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MINISTRY OF SUPPLY

ATOMIC WEAPONS RESEARCH ESTABLISHMENT

REPORT No. T 1/53

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May, 1953

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ATOMIC WEAPONS RESEARCH ESTABLISHMENT

MATERIALS RESEARCH DIVISION

REPORT No. T1/53

(SAM Branch)

Some Preliminary Results from the Monte Bello Tests, Relevant to Defence, including Civil Defence

W. J. Moyce

Summary

This report presents a brief statement of provisional and general results of some aspects of the Monte Bello trial which have a bearing on Defence. It is not intended as an official advance summary of the final report on the trial but should form a useful first guide to many problems.

May, 1953.

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1. Introduction

The preparation of the full report on the Monte Bello trial is a formidable task and may take some time. Apart from the task of compilation, the interpretation of some of the experimental observations has presented difficulties. In the meantime, however, several enquiries have arisen from various bodies calling for preliminary data. The object of this report is to present, very briefly, the provisional general results of some aspects of the trial which have a bearing on Defence. The findings presented here are not necessarily final, but should form a useful adequate first guide to many problems. This paper is not intended as an official advance summary of the final report on the Monte Bello trials.

2. The Trial Conditions

The weapon was exploded in H.M.S. Plym, a frigate lying about 400 yards off shore from Trimouille Island. The depth of water was about 40 feet and the weapon centre was about 9 feet below the water line. Figure I gives a map of the area, together with other data to be referred to later.

From a balloon ascent made at H + 1 hour the variation of wind speed and direction was determined. The ground wind was southerly (175°) and of speed 15 knots. With increasing height the wind direction changed towards the east until at 6,000 feet it was slightly north of east (77°) at a speed of 10 knots. The change in direction with height was then reversed so that the wind turned through south to become westerly at 20,000 feet at a speed of 64 knots. The wind speed decreased steadily up to 6,000 feet and then increased.

3. Air Blast

3.1 Peak Pressure - Distance Relationship

The ground level peak pressure - distance curve is shown in Figure 2.

The following are values of the duration of the positive phase of the blast pressure at various distances, as read from a smoothed curve through observational points.

Distance feet	Duration seconds
2,500	0.6
3,000	0.7
5,000	0.9
7.500	1.0

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In the region of blast pressure varying from 7 lbs. per sq. inch to 10 lbs. per sq. inch pressure-time relation approximately closely to the Friedlander form

$$p = p_o (1 - t/\tau)e^{-t/\tau}$$

where p is hydrostatic blast over pressure at a point at time t

p_o is the peak pressure at the point

τ is the duration of the positive phase of blast pressure.

The equation was somewhat less satisfactory at higher and lower pressures, but was still sufficiently acceptable for design use.

3.2 Blast Damage

3.2.1 Anderson Shelters

Standard Anderson Shelters, with sandbag covering and blast wall construction were located at 460, 510, 600, 920 and 1,130 yards from ground zero. Mean blast pressures, in pounds/sq. inch, recorded inside the shelters are shown in the following table.

Distance (yds.)	Presentation		
	Front	Side	Rear
460	NR	NR	NR
510	38	27	40
600	28	21	28
920	16	7	14
1130	8.5	4	5.5

Front presentation implies blast wall facing towards event.
Rear " " " " " away from event.
Side " " shelter side on to event.

Shelters at 460, 510 and 600 yards suffered damage including demolition of blast walls, removal of sandbag covering and some displacement of the corrugated iron.

At 920 and 1,130 yards the shelters suffered relatively little damage.

Civil defence authorities consider that there might have been some 50% survival from blast damage of personnel in shelters at 460 yards and some 90 per cent at 600 yards, fatal casualties being mainly due to secondary blast effects (e.g. debris) and not to direct effects on the person of the blast pressure itself. The front presentation appears the most hazardous, due to the collapse of the blast wall into the shelter. At such distances, however, the survival from the effects of gamma flash would have been virtually nil.

