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OPERATION TOTEM - TEAM REPORT

GROUP 9 TEAM R.S.1

REPORT NO. T6/54

Radio-Active Sampling and Analysis Report

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(AERE)

Summary

Part No.1 describes the collection of samples of the airborne radioactive dust at 400 miles and 1,100 miles from Totem 1 and at 400 miles from Totem 2. Examination of the records from gamma-detecting equipment installed in the sampling aircraft enabled estimates to be made of the cloud shape and size and specific activity at the sampling height.

Part No.2 describes the decay and absorption analysis of the 400 mile samples referred to above together with a Canberra Flight sample from Totem 1. The activity of each sample has been separated into Np^{239} and fission product components. Curves are shown of the decay of the fission products, of the decay of the total activity and of the change of the ratio of the component activities with time, between H+30 and H+300 hours.

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Part 1

1. Introduction

Samples of the airborne radioactive dust were required after it had travelled approximately 400, 1,200 and 3,000 nautical miles from the Totem explosions in order that analyses could be carried out by:

1. Team R.C.3 at Salisbury
2. Team R.S.1 at Woomera
3. Health Physics Division, AERE.

2. Instruments and Equipment

2.1 Aircraft

At 400 miles

Six Lincoln aircraft were based at Woomera.

At 1,200 miles

Six Lincoln aircraft were based at Richmond near Sydney.

At 3,000 miles

Three Bristol Freighter aircraft were based at Whenuapai in North Island, New Zealand, and three Mustang aircraft in South Island.

2.2 Collecting Equipment

Four standard AERE pattern filter carriers were mounted in the usual way under the wings of each of the aircraft. Each carrier was fitted with a Filter type G (special) Mk. IV supplied by CDEE and in flight air passed radially through the filter leaving any suspended particles on its inside surface.

2.3 Cloud Detecting Equipment

Cloud detecting equipment was fitted in each of the Lincoln aircraft. Basically it consisted of a Monitor Radiation type 1021 suitably modified for aircraft use and powered from the 24 volt aircraft supply via a rotary converter. The Geiger tube used was a Type GMIB enclosed in a bakelite tube of one eighth inch wall thickness.

In addition the instruments in the Woomera aircraft had provision for switching in an alternative input from a Geiger tube type CV 2140 (B6 thin wall immersion type) mounted in the normal Probe Unit type 1021. The sensitivities of these tubes to extended sources of gamma radiation of energy about 1.4 Mev are in the ratio of 20 to 1 and the use of the CV 2140 allowed a greater activity range coverage at the closer distance.

No detecting equipment was fitted in the New Zealand aircraft.

4. Procedure (Totem 1)

4.1 At 400 Miles

About 24 hours before the event a background sortie was carried out on advice from Team M.S.1. This showed that a negligible amount of radio-activity would be collected in the absence of the cloud from the explosion.

On D-1 day Team M.S.1 supplied a prediction of the cloud position and size about six hours after the explosion which assisted in planning the interception. Immediately after the explosion information was supplied on the probable position of the cloud, its size and direction of motion at various intervals of time after H hour. Five aircraft were despatched to patrol parallel lines 10 miles apart at about 400 miles from T1 and at right angles to the expected line of advance of the cloud.

The plan was for each aircraft to announce by a code word when it had intercepted the cloud, then to make four complete traverses of the cloud, two in each of two perpendicular directions. The controller was able to move aircraft in the knowledge of interceptions made by other aircraft or to move the whole search pattern in position or height if further information from Team M.S.1, required it.

In the event the operating height was changed from 13,000 to 14,000 feet but otherwise no change in plan was required as all five aircraft made suitable interceptions. The mean time of interception was H + 11 hours.

The filters from the first aircraft were measured on arrival at Woomera and were found to be well in excess of the minimum requirements of Team R.C.3. Because of their high activity these filters were then left, together with those from the other aircraft, until H + 24 hours, when the normal work could be carried out.

Ten filters were despatched to Team R.C.3. at Salisbury and the other ten were sent to Salisbury for immediate return to AERE by air under diplomatic immunity. A portion of one of the latter was retained for analysis at Woomera (see Part No. 2 of this report).

4.2 At 1,200 Miles

Similar information to that described above was supplied to the Richmond controller. One Lincoln aircraft carried out a background sortie on D day and again obtained negligible activity.

Another was despatched to endeavour to make an interception in the region of 800 miles in view of certain discrepancies between the cloud position reported by the Lincolns at 400 miles and the USAF B.29's operating from Richmond at 600 miles. This aircraft made a good interception at about H + 25 hours, but unfortunately reported its position wrongly. Its four filters were measured after landing at Richmond and on their arrival at Woomera and were found to be of the same order of activity as those collected at 400 miles.

The remaining aircraft were despatched to Townsville, a more suitable base in view of the north easterly direction of the cloud movement. The reported interception at 800 miles showed that the most likely region to search was the area to the south east of Townsville and this was done with five aircraft between H + 44 hours and H + 51 hours, the distance from T1 being approximately 1,100 miles. All aircraft filters showed significant activity on landing, despite the fact that the best region had not been searched, due to the false position report at 800 miles.

2.4 Filter Monitoring Equipment

After landing, the filters were tested for beta activity using a Monitor type 1021 with a Geiger tube type CV 2140.

