

B. <u>Film Distribution</u>

Forty-one film badges were placed 100 yards apart along the Access Road, beginning 100 yards from Ground Zero, and forty-one badges were placed in an identical manner along the Generator Road. In addition, a film was placed at Ground Zero. The Access Road ran due west of Ground Zero, and the Generator Road ran due south of

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Ground Zero.

Film badges identical to the regular badges described above were placed in lead pigs 300, 600, 900, 1200, and 1500 yards from Ground Zero along the Access Road. The pigs were tubular with 4" thick walls and inside diameter of about 4". The pigs transmit only 0.1% of the incident radiation from a betatron operating at an effective energy of 3.0 mev. Thus, any significant exposure found on the film inside the lead pigs would be a measure of the neutron induced activity.

The regular badges were also used with the mouse-trap gadgets, which were located 500, 1000, and 2000 yards from Ground Zero along the Access Road.

C. Film Recovery

On the first four tests all films were recovered. On the fifth test, F, six of the nine films located within a radius of 200 yards from Ground Zero were not recovered. The heat and blast effects on the film badges are shown very well by Figs. 3, 4, and 5. On all tests film recovery was started within one to two hours after detonation and was completed in five to six hours.

III. Results

Gamma radiation exposure as a function of the actual distance from the point of detonation to the films is shown in Figs. 6 through 10 for tests A, B_1, E, B_2, and F, respectively. The data on which

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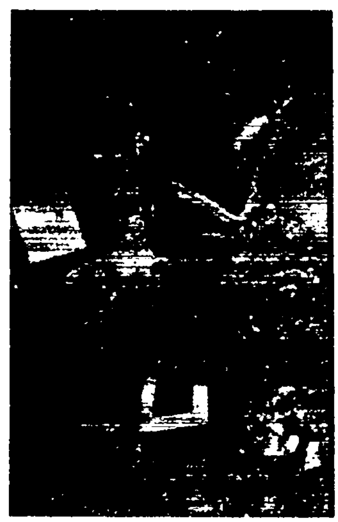
1600 YARD FILM BADGE STATION
AFTER TEST B_2.

400 YARD FILM BADGE STATION
AFTER TEST B_2.

300 YARD FILM BADGE STATION
AFTER TEST B_2.



200 YARD FILM BADGE STATION
AFTER TEST B_2.

Figure 3

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ALUMINUM FILM CONTAINER LOCATED 500 YARDS FROM GROUND ZERO ON TEST F.

FILM CONTAINER LOCATED 400 YARDS FROM GROUND ZERO ON TEST B_1.

MOUSE-TRAP GADGET

Figure 4

[redacted]

[redacted]

MOUSE TRAP GADGET

LEAD PIG FOR CONTAINING
FILM BADGE.

FILM BADGE IN LEAD PIG LOCATED
300 YARDS FROM GROUND ZERO
BEFORE TEST F.

FILM BADGE IN LEAD PIG LOCATED
300 YARDS FROM GROUND ZERO
AFTER TEST F.

Figure 5

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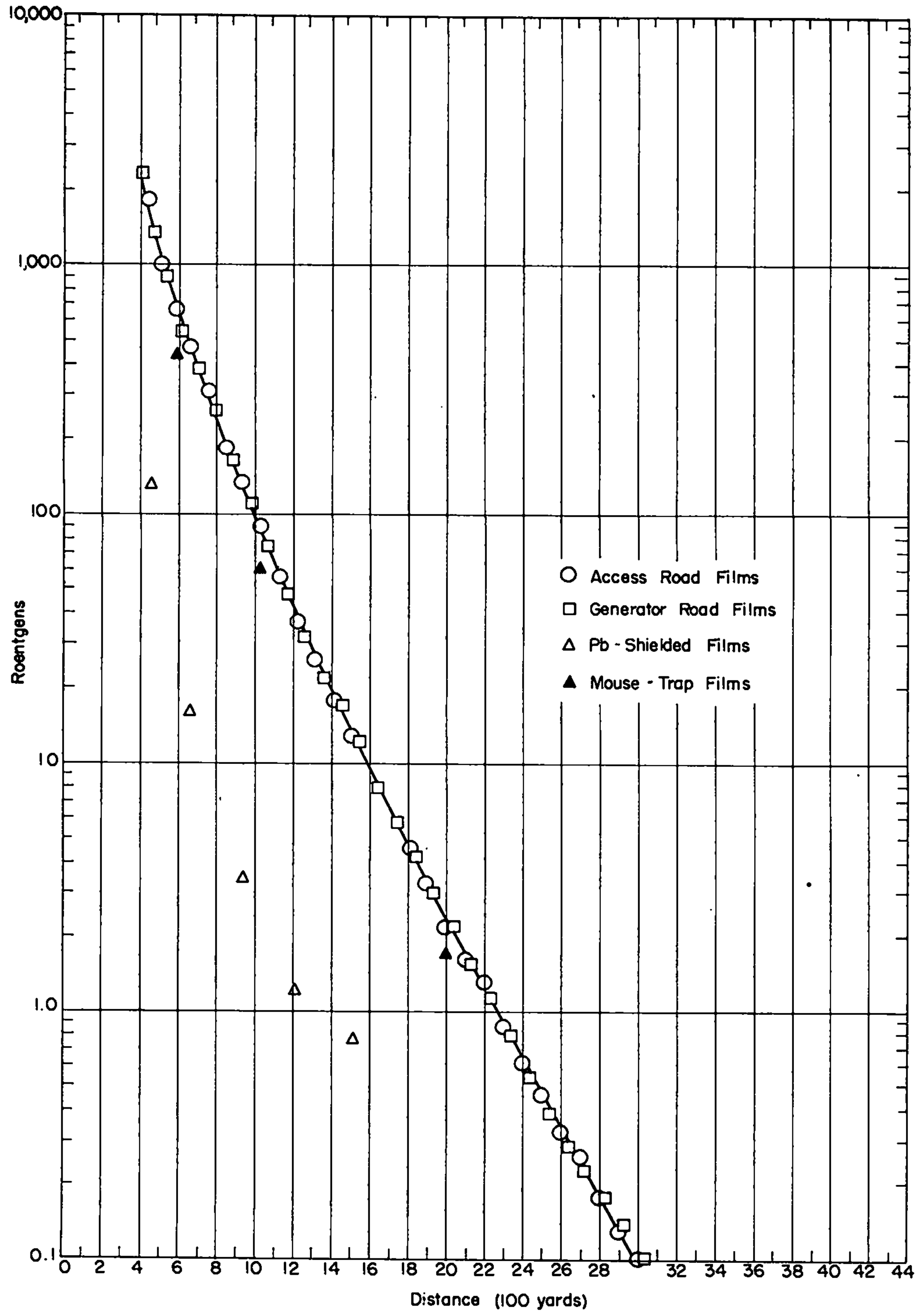

