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OPERATION PLUMBBOB

Summary Report, Test Group 57

Nevada Test Site
May-October 1957

Sandia Corporation
Albuquerque, NM

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Operation Plumbbob
Biomedical Evaluation
Decontamination

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Operation Plumbbob Test Group 57 conducted a one-point detonation for the purpose of studying hazards from accidents. The objectives were to estimate the immediate and long-term distribution of plutonium and gain an understanding of how this distribution comes about, to conduct a biomedical evaluation of plutonium-laden environments, to investigate relevant methods of decontamination, and to evaluate alpha field survey instruments and monitoring procedures.

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FOREWORD

This report has had classified material removed in order to make the information available on an unclassified, open publication basis, to any interested parties. This effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

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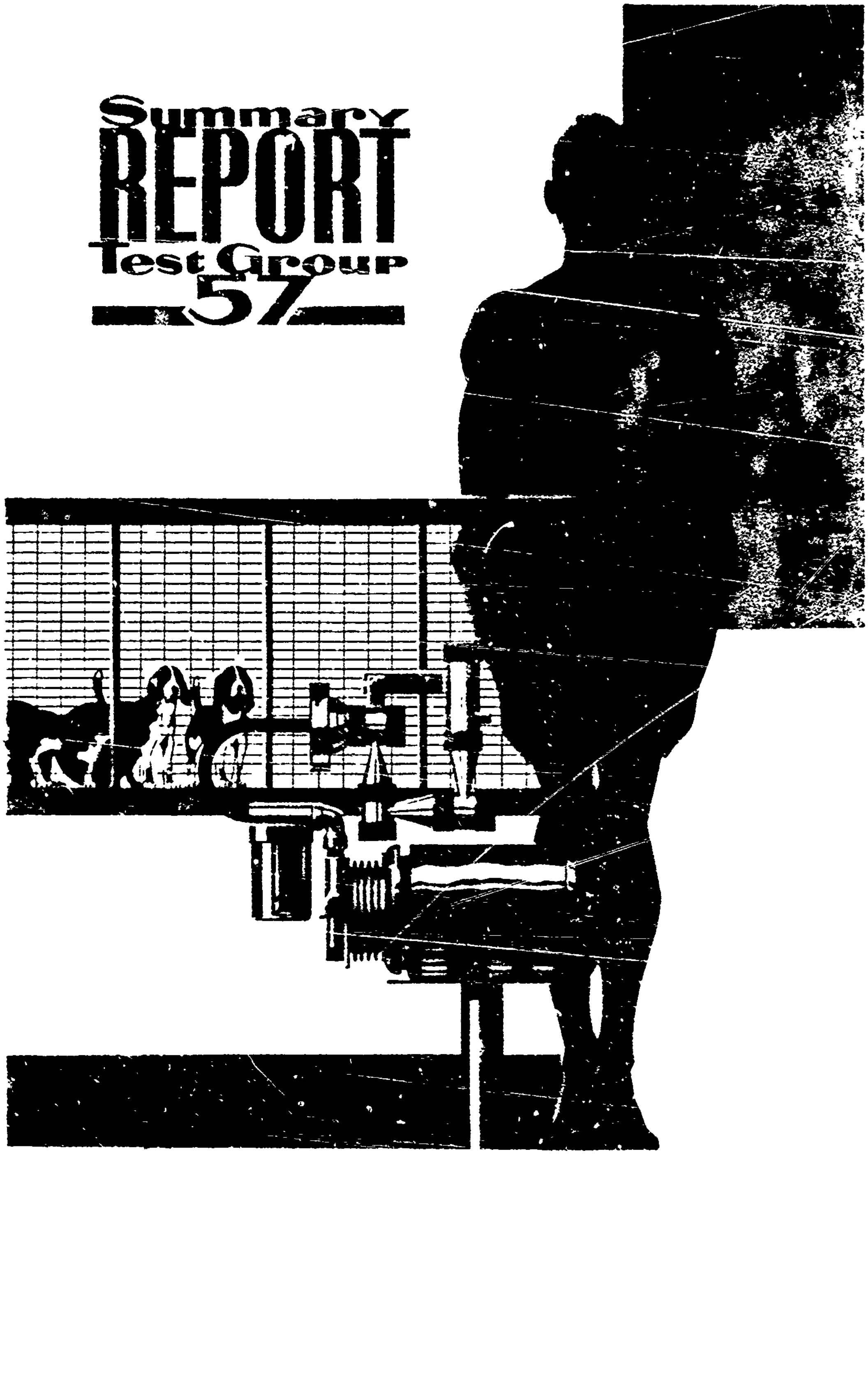
Summary REPORT Test Group 57



ABSTRACT

On April 24, 1957, Operation Plumbbob Test Group 57 conducted a one-point detonation for the purpose of studying the plutonium hazards from accidents The objectives were to estimate the immediate and long-term distribution of plutonium and gain an understanding of how this distribution comes about, to conduct a biomedical evaluation of plutonium-laden environments, to investigate relevant methods of decontamination, and to evaluate alpha field survey instruments and monitoring procedures. In the order mentioned, these objectives define four programs designated as 71, 72, 73, and 74, respectively.

The results of Program 74 show that field survey methods can be relied upon to delineate the areas contaminated by an accident, and the results of Program 73 show that decontamination can be carried out successfully. Through analyses of collecting pans, Program 71 determined the areas covered by significant levels of contamination. Strictly speaking, these particular contours are only valid for the particular wind structure which obtained at the time of the shot, but it is expected that a basic fallout model will be prepared from these data which will permit extrapolation to other wind conditions.

Air samplers indicated high airborne concentrations of respirable plutonium remarkably far downwind. Nevertheless, the amounts of plutonium picked up by animals exposed by Program 72 do not seem excessive. A full evaluation of these animal data has yet to be carried through, since the biological processes being studied are very slow.

ACKNOWLEDGMENTS

Conception of Test Group (TG) 57 experimentation began January 18, 1957. Field readiness was achieved by April 10. Experience and technical competence made possible much that was done. Most impressive was the fact that enthusiasm and determination compensated where experience was lacking. Although broad plans were generated at or near Program Director levels, they were improved and refined by all who worked on them. Exemplary performance was so much the rule that all participants deserve praise in like measure.

In an operation so hastily contrived and so quickly executed, outside support becomes the success determinant. This was so extraordinarily true of the TG 57 effort that especial commendation is given to:

Phil Allen, of the U.S. Weather Bureau, for his guidance through two disheartening weeks of weather delays.

Bill Johnson and the REECO Health and Safety Division personnel who some three times placed or replaced the 4,000 sticky pans over the 70-square-mile test field and recovered 3,500 pans postshot.

Claude Benedix, of the S-6 office, whose serious appraisal of field construction requests saved numerous oversights.

Jesse Friesen, REECO Area 13 foreman, who somehow made all the unreasonably last-minute needs materialize along with the others.

Charley Smith, REECO operating engineer, for his devotion to the Project and the careful logging of Area 13 activities to make record of many meaningful incidents that would otherwise now be forgotten.

Gordon Dunning, of DBM/AEC, for his continual encouragement and support.