At 920 and 1,130 yards there would have been no casualties from blast, and incidentally, little risk from the effect of gamma flash.

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3.2.2 Concrete Cubicles

Reinforced concrete cubicles, 12 feet cube were exposed to the blast. There were three types of cubicle, varying in wall thickness and the mesh of reinforcement. The following table gives some details:-

Thickness of Wall and Roof	Mesh of Reinforcement		Dia. of Rods (mild steel)
	Walls	Roof	
$6\frac{3}{4}$"	9"	$7\frac{1}{2}$"	$\frac{5}{8}$"
$9\frac{3}{4}$"	$6\frac{1}{2}$"	$4\frac{1}{2}$"	$\frac{3}{8}$"
12"	9"	$5\frac{1}{2}$"	$\frac{3}{8}$"

The concrete was a mixture of 1 cement, 1.4 sand and 2.8 of $1\frac{1}{4}$ inches aggregate (parts by volume). The aggregate was of local rock and rather soft and weak. The water/cement ratio was 0.5. This produced a crushing strength of 6 inches cubes of over 2,000 p.s.i. in 7 days.

The cubicles faced the event squarely. In the rear wall was a tapered opening about 2 feet high × 1 foot 6 inches broad into which a pile of four tapered blocks fitted to close this entrance prior to the explosion.

A $9\frac{3}{4}$ inch wall thickness cubicle was 600 yards from the explosion. Its front wall failed and was pushed inside the cubicle. The side walls were fractured and had a slight outward bowing (about 1 inch). The rear wall had minor hair cracks. The roof showed cracks along the line of the inside of the side walls and had failed completely along the line of the front wall.

At 990 yards, $6\frac{3}{4}$ inch and $9\frac{3}{4}$ inch walled cubicles showed fine hair cracks. There was no damage to the 12 inch walled cubicle at this distance, nor to one with a $9\frac{3}{4}$ inch wall at 1,320 yards.

In all cases the tapered blocks closing the rear entrance had been thrown outwards.

4. Water Shock

The underwater shock was relatively feeble, and significant recordings were obtained at two points only. The results were:-

Depth of gauges - 22 feet.

Distance from weapon (feet)	Pressure p.s.i.
960	270
1185	20
1380	0

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5. Earth Movements

Figure 3 shows recorded transient earth movements and accelerations. It will be noted from the scatter in the results that too much reliance should not be placed upon them at this stage. In the absence of knowledge concerning the geological structure of the earth, the results should be regarded only as illustrative of behaviour in a particular situation, and should not be taken as applicable to other sites.

The crater was a saucer shaped depression about 800 feet diameter and 20 feet deep at the centre.

6. Fires

Some outbreaks of fire took place amongst the parched grass-like vegetation on Trimouille. It appeared that these were not due to radiant heat from the weapon, but arose from ignition by hot fragments of H.M.S. Plym. The inference is that the water column formed an effective shield against the direct thermal effects of the radiation.

7. The Gamma Flash

7.1 The Dose - Distance Relationship

The decay of short lived fission products from the weapon gives rise to an intense pulse of gamma radiation. A large proportion of the dose from this is received in a few seconds. Figure 4 shows the total dose (recorded by films) as a function of distance from the weapon.

7.2 Gamma Energies

In applying these results to shielding problems (using for example the methods given by Liston and Cave, HER Report H13/51) it would be desirable to know what assumed energy of photon would give the right answer. Naturally, the actual gamma ray flux consists of a continuous spectrum of a quite unpredictable nature.

The spectrum will of course vary with the distance from the weapon, largely due to Compton scatter. No data are available from the trial which can lead to an estimation of these spectra. The trend of the dose distance curve is similar to that which would be calculated on the assumption that the original photons were all of about 3 Mev energy; one must be careful not to draw any further conclusions from this statement.