3. Installation

3.1 Collecting Equipment

The filter carriers were mounted by maintenance personnel of the RAAF and RNZAF.

3.2 Detecting Equipment

The Lincolns were fitted with the detecting equipment at the RAAF Station at Amberley, near Brisbane under the supervision of the Team Leader, using spare radar instrument racks.

All Lincoln crews partaking in the operation were instructed in the use of the equipment, particularly the wireless operators who were allotted the task of observing the monitoring readings in flight. This was done at Amberley before the aircraft moved to their operational bases. Test flights at altitudes up to 20,000 feet were carried out for practice and also to measure background activity readings likely to be encountered.

The maintenance of the equipment was undertaken by the radar maintenance personnel of No. 82 (Bomber) Wing, RAAF.

3.3 Filter Monitoring Equipment

At Woomera this was set up in the hangar space allotted to the project.

At Richmond it was set up under the supervision of Sqn. Ldr. G. T. Dick who was in control of the operation of the aircraft at 1,200 miles.

No information is available on the New Zealand installation.

3.4 Aircraft Bases and Communications

At Woomera complete facilities for the Lincoln Squadron were provided by the RAAF. An Operations Room was set up in the Range Headquarters under the control of Sqn. Ldr. E. T. Pickerd, RAAF who controlled the detailed planning of the flying tasks at Woomera.

A similar organisation was set up at Richmond under the control of Sqn. Ldr. G. T. Dick, RAAF.

Communications between the bases were by special direct RAAF channels and the usual communication was available between each base and its aircraft when in flight.

Information on cloud position supplied by Team M.S.1 was transmitted from Emu to the Operation Room at Woomera, and immediately from there to Richmond. All information for the RNZAF was passed directly from Emu.

The filters were sent to the Team Leader at Woomera for further measurement and allocation. It was found that the four filters from one aircraft were of insufficient activity for use, but the remaining twenty filters were above the minimum requirement. They were divided equally between Team R.C.3 and AERE and despatched as above.

4.3 At 3,000 Miles

In view of the unfavourable direction of the cloud movement Team M.S.1 advised the RNZAF to abandon operations at an early stage and no samples were obtained.

5. Results (Totem 1)

5.1 Filter Activities

Aircraft No.	Filter No.	Height of Collection (Feet)	Approx. Distance Nautical Miles	Approx. Beta Activity	Distribution
47	(W1, W2 (W3, W4	13,000	400	10^8 dis./sec. at 1 day	(Team R.C.3. (AERE *
52	(W5, W6 (W7, W8	14-15,000	400	3×10^8 dis./sec. at 1 day	(Team R.C.3. (AERE
53	(W9, W10 (W11, W12	14,000	400	4×10^7 dis./sec. at 1 day	(Team R.C.3. (AERE
54	(W13, W14 (W15, W16	14,000	400	10^8 dis./sec. at 1 day	(Team R.C.3. (AERE
56	(W17, W18 (W19, W20	14,000	400	10^8 dis./sec. at 1 day	(Team R.C.3. (AERE
25	25-1, 25-2) 25-3, 25-4)	14,000	800	3×10^7 dis./sec. at 4 days	(Team R.C.3. (AERE
21	21-3, 21-4) 21-5, 21-6)	Probably 10-12,000	1,100	10^4 dis./sec. at 4 days	(Team R.C.3. (AERE
26	26-1, 26-2) 26-3, 26-4)	Probably 15,000	1,100	2×10^5 dis./sec. at 4 days	(Team R.C.3. (AERE
27	27-1 to) 27-4)	13,500	1,100	10^3 dis./sec. at 4 days	(Not used
37	37-1, 37-2) 37-3, 37-4)	10-11,000	1,100	10^5 dis./sec. at 4 days	(Team R.C.3. (AERE
40	40-1, 40-2) 40-3, 40-4)	10-12,000	1,100	3×10^5 dis./sec. at 4 days	(Team R.C.3. (AERE

* A portion of filter W3 was retained for analysis at Woomera.

The collection heights of the aircraft at 1,100 miles are discussed in Paragraph 6.2.

5.2 Detecting Equipment Observations

Typical records of instrument observations obtained at 400 miles are shown in Figures 1 and 2 where the meter reading (standardised to the CV 2140 sensitivity) is plotted against time of observation.

From Figure 1 it is apparent that the times of entry and exit from the cloud are fairly well defined, as well as the intensities of activity encountered. Figure 2 is typical of three cases where the aircraft encountered such intense activity that in addition to the instrument going off scale the outside of the aircraft became contaminated sufficiently to maintain a high "background" reading on the instrument even after leaving the cloud. From the record however, it is still possible to determine the entry and exit points. Estimates can also be made of the intensity encountered.

The aircraft which made the interception at 800 nautical miles was equipped only with the more sensitive Geiger tube and in addition executed a complicated flight path after interception. Thus its observation record is very difficult to interpret. However, in view of the activity collected on its filters assumptions can be made about the concentration and gamma dose encountered, compared with those at 400 miles.

The aircraft which intercepted at 1,100 nautical miles encountered activities at least 100 times lower than the 400 mile aircraft, and the dose rates are negligible.

In view of the relatively high contamination levels estimates are given below of the maximum concentrations encountered and the integrated gamma dose received by the crew members during the flight in terms of a gamma emitter of energy 1.4 Mev. These estimates are based on the observation records.