Figure 6

TEST A - Gamma Radiation Exposure vs. Distance

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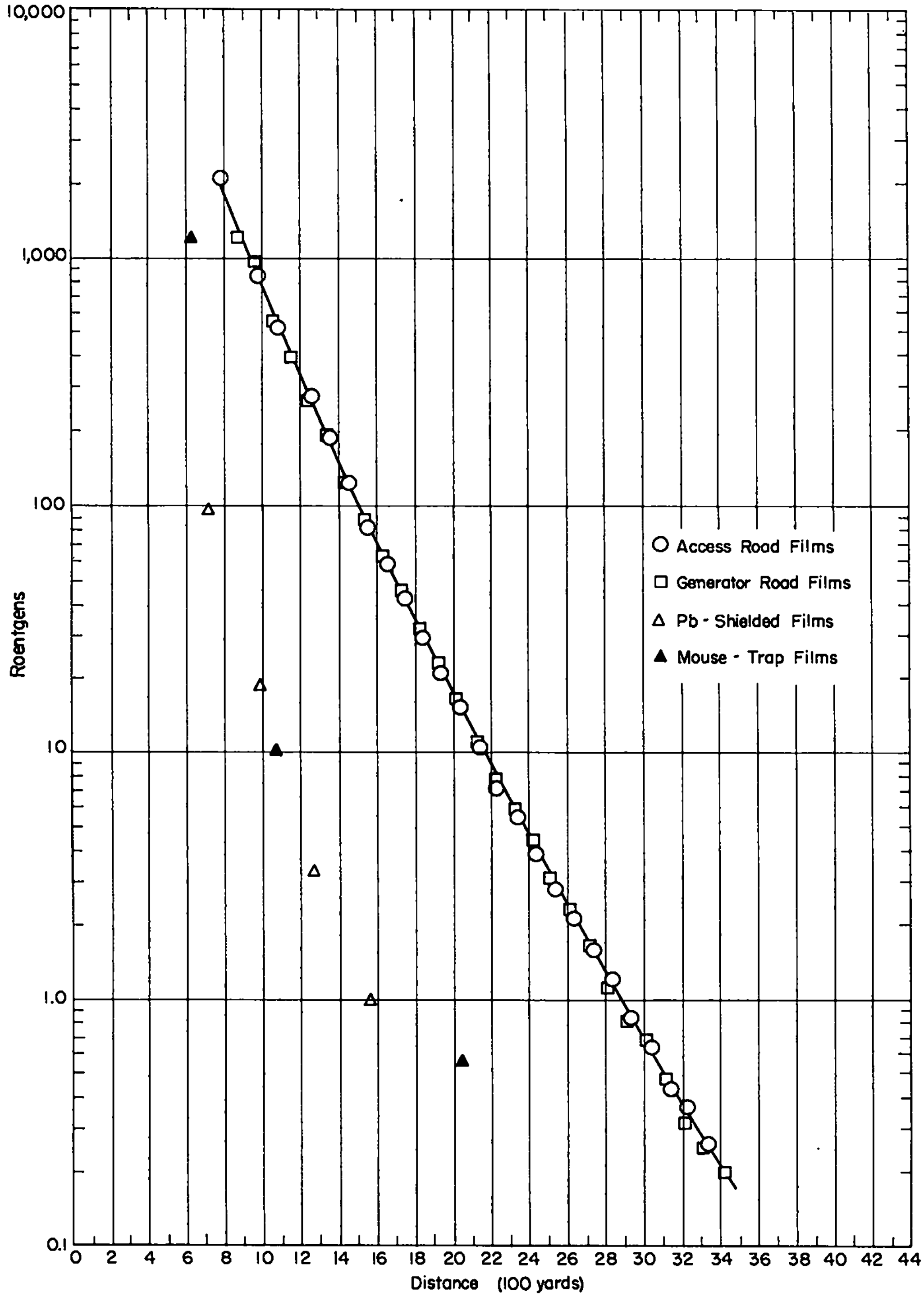

Figure 7
TEST B_1 - Gamma Radiation Exposure vs. Distance

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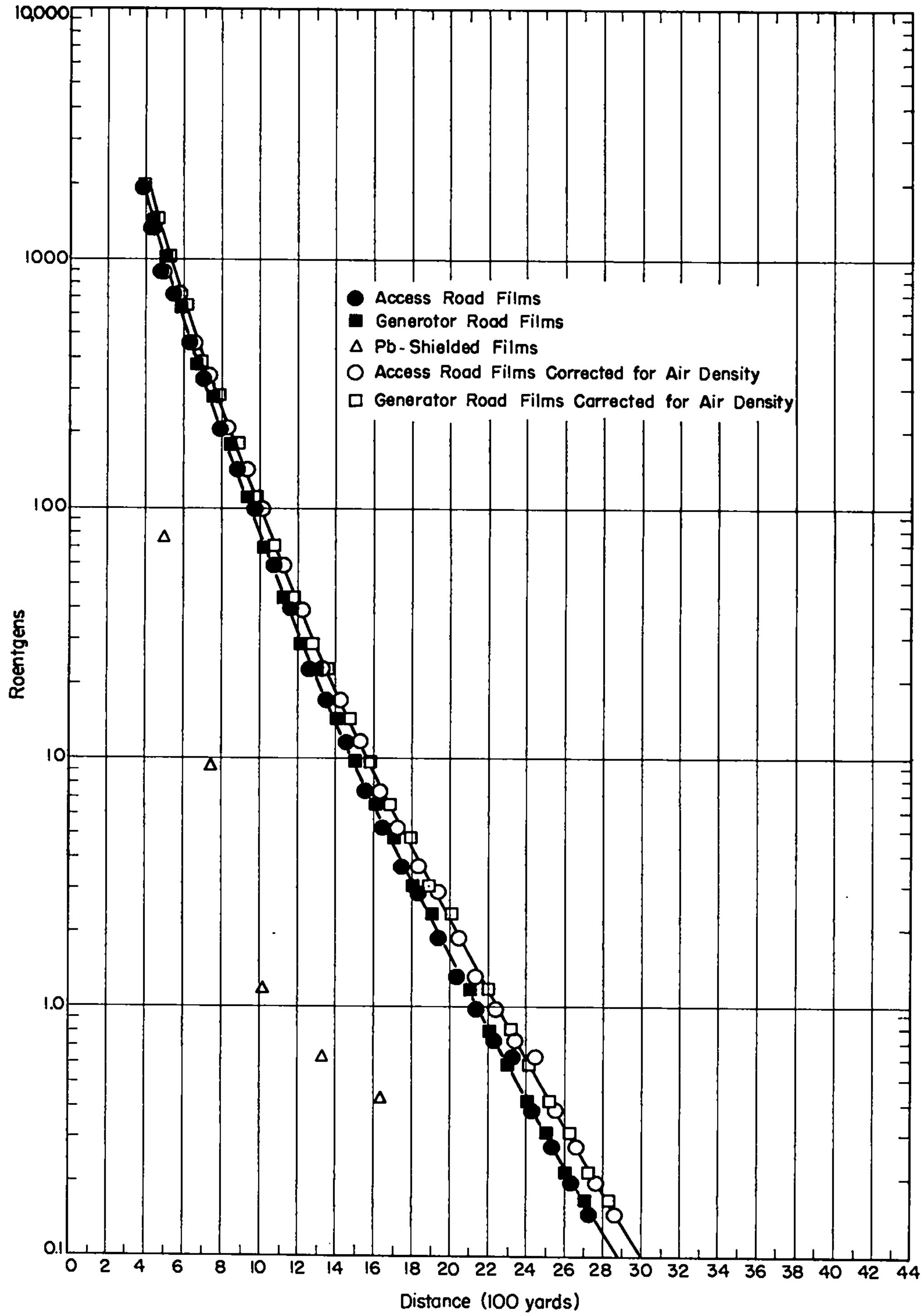

