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## Experiments to Study the Release of Particulate Material During the Combustion of Plutonium, Uranium and Beryllium in a Petrol Fire

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## Summary

Known quantities of plutonium, uranium and beryllium metals were burnt to oxide in a controlled petrol fire. A fraction of the oxide was released in particulate form in the plume from the fire and was sampled during travel downwind. Air concentrations and deposition levels were measured. The degrees of inhalation hazard which would be produced under these circumstances, and the fraction of oxide dispersed, have been estimated

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## 1. INTRODUCTION

There were two objectives in this series of field trials. The first was to determine the fraction of material released in particulate form as a result of the combustion of plutonium, uranium and beryllium metal specimens in a controlled petrol fire. The second was to measure the subsequent distribution of the material downwind. The fine particulate material, which would reach the lungs if inhaled, was of primary interest.

In this report the experimental procedures employed on the trials and in the analysis of the samples are described. The results from the experiments with plutonium and uranium are given in detail, but the analysis of the samples collected during the experiments with beryllium is not yet complete. It is intended to produce this information in an Addendum to this report in due course. The information indicates the extent to which the dispersion of metal oxides occurred.

Devices to sample the airborne concentration and the amount deposited were set out to form an array covering a $90^{o}$ arc to ranges of 2000 yd and 4000 yd, respectively. The salient meteorological variables, i.e., wind speed, direction, air temperature, and lateral and vertical gustiness, were measured at a number of heights during the period of each experiment.

## 2. EXPERIMENTAL PROCEDURES

### 2.1 The Petrol Fire System

From discussions at the Fire Research Station, Boreham Wood, Hertfordshire, it was ascertained that in a petrol fire above a large area of fuel, the maximum temperature reached is about $1100^{o}C$ and that in such a fire the temperatures are relatively stable. This peak temperature represents a balance between heat from combustion and loss by radiation. Small unconfined petrol fires exhibit large temperature fluctuations due to the wind. Therefore, it was decided to experiment

with a small petrol fire confined within a chimney. It was anticipated that such a fire would be stable and represent a section of a large fire. Some evidence on the first point was provided in a Fire Research Station report [1].

After some preliminary experiments the system shown in Figure 1 was constructed. The chimney was 11 ft high and 4 ft square with an air gap all round at the base. Petrol was allowed to flow into the steel tray at such a rate that the level in the tray remained approximately constant and steady burning conditions were established. The nature of the fire, whether it burnt clear or gave a smokey plume, was determined by this air gap and in practice a height of 12 in. was found to be satisfactory. The emission of some smoke was found to be an advantage as it permitted the track of the plume across the array to be readily observed. Typical photographs of the emission during the experiments are shown in Figure 2. The temperatures at selected points along the vertical axis of the fire were measured by chromel-alumel thermocouples. Ten such thermocouples were used and a continuous record obtained with an ARL type galvanometer recorder. A typical temperature profile is given in Figure 3. It is seen that the temperature range within the fire was about 800° - 1100°C. Screens were placed around the base of the chimney (see Figure 2) to reduce the effects of wind gustiness, which was the main cause of variation in the fire temperature. In the absence of screens the fluctuations in the temperature profile were much greater than those shown in Figure 3 (by the standard deviations). A fire of this kind could be maintained constant for an hour or more and a fuel consumption of about 60 gal/hr was found to be suitable. A section of a similar area of a large unconfined petrol fire reaching these temperatures would burn only about 10 gal/hr. The larger fuel consumption is reasonable because the heat losses by radiation and convection from the small system are greater than those from the inner zone of a large fire. From a comparison of the energy released by the combustion of the fuel and the temperature of the gases in the chimney it is found that only a small fraction of the oxygen available is removed by combustion processes. Therefore, lack of oxygen was not a controlling factor in the oxidation of the metal specimens.

The metal specimens, in the form of sheet or rod, were suspended in stainless steel baskets at selected heights in the chimney determined by the temperature at which oxidation was required. In all

experiments additional thermocouples were placed in contact with the specimens so that the temperature could be directly observed. The temperature could be adjusted to some extent by changing the petrol supply rate.

## 2.2 Apparatus for Sampling the Aerosol Cloud

The material dispersed downwind was sampled in the following ways:-

### 2.2.1 Airborne Concentration

Two types of apparatus were used to measure the airborne concentration. One of these was the cascade impactor which was modified so that the air leaving the last impaction stage passed through an Oxoid filter. (The Oxoid filter is a cellulose membrane whose collection efficiency remains almost 100% even at submicron sizes.) With the other apparatus a sample was obtained by drawing the air through an Oxoid filter mounted in a suitable holder, the air inlet of which is approximately isokinetic. Both types of equipment were suspended so that the air intakes were 5 ft above ground and were kept into the wind by means of vanes. Air was drawn through the samplers by suction pumps powered by 12 V batteries. The sampling rate for both instruments was about 15 litres/min. A typical sampling station is shown in Figure 4. In addition, cascade impactors were carried on the cables of two balloons at selected heights up to 300 ft and on four 30 ft high masts. This was done as a first attempt towards measuring the variation of airborne concentration with height. The height of 300 ft was the maximum attainable with the balloons available.

### 2.2.2 Material Deposited

In order to avoid the difficulties of analysing sand or earth samples for small quantities (generally less than 1 mg) of the metals used, the deposition of material from the cloud was studied by collecting samples on glass plates coated with a thin film of petroleum jelly. These were supported on tripods at a height of 3 ft above the ground. Two sizes of plate were used:-

one 9 in. by 3 in. and the other 12 in. square. The larger size was used at the greater ranges in order to obtain an adequate sample for analysis. The ground over which the experiments were conducted was covered to a considerable extent with low scrub about 1 ft high, but with the plates at a height of 3 ft it was considered that the local influence of this vegetation on the distribution of particulate material would be largely avoided.

In the case of plutonium the specific activity is great enough to permit a survey of the contaminated area with a survey meter using either an $\alpha$ probe or a probe which responded to its 17 keV X-ray emission.

## 2.3 The Sampling Array

The array of sampling devices was in the form of straight lines across wind at selected ranges to cover a $90^{o}$ arc. The actual arrays are shown in Figures 15, 16, 20 and 21. It was found to be practicable to set out an array, including tripods, batteries and pumps, in about 6 - 8 hr provided all preparations, including loading the equipment into vehicles, had been completed the day before. With everything ready by mid-afternoon, there was sufficient time to perform the experiment and switch off all electrical equipment before dusk. The samples were collected during the next day. The cascade impactor samples were unlikely to have been affected by this delay, but the deposition collector plates may have collected some additional deposit over this relatively long period.

The direction chosen for the axis of the array was restricted to one of the eight major points of the compass because a square grid of points had been marked out on the ground by survey and at any range a line of sampling devices along a direction approximately normal to the mean wind direction was required. Therefore, any attempt to place the sampling stations on lines other than along or at $45^{o}$ to this grid would have meant additional survey and time was not available for this. This practice proved to be somewhat inflexible. For example, if a wind direction of $160^{o}$ east of north was predicted, then the possible directions for the axis of the array were $135^{o}$ and $180^{o}$. If $180^{o}$ were chosen and the actual wind direction was $145^{o}$, then the experiment had to be delayed whilst part of the array was moved. This involved moving sampling devices and tripods and re-siting them.

## 2.4 Analysis of Samples

The number of samples for analysis from each experiment was about 720, i.e., 600 from the cascade impactors and 120 deposition samples. Hence, the total number of samples for analysis from the six experiments was about 4000. This meant that the techniques had to be kept as simple, and the number of manipulations required for each process as few, as was commensurate with a reasonable degree of accuracy.

In the case of both plutonium and uranium it was decided to use the radioactivity as a means of estimation, so that the problem became one of mounting the specimens for α counting. For the cascade impactor samples, which were on glass discs, it was found to be practicable to mount these on a counting tray. For transit from Maralinga each impaction disc had been covered by a second one. These were parted and the two placed with the activity uppermost on a counting tray. The residual petroleum jelly was burnt off in an oven at about 200°C, it having been previously determined that the process did not give rise to any losses. Each sample was then ready for counting. As an independent check, a number of the uranium samples were analysed subsequently by the fluorimetric method. Good agreement between the two methods was obtained. The Oxoid filters were counted directly.

Each deposition sample consisted of a paper tissue with which the film of petroleum jelly carrying the deposited oxide was removed from the glass plate. The petroleum jelly was found to harden and came away readily from the glass plate if the tissue drawn across the surface was wrapped around a straight-edge. The method used to prepare these samples was as follows:-

The paper and petroleum jelly were destroyed by charring in a furnace at 600°C for 30 min. Residual organic material was removed by treatment with perchloric/nitric acid mixture. In the case of uranium this brought the oxide into solution. The residue from the acid treatment was dissolved in 5N nitric acid, any silica was removed by centrifuging and an aliquot mounted on an aluminium tray for counting. It was found that the perchloric/nitric acid treatment did not dissolve the $PuO_2$ and the residue was fused with potassium bisulphate at 500°C for 2 hr [2]. The fused residue was dissolved in water, traces of silica were removed by centrifuging and a sample was prepared for counting. The recovery of

uranium was found to be 94 ± 2% and of plutonium, 47 ± 5%. The low recovery for plutonium was accepted only after a set of calibration experiments had shown in to be reproducible.

The analysis of samples containing microgram quantities of beryllium proved to be a lengthy task and one requiring considerable skill. The method employed was rather more complicated than that used for plutonium and uranium. Essentially the same method was used for both cascade impactor and deposition samples: the organic material was destroyed by a perchloric/nitric acid treatment, preceeded by charring if necessary. Interfering ions were removed by a CG400 resin column and by extraction with EDTA. Beryllium is extracted as the acetyl acetonate in chloroform and determined by the absorption at 2950 Å using a spectrophotometer.

## 2.5 Meteorological Measurements

These measurements fall into two groups. The first, of the more conventional kind, i.e., wind speed and direction at heights of interest, was made by the Australian Meterological Service team, using free balloon ascents of which 4 or 5 were made during the course of each experiment. The weather forecast, particularly wind direction and speed, was also provided by this team. The second group consisted of the measurement of wind speed, air temperature and turbulence at selected heights up to 300 ft by means of equipment based on a CDEE, Porton design [3].

### 2.5.1 Measurement of Turbulence

Any attempt to understand and to treat theoretically the dispersion of particulate material in the atmosphere must take into account the fluctuations in the wind velocity. The time scale of these fluctuations can be very wide so that in an experiment the period of emission will determine the extent to which the plume is spread normal to the mean wind direction. These fluctuations are a manifestation of the turbulent mixing process. The simplest requirement is to make measurements of the instantaneous wind speed along three mutually perpendicular directions. Experimentally this is difficult to do. However, in the case of an experiment in which the mean wind direction is sensibly constant the variation in wind speed in this direction will be

of minor importance when compared with the components normal to this direction. Therefore, measurement of the instantaneous vertical and lateral components of wind speed can be made by determining the angle between the mean wind and the instantaneous and the mean wind directions in the vertical and horizontal planes.

In the type of instrument developed at CDEE, Porton, the instantaneous direction is given by a light vane coupled to a micro-torque potentiometer. In the vertical plane the angle $\theta$ is measured about the horizontal, whereas in the horizontal plane the mean wind direction has to be arbitrarily selected. By using a high speed spark recorder two readings per second are obtained. If $\omega'$ is the instantaneous value of the vertical speed, $\bar{u}$ is the mean wind speed in a horizontal direction and $\theta'_z$ the instantaneous value of the angle, then

$$\frac{\omega'}{\bar{u}} = \tan \theta'_z \sim \theta'_z.$$

The RMS average value of $\theta'_z$ may be obtained by summation $\left(\sqrt{\frac{\Sigma_m \theta'^2_z}{m}}\right)$ or by assuming a normal error distribution about the horizontal and plotting the cumulative fluctuations (as fractions of the total) against the fluctuation magnitude and position on arithmetic probability paper. The second method also gives the mean wind direction: this property was of most value in the evaluation of the fluctuations in the horizontal plane, but did show the mean wind to be horizontal in the vertical plane. In our experiments both methods led to the same numerical value, which will be denoted by $\sigma_z$, but the second method was used to obtain the mean wind direction. The eddy diffusion coefficient, $C_z$, defined by Sutton is given by

$$C_z^2 = \frac{4N^n}{(1-n)(2-n)\bar{u}^n}\left(\frac{\omega'^2}{\bar{u}^2}\right)^{1-n} = \frac{4N^n\theta_z^{2(1-n)}}{(1-n)(2-n)\bar{u}^n},$$

where N is a macro-viscosity, the value of which depends on the roughness of the ground, and a reasonable value is $10^2$ cm$^2$ sec$^{-1}$; and n is a number related to the diffusing power of turbulence. For

zero temperature gradient conditions n is given the value 0.25. If these values are inserted in the equation for $C_z$, we have

$$C_z \approx \frac{\bar{\theta}^{\frac{1-n}{2}}}{\bar{u}^{n/2}} = \frac{\sigma_z^{1-n}}{\bar{u}^{n/2}} .$$

The lateral fluctuations $\sigma_y$, $C_y$, were examined in the same way.

Although these field experiments were largely exploratory in nature and were not designed as a study in aerosol diffusion, it was intended that the results should be examined for the effects of atmospheric turbulence. Hence the need to make these rather elaborate measurements.

## 2.6 Comments on the Performance of the Equipment

It was not surprising that some of the equipment and apparatus proved to be less satisfactory on the range than had been hoped. The conditions were severe and often there was inadequate time to make the same careful adjustments as were possible in the laboratory. However, it was found to be practicable to move part of the array at short notice, and quite quickly, so that the equipment was reasonably satisfactory from this aspect. To simplify this procedure and to reduce the amount of rough handling to which instruments would be subject during such a change in array, there need to be tripods and stands at all sampling sites so that the devices only need be moved. The towers and balloons could not be moved quickly so that it proved possible to use two of each on only four of the six experiments. Improvements in both these systems were made during the course of the trials.

The simple device designed to obtain a single sample failed because the deposit on the Oxoid filter was shaken off during transport on the range. Fortunately, these instruments were placed at the same stations as the cascade impactors and, at an early stage in the analysis of samples, it was found that the amount on the filter from these samplers was about the same as that on the same type of filter in the last stage of the cascade impactor at the same site. In these circumstances all these samples were discarded.

# 3. DETAIL OF EXPERIMENTS AND RESIDUAL MATERIALS LEFT AT SOURCE

## 3.1 General

A total of six experiments, two each with plutonium, uranium and beryllium, were carried out in which a metal specimen was

oxidised at a selected zone in the fire system already described. The duration of each experiment was about 30 min, which is the maximum period the wind could be expected to remain reasonably constant in direction. The weather conditions selected for each experiment corresponded approximately to zero temperature gradient or average conditions, but this, together with a suitable wind velocity, was not easy to realise from a forecast. Dispersion on the range site was restricted to a sector of - 90° through north to + 180° and because winds appropriate in direction to this, admittedly wide angle, occurred (during daylight hours) only about once in 7 days, it was not practicable to limit the weather conditions too severely. It was observed that the smoke plume from the fire rose steadily as it travelled downwind reaching about 200 ft at 500 yd after which the ascent ceased.

### 3.2 Plutonium

The amount of plutonium metal used in each experiment was about 200 g in the form of a rod some 3 in. long. The conditions for oxidation were made quite different in the two experiments in order to obtain the maximum amount of information on the effect of rate of heating and temperature on the fraction dispersed.

In the first experiment the plutonium specimen (2 03 g) was placed at a position in the chimney where the fire temperature would be expected to be about 850°C. The fire was established as quickly as possible, the temperature of the metal rose to about 860°C in 10 min and remained at approximately this temperature for about 23 min. The record of sample temperature against time is shown in Figure 5. After cooling, it was found that the specimen was little changed in shape and was covered with a hard layer, which was assumed to be oxide. Its weight was 176.5 g and a total of 37 g of fragments were collected in a tray which had been placed for this purpose below the basket containing the metal sample. Thus, only a very small fraction of the sample had been dispersed downwind. An estimate, obtained by chipping the oxide layer away from the residual metal, suggests that the main residue consisted of about 114 g metal and 62 g oxide. If all the fragments collected were oxide (although there were, in fact, traces of iron oxide flakes from the chimney and of sand) the amount remaining corresponded to 201 g of metal. Thus this assessment suggests that 1% of the metal sample was dispersed by the fire from the chimney over a total period of about 30 min.

In the second experiment the temperature of the metal specimen was raised slowly to about 500°C over a period of about 50 min (i.e., at about 10°C/min). At this temperature the onset of rapid oxidation was indicated by a rapid rise in temperature of the metal above the temperature of the fire. This agreed with earlier laboratory experiments and is shown in the temperature versus time record for the experiment given in Figure 6. The temperature of the fire around the sample was then reduced somewhat, by cutting back the fuel supply, so that oxidation should proceed without additional heating. However, it was important to maintain an up-draught through the chimney to ensure the dispersion of finely divided oxide. It was found that the initial temperature rise of the sample continued for about 20 min, and the maximum temperature was 725°C. Some 6 min later the temperature had fallen to 610°C at which it remained constant until the end of the experiment. It was found that the metal had been converted almost completely into a mass of oxide fragments. Some of these appear as needle shaped crystals. The weight of oxide recovered from the chimney was 222.2 g equivalent to 195.8 g of metal. The initial weight of the sample was 202.4 g, so that the amount dispersed was about 7 g. However, this material was not recovered until 2 days after the experiment and there was some dispersal of plutonium by the wind during the intervening period. This was confirmed by the surveys of the contamination which were carried out immediately after the experiments and later. Thus, the amount dispersed during the experiment and over the subsequent period was about 3%. This is probably an upper limit because it proved to be impracticable to recover all the plutonium debris from the fire system.

The particle size distributions for the $PuO_2$ residues collected in the tray sited beneath the specimen were determined by sieving. The results from both experiments are shown in Figure 7. It is seen that the residual material is quite coarse with a mass median size approaching 1 mm.

### 3.3 Uranium

The uranium metal samples were in the form of five sheets (of dimensions about 6 in. × 4 in. × 0.0625 in.) with a total weight of about 2400 g. This form was selected in order to obtain an adequate rate of oxidation (order of $g/cm^2$ /hr) and hence, of particulate dispersal, over the planned experimental period of about 30 min. The temperature of the fire zone in which the metal sample was placed was 1050°C, in both experiments.

In the first experiment a complete specimen temperature versus time record was not obtained. The temperature of the metal rose rapidly to above the melting point and after 15 min fell to the normal fire temperature. There was some evidence that the thermocouple had separated from the metal.

In the second experiment a complete temperature versus time record was obtained; this is shown in Figure 8. The metal temperature rose rapidly to about 1350°C in about 3 min and remained above the melting point for about 7 min. Subsequently it fell to, and remained in the region of, 1050° - 1100°C over the period 10 - 27 min after the start. The fire was then switched off, the temperature of the metal fell to about 500°C and remained at about this temperature for longer than an hour. The total operation time of the recorder was 72 min so that beyond this time there is no record of the temperature, but experience suggests that the oxidation of the uranium would have gone more or less to completion. In fact about 300 g of metal remained unoxidised. Thus, although emission from the fire would have taken place during the first 30 min period, oxidation proceeded to completion over a longer period, during which time some particulate material may have been dispersed. The cascade impactors were switched off over the subsequent 2 hr, but the deposition collector plates, more particularly those close in, could have accumulated uranium oxide over a much longer period.

The material recovered from the chimney was found to contain both oxide and metal. The size distributions are shown in Figure 9 and are seen to be similar. The curvature exhibited by both plots for sizes smaller than 100 μ may correspond to the depletion of the smaller sizes through dispersal. If 10% of the total mass is assumed to be in sizes lost in this way and the curves are shifted accordingly, a linear log-normal probability relation is obtained.

By collecting all the oxide together, including some which had to be scraped off the residual metal and from the basket and petrol tray, it was possible to obtain a crude estimate of the amount dispersed from the chimney. These results are given in Table 1. The accuracy of these estimates of the amounts dispersed is not very high. It is considered impracticable to carry out a sample analysis which would give a more realistic value or to obtain a quantitative recovery of the uranium metal.

### 3.4 Beryllium

The beryllium metal samples were in the form of 20 sheets (6 in. × 4 in. × 0.090 in.) of total weight about 1½ kg. They were placed in a zone in the fire in which the temperature was about 1080°C. The temperature versus time records are shown in Figures 10 and 11. The oxidation reaction took place without any marked increase in temperature of the metal above that of the fire. It was found that the oxidised sheets retained their original shape, but could be broken easily by hand (see Figure 12). Because beryllium has a low atomic weight, it is not possible to estimate, even crudely, the fraction which may have been dispersed from the initial and final weight, because oxidation was not complete. It appears likely that a small fraction was dispersed because the inside of the chimney was found to be coated with a white deposit. The airborne concentration in the chimney during the recovery of the material was 10 $\mu g/m^3$.

In a third experiment plates were placed in the fire in regions where the temperatures were in the range 600° - 950°C in an attempt to determine whether or not there was a temperature at which oxidation was rapid and perhaps self-sustaining. It is known from general experience with the oxidation of metal surfaces that a rapidly formed layer of oxide may preclude or slow down markedly further oxidation. However, it was found that the metal specimens remained at sensibly the temperature of the surrounding fire. The rate of oxidation increased steadily with temperature. A plot of the oxidation rate against 1/T is shown in Figure 13.

## 4. RESULTS OBTAINED FROM THE ARRAY OF SAMPLING STATIONS

### 4.1 Plutonium: Air Concentration

The results obtained with the cascade impactors are summarised in Tables 2 and 3. Plutonium was found on the impactors out to a range of 2000 yd from the fire. It was found to be distributed, rather unevenly, across the entire array and some was probably dispersed outside the array and not sampled at all. The amounts detected were very small, except at 200 yd during the first experiment. It is known from laboratory experiments that the mass median sizes for stages 2, 3 and 4 of the impactor are about 4, 1.3 and 0.5 μ respectively. The masses

of spherical particles of these diameters are 390, 13 and 0.75 μμg, respectively. Inspection of the results shows that for many of the samples, particularly those from stages 1 and 2, the amount of material on a stage is markedly less than the amount required for one particle of mass median size. It has been found by auto-radiography of a selected set of samples that the activity is contained in one or a very few particles. Thus, the airborne concentration was too small to permit a size distribution to be obtained. However, there is a very clear indication that, in effect, all the material was in the hazardous size range from the aspect of inhalation at ranges beyond 200 yd. If the samples obtained by the cascade impactors in the first experiment at 200 yd are assumed to represent the hazard at this range, it is seen that the maximum total amount collected on stages 2 - 5 is about 240 μμc (station No. 2). This amount, if inhaled, would result in a dose of about 40 mrem to the lungs.

The effect of the up-draught through the chimney on the amount of relatively coarse material dispersed is shown by the much greater activity at 200 yd in the case of the first experiment than in the second. At 500 yd and beyond, the average sizes for the cascade impactor samples are very similar from both experiments. This result suggested that the total amount of the fine particulate released was about the same in the two experiments.

The distribution observed in the airborne concentration across the array at all ranges suggests that the rate of emission of material from the fire may have been very approximately constant, except for the effects of wind gustiness on the temperature profile and turbulence within the fire; it certainly did not occur only at particular times such as the beginning or the end. This is not an unexpected result and it is found from a comparison of the temperature versus time records, the fluctuations in wind direction, and both the airborne and deposition sample results, that there is no marked correlation between the stage of oxidation and dispersal. The simplest way of assessing the results is to determine how the average cross-wind sample for any particular range decreases with increasing range. This form of presentation is shown in Figure 14. In the first experiment the metal was heated rapidly to about 850°C and the specimen was found at the end to have retained its original shape and to be encased in a hard layer of oxide. Therefore, it is probable that the bulk of the particulate emission which occurred took place early in the experiment or when the specimen experienced a rapid temperature change: one such temperature change occurred half way through the

experiment. The cascade impactor results for 200 yd suggest two puffs, one approximately along the mean wind direction and one somewhat to the south. The wind records show that the second one could have occurred at about half-way through the experiment at which period the temperature of the specimen, having fallen steadily to about 730°C, rose sharply to 850°C. However, only the plume along the mean wind direction is discernible at 500 yd and at greater ranges the results are approximately uniform across the entire array. In the case of the second experiment the most marked temperature change occurred shortly after the metal temperature reached 500°C when it rose steeply to 725°C followed by cooling to 600°C, but no well defined plumes are indicated at any range by the results. Again, this may have been due to the reduction in fire temperature and associated up-draught.

### 4.2 Plutonium: Deposited Material

Satisfactory analytical results were obtained only for the samples from beyond 500 yd from the first experiment and for all those from the second experiment. These are summarised in Tables 4 and 5. The activity was found to be distributed across the whole array in a similar manner to the air concentrations although there is no simple relationship between the amounts measured by impactor and deposition plate, at individual sites. This is not a particularly surprising result in view of the small amount of activity dispersed and the very small particle sizes present in the samples of airborne material obtained at the ranges (200, 500 and 1000 yd) at which both kinds of sampling were carried out. Further, the somewhat intermittent nature of the source, which is demonstrated by the samples of airborne material, was also shown by the patchy nature of the contamination on the ground.

In addition to the samples obtained on the glass plates, surveys of the contaminated areas were carried out after each experiment. In this way a record of the deposition after the first experiment is available. The surveys are shown in Figures 15 and 16. The deposition from the second experiment was overlaid on the residual contamination from the first. However, the level of deposition was much higher on the second occasion, so that except for the area within about 20 yd of the fire, the correction is negligible. The survey after the second experiment was repeated 12 days later. During this period strong winds (20 - 30 m.p.h.) blew from the south-west for about 3 days. This second survey showed that some residual activity in the chimney and tray had been dispersed by the south-westerly wind. The original area was essentially unchanged.

## 4.3 Uranium: Air Concentrations

The results obtained with the cascade impactors are summarised in Tables 6 and 7. As in the experiments with plutonium, uranium was found to have been dispersed across the whole 90° arc of the array and probably outside it. To some extent the variation in sample sizes across the array at any one range is less pronounced than that observed with the plutonium oxide samples, but the more important difference is that the mass of uranium dispersed is clearly much greater. Thus, at 500 yd the average cascade impactor total sample was about 10 µg for plutonium and about 0.3 µg for uranium. The decrease of average sample with range is shown in Figure 17. The quantities measured on each stage are adequate to permit the particle size distributions to be estimated. These are shown in Figure 18 from which it is seen that the airborne material beyond 100 yd from the source was of essentially the same particle size distribution in both experiments. About 50% of the uranium oxide particles are smaller than 3 µ in diameter and this fraction would constitute the inhalation hazard. The average value at 100 yd was about 1.5 µg and at 200 yd about 0.5 µg (see Figure 17).

## 4.4 Uranium: Deposited Material

The results obtained by the analysis of the samples collected on the deposition plates are summarised in Tables 8 and 9. In the case of the first experiment, the cross-wind profile of the contamination density (µg/m²) shows a distinct axial peak out to about 100 yd. If these results are plotted in a cumulative fashion on arithmetic probability paper, a set of straight lines is obtained (see Figure 19) which confirm that cross-wind profile follows the normal error law. The standard deviations correspond closely to the standard deviation found for the lateral fluctuations in wind direction. However, at ranges beyond 100 yd, this distribution disappears and material appears to be more or less evenly spread across the entire array. In the second experiment the close-in region of contamination indicates two areas with marked cross-wind profiles and as a result the effect is not so clearly defined as in the earlier experiment.

With natural uranium at the levels of contamination observed, a field survey of the contamination is not possible. Therefore, the contamination contours have been constructed from the deposition sample data alone. These are shown in Figures 20, 21(a) and 21(b).