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Chapter 1

MOTIVATION AND MISSION

1.1 HISTORICAL RESUME

Concern for the biomedical effects of plutonium predates the physical existence of plutonium* in any but miniscule quantities. A major factor in the choice of a site for the Hanford Works (1944), the original U.S. plutonium-production plant, was the possibility of plutonium contamination of the environs from a reactor accident. Appreciate, too, that the Hanford reactor was the first planned for more than a kilowatt rating.[1] From this worrisome beginning, more breeder reactors were built and operated. Biomedical programs, intensive and numerous, grew with the industry to the extent that some claim that more is known of plutonium as a noxious agent than of any other substance. Radiological standards, in the form of maximum permissible levels (MPL) in body organs considered critical and maximum permissible concentrations in air and drinking water, are common knowledge throughout the atomic industry. Plutonium is an alpha emitter and therefore no real external hazard. Fortunately, the oxides of plutonium formed in a one-point detonation are essentially insoluble in the fluids of the GI tract (0.003 percent). Once in the stomach, their stay in the body is short, for they are excreted as an inert material with virtually no body assimilation. Inhalation is a different mechanism entirely and one which presents a considerable threat. Any particle small enough to reach the lower respiratory tract apparently has an excellent chance of clinging to alveolar surfaces and staying to do radiation damage locally, with a half life of approximately 1 year. Some of the finer particulate matter so captured may be taken directly into the blood stream over a period of several days. This material stays as a blood burden until its trace solubility allows eventual assimilation to the extent of some 70 percent of the material carried. This 70 percent is distributed principally in bone where it remains indefinitely as far as human life span is concerned. One cannot outlive the influence, because the alpha half life of plutonium-239 is of the order of 20,000 years.

*In historic times, that is.

Even so, transport of the nine units to NTS was carefully routed and executed.

1.2 THE 56 PROJECT - NTS

Redwing was to include the first actual safety tests* of as-built devices, but worry about the long transport distance with the unattractive alternative of weapon assembly in Eniwetok produced, in July 1955, the plan of a one-point nuclear safety series at NTS timed to precede Redwing shipments. Called 56-Project-NTS, the series actually was run in November 1955 and January 1956.

Even when one-point nuclear safety is assured, an insidious problem remains for the plutonium-bearing weapon; i.e., plutonium dispersal and contamination from an HE accident. Upon hearing that Los Alamos had planned the safety series without a study of this problem, Sandia's Weapons Effects Department (5110) asked permission to do a simple plutonium contamination check.

1.3 TRANSPORT AND STORAGE

At best, the data from 56-Project were fragmentary.

To meet this need, the LASL H-division considered the data against their considerable experience with the biomedical implications of plutonium and predicted the nature and extent of hazards to be expected from a weapon accident.[3] Obviously, quantitating accident outcomes on such meager field results had to be severely extrapolative, but the criteria were set to err on the conservative side. It should be emphasized here that when the public is exposed to radiation, the permissible air concentrations should not exceed one-tenth those permissible in industry.[4]

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*Safety test here connotes firing a complete experimental or standard nuclear weapon at one detonator of its multidetonator system. This is the so-called "one-point detonation." Belief is that such firing gives a probability of nuclear yield equivalent to or greater than that likely from detonation in physical impact or fires, particularly aircraft-fuel fires.

As 1956 wore on, the inconvenience of these restrictions pinched to the point where the scanty information on which they were based became steadily more suspect. A more definitive evaluation of plutonium contamination was pressed for, a demand which climaxed with a meeting of a broadly representative group in Los Alamos on November 22, 1956. There it was decided that the evaluation was imperative, and the group recommended to the Albuquerque Operations Office of AEC (ALO) that a one-point firing on the ground and in the open early in April 1957. The group also urged that a responsible agency be quickly designated to select a test site in the short time available.

1.4 GENESIS OF PROJECT 57

A few weeks later, the manager of the Albuquerque Operations Office, with the sanction of DMA, requested Sandia to assume responsibility for arranging the experimental program, appointing a test director, and selecting a test site as soon as possible.

About the first of January 1957, the Test Director and several members of the Sandia Corporation Weapons Effects Department, with the help of ALO Test Division, began a search for a test site which had an extremely low plutonium background and a reasonably flat area of about 50 square miles. In addition, it was thought preferable to find a site where mountain-valley drainage currents would induce a large amount of shear in either the early night or very early morning hours, likely shot times. It quickly became clear that no portion of the Nevada Test Site could be relinquished to this experiment because of the unknown length of time before the area could be returned to unrestricted or even mildly restricted use. Also, because of the size of the job and the time available, it was thought that remoteness from supply and support functions would make the task impossible. A close survey of areas contiguous with NTS focused attention rather quickly on two dry lake valleys: the Papoose Lake area and the large valley adjoining Groom Lake and northwest of it. Several of the planning group examined these two locations from the air, looking also for additional sites that might have been overlooked in the map study.

This air survey immediately preceded the first general meeting of Project 57 on January 18, 1957, at which time outlines of experiments were drawn.

1.5 PROJECT 57 ACTIVATED

The first general meeting was composed of members of the following organizations: DMA/AEC, HQ/AFSWP, ALO/AEC, AFSWC, FC/AFSWP, LASL, AEP/Rochester, UCRL, AEP/UCLA, DBM/AEC, Sandia Corporation, and agencies from which support was expected, such as the U.S. Weather Bureau, the U.S. Public Health Service, and Reynolds Electric and Engineering Company (REECO). It was learned that the AEP/UCLA had made measurements in both Papoose Lake and Groom Lake areas and had discovered considerably greater plutonium background in the former site. Therefore, it was agreed that the Groom Lake valley should be the test site, if possible, and that the consent of the U.S. Air Force which controlled it should be sought immediately.

Because the number of measurements of background in the two valleys did not give overwhelming evidence of the superiority of the Groom Lake area, more extensive soil sampling throughout the area was required. A check of grazing rights prior to the meeting indicated that the livestock problem had presumably been eliminated, yet the aerial inspection showed

60 to 80 cattle in the area. Finally, it was thought extremely important to start an immediate meteorological survey to determine the drainage pattern in the bowllike topography of the Groom Lake area and to find how this drainage pattern faired into the higher wind structure.

The remainder of the meeting was devoted to outlining specific experimental programs by separate committee action. Three committees met to consider Particulate Physics, Biomedical Experiments, and Plutonium Decontamination. The objectives each group set for itself and the scope of experimentation became the separate programs of Project 57 and are included in the following chapters, as is the program—added later—for field measurements with alpha instruments and for field monitor training.

1.6 TEST GROUP 57

Because Project 57 would overlap preparations for Operation Plumbbob, it was renamed Test Group 57 and made a formal part of Plumbbob. Its organizational structure is shown in Figure 1.1.

1.7 GENERAL AIMS

Four broad needs underlay the TG 57 effort:

1. Means of estimating immediate distribution and long-term redistribution of plutonium from a nonnuclear detonation and an understanding of how they come about.
2. Biomedical evaluation of likely plutonium-laden environments.
3. Methods of decontamination of ground areas, pavements, building materials, etc.
4. Alpha survey instruments and field monitoring procedures to enable prompt estimation of contaminant deposition. Implicit here is an appreciation of the requirement for personnel trained in the ways of field alpha monitoring for accident situations.

In the order mentioned, these needs bespeak the general aims of the four TG 57 programs designated 71, 72, 73, and 74, respectively.

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5. Nuclear Safety Working Group, Safety Criteria for the Storage and Handling of Sealed-Pit Weapons Containing Plutonium to the Joint Board on Future Storage of Atomic Weapons, Report No. 1956-2, November 19, 1956.

