[redacted] UK UNCLASSIFIED

Downgraded 1 April 1984. YMA

T 45/54

[redacted] C

COPY No. 82
38 PAGES

Record Copy.

REGRADED BY AWRE ON 5 MAY 1961
FROM S/A/G
TO CONF.

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

ATOMIC WEAPONS RESEARCH ESTABLISHMENT

TOTEM - Nuclear Radiation Measurements.

REPORT No. T 45/54

R02690

B 0135

[redacted] CONFIDENTIAL

THIS DOCUMENT IS THE PROPERTY OF U.K. ATOMIC ENERGY AUTHORITY, and is intended only for the personal information of

Title Copy.

and of those officers under him whose duties it affects. He is personally responsible for its safe custody and that its contents are disclosed to those officers and to them only.
The document will be kept in a locked safe when not in actual use.

[redacted]

UK UNCLASSIFIED

[redacted] SECRET

A.W.R.E.
Aldermaston, Berks.

January, 1955

THIS DOCUMENT IS THE PROPERTY OF THE U.K. ATOMIC ENERGY AUTHORITY
AND ATTENTION IS CALLED TO THE PENALTIES ATTACHING
TO ANY INFRINGEMENT OF THE OFFICIAL SECRETS ACTS

It is intended for the use of the recipient only, and for communication to such officers under him as may require to be acquainted with its contents in the course of their duties. The officers exercising this power of communication are responsible that such information is imparted with due caution and reserve.

Any person other than the authorised holder, upon obtaining possession of this document, by finding or otherwise, should forward it together with his name and address in a closed envelope to:-

THE DIRECTOR, ATOMIC WEAPONS RESEARCH ESTABLISHMENT
ALDERMASTON, BERKSHIRE.

Letter postage need not be Prepaid, other postage will be refunded. All persons are hereby warned that the unauthorised retention or destruction of this document is an offence against the Official Secrets Acts.

[redacted]

United Kingdom Atomic Energy Authority

ATOMIC WEAPONS RESEARCH ESTABLISHMENT

OPERATION TOTEM - GROUP REPORT
GROUP 8 RADIOLOGICAL HAZARDS AND MEASUREMENTS

REPORT NO. T45/54

Preliminary Report on Nuclear Radiation Measurements by RH Group at Operation TOTEM

Lt. Col. K. Stewart, R.E.

Summary

The RH Group measurements are summarised.

Curves for the variation with time and distance of the dose-rate due to the initial radiation are presented. The fall-outs are mapped and dose rate decay curves given. The radiobiological, decontamination, radiac, and nuclear instrumentation work is indicated. Health Control is the subject of a separate report. There are six tables and seventeen figures.

Approved for publication on 7th September, 1954

Initial Distribution

Internal

No.	1	DAWRE, Sir William Penney
	2	DDAWRE/FH, Dr. A. H. Davis
	3	CS(S), Mr. C. A. Adams
	4	SSMD, Mr. G. L. Hopkin
	5	SSPD, Dr. J. Corner
	6	SSRD, Mr. A. R. Greatbatch
	7	SST and ED, Mr. R. Pilgrim
	8	DSSM, Dr. D. T. Lewis
	9	DSSR, Dr. J. A. T. Dawson
	10	SC/EM, Mr. P. A. White
	11	SH/PR, Mr. D. E. Barnes
	12	SPT, Mr. J. T. Tomblin
	13	SDP, Dr. H. H. M. Pike
	14	SWP, Mr. E. P. Hicks
	15	RAF/AWRE, G/Cpt. J. R. MacLachlan

External

No.	16-17	Director of Physical Research, Admiralty. (Mr. C. A. Luxford)
	18-20	Scientific Adviser to the Army Council, War Office. (Mr. H. A. Sargeaunt)
	21	Deputy Scientific Adviser, Air Ministry. (Dr. B. G. Dickins)
	22-28	Chief Scientific Adviser, Home Office. (Dr. R. H. Purcell)
	29	Controller of Atomic Weapons, Ministry of Supply. (Lt.Gen. Sir Frederick Morgan)
	30	Director of Atomic Energy Research Establishment. (Sir John Cockcroft)
	31	Dr. J. H. Loutit, D.R.M.U., M.R.C., A.E.R.E.

This report should be returned to Chief Information Officer, AWRE, Aldermaston, Berkshire, when the recipient has no further use for it.

Table of Contents

		Page
List of Tables		4
List of Figures		4
1.	Introduction	5
	Part I. Totem 1	5
2.	Initial Gamma Radiation	5
	2.1 Air-Dose - Distance Relationship	5
	2.2 Reduction in Dose by Shielding	7
	2.3 Angular Distribution of Radiation	8
	2.4 Spectral Intensity of Radiation	9
	2.5 Radiation Intensity - Time Relationship	9
3.	Radioactive Material	9
	3.1 Radio-active Survey	9
	3.2 Gamma Dose-Rate Decay	10
	3.3 Beta-Gamma Dose-Rate Ratio	10
	3.4 Examination of Radio-active Deposit	10
	3.5 Airborne Activity	11
	Part II. Totem 2	12
4.	Initial Gamma Radiation	12
	4.1 Air-Dose - Distance Relationship	12
	4.2 Angular Distribution of Radiation	12
	4.3 Spectral Intensity of Radiation	12
	4.4 Radiation Intensity - Time Relationship	12
5.	Radioactive Material	12
	5.1 Fall-Out Survey	12
	5.2 Gamma Dose-Rate Decay	13
	5.3 Beta-Gamma Dose-Rate Ratio	13
	Part III. Miscellaneous Topics	14
6.	Radio-Biological Measurements	14
7.	Decontamination Techniques	14
8.	Radiac Instruments	14
9.	Nuclear Instrumentation	14
	9.1 General	14
	9.2 Counting Equipment	14
	9.3 Air Monitors	15
	9.4 Personnel Monitors	15
	9.5 Miscellaneous Instruments	15
10.	Induced Radio-activity in Water and Petrol	16
	Part IV. General Conclusions	17
11.	Organisation	17
12.	Site Lay-Out	17
13.	Experimental Results	17
	13.1 Initial Nuclear Radiations	17
	13.2 Residual Radio-activity	17
	Appendix A - Personal Responsible for RH Group Tasks	18

List of Tables

			Page
Table	I	Variation of Dose with Height at 5,100 ft. Distance	7
Table	II	Doses in Vicinity of Concrete Cubicles and Slabs	8
Table	III	Doses in Steel Box/Centurion Tank	8
Table	IV	Beta/Gamma Dose-Rate Measurements (Totem 1)	10
Table	V	Beta/Gamma Dose-Rate Measurements (Totem 2)	13
Table	VI	Nuclear Instruments Used by Field Personnel	16

List of Figures

Figure	1	Gamma Air Dose - Distance Relationship (Totem 1)	22
Figure	2	Gamma Air Dose - Results of Different Measurement Systems (Totem 1)	23
Figure	3	Reduction Factors for Concrete Shelters and Slabs (Totem 1)	24
Figure	4	Angular Distribution of Gamma Radiation (Totem 1)	25
Figure	5	Gamma Dose Measurements with Phosphate Glass Dosimeters (Totem 1)	26
Figure	6	Transmission of Radiation by Steel and Lead (Totem 1)	27
Figure	7	Gamma Dose Rate - Time Curve (Totem 1)	28
Figure	8	Time - Fraction of Dose Delivered in 1 Second (Totem 1)	29
Figure	9	Survey of Residual Contamination (Totem 1)	30
Figure	10	Decay of Gamma Dose Rate with Time (Totem 1)	31
Figure	11	Gamma Air Dose Distance Relationship (Totem 2)	32
Figure	12	Angular Distribution of Gamma Radiation (Totem 2)	33
Figure	13	Gamma Dose Measurements with Phosphate Glass Dosimeters (Totem 2)	34
Figure	14	Transmission of Radiation by Steel and Lead (Totem 2)	35
Figure	15	Integrated Dose - Time Curves (Totem 1 and 2)	36
Figure	16	Survey of Residual Contamination (Totem 2)	37
Figure	17	Decay of Gamma Dose Rate with Time (Totem 2)	38

[redacted]

[redacted]

1. Introduction

1.1 At an atomic weapon trial the experimental observations made have to satisfy a variety of needs. During Totem the objects of the measurements carried out by the RH Group were:

(a) To obtain a body of reliable empirical data as to initial gamma radiation and deposition of radio-active material.

(b) To obtain quickly sufficient information to permit further operations on the site under agreed conditions of radiation safety.

The primary experimental premise was that all observations were to be made with the greatest accuracy obtainable. This posed many problems and necessitated a considerable calibration programme which is not yet complete but has shown itself to be essential. In certain cases, because the method of measurement was on trial and comparison between methods might help determine the characteristics of a particular device, a number of devices were used to determine the same parameter.

1.2 In this preliminary report it is not intended to describe in detail the experimental methods used nor the layout of the ground. These matters together with the detailed analysis of the results and comparisons with theory will be given in the reports prepared by teams concerned.

1.3 The tasks undertaken and those responsible are listed at Appendix A.

Part I. Totem 1

2. Initial Gamma Radiation

2.1 Air-Dose - Distance Relationship

2.1.1 This was determined by means of films and phosphate glass, potassium chloride crystal, quartz fibre and chemical dosimeters. The films, which had been specially prepared, calibrated and exposed so as to give a response as much as possible independent of the radiation energy, were the basic means of measuring the dose-distance relationship. The other devices were included for a number of reasons, viz:

(a) Doubts that a film, owing to its geometry, poor response at low energies, (i.e. < 70 kev), and perhaps unknown response above one Mev, gives a true measure of dose.

(b) Both the special glass and halide crystal are devices which might prove more satisfactory for the task in the future. On the empirical side their use as flash dosimeters is planned.

(c) One chemical device was tested because of its possible use as a dosimeter.

(d) The other chemical system used - the ferrous - ferric ion reaction - was introduced because the reaction is considered to be energy independent over a wide range (50 kev to several Mev) and is still quantitative at very high dose rates. It was however used only on a very limited scale.

(e) From the known energy responses of the several devices it seemed possible that some indication of the spectrum and the changes it undergoes with distance might be obtained.

2.1.2 For the period during which the larger fraction of the dose is received the elevation of the fireball/cloud as seen from the film stakes is low, so that it was of interest to compare the doses indicated by films vertical and facing the burst with those obtained with horizontal films. At distances beyond 3000 ft. the doses indicated by the vertical films were up to 25 per cent higher than those given by the horizontal ones. The difference disappears at distances within 3000 ft. The shape of the curve is markedly different from published American air-burst data. The results are shown in Figure 1.

2.1.3 The results obtained with the KCl crystals are in fair agreement with the films, whereas those obtained by the phosphate glass are, within their operating range, greater. The chemical dosimeter results are smaller than the film. (see Figure 2). No useful results were obtained with the Fe^{++}/Fe^{-++} ion system, essentially because of the rigors of the field trial, circumstances to which it had not been exposed previously.

2.1.4 The films were half enclosed in sheet tin, one mm. thick, to give a sensibly uniform response down to 70 kev; below this energy there is a sharp cut-off, so that if a considerable proportion of the radiation were below this value the film results would be low. The KCl crystals were also fitted with the filters (1.14 mm. thick): in some cases the filter was cylindrical with the ends left open and in others only a band about the middle was left uncovered. The absence of undue coloration at this central portion indicated that the very soft component was not significant,

2.1.5 The variation of dose with height was determined by exposing a number of films on the T2 tower, which was 5,100 ft. distant. The results are summarised in Table I. The film used was near its lower limit of density so that these results are not of high accuracy. Although the scatter among the individual results is considerable the air dose at the top of the tower seems to be about a quarter more than at the base.

Table I

Variation of Dose with Height at 5,100 ft. Distance

Height above ground (ft.)	Dose (r.)	Height above ground (ft.)	Dose (r.)
3	24	51	31
6	23	54	29
9	29	57	29
12	32	60	24
15	24	63	33
18	-	66	35
21	40	69	29
24	41	72	26
27	25	75	29
30	24	78	33
33	24	81	37
36	24	84	30
39	33	87	38
42	24	90	36
45	22	93	24
48	26	96	33

2.2 Reduction in Dose by Shielding

2.2.1 These experiments were designed to give useful practical answers and at the same time to have as far as possible a geometry which would permit theoretical study. The arrangements included shielding by earth, concrete and steel, and were:

(a) A series of slit trench/foxhole positions suitably oriented to the burst. The films were displayed in a suitable array to determine the variation with depth.

(b) A series of concrete slabs some set in an earth mound and some free (a Civil Defence requirement).

(c) A set of concrete cubicles (primarily a Ministry of Works structural test).

(d) A steel box representing a ship's compartment (A RNSS requirement). A cubical array of films was set up within the box.