Concrete cubicles of wall thickness $6\frac{3}{4}$ inches, $9\frac{3}{4}$ inches and 12 inches at 900 yards appeared, from somewhat incomplete data, to give the same reduction of dose inside as they would from a parallel gamma beam of about 1 Mev photons. At 1,320 yards a cubicle with a $9\frac{3}{4}$ inch wall appeared to reduce the dose by an amount equivalent to the reduction expected from a parallel $1\frac{1}{2}$ Mev beam. This latter result implies an energy higher than $1\frac{1}{2}$ Mev at 900 yards, and does not appear to be consistent with a value of 1 Mev at 900 yards. The difference between the results might be within the errors inherent in experiment and calculation.

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7.3 Protection against the Gamma Flash

7.3.1 Anderson Shelters

The Anderson shelters were about 6 feet high internally, the floors being 3 feet below ground level.

The data obtained are somewhat confusing in that there is considerable scatter in the plot of the observations. Taking a very broad view of the results, it could perhaps be said that the distance at which a median lethal dose of 400 r. near the floor of the shelter would be expected is about 800 yards. The dose higher in the shelter, and thus above ground level was of the order of twice that near the floor and below ground level and consequently the 400 r. distance at these levels is about 900 yards. A dose of 150 r., which may be regarded as, in general, non-lethal, would be received below ground at about 900 yards.

7.3.2 Concrete Cubicles

The mean results for total doses inside the cubicles are :-

12 inch wall	190 r.	at 990 yards
$9\frac{3}{4}$ inch wall	3,000 r.	at 600 yards
	270 r.	at 990 yards
	50 r.	at 1,320 yards
$6\frac{3}{4}$ inch wall	460 r.	at 990 yards

The 400 r. distances for a $6\frac{3}{4}$ inch, $9\frac{3}{4}$ inch and 12 inch wall cubicle are thus about 1,000, 950 and 900 yards respectively. The 150 r. distances are respectively about 1,100 and 1,050 yards for the $9\frac{3}{4}$ inch and 12 inch cubicles. This distance for the $6\frac{3}{4}$ inch cubicle may be in the region of 1,300 yards.

7.3.3 Slit Trenches

The slit trenches were nominally 6 feet x 2 feet x 6 feet deep. In open trenches, facing the event broadside on, personnel standing erect would receive the median lethal dose of 400 r. at about 850 yards. Personnel who were prone in such trenches of 3 feet depth or more would receive 400 r. at 700 yards. In the open 400 r. is experienced at about 1,300 yards. A 1 foot cover of earth over the trench cuts down the dose by a factor of about 5, and moves the 400 r. dose for personnel erect in the trench in to about 650 yards.

A dose of 150 r. is received in the erect position at 1,050 yards in open, and 800 yards in covered, broadside on, trenches. In the 3 feet deep, prone position this dose is received at 850 yards in open, and 650 yards in covered, trenches. The dose in open trenches facing end on to the event may be as much as doubled.

8. The Radioactive Fall-Out

8.1 Over Land

A large proportion of the fission products taken up in the cloud and plume returned to the ground over a large area. Subsequent examination of the ground showed evidence of disturbance by a form of rain from the plume, and it is to be presumed that this rain brought down the bulk of the activity deposited.

19120011

The effect of the wind was to spread out the activity in the manner shown in Figure 1, which gives gamma dose rate contours calculated at H + 1 hour from data obtained with monitors on land on D + 20 days. For the purpose of this figure a decay law of $t^{-1.2}$ has been assumed. This is probably too low a power for this purpose. As is to be expected no single power suffices, but there are indications that a $t^{-1.3}$ law may be a better working rule and would avoid unnecessarily high predictions of future dose rates which the $t^{-1.2}$ law can give.