TEST GROUP 57

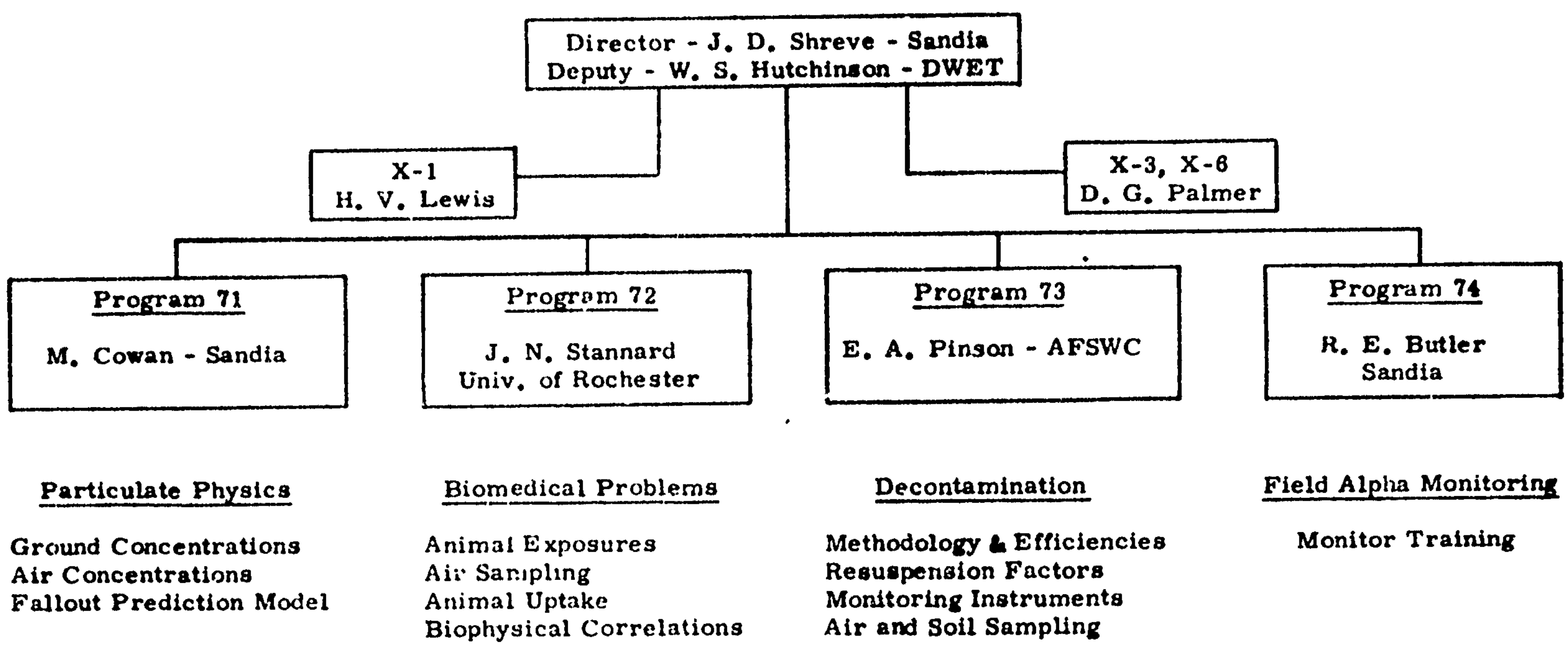
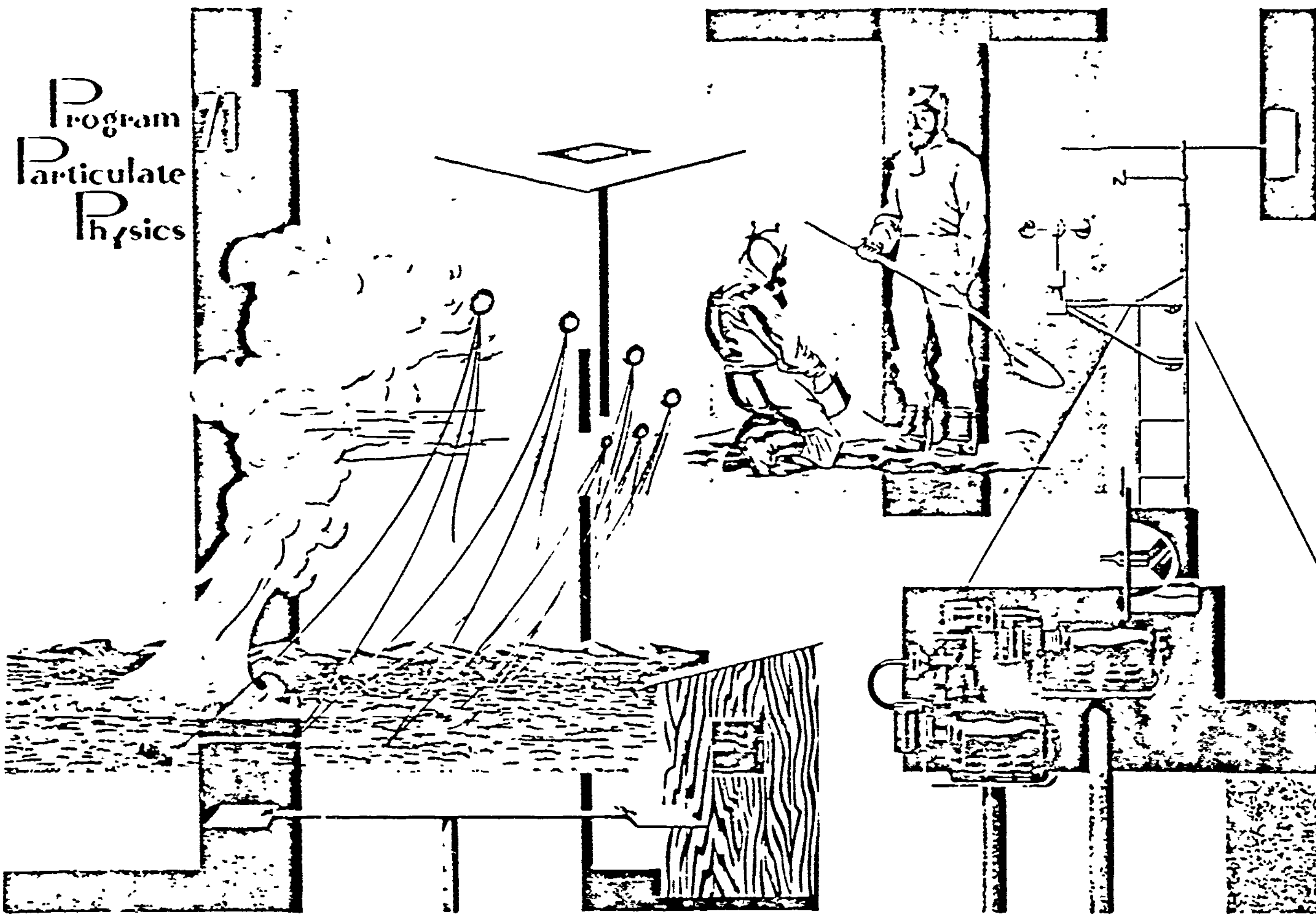


Fig. 1.1—Organizational structure of Test Group 57.


Program
Particulate
Physics

Chapter 2

PROGRAM 71 - PARTICULATE PHYSICS

2.1 OBJECTIVES

1. Measure plutonium uptake by air samplers during the fallout period and the ultimate ground-surface concentrations.

3. Learn as much as possible about the physical nature of plutonium-bearing particulates (size, shape, density).
4. Study translocation of contaminants by weather after deposition, both surface exchange and migration in depth.
5. Compare fallout characteristics of plutonium with those of uranium.*

2.2 TEST SITE (AREA 13)

The instrumentation most basic to Program 71 was an array of more than 4,000 passive fallout collectors (sticky pans), carefully positioned throughout an area of about 70 square miles. Since the field grid used by all programs for instrument location designations grew out of the survey necessary to effect sticky-pan placement, it is appropriate to describe the test field at this point.