Aircraft No.	Total Gamma Dose	Residual Dose Rate on Landing	Time in Cloud	Max. Concentration Encountered
47	50 mr.	12 mr./hr.	10 min.	30 μc/m.³
52	120 mr.	25 mr./hr.	45 min.	30 μc/m.³
53	10 mr.	0.2 mr./hr.	55 min.	10 μc/m.³
54	6 mr.	0.2 mr./hr.	30 min.	10 μc/m ³
56	45 mr.	10 mr./hr.	10 min.	30 μc/m.³
25	~ 50 mr.	~ 2 mr./hr.	~ 150 min.	~ 10 μc/m ³

6. Discussion (Totem 1)

6.1 Cloud Shape and Size

According to the observation records, the five aircraft at 400 miles made a total of 15 traverses of the cloud spread over an interval of about 3 hours. Thus there are 30 entry and exit points available to define the limits of the cloud. These were plotted by the respective navigators as air positions relative to a coincident air/ground position at H + 11 hours, thus giving the true ground positions of the respective entry and exit points at this mean time. It is possible to draw a smooth curve (Figure 3) through 19 of the 30 defining points, the others being scattered about this curve, probably due to accidental errors. In addition contours of activity have been drawn which confirm the general shape of the boundary as depicted.

Thus Figure 3 represents a horizontal cross-section of the cloud at 14,000 feet and at approximately 400 miles from T1.

6.2 <u>The Richmond-Based Operation</u>

This was under the control of an RAF navigation officer with no specialised scientific background, and for this reason emphasis was laid on the collection of samples, the detecting equipment being used only to indicate the presence of the cloud. Thus no evidence is available about the shape or size of the cloud at 1,100 miles.

In addition the false position report (see paragraph 4.2) and the time taken to move the aircraft to Townsville resulted in the aircraft encountering the cloud almost immediately over Townsville instead of to the south east, as intended. Thus several of the aircraft collected their samples while climbing or descending, at heights below that of the presumed centre of the cloud.

Evidence about the true height of collection depends on the observation records and on subsequent particle size analysis carried out at AERE. This evidence is summarised below.

Aircraft No.	Height of Collection	Remarks
21	10-12,000 ft.	No records available. Based on abnormal particle sizes.
26	15,000 ft.	Instrument unserviceable. Based on normal particle size.
27	13,000 ft.	Contact with cloud on descent to base.
37	10-11,000 ft.	Main contact on ascent from base.
40	10-12,000 ft.	Contact on ascent from base.

7. <u>Procedure (Totem 2)</u>

7.1 <u>At 400 Miles</u>

About 24 hours before the explosion the usual background sortie was carried out and an insignificant amount of activity was collected.

After the explosion the usual information was supplied by Team M.S.1 except that the height could not be specified, but was given as greater than 20,000 feet. Four aircraft were despatched to patrol lines as before but in addition arranged to give vertical coverage. At about the expected time two aircraft reported contact with the cloud and then carried out traverses as before, the mean time of contact being H + 10½ hours. The other two aircraft were withdrawn before making contact, to avoid unnecessary contamination.

After preliminary measurement which showed the filters to be well above the minimum requirement they were left until H + 24 hours before starting work on them.

The four more active filters were despatched to Team R.C.3 and the other four returned immediately to AERE via Salisbury, a portion of one of the latter being retained for analysis at Woomera.

7.2 At 3,000 Miles

Although not originally planned, the organisation at this distance was kept on for Totem 2, in view of the failure to obtain samples on the previous occasion.

However, as the direction of cloud movement was again unfavourable, Team M.S.1 advised that the operations be abandoned, and no samples were obtained.

8. Results (Totem 2)

Aircraft No.	Time Within Cloud	Max. Gamma Concentration Encountered	Approx. Beta Activity of Filters	Distribution of Filters
47	45 min.	10 $\mu c/m^3$	3×10^7 dis./sec. at 1 day	AERE
52	60 min.	30 $\mu c/m^3$	6×10^7 dis./sec. at 1 day	Team R.C.3

The figures in the second and third columns are derived from the detection equipment records.

These records are similar to those obtained previously and again entry and exit points, as well as intensities, are well defined.

9. Discussion (Totem 2)

On this occasion the two aircraft made a total of ten traverses of the cloud spread over about one hour. The twenty entry and exit points were plotted as before, giving the true ground position at H + 10½ hours. The smooth curve of Figure 4 has been drawn through 12 of these defining points, and again in addition contours of activity have been drawn. Figure 4 represents a horizontal cross-section of the cloud at 20,000 feet and approximately 400 miles from T2.

Crews were issued with film badges and pocket dosimeters on this occasion, and all measurements of contamination were made by R.H.Group.

10. Conclusions (Totem 1 and 2)

The cloud detection equipment worked satisfactorily, although equipment designed specifically for aircraft used would be preferable.

In view of the unexpected contamination hazard it may be desirable in any future operation to limit the number of aircraft entering the cloud to a minimum.

The success of the detection equipment in this operation means that only as many aircraft as are needed to collect the required number of samples need enter the cloud, at least at 400 miles.

To ensure the collection of samples at 3,000 miles, it is necessary to plan the aircraft bases to allow for a wider range of cloud movement direction.

11. Group Composition

H. J. Gale (Group Leader and Team Leader R.S.1). Responsible for the collection and distribution of the samples of airborne activity, and for the analysis of selected samples.