## 4.5 Samples of Airborne Material Collected at Heights of 30 - 300 ft

As described in the experimental procedures, an attempt was made to obtain some indication of the distribution of airborne activity with height. Good results were obtained from the second plutonium experiment, both uranium experiments and possibly the second beryllium experiment. The results are summarised in Table 10. It is seen that, in the first three cases at least, material was distributed more or less uniformly with height up to 300 ft at the range (500 yd) at which these measurements were made. From the results of the uranium experiments, the particle size distributions can be estimated and these are included in Figure 18. The average size distribution corresponds closely to those observed with samples collected near the ground. These results indicate clearly that material of this kind will be swept at least to these heights by the up-draughts from a fire.

## 4.6 Beryllium Experiments

Because the analysis of samples for beryllium takes much longer than for uranium and plutonium, it has proved practicable to complete at this time the assay of only a small fraction of all the samples collected. However, the appearance of the residual material at the source suggested that only a small fraction was likely to have been dispersed and this conclusion has been borne out by the measured levels of deposition. The results are summarised in Table 11. The average levels of contamination at 20, 50 and 100 yd were 33, 5.2 and 4.9 $\mu g/m^2$, respectively. At 500 yd the mean of four samples analysed is 4.3 $\mu g/m^2$. Of eight cascade impactor samples analysed, six were smaller than 0.1 $\mu g$. In the experiments with uranium, the deposition levels out to 100 yd down-wind were mostly in the range 100 - 10000 $\mu g/m^2$ and for plutonium the corresponding range of contamination levels was 10 - 1500 $\mu g/m^2$. It is seen that probably less material was dispersed in the beryllium experiments than was the case with either plutonium or uranium.

## 4.7 Meteorological Observations

The meteorological observations made are summarised in Table 12. These data are averaged over the time for which the fire system was in operation. Although the actual measurements were

numerous, it is, nevertheless, clear that relationships such as temperature and wind profiles with height, and wind direction with height were not measured in the detail and to the accuracy which is needed in experiments of this kind. Thus, the lateral wind fluctuations measured at 30 ft do not account for the observed spread of material across the 90° arc of the array. In most cases the maximum wind fluctuations are less than 45°, the exception being the second experiment with plutonium. Both lateral and vertical fluctuations in wind direction were found to be distributed normally about the mean wind direction and the horizontal, respectively (see Figure 22). The period of combustion was about 30 min and in this time the plume of hot gases and particulate material from the fire would be markedly affected by the larger eddies. The sampling period was always larger than the duration of the fire. It is well established that with a steady emission and a brief sampling period of about 3 min, a maximum airborne concentration is observed in the mean wind direction, but that as the sampling time increases this maximum becomes less marked. With a buoyant plume rising to several hundred feet, any wind shear over this height will also play a part in making the distribution approximately uniform over a considerable arc about the mean wind direction.

## 5. DISCUSSION

The experimental results give a clear indication of the order of magnitude of the average airborne concentrations and contamination levels which are likely to be produced down-wind of a petrol fire in which plutonium, uranium or beryllium is involved. Also, it is possible to estimate the total amount of material dispersed from the fire and the fraction which would be in the hazardous size range from the aspect of inhalation.

The object of the experiments was to obtain a measure of the hazard which could arise if any of these metals were involved in a fire, rather than to obtain data for a theoretical study of aerosol diffusion. Naturally, the second possibility might have been realised if the emission of particulate material had been steady and the wind conditions sufficiently stable. The results show that this was not the case. However, it is possible to examine the results in the light of Sutton's theory of eddy diffusion.

A check of the results from any one experiment may be made by estimating the total amount of material dispersed. A second method is to assume that the rate of deposition is related to the airborne concen-

tration by a deposition velocity. Although attractive in its apparent simplicity, this latter method can be difficult to apply because when the aerosol contains a wide range of particle sizes, the rate of deposition of material will be determined by the larger sizes and not by the mass median size. Moreover, the cascade impactor does not provide a representative sample of the coarser material, i.e., diameter greater than 20 μ.

For a continuous point source at height, h, the concentration, x(x,y,z) (units /m$^3$), at a position x,y,z downwind is given, according to the theory of Sutton [4] by

$$\chi(x,y,z) = \frac{Q}{\pi C_y C_z u x^{2-n}} \exp\left[-\frac{y^2}{C_y{}^2 x^{2-n}}\right]\left\{\exp\left[-\frac{(z-h)^2}{C_z{}^2 x^{2-n}}\right]\right. \quad \ldots.(1)$$

$$\left. + \exp\left[-\frac{(z+h)^2}{C_z{}^2 x^{2-n}}\right]\right\},$$

where Q is the rate of emission in units/sec, u is the wind speed m/sec, $C_y$ and $C_z$ are the eddy diffusion coefficients and n is the number describing the effect of atmospheric turbulence on diffusion. It is customary to assume the cloud is of finite width with a concentration at the edge equal to 0.1 the axial value. Making this assumption, the average value of the concentration $\bar{x}$ is given approximately by

$$\chi(x,y,z) \simeq \frac{Q}{3\pi^{1/2} C_y C_z u x^{2-n}} \left\{\exp\left[-\frac{(z-h)^2}{C_z{}^2 x^{2-n}}\right]\right. \quad \ldots.(2)$$

$$\left. + \exp\left[-\frac{(z+h)^2}{C_z{}^2 x^{2-n}}\right]\right\}.$$

Equations (1) and (2) are applicable only in the absence of deposition. Modified relationships to take deposition in account have been derived [5] [6], but will not be quoted here because it has been found that the experimental data are inadequate to permit their application. By suitable integration, equation (1) will give the down-wind concentration due to a horizontal or vertical line source, or an area source. The latter form is suggested by some of the results.

More recent studies by Pasquill [7] and by Hay and Smith [8] have led to a relationship of the form:-

$$\frac{d\sigma_c}{dx} \approx \frac{2}{3}\beta i^2 \qquad \ldots.(3)$$

in which $\sigma_c$ is the standard deviation of the crosswind profile of the aerosol cloud (assumed Gaussian), $i^2$ is the intensity of turbulence (and is equal to the variance of the wind fluctuations) and $\beta$ is a constant which relates the Langrangian and Eulerian time scales of the turbulence and has a value of about 4.[9]. The values of $i^2$ were determined by the gustiness measurements but the expected Gaussian crosswind distributions of the aerosol concentrations were not realised.

Inspection of the cascade impactor and deposition samples shows that in most cases the material was dispersed across the entire $90^o$ arc of the array, and even beyond, in a rather random fashion. The cross-wind profile which would be expected from equations (1) and (3) was observed clearly in the deposition produced from the first experiment with uranium out to about 100 yd. The widespread distribution of particulate material from the fire appears to have been due to the effects of gustiness on the fire itself. It is well known that a change in temperature can cause an oxide layer to break away from a metal surface and a release of oxide particulate probably occurred as the result of temperature fluctuations in the flame zone in the vicinity of the metal. This effect would be expected to be most pronounced for the extreme lateral fluctuations in wind direction so that the emission would be enhanced when these occurred. Any increase in turbulence within the chimney would have a similar effect. In these circumstances the normal Gaussian crosswind distribution of our concentration and deposition would not be observed. This effect would be realised, perhaps to an even greater extent, in the dispersion from an unconfined fire. Thus, the only practicable way of treating the results was to determine average values for either the cascade impactor or deposition samples for each of the nominal ranges. Mean values for the ranges were also determined from the known geometry of the array. The meaning which may be attached to an average value of this kind is determined largely by the associated estimate of variance. If the material were dispersed uniformly across the array at any selected range, then the error in each separate measurement would be the sum of the errors due to physical and chemical manipulation of the sample during analysis and the error in counting at the end point.

The error in the mean would be given by $\sqrt{\frac{\Sigma_n (\bar{x} - x_i)^2}{n(n-1)}}$

the standard error of the mean. However, if the material were randomly distributed across the array, it would be more appropriate to employ the standard deviation as the measure of spread in a particular set of results. It is also of interest to examine, in addition, the standard deviation applicable to the mean value due to counting statistics. The results of examining the data in these three ways are shown in the tabulated experimental results. In the subsequent evaluation of the results the standard error of the mean will be used to illustrate the likely range in which the true value would be. This is assumed to be a reasonable mode of examination of the data because the wind direction varied continuously and randomly across the array and there is no real indication that the emission, although only approximately uniform, occurred spasmodically - or at particular periods of the experiment.

The results obtained for some cascade impactors are peculiar in the sense that there is variation between the amounts found on the five stages. Generally, the graduation from stage to stage is found to be regular. Examination of the experimental procedures from handling in the field, through transportation to analysis does not suggest any reason to seriously doubt the results. In many cases it is likely to be due simply to counting statistics. Certain results, e.g., Table 3, range 500 yd, are clearly anomalous and are not understood. (Cross contamination between instruments is not a likely explanation.) However, the anomalous readings are few in number and have been discarded.

Before attempting to analyse the airborne and deposition sample data it is worthwhile to examine the meteorological measurements. These, together with derived values for the eddy diffusion coefficients, are summarised in Table 12. The turbulence coefficients $C_y$ and $C_z$ have been calculated by using the formula suggested by Sutton [3] , on the assumption that $n = 0.25$. The parameter n is defined by

$$\frac{u_2}{u_1} = \left(\frac{z_2}{z_1}\right)^{\frac{n}{2-n}},$$

where $u_1$ and $u_2$ are mean wind speeds at two heights, $z_1$ and $z_2$. From the measured values for $\bar{u}$ at heights up to 300 ft it is possible to estimate n directly. It is found that $n \sim 0.1$ for the two plutonium experiments and $\sim 0.2$ for those with uranium. Thus, in the latter case, the measured value of n is close to that suggested by Sutton for zero

temperature gradient or average conditions. By contrast the plutonium experiments were carried out under conditions tending somewhat towards lapse. The average temperature gradients are in agreement with this assessment. Both gradients are incorporated in the Richardson's number, defined by

$$Ri = \frac{g\left(\frac{\partial \bar{T}}{\partial z} - T'\right)}{\bar{T}\left(\frac{\partial \bar{u}}{\partial z}\right)^2}$$

where $T'$ is the adiabatic lapse rate and is $\sim 1^{\circ}C/100$ m. $\bar{T}$ is the average temperature and g is the gravitational constant. For laminar flow $Ri > 1$, for turbulent flow $Ri < 1$ and for $Ri = 0$ zero temperature gradient conditions are obtained. In the case of the plutonium experiments the value of Ri are found to be - 2 and - 37 for the first and second experiments, respectively. For the uranium experiments, the corresponding values are about + 0.06 and 0.02. Thus, it is clear that the meteorological conditions existing during the plutonium experiments were tending towards lapse, whereas for the uranium experiments they were close to zero temperature gradient. The introduction of the observed values of n leads to no significant changes in the values for $C_y$ and $C_z$.

If all the results are viewed together it is seen that they form a definite pattern. The experimental observation (in the case of the uranium experiments), that the plume rose steadily during about the first 500 yd of travel down-wind to a height of about 200 ft and thereafter did not rise visibly, suggests that any comparison with eddy diffusion theory can only be made beyond this range. This observation is in qualitative agreement with the obserbed distribution with height at 500 yd. The data are scarce, but suggest strongly that the airborne concentration, as measured by cascade impactors, was roughly constant with height up to at least 300 ft. If it is assumed that the effects of plume buoyancy have died out at 500 yd range and the source may be regarded as a "wall" of finite width and height H, the concentration $\chi$ at distance x beyond 500 yd is given approximately by

$$\chi = \frac{2Q}{uC_z x^{1-\frac{n}{2}}} \int_0^H \exp\left[-\frac{h^2}{C_z^2 x^{2-n}}\right] dh,$$

where Q is in units/$m^2$/sec and the effect of finite width has been omitted. The dependence of $\chi$ on range is shown in Figures 14 and 17. In the case of the experiments with uranium the calculated curve is in good agreement with the observations although measurements did not extend far enough down-wind for a really satisfactory comparison to be made. The results from the plutonium experiments are not in agreement with the estimates made in this way unless the range for stabilisation is extended to about 1000 yd. This may not be an unreasonable assumption in view of the relatively greater degree of instability in the atmosphere. Unfortunately, no record of the visual observations made on these two experiments was kept.

The average deposition levels measured for each essentially cross-wind set of sampling stations are plotted against the actual mean ranges in Figures 23 and 24 for plutonium and uranium, respectively. In the case of the experiments with plutonium, the curve is complete for all ranges only for the second experiment. However, the limited data from the first experiment show a similar relationship. The "step" in the curve at the range interval 200 - 600 yd indicates the deposition of relatively coarse particulate from the plume which is not reflected in the cascade impactor samples. The decrease in slope of the curve beyond 1000 yd is in accord with the airborne sample data. The results for the two uranium experiments are different in that the deposition level shows a marked increase at about 1000 yd when compared with that in the region 200 - 600 yd. This is not shown by airborne sample data which suggest that this material was in the particle size range $> 20\mu$. In order to show such a pronounced peak at 1000 yd, the effective height of emission would be expected to have been about 150 ft, which is readily accounted for by the observed plume buoyancy. Again, such material would not have been adequately sampled by the balloon/tower borne cascade impactors. Integration of these average deposition level versus range curves leads to estimates of the total amounts deposited on the array.

$$\text{Total amount found on array} = \frac{\pi}{2} \int_0^x \bar{G}_x x . dx, \qquad \ldots.(3)$$

where $\bar{G}_x$ is the mean deposition level at range x and the deposit is assumed to cover a $90^o$ arc. These estimates are shown in Table 13.

From the detailed measurements of deposition it is possible to construct a set of fallout contours. These are shown in Figures 15, 16, 20 and 21, and it is clear that imagination has had to play a very con-

siderable part. Nevertheless, it is worthwhile to perform an integration to show that this interpretation of the results is not in gross disagreement with the other estimates of the total amount dispersed. The areas within the several contours which have been plotted were determined with a planimeter and a plot of area versus contamination level obtained (see Figures 25 and 26). This plot was augmented by values calculated from Figures 23 and 24. Then, for area dA lying between areas A and A + dA the contamination level is $G_A$ and the total amount is given by

$$\int_0^{A_T} G_A dA,$$

where $A_T$ is the area of the largest closed contour. These estimates are given in Table 13 and are seen to be in reasonable agreement with those obtained by the calculation used in equation (3).

In order to compare these estimates of the amount dispersed with those obtained by examination of the debris left at the source, it is necessary to take into account the general course of each experiment. Thus, the fraction of metal oxidised to loose oxide in the first experiment with plutonium was about 0.2, whereas in the second, oxidation was complete. The estimates of amounts dispersed which were obtained from examination of the debris left in the fire apparatus show that the quantities were small, of the order of a few grams, but do not define them more accurately. In both cases the material was dispersed mainly about the axis of the array. The values obtained by integration over the fallout field are likely to be more reliable and are in reasonable agreement with these other estimates. From the relative amounts of loose oxide formed in the two experiments it would be expected that the amount for the first experiment estimated from the second, for which the data is more complete, would be about 0.3 g which compares well with the estimated value of 0.2 g. It may be concluded that about 1% of the metal will be dispersed as oxide if combustion to loose oxide is complete. Certain features of the two uranium experiments were somewhat different from one another. In the first one about half the metal was oxidised to loose oxide, whereas in the second, oxidation was almost complete. In the first experiment deposition occurred close to the axis of the array at the closer ranges and subsequently spread out to cover the entire array. Hence, the two values for the amount dispersed about 80 g according to the residues, which may be a little low because of contamination with iron-oxide and sand, and the estimate of about 120 g from the observed deposition on the array,

are in reasonable agreement and indicate a value of about 100 g (4%) for the amount dispersed. In the second experiment, the residues suggest a value of 120 g dispersed, which is in agreement with the smaller value for the first experiment as oxidation was nearly complete. The amount found on the array was about 100 g and this value may be low because of dispersal outside the array which is suggested by the contour plot shown in Figure 21(a). The ratios of the estimates dispersed to the total quantities of oxide produced are 0.057 and 0.061 for the first and second experiments, respectively. Hence, the results of both experiments suggest that the amount of uranium dispersed was about 6% of the total oxidised.

If a complete record of the airborne material with height and across wind had been obtained (at 500 yd), then it would have been possible to estimate the amount available for deposition beyond this range and the total amount released. However, the experimental data are incomplete and only a crude estimate is possible. If the average airborne concentration is $\bar{\chi}$ and the air sampling rate through the cascade impactor is 15 litres/min, then the total sample collected at range x in t sec will be given by

$$A_x = 2.5 \times 10^{-4} t\bar{\chi}.$$

The total amount in the cloud at any range is given by

$$Q = \int\int \chi \bar{u}\, dy\, dz$$

and Qt the fraction of the total released and not deposited within the range of interest is given by

$$Qt = 4 \times 10^{3} \bar{u} \int_{0}^{H} \int_{y_1}^{y_2} A_x(y,z)\, dy\, dz.$$

If $A_x(y,z)$ is determined as a function of y and z, this integral can be evaluated. To use the data available it is necessary to assume $A_x$ is constant with height and across wind, so that the relationship becomes

$$Qt = 2 \times 10^{3} \pi \bar{u} H x A_x.$$

Estimates obtained in this way are given in Table 13.

The estimate of the total amount of airborne material at 500 yd for the second plutonium experiment is seen to be $7 \times 10^{-3}$ g or 0.0035% of the amount of metal coverted to oxide. In laboratory experiments [6] it was found that about 0.05% of the oxide formed was in the

size range ≤ 3 μ and such particulate material would be expected to be deposited only slowly during travel downwind: in fact, the observed deposition at the greater ranges 3000 and 4000 yd would be expected to be due to the finer particulate. If it is accepted that such material, which is formed in part by the break-up of the oxide on cooling, may not all have left the fire and some was deposited closer in than 500 yd, it appears that there is reasonable agreement between the laboratory and field experiments. The larger value of 0.05% is clearly a satisfactory safe value to use in estimation of the airborne hazard down-wind from a fire involving plutonium. The estimated values of Qt for the uranium experiments are considerably larger than the other estimates of the total amount dispersed. This shows that although material is distributed to heights about 300 ft and across the array, it is not a uniform distribution. This result was not unexpected.

The deposition velocity, $V_D$, is defined by the relationship

$$\text{Rate of deposition} = V_D \bar{\chi}.$$

The total sample collected at range x in t sec will be given by

$$A_x = 2.5 \times 10^{-4} t \bar{\chi}.$$

If the mean total deposition created over time t sec is $G_x$, then

$$V_D = 2.5 \times 10^{-2} \times \frac{G_x}{A_x} \text{ cm/sec.}$$

Values for $V_D$ calculated in this way are given in Table 14. In the case of the plutonium experiments the samples of airborne material were too small to represent correctly the airborne material, except for those obtained during the first experiment at 200 yd. In this latter case a velocity rather smaller than would be expected is obtained. For the uranium experiments there is reasonable agreement in some cases. The anomalous values, e.g., at 1000 yd for the first experiment, may well be due to the contribution to the deposition from coarse particles swept up on the buoyant plume which are not correctly sampled by the cascade impactor.

## 6. CONCLUSIONS

From the overall examination of the results it has been seen that they are consistent one with another. Both the experiments with uranium produced very similar airborne concentrations and comparable deposition patterns. The plutonium experiments, which were carried out under slightly more unstable meteorological conditions gave a similar result. All four experiments suggest that the plume of smoke, oxide particulate and hot gases rose steadily as it travelled downwind for 500 or even 1000 yd. At this sort of range the plutonium and uranium particulate material was dispersed to heights in excess of 300 ft and spread over an arc of $90^{o}$ or more.

The samples of airborne material collected by the cascade impactors indicate the level of dose which individuals would inhale if exposed to the cloud.

The maximum sample of airborne plutonium, 186.0 μμc, was collected during the first experiment at 200 yd. If the material collected on stages 2 - 5 of the impactor is regarded as that which would reach the lower respiratory tract and the lungs (of which about a quarter would be retained initially), then the peak value is about 240 μμc. At all other ranges the samples were much smaller than the few large samples collected at 200 yd. Thus, if for convenience the amount of plutonium is scaled to 1 kg, the maximum dose an individual would inhale is $1.2 \times 10^{3}$ μμc which would result in a dose of 0.2 rem to the lungs. Therefore, no significant inhalation hazard would be produced at 200 yd and beyond down-wind as the result of burning several kg of metal. The data suggests that at 100 yd range the amount might be ten times greater, but the objections to such an extrapolation are obvious

The experiments with natural uranium are of more interest if translated to apply to enriched uranium for which the specific activity is about 100 times greater. If this is done it is found that the maximum value at 100 yd (from 1 kg of metal) is about $10^{-4}$ μc which if inhaled would result is a dose of 5 mrem to the lungs.

Although only a small part of the samples collected during the experiments with beryllium has been analysed, the number of results is sufficient to show that only a very small fraction of the oxide formed during combustion is released in particulate form.

From the several estimates of the amounts of material deposited on the sampling array it may be concluded that up to about 1% was

dispersed from the fire in the case of plutonium, about 6% with uranium and less than 1.0% with beryllium.

From the data presented in Figures 25 and 26 it is found that the areas contaminated to a level of 1000 $\mu g/m^2$ or more per kg of metal oxidised would be about 2500 $m^2$ and about 800 $m^2$ for plutonium and uranium respectively. The difference appears to be due to the larger proportion of more finely divided oxide which was formed from uranium. Thus, in the oxide residues, the fractions smaller than 100 $\mu$ were about 20% and 5% for uranium and plutonium, respectively.

Although the results are insufficient to permit a full comparison with theory to be made, they are adequate to show general agreement. The four areas in which more detailed measurements are required are:-

(1) The distribution of airborne material close to the source in order to understand the initial rise of the buoyant plume.

(2) The distribution of airborne material with height.

(3) The air concentration at ranges beyond 2000 yd where the effects of the plume buoyancy are expected to disappear.

(4) A more uniform coverage of deposition samples to permit a more accurate definition of contamination contours.

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Major W. G. McDougall:
Major J. McLean: Deputy team leaders and responsible for overall organisation of activities at different times.

Mr. E. J. Chatfield: Responsible for the design and operation of the controlled petrol fire and for the temperature measurements.

| | |
|---|---|
| Mr. R. F. Carter: | Responsible for air sampling devices and health physics. |
| Mr. J. R. Harvey:<br>Mr. A. Robson: | Analysis of micro-meteolorogy records and estimation of fallout contours. |
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| Mr. H. L. Green )<br>Mr. P. G. Manning) | Analysis of samples at Maralinga. |
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| Mr. S. T. Brown )<br>Mr. E. W. Pollard ) | Photography. |
| Mr. R. Acaster )<br>Mr. D. J. Britton ) | General operations. |

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TABLE 1

Estimate of Amount of Uranium Dispersed

| Nature of Material | Experiment | |
|---|---|---|
| | No. 1 | No. 2 |
| Initial Mass of Uranium, g | 2394 | 2408 |
| Mass of Metal Recovered (The surface was partially oxidised so these values may be slightly high), g | 1036 | 352 |
| Mass of Oxide (Expressed as metal) recovered from basket and petrol tray (this may have contained some iron oxide), g | 1280 | 1930 |
| Mass of Uranium Dispersed, g | 78 | 126 |