Figure 8
TEST E - Gamma Radiation Exposure vs. Distance

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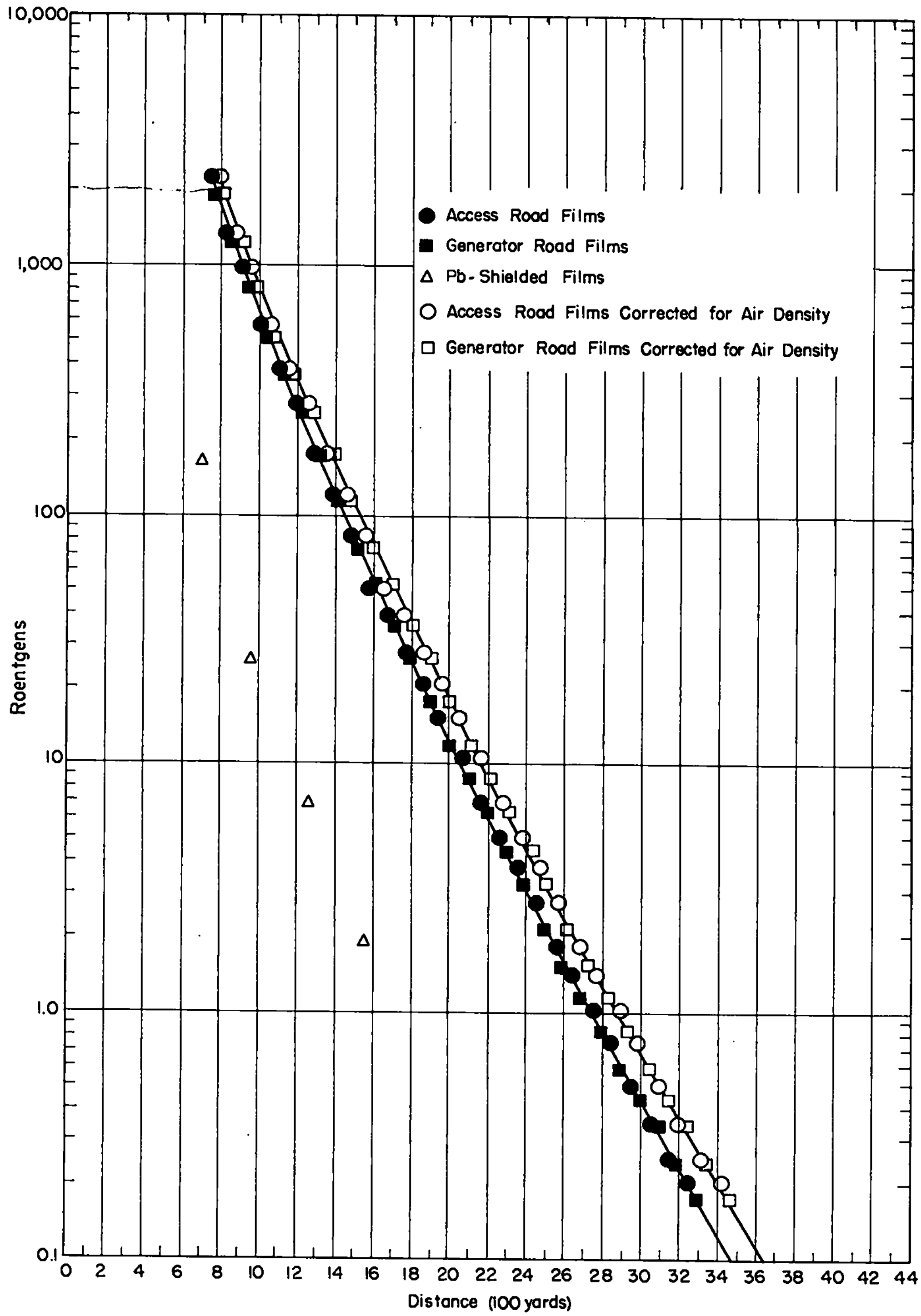

Figure 9

TEST B_2 - Gamma Radiation Exposure vs. Distance

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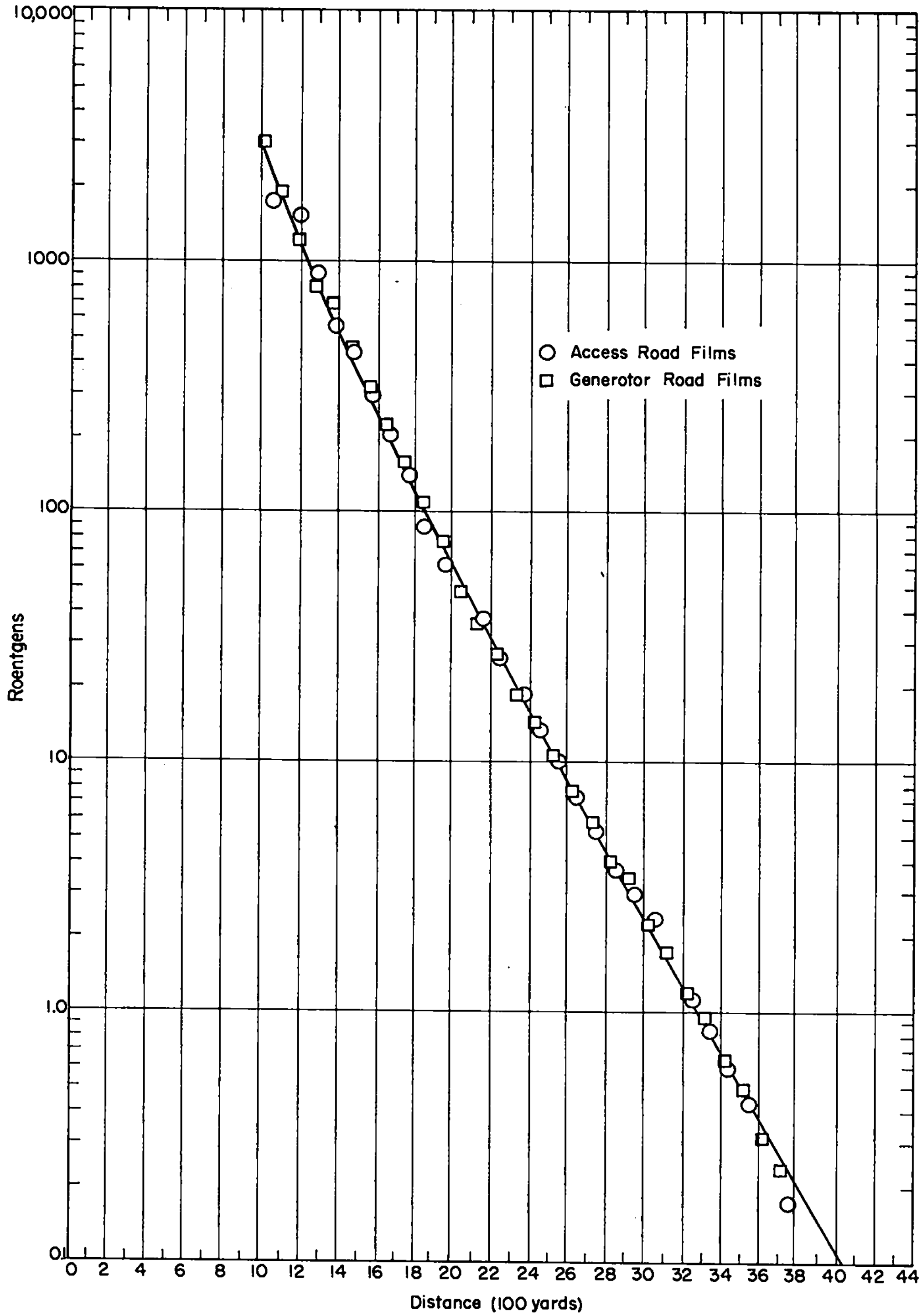