(e) A Centurion tank. A War Office requirement.

2.2.2. The results obtained with shields of various kinds are summarised in Tables II and III and are plotted in Figure 3. The film badge was used to measure the dose in all cases.

Table II

Doses in Vicinity of Concrete Cubicles and Slabs

Distance (ft.)	Device	Free air or front surface dose (r.)	Dose within cubicle or behind shield (r.)
1,090	Cubicle*	2×10^6 (estimated)	>9,000
1,400	Cubicle*	5×10^4 (estimated)	>9,000
1,910	Cubicle*	8,330	3,000
1,800	Slabs 3 in.	12,500 (air)	2,550
	6	8,100	1,450
	9	(Surface)	1,005
	12		900
2,100	Slabs 3		2,005
	6	5,400 (air)	885
	9	3,600 (surface)	440
	12		355
2,520	3	1,850 (air)	610
	6	2,000 (surface)	338
	9		163
	12 in.		97

Table III

Doses in Steel Box/Centurion Tank

Distance (ft.)	Device	Free air-dose (r.)	Dose at stated position inside (r.)
1,050	Tank	10^5 (estimated)	Driver 6,000 Gunner 6,400 Loader 4,130 Behind glacis plate (3 in. thick) 7,400
3,300	Steel Box, 8ft. cube, $\frac{1}{2}$ in. thick.	300	Overall average 122 Cube Centre 140 Centre front face (6 in. in) 167 Centre rear face (6 in. in) 127

2.3 Angular Distribution of Radiation

2.3.1 This was an RNSS experiment employing specially designed multichannel collimators and dosimeters of various types mounted on lead

*Front and Roof Thicknesses - 3 or 4 in.
Sides and Back - 1 to 3 in.
Concrete Density - 2.32 or 2.72 g./c.c.

blocks. The collimator results are shown in Figure 4.

There are two points of interest. The indirect component of the radiation decreases with increasing distance. This is the reverse of the result obtained with a small monochromatic source. This effect is supported by the results from other trials. At glancing angles to the ground the intensity shows an increase in all directions. This is probably due to scatter from the ground.

2.3.2 The doses at the front, top, side and rear faces of 6 in. lead cubes mounted at a height of 5 ft. were measured. The doses on the front face and top of the cube were substantially the same as the free air dose. The readings at the sides were equal. At the shorter distances the dose was only about half the free air dose, but the deficiency became less as the distance increased. The dose behind the block was of the order of 10 per cent of the free air dose. (See Figure 5)

2.3.3 The glass dosimeters exposed to measure the total air dose were covered with a 1.27 mm. thick lead filter in which a hole equivalent to 10 per cent of the surface area was left uncovered to avoid complete removal of the soft component. The doses were generally about 50 per cent greater than those measured by film. In addition a comparison was made between filtered and unfiltered glass dosimeters located on the top and to the rear of the lead blocks. These results are also summarised in Figure 5. From the known response of the filtered glass it may prove possible to estimate the changes in the overall quantity of the radiation and in the back-scattered radiation with distance.

2.4 Spectral Intensity of Radiation

The method was to determine the dose measured by an ion chamber or a film, within a spherical shell of known thickness. As an attempt to determine the effective energy of the radiation for comparison with theoretical shielding calculations, the dose was measured inside lead and steel shells by means of small air wall ion chambers. The results are shown in Figure 6. The enhancement of the dose by thin layers of lead or steel suggests the presence of hard radiation.

2.5 Radiation Intensity - Time Relationship

2.5.1 The variation of dose-rate of the flash gamma radiation from a few microseconds to one second shows the rate at which the dose is delivered.

2.5.2 Measurement was at only one distance, 2625 yd. The instrument consisted of a scintillator, amplifier and CRO display which was photographed. The results are shown in Figures 7 and 8. The recording time was only one second so that comparison with the total dose measured by a film badge is necessary to determine the overall rate of delivery of the dose. It is seen that about 60 per cent of the total dose is received in 0.1 sec.

2.5.3 The dose-rate time curve (Figure 7) exhibits a bump in the region of 10-200 msec. If the other sections of the curve are connected smoothly together and the difference between the curves plotted against time, this component is found to have a half-life of about 33 msec.

3. Radio-active Material

3.1 Radio-active Survey

A comprehensive survey of the gamma dose-rate was made to a distance of about 20 miles down wind to determine the degree of ground contamination.

Some beta dose rates were also measured. The results are shown in Figure 9. The pattern shows the effect of the very stable meteorological conditions at the time. Within a 200 yd. radius of the tower the ground surface presented a fused appearance. Over the first mile there were fused particles of earth and tower of widely varying shapes and sizes (aggregrates of and single pellets from several mm. in diameter downwards) which, contrary to expectation, tended to increase in average size with distance. Because of their variable specific activity and generally brownish appearance it seems most likely that the particles were formed from liquified earth rather than by condensation. Beyond a mile the deposit was finer and less easy to distinguish on the ground.

3.2 Gamma Dose-Rate Decay

A special recording dose-rate meter was developed for this measurement. In Totem 1 the equipment was not sited until H plus 7½ hr. from which time reliable records were obtained. (In Totem 2 records were obtained from H plus 1 hr.). The time of arrival, build-up and decay of the fall-out activity prior to H plus 1 hr. was also observed at various distances and the decay relationship from arrival time onwards deduced. The overall decay to any time was somewhat greater than that corresponding to the well known relationship $D_t = D_1\ t^{-1.2}$ (See Figure 10).

3.3 Beta/Gamma Dose-Rate Ratio

Special instruments were developed and this ratio was determined at various times from one to 16 days after burst. The instruments comprised an ionisation chamber with a series of absorbers. The chamber was suspended one metre above the ground from a length of dexion and the amplifier and indicator units were placed some 12 ft. away. The results are summarised in Table IV.

Table IV

Beta/Gamma Dose-Rate Measurements

Time (days)	Beta/Gamma Ratio		Remarks
	Observed	Calculated	
1.4	10	8	Smooth Claypan
3.2	4.7	6	
16.2	1.2	3.5	Crater

3.4 Examination of Radio-active Deposit:

3.4.1 An examination was made of radio-active material from the crater and fall-out zones from two aspects.

(a) The distinction between fission products, or more precisely bomb debris, and neutron induced activity in the crater area.

(b) The identification of the high energy beta and gamma emission at very early times after burst.

3.4.2 It was found that the active material could be divided relatively easily into two classes: that which had been fused and that which had not. The former decayed in the way fission products would be expected

to decay, whereas the latter decayed with a half-life corresponding to Si^{31}. The decay of only one such fragment (SiO_2), collected about 1,000 ft. from ground zero was followed.

3.4.3 A number of the more nearly spherical pellets of material which had undergone fission were examined to determine whether or not there was any size-activity relationship. None was found.

3.4.4 The laboratory examination of several samples of activity was attempted. The beta spectrometer proved to be a most useful tool. Thus the 3.5 Mev beta of Sr^{92} was identified, both in a fall-out fragment and in a chemically separated specimen.

3.5 Airborne Activity

Air sampling was done above, and downwind from, contaminated areas to determine the degree of air-borne activity. Samples were taken both statically and from a moving land-rover. In general the static samples showed very little activity with hardly any correlation to gamma dose-rate. Samples collected near the tailboard of the moving landrover were found to be more hazardous, with levels up to 3 times the maximum permitted level.

Part II. Totem 2

4. Initial Gamma Radiation

4.1 Air-Dose - Distance Relationship

4.1.1 The results for Totem 2, shown in Figure 11 and are very similar to those for Totem 1 (cf Figure 1.). At the nearer distances (2,000 ft.) the dose from Totem 1 was about 10 per cent greater than for Totem 2 and at greater distances (8,000 ft.) about the same amount smaller. At the intermediate distances the results were practically identical.

4.1.2 In contrast to the Totem 1 results, those from Totem 2 with the KCl crystals were about 80 per cent higher than those obtained with the films. Glass and chemical dosimeters were not used. The ferrous-ferric system was tried but was again unsuccessful.

4.1.3 A number of a special type of high range quartz fibre dosimeters incorporating evacuated chambers were placed at two positions and gave self-consistent results which are in close agreement with those of the KCl crystals.

4.2 Angular Distribution of Radiation

4.2.1 The results obtained with the collimators are shown in Figure 12 and are in good agreement with those of Totem 1.

4.2.2 An experiment was made with 6 in. lead cubes, this time at a height of 2 ft. Films were placed above and on the front and rear faces. The results confirm those of Totem 1. Glass cubes were placed above and behind the blocks. The results are shown in Figure 13, and show some difference, which may prove to be significant, from Totem 1 results.

4.3 Spectral Intensity of Radiation

The results of further experiments with steel and lead shells over a range of distances from 750 to 3,000 yd. are shown in Figure 14. The Totem 2 results are similar to those of Totem 1 except that at 3,000 yd. there is rather less enhancement.

4.4 Radiation Intensity - Time Relationship

The radiation intensity-time records were of exactly the same shape over the period 60 μsec. to 1 sec., but the dose delivered in that time was only 0.43 r. for Totem 2 compared with 0.58 r. for Totem 1. The arrangement for the measurement was the same as for Totem 1 and at the same distance of 2,625 yd. The total dose measured by films at the site was 0.75 r. for Totem 2 and 0.69 r. for Totem 1. The ratio : $\frac{\text{Integrated dose}}{\text{Total Dose}}$ is plotted as a function of time in Figure 15.

5. Radio-active Material

5.1 Fall-Out Survey

The fall-out plot is shown in Figure 16. For Totem 2 meteorological conditions with high humidity and high turbulence were quite different from those for Totem 1 and it can be seen by comparison with Figure 9, that this has resulted in much greater dispersion of the activity. Within a given dose-rate contour the amount deposited for Totem 2 was only a quarter of that for Totem 1.

5.2 Gamma Dose-Rate Decay

For Totem 2 it was found possible to site the instruments within 1 hr. of the explosion so that a complete overlap with the pre-sited fall-out instruments was obtained. The observed decay of gamma dose-rate with time was (within experimental error) identical with that for Totem 1. (See Figure 17 and cf. Figure 10).

5.3 Beta/Gamma Dose Rate Ratio

The beta/gamma ratio was again measured and results are shown in Table V.

Table V

Beta/Gamma Dose-Rate Measurements

Time (days)	Beta/Gamma Ratio		Remarks
	Observed	Calculated	
0.05	9.3	19	Claypan
0.22	15	14	Rough
1.04	10	12	Ground
4.2	4.8	5	

Part III. Miscellaneous Topics

6. Radio Biological Measurements

Two wild animals (a rabbit and a turkey chick) were shot locally in the fall-out region on D + 8 and assayed in the U.K. on D + 35. The radio-activity absorbed suggests that a dose of 1 rad or less had been received. Fission products from the cloud and from fall-out material were flown back to the Radiobiological Research Unit of the Medical Research Council at AERE and were there fed to experimental animals. The main hazards were to the thyroid and bone. The laboratory assay is being integrated with the existing long-term research programme.

7. Decontamination Techniques

Samples of building material, paints and varnishes, fabrics and preservatives were exposed to contamination with a view to investigating both fundamental and applied properties. 4 in. square samples were standardised and to facilitate counting a special lead castle with in-built collimation was devised. In the event dust contamination was limited to spherical fall-out particles of 0.2 to 1 mm. diameter, and decontamination down to tolerance level was usually effected by merely inverting the sample tray. Further exposure was therefore contrived by carrying samples in a vehicle driven through the active area. It may be concluded that although spherical fall-out particles would be difficult to remove from soil and rough ground, streets would be readily decontaminable by merely hosing down and brushing. Of the fabrics, nylon and terylene acquired only a quarter of the activity attracted to cotton twill and a half of that on acetate twill.

8. Radiac Instruments

Field trials were made of a variety of prototye radiac instruments. In general the instruments stood up well to field conditions; there was however a wide variation in the response of the different types and it is not yet possible to say which are the best. Three types of dosimeters were tested (cf. Section 2.1): phosphate glass cubes, treated KCl crystals and a chemical system consisting of a blue solution of formazon dye in carbon tetrachloride. In all cases the specimens were filtered such that about 10 per cent of their surface area was left exposed. This partially corrected for excessive absorption by the filter in the lower energy range (< 70 kev). The results were self consistent, but distinct differences were shown between the several types. It seems probable that this is a high energy effect and an investigation of irradiation at energies up to 15 Mev is at present being made.

9. Nuclear Instrumentation

9.1 Rack-mounted counting and monitoring equipment was shipped out from the U.K. The rack bays were each fitted with six extractor fans to improve the air flow over the individual panel units. Most of the counting equipment was installed in an air conditioned Nissen hut whose internal temperature was kept below 110° Fahrenheit.