Closure status
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TABLE 2

Analysis of Cascade Impactor Samples (Results in mμc) 1st Plutonium Experiment

| Lane | | Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | Totals | Mean | SE of Mean | Standard Deviation | Estimate of Inherent SD Due to Counting Statistics | Average Air Concentration in Lms in mμc. sec/ft³ per kg of Metal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 yd | STAGE | 1 | 0.048 | 752 | | 711 | 1850 | 0.085 | 13.2 | 518 | 1510 | 15.3 | 97.0 | 0.150 | 0.123 | 3.68 | 0 | 0.038 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.076 | 0 | | | | | | | | | 5467.7 | 248.5 | | | | |
| | | 2 | 0.014 | 181 | 0.009 | 5.16 | 0.918 | 6.73 | 91.7 | 71.6 | 19.3 | 0.147 | 0 | 0.116 | | | | | | | | | | | | | | | | | | | | | 377.4 | 17.15 | | | | |
| | | 3 | 1.04 | 56.4 | 0.082 | 2.55 | 1.66 | 3.35 | 14.2 | 63.9 | 5.5 | 0 | 0 | 0 | | | | 0.053 | 0.014 | 0.065 | 0.170 | 0.138 | 0.266 | 0.008 | 0 | 0 | 0 | | | | | | | | | 149.5 | 6.80 | | | | |
| | | 4 | 0.043 | 1.02 | 0 | 0.254 | 0.111 | 0.049 | 0.047 | 0.486 | 0.216 | 0.012 | 0 | 0.032 | | | | 0 | 0.326 | 0.026 | 0.024 | 0 | 0.120 | 0.096 | 0.120 | 0.072 | 0 | | | | | | | | | 3.179 | 0.145 | | | | |
| | | 5 | 0 | 0 | 0.021 | 0 | 0 | 0 | 5.40 | 0 | 0.026 | 0 | 0 | 0 | 0.098 | 0 | 0.131 | 0.048 | 0.239 | 0.239 | 0.048 | 0 | 0 | 0.072 | 0 | 0 | 0.263 | | | | | | | | | 5.737 | 0.261 | | | | |
| | | Total | 1.145 | 990.4 | 711.1 | 1858 | | 2.774 | 23.329 | 629.3 | 1646 | 40.34 | 97.16 | 0.150 | 0.271 | 3.778 | 0 | 0.169 | 0.109 | 0.603 | 0.358 | 0.293 | 0.249 | 0.386 | 0.211 | 0.196 | 0.072 | 0.296 | | | | | | | | 5002.8 | 272.9 | | | | |
| 500 yd | STAGE | 1 | 0.533 | 0.055 | 0.030 | 0.030 | 0.232 | 0.055 | 0 | 0.105 | 0.105 | 0.055 | 0.282 | 0.086 | 0.118 | 0 | 0 | 0 | 0.008 | 0.024 | 0.028 | 0.051 | 0.111 | 0 | 0.035 | 0 | 0 | 0.033 | | | | | | | | 1.756 | 0.084 | | | | 4800 |
| | | 2 | 0.415 | 0.034 | 0.066 | 0.051 | 0.059 | 0.026 | 10.4 | 7.00 | 0 | 0.101 | 0 | 0.251 | 0.026 | 0.035 | 0.188 | 0 | 0.141 | 0.051 | 0.064 | 0.074 | 0.023 | | | | | | | | | | | | | 19.075 | 0.908 | | | | |
| | | 3 | 0.034 | 0.141 | 0.029 | 0.105 | 0 | 0.020 | 0.068 | 0.899 | 0.910 | 0.044 | 0.026 | 0.044 | 0.039 | 0 | 0.047 | 0.054 | 0.071 | 0.105 | 0.094 | 0.101 | 0.034 | | | | | | | | | | | | | 2.865 | 0.136 | | | | |
| | | 4 | 0 | 0.022 | 0.026 | 0 | | 0.026 | 0 | 0 | 0 | 0 | 0.148 | 0.192 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | | | 0.414 | 0.020 | | | | |
| | | 5 | 0 | 0.084 | 0 051 | 0 | 0 | 0 | 0.005 | 0.050 | 0 | 0 | 0 | 0 | 0.059 | 0.041 | 0 | 0.038 | 0.039 | 0.103 | 0.002 | 0.069 | 0.199 | | | | | | | | | | | | | 0.740 | 0.035 | | | | |
| | | Total | 0.982 | 0.336 | 0.202 | 0.186 | 0.291 | 0.127 | 10.473 | 8.054 | 1.015 | 0.200 | 0.456 | 0.573 | 0.242 | 0.076 | 0.235 | 0.092 | 0.251 | 0.259 | 0.207 | 0.244 | 0.349 | | | | | | | | | | | | | 24.850 | 1.183 | 0.59 | 2.74 | 0.18 | 23.6 |
| 1000 yd | STAGE | 1 | 0.102 | 0 | 0 | 0.314 | 0.050 | 0.019 | 0 | 0 | 0 | 0.017 | 0 | 0 | 0.023 | 0.174 | 0.135 | 0.004 | 0 | 0 | 0.020 | 0.017 | 0.043 | | | | | | | | | | | | | 0.918 | 0.044 | | | | |
| | | 2 | 0.060 | 0.023 | 0.014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.038 | 0 | 0.110 | 0.038 | 0 | 0.174 | 0.011 | | | | | | | | | | | | | 0.901 | 0.043 | | | | |
| | | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0.048 | 0.008 | 0 | 0.226 | 0.110 | 0.041 | 0 | 0 | 0.038 | 0 | 0.110 | 0.038 | 0 | 0.174 | 0.011 | | | | | | | | | | | | | 0.448 | 0.021 | | | | |
| | | 4 | 0.029 | 0.147 | 0.118 | 0.052 | 0.009 | 0 | 0 | 0 | 0 | 0 | 0.050 | 0.063 | 0 | 0.108 | 0.002 | 0.065 | 0.014 | 0.064 | 0 | 0.029 | 0.053 | | | | | | | | | | | | | 1.225 | 0.058 | | | | |
| | | 5 | 0.002 | 0 | 0 | 0.010 | 0.051 | 0.045 | 0 | 0 | 0.135 | 0 | 0 | 0.089 | 0.082 | 0.087 | 0.038 | 0 | 0.058 | 0 | 0.265 | 0.096 | 0.020 | 0 | | | | | | | | | | | | | 0.593 | 0.028 | | | | |
| | | Total | 0.193 | 0.170 | 0.132 | 0.376 | 0.110 | 0.064 | 0.048 | 0.147 | 0.010 | 0.276 | 0.249 | 0.186 | 0.110 | 0.526 | 0.181 | 0.127 | 0.124 | 0.566 | 0.118 | 0.269 | 0.107 | | | | | | | | | | | | | 4.085 | 0.195 | 0.031 | 0.144 | 0.10 | 3.9 |
| 1500 yd | STAGE | 1 | 0 | 0.077 | 0.086 | 0.265 | 0 | 0.029 | 0 | 0.020 | 0.154 | 0 | 0.008 | 0 | 0 | 0.234 | 0.067 | 0.002 | 0 | 0.104 | 0.051 | 0.099 | 0 | 0.377 | 0.075 | 0.101 | 0.025 | 0.075 | 0 | 0.050 | 0.025 | 0.050 | | | 1.974 | 0.066 | | | | |
| | | 2 | 0.029 | 0.077 | 0.007 | 0 | 0 | 0.077 | 0 | 0.213 | 0.002 | 0.047 | 0.214 | 0.162 | 0 | 0.028 | 0.164 | 0.187 | 0.050 | 0.050 | 0.226 | 0 | 0 | 0.075 | 0.201 | 0.025 | 0.175 | 0.126 | 0.050 | 0.100 | 0.075 | 0.100 | | | 2.460 | 0.082 | | | | |
| | | 3 | 0.094 | 0.094 | 0.140 | 0.351 | 0.094 | 0.235 | 0.211 | 0.235 | 0.117 | 0.187 | 0.012 | 0.038 | 0.053 | 0 | 0 | 0.042 | 0.100 | 0.075 | 0.201 | 0.050 | 0.150 | 0.020 | 0 | 0.142 | 0.072 | 0 | 0 | 0.127 | 0.076 | 0 | | | 2.916 | 0.097 | | | | |
| | | 4 | 0 | 0 | 0 | 0 | 0 | 0.111 | 0.240 | 0.018 | 0.004 | 0.018 | 0 | 0 | 0 | 0.007 | 0.019 | 0.071 | 0 | 0.115 | 0.131 | 0.018 | 0 | 0.213 | 0.017 | 0.005 | 0.112 | 0 | 0.026 | 0 | 0 | 0.050 | | | 1.175 | 0.039 | | | | |
| | | 5 | 0.066 | 0.062 | 0.051 | 0.099 | 0.016 | 0.054 | 0 | 0.068 | 0.005 | 0.032 | 0.044 | 0 | 0 | 0.165 | 0.068 | 0 | 0.037 | 0.043 | 0.024 | 0.141 | 0 | 0.019 | 0 | 0 | 0.010 | 0 | 0.129 | 0.016 | 0 | 0 | | | 1.149 | 0.038 | | | | |
| | | Total | 0.189 | 0.310 | 0.284 | 0.715 | 0.110 | 0.506 | 0.451 | 0.554 | 0.282 | 0.284 | 0.278 | 0.200 | 0.053 | 0.434 | 0.318 | 0.302 | 0.187 | 0.387 | 0.633 | 0.308 | 0.150 | 0.704 | 0.293 | 0.273 | 0.394 | 0.201 | 0.205 | 0.293 | 0.176 | 0.200 | | | 9.674 | 0.322 | 0.031 | 0.169 | 0.12 | 6.5 |
| 2000 yd | STAGE | 1 | 0 | 0 | 0 | 0 | 0.050 | 0.070 | 0 | 0.094 | 0 | 0 | 0.010 | 0 | 0 | 0 | 0 | 0.072 | 0.065 | 0.002 | 0 | 0.026 | | | | | | | | | | | | | 0.329 | 0.016 | | | | |
| | | 2 | 0 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0.052 | 0.050 | 0 | 0.022 | 0 | 0 | 0.019 | 0.005 | 0 | 0.012 | 0 | 0.183 | 0.048 | | | | | | | | | | | | | 0.413 | 0.026 | | | | |
| | | 3 | 0 | 0.019 | 0 | 0 | 0.024 | 0.034 | 0.121 | 0.032 | 0 | 0.155 | 0.048 | 0 | 0 | 0.190 | 0.462 | 0 | 0 | 0.092 | 0.012 | 0 | | | | | | | | | | | | | 1.189 | 0.059 | | | | |
| | | 4 | 0.117 | 0 | 0 | 0.089 | 0.112 | 0.112 | 0 | 0.045 | 0.089 | 0.023 | 0.067 | 0.016 | 0.067 | 0.246 | 0.023 | 0.412 | 0.202 | 0 | 0.246 | 0.135 | | | | | | | | | | | | | 1.701 | 0.085 | | | | |
| | | 5 | 0.055 | 0.088 | 0.017 | 0 | | 0.096 | 0 | 0.034 | 0.035 | 0 | 0.067 | 0.040 | 0.054 | 0 | 0.008 | 0.017 | 0 | 0 | 0.306 | 0.072 | | | | | | | | | | | | | 0.889 | 0.047 | | | | |
| | | Total | 0.172 | 0.129 | 0.017 | 0.089 | 0.186 | 0.312 | 0.121 | 0.257 | 0.174 | 0.173 | 0.214 | 0.056 | 0.121 | 0.455 | 0.498 | 0.201 | 0.219 | 0.094 | 0.747 | 0.281 | | | | | | | | | | | | | 4.521 | 0.226 | 0.038 | 0.172 | 0.11 | 4.5 |

NOTES: (1) Average air concentration × time = $\frac{\text{cascade impactor sample}}{\text{sampling rate}}$.

(2) Specific activity of plutonium assumed to be 61.3 mμc/μg.

(3) The results for stations 13, 14 and 15 are incomplete and have been omitted from the totals and averages.

TABLE 3

Cascade Impactor Slide Analysis for Plutonium - Second Experiment (Values in muc)

| Station | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | Mean | SE of Mean | Standard Deviation | Estimate of Inherent SD Due to Counting | Average Air Concentration x Time in muc. sec/m³ per kg Metal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 yd | STAGE | 1 | 0.361 | 0.068 | 0.038 | 0.031 | 0.108 | 0.062 | 0.145 | 0.039 | 0.037 | 7.86 | 0.009 | 0 | 0.047 | | 0.004 | 0.041 | 0.105 | 0.124 | 0.141 | 0.067 | 0.080 | 0.074 | 0.082 | 0.072 | 0.163 | | | | | | 0.390 | | | | |
| | | 2 | 0 | 0.024 | 0.062 | 0.055 | 0.083 | 0.049 | 0.067 | 0.222 | 0.650 | 0.722 | 0.153 | 2.14 | 0.041 | 1.27 | 0.578 | 0 | 0.711 | 0.711 | 0.631 | 0.658 | 0.793 | 0.335 | 0.842 | 0.684 | 0.067 | | | | | | 0.462 | | | | |
| | | 3 | 0.022 | 0.127 | 0.111 | 2.24 | 0.145 | 0.117 | 0.005 | 0.047 | 0.086 | 0.011 | 0.049 | 0.125 | 0.066 | 0.483 | 0.008 | 0.046 | 0.015 | 0 | 4.12 | 6.01 | 1.13 | 1.08 | 1.13 | 0 | 0.108 | | | | | | 0.691 | | | | |
| | | 4 | 0.166 | 0.78 | 0.005 | 0 | 0.022 | 0.011 | 0.008 | 0.065 | 1.44 | 0.019 | 0.046 | 2.96 | 0.125 | 0.137 | 0.108 | 0 | 0 | 0.031 | 0.622 | 0.105 | 0.918 | 0.571 | 0 | 0.025 | 0.074 | | | | | | 0.302 | | | | |
| | | 5 | 0.021 | 0 | 0 | 0.124 | 0.043 | 0 | 0.029 | 0 | 0.021 | 0 | 0.005 | 0.226 | 0 | 0 | 0 | 0.026 | 0.006 | 0 | 0 | 0.062 | 0 | 0 | 0 | 0.006 | 0.066 | | | | | | 0.026 | | | | |
| | | Total | 0.570 | 0.297 | 0.216 | 2.45 | 0.401 | 0.239 | 0.254 | 0.373 | 2.23 | 8.61 | 0.262 | 5.45 | 0.279 | 1.89 | 0.698 | 0.113 | 0.837 | 0.866 | 5.51 | 6.90 | 2.92 | 2.06 | 2.05 | 0.787 | 0.478 | | | | | | 1.871 | 0.46 | 2.3 | 0.2 | 37.4 |
| 500 yd | STAGE | 1 | 0.074 | 0.099 | 0 | 0.472 | 0.149 | 0 | 0 | 0.099 | 0 | 0 | 0 | 0 | 0.164 | 0.163 | 0.192 | 0.191 | 0.157 | 0.126 | 0.129 | 0.120 | 0.178 | | | | | | | | | | 0.110 | | | | |
| | | 2 | 0.969 | 0 | 0 | 0 | 0.969 | 0.969 | 0.051 | 0 | 1.08 | 0 | 0.262 | 0.003 | 0.035 | 0 | 0.027 | 0 | 0.518 | 0.123 | 0 | 0.049 | 0.518 | | | | | | | | | | 0.265 | | | | |
| | | 3 | 0.076 | 0.294 | 0.332 | 0.230 | 0.242 | 0.242 | 122.0* | 0 | 0.089 | 0.038 | 3.44 | 0.064 | 0.025 | 0.080 | 0.045 | 0.059 | 0 | 0 | 0.074 | 0 | 0.081 | | | | | | | | | | 0.271 | | | | |
| | | 4 | 0 | 0 | 0 | 0.074 | 0.074 | 0 | 0.025 | 0.050 | 0 | 0 | 0.123 | 0.050 | 0.168 | 0.053 | 0.030 | 0.010 | 0.057 | 0 | 0.088 | 0.035 | 0.014 | | | | | | | | | | 0.041 | | | | |
| | | 5 | 0.017 | 0.073 | 0 | 0 | 0 | 0 | 0 | 0.035 | 0 | 0 | 0.030 | 0 | 0.184 | 0.082 | 0 | 0.065 | 0 | 0 | 0.031 | 0.080 | 0 | | | | | | | | | | 0.028 | | | | |
| | | Total | 1.136 | 0.466 | 0.332 | 0.776 | 1.434 | 1.21 | 122.1 | 0.184 | 1.17 | 0.038 | 3.86 | 0.117 | 0.576 | 0.378 | 0.294 | 0.325 | 0.732 | 0.249 | 0.322 | 0.284 | 0.791 | | | | | | | | | | 0.715 | 0.21 | 0.88 | 0.15 | 14.3 |
| 1000 yd | STAGE | 1 | 0.005 | 0.032 | 0.014 | 0.057 | 0.083 | 0.041 | 0.051 | 0.062 | 0 | 0 | 0.046 | 0 | | | | | | | | | | | | | | | | | | | 0.019 | | | | |
| | | 2 | 0.127 | 0 | 0 | 0.026 | 0 | 0 | 0.127 | 0 | 0 | 0 | 0 | 0.153 | 0 | 0.026 | 0 | 0 | 0 | 0 | 0.153 | 0 | 0 | | | | | | | | | | 0.029 | | | | |
| | | 3 | 0 | 0 | 0 | 0.078 | 0.024 | 0.029 | 0 | 0.080 | 0 | 0 | 0 | 0.718 | 0.208 | 0 | 0.059 | 0 | 0.024 | 0 | 0.008 | 0 | 0.041 | | | | | | | | | | 0.060 | | | | |
| | | 4 | 0.012 | 0 | 0.012 | 0.052 | 0.057 | 0.074 | 0.030 | 0.028 | 0.048 | 0.096 | 0.290 | 0 | 0 | 0.041 | 0 | 0 | 0.003 | 0 | 0.061 | 0 | 0.021 | | | | | | | | | | 0.039 | | | | |
| | | 5 | 0.059 | 0.002 | 0.022 | 0.035 | 0 | 0.008 | 0 | 0 | 0 | 0 | 0.065 | 0.013 | 0.153 | 0.075 | 0 | 0 | 0 | 0.004 | 0.035 | 0 | 0.018 | | | | | | | | | | 0.023 | | | | |
| | | Total | 0.203 | 0.034 | 0.048 | 0.248 | 0.164 | 0.152 | 0.208 | 0.170 | 0.048 | 0.096 | 0.401 | 0.884 | 0.361 | 0.142 | 0.059 | 0 | 0.027 | 0.004 | 0.257 | 0 | 0.080 | | | | | | | | | | 0.171 | 0.044 | 0.20 | 0.10 | 3.4 |
| 1500 yd | STAGE | 1 | 0.055 | 0 | 0.103 | 0.084 | 0.027 | 0.163 | 0 | 0 | 0.029 | 0 | 0 | 0.096 | 0.029 | 0 | 0.002 | 0.050 | 0 | 0 | 0.038 | 0 | 0.055 | 0 | 0 | 0.027 | 0.151 | 0 | 0 | 0.026 | 0 | 0 | 0.031 | | | | |
| | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.050 | 0 | 0.302 | 0 | 0 | 0.026 | 0 | 0 | 0 | 0 | 0 | 0 | 0.051 | 0.051 | 0 | | 0 | 0 | 9.40 | 0.051 | 0 | 0 | 0 | 0 | 0.016 | | | | |
| | | 3 | 0 | 0.134 | 0.035 | 0.164 | 0.013 | 0 | 0.050 | 0 | 0.421 | 0.076 | 0 | 0 | 0.025 | 0 | 0.075 | 0.075 | 0.049 | 0.099 | 0.013 | 0 | 0 | 0 | 0.026 | 0.041 | 0.008 | 0.172 | 0.024 | 0 | 0.045 | 0.027 | 0.052 | | | | |
| | | 4 | 0 | 0 | | 0 | 0 | 0.025 | 0 | 0.075 | 0 | 0 | 0 | 0 | 0.202 | 0 | 0.025 | | 0.029 | 0.797 | 0.014 | 0 | 0 | 0.022 | 0.138 | 0.040 | 0.014 | 0.031 | 0.019 | 0.011 | 0 | 0.129 | 0.052 | | | | |
| | | 5 | 0 | 0.055 | 0 | 0.094 | 0.086 | 0.026 | 0.021 | 0.063 | 0 | 0 | 0 | 0.106 | 0 | 0.058 | 0.005 | 0 | 0 | 0.013 | 0 | 0.038 | 0.049 | 0.013 | 0.063 | 0 | 0.080 | 0.099 | 0.043 | 0.042 | 0.018 | 0.033 | 0.034 | | | | |
| | | Total | 0.055 | 0.189 | 0.138 | 0.342 | 0.126 | 0.214 | 0.121 | 0.138 | 0.752 | 0.076 | 0 | 0.228 | 0.256 | 0.058 | 0.107 | 0.125 | 0.078 | 0.909 | 0.065 | 0.089 | 0.104 | 0.035 | 0.227 | 0.108 | 9.65 | 0.353 | 0.086 | 0.079 | 0.063 | 0.189 | 0.185 | 0.036 | 0.196 | 0.11 | 3.7 |
| 2000 yd | STAGE | 1 | 0 | 0 | 0.076 | 0.254 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.050 | 0 | 0.026 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | 0.020 | | | | |
| | | 2 | 0.174 | 0.176 | 0.005 | 0.227 | 0.141 | 0.035 | 0.137 | 0.034 | 0.049 | 0.018 | 0.029 | 0.136 | 0.103 | 0.008 | 0.117 | 0.005 | 0 | 0.133 | 0.036 | 0 | | | | | | | | | | | 0.078 | | | | |
| | | 3 | 0.124 | 0.018 | 0.029 | 0.089 | 0.049 | 0.035 | 0.035 | 0.029 | 0 | 0 | 0.102 | 0.076 | 0.076 | 0.051 | 0 | 0.203 | 0.026 | 0.127 | 0.026 | 0.153 | | | | | | | | | | | 0.063 | | | | |
| | | 4 | 0.153 | 0.077 | 0.153 | 0 | 0 | 0.127 | 0.228 | 0.228 | 0 | 0.051 | 0.017 | 0 | 0.039 | 0 | 0.026 | 0.029 | 0.023 | 0 | 0.014 | 0 | | | | | | | | | | | 0.055 | | | | |
| | | 5 | 0.023 | 0.017 | 0.023 | 0.109 | 0 | 0.015 | 0.030 | 0.065 | 0.019 | 0 | 0.035 | 0 | 0.123 | 0.049 | 0.140 | 0.140 | 0.113 | 0.056 | 0.144 | 0.108 | | | | | | | | | | | 0.064 | | | | |
| | | Total | 0.474 | 0.271 | 0.286 | 0.679 | 0.190 | 0.212 | 0.430 | 0.356 | 0.068 | 0.069 | 0.183 | 0.212 | 0.391 | 0.108 | 0.309 | 0.377 | 0.162 | 0.316 | 0.220 | 0.261 | | | | | | | | | | | 0.279 | 0.033 | 0.147 | 0.11 | 5.6 |

*These values were disregarded in the estimation of mean values.

NOTES: (1) Average air concentration × time = $\frac{\text{cascade impactor sample}}{\text{sampling rate}}$

(2) Specific activity plutonium assumed to be 61.3 muc/µg.

TABLE 4

First Plutonium Experiment: Deposition Results ($\mu c/m^2$) Versus Range

| Station / Range, yd | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1000 | $2.53 \times 10^{-3}$ | $9.19 \times 10^{-4}$ | $6.89 \times 10^{-4}$ | $9.19 \times 10^{-4}$ | $2.30 \times 10^{-4}$ | $4.60 \times 10^{-3}$ | $2.30 \times 10^{-3}$ | $6.89 \times 10^{-4}$ | $9.19 \times 10^{-4}$ | $2.30 \times 10^{-4}$ |
| 1500 | 0 | 0 | 0 | 0 | 0 | 0 | $5.23 \times 10^{-2}$ | 0 | 0 | 0 |
| 2000 | $1.13 \times 10^{-4}$ | 0 | 0 | 0 | 0 | 0 | 0 | $2.30 \times 10^{-4}$ | $7.49 \times 10^{-4}$ | $1.15 \times 10^{-4}$ |
| 3000 | $1.15 \times 10^{-4}$ | $4.02 \times 10^{-4}$ | $5.74 \times 10^{-4}$ | 0 | $1.15 \times 10^{-4}$ | $1.66 \times 10^{-3}$ | 0 | $1.72 \times 10^{-4}$ | $1.15 \times 10^{-4}$ | 0 |
| 4000 | $1.72 \times 10^{-4}$ | 0 | 0 | 0 | $4.60 \times 10^{-4}$ | $2.87 \times 10^{-4}$ | $1.72 \times 10^{-4}$ | 0 | $2.30 \times 10^{-4}$ | $1.72 \times 10^{-4}$ |
| Station / Range, yd | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 1000 | $4.60 \times 10^{-4}$ | $6.89 \times 10^{-4}$ | $4.60 \times 10^{-4}$ | $9.19 \times 10^{-4}$ | $2.07 \times 10^{-3}$ | 0 | $1.61 \times 10^{-3}$ | $6.89 \times 10^{-4}$ | $2.77 \times 10^{-3}$ | 0 |
| 1500 | 0 | 0 | $5.34 \times 10^{-4}$ | $2.15 \times 10^{-3}$ | $1.08 \times 10^{-3}$ | 0 | $2.17 \times 10^{-3}$ | $2.17 \times 10^{-3}$ | $6.53 \times 10^{-3}$ | $1.63 \times 10^{-3}$ |
| 2000 | 0 | $5.89 \times 10^{-5}$ | $1.16 \times 10^{-4}$ | $3.49 \times 10^{-4}$ | $2.91 \times 10^{-4}$ | 0 | $5.89 \times 10^{-5}$ | 0 | $3.49 \times 10^{-4}$ | 0 |
| 3000 | $2.30 \times 10^{-4}$ | $5.74 \times 10^{-5}$ | 0 | 0 | 0 | $4.62 \times 10^{-4}$ | 0 | 0 | $1.16 \times 10^{-4}$ | $2.32 \times 10^{-4}$ |
| 4000 | - | - | - | - | - | - | - | - | - | - |
| Station / Range, yd | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 1000 | $6.89 \times 10^{-4}$ | | | | | | | | | |
| 1500 | $1.63 \times 10^{-3}$ | $3.26 \times 10^{-3}$ | $8.53 \times 10^{-4}$ | $6.26 \times 10^{-4}$ | $6.83 \times 10^{-4}$ | $2.28 \times 10^{-4}$ | $5.74 \times 10^{-5}$ | 0 | - | 0 |
| 3000 | 0 | 0 | | | | | | | | |

TABLE 5

Second Plutonium Experiment: Deposition Samples ($\mu c/m^2$) Versus Range

| Station / Range, yd | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 7.9 | 13.4 | 11.4 | 14.7 | 12.3 | 26.2 | 86.5 | 42.4 | 46.4 | 68.0 |
| 50 | 15.0 | 9.0 | 6.5 | 13.4 | 9.6 | 10.8 | 8.3 | 12.3 | 14.7 | 10.4 |
| 100 | $7.2 \times 10^{-1}$ | $6.0 \times 10^{-1}$ | 4.6 | 4.5 | 2.2 | 3.1 | 4.8 | 1.3 | $3.2 \times 10^{-1}$ | 1.2 |
| 150 | $2.3 \times 10^{-1}$ | $3.3 \times 10^{-3}$ | $2.8 \times 10^{-3}$ | $9.8 \times 10^{-1}$ | 2.3 | 2.3 | $1.1 \times 10^{-1}$ | $7.4 \times 10^{-2}$ | $3.6 \times 10^{-3}$ | $3.2 \times 10^{-2}$ |
| 200 | $1.9 \times 10^{-2}$ | $1.1 \times 10^{-2}$ | $7.7 \times 10^{-1}$ | $4.7 \times 10^{-2}$ | $4.7 \times 10^{-1}$ | $8.5 \times 10^{-1}$ | $4.9 \times 10^{-2}$ | $8.9 \times 10^{-3}$ | $1.2 \times 10^{-2}$ | $9.1 \times 10^{-3}$ |
| 500 | 16.3 | $2.5 \times 10^{-1}$ | 20.6 | $2.8 \times 10^{-1}$ | $8.7 \times 10^{-2}$ | $1.2 \times 10^{-2}$ | $3.0 \times 10^{-2}$ | $3.8 \times 10^{-2}$ | $3.2 \times 10^{-1}$ | $8.7 \times 10^{-3}$ |
| 1000 | 0 | $1.24 \times 10^{-3}$ | 0 | $9.28 \times 10^{-4}$ | $3.15 \times 10^{-4}$ | $1.56 \times 10^{-3}$ | $6.21 \times 10^{-4}$ | $3.15 \times 10^{-4}$ | 0 | $4.34 \times 10^{-3}$ |
| 1500 | $5.83 \times 10^{-4}$ | $5.23 \times 10^{-4}$ | $5.23 \times 10^{-4}$ | $3.51 \times 10^{-4}$ | $4.08 \times 10^{-4}$ | $5.83 \times 10^{-4}$ | $8.74 \times 10^{-4}$ | $3.51 \times 10^{-4}$ | $3.51 \times 10^{-4}$ | $2.91 \times 10^{-4}$ |
| 2000 | $3.55 \times 10^{-4}$ | $7.11 \times 10^{-4}$ | $1.01 \times 10^{-3}$ | $1.18 \times 10^{-4}$ | $2.96 \times 10^{-4}$ | 0 | $2.96 \times 10^{-4}$ | 0 | 0 | $2.96 \times 10^{-4}$ |
| 3000 | 0 | 0 | 0 | | 0 | 0 | $7.43 \times 10^{-3}$ | $8.94 \times 10^{-5}$ | 0 | 0 |
| 4000 | $6.02 \times 10^{-5}$ | | $1.06 \times 10^{-4}$ | 0 | $1.51 \times 10^{-4}$ | $1.21 \times 10^{-4}$ | $3.02 \times 10^{-3}$ | $6.02 \times 10^{-3}$ | $3.02 \times 10^{-3}$ | |

| Station / Range, yd | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 26.4 | 44.4 | 52.4 | 61.5 | 39.4 | 19.7 | 9.8 | 8.9 | 2.3 | 4.55 |
| 50 | 9.5 | 3.4 | $7.3 \times 10^{-1}$ | 3.7 | 2.0 | $5.6 \times 10^{-1}$ | 1.4 | $5.7 \times 10^{-1}$ | $1.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |
| 100 | $9.0 \times 10^{-2}$ | $2.5 \times 10^{-1}$ | $9.5 \times 10^{-1}$ | $6.4 \times 10^{-2}$ | $5.2 \times 10^{-1}$ | $2.5 \times 10^{-2}$ | $1.7 \times 10^{-2}$ | $1.6 \times 10^{-2}$ | $2.6 \times 10^{-1}$ | |
| 150 | $6.2 \times 10^{-2}$ | $3.2 \times 10^{-2}$ | $1.0 \times 10^{-2}$ | $9.6 \times 10^{-2}$ | $1.5 \times 10^{-2}$ | $2.1 \times 10^{-2}$ | $2.3 \times 10^{-2}$ | $6.8 \times 10^{-3}$ | | |
| 200 | $5.3 \times 10^{-2}$ | $6.6 \times 10^{-2}$ | $1.0 \times 10^{-2}$ | $8.5 \times 10^{-3}$ | $7.7 \times 10^{-4}$ | $1.1 \times 10^{-2}$ | $3.2 \times 10^{-2}$ | $5.5 \times 10^{-2}$ | $1.0 \times 10^{-2}$ | $4.9 \times 10^{-3}$ |
| 500 | $4.2 \times 10^{-2}$ | $3.0 \times 10^{-3}$ | $1.3 \times 10^{-2}$ | $1.7 \times 10^{-2}$ | $1.6 \times 10^{-1}$ | $1.1 \times 10^{-2}$ | $3.0 \times 10^{-2}$ | $1.7 \times 10^{-3}$ | $9.0 \times 10^{-3}$ | $1.7 \times 10^{-2}$ |
| 1000 | 0 | $6.21 \times 10^{-4}$ | 0 | $6.21 \times 10^{-4}$ | $9.28 \times 10^{-4}$ | $1.24 \times 10^{-3}$ | 0 | $6.21 \times 10^{-4}$ | $1.24 \times 10^{-3}$ | $1.56 \times 10^{-3}$ |
| 1500 | $4.08 \times 10^{-4}$ | $7.57 \times 10^{-4}$ | $3.43 \times 10^{-4}$ | 0 | $2.85 \times 10^{-4}$ | $5.74 \times 10^{-3}$ | $1.15 \times 10^{-4}$ | $1.71 \times 10^{-4}$ | 0 | 0 |
| 2000 | $1.19 \times 10^{-4}$ | 0 | $1.77 \times 10^{-4}$ | $2.36 \times 10^{-4}$ | 0 | $1.77 \times 10^{-4}$ | $3.55 \times 10^{-4}$ | $0.60 \times 10^{-4}$ | 0 | 0 |
| 3000 | 0 | 0 | $2.98 \times 10^{-5}$ | $1.36 \times 10^{-4}$ | $1.36 \times 10^{-4}$ | $6.02 \times 10^{-3}$ | $1.06 \times 10^{-4}$ | $9.04 \times 10^{-5}$ | $6.02 \times 10^{-5}$ | $3.02 \times 10^{-5}$ |
| 4000 | | | | | | | | | | |

| Station / Range, yd | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | Total | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | $2.3 \times 10^{-1}$ | | | | | | | | 598.8 | 28.5 |
| 50 | $5.1 \times 10^{-2}$ | | | | | | | | 131.96 | 6.28 |
| 100 | | | | | | | | | 25.54 | 1.34 |
| 150 | | | | | | | | | 6.30 | 0.35 |
| 200 | $1.6 \times 10^{-3}$ | $9.3 \times 10^{-3}$ | $7.0 \times 10^{-3}$ | $9.3 \times 10^{-3}$ | | | | | 2.5244 | 0.105 |
| 500 | $1.5 \times 10^{-1}$ | | | | | | | | 1.48 | $7.8 \times 10^{-2}$ |
| 1000 | $1.56 \times 10^{-3}$ | | | | | | | | $177.1 \times 10^{-4}$ | $8.43 \times 10^{-4}$ |
| 1500 | 0 | $5.74 \times 10^{-5}$ | $5.74 \times 10^{-5}$ | 0 | $4.72 \times 10^{-4}$ | 0 | $2.38 \times 10^{-4}$ | 0 | $77.932 \times 10^{-4}$ | $2.78 \times 10^{-4}$ |
| 2000 | | | | | | | | | $42.06 \times 10^{-4}$ | $2.21 \times 10^{-4}$ |
| 3000 | 0 | $6.02 \times 10^{-5}$ | | | | | | | $87.27 \times 10^{-5}$ | $4.16 \times 10^{-5}$ |
| 4000 | | | | | | | | | $55.88 \times 10^{-5}$ | $3.98 \times 10^{-5}$ |