Figure 10

TEST F - Gamma Radiation Exposure vs. Distance

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these curves are based are included in Tables I through V. No correction is made here for the movement of the ball of fire or cloud.

A 10% temperature correction was applied to the films on tests E and B_2, the temperatures being minus 5.1 and minus 2.6 degrees Centigrade, respectively. On the other tests the temperatures at the time of detonation were essentially the same as the temperature at which the films were calibrated.

Corrections for the effects of orientation of the film with respect to the direction from the detonation were made for all films located within 500 yards of Ground Zero on tests A and E. The films at further distances required no correction. The films located within 500 yards of Ground Zero on the other tests were $>$3000 r, which is above the limit of the Adlux film, and consequently could not be interpreted.

The air density was identical during tests A, B_1, and F, and lower by a factor of 1.05 on tests E and B_2. The curves for E and B_2, corrected and uncorrected for air density, that is, normalized to the other three tests, are shown in Figs. 8 and 9.

The exposures received by the films located in the lead pigs are shown in Figs. 6 through 9; the pigs were not used on test F. The data for these points are listed in Table VI, together with the total gamma radiation exposure received by the non-lead-shielded films at

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Table I

Gamma Radiation Exposure Versus Distance

Test A

Access Road			Generator Road		
Dist. to Point of Detonation d (yards)	Exposure (Roentgens) R	$Rd^2(x10^6)$	Dist. to Point of Detonation d (yards)	Exposure (Roentgens) R	$Rd^2(x10^6)$
360	>3000		370	>3000	
390	>3000		410	2350	395
450	1850	375	470	1360	300
510	1000	260	540	900	262
590	670	233	620	550	211
670	470	211	710	390	196
760	310	179	800	260	166
850	187	135	890	165	131
940	136	120	980	110	106
1030	90	95	1070	75	86
1130	56	72	1170	48	66
1220	37	55	1260	32	51
1320	26	45	1360	22	41
1420	18	36	1460	17	36
1510	12.8	29	1550	12.5	30
1810	4.6	15	1650	8.1	22
1900	3.3	12	1750	5.9	18.1
2000	2.2	8.8	1850	4.2	14.4
2100	1.6	7.1	1940	3.0	11.3
2200	1.3	6.3	2040	2.2	9.2
2300	.87	4.6	2140	1.55	7.1
2400	.61	3.5	2240	1.12	5.6
2500	.46	2.9	2340	.80	4.4
2600	.33	2.2	2440	.55	3.3
2700	.26	1.9	2540	.39	2.5
2800	.18	1.4	2640	.29	2.0
2900	.13	1.1	2730	.23	1.7
3000	.10	.90	2830	.18	1.4
			2930	.14	1.2
			3030	.10	.92

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Table II

Gamma Radiation Exposure Versus Distance

Test B_1

Access Road: Dist. to Point of Detonation d (yards)	Access Road: Exposure (Roentgens) R	Access Road: $Rd^2(x10^6)$	Generator Road: Dist. to Point of Detonation d (yards)	Generator Road: Exposure (Roentgens) R	Generator Road: $Rd^2(x10^6)$
720	>3000		700	>3000	
800	2100	1340	790	2100	1311
890	1200	950	880	1200	930
990	840	823	970	970	913
1080	520	606	1060	550	618
1170	390	534	1160	390	525
1270	270	435	1250	260	406
1360	184	340	1350	190	346
1460	123	262	1440	125	259
1560	82	200	1540	88	209
1660	58	160	1640	62	167
1750	43	132	1740	45	136
1850	29	99	1830	32	107
1950	21	80	1930	23	86
2050	15.2	64	2030	16.5	68
2150	10.6	49	2130	11.0	50
2240	7.2	36	2230	7.8	39
2340	5.5	30	2330	5.9	32
2440	3.9	23	2430	4.4	26
2540	2.8	18	2520	3.2	20
2640	2.1	14.6	2620	2.3	15.8
2740	1.6	12.0	2720	1.64	12.1
2840	1.2	9.7	2820	1.12	8.9
2940	.83	7.2	2920	.82	7.0
3040	.64	5.9	3020	.69	6.3
3140	.43	4.2	3120	.47	4.6
3230	.36	3.8	3220	.32	3.3
3330	.26	2.9	3320	.25	2.8
3430	.20	2.4	3420	.20	2.3

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Table III

Gamma Radiation Exposure Versus Distance

Test E

Access Road: Dist. to Pt. of Deton. d(yds.)	Access Road: Expos. Roent. R	Access Road: Rd^2 x10^6	Access Road: Dist. Corr. for Air Density d'(yds.)	Generator Road: Dist. to Pt. of Deton. d(yds.)	Generator Road: Expos. Roent. R	Generator Road: Rd^2 x10^6	Generator Road: Dist. Corr. for Air Density d'(yds.)
380	1920	277	400	390	2000	304	410
420	1350	240	440	440	1470	285	460
470	890	197	490	500	1040	260	520
540	730	213	570	580	650	219	610
620	460	177	650	660	390	170	690
700	330	162	740	750	280	158	790
790	210	131	830	840	183	129	880
880	145	112	920	930	113	98	980
970	100	97	1020	1020	72	75	1070
1070	60	69	1120	1120	45	56	1180
1160	40	54	1220	1210	29	42	1220
1260	23	36	1320	1300	23	39	1360
1350	17.5	32	1420	1400	14.8	28	1470
1450	12.0	25	1520	1500	9.8	22	1580
1550	7.4	17.7	1630	1600	6.6	17	1680
1640	5.3	14.2	1720	1700	4.9	14	1780
1740	3.7	11.2	1830	1800	3.1	10	1890
1840	2.9	9.8	1930	1900	2.4	8.6	2000
1940	1.90	7.1	2040	2100	1.2	5.3	2200
2030	1.34	5.5	2130	2200	.83	4.0	2310
2130	.99	4.5	2240	2300	.61	3.2	2420
2230	.75	3.7	2340	2400	.43	2.5	2520
2330	.64	3.5	2450	2500	.32	2.0	2620
2430	.39	2.3	2550	2600	.22	1.5	2730
2530	.28	1.8	2660	2700	.17	1.2	2840
2630	.20	1.4	2760				
2730	.15	1.1	2870				