9.2 Counting Equipment

(a) Alpha counters: Scintillation type 1093; scalers type 1221; and counters type 1258.

(b) Beta counters: Geigers with 2 mg./cm^2. end windows, lead castles type 1065 and quenching probes type 1014; scalers type 1009 and 1221; timing units type 1003; power unit type 1007.

(c) Beta liquid counters: Liquid counters with M12 geiger; quenching probes type 1014; scalers type 1221; power unit type 1007.

(d) Gas-flow counter: Methane flow counter with amplifier type 1049; scalers type 1009 and 1221; timer type 1003.

9.3 Air Monitors

Continuous air monitoring for alpha and beta was required in only one building. The continuous recorder type 1296 was used. A 48 volt battery air sampler based on the standard Electrolux mains type sampler was used in the field.

9.4 Personnel Monitors

Six monitors type 1021 were used on site and a further three at Woomera. Two monitors type 1295 were used by the Laundry at Woomera. The hand and feet monitors type 1027 were installed adjacent to the decontamination showers. A Contamination meter type 1092 was used to supplement the type 1021 in the preliminary monitoring of personnel returning from the radio-active area. Experience showed that the alpha probes of the type 1021 and 1295 were too fragile for desert use. An alpha assay castle type 1258 used with a type 1021 proved useful and reliable.

9.5 Miscellaneous Instruments

Instruments were issued for personnel protection in the field, survey and record purposes. These instruments are listed in Table VI.

Table VI

Nuclear Instruments Used by Field Personnel

Serial	Type	Quantity	Purpose
1	1043 (Mod)	6	To measure dose-rates in region 0 - 16 mr./hr.
2	1092 D	20	Service trials as contamination monitor. Ranges: Mk.1 0-10 mr./hr. 2 0-50 mr./hr.
3	1244	12	Integrating dosimeter with alarm at 120 mr.
4	1295	6	Portable alpha, beta, gamma monitor based on 1021
5	1312	20	Gamma - Survey monitor based on 1155. Ranges: 1. 0-10 r./hr. × 1 × 100
6	1313	25	Gamma - Survey monitor based on 1193. Ranges: 0-50 mr./hr. × 1 × 10 × 100
7	1314	9	Beta - Survey monitor based on 1043. Ranges: 0-5 rep/hr. × 1 × 10
8	Air wall ion chamber	5	(a) Measurement of β/γ ratio (b) Standard for comparison with field monitors. Ranges : 0-0.1 r./hr. × 1 × 10 × 100

10. Induced Radio Activity in Water and Petrol

A programme of counting has been carried out on tray samples prepared from specimens of water and petrol irradiated in Totem 1 and in some cases the beta energy of the activity has been determined by absorption measurements. It is concluded that the long term active isotope present is probably S^{35}. Due to lack of data no estimate can be made of the short half-life activity. The health hazard due to drinking water exposed in the Centurion tank (cf. Section 2.2 1e) was found to be negligible on or after D + 18, on which day the counts were first made.

Part IV. General Conclusions

11. Organisation

The organisation of the group was generally satisfactory. A more logical breakdown would have been into four parts:-

(a) Initial nuclear radiation measurements.

(b) Residual radio-activity measurements.

(c) Nuclear control.

(d) Nuclear instrumentation.

In practice a straightforward sub-division of this kind was achieved to a large degree, but the co-ordination of experiments was sometimes a little difficult. Sharing of personnel between teams and with other groups (such as the Army Equipment Group) was not found to be satisfactory.

Shortage of transport and its unreliability was a major inconvenience.

12. Site Lay-Out

The lay-out of the site was generally satisfactory. Experience showed the need for dust-proof and improved laboratory conditions. The lack of well surfaced roads resulted in trouble from dust and caused considerable damage to equipment.

13. Experimental Results

13.1 Initial Nuclear Radiations

The film measurements of flash against distance gave a self-consistent curve for each explosion. The other dosimeters also gave self consistent curves but were not in agreement with the films nor with each other. These discrepancies which may be due to energy or geometrical considerations are being investigated.

The experiments on the effect of shields of theoretical and practical importance gave useful results, but their interpretation is influenced by the same factors. It is expected that some information will be gained about the energy distribution of the radiation.

Satisfactory intensity-time results were obtained down to 60 μ sec. after burst, but attempts to obtain earlier observations were unsuccessful.

A good indications of the directional distribution of the radiation was obtained.

13.2 Residual Radio-activity

Satisfactory plots of the fall-out contamination were obtained to a distance of 18 miles for Totem 1 and 5 miles for Totem 2. The plots were generally very similar but showed differences due to the widely different meteorological conditions. Mutually consistent curves for the gamma dose-rate decay were obtained from a few minutes after the burst up to 800 hr.

The β/γ ratio was measured satisfactorily at several times from 1 hr. to 16 days after the burst. The measured ratio agreed well with predicted values.

Appendix A

Personnel Responsible for RH Group Tasks

1. The following list shows the tasks undertaken by the RH Group at Operation TOTEM, 1953. Where appropriate the person responsible for co-ordinating a number of measurements is named. The staff concerned in each experiment are shown in alphabetical order after the person responsible for organising the experiment.

GROUP LEADER, RH GROUP - Lt. Col. K. Stewart, R.E. (AWRE).

INITIAL GAMMA RADIATION - G. C. Dale (SHP/AWRE).

2.1 Free Air Dose - Distance Relationship and processing of all film badges and dosimeters.

G. C. Dale	
R. F. Barnaby	(SHP/AWRE).
J. A. Carr	(SHP/AWRE).
C. B. Lax	(Home Office).
R. A. Siddons	(SSPD/AWRE).
J. H. Williams	(RNSS).

Measuring devices included films, phosphate glass cubes, KCl crystals, chemical dosimeters, high range quartz fibre dosimeters and ferrous-ferric ion solutions.

2.2 Shielding - for TOTEM 1 only

(a) Concrete Slabs - Provided by the Home Office.
C. B. Lax.

(b) Concrete Cubicles - Provided by Home Office/Ministry of Works.
G. C. Dale.

(c) Steel Ships Deckhouse - Provided by RNSS.
Dr. B. W. Soole (RNSS).
J. H. Williams.

(d) Centurion Tank - Provided by Army Equipment Group.
G. C. Dale.

(e) Military Earthworks - Provided by Army Equipment Group.
Major L. Cave, R.A.O.C. (War Office)
Major P. Crooke, R.E. (War Office)
R. A. Siddons.

2.3 Angular Distribution of Radiation

B. W. Soole.

(a) Steel Collimators.
B. W. Soole.

(b) Lead Blocks.
B. W. Soole.
J. H. Williams.

[redacted]

2.4 Spectral Intensity

(a) Totem 1
B. W. Soole.

(b) Totem 2

(i) Ranges of 3000 yd.
B. W. Soole.

(ii) Ranges less than 3000 yd.
L. Cave.
R. A. Siddons.

2.5 Radiation Time-Intensity Relationship

J. F. Hogg (AERE).

3. Residual Radiations

3.1 γ Dose Rate Decay

Capt. W. N. Saxby, R.E. (SHP/AWRE).

(a) 10 - 150 min.
Major W. T. M. Gaskell, R. Sigs. (SHP/AWRE).
J. F. Hogg.
R. Powell (AERE).
W/Cdr. J. Stewart, RAF. (War Office).

(b) 60 min. to 1,500 hr.
W. N. Saxby.
J. F. Hogg.
R. Powell.

3.2 Radiological Surveys

W. T. M. Gaskell.

Field Work

W. T. M. Gaskell.
L. Cave.
P. Crooke.
Capt. J. Gaylard, AMF (Australian Army).
Lt. C. L. Jenkinson, RAE (Australian Army).
S/Ldr. R. Noble, RAAF (Australian Air Board).
F/Lt. O. B. Parker, RAF (RAF/AWRE).
J. Stewart
G. de V. Stupart (SLT/AWRE).
S/Ldr. A. D. Thomas, RAAF (Australian Air Board).

Compilation of Maps

W. N. Saxby.

3.3 Ratio of Dose to γ Dose

R. A. Kendall (D.R.P. Canada and SHR/AWRE).

3.4 Examination of Radio-active Deposits

K. Stewart.
R. A. Kendall.

3.5 Airborne Activity

P. A. Carter (SHP/AWRE).
P. C. Gibbs (SSTD/AWRE).

3.6 Radiobiological Measurements

Dr. J. Loutit (Director, MRC, RBRU, AERE).

4. Decontamination Techniques

J. Austin (SC/EM/AWRE).
Dr. D. G. Stevenson (SC/EM/AWRE).

5. Test of Radiac Instruments

5.1 Initial Radiation

J. A. Carr.

5.2 Residual Radiation

J. F. Hogg.

6. Nuclear Instrument Servicing

R. J. Ellis (SHP/AWRE).
J. F. Hogg.
P. Jennison (SHP/AWRE).
R. Powell.
D. S. Rogers (SHP/AWRE).
R. F. White (SHP/AWRE).

Part Time

R. Cambray (AERE).
T. H. Storr (SHP/AWRE).

7. Induced Activity in Water and Petrol (Work in U.K. Only).

F/Lt. P. Clay,(RAF/AWRE and SHP/AWRE).

8. Health Control

K. Stewart.

8.1 (a) Health Controller.
K. Stewart.

(b) Assistant Health Controller.
W. N. Saxby.

(c) Medical Officer.
Maj. T. E. Field, RAMC (War Office).

(d) Clerical Officer.
R. H. Giles (SHP/AWRE).

8.2 Personnel Film Badges and Dosimeters

G. C. Dale.
G. F. Barnaby.
J. A. Carr.
C B. Lax.
R. A. Siddens.
J. H. Williams.

8.3 Decontamination

J. Austin.
D. G. Stevenson.
Lt. Col. Batchelor (Home Office/CD).
Capt. R. F. C. Butler, REME (War Office).

8.4 Health Physics Subsidiary Trials

J. A. Carr.

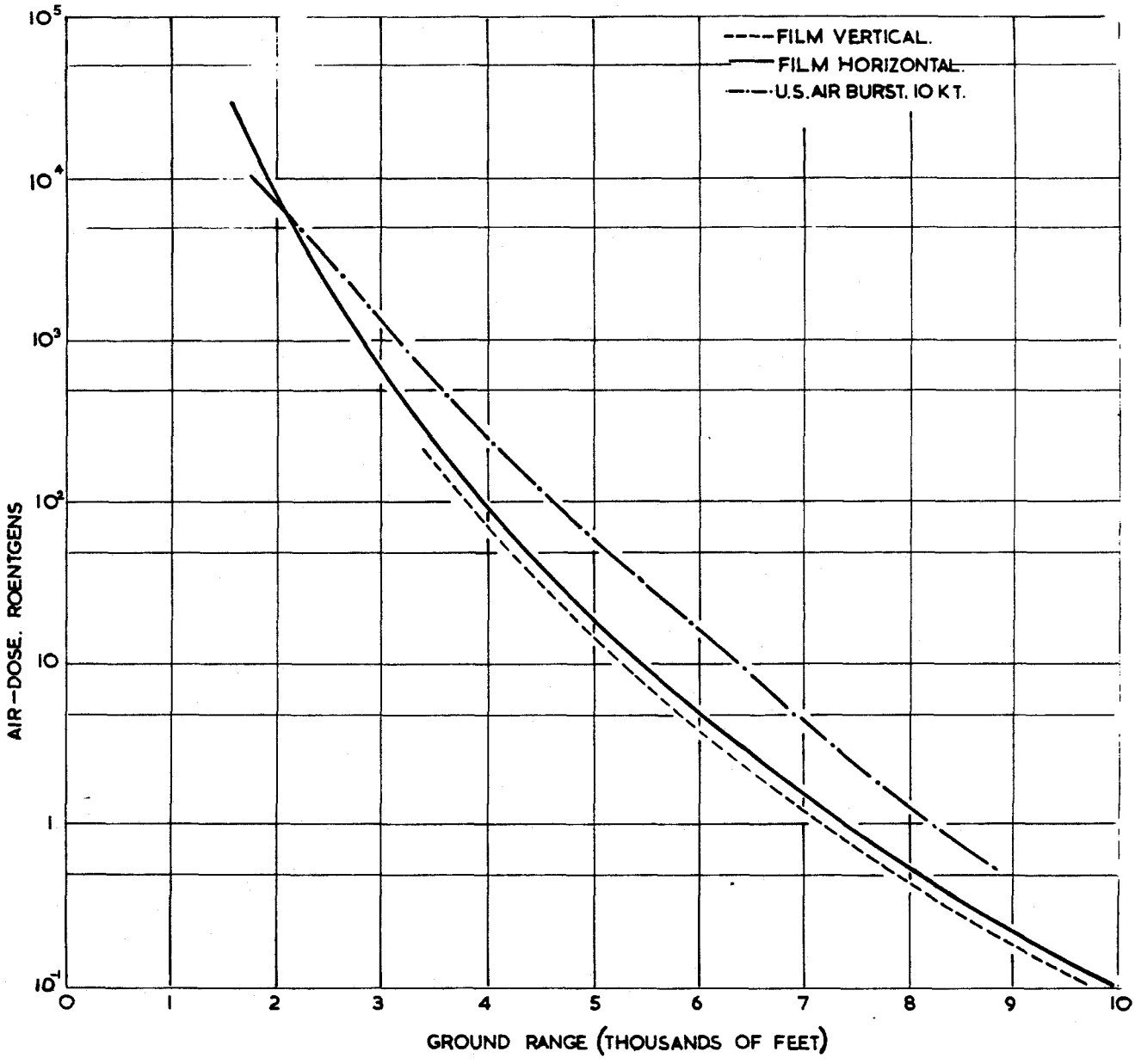


FIGURE I.