TABLE 6

First Uranium Experimental Cascade Impactor Samples (μμc)

| Station | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | Totals | Mean | SE of Mean | Standard Deviation | Estimate of Inherent SD due to Counting | Average Air Concentration × Time μc-sec/$m^3$ for 1 kg Metal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range, yd 100 | 1 | | | | | | | 0.396 | 1.03 | 1.05 | 0.334 | 0.167 | 0.056 | | | | | | | | | | | | | | | | | | | | 3.033 | 0.506 | | | | |
| | 2 | | | | | | | 0.221 | 0 | 0 | 0 | 0 | 0.139 | | | | | | | | | | | | | | | | | | | | 0.360 | 0.060 | | | | |
| | 3 | | | | | | | 0 | 0 | 0 | 0.028 | 0.028 | 0.028 | | | | | | | | | | | | | | | | | | | | 0.084 | 0.014 | | | | |
| | 4 | | | | | | | 0.396 | 0.666 | 0.555 | 0.527 | 0.666 | 0.444 | | | | | | | | | | | | | | | | | | | | 3.254 | 0.542 | | | | |
| | 5 | | | | | | | 0 | 0 | 0 | 0.027 | 0.031 | 0 | | | | | | | | | | | | | | | | | | | | 0.058 | 0.010 | | | | |
| | Total | | | | | | | 1.013 | 1.696 | 1.605 | 0.916 | 0.892 | 0.667 | | | | | | | | | | | | | | | | | | | | 6.789 | 1.132 | 0.170 | 0.420 | 0.137 | $2.74 \times 10^2$ |
| 200 | 1 | | | | 0.057 | 0.029 | 0.057 | 0.029 | 0.228 | 0.286 | 0.143 | 0 | 0.202 | 0.143 | 0.086 | 0.114 | 0.143 | 0.172 | 0.114 | 0.114 | 0.086 | 0.114 | 0.057 | 0.029 | 0.086 | | | | | | | | 2.289 | 0.109 | | | | |
| | 2 | | | | 0.120 | 0 | 0.059 | 0.030 | 0 | 0.030 | 0 | 0 | 0.298 | 0 | 0 | 0 | 0.269 | 0.030 | 0.030 | 0 | 0 | 0 | 0 | 0 | 0.089 | | | | | | | | 0.955 | 0.045 | | | | |
| | 3 | | | | 0 | 0.028 | 0.083 | 0.111 | 0 | 0.028 | 0 | 0 | 0 | 0.083 | 0 | 0.028 | 0 | 0 | 0 | 0.028 | 0.056 | 0 | 0 | 0.028 | 0.028 | | | | | | | | 0.501 | 0.024 | | | | |
| | 4 | | | | 0.177 | 0.059 | 0.029 | 0.236 | 0.147 | 0.059 | 0.089 | 0 | 0.296 | 0.118 | 0.147 | 0.089 | 0.059 | 0.059 | 0 | 0.029 | 0.029 | 0.089 | 0.029 | 0.059 | 0.029 | | | | | | | | 1.828 | 0.087 | | | | |
| | 5 | | | | 0 | 0 | 0.005 | 0.044 | 0.022 | 0.005 | 0 | 0.051 | 0 | 0.020 | 0 | 0.003 | 0 | 0 | 0 | 0 | 0 | 0 | 0.044 | 0.005 | 0.009 | | | | | | | | 0.208 | 0.010 | | | | |
| | Total | | | | 0.354 | 0.116 | 0.233 | 0.450 | 0.397 | 0.408 | 0.232 | 0.051 | 0.796 | 0.364 | 0.233 | 0.234 | 0.471 | 0.261 | 0.144 | 0.171 | 0.171 | 0.203 | 0.130 | 0.121 | 0.241 | | | | | | | | 3.781 | 0.275 | 0.036 | 0.166 | 0.083 | $6.65 \times 10^2$ |
| 500 | 1 | 0.135 | 0.054 | 0 | 0 | 0 | 0 | 0.135 | 0.162 | 0 | 0.027 | 0 | 0.135 | 0.162 | 0.135 | 0.054 | 0.108 | 0.162 | 0.108 | 0.108 | 0.108 | 0.027 | | | | | | | | | | 1.620 | 0.077 | | | | |
| | 2 | 0.029 | 0.085 | 0.114 | 0 | 0.141 | 0 | 0.056 | 0 | 0 | 0.029 | 0 | 0 | 0.056 | 0.114 | 0 | 0 | 0.056 | 0 | 0 | 0 | 0 | | | | | | | | | | 0.680 | 0.032 | | | | |
| | 3 | 0.029 | 0.170 | 0.142 | 0.057 | 0.142 | 0.142 | 0.029 | 0.057 | 0 | 0.029 | 0 | 0 | 0.029 | 0.057 | 0 | 0.170 | 0.057 | 0.029 | 0.057 | 0.085 | 0.029 | | | | | | | | | | 1.310 | 0.062 | | | | |
| | 4 | 0.084 | 0 | 0.028 | 0.084 | 0 | 0.028 | 0 | 0 | 0 | 0.140 | 0.195 | 0 | 0.056 | 0.168 | 0 | 0 | 0 | 0 | 0 | 0.028 | 0 | | | | | | | | | | 0.811 | 0.039 | | | | |
| | 5 | 0.011 | 0 | 0.026 | 0.007 | 0.036 | 0 | 0 | 0 | 0.105 | 0.063 | 0.008 | 0.020 | 0 | 0 | 0.048 | 0 | 0 | 0 | 0.019 | 0 | 0.046 | | | | | | | | | | 0.389 | 0.019 | | | | |
| | Total | 0.288 | 0.309 | 0.310 | 0.148 | 0.319 | 0.170 | 0.220 | 0.219 | 0.105 | 0.288 | 0.213 | 0.155 | 0.303 | 0.474 | 0.102 | 0.278 | 0.275 | 0.137 | 0.184 | 0.221 | 0.102 | | | | | | | | | | 4.810 | 0.230 | 0.021 | 0.095 | 0.076 | $5.55 \times 10^2$ |
| 1000 | 1 | 0 | 0 | 0.018 | 0 | 0 | 0.024 | 0.019 | 0 | 0 | 0 | 0 | 0.005 | 0.008 | 0 | 0 | 0 | 0.125 | 0.138 | 0.161 | 0 | 0.094 | 0.005 | | | | | | | | | | 0.597 | 0.028 | | | | |
| | 2 | 0.011 | 0 | 0.173 | 0 | 0.022 | 0 | 0 | 0.057 | 0.096 | 0 | 0.170 | 0 | 0 | 0 | 0 | 0.084 | 0 | 0.105 | 0 | 0 | 0 | | | | | | | | | | 0.718 | 0.034 | | | | |
| | 3 | 0.096 | 0.053 | 0.208 | 0 | 0 | 0.073 | 0.057 | 0.011 | 0.126 | 0 | 0 | 0 | 0 | 0 | 0.150 | 0 | 0.060 | 0 | 0 | 0.090 | 0 | 0.030 | | | | | | | | | | 0.954 | 0.045 | | | | |
| | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.125 | 0.138 | 0.161 | 0 | 0.094 | 0.057 | 0.027 | 0.019 | 0.164 | 0 | 0.007 | 0 | 0 | 0.095 | | | | | | | | | | 0.887 | 0.042 | | | | |
| | 5 | 0.011 | 0 | 0 | 0.059 | 0.171 | 0.062 | 0.048 | 0 | 0.056 | 0.042 | 0 | 0 | 0.034 | 0.080 | 0.043 | 0.012 | 0 | 0 | 0 | 0.023 | 0.057 | | | | | | | | | | 0.698 | 0.033 | | | | |
| | Total | 0.118 | 0.053 | 0.399 | 0.059 | 0.217 | 0.154 | 0.105 | 0.193 | 0.416 | 0.203 | 0.175 | 0.102 | 0.091 | 0.257 | 0.062 | 0.445 | 0.138 | 0.273 | 0.090 | 0.117 | 0.187 | | | | | | | | | | 3.854 | 0.184 | 0.026 | 0.118 | 0.076 | $4.45 \times 10^2$ |
| 1500 | 1 | 0.107 | 0.012 | 0.043 | 0.025 | 0 | 0 | 0 | 0.019 | 0 | 0 | 0.092 | 0.023 | 0.070 | 0.062 | 0 | 0 | 0.033 | 0 | 0 | 0 | 0 | 0 | 0.052 | 0.008 | 0.019 | 0 | 0.080 | 0 | 0 | 0 | 0.049 | 0.694 | 0.022 | | | | |
| | 2 | 0. | 0 | 0. | 0 | 0.013 | 0.017 | 0 | 0.044 | 0.105 | 0 | 0.053 | 0 | 0.132 | 0 | 0.114 | 0.175 | 0 | 0.156 | 0.103 | 0 | 0 | 0.033 | 0 | 0.129 | 0 | 0.111 | 0 | 0.035 | 0.034 | 0 | 0.050 | 1.304 | 0.042 | | | | |
| | 3 | 0.078 | 0 | 0.010 | 0 | 0.172 | 0 | 0.049 | 0 | 0.084 | 0 | 0.032 | 0.127 | 0 | 0 | 0.057 | 0 | 0 | 0.025 | 0.096 | 0.062 | 0 | 0 | 0.042 | 0 | 0.169 | 0 | 0 | 0.070 | 0 | 0.025 | 0.096 | 1.194 | 0.039 | | | | |
| | 4 | 0 | 0 | 0.073 | 0.032 | 0 | 0 | 0.010 | 0.033 | 0.084 | 0 | 0 | 0 | 0.156 | 0.056 | 0.135 | 0.008 | 0.062 | 0.014 | 0 | 0.098 | 0 | 0.031 | 0 | 0.109 | 0.098 | 0 | 0.077 | 0.058 | 0.002 | 0 | 0 | 1.136 | 0.037 | | | | |
| | 5 | 0.080 | 0.069 | 0 | 0.103 | 0 | 0.101 | 0 | 0.014 | 0.043 | 0 | 0 | 0.078 | 0.032 | 0 | 0.033 | 0.049 | 0.178 | 0 | 0.211 | 0.050 | 0.029 | 0.058 | 0 | 0.063 | 0 | 0.014 | 0 | 0 | 0.099 | 0.042 | 0 | 1.346 | 0.043 | | | | |
| | Total | 0.265 | 0.081 | 0.126 | 0.160 | 0.185 | 0.118 | 0.059 | 0.110 | 0.316 | 0 | 0.177 | 0.228 | 0.390 | 0.118 | 0.339 | 0.232 | 0.273 | 0.195 | 0.410 | 0.210 | 0.029 | 0.122 | 0.094 | 0.309 | 0.286 | 0.125 | 0.157 | 0.163 | 0.135 | 0.067 | 0.195 | 5.674 | 0.183 | 0.018 | 0.103 | 0.076 | $4.42 \times 10^2$ |
| 2000 | 1 | 0 | 0.087 | 0.023 | 0.070 | 0 | 0.197 | 0 | 0 | 0 | 0 | 0.193 | 0 | 0.004 | 0 | 0.035 | 0.103 | 0 | 0.028 | 0 | 0.008 | 0.105 | | | | | | | | | | 0.853 | 0.041 | | | | |
| | 2 | 0 | 0.015 | 0 | 0 | 0 | 0.022 | 0.017 | 0.045 | 0 | 0.062 | 0.025 | 0 | 0 | 0.123 | 0.101 | 0 | 0 | 0.008 | 0.034 | 0.017 | 0 | | | | | | | | | | 0.469 | 0.022 | | | | |
| | 3 | 0.035 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.040 | 0 | 0 | 0.062 | 0 | 0 | 0 | 0 | 0 | 0.018 | 0 | 0.002 | | | | | | | | | | 0.157 | 0.007 | | | | |
| | 4 | 0 | 0 | 0.065 | 0 | 0.074 | 0.022 | 0 | 0.061 | 0 | 0 | 0 | 0.002 | 0 | 0.045 | 0.006 | 0.062 | 0.020 | 0 | 0 | 0 | 0 | | | | | | | | | | 0.357 | 0.017 | | | | |
| | 5 | 0.178 | 0 | 0 | 0 | 0.070 | 0 | 0 | 0.046 | 0 | 0.252 | 0 | 0 | 0.186 | 0.015 | 0.024 | 0.053 | 0 | 0 | 0.010 | 0.392 | 0 | | | | | | | | | | 1.226 | 0.058 | | | | |
| | Total | 0.213 | 0.102 | 0.088 | 0.070 | 0.144 | 0.241 | 0.017 | 0.152 | 0 | 0.354 | 0.218 | 0.002 | 0.252 | 0.183 | 0.166 | 0.218 | 0.020 | 0.036 | 0.062 | 0.417 | 0.107 | | | | | | | | | | 3.062 | 0.146 | 0.025 | 0.114 | 0.069 | $3.53 \times 10^2$ |

NOTE: (1) Average air concentration × time = $\frac{\text{Cascade impactor sample}}{\text{sampling rate}}$

(2) Specific activity of natural uranium assumed to be 0.69 μμc/μg.

TABLE 7

Second Uranium Experiment: Cascade Impactor Samples (μμc)

| Station | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | Totals | Mean | SE of Mean | Standard Deviation | Estimate of Inherent SD due to Counting | Average Air Concentration × Time* in μg-sec/m³ for 1 kg Metal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range, yd 200 | 1 | - | 0 | 0.029 | 0.087 | 0 | 0.146 | 0.087 | 0 | 0.029 | 0 | 0.262 | 0.175 | 0.117 | 0 | 0.029 | 0 | 0 | 0.029 | 0.146 | 0 | 0.204 | | | | | | | | | 1.340 | 0.067 | | | | |
| | 2 | - | 0.059 | 0 | 0.117 | 0 | 0.059 | 0.174 | 0 | 0.087 | 0.146 | 0.350 | 0.087 | 0.146 | 0.117 | 0.174 | 0.117 | 0.087 | 0 | 0.117 | 0 | 0.029 | | | | | | | | | 1.866 | 0.093 | | | | |
| | 3 | | 0.314 | 0.257 | 0 | 0.228 | 0 | 0.086 | 0 | 0.057 | 0.029 | 0.086 | 0.086 | 0.086 | 0 | 0 | 0 | 0.029 | 0 | 0.172 | 0 | 0 | | | | | | | | | 1.430 | 0.072 | | | | |
| | 4 | | 0.139 | 0.028 | 0.139 | 0.028 | 0.167 | 0.167 | 0.195 | 0.084 | 0.056 | 0.334 | 0.222 | 0 | 0 | 0.073 | 0.108 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | 1.740 | 0.087 | | | | |
| | 5 | | 0.057 | 0 | 0.152 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.073 | 0 | 0 | 0 | 0.023 | 0 | 0.030 | 0 | 0 | | | | | | | | | 0.335 | 0.017 | | | | |
| | Total | | 0.569 | 0.314 | 0.495 | 0.256 | 0.372 | 0.514 | 0.195 | 0.257 | 0.231 | 1.032 | 0.570 | 0.422 | 0.117 | 0.276 | 0.225 | 0.139 | 0.029 | 0.465 | 0 | 0.233 | | | | | | | | | 6.711 | 0.336 | 0.059 | 0.260 | 0.12 | $8.1 \times 10^{3}$ |
| 500 | 1 | | 0.020 | 0.132 | 0.072 | 0.071 | 0 | 0.004 | 0 | 0.030 | 0 | 0.112 | 0 | 0 | 0 | 0.056 | 0 | 0.196 | 0 | 0 | 0.140 | | | | | | | | | | 0.851 | 0.043 | | | | |
| | 2 | 0.084 | 0.056 | 0.028 | 0.056 | 0.028 | 0 | 0.134 | 0 | 0 | 0.072 | 0.030 | 0.111 | 0 | 0 | 0 | 0 | 0.112 | 0 | 0.028 | 0.112 | | | | | | | | | | 0.848 | 0.042 | | | | |
| | 3 | 0 | 0.076 | 0.114 | 0 | 0.011 | 0 | 0 | 0.029 | 0.046 | 0.013 | 0.032 | 0 | 0.011 | 0.046 | 0.174 | 0.017 | 0.009 | 0.141 | 0.055 | 0.074 | | | | | | | | | | 0.657 | 0.033 | | | | |
| | 4 | 0 | 0.130 | 0.047 | 0.072 | 0 | 0.114 | 0 | 0.051 | 0.021 | 0.138 | 0 | 0.056 | 0 | 0.028 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | 0.284 | 0.014 | | | | |
| | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.026 | 0.083 | 0 | 0 | 0.002 | 0.011 | 0 | 0 | 0 | 0.008 | 0.116 | 0.036 | 0.002 | 0 | | | | | | | | | | 3.479 | 0.174 | 0.027 | 0.122 | 0.10 | $4.2 \times 10^{3}$ |
| | Total | 0.084 | 0.282 | 0.321 | 0.314 | 0.110 | 0.114 | 0.114 | 0.163 | 0.097 | 0.223 | 0.176 | 0.178 | 0.011 | 0.074 | 0.230 | 0.025 | 0.433 | 0.177 | 0.119 | 0.326 | | | | | | | | | | 0.402 | 0.019 | | | | |
| 1000 | 1 | 0 | 0 | 0.055 | 0 | 0 | 0 | 0.055 | 0 | 0.055 | 0.083 | 0.013 | 0.083 | 0 | 0 | 0.050 | 0 | 0 | 0 | 0 | 0.008 | 0 | | | | | | | | | 0.782 | 0.037 | | | | |
| | 2 | 0.043 | 0 | 0.104 | 0.079 | 0 | 0.135 | 0 | 0 | 0.043 | 0 | 0.081 | 0 | 0.054 | 0 | 0.108 | 0 | 0 | 0.054 | 0 | 0 | 0.081 | | | | | | | | | 0.265 | 0.013 | | | | |
| | 3 | 0.089 | 0 | 0 | 0 | 0 | 0.059 | 0 | 0 | 0 | 0 | 0 | 0.059 | 0 | 0 | 0.029 | 0 | 0 | 0.029 | 0 | 0 | 0 | | | | | | | | | 0.174 | 0.008 | | | | |
| | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.029 | 0 | 0 | 0 | 0 | 0.029 | 0 | 0.058 | 0 | | | | | | | | | 1.840 | 0.088 | | | | |
| | 5 | 0.072 | 0 | 0 | 0.005 | 0 | 0.090 | 0 | 0 | 0.284 | 0.055 | 0 | 0.112 | 0.186 | 0.195 | 0.186 | 0.083 | *0.007 | 0.187 | 0.065 | 0 | 0.126 | 0.410 | 0.066 | 0.081 | | | | | | 3.463 | 0.165 | 0.019 | 0.086 | 0.10 | $4.0 \times 10^{3}$ |
| | Total | 0.204 | 0 | 0.159 | 0.084 | 0 | 0.284 | 0.055 | 0 | 0.112 | 0.186 | 0.195 | 0.186 | 0.083 | *0.007 | 0.187 | 0.065 | 0 | 0.126 | 0.410 | 0.066 | 0.081 | | | | | | | | | 1.907 | 0.066 | | | | |
| 1500 | 1 | 0.035 | 0.012 | 0.060 | 0.163 | 0 | 0.057 | 0.044 | 0 | 0.007 | 0 | 0.077 | 0.050 | 0.117 | 0 | 0.168 | 0.087 | 0 | 0 | 0 | 0.096 | 0 | 0 | 0.127 | 0.123 | 0.104 | 0.222 | 0 | 0.096 | 0.262 | 1.270 | 0.044 | | | | |
| | 2 | 0 | 0.086 | 0 | 0 | 0.030 | 0.044 | 0.060 | 0.132 | 0 | 0.141 | 0 | 0.002 | 0.002 | 0.010 | 0.268 | 0 | 0.078 | 0.044 | 0 | 0 | 0.114 | 0 | 0.107 | 0 | 0 | 0 | 0 | 0.152 | 1.175 | 0.040 | | | | |
| | 3 | 0.032 | 0 | 0.102 | 0 | 0 | 0 | 0 | 0 | 0.044 | 0 | 0.277 | 0 | 0.008 | 0.023 | 0.010 | 0.089 | 0.109 | 0 | 0.057 | 0 | 0.145 | 0.024 | 0 | 0 | 0.071 | 0.112 | 0 | 0.072 | 1.175 | 0.040 | | | | |
| | 4 | 0.086 | 0.012 | 0.082 | 0 | 0.026 | 0.172 | 0 | 0.302 | 0.144 | 0 | 0.181 | 0.180 | 0.078 | 0 | 0 | 0.008 | 0 | 0 | 0 | 0.004 | 0.232 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.507 | 0.052 | | | | |
| | 5 | 0.079 | 0.316 | 0.129 | 0 | 0.140 | 0.221 | 0 | 0 | 0 | 0 | 0.023 | 0.017 | 0 | 0 | 0.040 | 0 | 0 | 0 | 0 | 0.142 | 0 | 0 | 0 | 0.037 | 0 | 0.027 | 0 | 0.100 | 0 | 1.271 | 0.044 | | | | |
| | Total | 0.232 | 0.426 | 0.373 | 0.163 | 0.196 | 0.494 | 0.104 | 0.434 | 0.195 | 0.141 | 0.558 | 0.249 | 0.205 | 0.033 | 0.486 | 0.184 | 0.187 | 0.044 | 0.057 | 0.242 | 0.377 | 0.138 | 0.127 | 0.267 | 0.104 | 0.293 | 0.112 | 0.196 | 0.486 | 7.130 | 0.246 | 0.027 | 0.147 | 0.11 | $5.95 \times 10^{3}$ |
| 2000 | 1 | 0.066 | 0.073 | 0.130 | 0.008 | 0 | 0 | 0 | 0 | 0 | 0.258 | 0 | 0.123 | 0.041 | 0.055 | | 0.084 | 0 | 0.067 | 0 | 0 | 0.016 | | | | | | | | | 0.921 | 0.044 | | | | |
| | 2 | 0 | 0 | 0.124 | 0.234 | 0.031 | 0.057 | 0.074 | 0.012 | 0.030 | 0.059 | 0 | 0.078 | 0 | 0.196 | 0.234 | 0.021 | 0.161 | 0 | 0.071 | 0.041 | 0 | | | | | | | | | 1.423 | 0.068 | | | | |
| | 3 | 0 | 0.094 | 0 | 0.093 | 0.120 | 0.021 | 0 | 0 | 0.110 | 0 | 0 | 0 | 0.126 | 0 | 0.135 | 0.177 | 0.079 | 0.029 | 0 | 0.032 | 0.048 | | | | | | | | | 1.064 | 0.051 | | | | |
| | 4 | 0.055 | 0.018 | 0.062 | 0.006 | 0.080 | 0 | 0.022 | 0.105 | 0.064 | 0.148 | 0 | 0 | 0 | 0 | 0.006 | 0 | 0.019 | 0 | 0.021 | 0 | 0 | | | | | | | | | 0.606 | 0.029 | | | | |
| | 5 | 0.022 | 0 | 0 | 0.050 | 0 | 0 | 0 | 0.007 | 0 | 0.283 | 0 | 0.057 | 0.164 | 0.019 | 0 | 0 | 0.038 | 0 | 0 | 0.030 | 0.035 | | | | | | | | | 0.705 | 0.034 | | | | |
| | Total | 0.143 | 0.185 | 0.316 | 0.391 | 0.231 | 0.078 | 0.096 | 0.124 | 0.204 | 0.748 | 0 | 0.258 | 0.331 | 0.270 | †0.375 | 0.282 | 0.297 | 0.096 | 0.092 | 0.103 | 0.099 | | | | | | | | | 4.719 | 0.225 | 0.036 | 0.162 | 0.11 | $5.43 \times 10^{3}$ |

NOTES: (1) *Minus Stage 4. †Minus Stage 1.

(2) Average air concentration × time = $\frac{\text{Cascade impactor sample}}{\text{sampling rate}}$.

(3) Specific activity of natural uranium assumed to be 0.6 μμc/μg.

TABLE 8

First Uranium Experiment: Deposition Samples ($\mu g/m^2$) versus Range

| Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | Average Deposition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range, yd 20 | 122 | 229 | 795 | 2450 | 8500 | 5770 | 7660 | 8450 | 8920 | 8640 | 5180 | 3243 | 377 | 4 | 24 | 11 | | | | | | | | | | | | | | | | 3773 |
| 50 | 9 | 28 | 58 | 373 | 730 | 957 | 3190 | 4520 | 625 | 3570 | 1591 | 900 | 67 | 62 | 65 | 79 | | | | | | | | | | | | | | | | 1050 |
| 100 | 0 | 0 | 0 | 149 | 506 | 3160 | 6920 | 4860 | 1500 | 3440 | 4690 | 1130 | 52.6 | 0 | 0 | 0 | 129 | 129 | | | | | | | | | | | | | | 1340 |
| 150 | 25 | 0 | 0 | 97 | 0 | 0 | 38 | 146 | 25 | 109 | 109 | 72 | 0 | 0 | 0 | 0 | 25 | 0 | | | | | | | | | | | | | | 36 |
| 200 (235) | 4.7 | 0 | 4650 | 188 | 94 | 94 | 117 | 117 | 117 | 141 | 141 | Missing | 70.4 | 305 | 141 | 305 | 305 | 70.4 | 144 | 188 | 350 | 70.4 | 70.4 | 70.4 | 188 | | | | | | | 140(2) |
| 500 (580) | 40.5 | 0 | 0 | 64.1 | 212 | 0 | 0 | 0 | 0 | 0 | 64.1 | 40.5 | 0 | 0 | 0 | 70.4 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | 24 |
| 1000 (1120) | 500 | 470 | 470 | 406 | 180 | 111 | 87.8 | 470 | 111 | 23.7 | 180 | 152 | 111 | 206 | 70.4 | 111 | 135 | 235 | 70.4 | 152 | 135 | | | | | | | | | | | 150 |
| 1500 (1680) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 240 | 0 | 0 | 0 | 0 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 2000 (2240) | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 0 | | | | | | | | | | | |

NOTES: (1) Average values of range are given in ( ).