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Table IV

Gamma Radiation Exposure Versus Distance

Test B_2

Access Road				Generator Road			
Dist.to Pt. of Deton. d(yds.)	Expos. Roent. R	Rd^2 $x10^6$	Dist.Corr. for Air Density d'(yds.)	Dist.to Pt. of Deton. d(yds.)	Expos. Roent. R	Rd^2 $x10^6$	Dist.Corr. for Air Density d'(yds.)
740	2270	1240	777	760	1930	1115	800
820	1330	890	860	850	1220	880	890
910	990	820	955	940	820	720	990
1000	570	570	1050	1030	510	540	1080
1100	380	460	1160	1130	375	480	1190
1190	280	400	1250	1220	260	390	1280
1280	177	290	1340	1320	178	310	1390
1380	121	230	1450	1410	116	230	1480
1480	83	180	1550	1510	74	170	1580
1570	61	150	1650	1610	53	137	1690
1670	40	110	1750	1700	36	104	1780
1770	28	88	1860	1800	27	87	1890
1860	21	73	1950	1900	18.2	66	2000
1940	15.4	58	2040	2000	12.0	48	2100
2060	10.6	45	2160	2100	8.9	39	2200
2160	7.1	33	2270	2200	6.4	31	2310
2260	5.1	26	2370	2300	4.5	24	2420
2350	3.8	21	2470	2390	3.3	18.8	2510
2450	2.8	17	2570	2490	2.2	13.6	2610
2550	1.85	12	2680	2590	1.58	10.6	2720
2650	1.43	10	2780	2690	1.16	8.4	2820
2750	1.03	7.8	2890	2790	.84	6.5	2930
2850	.76	6.2	2990	2890	.60	5.0	3030
2950	.51	4.4	3100	2990	.45	4.0	3140
3050	.36	3.3	3200	3090	.36	3.4	3240
3150	.26	2.6	3310	3190	.25	2.5	3350
3250	.21	2.2	3410	3290	.18	1.9	3450

[redacted]

[redacted]

Table V

Gamma Radiation Exposure Versus Distance

Test F

Access Road			Generator Road		
Dist. to Point of Detonation d (yards)	Exposure (Roentgens) R	$Rd^2(\times 10^6)$	Dist. to Point of Detonation d (yards)	Exposure (Roentgens) R	$Rd^2(\times 10^6)$
1000	3000	3000	1000	3000	3000
1040	2100	2271	1080	1900	2216
1180	1500	2088	1170	1200	1643
1270	890	1435	1260	780	1238
1370	550	1032	1350	680	1239
1460	430	916	1450	450	946
1560	300	730	1540	310	735
1650	200	544	1630	220	584
1750	137	420	1730	157	470
1840	88	298	1820	109	361
1940	61	230	1920	76	280
2040	48	200	2020	48	196
2130	37	168	2120	36	162
2230	26	129	2210	27	132
2330	18.6	101	2310	18.5	99
2430	13.6	80	2400	14.6	84
2530	10.2	65	2500	10.7	67
2620	7.3	50	2600	7.7	52
2720	5.3	39	2700	5.8	42
2820	3.7	29	2800	4.0	31
2920	2.9	25	2890	3.4	28
3020	2.3	21	2990	2.2	20
3120	1.50	14.6	3090	1.70	16.2
3220	1.15	12.0	3190	1.18	12.0
3310	.82	9.0	3290	.93	10.0
3410	.60	7.0	3390	.63	7.2
3510	.42	5.2	3480	.48	5.8
3610	.31	4.0	3580	.31	4.0
3710	.17	2.3	3680	.23	3.1

[redacted]

[redacted]

Table VI

Exposure Due to Neutron Induced Activity

Distance (yards)	Neutron Induced Exposure (Roentgens)	Total Gamma Exposure (Roentgens)	Per Cent
		Test A	
450	130	1850	7.0
670	16	470	3.4
940	3.4	136	2.5
1220	1.2	37	3.2
1510	.76	12.8	5.9
		Test B_1	
720	95	~ 3000	~ 3.2
990	18.5	840	2.2
1270	3.3	270	1.2
1560	.98	82	1.2
		Test E	
490 *	77	890	8.7
740 *	9.4	330	2.8
1020 *	1.2	100	1.2
1320 *	.63	23	2.7
1630 *	.43	7.4	5.8
		Test B_2	
690 *	163	~ 3500	~ 4.7
950 *	26	990	2.6
1250 *	6.9	280	2.5
1550 *	1.9	83	2.3

* Corrected for Air Density

[redacted]

[redacted]

the same distances. From this data it appears that the exposure due to neutron induced activity in the film, badge, and stake averages from 3 to 5% of the total gamma radiation exposure measured by the film.

The contribution of the radioactivity from the ground was found to be $<<$ 1% of the total exposure. For example, 1000 yards from Ground Zero on test F, a level of 0.16 r/hr was measured with an ionization chamber at the time of film recovery, 5 hours after detonation. The half-life of the radioactivity from the ground was found to be approximately 10 hours. Thus, the ground activity contributed a total of 0.9 r, which is insignificant compared to 3000 r, the total exposure.

The results from the mouse-trap gadgets for tests A and B_1 are shown in Figs. 6 and 7. The data for these points are listed in Table VII, together with the total gamma radiation exposure received by the regular films at the same distances. On test A, from 590 to 2000 yards, the fraction of the gamma radiation, reaching the film before the blast, increases from 66 to 77%. On test B_1, however, the fraction is very much less, being about 27 and 3.7% at distances of 630 and 2050 yards, respectively. There is a possibility that the mouse-traps were sprung prematurely on test B_1. It is interesting to note that the mouse-trap data and the points representing the neutron induced activity appear to fall along the same curve on this test.

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Table VII

Mouse-Trap Gadgets

Distance (yards)	Film Exposure in Mouse-Trap Gadgets (Roentgens)	Total Gamma Exposure (Roentgens)	Per Cent
	Test A		
590	440	670	66
1030	60	90	67
2000	1.7	2.2	77
	Test B_1		
630	1200	~ 4400	~ 27
1080	10	520	1.9
2050	.56	15	3.7

[redacted]

[redacted]

Unfortunately, the mouse-traps were not used on subsequent tests.

The product of the exposure in roentgens times the square of the distance is plotted in Fig. 11 as a function of distance for the five tests. The points fall along straight lines, on the semi-log plot, over the range measured.

IV. Discussion of Results

The 400 r level was 700, 1150, 690, 1140, 1470 yards slant range for tests A, B_1, E, B_2, and F, respectively, as shown in Fig. 12. The data obtained from the Bikini and Sandstone tests are also included. This level appears to vary only slightly with distance with yields greater than about 20 KT. At lower yields the distance decreases fairly rapidly, dropping from 1400 yards at about 20 KT to 700 yards at 1 KT.

The apparent mean free path of the gamma radiation calculated from Fig. 11 varies from 400 to 420 yards. At Sandstone an apparent mean free path of 350 yards was measured. This difference is probably due to the difference of air densities at Sandstone and Ranger. At Ranger the air density was about 1.08×10^{-3} gm/cc.