R. S. Cambray (Team Leader R.S.2) Responsible for the measurement of the deposited activity and for the operation of one aircraft equipment.

W. C. T. Munnoch (R.S.2). Responsible for the operation of the other aircraft equipment.

(The operations and activities of Team R.S.2 are covered by a separate report in this series, namely No. T7/54).

12. Acknowledgments

Acknowledgments are due to all those who rendered assistance in the tasks, particularly to the Royal Australian Air Force and the Royal New Zealand Air Force.

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TYPICAL RECORDS OF CONCENTRATIONS RECORDED AT 400 MILES.

FIG. I.

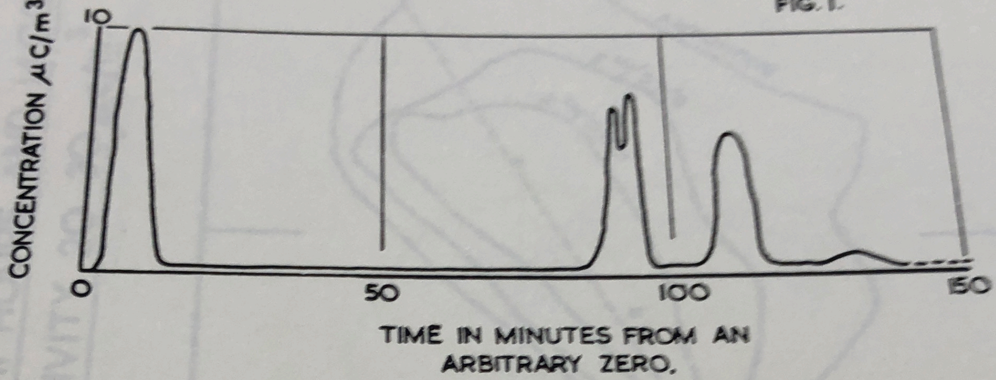


FIG. 2.

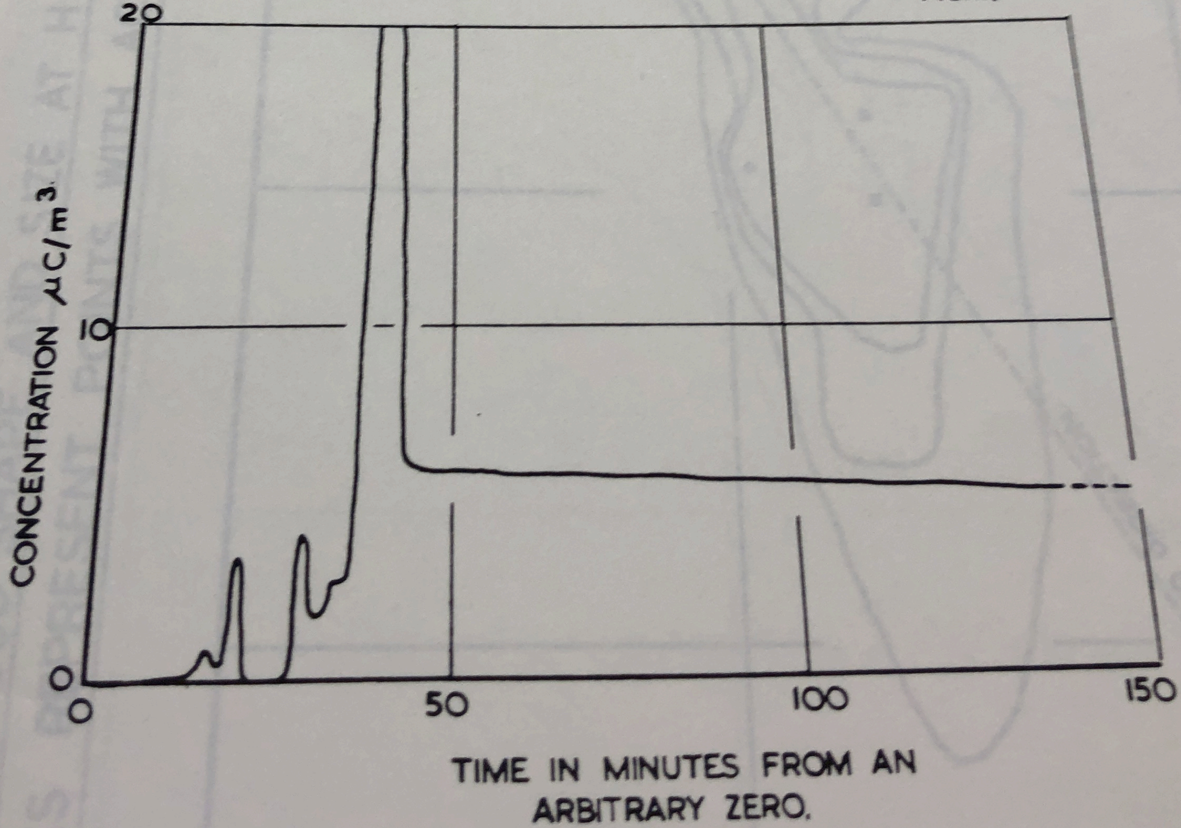


FIG. 3. TOTEM I CLOUD SHAPE AND SIZE AT H+11 HOURS AND 14,000 FEET. [redacted] THE SMALL SQUARES REPRESENT POINTS WITH ACTIVITY 20-30 $\mu c/m^3$.