(2) Value at Station 3 omitted.

TABLE 9

Second Uranium Experiment: Deposition Samples ($\mu g/m^2$) versus Range

| Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1- | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | Average Disposition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range, yd 20 | 494 | 748 | 1310 | 639 | 2420 | 1124 | 338 | 435 | 659 | 1367 | 3177 | 4930 | 4400 | 6710 | 7400 | 7300 | | | | | | | | | | | | | | | | |
| 50 | 151 | 103 | 194 | 135 | 145 | 418 | 136 | 153 | 142 | 477 | 600 | 1023 | 1076 | 3160 | 1318 | 960 | | | | | | | | | | | | | | | | 2716 |
| 100 | 368 | 170 | 426 | 485 | Missing | 442 | 384 | 608 | 400 | 464 | 400 | 580 | 526 | 107 | 109 | 2520 | 2400 | 680 | | | | | | | | | | | | | | 637 |
| 150 | 382 | 149 | 184 | 184 | 184 | 210 | 9 | 29 | 0 | 20 | 40 | 29 | 232 | 250 | 953 | 57 | 126 | 66 | 1194 | | | | | | | | | | | | | 710 |
| 200 | 14.1 | 6.8 | 20.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.7 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | 226 |
| 500 | 10 | 0 | 6 | 12.2 | 0 | 0 | 4.14 | 6.0 | 14.1 | 0 | 20.5 | 4.14 | 6 | 0 | 20.5 | 6 | 0 | 16.5 | 0 | 20.5 | 16.5 | | | | | | | | | | | 2.6 |
| 1000 | 11.3 | 37 | 43.2 | 10 | 22.3 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 4.1 | 86.2 | 16.5 | 0 | 16.5 | 0 | 6.0 | 0 | 12.2 | | | | | | | | | | | 8.2 |
| 1500 | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 15 | 16 | 0 | 8 | 19 | 19 | 9 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 14.8 |
| 2000 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 44 | 5 | 0 | 7 | 9 | 0 | | | | | | | | | | | 3.6 |
| 3000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4.2 |

TABLE 10

Samples of Airborne Material Collected in Height Interval 30 - 300 ft at 500 yd Range

(Plutonium in μμc, Uranium in μg)

| Experiment | Impactor Stage | Height | | | | | |
|---|---|---|---|---|---|---|---|
| | | 30 | 30 | 150 | 200 | 250 | 300 |
| 2nd Plutonium | 1 | 0.041 | 0.0 | 0.050 | 0.0 | 0.146 | 0.0 |
| | 2 | 0.086 | 0.006 | 0.061 | 0.140 | 0.078 | 0.016 |
| | 3 | 0.0 | 0.075 | 0.059 | 0.048 | 0.020 | 0.0 |
| | 4 | 0.107 | 0.024 | 0.035 | 0.0 | 0.045 | 0.106 |
| | 5 | 0.031 | 0.0 | 0.123 | 0.086 | 0.0 | 0.141 |
| | Total | 0.265 | 0.105 | 0.328 | 0.274 | 0.289 | 0.263 |
| Grid Reference | | 3549 | 3551 | 3550 | 3552 | 3550 | 3552 |
| 1st Uranium | 1 | 0.0 | 0.088 | 0.0 | 0.0 | 0.0 | 0.071 |
| | 2 | 0.113 | 0.0 | 0.0 | 0.0 | 0.0 | 0.107 |
| | 3 | 0.0 | 0.100 | 0.0 | 0.071 | 0.071 | 0.036 |
| | 4 | 0.010 | 0.070 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 5 | 0.0 | 0.010 | 0.016 | 0.016 | 0.059 | 0.081 |
| | Total | 0.123 | 0.268 | 0.016 | 0.087 | 0.130 | 0.295 |
| Grid Reference | | 3850 | 4050 | 3950 | 4150 | 3950 | 4150 |
| 2nd Uranium | 1 | 0.025 | 0.0 | 0.087 | 0.178 | 0.0 | 0.013 |
| | 2 | 0.058 | 0.042 | 0.081 | 0.055 | 0.0 | 0.074 |
| | 3 | 0.0 | 0.260 | 0.120 | 0.0 | 0.120 | 0.0 |
| | 4 | 0.0 | 0.0 | 0.159 | 0.123 | 0.085 | 0.010 |
| | 5 | 0.0 | 0.025 | 0.030 | 0.0 | 0.330 | 0.153 |
| | Total | 0.083 | 0.327 | 0.477 | 0.356 | 0.535 | 0.153 |
| Grid Reference | | 3850 | 4050 | 3950 | 3849 | 3950 | 3849 |

TABLE 11

Sample Analysis - Second Beryllium Experiment

| Range, yd | Deposited Material, $\mu g/m^2$ | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | Average |
| 20 | 39.8 | - | 22.0 | - | 26.9 | 20.2 | 6.2 | 16.2 | 22.6 | - | 25.3 | 20.4 | 46.2 | 92.2 | 25.8 | 13.8 | 8.7 | 30.1 | 118 | 33.3 |
| 50 | 5.92 | 4.73 | 3.33 | - | 9.46 | 3.44 | 4.08 | - | - | 14.7 | - | 1.72 | 2.47 | 2.26 | - | 7.7 | 2.04 | - | - | 5.16 |
| 100 | 97.8 | 0.0 | 18.3 | 9.02 | 16.5 | 2.04 | 4.83 | 5.16 | - | 0.54 | 1.08 | - | - | 0.11 | - | - | 2.16 | - | - | 4.44* |
| 500 | - | - | - | - | - | - | - | - | 6.88 | - | 6.30 | - | 1.72 | - | 2.30 | - | - | - | - | - |

| Height, ft | Airborne Material, $\mu g$ at 500 yd | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | | | | | | | | 0.0 | | 0.06 | | 0.0 | | 0.0 | | | | | |
| 30 | | | | | | | | | | 0.01 | | | | 0.16 | | | | | |
| 200 | | | | | | | | | | 0.70 | | | | | | | | | |
| 300 | | | | | | | | | | 0.0 | | | | | | | | | |

*Excluding the value of 97.8 $\mu g/m^2$ at Station 1.

TABLE 12

Summary of Meteorological Observations at Wewak

| Serial No. | Experiment | Period | Mean Wind Speed, m.p.h. at Heights, ft | | | | Mean Wind Direction at Height of 30 ft | Turbulence | | | | | | | | | | Mean Value Vertical Turbulence | | Average Values of Air Temperature, °C | | | | Humidity | Cloud |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 30 | 100 | 200 | 300 | | Lateral | | Maximum Variations in Wind Direction at Times | Vertical: at Heights, $\sigma^{\circ}_{z}$ | | | | | | | | | | | | | | |
| | | | | | | | | $\sigma^{\circ}_{y}$ | Cy | | 30 | 100 | 200 | 300 | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | $\sigma^{\circ}_{z}$ | $C_z$ | Ground Level | 100 ft | 200 ft | 300 ft | | |
| 1 | Plutonium No. 1 | 1517 - 1550 | (6.3)[1] 9.2 | - | - | (10.5) 250 - 500 | 93° (96 97 95)[2] | 10 | 0.18 | + 34° at 1531.5<br>- 40° at 1539.8 | 6.0 | - | 9.5 | 9.0 | | | | 8.2 | 0.15 | 18.8 | - | 17.9 | 17.5 | 72% | ¾ 3000 ft<br>¾ 10000 ft |
| 2 | Plutonium No. 2 | 1510 - 1550 | (6.4) 9.7 | - | - | 10.7 | 73.5° (60 63 75) | 27 | 0.43 | + 68° at 1515<br>- 68° at 1516.4<br>1518.9 | 9.8 | - | 10.3 | 11.4 | | | | 10.5 | 0.19 | 28.7 | - | 24.4 | 24.4 | 25% | ⅓ 5000 ft |
| 3 | Uranium No. 1 | 1600 - 1635 | (8.7) - | 15.4 | 15.0 | 15.6 | 176° (162° 157° 147°) | 11.5 | 0.19 | + 37° at 1612.5<br>- 39° at 1608.2<br>1623.2 | 7.2 | 8.8 | 8.8 | 10.0 | | | | 8.7 | 0.15 | 18.2 | 18.5 | 18.4 | 17.4 | 20% | Cloudless |
| 4 | Uranium No. 2 | 1615 - 1650 | (8.3) 12.9 | 15.0 | 15.8 | 16.3 | 161° (157 161 163) | 7.8 | 0.14 | + 26.4° at 1646<br>- 25° at 1621.8 | 4.6 | 5.6 | 7.2 | 6.8 | | | | 6.1 | 0.11 | 17.1 | 17.2 | 16.8 | 16.1 | 38% | ⅓ 3500 ft |

NOTES: (1) Values in ( ) are speeds at ground level.

(2) The figures in ( ) are mean values at ground level, and in the ranges 0-250 ft and 250-500 ft from balloon ascents in descending order, respectively.

(3) The large variations in wind direction ($\geq 2\sigma_y$):

Serial 1 - were almost entirely positive up to 1532 and negative after 1538.

Serial 2 - occurred at 1515.0 to 1515.2 and 1533 - 1535.8 (positive) and 1516.4 to 1518.9 and 1525.5 (negative).

Serial 3 - occurred at 1607.7 to 1608.2 and 1622.8 to 1624.3 (negative) and 1609.9 to 1619.4 (positive).

Serial 4 - occurred at 1620.6 to 1627.8 (negative) and 1629 to 1648 (positive).

TABLE 13

Estimates of Amounts Deposited on Array or Dispersed

| Experiment | Amounts Used, g | From Residue in Fire, g | Integration of Average Cross-Wind Deposition Level, g | Integration of Deposition Contours, g | Integration of Airborne Material at 500 yd, g |
|---|---|---|---|---|---|
| 1st Plutonium | 203 | ~ 2 | | 0.2 | |
| 2nd Plutonium | 202.4 | ~ 6.6 | 1.9 | 1.7 | $7 \times 10^{-3}$ |
| 1st Uranium | 2394 | 78 | 126 | 114 | 300 (1) |
| 2nd Uranium | 2408 | 126 | 102 | 94 | 600 (1) |

NOTE: (1) These values are much larger than the estimate obtained by other methods and indicate that the air concentration was not uniform to 300 ft across the array.

TABLE 14

Estimate of a Deposition Velocity

| Experiment | Range, yd | Ax, | Gx, | $V_D$ cm/sec | Particle Diameter (μ) | |
|---|---|---|---|---|---|---|
| | | | | | Calculated from $V_D$ | Mass Median Observed |
| | | μc × $10^8$ | μc/$m^3$ | | | |
| 1st Plutonium | 200 | 250 | ≥ 0.01 | ≥ 1 | 5.46 | |
| | 500 | 1.18 | 0.002 | | | |
| | 1000 | 0.195 | 1.16 × $10^{-3}$ | 149 | 66 | |
| | 1500 | 0.323 | 2.71 × $10^{-3}$ | 210 | 79 | |
| | 2000 | 0.226 | 1.21 × $10^{-3}$ | 13.4 | 20 | |
| 2nd Plutonium | 500 | 0.715 | 7.8 × $10^{-3}$ | 2700 | 280 | |
| | 1000 | 0.171 | 8.43 × $10^{-4}$ | 123 | 60 | |
| | 1500 | 0.185 | 2.78 × $10^{-4}$ | 38 | 34 | |
| | 2000 | 0.279 | 2.2 × $10^{-4}$ | 20 | 24 | |
| | | μg | μg/$m^3$ | | | |
| 1st Uranium | 200 | 0.398 | 140 | 8.8 | 19 | 3 |
| | 500 | 0.329 | 24 | 1.8 | 8.5 | 4 |
| | 1000 | 0.266 | 150 | 14 | 24 | 2 |
| | 1500 | 0.266 | 9 | 0.85 | 5.9 | 1.7 |
| | 2000 | 0.212 | 1 | 0.12 | 2.2 | 1.2 |
| 2nd Uranium | 200 | 0.488 | 2.6 | 0.13 | 2.3 | 3.2 |
| | 500 | 0.252 | 8.2 | 0.80 | 5.7 | 3.2 |
| | 1000 | 0.239 | 14.8 | 1.6 | 8.0 | 0.85 |
| | 1500 | 0.356 | 4 | 0.28 | 3.3 | 2.1 |
| | 2000 | 0.326 | 4 | 0.31 | 3.5 | 3.0 |

TABLE 14

imate of a Deposition Velocity

| Particle Diameter (μ) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mass Median Observed | Calculated from $V_D$ | $V_D$ cm/sec | $G_{x_3}$ | | $A_{x_3}$ | | $\mu c \times 10^8$ | $\mu c/m^2$ | | Hg | $Hg/m^2$ |
| | | | | | | | 250 | ≥ 0.01 | | 0.398 | 140 |
| | | | | | | | 1.18 | $0.002_3$ | | 0.329 | 24 |
| | | | | | | | 0.195 | $1.16 \times 10^{-3}$ | 149 | 0.266 | 150 |
| | | | | | | | 0.323 | $2.71 \times 10^{-3}$ | 210 | 0.266 | 9 |
| | | | | | | | 0.226 | $1.21 \times 10^{-3}$ | 13.4 | 0.212 | 1 |
| | | | | | | | | ≥ 1 | | | |
| | | 5.46 | | | | | 0.715 | $7.8 \times 10^{-2}$ | 2700 | | |
| | | | | | | | 0.171 | $8.43 \times 10^{-4}$ | 123 | | |
| | | | | | | | 0.185 | $2.78 \times 10^{-4}$ | 38 | | |
| | | | | | | | 0.279 | $2.2 \times 10^{-4}$ | 20 | | |
| | | 66 | | 280 | | | | | | | |
| | | 79 | | 60 | | | | | | | |
| | | 20 | | 34 | | | | | | | |
| | | | | 24 | | | | | | | |

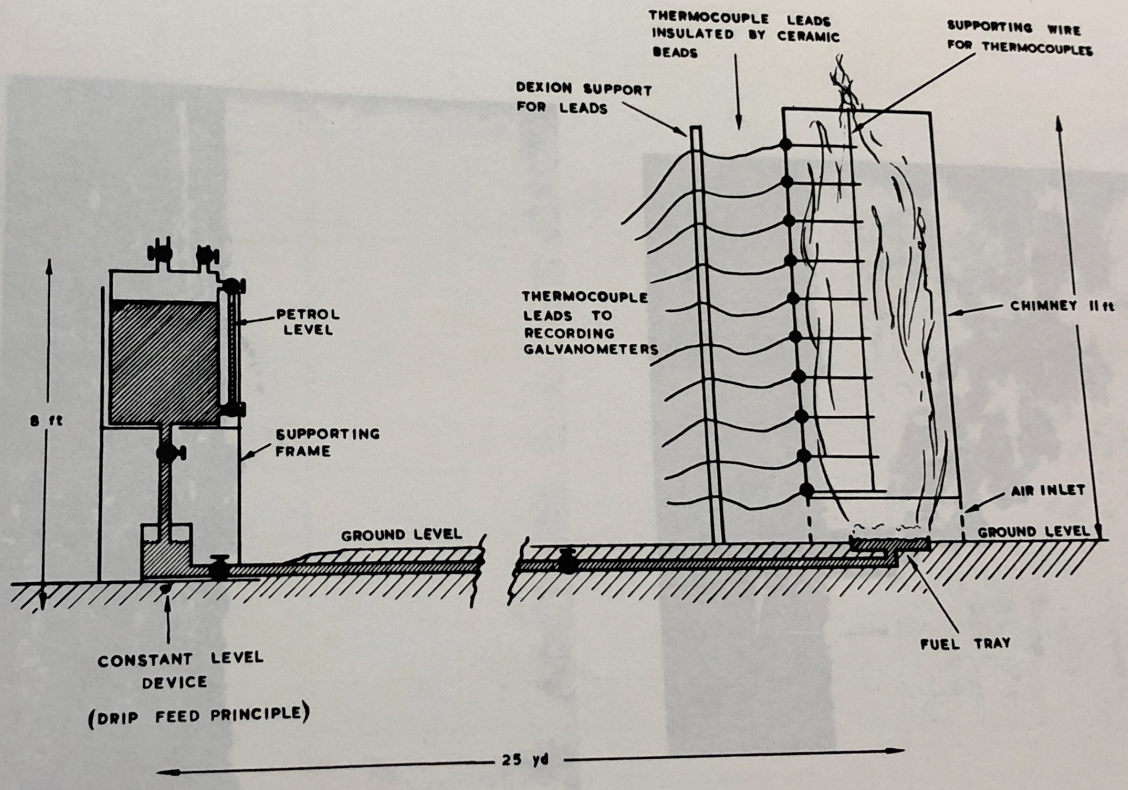



FIGURE 1. DIAGRAM OF FIRE SYSTEM

FIGURE 2. FIRE APPARATUS IN OPERATION

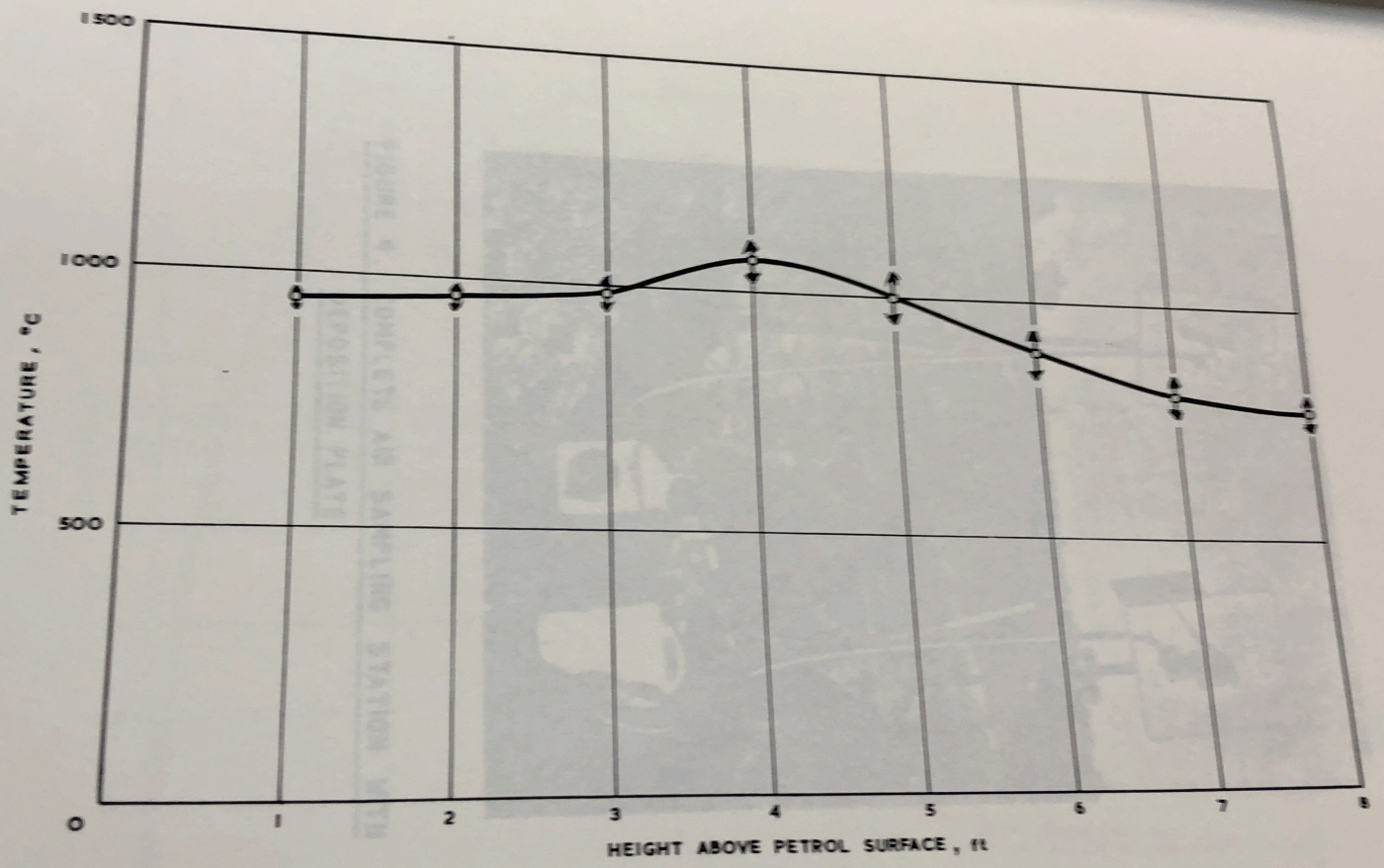



FIGURE 3. TYPICAL TEMPERATURE PROFILE IN FLAME ZONE – THE STANDARD DEVIATIONS ABOUT THE MEAN VALUES OF TEMPERATURE ARE SHOWN