From a knowledge of the yield or KT of the bomb on one of the tests, it should be possible to determine the yield of the other four bombs from the ratios of the gamma radiation exposure measured at a fixed distance. Table VIII gives the ratios, compared to test B_1, of the gamma radiation exposure times the distance squared (Rd^2), from

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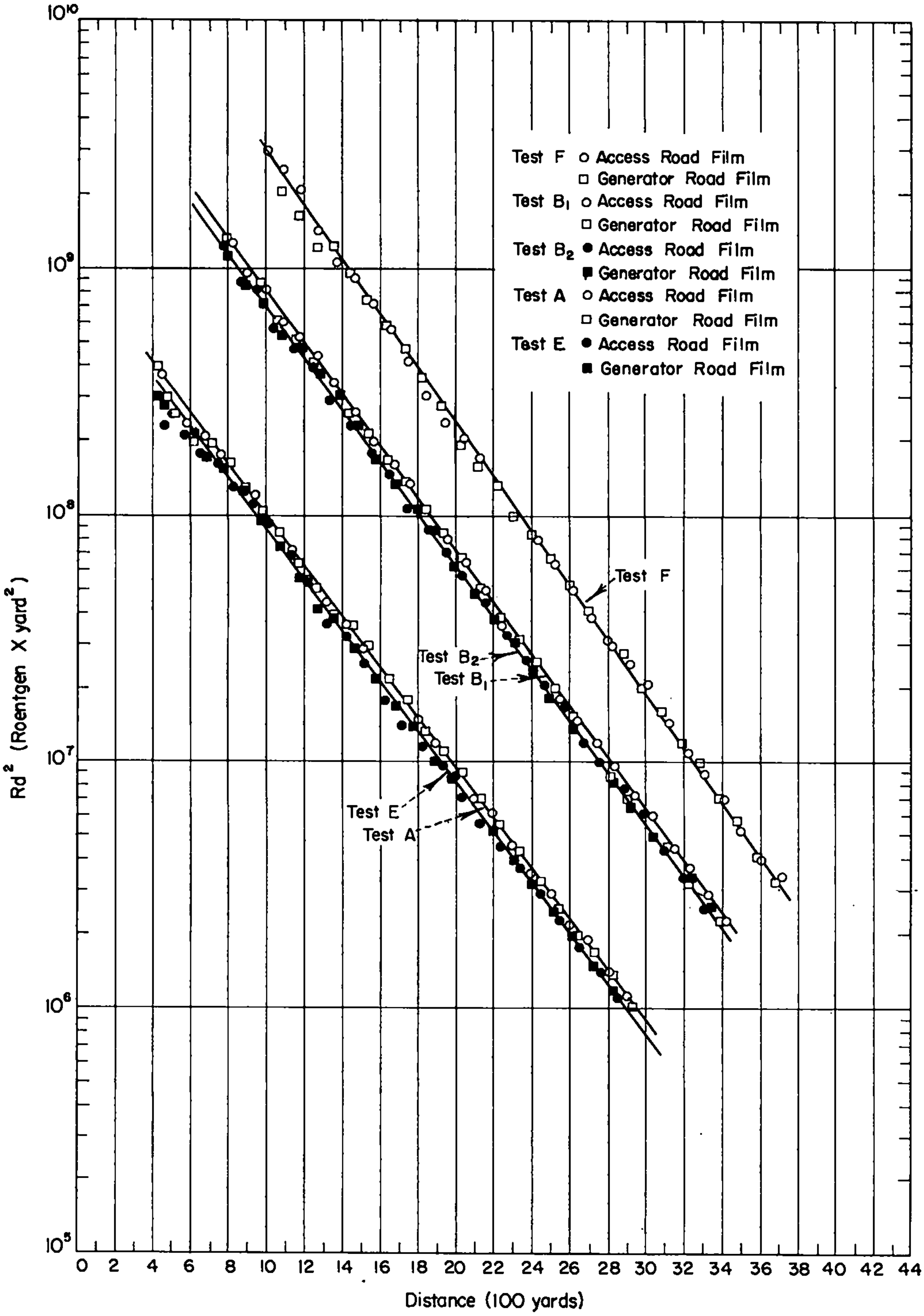

Figure 11

Gamma Radiation Times Distance Squared as a Function of Distance

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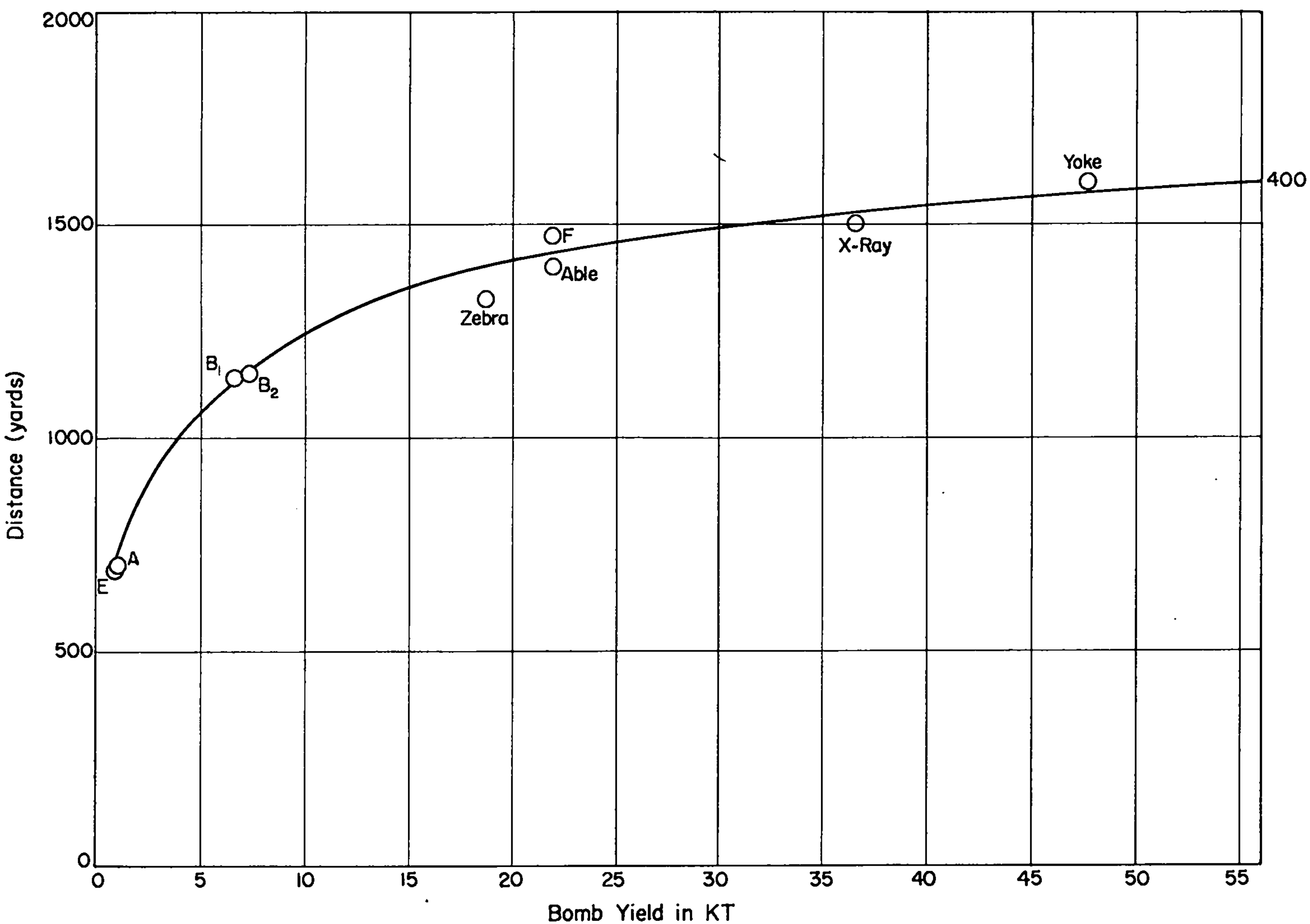