It should be borne in mind that while Figure 1 gives contours of equal dose rate, β radiation is also emitted in the disintegration of the fission products. How much this can contribute, in practice, to the physiological effects of the radiation seems to be a matter of some controversy. If the fall out took place on a perfectly flat surface the ratios of the physiological effect of the β and γ radiation have been estimated to be

Time	β/γ ratios
H + 1 hour	14
H + 1 day	9
H + 1 week	4.5

Thereafter the ratio would stay at about 4 although an increase would occur at much later times (~ 2 or 3 months). At first sight it might appear that neglect of the β contribution could lead to gross under-estimation of dose received. On the other hand small irregularities in the ground could provide a marked measure of β shielding.

Observations at Monte Bello did not give a definite answer to this problem.

8.2 Over Sea

The fission products falling into, or remaining in, the water became dispersed within it and so provide a less serious radiation hazard. The general level of β activity in the lagoon was about 3×10^{-2} micro curies/cc. after two days. There was no evidence of greater activity over the crater. It was also found that the gamma dose received in fission product contaminated water was 24 r./hr./100 μc./cc.. The dose on the water surface would be about half of this, so the water activity at Monte Bello soon gave rise to a negligible gamma hazard.

Experience at Monte Bello was that the activity of the water did not constitute a serious hazard to navigation. Some build up of contamination occurred on the sides of ships and in condensers and other pipes, but this dispersed to a large extent on removal to clean waters. The conclusion is that contamination of ships by the active water, although a nuisance with regard to subsequent maintenance, repairs and cleaning up, would not restrict operations.

8.3 Energies of γ from Fall-Out

There were no observations at Monte Bello which gave a line on this question. The energies in the radiation would have some bearing on the probability of survival of personnel who were indoors at the time of the fall-out, and who stayed inside for some time afterwards. From a study of the decay systems of fission products it is estimated that an initial energy of about 1 Mev would be appropriate for use in such considerations.

19120012

9. Water Waves

The waves produced by the explosion at Monte Bello were not investigated. The following estimates of the waves to be expected from such a burst have been made by Sir William Penney.

A nominal (20KT) bomb exploded on the surface on an open stretch of water 40 feet deep will produce a wave

15 feet above still water at 500 yards
5 feet above still water at 1,000 yards
$2\frac{1}{2}$ feet above still water at 2,000 yards

The waves will break out to 500 yards. If the water was 25 feet deep, wave heights would be 80 per cent of those given above.

If the waves fall on a shelving beach, their heights will be 25 per cent greater.

The wave heights depend on tonnage as the following examples illustrate:-

80KT. in 40 feet water gives a 20 feet crest at 600 yards
5KT. in 40 feet water gives a 10 feet crest at 400 yards.

10 Acknowledgments

The material for the information given in this paper was collected from many sources connected with the Monte Bello trial, much of it in the course of informal discussions.