GAMMA AIR-DOSE-DISTANCE RELATIONSHIP. TOTEM I.

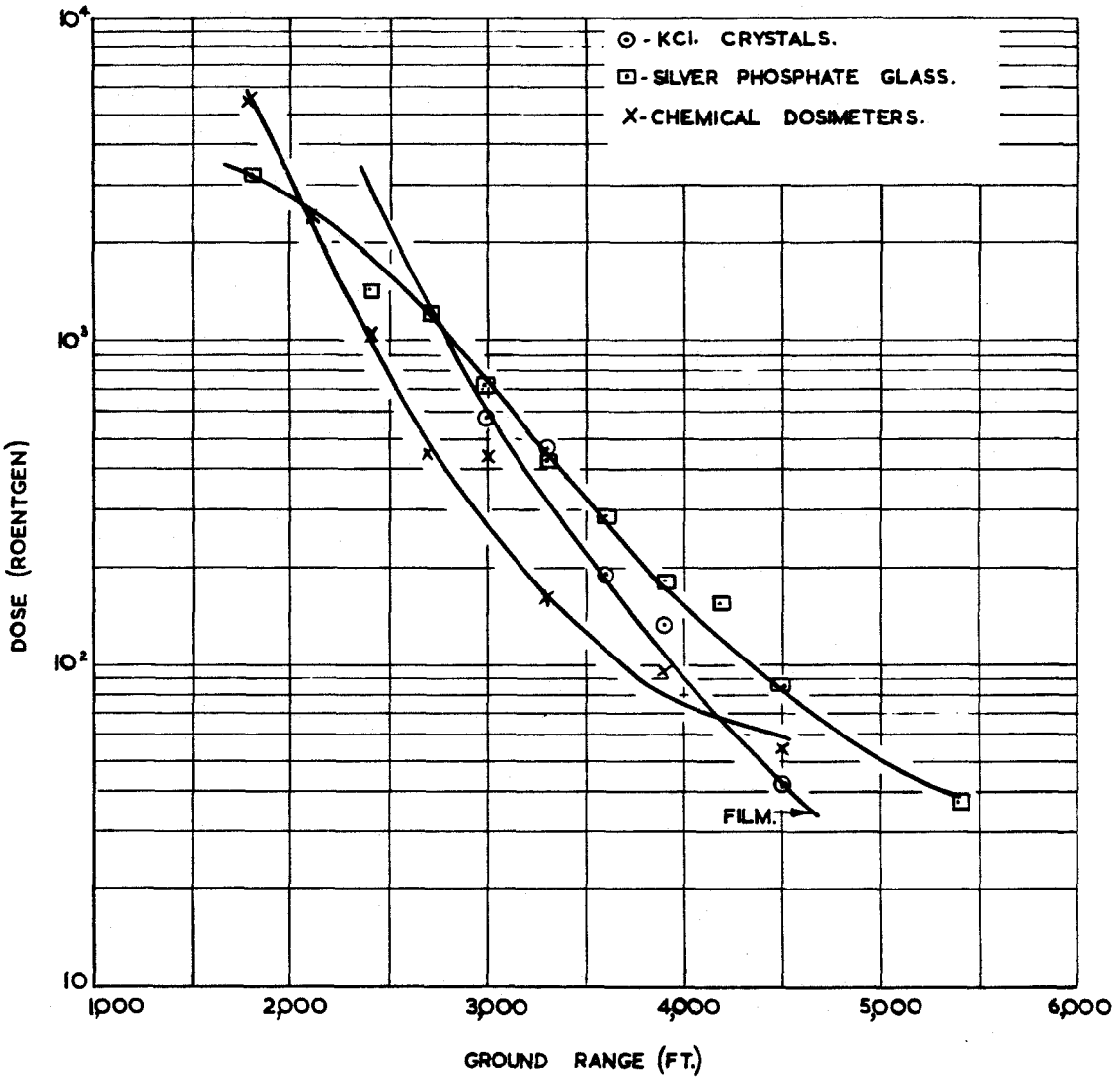


FIGURE 2.

GAMMA AIR-DOSE - RESULTS OF DIFFERENT MEASUREMENT SYSTEMS. TOTEM I.

[redacted]

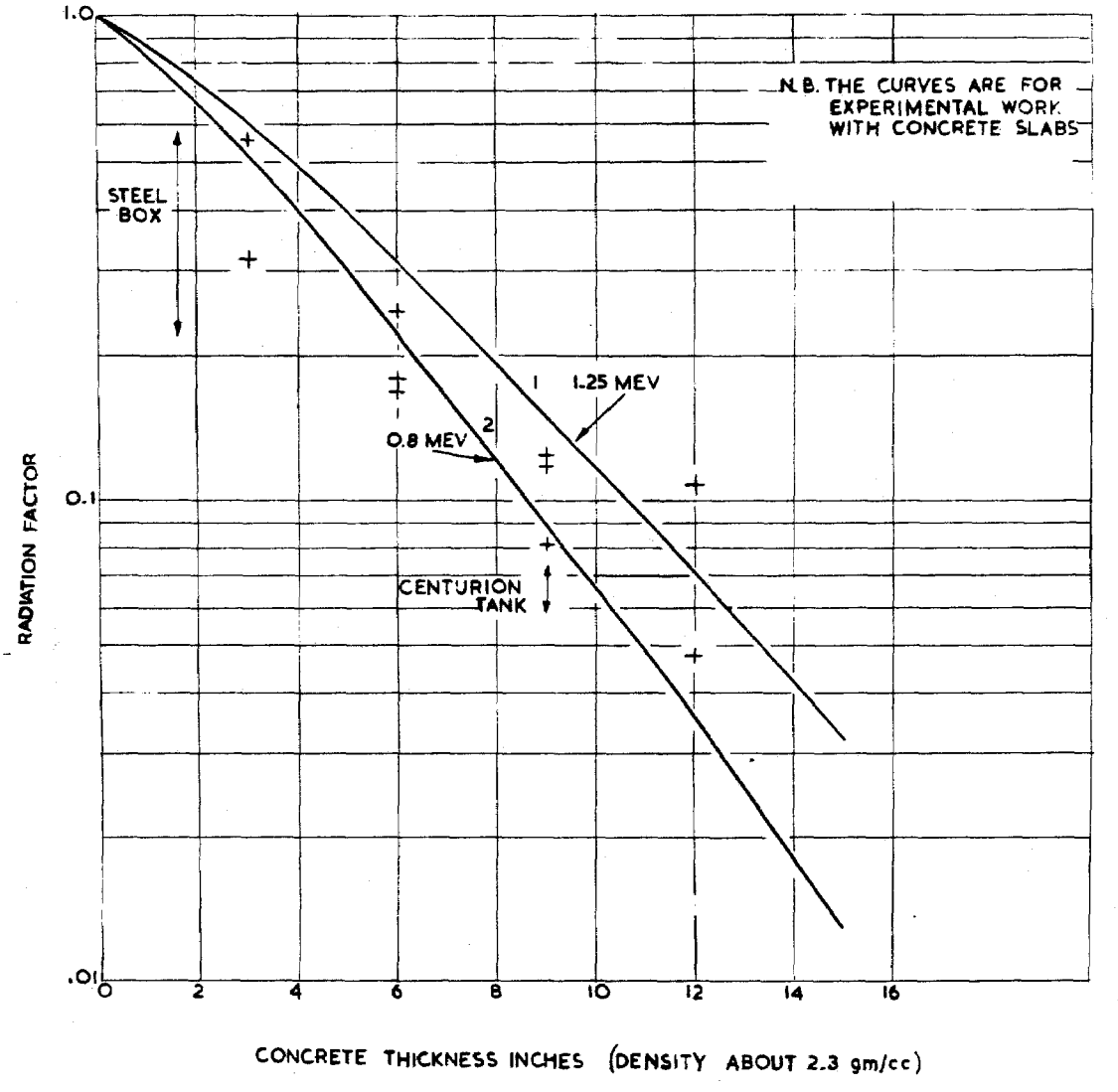


FIGURE 3.

REDUCTION FACTORS FOR CONCRETE SHELTERS AND SLABS

TOTEM. 1.

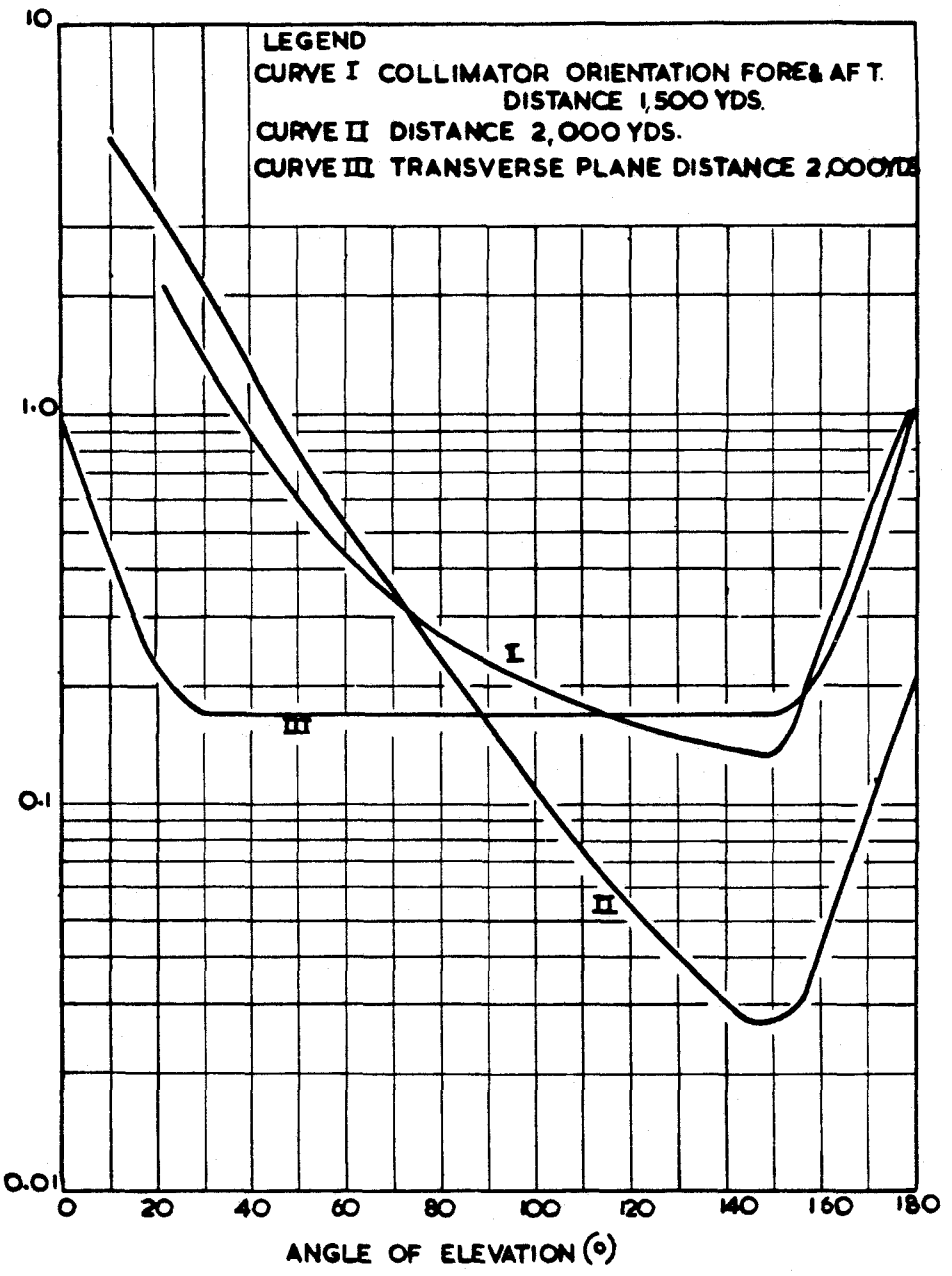


FIGURE 4.