Figure 12

Distance of the 400r Level as a Function of Bomb Kilotonage

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Table VIII

Ratios, Compared to Test B_1, of Gamma Radiation Exposure Times the Distance Squared (Rd^2)

	Fireball Results		1000 yards		1500 yards	
Test	KT	Ratio	$Rd^2 \times 10^6$	Ratio	$Rd^2 \times 10^6$	Ratio
A	1.5	.203	100	.125	30.5	.132
B_1	7.4	1.00	800	1.00	242	1.00
E	.94	.127	88	.110	27.2	.117
B_2	6.7	.904	690	.863	209	.864
F	22	2.98	3000	3.75	840	3.47

	2000 yards		2500 yards		3000 yards	
Test	$Rd^2 \times 10^6$	Ratio	$Rd^2 \times 10^6$	Ratio	$Rd^2 \times 10^6$	Ratio
A	9.5	.132	2.9	.133	.90	.139
B_1	72	1.00	21.8	1.00	6.5	1.00
E	8.4	.117	2.6	.119	.81	.125
B_2	62	.862	18.6	.853	5.6	.862
F	237	3.29	67	3.07	19	2.93

[redacted]

Fig. 11, at distances of 1000, 1500, 2000, 2500, and 3000 yards. These ratios are compared to the ratios of the yields measured by the fireball method, again using test B_1 as the standard. The ratios for test B_2 are essentially constant for each distance. The ratios for tests A and E increase slightly as the distance increases, whereas the ratios for test F decrease from 3.75 at 1000 yards to 2.93 at 3000 yards. The variation in the ratios may be explained with the aid of Fig. 13, where the ordinate of the Rd^2 versus d curves have been shifted so that the points at 3000 yards fall on one another, no change in the abscissa being made. As may be seen, the curves for tests A and E fall along one line, the curves for B_1 and B_2 fall along another line with a slightly different slope, while the curve for test F has still another slope. If the curves for all five tests had fallen on the same line, the ratios would have, of course, been constant. The most reasonable explanation for this lack of parallel displacement probably lies in the movement of the ball of fire as the gamma radiation is emitted. Because of the upward movement of the ball of fire, the actual effective distance to the films is somewhat larger than that given in the Table and Figures. The smaller slope for test F indicates that the rate of movement of the ball of fire was greater than it was for tests B_1 and B_2. Similarly, the larger slopes obtained on the A and E tests indicate a smaller rate than for tests B_1 and B_2. It seems reasonable that the ball of fire would rise

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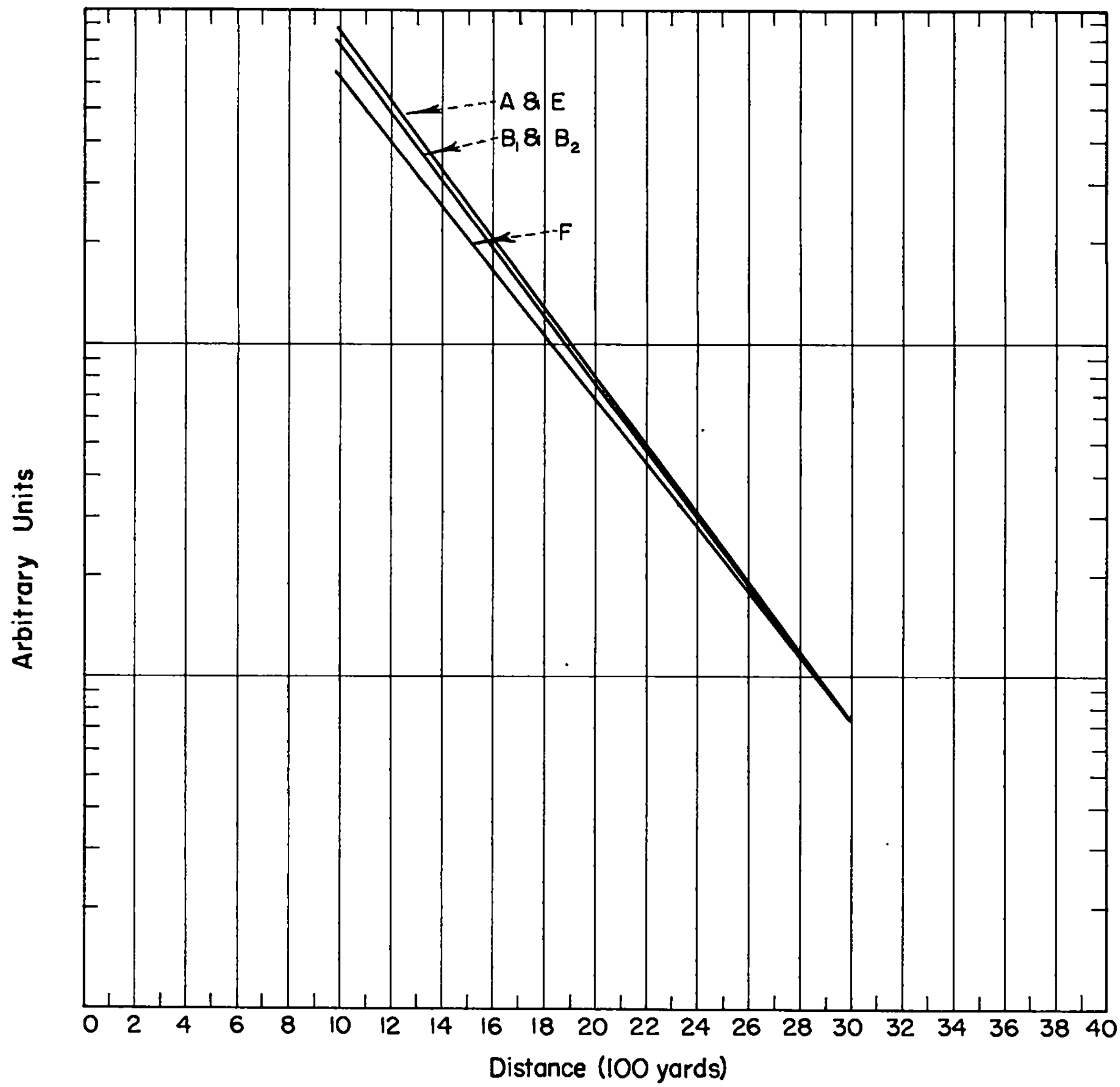

Figure 13
Normalized Ordinate in Arbitrary Units vs. Distance
(as explained in text)

[redacted]

more rapidly as the yield increases. Since this rise would have more effect on the values obtained at the smaller distances, the ratios of the curves at 3000 yards were taken to determine the bomb yield.