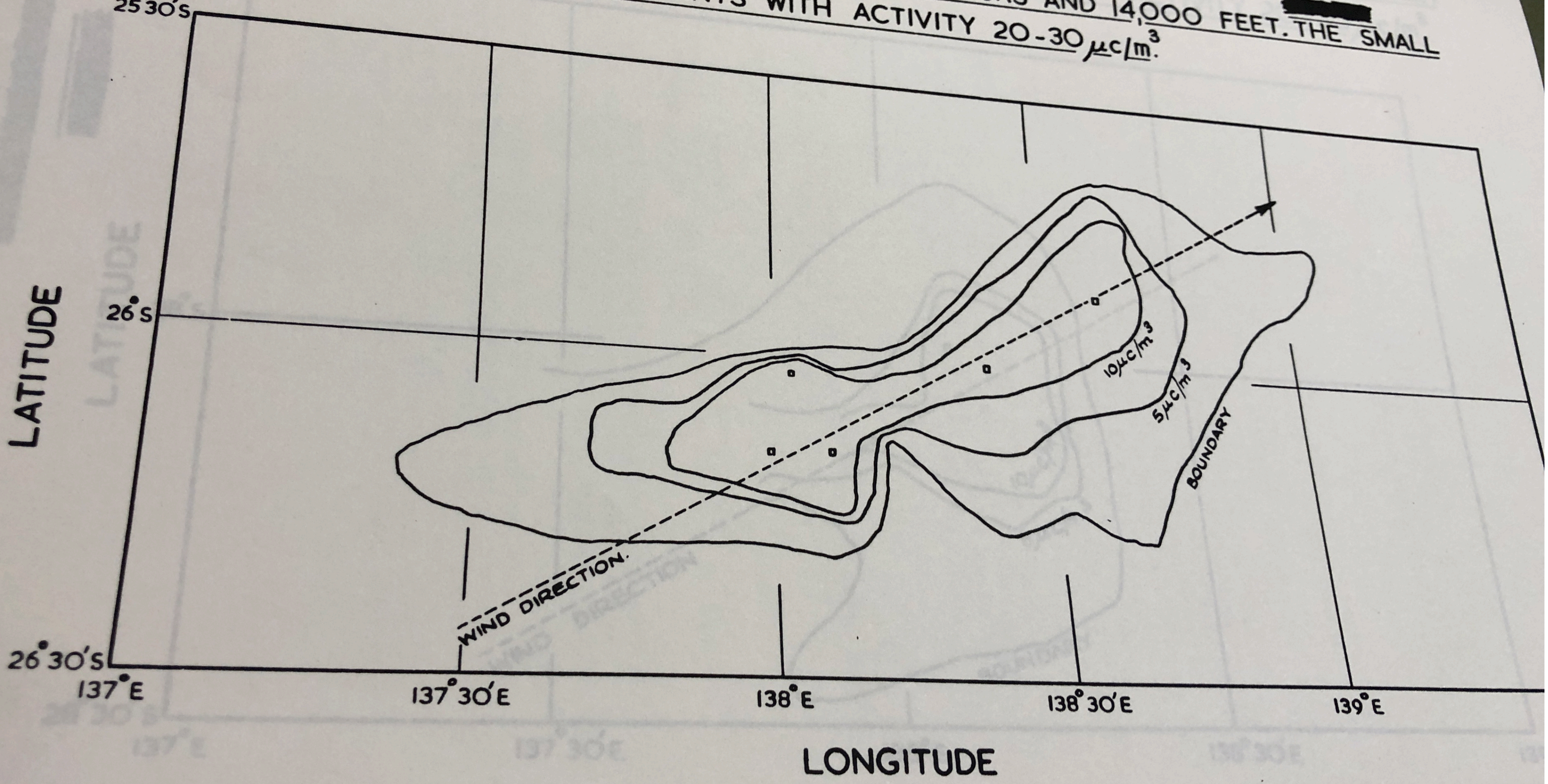
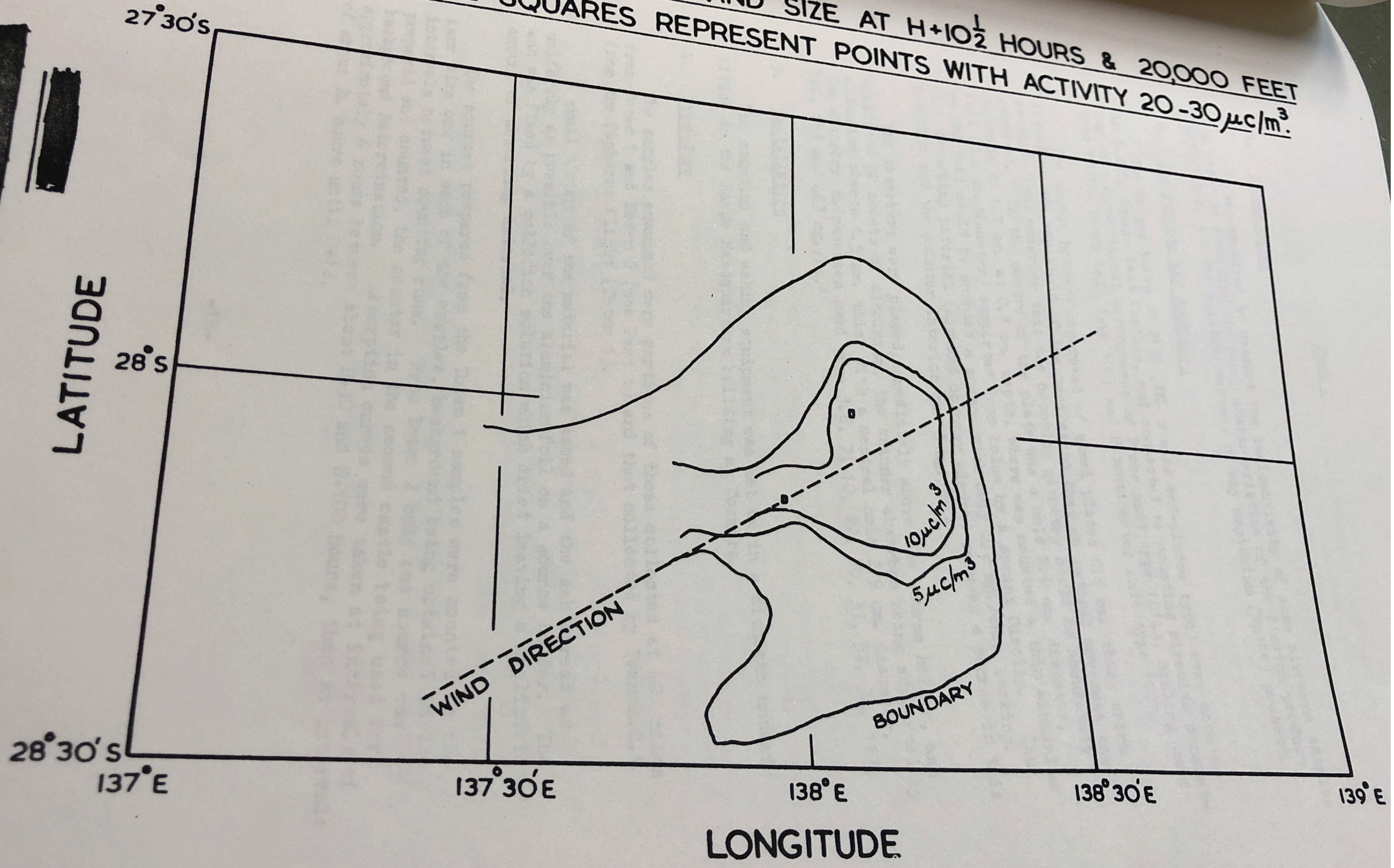