The test field comprised four zones (Figure 2.1), each with a square grid of a different dimension:

Zone	Approximate size (ft)	Grid dimension (ft)
A	250 x 250	50
B	5,000 x 5,000	250
C	20,000 x 30,000	500
D	40,000 x 30,000	1,000

*This is of interest for Sandia experiments using uranium as a stand-in for plutonium in tests of weapon accident fallout.

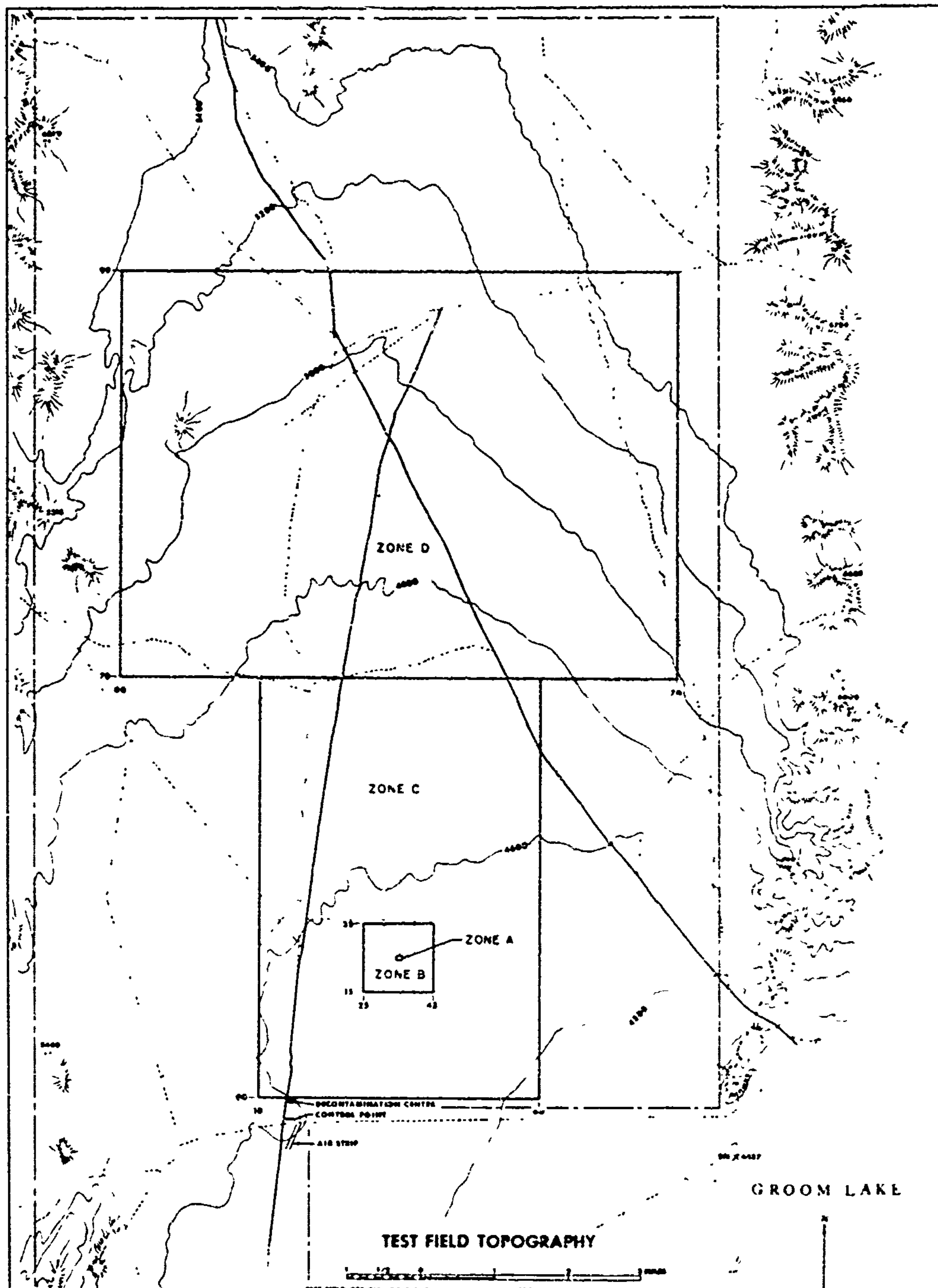


Fig. 2.1—Facilities layout, instrumentation array, and general topography of Area 13.

The net result, since grid lines of B, C, and D commanded separate numbers, was a nonlinear grid but one easily understood. The location of support functions and facilities so important to the over-all operations are also shown in the figure. Ground zero (GZ) was the center point of Zone A, and the southernmost boundary of the test field coincided with the northeastern corner of the Nevada Test Site. The major topographic contour lines are included to mark the flat valley floor gently sloped toward the dry bed of Groom Lake.

2.3 THE FALLOUT EXPERIMENT

The elements of Program 71 are well pictured in the chapter illustrations.

2.3.1 Fallout Collector Array.

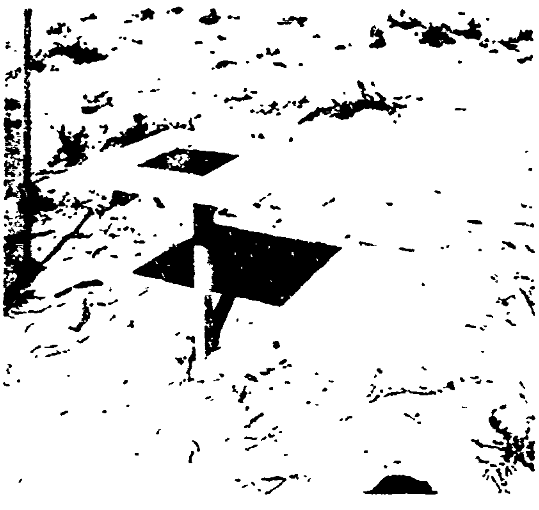


Fig. 2.2—Fallout collector station.

The most numerous and extensive instrumentation in Program 71 was the array of more than 4,000 fallout collectors. The sensor of each was a simple 9-inch square of galvanized steel sprayed with alkyd resin which remained tacky for days and captured impinging particles. Each sticky pan was centered on a 2-foot square of plywood held horizontally about 18 inches aboveground by a driven 2-x-2-inch wooden stake (Figure 2.2). One such station was placed at each grid intersection throughout the field.

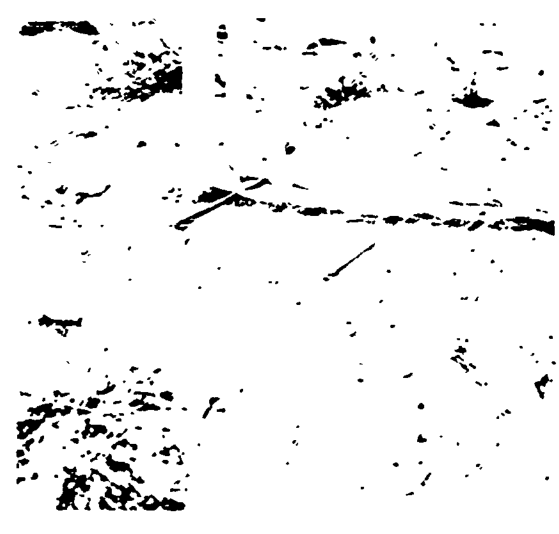


Fig. 2.3—Surface-level fallout collector station.

The mass of data to be derived from a radiochemical analysis of each pan was to provide information for drawing isoconcentration contours throughout the field. In Zone A, very close to the shot point, it was thought that sticky-pan collector stands would not withstand the blast. Here the instrumentation used consisted of 1-foot-square pans containing a 1-inch depth of local soil and set in the ground with the top surface flush with the surrounding earth (Figure 2.3). One such collector was placed in the center of each of the 50-foot squares into which Zone A was divided. Recovery of pans after the shot was accomplished by simply pouring the contents of each pan into a separate plastic bag for shipment to the laboratory for analysis.