Table IX compares the bomb yields, obtained from the Rd^2 ratios at 3000 yards, to the results of the fireball method. The fireball measured value of 7.4 KT for test B_1 was used as a standard. Remarkably good agreement is obtained for tests B_1, E, B_2, and F. For test A, however, the film method gave about a 30% lower yield than that of the fireball method; that is, 1.03 compared to 1.50 KT. There is no reason to believe that the film measurements for test A are not as reliable as those for the other tests; consequently, on the basis of this film method there might be an error in the fireball measurements of test A. Dr. F. Reines has recently informed the author that the expected or theoretically calculated yield for test A was 1.0 KT.

In Fig. 14, roentgens per KT is plotted as a function of distance for the Sandstone and Ranger tests. Within the experimental error, the curves are in good agreement from 400 to 1400 yards. No explanation is known at the present time for the disagreement found between the two curves beyond 1400 yards.

V. Conclusions

It appears that the measurement of gamma radiation exposure as a function of distance can be used to determine the bomb yield with an

[redacted]

Table IX

Yield from

Gamma Radiation Exposure Versus Distance Measurements

All Tests Normalized to Fireball Measurement

of Test B_1 (7.4 KT)

Test	KT from Fireball Measurements	KT from Rd^2 Ratios at 3000 yards	Per Cent Difference
A	1.5	1.03	31.3
B_1	7.4	7.4	0.00
E	.94	.924	1.70
B_2	6.7	6.37	4.92
F	22	21.7	1.36

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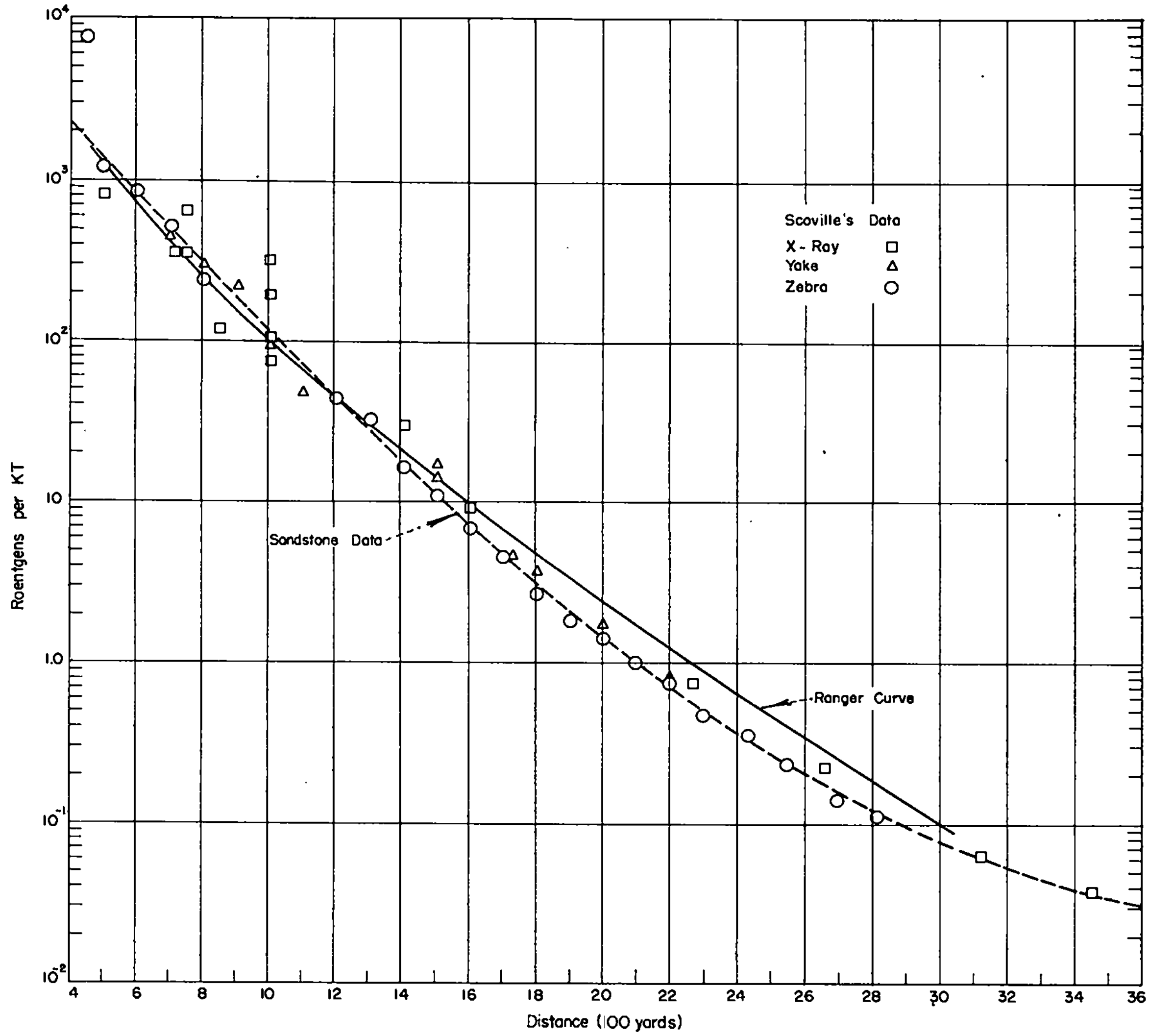

Figure 14
Gamma Radiation vs. Distance (Ranger and Sandstone)

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accuracy of approximately 5%.

The 400 r, LD50, level from gamma radiation emitted immediately after detonation from 1 KT bombs is about 700 yards. This distance increases to 1400 yards from approximately 20 KT bombs, from which point it remains essentially constant for increasing yields.

From the Ranger tests the apparent mean free path of gamma radiation is about 400 yards for an air density of 1.08×10^{-3} gm/cc.

The neutron induced activity in the film and container contributes about 3 to 5% of the total exposure found on the film.

The neutron induced activity in the soil contributes $\ll 1\%$ of the total exposure found on the film.

Further tests are required before any conclusions can be drawn as to the fraction of gamma radiation which reaches the film before the blast.

The film and badge were not considered entirely satisfactory. Films should be procured which are capable of measuring radiation up to 100,000 r. The film container or badge should be modified so that the film can be easily removed from the badge without removing the badge from the stake. Suggestions for improving this experiment will be given in a future report.

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References

1. G. Dessauer, "Five Drawings on Bikini and Trinity", AM-3508.

2. H. Scoville, Jr., Comdr. E. J. Hoffman, USN, and Lt. E. C. Vicars, USN, "Gamma Radiation Versus Distance - Operation Sandstone", 30 June 1948.

3. W. E. Ogle, "Neutron Measurements at Operation Ranger", 14 February 1951.

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