FIG. 4. TOTEM 2 CLOUD SHAPE AND SIZE AT H+10½ HOURS & 20,000 FEET
THE SMALL SQUARES REPRESENT POINTS WITH ACTIVITY 20-30 $\mu c/m^3$.



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Part 2

1. Introduction

It was required to measure the radioactivity of some airborne samples in order to determine the decay characteristics of the fission product activities, and the relative amounts of any neptunium (Np^{239}) present.

2. Instruments and Equipment

Two Geiger tubes CV 2139 (EHM 2 mica end-window type) were mounted in E.R.D. Square Lead Castles, and connected to counting circuits consisting of a conventional arrangement of Probe unit type 1014A, Scaling unit type 1221A, Power unit type 1007 and Potentiometer unit type 1007.

The source holders consisted of steel plates 0.6 cm. thick which fitted as the top shelf of the castles so that no lateral movement was possible thus ensuring that the counting geometry could be accurately repeated. In the centre of the plate was a hole 2.0 cm. diameter, tapering to 1.7 cm. at 0.3 cm. depth, where was mounted a thin aluminium foil (2.4 cm. diameter) supported from below by a spring Circlip. Thus on the foil could be mounted a source with only 2.8 mg./cm.² backing. The absorbing material (air and counter window) between a source in this position and the counter interior was 3 mg./cm.²

The absorbers were placed immediately above the source holder, and consisted of sheets of aluminium, the thinner absorbes being supported by aluminium sheets 1.5 mm. thick with a central hole 2.9 cm. diameter. The absorber thicknesses used were 3.6, 7, 10, 22, 30, 37, 52, 74, 117, 164, 193 and 463 mg./cm.²

3. Installation

The counting and ashing equipment was set up in a hitherto unused office in the Range Headquarters building at Woomera.

4. Procedure

The samples examined were portions of those collected at 400 miles from Totem 1 and Totem 2 (see Part 1) and that collected by Team R.C.1. from the Canberra flight (Totem 1).

A small amount of the material was ashed and the ash spread as uniformly as possible over the aluminium foil on a source holder. The ash was fixed by a collodion solution which dried leaving a negligible amount of absorbing material.

The sources prepared from the Totem 1 samples were counted at the same time one in each of the castles, background being obtained in the intervals between counting runs. From Totem 2 only one source was prepared and counted, the counter in the second castle being used for background determination. Absorption curves were taken at intervals of approximately 6 hours between about H+30 and H+100 hours, then at intervals of about 24 hours until D+12.

It was expected that the absorption and decay curves obtained would be due to a combination of fission products and neptunium activities. The readings were treated as follows to determine the relative amounts of each and to correct for the neptunium (Np^{239}) present.