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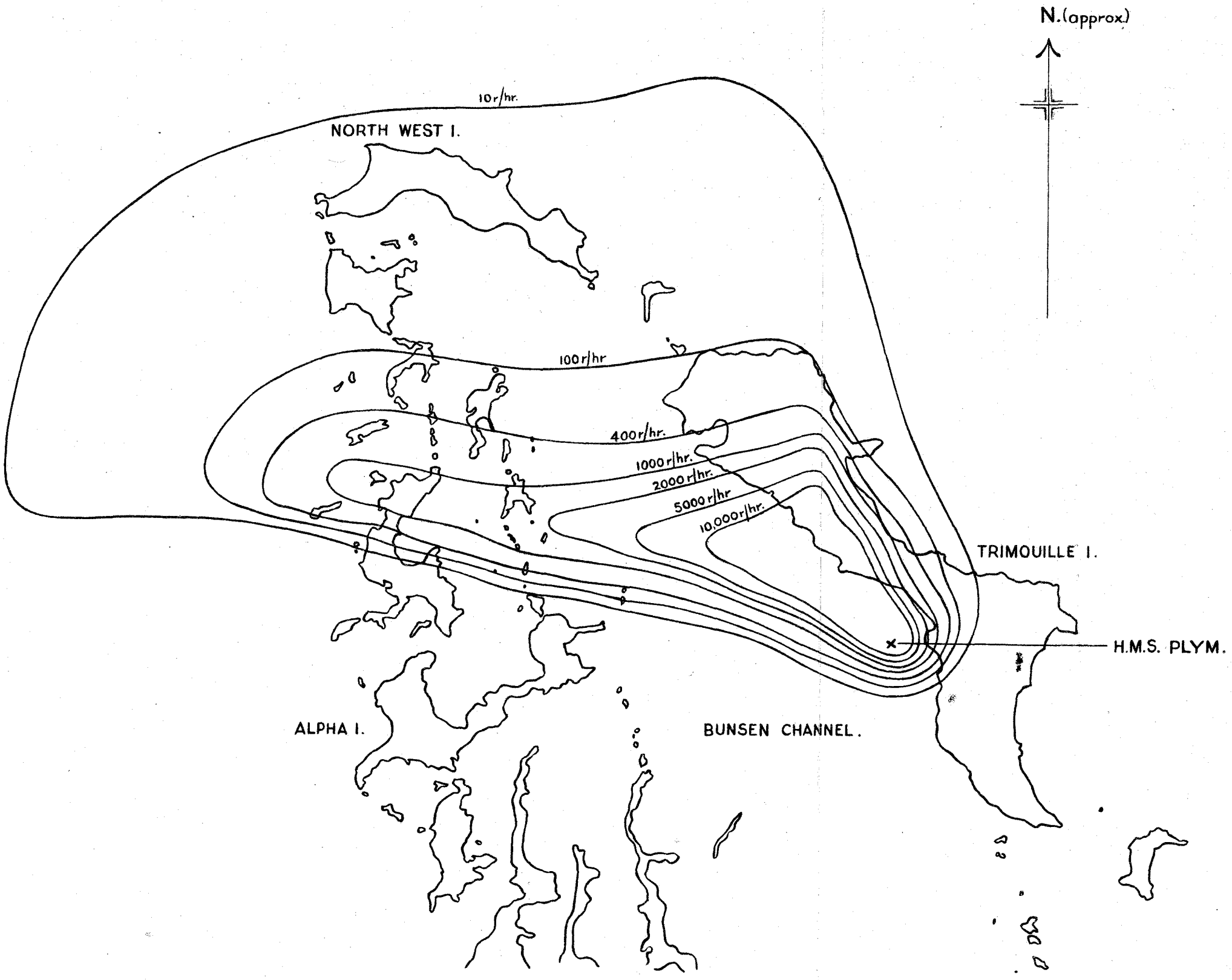
19120013



GAMMA DOSE RATE AT H+1hr.

FIG. 1.