ANGULAR DISTRIBUTION OF GAMMA RADIATION. TOTEM I.

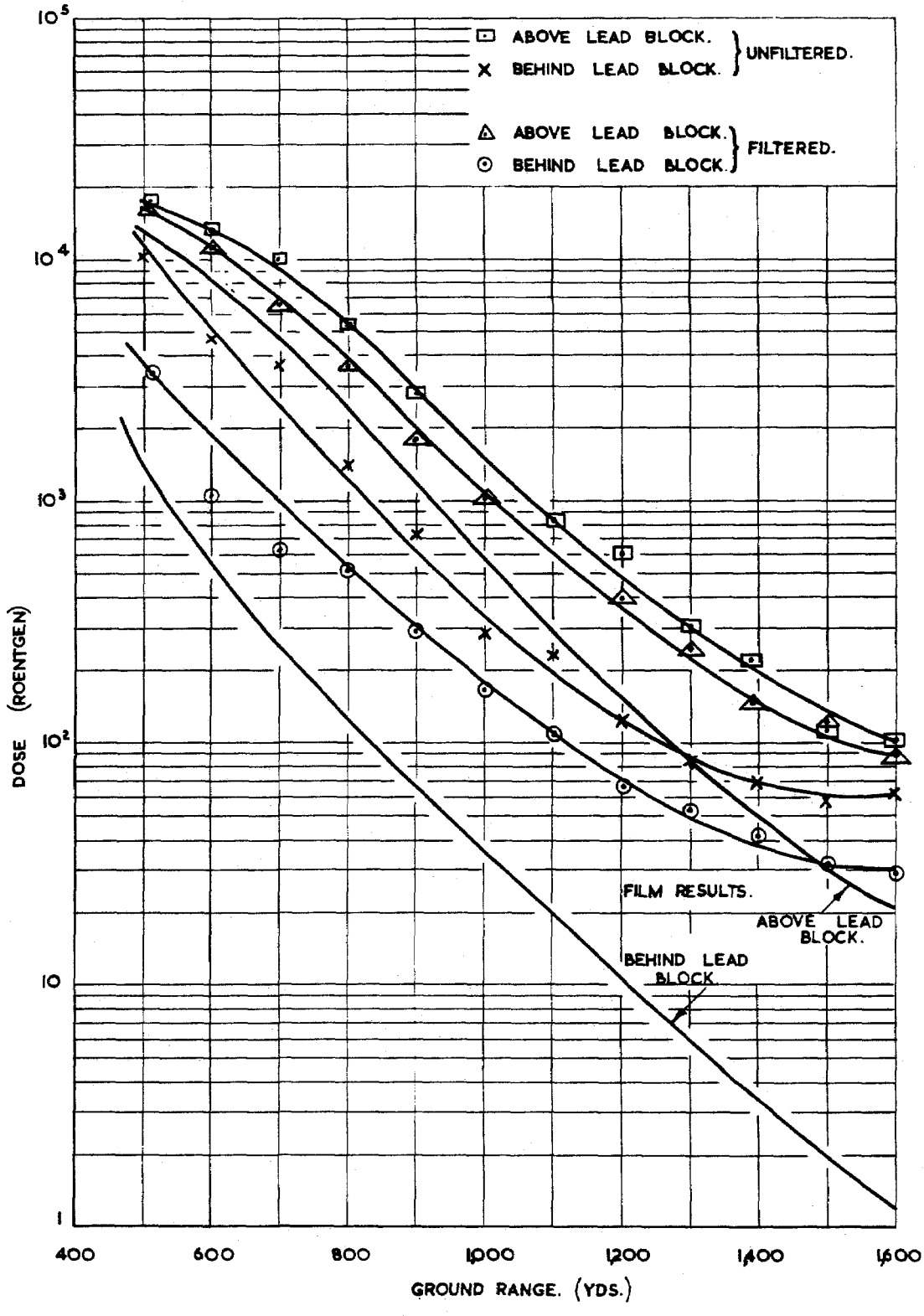


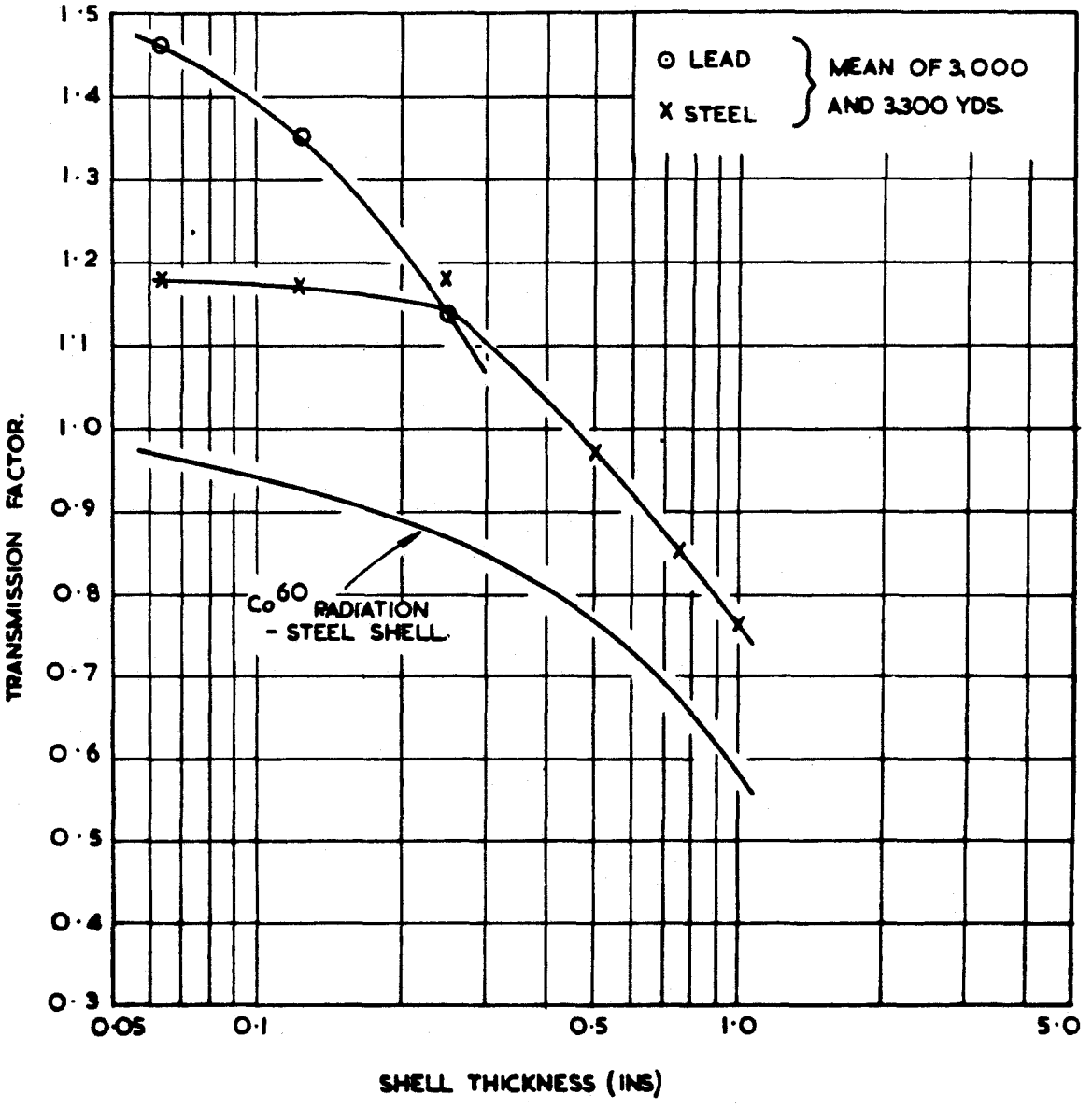
FIGURE 5.

GAMMA DOSE MEASUREMENTS WITH PHOSPHATE GLASS DOSIMETERS. TOTEM 1.

[redacted]

FIGURE 6.

TRANSMISSION OF RADIATION BY STEEL & LEAD TOTEM I.

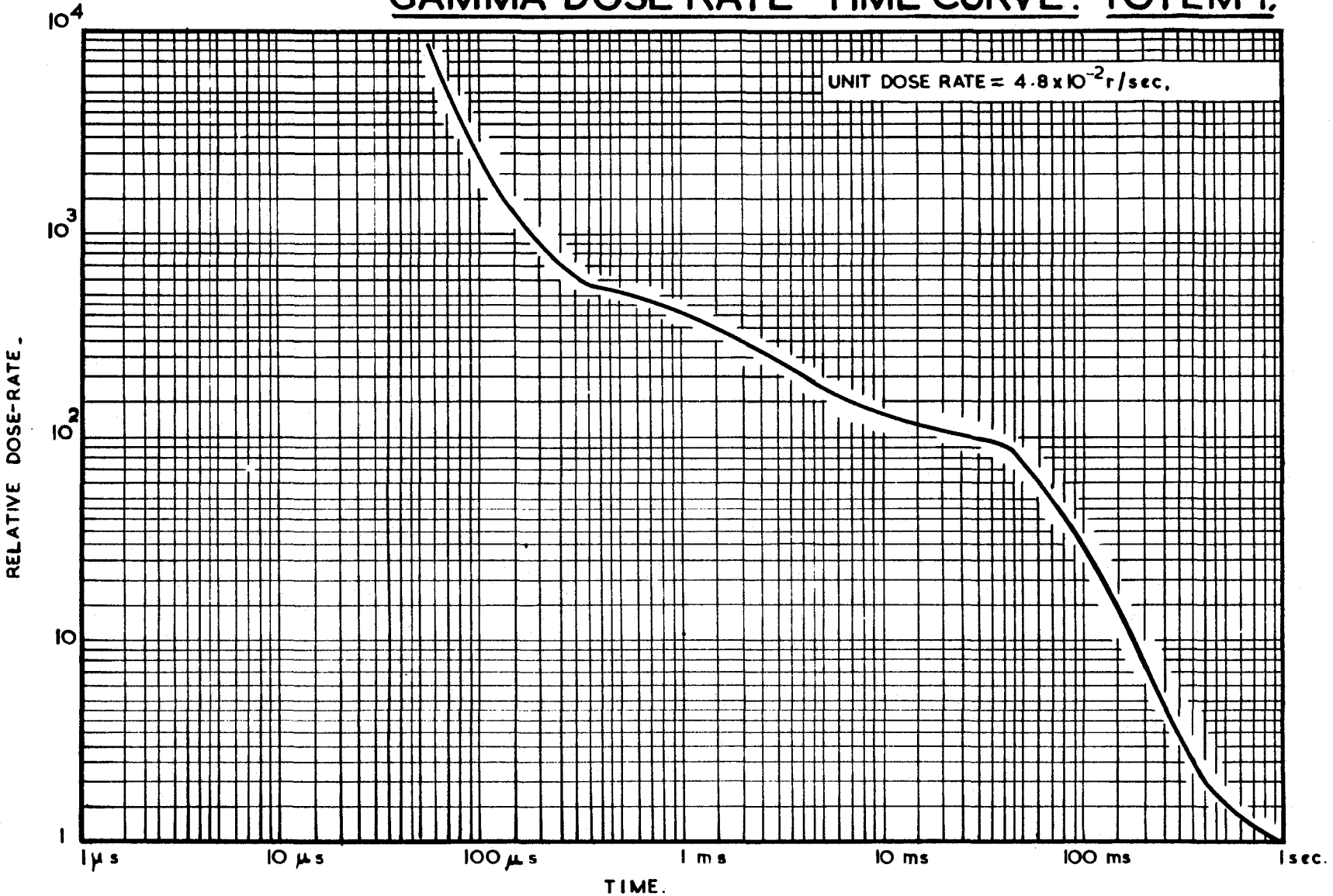


T45/54.

FIGURE 7.

[redacted]

GAMMA DOSE RATE - TIME CURVE. TOTEM I.



T45/54.