2.3.2 Air Samplers

Sixty-eight air sampler stations were spread throughout the instrumentation array as shown in Figures 2.4 and 2.5. Three types of samplers were used (Figure 2.6). The simplest of these is a one-stage filter, the collecting element of which is a 47-mm disk of millipore filter paper. The second type, termed a Rarripactor,* or cascade filter, is formed of two wire screens plus a millipore filter element. The screen facing the outside has 44-micron openings, and the second screen has 10-micron openings; millipore filter paper collects all particles larger than 0.02 micron in diameter. The third and most complex air sampler is the well-known Casella cascade impactor in which particle discrimination is accomplished by four nozzles which serially direct the incoming air against glass slides. Ensuing stages of the collector capture particles of decreasing but overlapping size ranges. The final stage, again a millipore filter, collects the residue. For density-two material (specific gravity =2), the approximate particle-diameter ranges expected on each of the slides are as follows:

Stage 1 - 10 to 200 microns
Stage 2 - 3 to 20 microns
Stage 3 - 1 to 7 microns
Stage 4 - 0.7 to 3 microns
Stage 5 - Millipore - 0.02 to 1 micron

A common suction pump was used for all air samplers. Its intake rate of approximately 17 liters per minute, or one cubic meter per hour, is roughly the breathing rate of standard man. One distinction between the air samplers, which may or may not be important, is the fact that the cascade impactor has an intake-port area of approximately 0.5 cm^2, whereas both the Rarripactor and the millipore one-stage filters have circular openings 4.7 centimeters in diameter. It has been said, intake-areawise, that the cascade impactor might correspond to a nose-breathing person, and the other filters might correspond to a mouth-breather. All air samples were mounted so that their openings were about 5 feet aboveground facing southward.

A simple variation of air sampling in the open was made at three stations where 8-foot plywood cubicles were placed over ordinary air sampling stations. Each cubicle had a simple window approximately 2 feet square in each of three sides and an ordinary door-opening in the fourth vertical face. A corresponding air sampler was set in the open adjacent to each of these cubicles so that sheltered and open samplings could be compared.

2.3.3 Balloon-Supported Precipitators

Electrostatic precipitators developed for early sampling of the detonation cloud were flown on strings from balloons tied 500 feet from ground zero at bearings of 345, 360, and 15 degrees. These in ruments, weather-vaned and gimbal-mounted to point continuously into the wind, are isokinetic in their sampling for normal wind-speed ranges. The volume sampled is directly proportional to wind speed, since impact pressure alone forces air through the chamber. Photographs of a typical precipitator are shown in Figure 2.7.

A much more extensive balloon-supported instrument rig was planned; the full design was exploited and all rigging was fabricated. A circle of cable 1,000 feet in diameter was to be flown 1,000 feet above the ground and centered on GZ. While it had been predicted that winds would die down very shortly after sunset and allow sufficient time (about 8 hours)

*Designed by H. L. Rarrick, of Sandia Corporation.

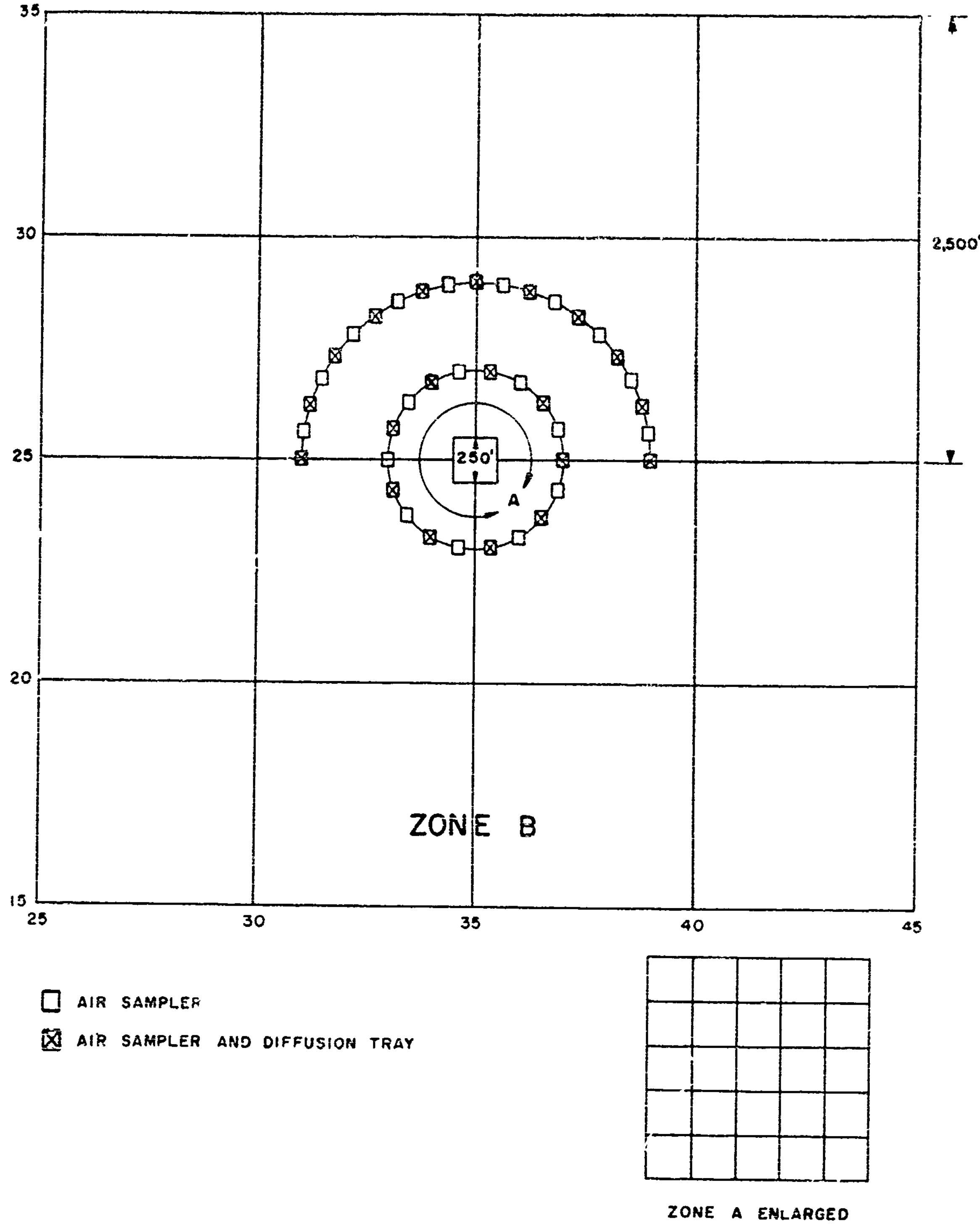


Fig. 2.4—Air-sampler and diffusion-tray stations in Zone B.