Each reading was first corrected for dead time losses and background, and then a decay curve corresponding to each absorber thickness was plotted. Using these decay curves, all the observations for a particular absorption curve were adjusted to a fixed time, thus producing an absorption curve effectively measured at this chosen time throughout. This was repeated for all the observed absorption curves, the adjustments in no case exceeding 5 per cent.

It can be shown[1] that providing a suitable time after burst is chosen there is a simple method for separating the fission product and neptunium components in the absorption curves. The criterion is that the fission products should have an appreciably longer half-life than the neptunium at the time considered and that their absorption curves should be quite distinct. These conditions are satisfied in the present case from about H+140 onwards.

In this region the decay of the fission products is such that the absorption curve does not change its shape appreciably over a 24 hour period, and thus any change in shape of the observed absorption curve is due to the change in the relative amounts of the rapidly decaying neptunium present. Thus from two successive absorption curves a simple regression analysis will suffice to determine the amounts of neptunium and fission products present.

Such an analysis was carried out for three pairs of curves, the resultant amounts being averaged. Then every observed point was corrected for the appropriate amount of neptunium, and the absorption curves for fission products alone drawn. Each curve was produced back through 3 mg./cm.^{2} to allow for the window and air thickness between the source and the counter interior, and similar corrections were made to the calculated neptunium amounts. Thus figures were produced of the fission product and neptunium activities, corrected to true zero absorber thickness, at times between about H+30 and H+300 hours.

5. Results

Curves are shown in Figures 1, 2 and 3 of the decay of the fission product and total activities, corrected to true zero absorber thickness, and also of the change with time of the ratio of the neptunium to fission product activities. The standard deviation of individual points on the curves is not greater than 5 per cent, and for the total activity curves is about 1 per cent.

The peak value of the neptunium to fission products activity ratio occurs in each case at about H+90 hours and the figures are :-

Totem 1	400 mile sample	2.8
Totem 1	Canberra sample	2.9
Totem 2	400 mile sample	3.8

For completeness and comparison results are quoted below of measurements made at AERE(2) on Totem 1 samples collected at 800 and 1,100 miles :-

400 mile sample	Ratio 1.2	at H+230 hours (see Figure 1A)
800 mile sample	Ratio 1.6	at H+230 hours
1,100 mile sample	Ratio 1.9	at H+230 hours

Figures for H+230 hours are quoted as the measurements at AERE could not be made before this time.

[redacted]

[redacted]

[redacted]

References

1. N. G. Stewart and H. J. Gale. To be published as an AERE document.

2. Miss E. M. R. Fisher and L. H. J. People. To be published as an AERE document.

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FIGURE. I. TOTEM I. 400 MILE SAMPLE. [redacted]