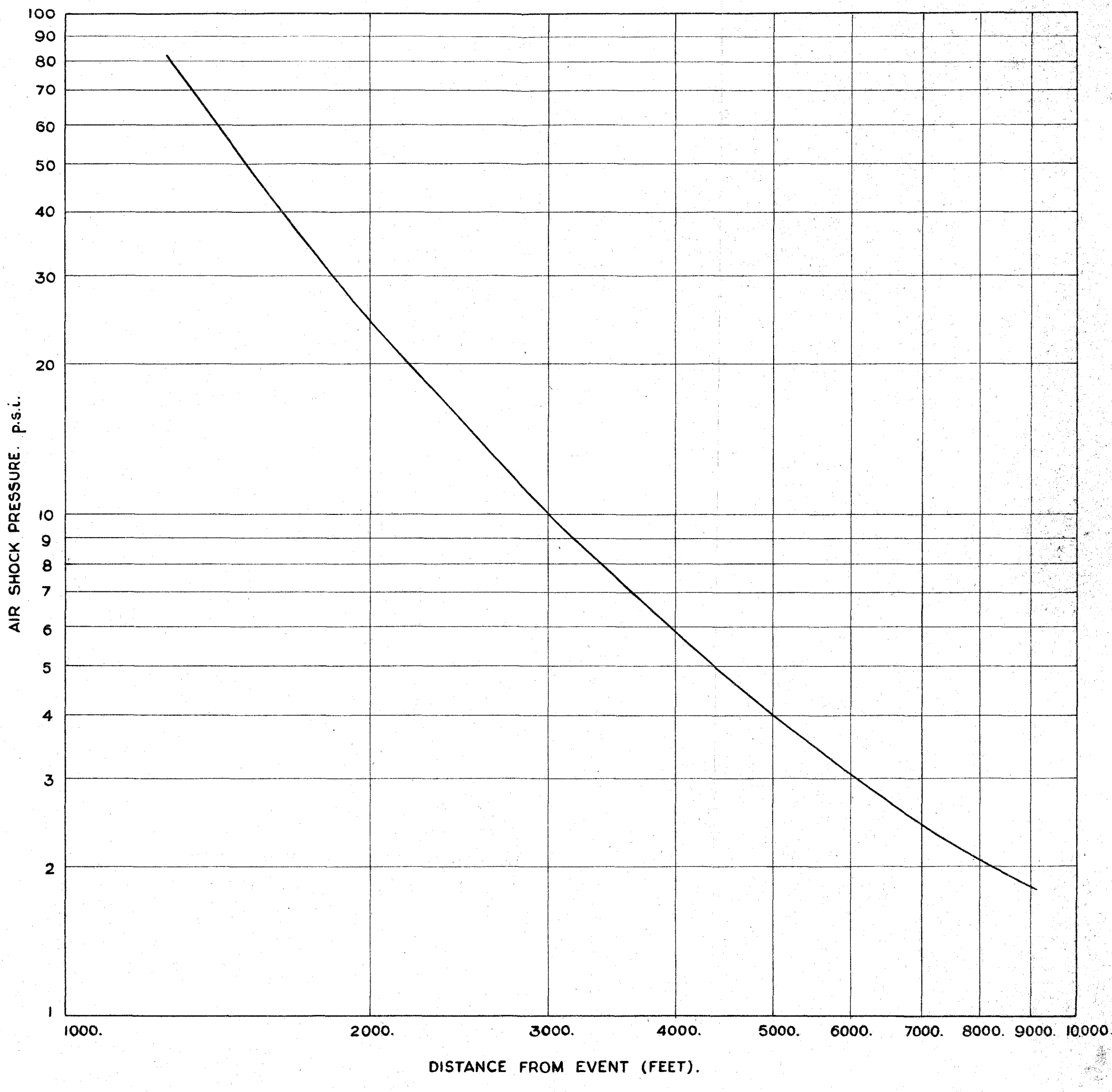

AIR SHOCK PRESSURE. p.s.i.
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
1000.
2000.
3000.
4000.
5000.
6000.
7000.
8000.
9000.
10,000.
DISTANCE FROM EVENT (FEET).

FIG. 2.

MAXIMUM ACCELERATION — DISTANCE.

PEAK TO PEAK DISPLACEMENTS.

UPWARDS

DOWNWARDS

OUTWARDS

INWARDS

UP and DOWN

Acceleration (g's)

100 10 1·0 0·1

100 10 1·0 0·1

10 1·0 0·1 0·01

10 1·0 0·1 0·01

1,000 5,000

Distance (ft.)

Peak to peak Displacement (ins)

1·0 0·3 0·1

1,000 5,000

Distance (ft.)
IN and OUT

1·0 0·5 0·1

Peak to peak Displacement (ins.)

1,000 5,000

Distance (ft.)

FIG. 3.