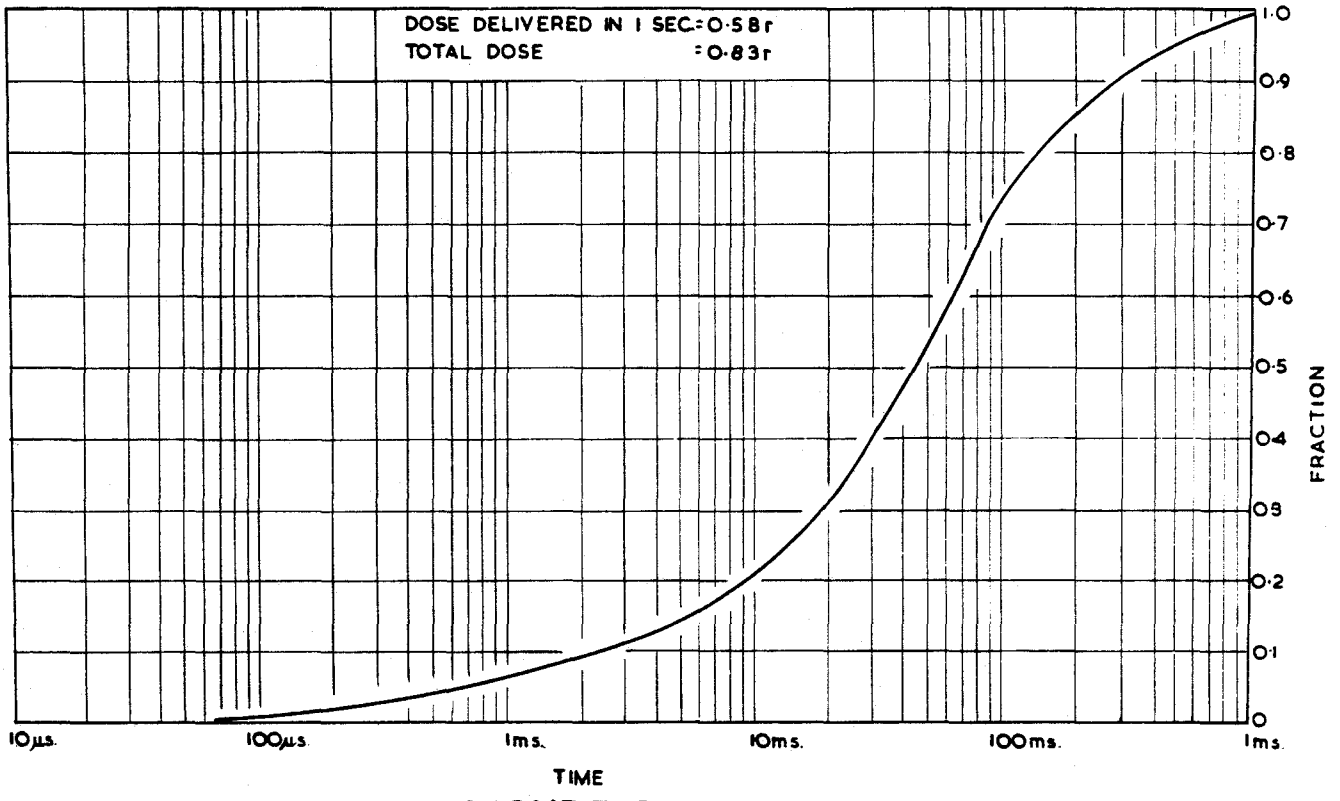


FIGURE 8.

TIME-FRACTION OF DOSE DELIVERED IN ONE SECOND TOTEM I.

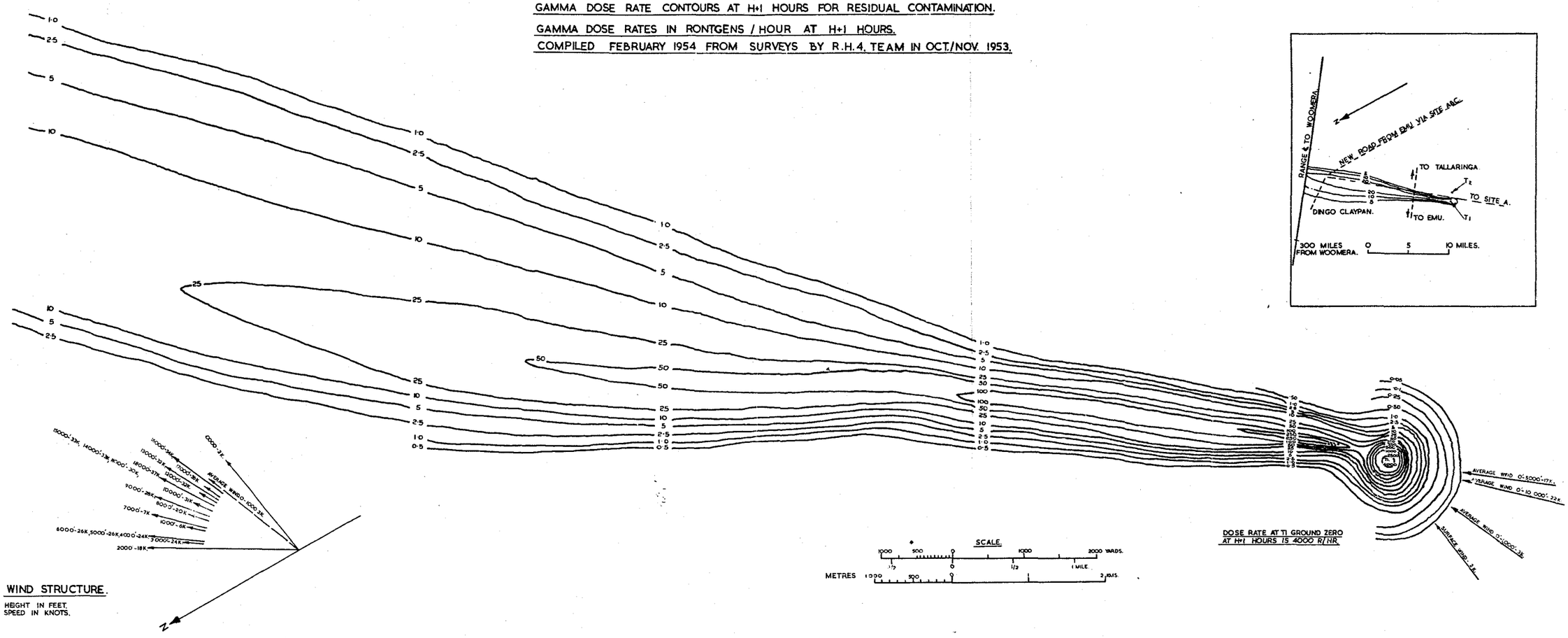
T45/54.

FIGURE 9.

SURVEY OF RESIDUAL CONTAMINATION. TOTEM I.

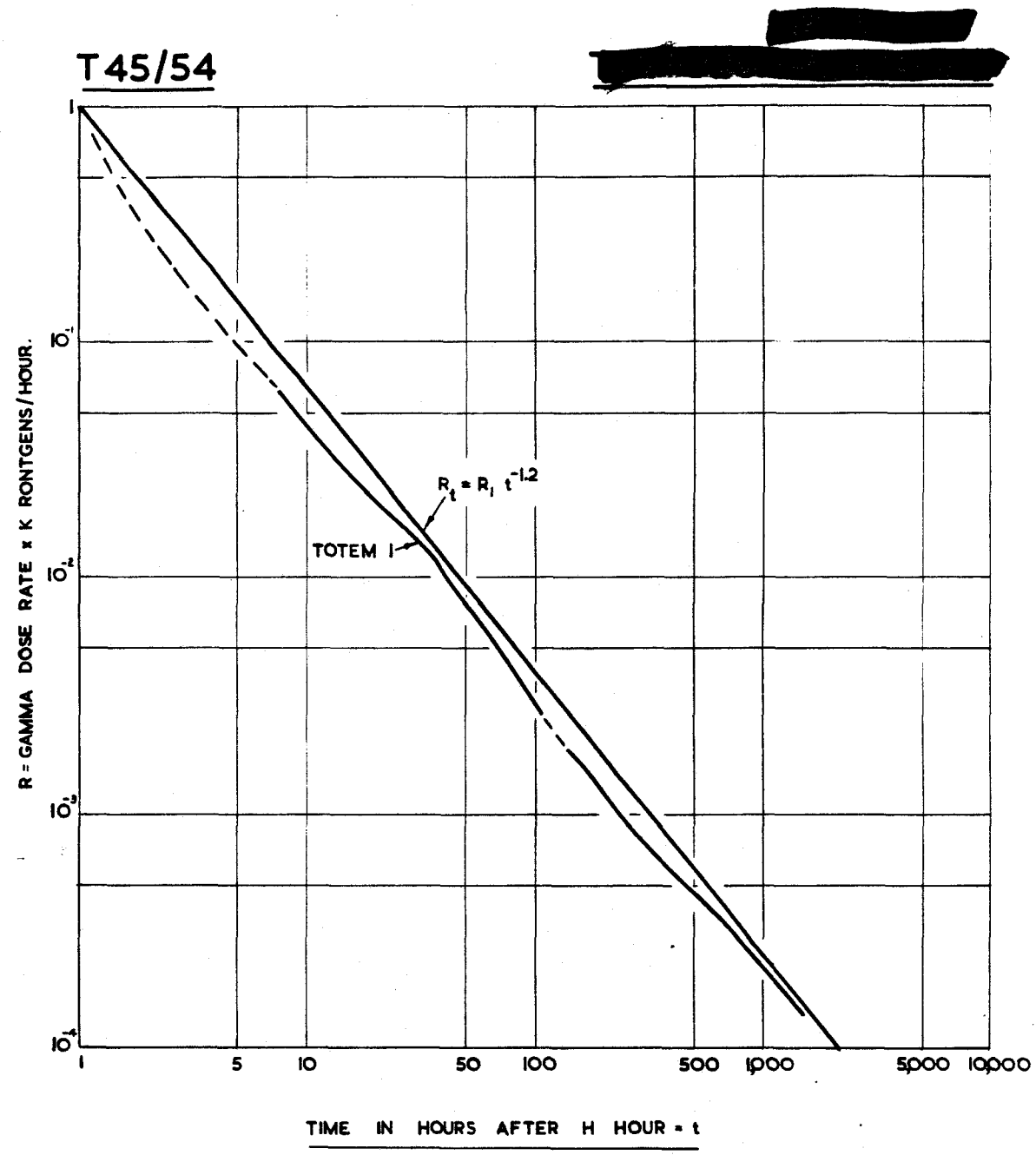
GAMMA DOSE RATE CONTOURS AT H+1 HOURS FOR RESIDUAL CONTAMINATION.
GAMMA DOSE RATES IN RONTGENS / HOUR AT H+1 HOURS.
COMPILED FEBRUARY 1954 FROM SURVEYS BY R.H.4. TEAM IN OCT./NOV. 1953.

[redacted]



WIND STRUCTURE.

HEIGHT IN FEET.
SPEED IN KNOTS.



TOTEM I

DECAY OF GAMMA DOSE RATE WITH TIME H+1 TO H+1500 HOURS

FIGURE 10

[redacted]

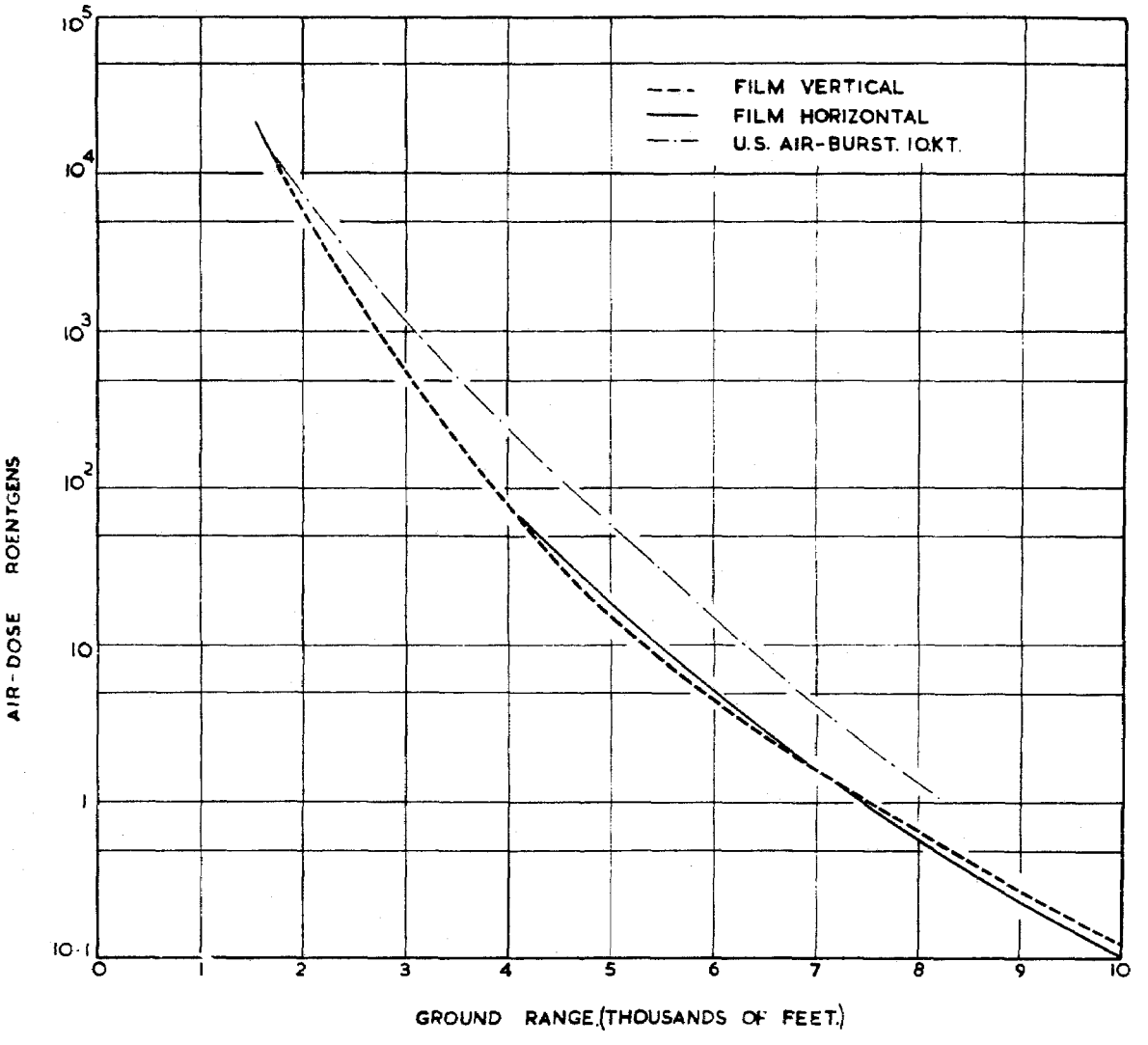


FIGURE 11.