FIGURE 4. COMPLETE AIR SAMPLING STATION WITH DEPOSITION PLATE

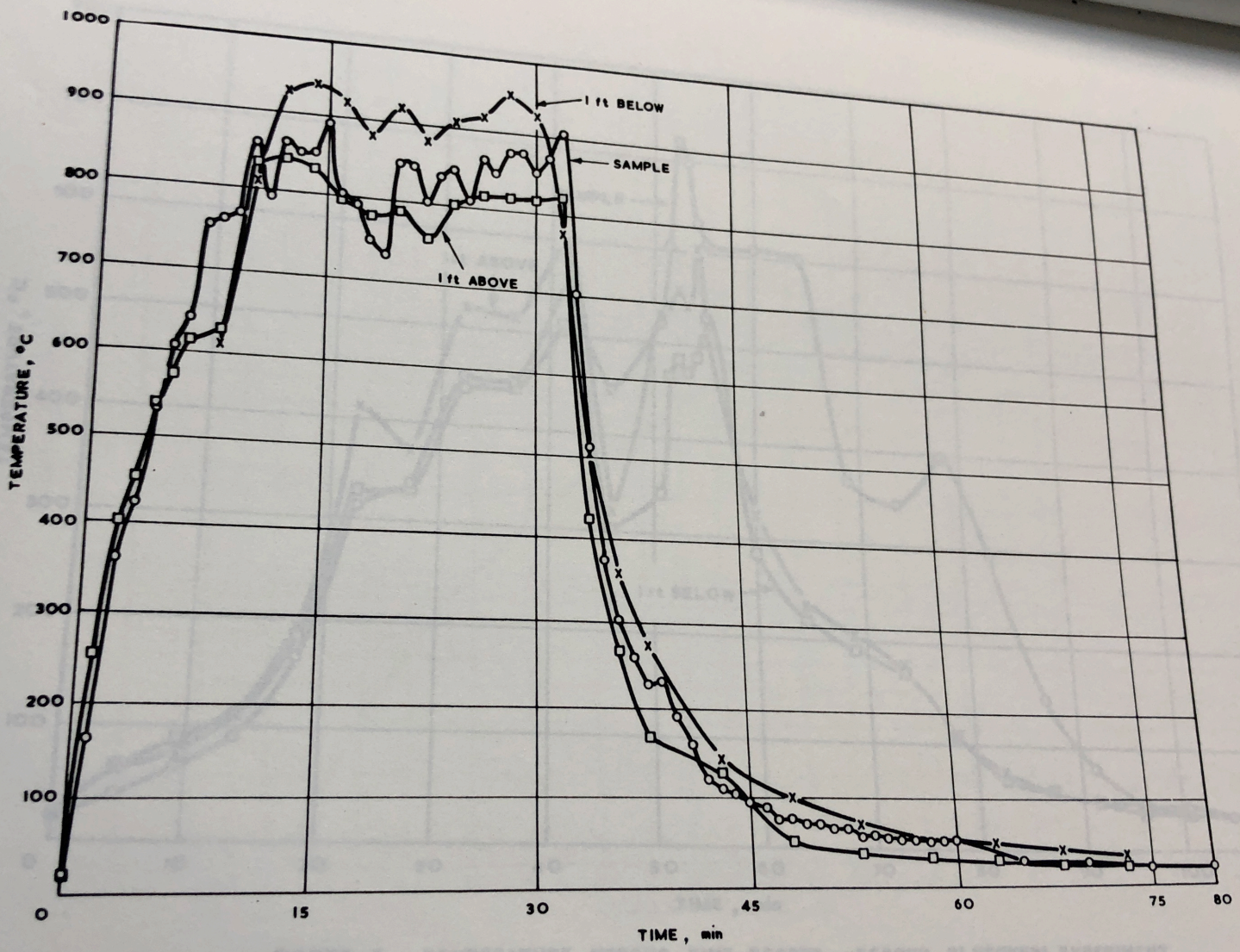



FIGURE 5. TEMPERATURE VERSUS TIME RECORD – FIRST PLUTONIUM EXPERIMENT

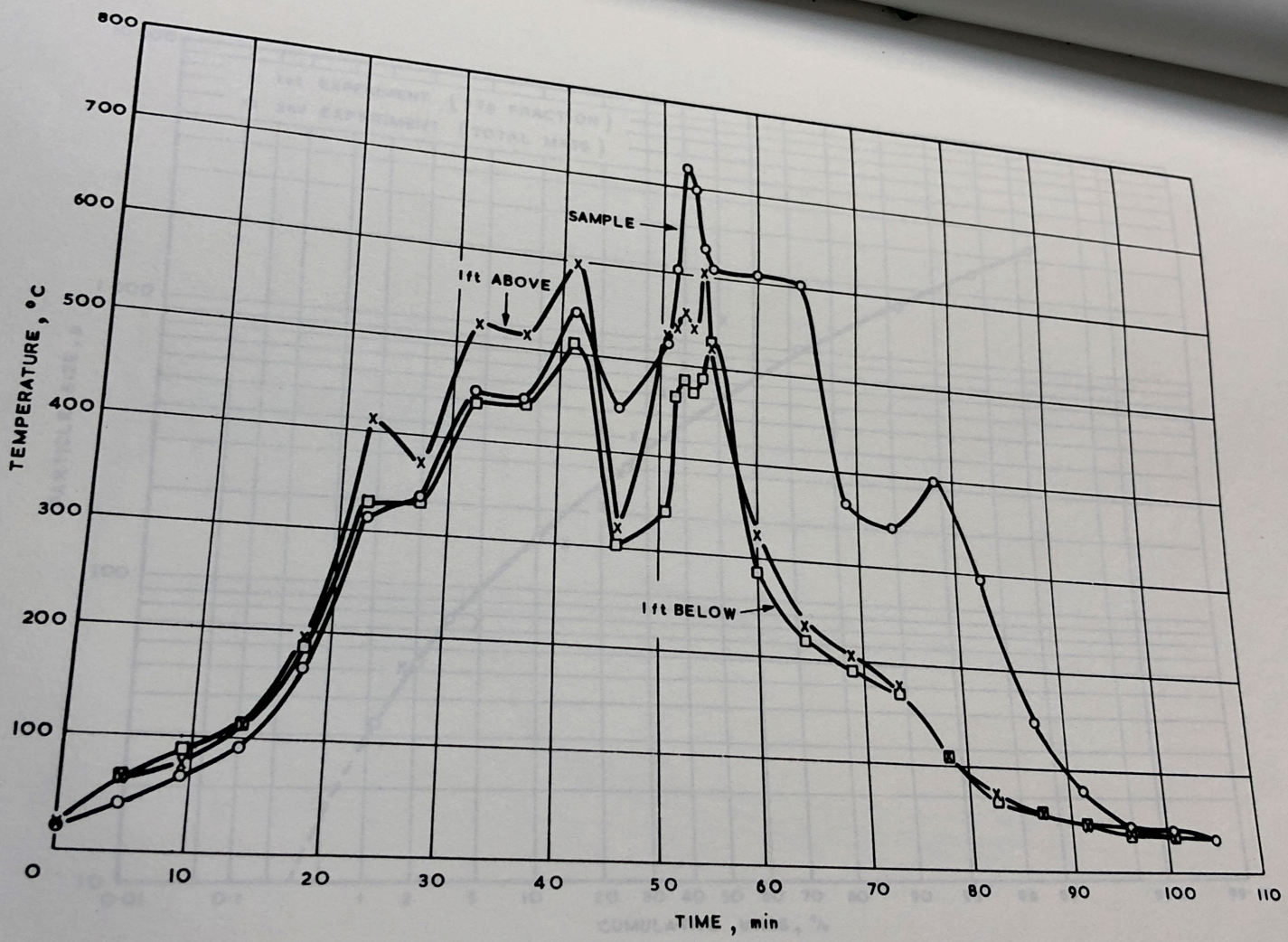



FIGURE 6. TEMPERATURE VERSUS TIME RECORD – SECOND PLUTONIUM EXPERIMENT

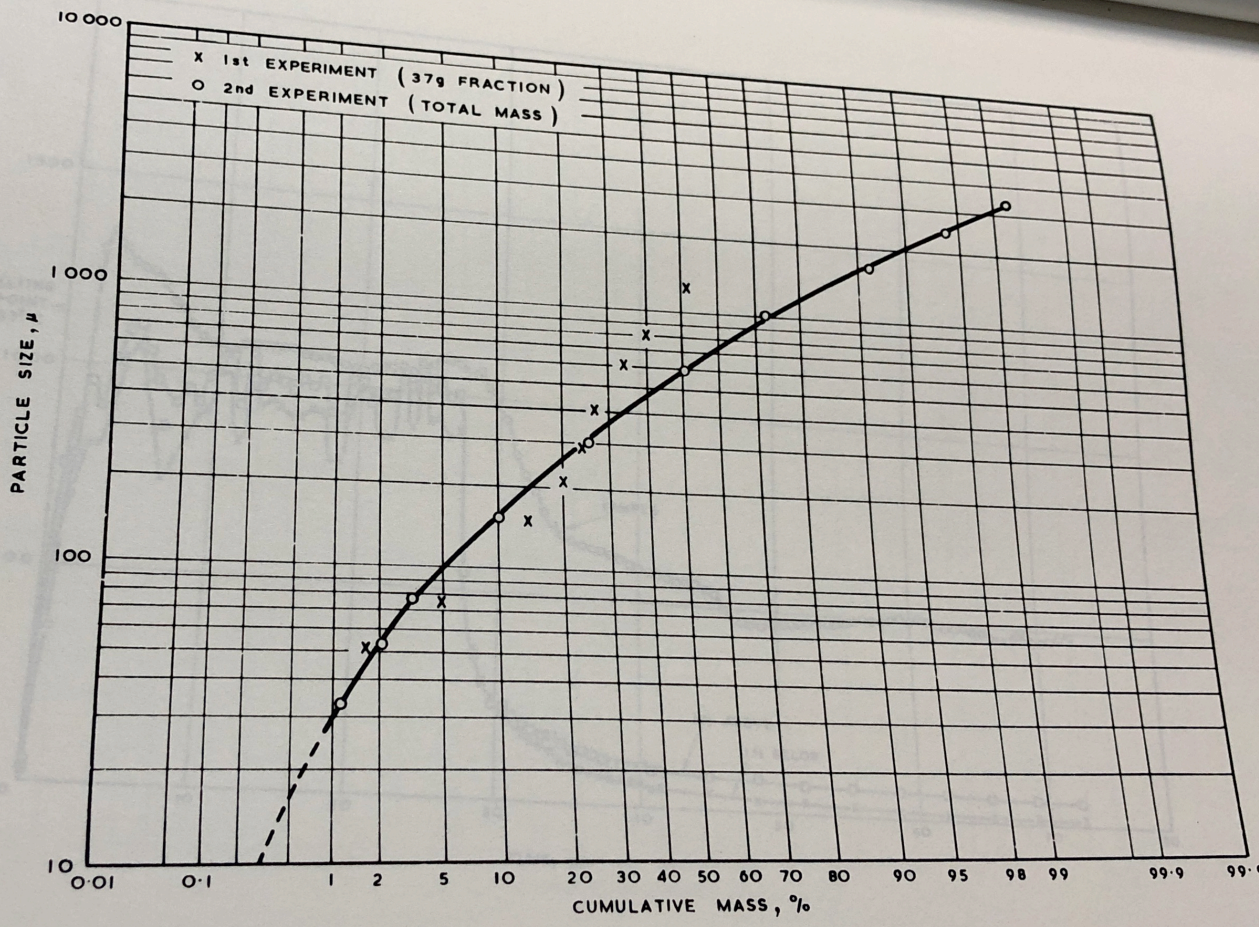



FIGURE 7. RESIDUES FROM PLUTONIUM EXPERIMENTS: PARTICLE SIZE VERSUS CUMULATIVE MASS

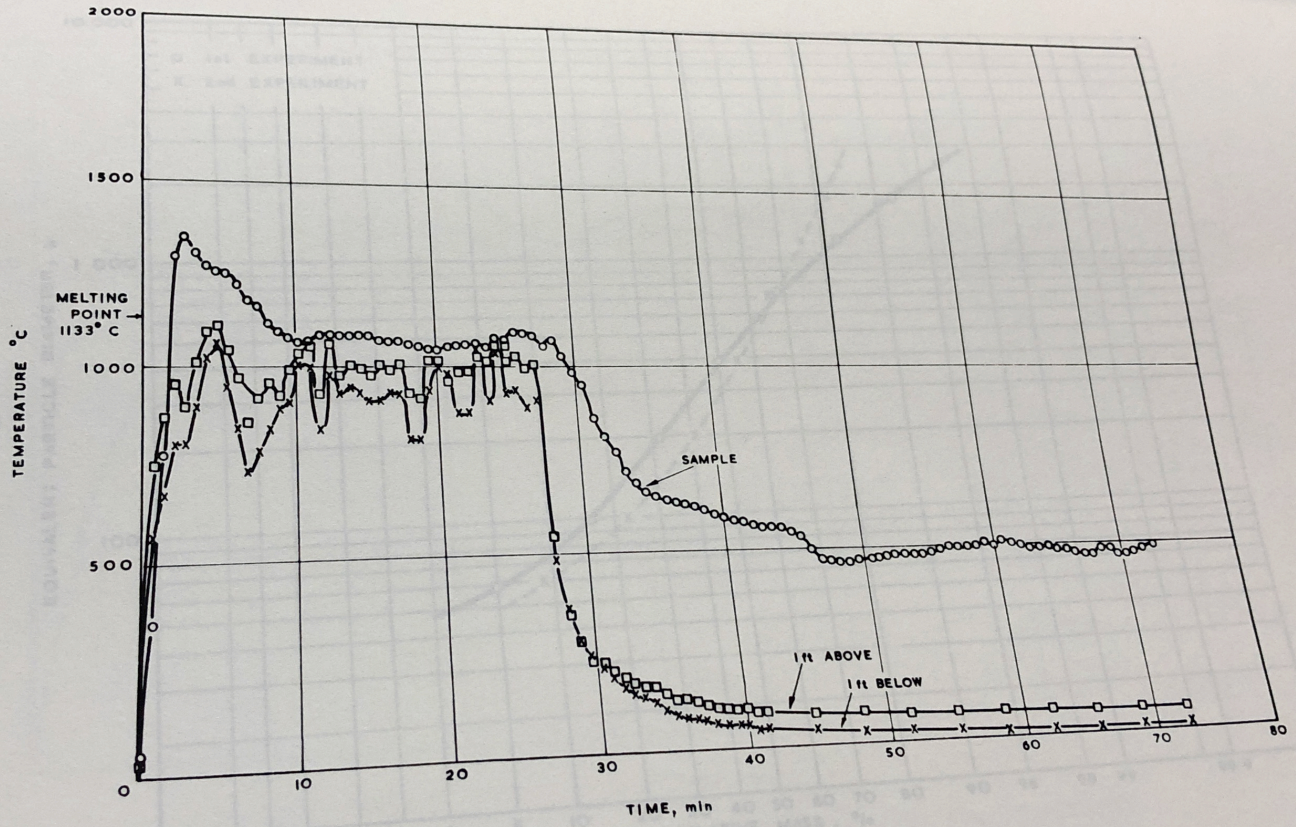



FIGURE 8. TEMPERATURE VERSUS TIME RECORD: SECOND URANIUM EXPERIMENT

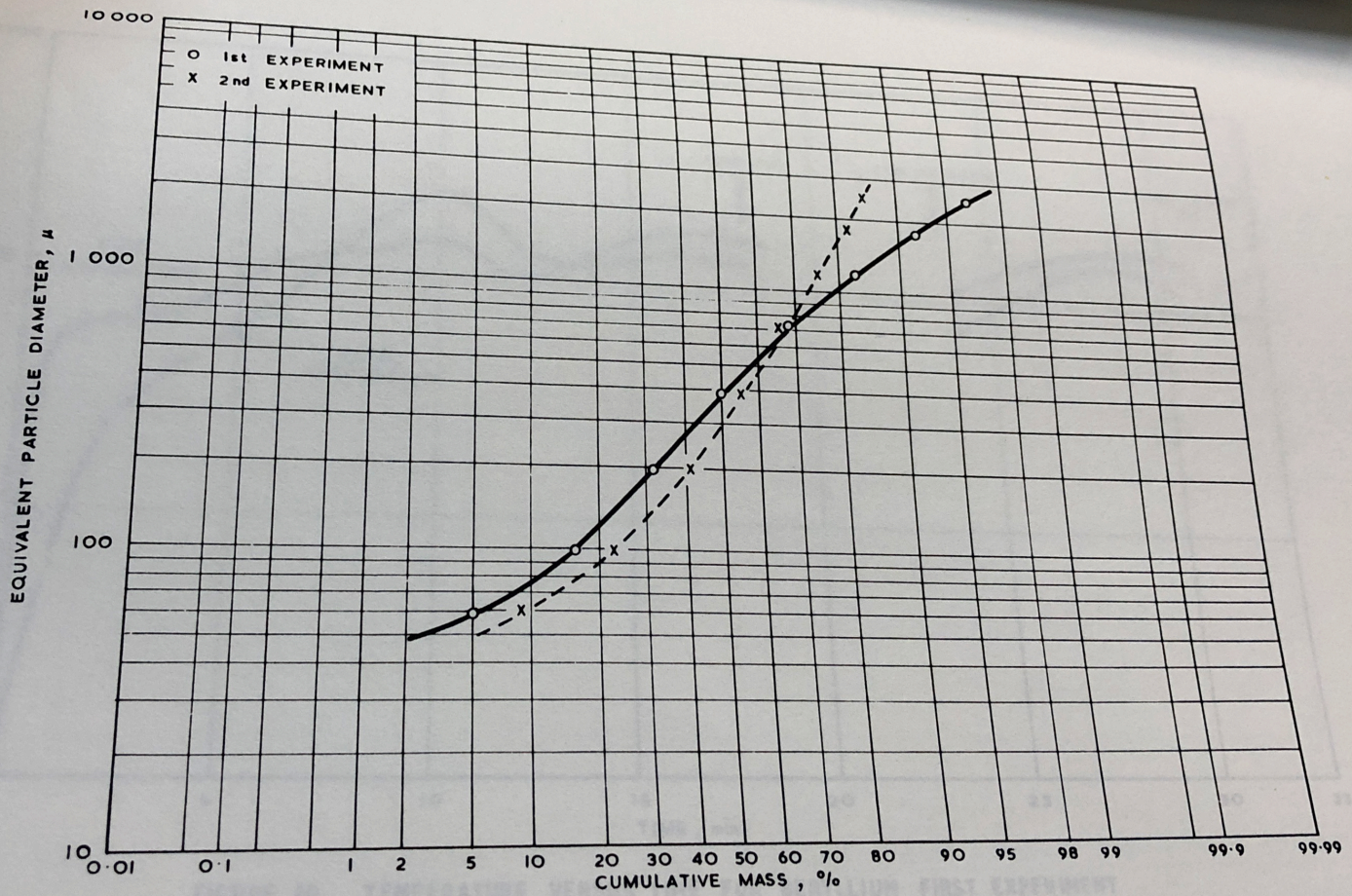



FIGURE 9. PARTICLE SIZE DISTRIBUTIONS OF RESIDUAL URANIUM OXIDE

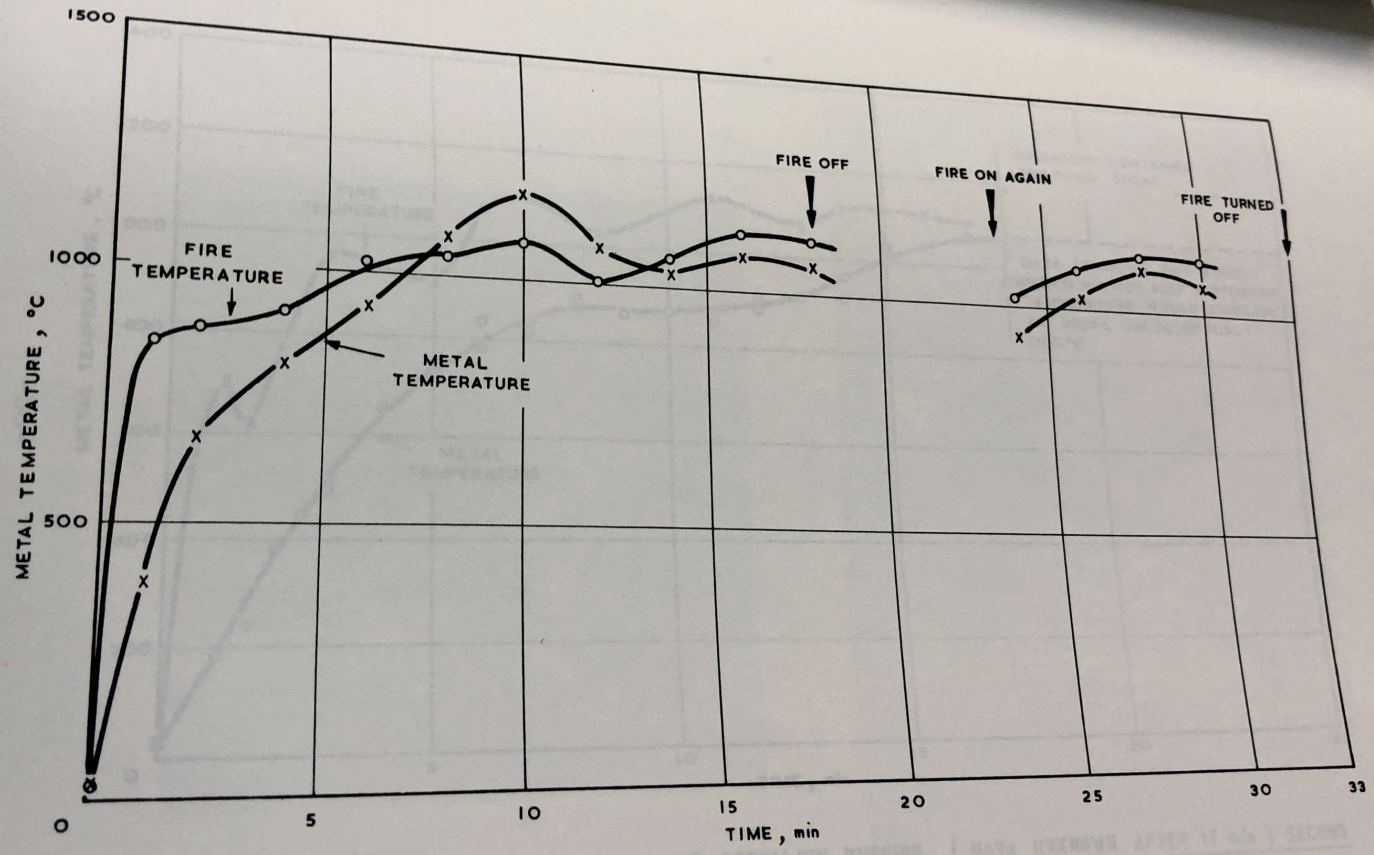



FIGURE 10. TEMPERATURE VERSUS TIME FOR BERYLLIUM FIRST EXPERIMENT

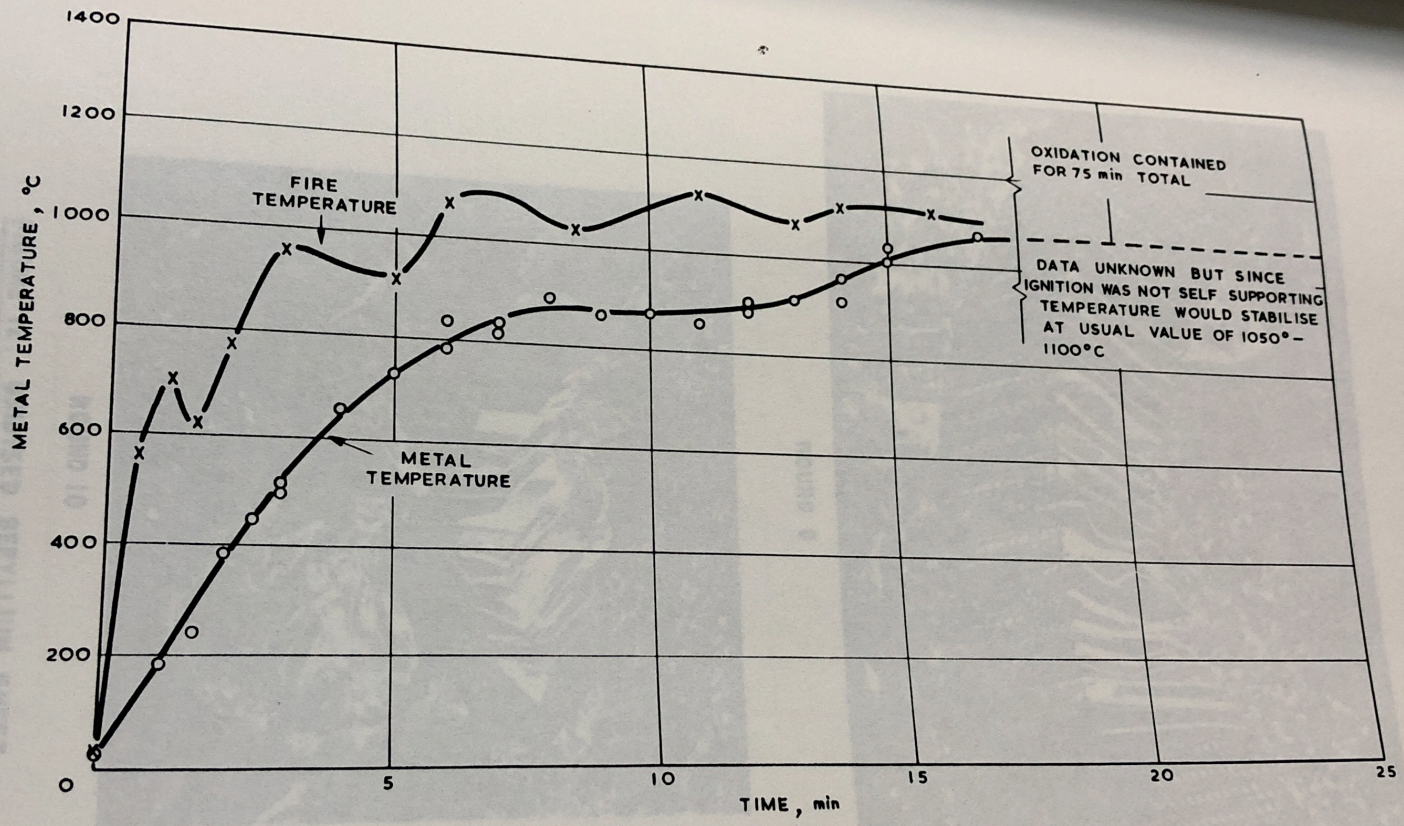
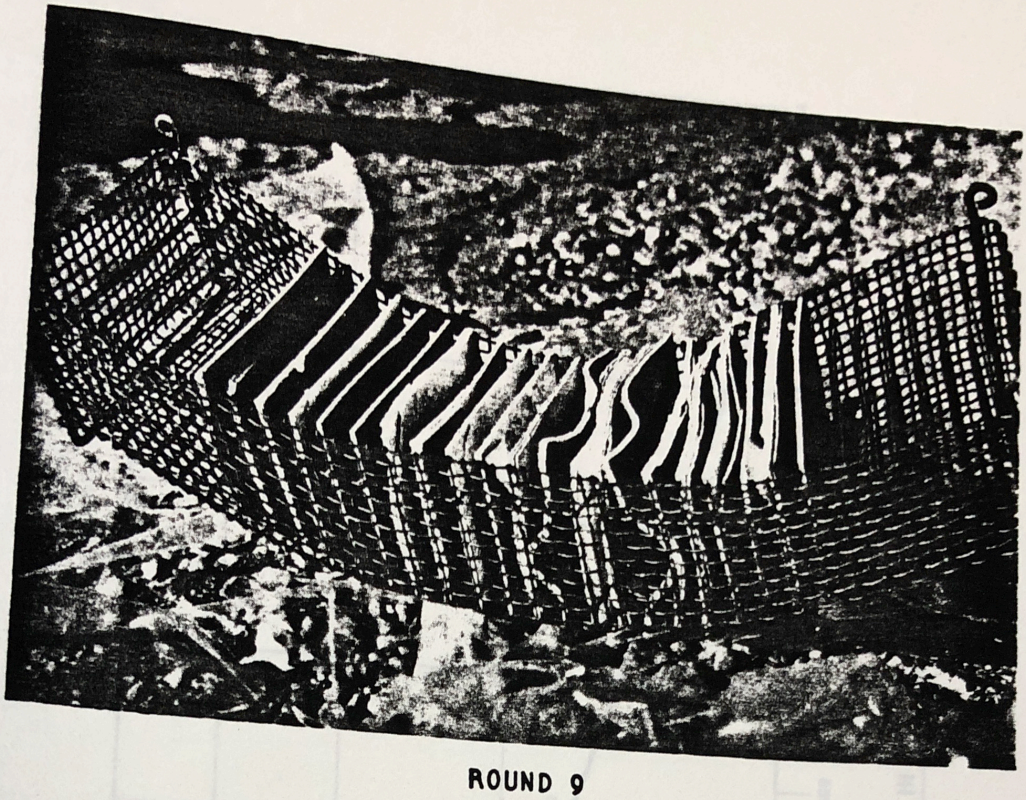
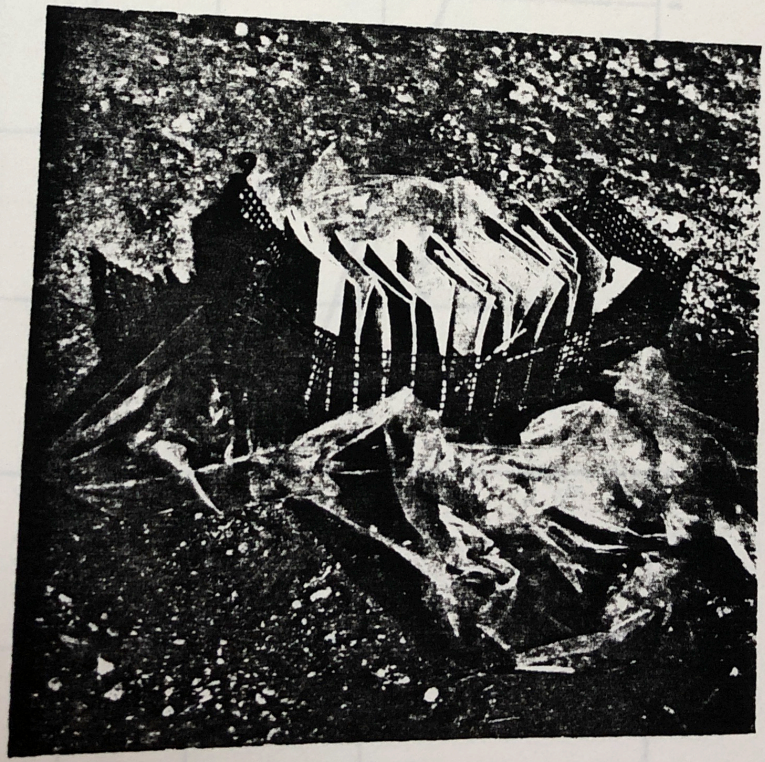



FIGURE 11. TEMPERATURE VERSUS TIME FOR BERYLLIUM BURNING. ( DATA UNKNOWN AFTER 17 min ) SECOND EXPERIMENT



ROUND 9



ROUND 10

FIGURE 12. OXIDISED BERYLLIUM SHEET

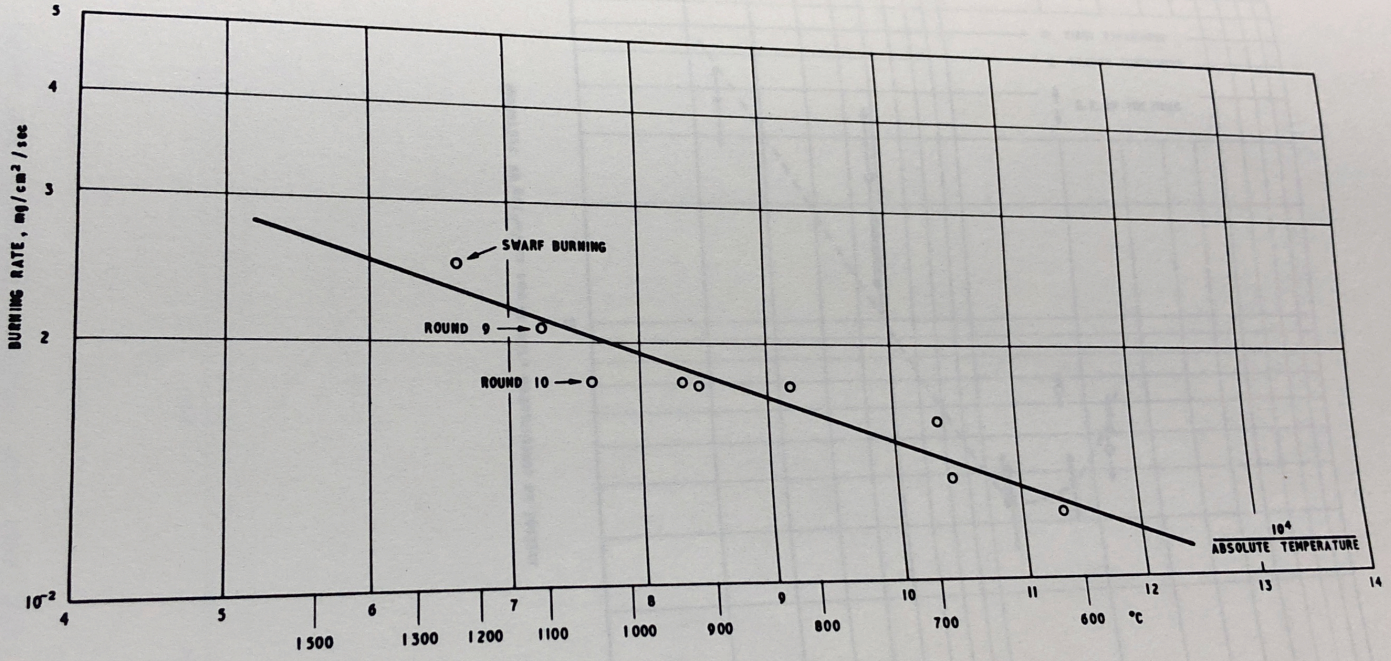



FIGURE 13. OXIDATION RATE OF BERYLLIUM IN PETROL FIRES (ARRHENIUS PLOT)