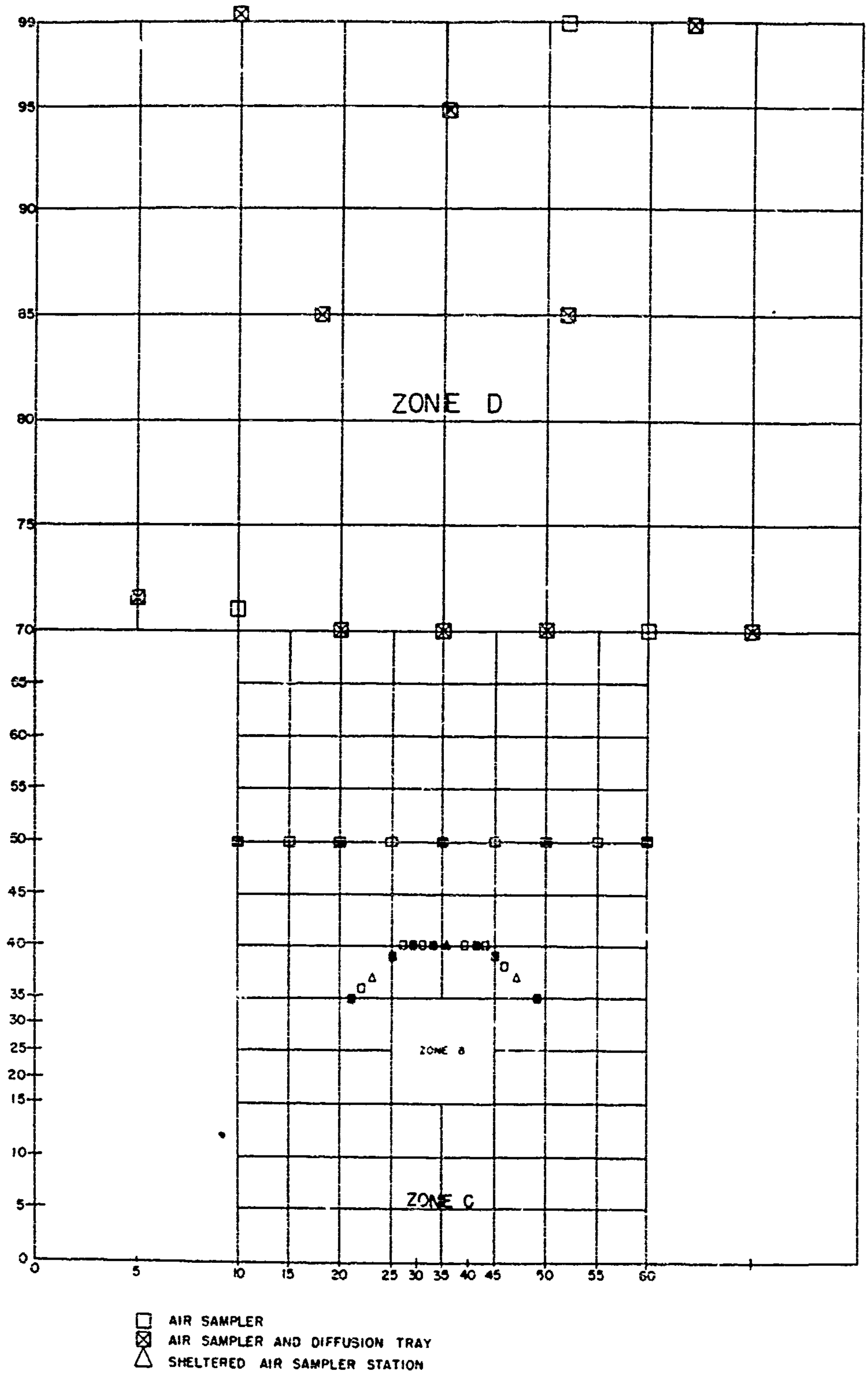
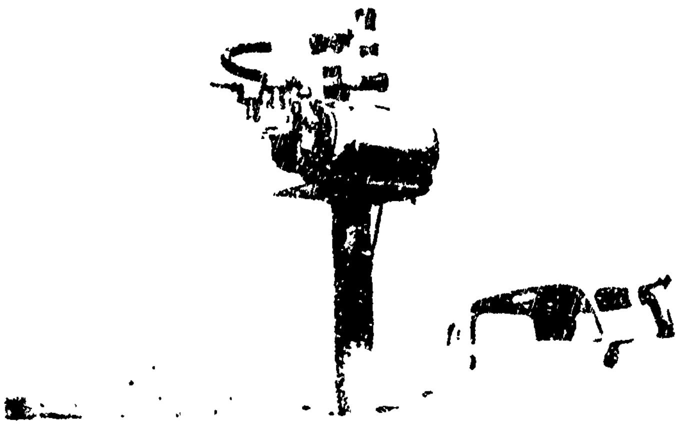
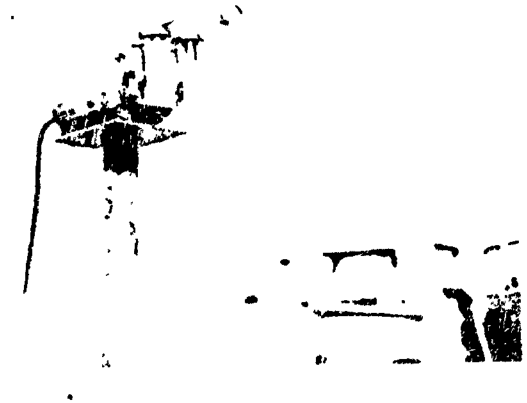


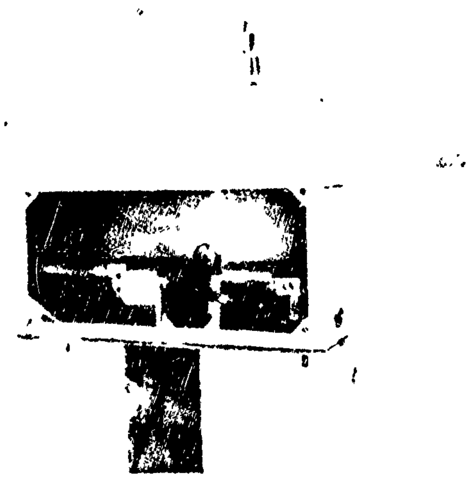
Fig. 2.5—Air-sampler and diffusion-tray stations in Zones C and D.



a. Cascade impactor (AC motor).



b. Cascade filter (AC motor).



c. Single-stage filter (DC motor).

Fig. 2.6—Air samplers, pumps, and motor.

Front view

Rear view

Fig. 2.7—Electrostatic precipitator for balloon suspensions.

for filling balloons and hoisting the high-flying circle, actual trials indicated that the intense heat lows typical of the Nevada desert persisted—not just one hour, but in some cases 4 or 5 hours—past sundown. Thus, the time of quiescent wind conditions immediately preceding anticipated shot time (first, at 2100 hours, then predawn to dawn) was not sufficient for raising the array. Therefore, the simpler scheme with much less extensive instrumentation was used, a considerable compromise of the original plan.

2.3.4 Diffusion Trays

A variation of the sticky-pan-collector approach to fallout was attempted in the form of sticky-pan pairs mounted in such a way that one plate faced sticky side up; the other, sticky side down. The intent here was to get a very rough particle-size discrimination; i.e., the pan facing down would collect only extremely small particles carried by vortices, eddies, etc., around the plate edge. Figures 2.4 and 2.5 show diffusion-tray locations.

2.3.5 Technical Photography

Among the requirements of Program 71 was the following photographic work undertaken by Edgerton, Germeshausen and Grier (EG&G):[2]

1. High-speed photographic coverage of the initial burst and subsequent self-luminous fragmentation.
2. Triangulative slow-motion pictures of the cloud of combustion products, entrained dust, and contamination.
3. Photogrammetric coverage with sequence cameras, taking about 1 frame each 15 seconds, to determine balloon locations to 10 feet and to follow cloud rise and shape changes.
4. Aerial photography from, roughly, 8,000 feet (about 12,500 feet msl) above terrain to document horizontal cloud growth and drift for the 10-minute period following zero time.

To accomplish this assignment, two ground stations, one 10,000 feet due west and one 10,000 feet due south of ground zero (grid coordinates 25-10 and 00-35, respectively) were manned through zero time to H+1 or H+2 minutes.