GAMMA AIR-DOSE - DISTANCE RELATIONSHIP TOTEM. 2.

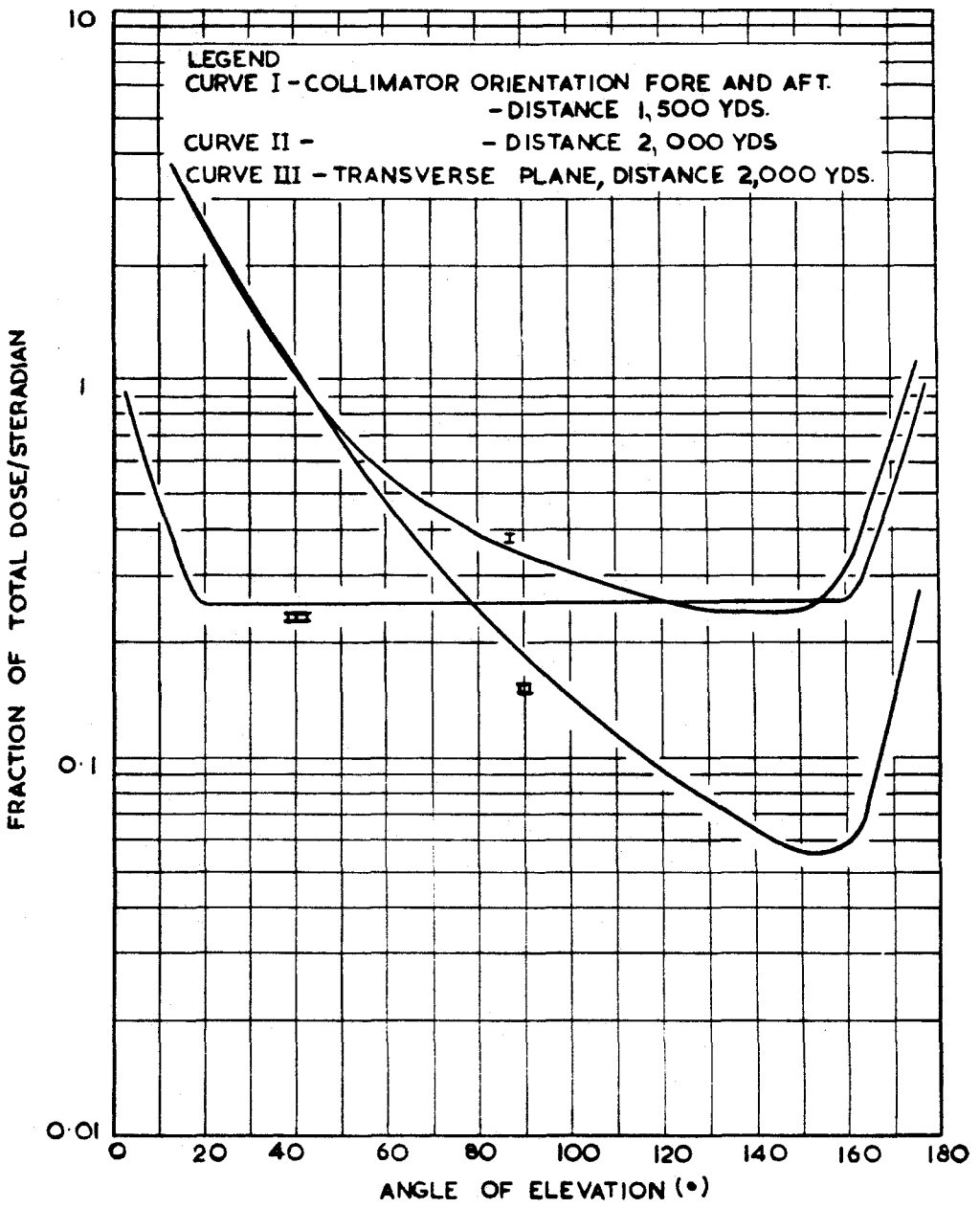


FIGURE 12.

ANGULAR DISTRIBUTION OF GAMMA RADIATION TOTEM 2.

[redacted]

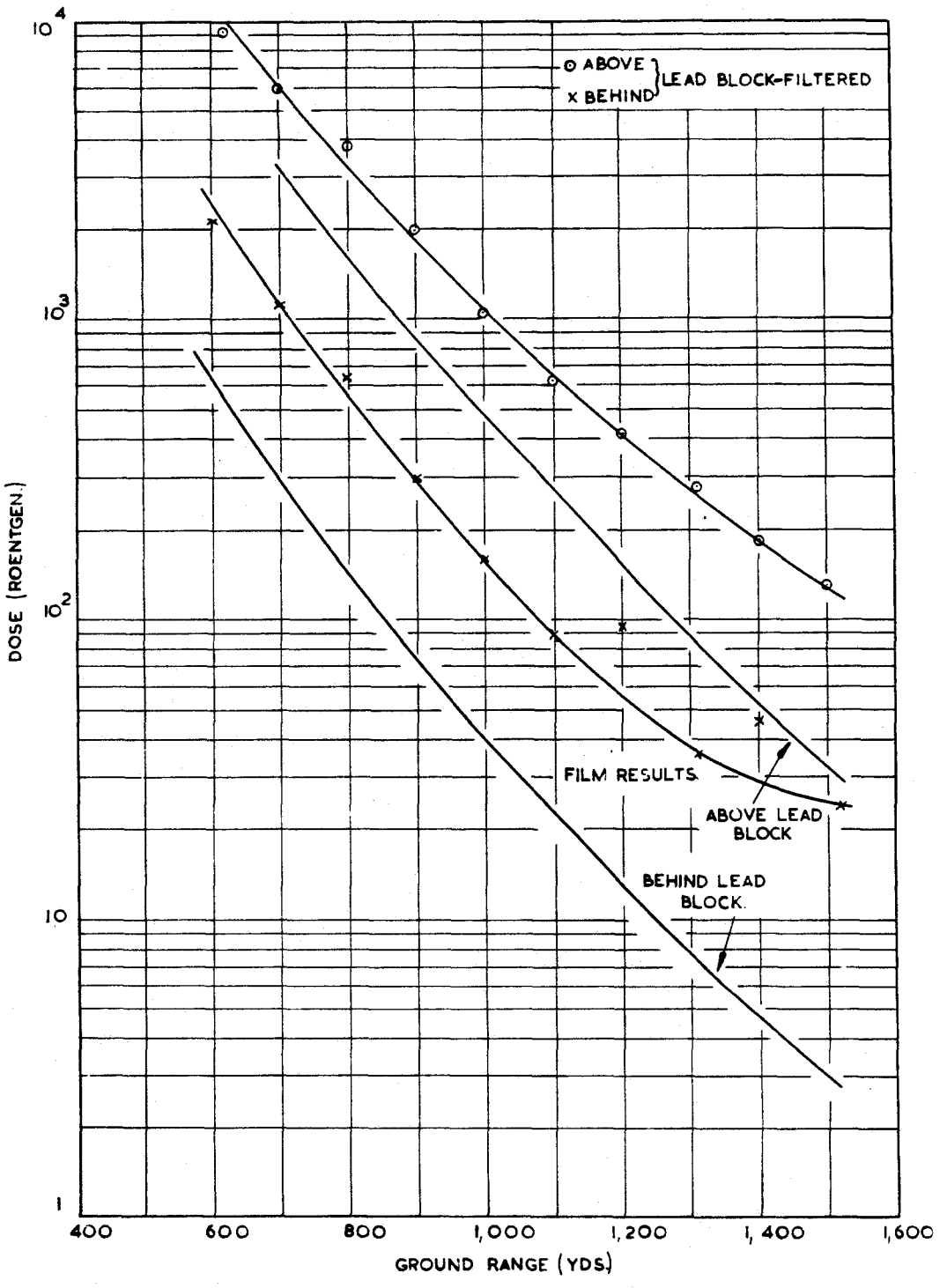
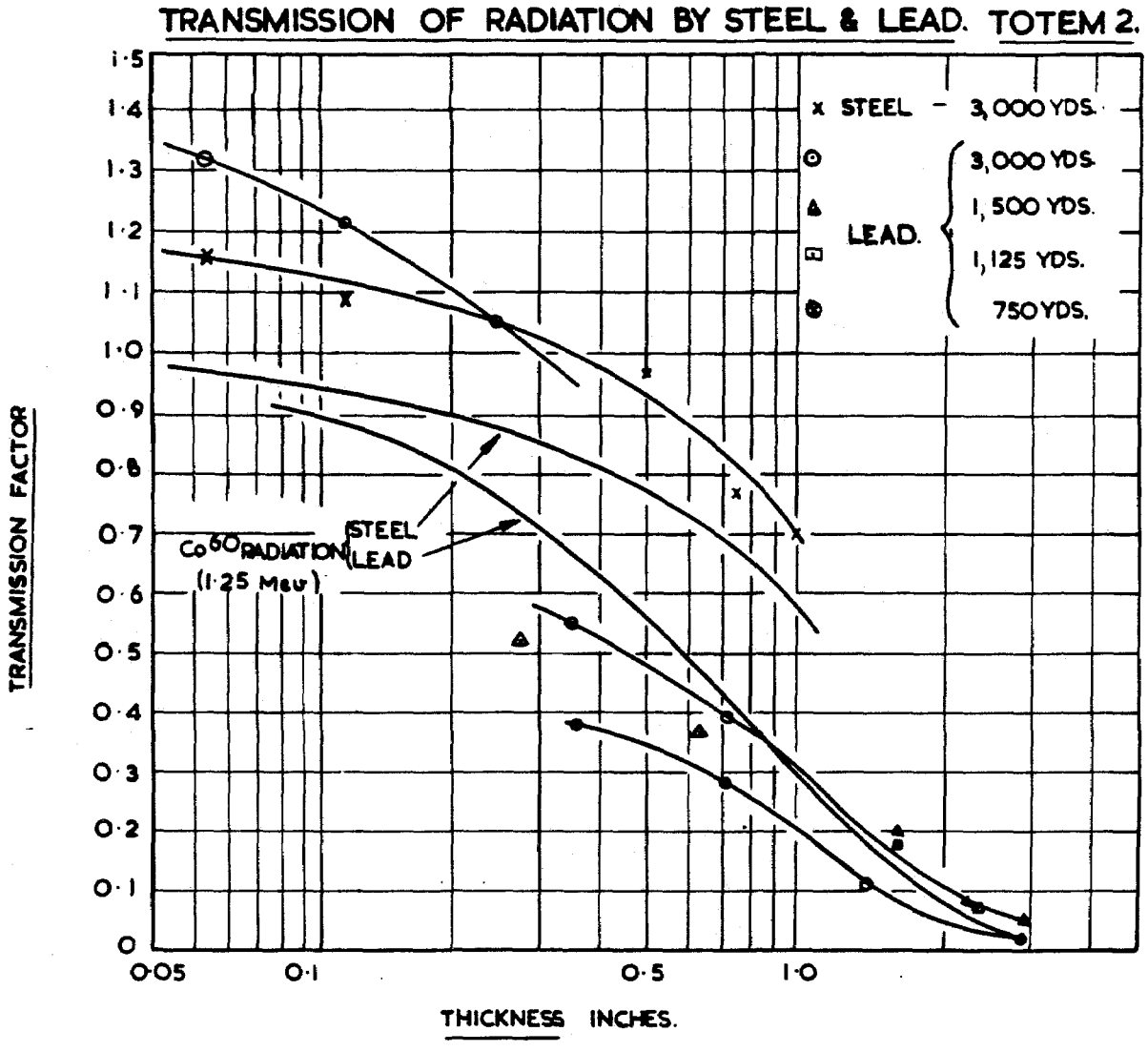


FIGURE 13.