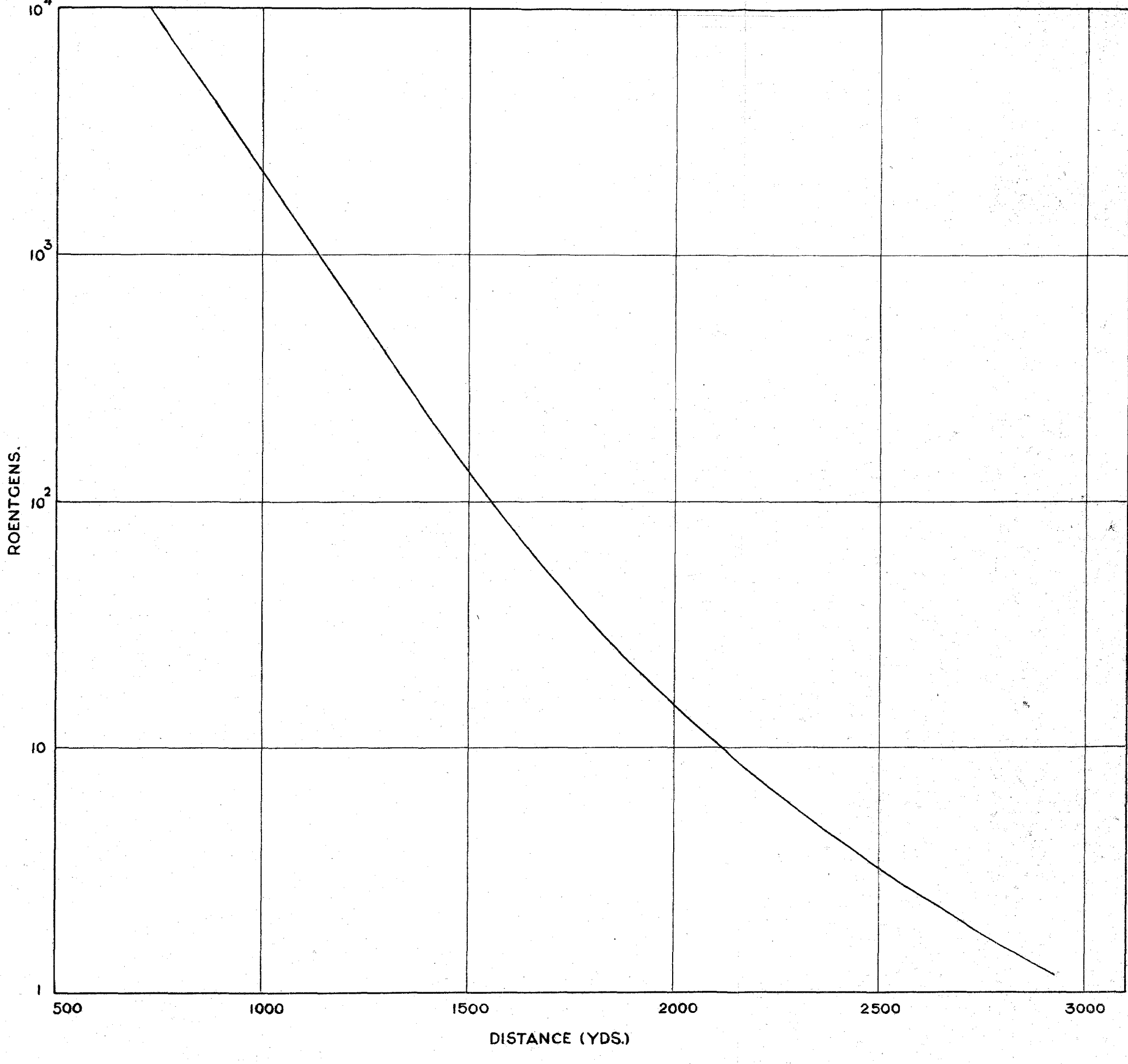

ROENTGENS.
10^4
10^3
10^2
10
1
500
1000
1500
2000
2500
3000
DISTANCE (YDS.)

FIG. 4.