2.4 LONG-TERM STUDIES

The instrumentation and experimental approach just described concern what might be termed the acute phase of the problem; i.e., deposition of material on the ground, air concentrations during the fallout period, etc. In any accident situation, the acute phase is certainly very important, but a decision must be made ultimately on the extent of rehabilitation possible for the contaminated area. To promote this end, the following long-term sets of measurements were attempted. Emphases here are: (1) Where is the material located; (2) how pronounced is the tendency of particulate matter to work its way deeper into the soil, eliminating—or at least lessening—the hazard to personnel; and (3) to what extent do the elements erode or translocate surface or near-surface contamination?

2.4.1 Soil Analyses

Samples of soil about 80 square inches in circular cross section and 4 to 5 inches deep were taken periodically at six locations* along the major hot line of the fallout pattern. Upon

*Grid coordinates 26-34, 29-31, 33-28, 39-27, 45-24, 67-27. Inverse to the usual abscissa-ordinate order for coordinates, the first coordinate mentioned is always the north-south position; the second, the east-west one.

removal from the field, each was sectioned in 1/4-inch increments (approximately 1 pound of dirt) and each increment was bagged separately. In general, all four bags composing the first inch were analyzed. Of the deeper increments, alternate bags, then every third, and finally one bag per inch were analyzed. The remaining increments were held for check analyses or reruns. Sampling and sectioning techniques are novel and will be fully described later.*

First schedules required sampling at 1, 2, 6, 12, and 24 weeks after detonation. Subsequently, decisions were made to sample at 1 year and at least yearly for several years.

2.4.2 Natural Resuspension Studies (Secondary Aerosol)

After the shot, 40-foot poles were placed at positions 35-35 and 50-50 to support four air samplers at 2, 5, 15, and 35 feet aboveground. The original installation was made with electrostatic precipitators, which are passive devices dependent upon impact pressure to force air through them. Therefore, continuous wind records were necessary. A wind-vane-anemometer set was put about 20 feet aboveground adjacent to the sampler string. Unfortunately, the precipitators, which are high-voltage devices, repeatedly failed in wet weather and electrical storms and were therefore replaced, after a month, by Rarripactors. These devices worked well, and the sampler bodies were changed at 2-week intervals for the remainder of the 24-week test period.

Supplemental weather information accrued from precipitation gages at positions 35-35 and 26-35.

2.4.3 Anniversary Measurements

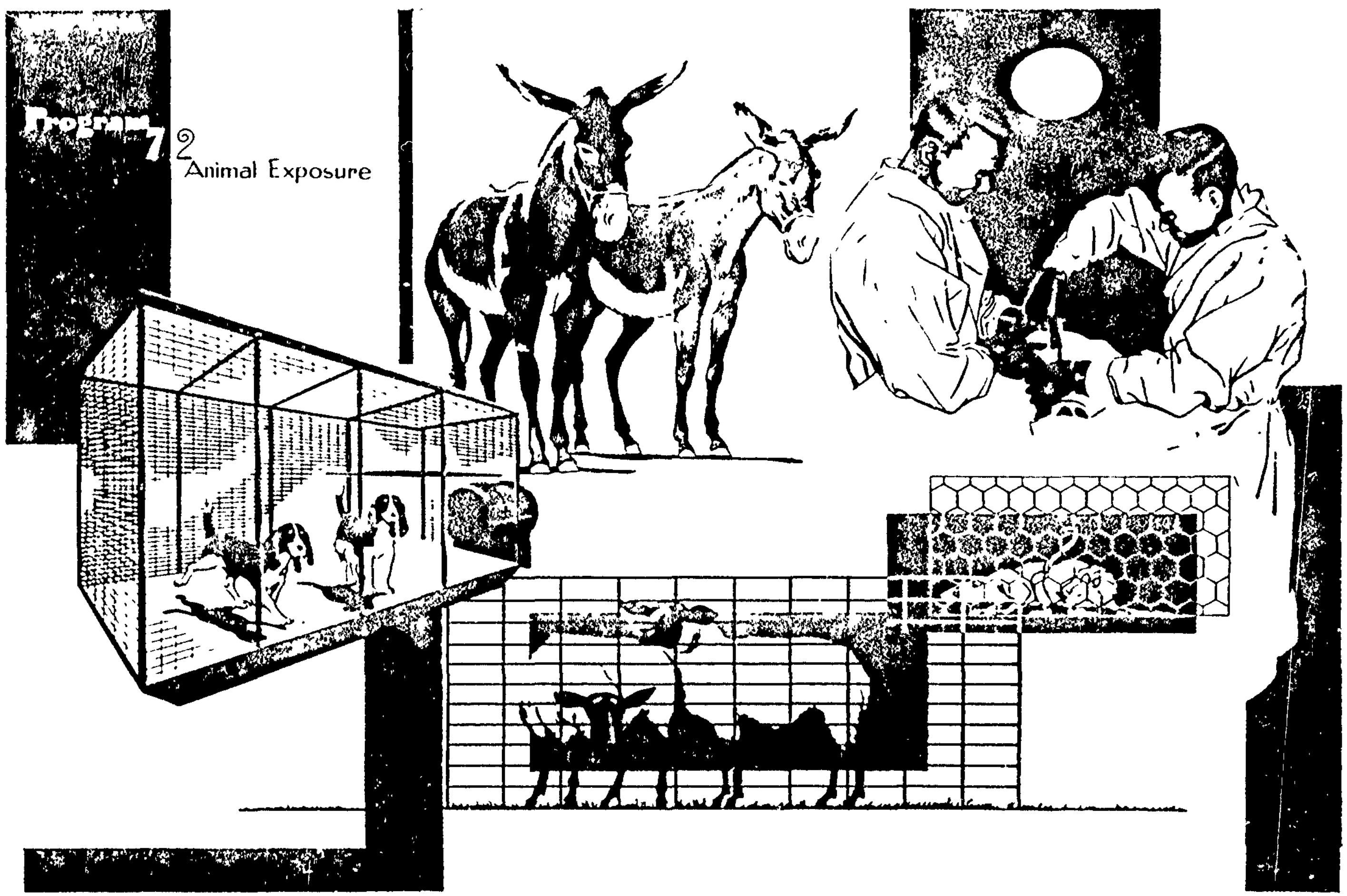
In December 1957, a general meeting of representatives from all programs was devoted to an exchange of information and discussions of what more could be done to increase understanding of plutonium contamination. Additions to the experimental effort of each program resulted. For Program 71, three principal experiments or experimental continuations evolved.

1. Set north and south-looking millipore air samplers at six locations on east-west line 35, at ground zero, and at four locations on line 21. All north-facing samplers operate when wind is from the north ±25°; south-facing samplers operate for a south wind. The intent is a discrimination of air concentrations typical of winds traversing hot and cold areas to serve as a refinement of the resuspension study.
2. Position two cascade impactors mounted back to back on a wind-vaned turntable at GZ, at 40-27, and at 50-21 and operate them for 1 week to study air sampling efficiency for upwind to downwind facings.
3. Sample soil, as mentioned, at the six hot-line locations, at the chronic-exposure animal stations (see Chapter 3), and at selected spots within the Program 73 array (Chapter 4) for cross-checks with previous Program 73 samplings by a different method.

*To be published as a Sandia Corporation TM authored by R. E. Foster, originator of the technique.

REFERENCES

1. M. Cowan, Jr., Plutonium Contamination From One-Point Detonation of an XW-25, Sandia Corporation ITR-1510, December 13, 1957.
2. Edgerton, Germeshausen and Grier, Inc., Operation Plumbbob - Shot NTS 57, EG&G Tasks in Timing/Firing and Photography, Report No. 277, May 11, 1957.