GAMMA DOSE MEASUREMENTS WITH PHOSPHATE GLASS DOSIMETERS. TOTEM 2.

[redacted].

FIGURE 14.



[redacted]

T45/54.

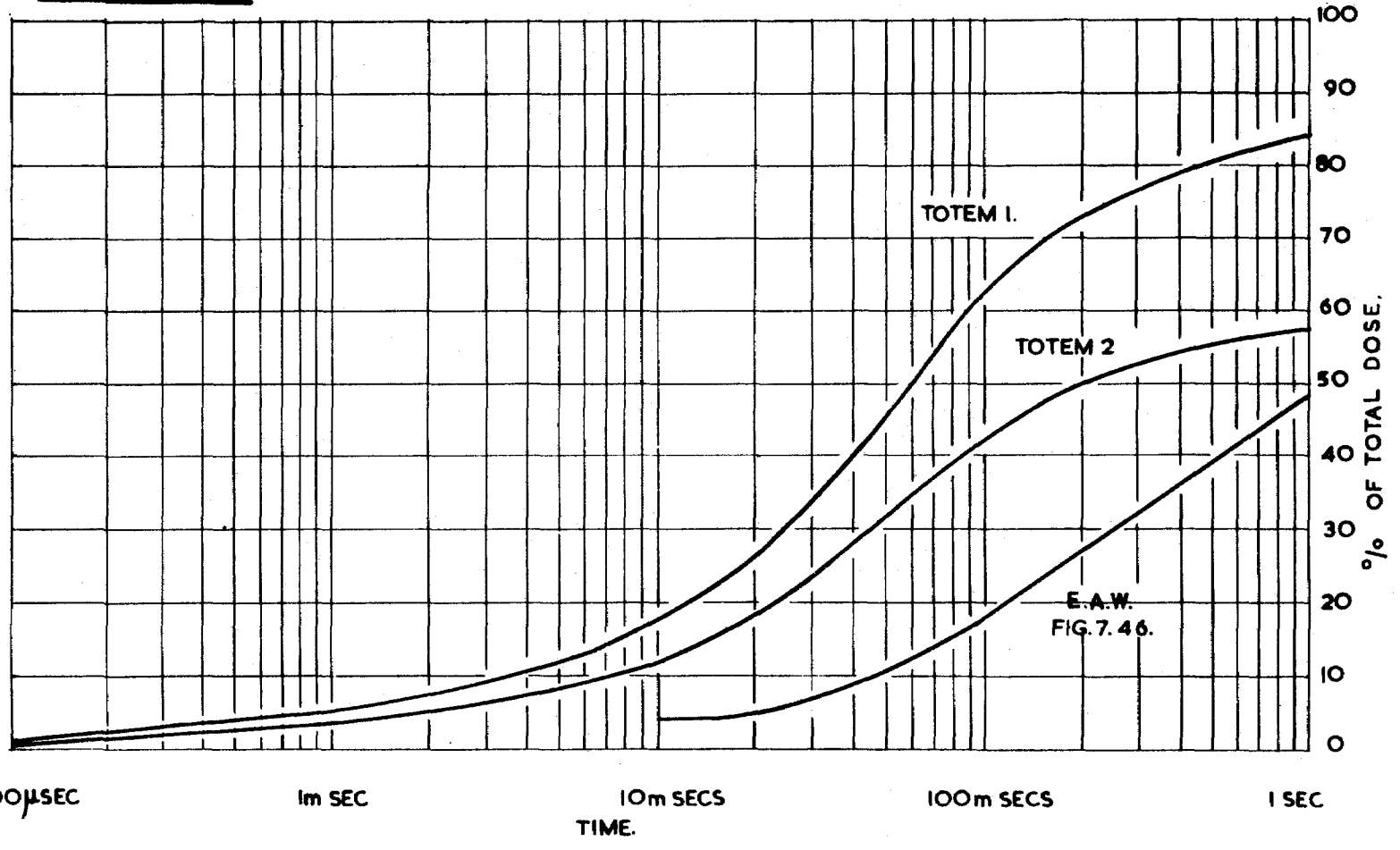


FIGURE 15.

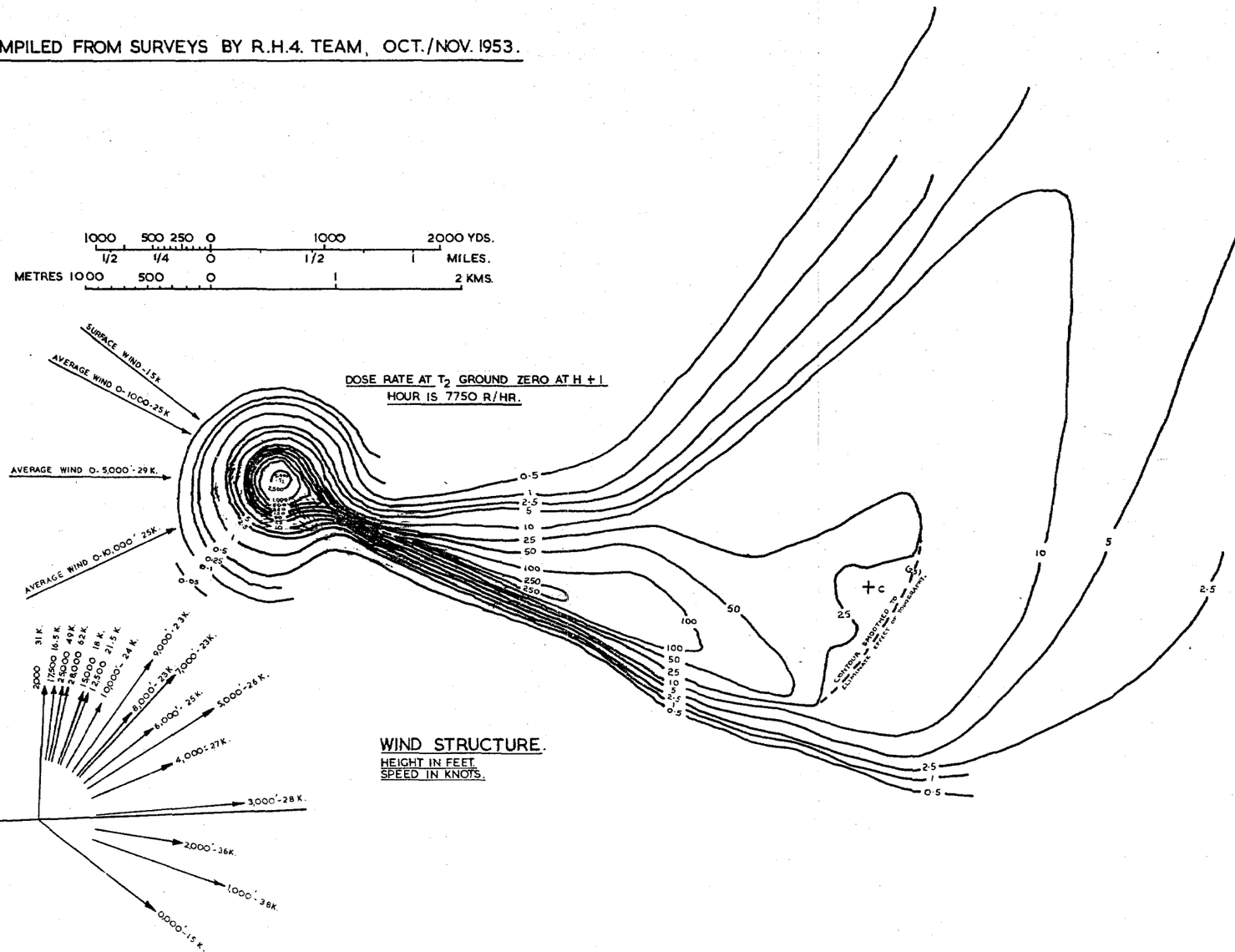
INTEGRATED DOSE-TIME CURVES. TOTEM 1 AND 2.

T45/54. FIGURE 16. SURVEY OF RESIDUAL CONTAMINATION. TOTEM 2.

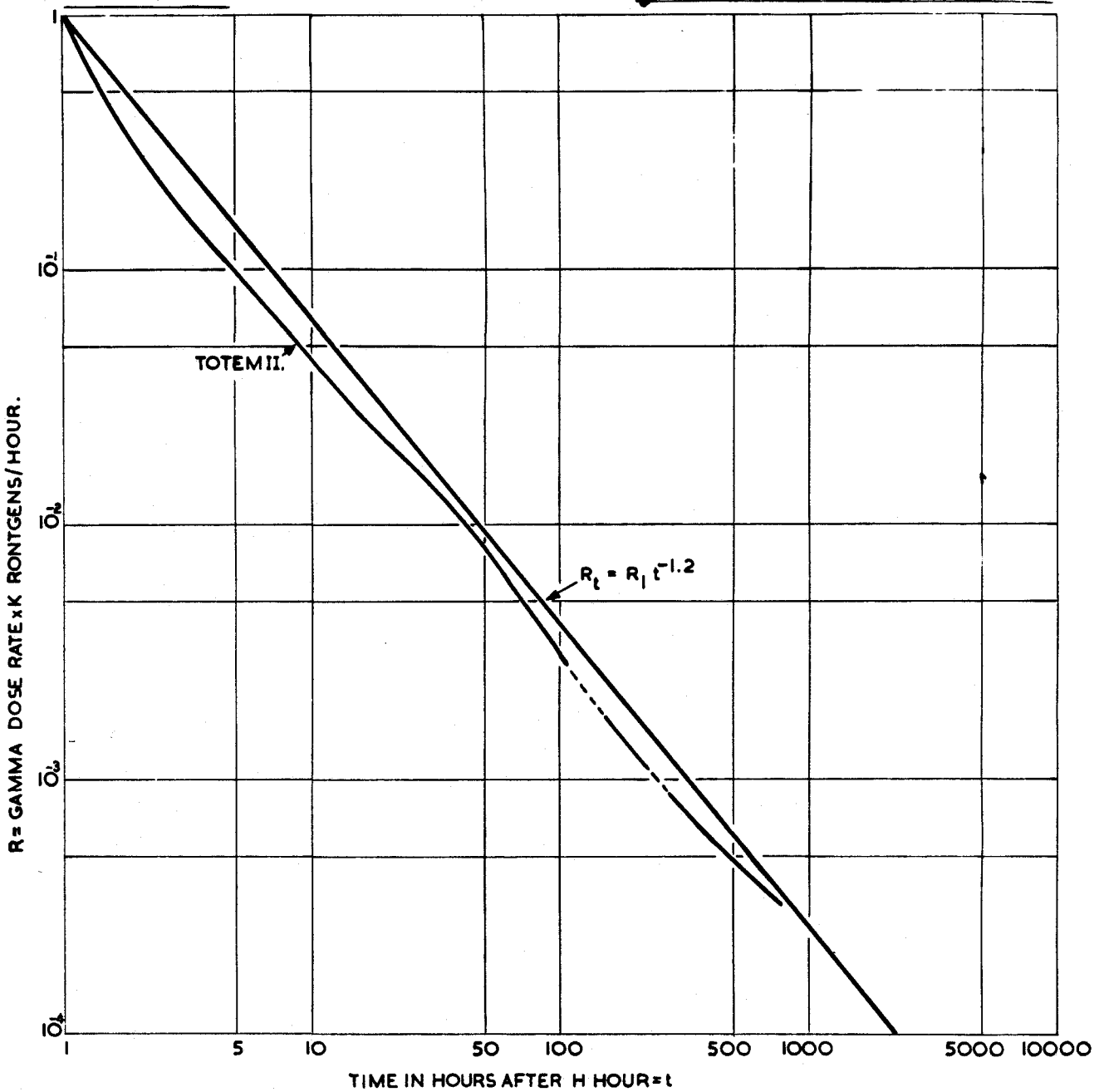
GAMMA DOSE RATE CONTOURS AT H + 1 HOURS FOR RESIDUAL CONTAMINATION

GAMMA DOSE RATES IN RONTGENS/HOUR.

COMPILED FROM SURVEYS BY R.H.4. TEAM, OCT./NOV. 1953.



T45/54



TOTEM 2

DECAY OF GAMMA DOSE RATE WITH TIME H+1 HOOR TO H+800 HOURS

FIGURE 17