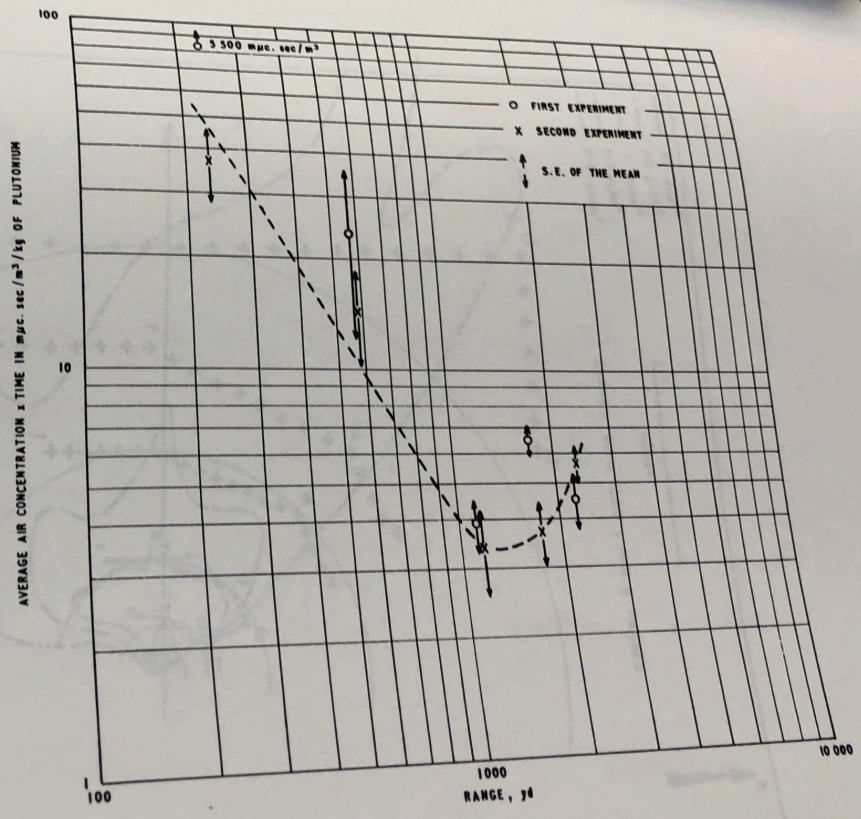



FIGURE 14. AIR CONCENTRATION OF OXIDE PRODUCED BY COMBUSTION OF PLUTONIUM IN A PETROL FIRE

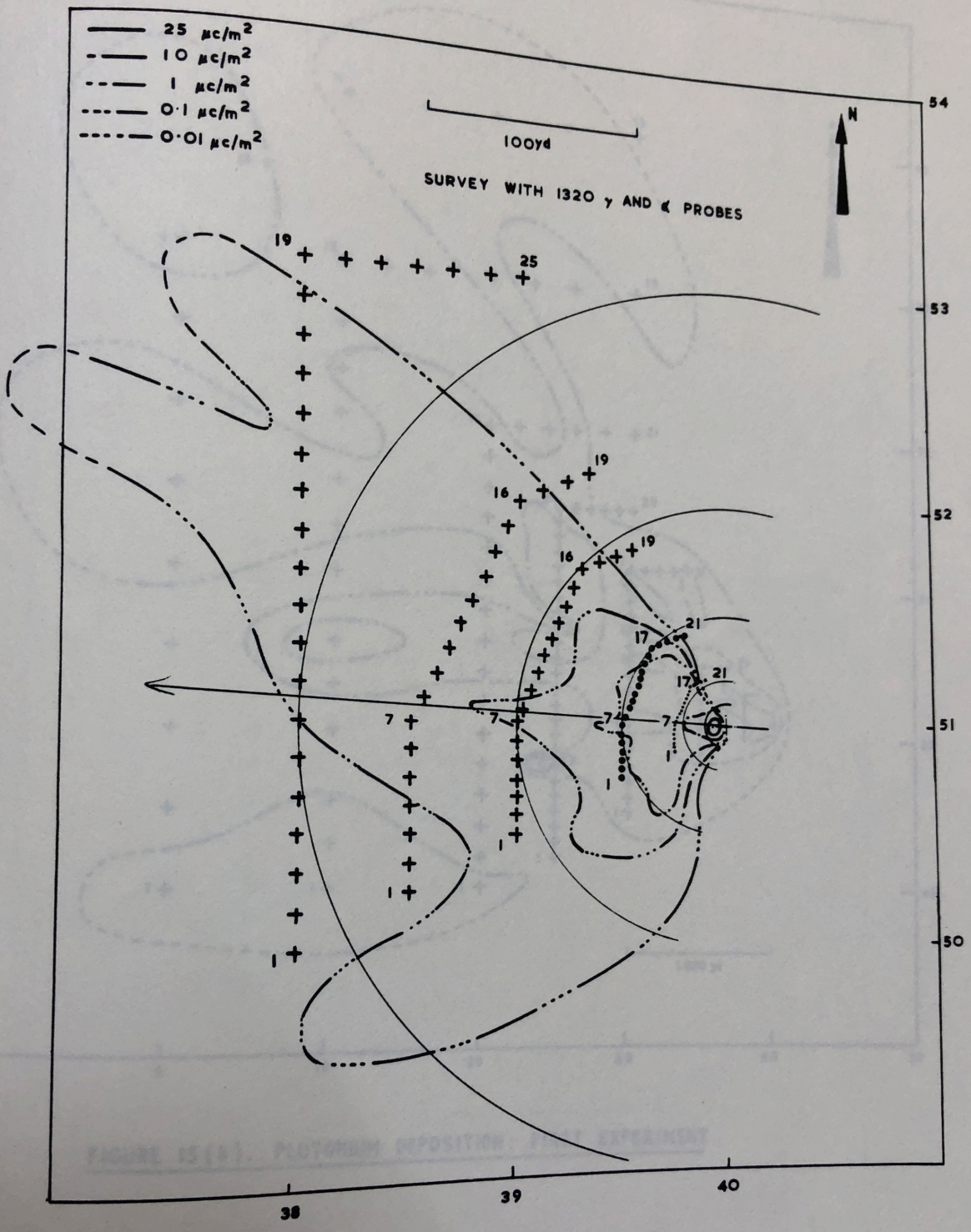



FIGURE 15 (a) PLUTONIUM DEPOSITION: FIRST EXPERIMENT

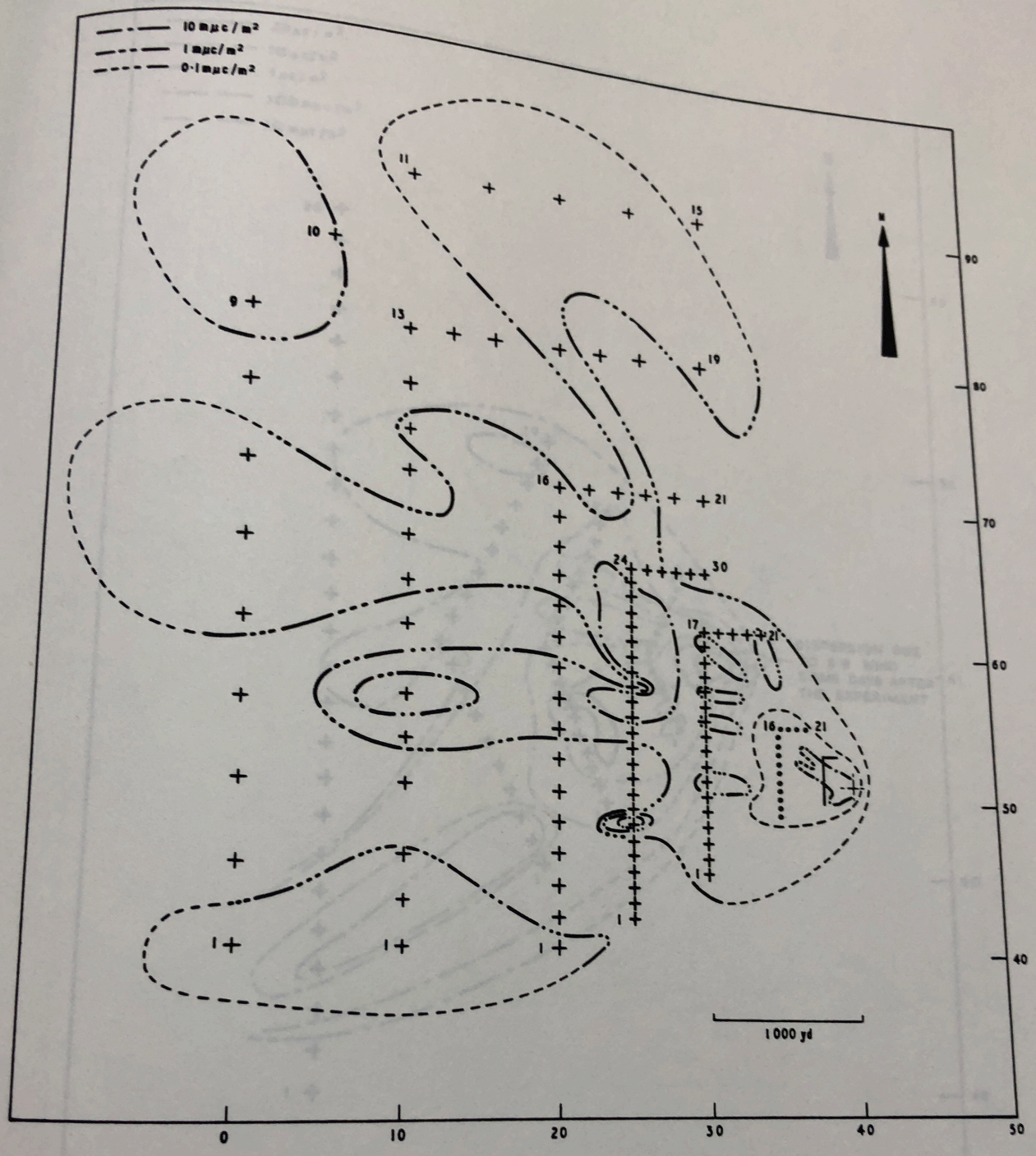



FIGURE 15(b). PLUTONIUM DEPOSITION: FIRST EXPERIMENT

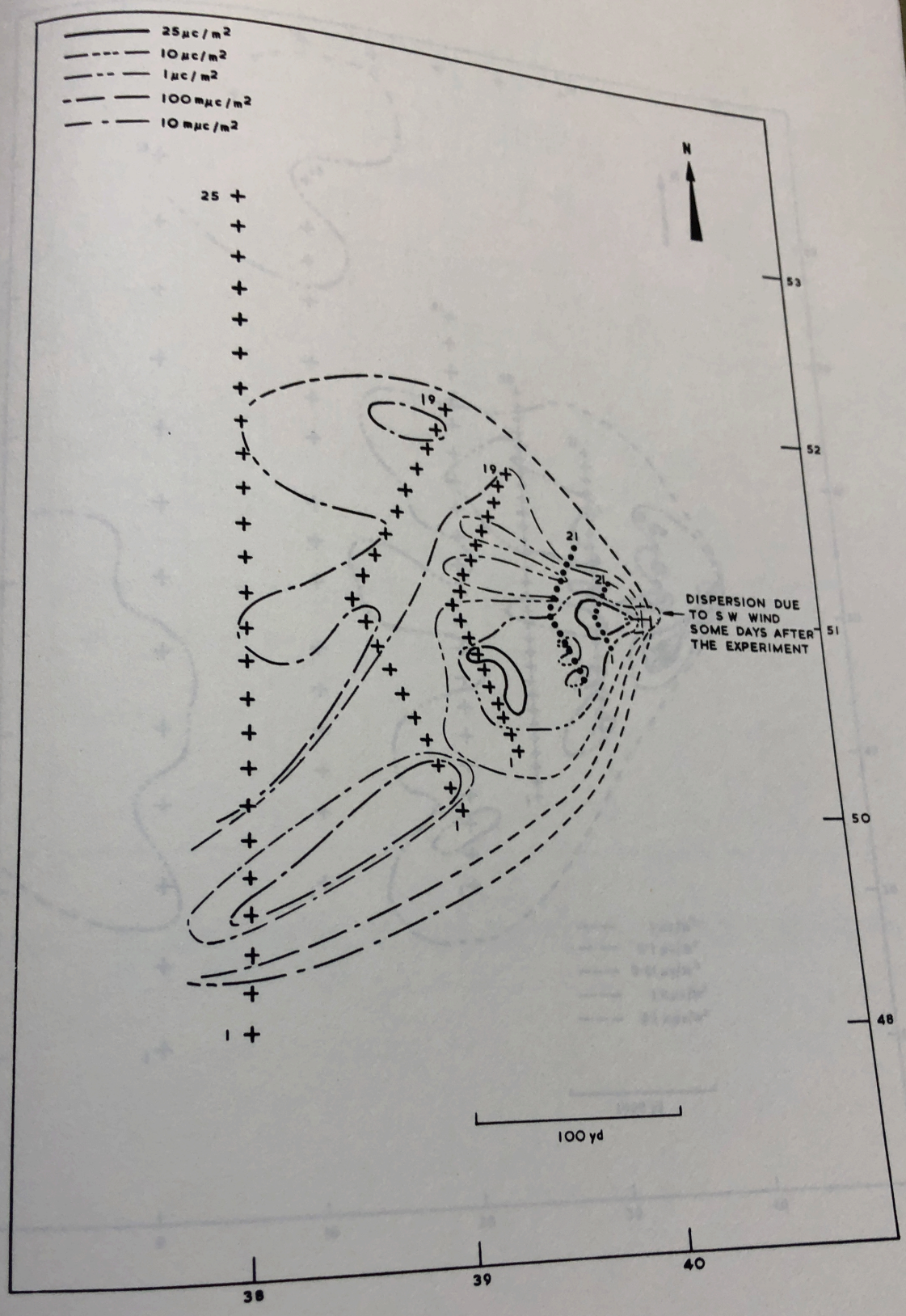



FIGURE 16 (a). PLUTONIUM DEPOSITION: SECOND EXPERIMENT

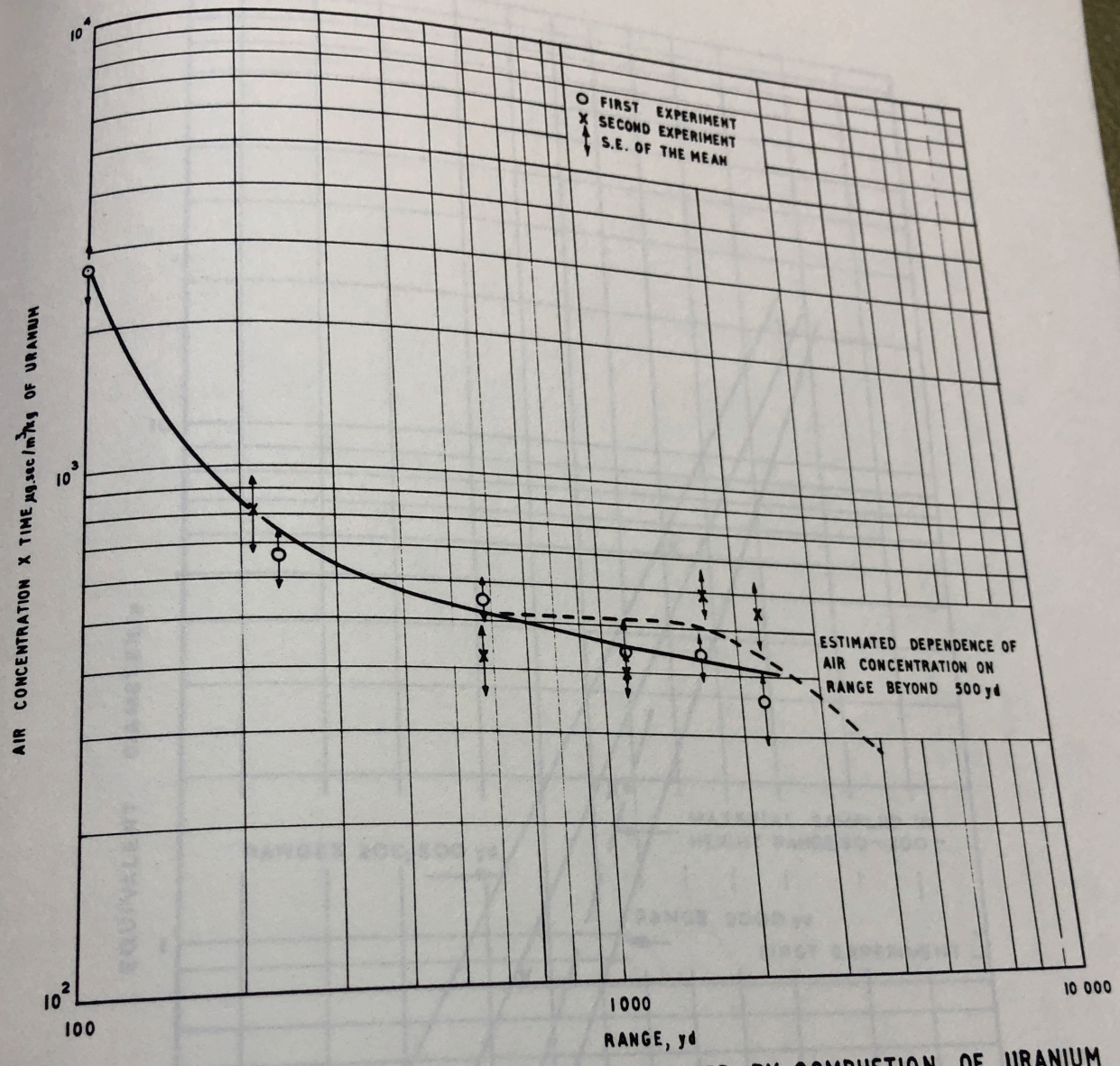



FIGURE 17. AIR CONCENTRATION OF OXIDE PRODUCED BY COMBUSTION OF URANIUM IN A PETROL FIRE

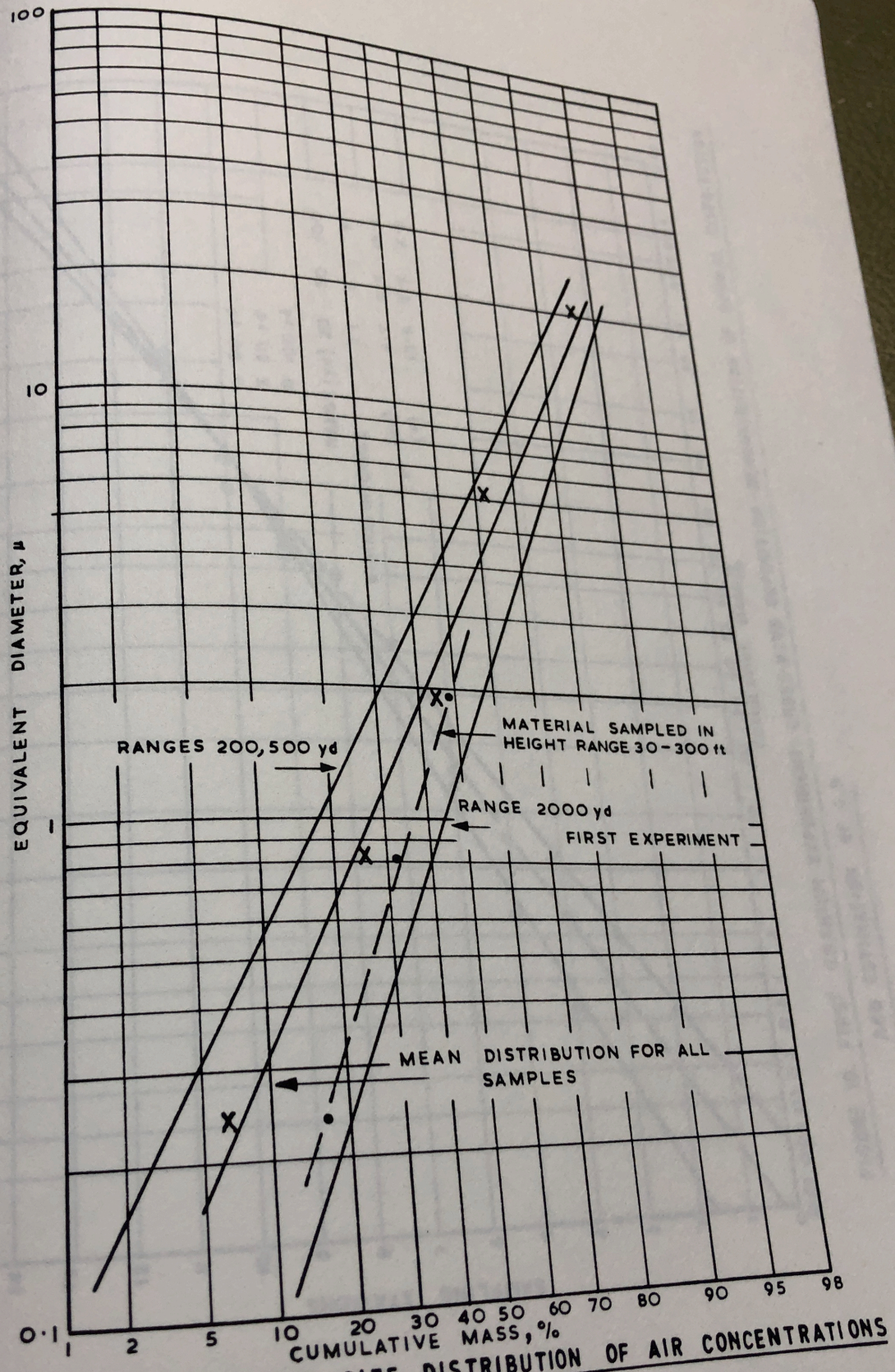



FIGURE 18. PARTICLE SIZE DISTRIBUTION OF AIR CONCENTRATIONS – URANIUM EXPERIMENTS

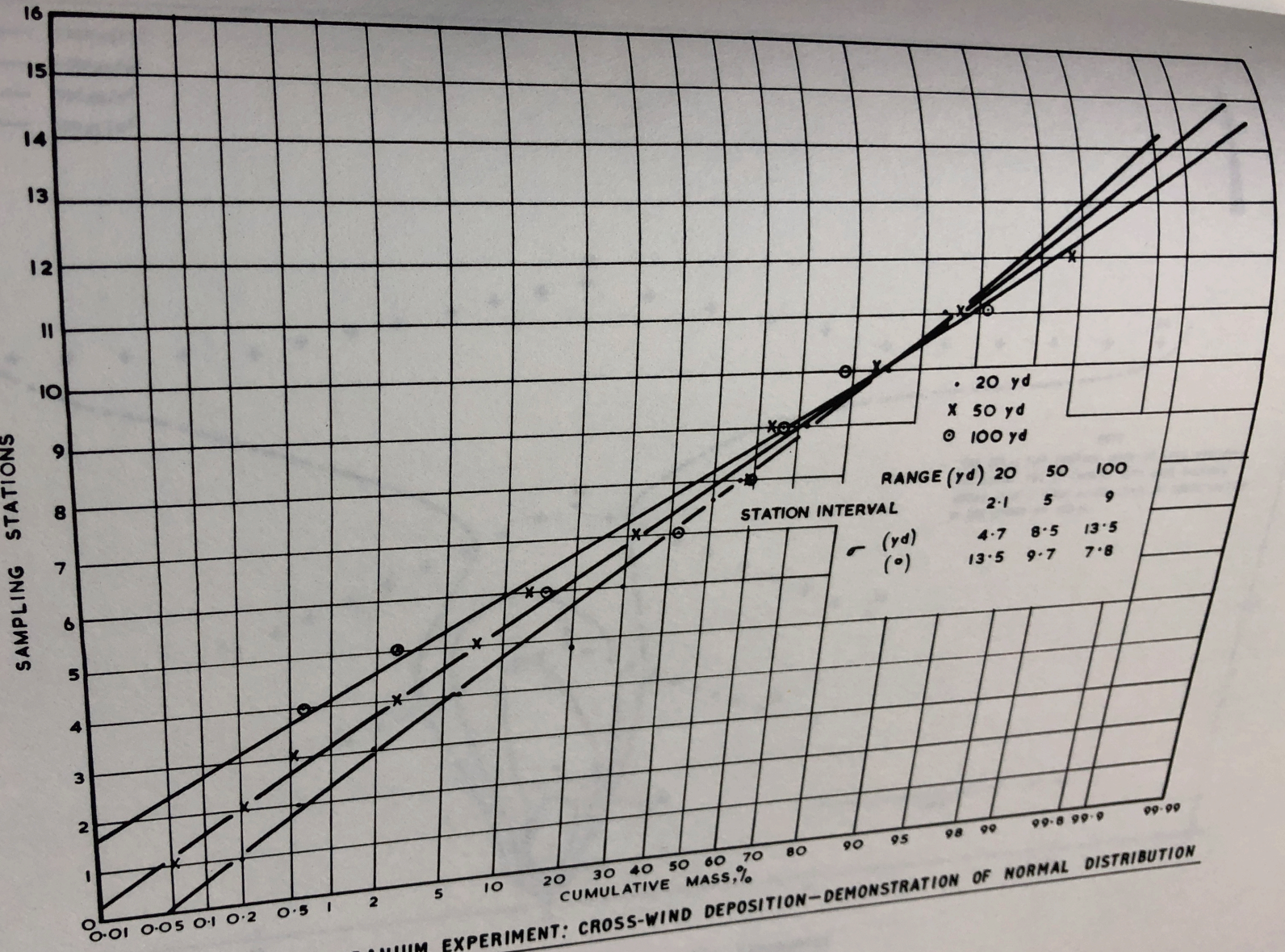



FIGURE 19. FIRST URANIUM EXPERIMENT: CROSS-WIND DEPOSITION—DEMONSTRATION OF NORMAL DISTRIBUTION AND ESTIMATION OF S.D

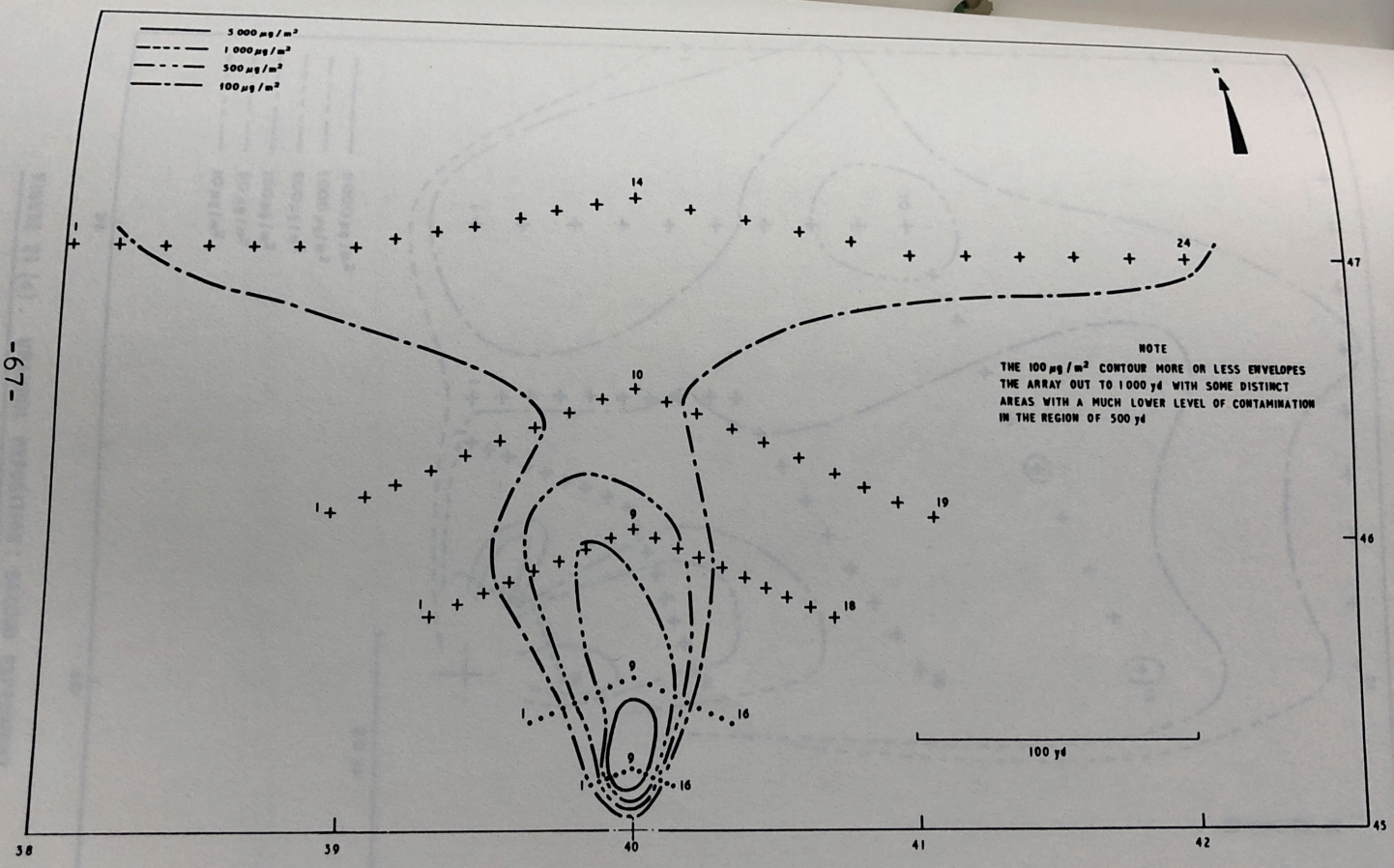



FIGURE 20. URANIUM DEPOSITION: FIRST EXPERIMENT