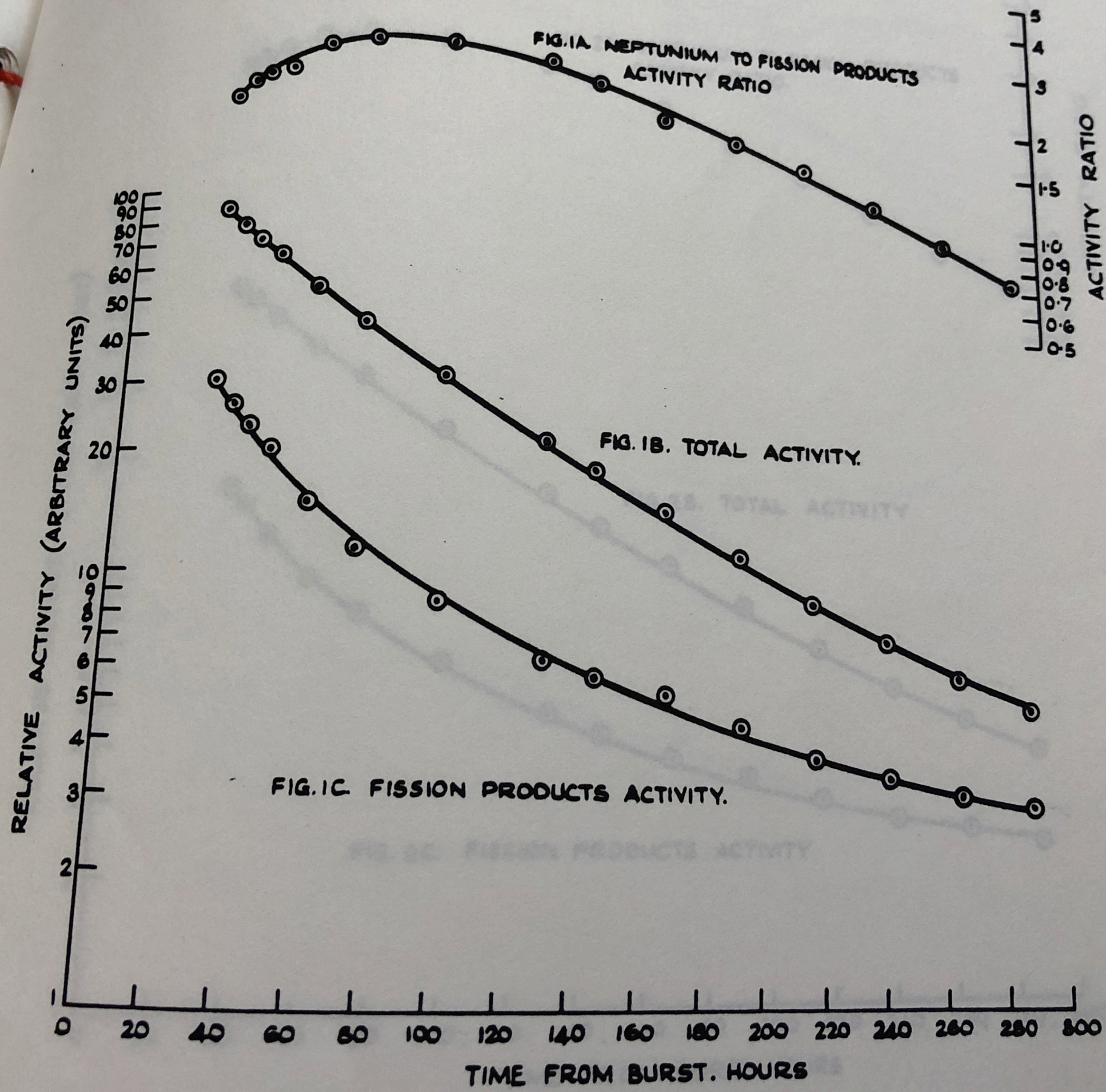

FIGURE 2. TOTEM I. CANBERRA FLIGHT SAMPLE. [redacted]

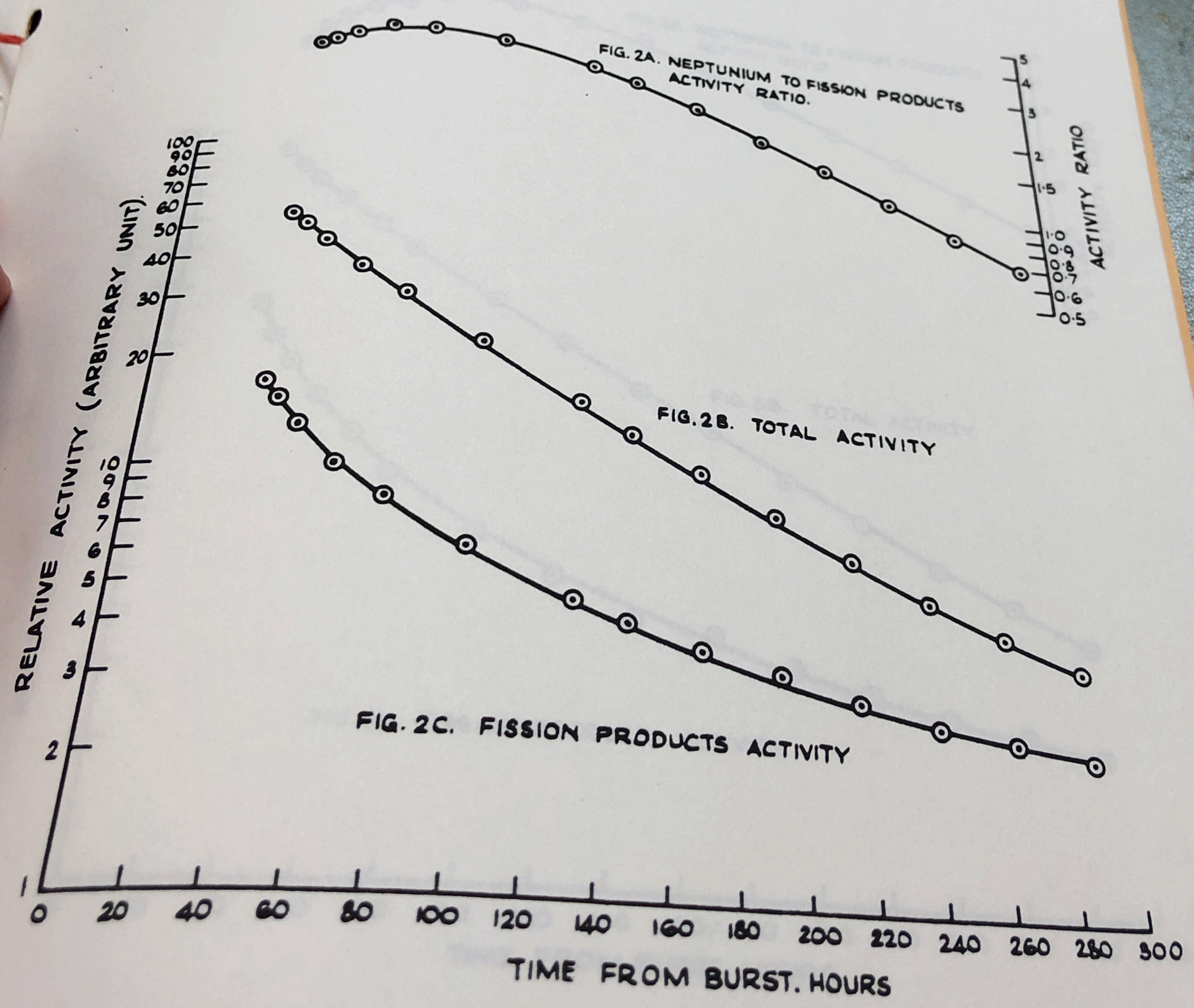

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FIGURE. 3. TOTEM 2. 400 MILE SAMPLE.