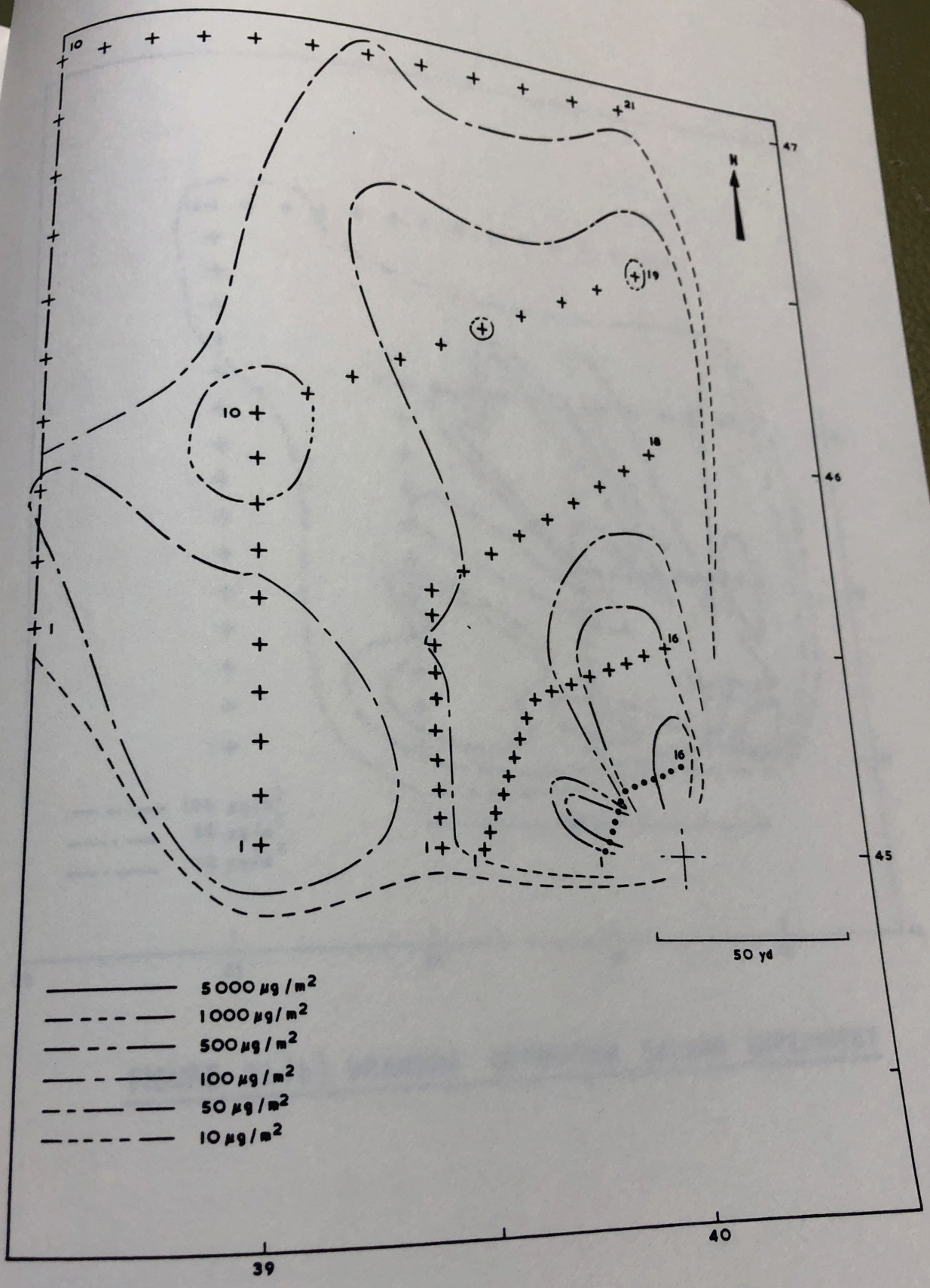



FIGURE 21 (a). URANIUM DEPOSITION: SECOND EXPERIMENT

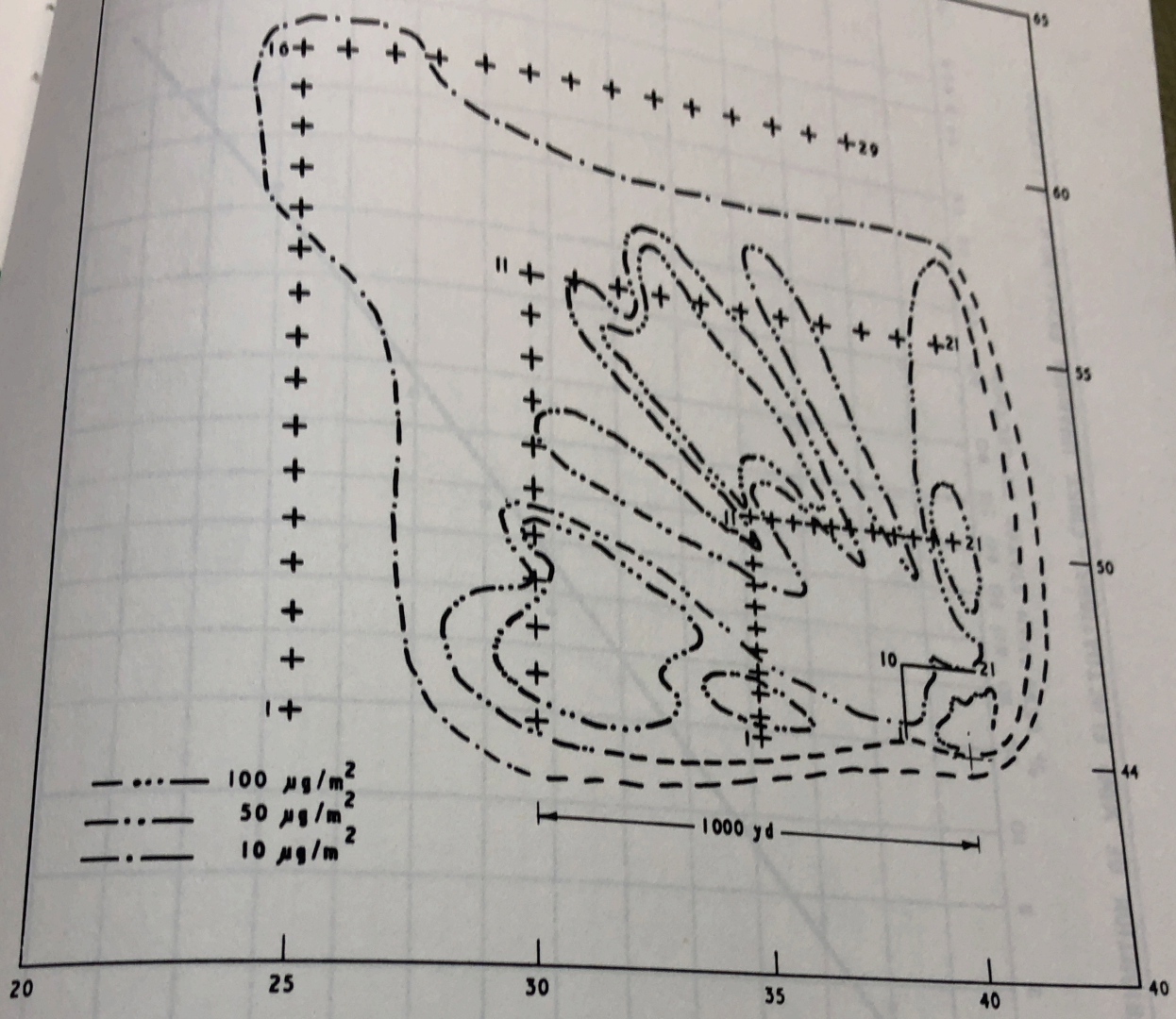



FIGURE 21 (b) URANIUM DEPOSITION SECOND EXPERIMENT

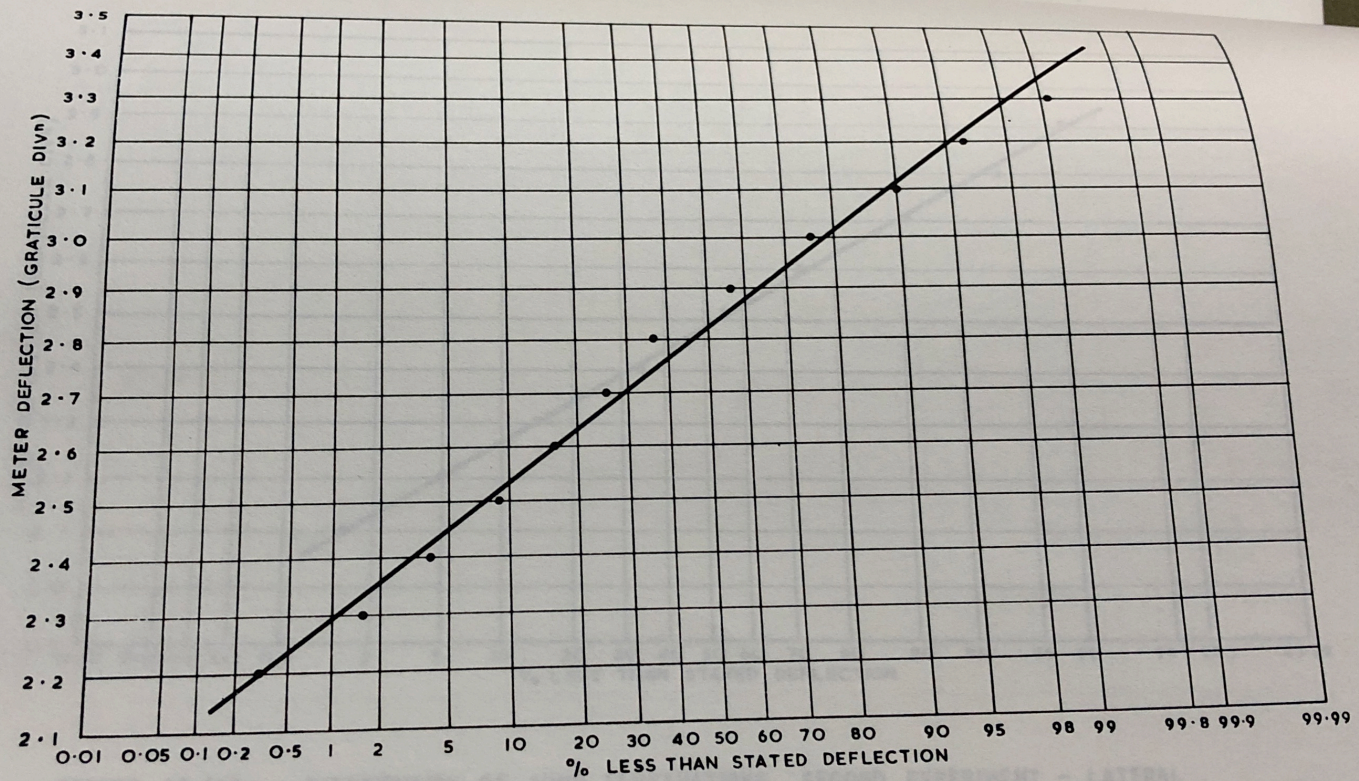



FIGURE 22 (a). DISTRIBUTION OF WIND FLUCTUATIONS – FIRST URANIUM EXPERIMENT – LATERAL

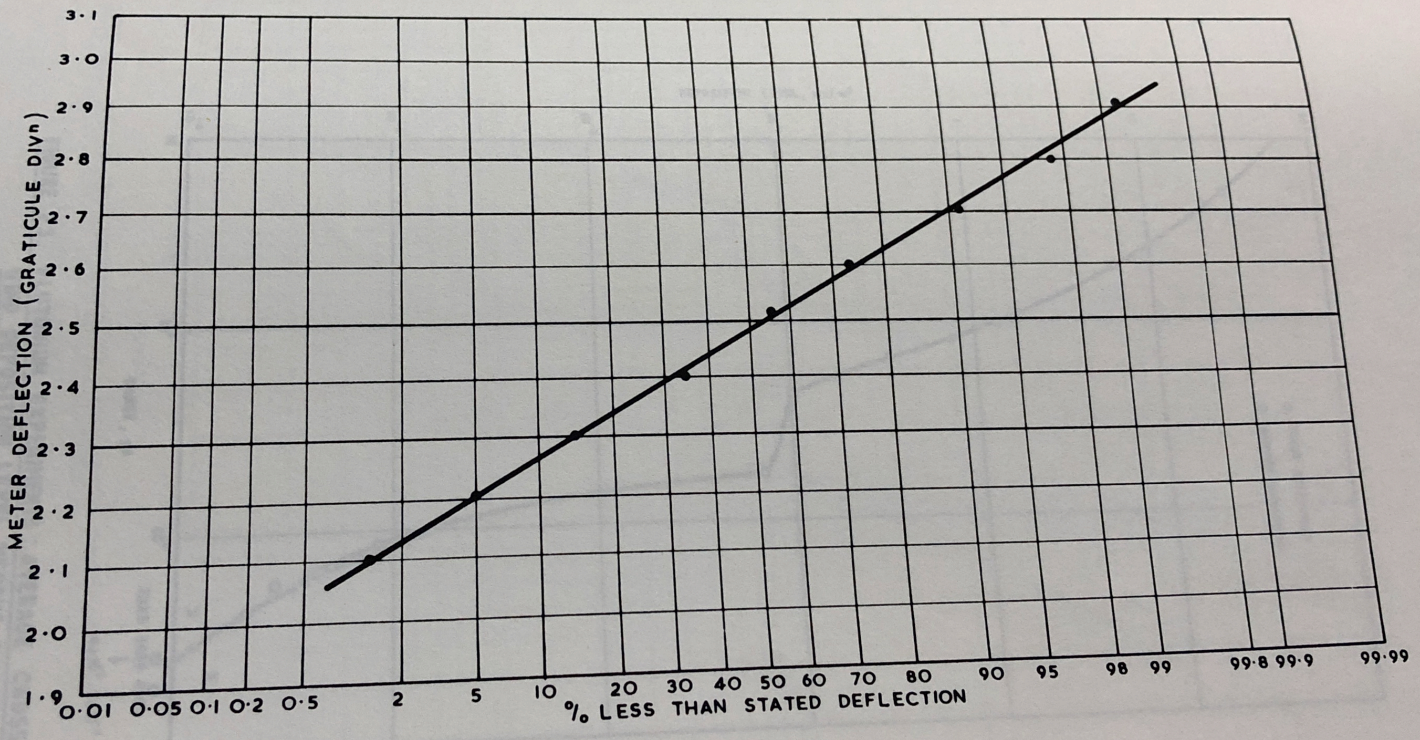



FIGURE 22 (b). DISTRIBUTION OF WIND FLUCTUATIONS SECOND EXPERIMENT – LATERAL

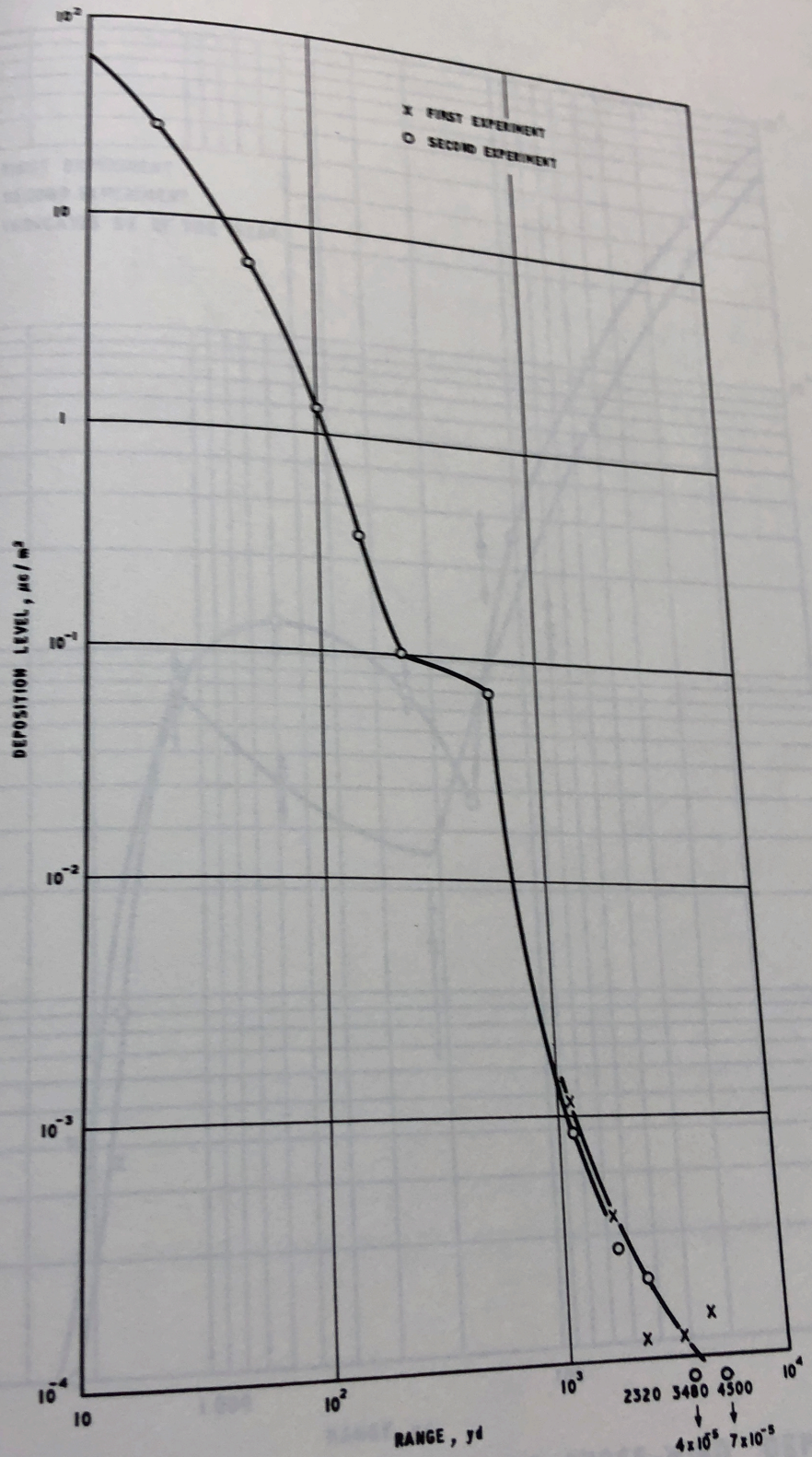



FIGURE 23. PLUTONIUM EXPERIMENTS: AVERAGE CROSS WIND DEPOSITION LEVEL VERSUS RANGE

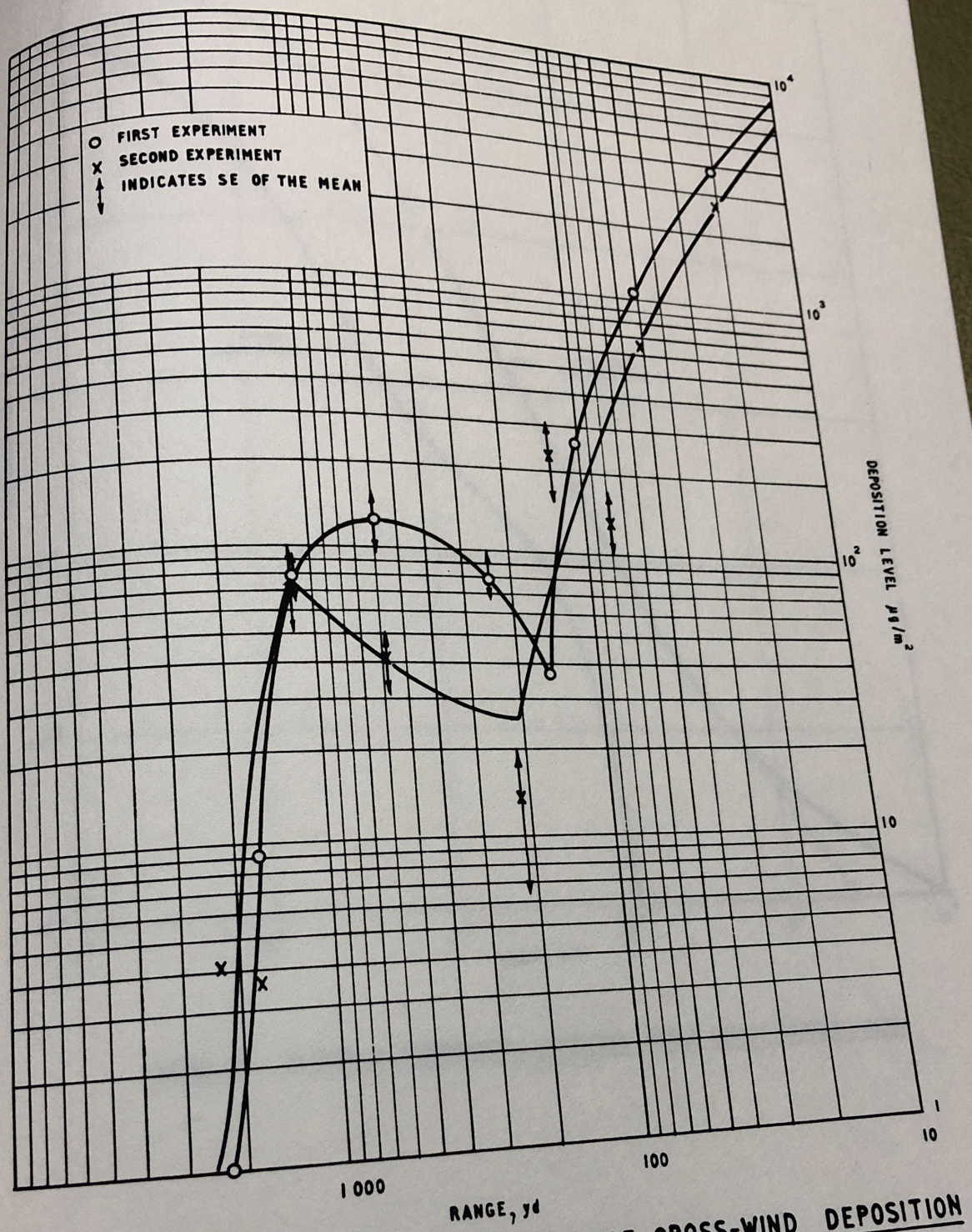



FIGURE 24. URANIUM EXPERIMENTS: AVERAGE CROSS-WIND DEPOSITION LEVEL VERSUS RANGE

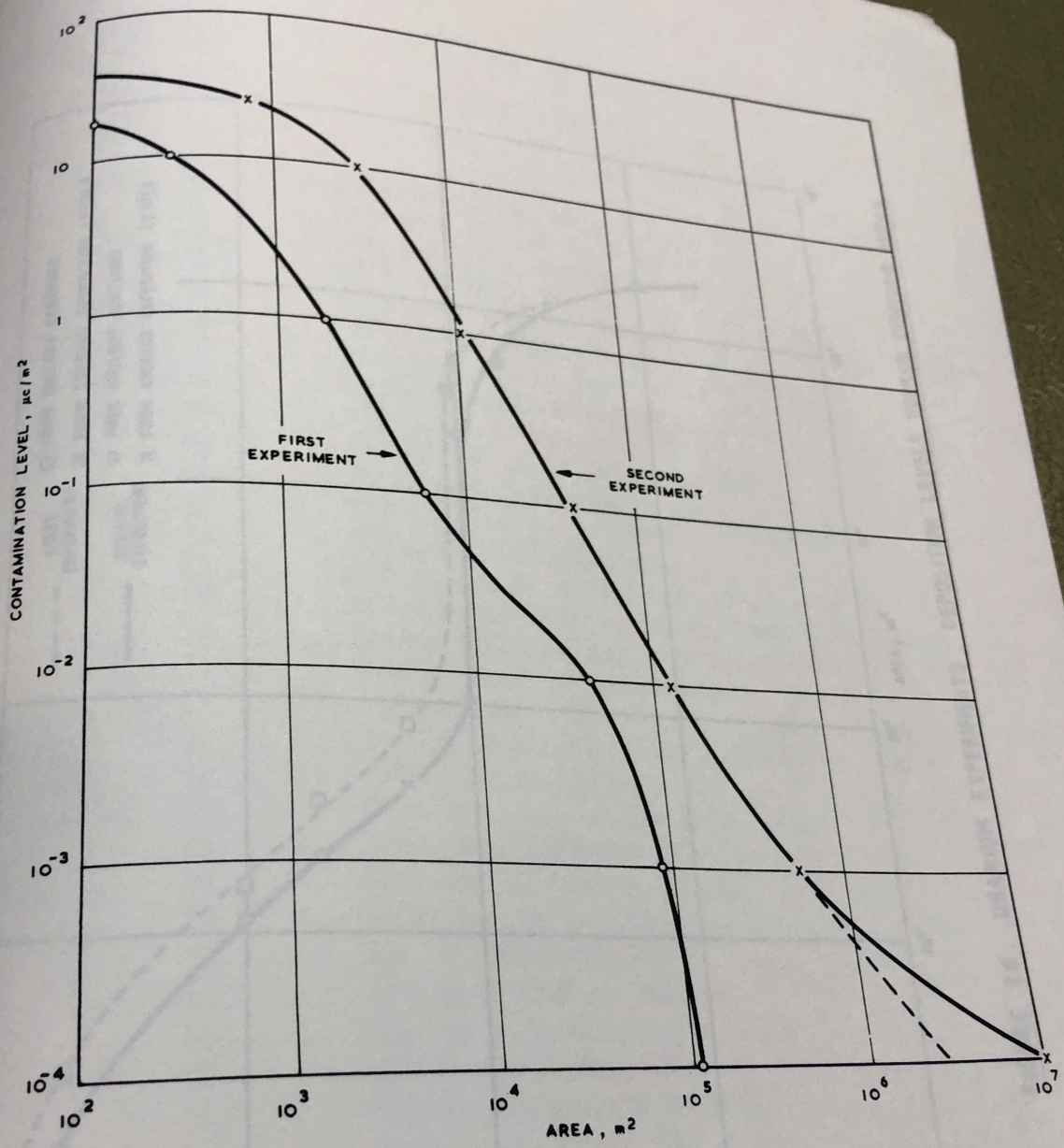



FIGURE 25. PLUTONIUM EXPERIMENTS: DEPOSITION LEVELS VERSUS CONTOUR AREAS

FIGURE 26. URANIUM EXPERIMENTS : DEPOSITION LEVELS VERSUS CONTOUR AREAS

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