Program 7
2
Animal Exposure

Chapter 3

PROGRAM 72 - BIOMEDICAL FIELD STUDY OF PLUTONIUM INHALATION

3.1 OBJECTIVES

1. Study uptake of plutonium by various animal species in a weapon-accident fallout environment, both for acute (cloud passage) and chronic (contaminant resuspension) exposures.
2. Continuously measure air concentration and particle-size spectra during full chronic-exposure period.
3. Correlate corresponding physical and animal measurements at various exposure locations chosen with respect to ground concentrations.

3.2 THE ANIMAL EXPERIMENT[1]

3.2.1 Exposure to Cloud Passage

To assess the hazards of exposure to direct fallout from the cloud, 26 dogs* and 31 albino rats were preplaced in the field as indicated in Table 3.1. The dog pens were open-mesh wire screen (Figure 3.1). At the time of the shot and for several hours thereafter, the protective barrels were placed outside the pens. The rats were placed in wire cages (three or four per cage) on the ground a few feet toward GZ from the dog pens. In addition, open-mesh cages with two rats each were flown from the balloon array cables at 500 and 1,000 feet above terrain at bearings of 345, 350, 18, and 30 degrees.

In the period from H+30 to H+120 minutes, 10 dogs from selected locations (Table 3.1) and all the rats were removed from the field. The dogs were decontaminated and returned to the autopsy preparation shed and trailers† in Mercury. All 50 rats were sacrificed by use of ether in the field (grounded rats at H+3 and flying rats at H+6 hours). Carcasses were returned to Mercury in polyethylene bags. Two of the dogs removed from the field were placed in metabolism cages for determination of plutonium excretion rates via urine and feces. Additional animals were removed on D+2, and the remainder on the prearranged schedule shown in Table 3.1.

*All dogs used were beagle types, 59 of the 109 were purebred and registered.

†Two house trailers were joined by a breezeway, equipped with utilities, and outfitted as an autopsy facility for Program 72 work.

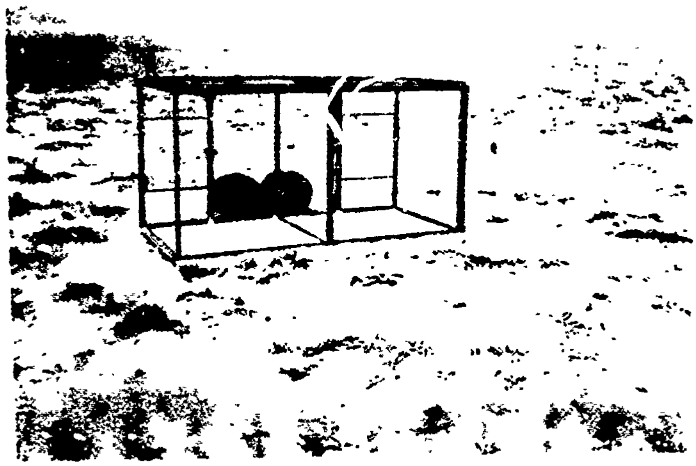
TABLE 3.1—ARRANGEMENT OF ANIMALS FOR ACUTE EXPOSURE

Positions[*]	Distance from GZ	No. of animals		Removal[†]
		Dogs	Rats	
1-2	500 ft N, 600 ft W	3	4	1 at H+1/2 to 2 hr 1 at P+4 1 remains
3-4	500 ft N, 200 ft W	2	4	1 at H+1/2 to 2 hr[‡] 1 at D+2
5-6	500 ft N, 200 ft E	2	3	1 at H+1/2 to 2 hr[‡] 1 at D+2
7-8	500 ft N, 600 ft E	3	4	1 at H+1/2 to 2 hr 1 at P+16 1 remains
9-10	1,000 ft N, 600 ft W	2	0	1 at P+16 1 remains
11-12	1,000 ft directly N	2	4	1 at H+1/2 to 2 hr 1 at D+2
13-14	1,000 ft N, 600 ft E	2	0	1 at P+8 1 remains
15-16	2,000 ft N, 800 ft W	2	4	2 at H+1/2 to 2 hr
17-18	2,000 ft N, 400 ft W	2	0	1 at P+8 1 at P+32
19-20	2,000 ft directly N	2	4	1 at H+1/2 to 2 hr 1 at D+2
21-22	2,000 ft N, 400 ft E	2	0	1 at P+4 1 at P+32
23-24	2,000 ft N, 800 ft E	2	4	2 at H+1/2 to 2 hr

[*]Represents double dog runs positioned on east-west lines.

[†]Refers to removal of dogs, all rats removed H+1/2 to 2 hr. P refers to placement day, approximately D+5.

[‡]Placed in metabolism cages for 10 days.



(a) Dog station for acute exposure.

(b) Dog station for chronic exposure.

Fig. 3.1—Dog stations.

3.2.2 Chronic Exposures

As soon as isoconcentration lines were established from alpha-meter survey readings, the chronic-exposure pens were set out. This occurred on D+5, hereafter called P+O. These locations and other details are shown in Table 3.2. A typical station appears in Figure 3.8. It is clear from the table that 24 dogs each were placed at nominal isolevel lines of 1,000, 100, and 10 μgm per square meter. However, only 18 of the 24 dogs at each contour line were scheduled for removal and sacrifice in the 24-week period of the chronic experiment; i.e., six spares were carried into the field in each group (see Table 3.3).

In the interest of introducing other animal species, three burros (nine total - all jennies) were staked adjacent to each complex of dog cages on P+1 day. At P+32 days, ten sheep (roughly three per isoconcentration line) were placed in vacated dog cages. At the same time, four extra dogs were set on the 100 $\mu gm/m^2$ lines. All animals of this group were sacrificed on P+160.

3.2.3 Tissue Assays

From every dog sacrificed, the following tissues were carefully dissected for radiochemical analysis: spleen, GI tract and contents, liver, several hilar lymph nodes, several mediastinal lymph nodes, whole lung, trachea, nasal mucosa, a femur, and a rib. Tissue analyses were made using wet digestion and conventional extraction procedures.

Only whole-lung measurements were made on the rats. On burros and sheep, partial lung, hilar lymph nodes, and a rib were analyzed. A special measurement of fetus uptake was performed for burros on the 100 $\mu gm/m^2$ line. One jenny foaled during the experiment. Little Diablo, the colt, carefully washed and decontaminated after weaning, now resides near Livermore, California.

3.2.4 Autoradiography

Preferential migration or attachment of plutonium in soft tissues and bone is a subject of considerable interest and importance. In an attempt to learn something of plutonium's tendencies in this regard, a large program of autoradiography was included. Tissues are dehydrated, mounted in paraffin, sectioned, and coated with NTA film. The exposure is continued as long as necessary. Bones are sawed longitudinally and each half is covered with film. As intimated, the study tries to determine the localization of activity within the tissue structure.

3.3 PHYSICAL MEASUREMENTS

Radiation instrumentation and air sampling in support of the acute animal exposures of Program 72 was supplied by the other three programs.

For the long-term, or chronic, experiment, Program 72 personnel operated, cycled, and maintained cascade impactors adjacent to each group of eight dogs. The original plan called for two impactors—one at 2 feet and one at 5 feet aboveground—for each eight-dog group, but contemplation of the near infinity of collector slides plus filters that would result from daily cycling for six months (5 per sampler per day) led to halving the instrumentation.

3.4 LONG-TERM PROGRAM

The six dogs per isoconcentration line carried as spares plus the extra dogs from the acute-chronic exposure cycle left some 24 animals undestined at the end of the field experiment. It was finally decided that these dogs should be held for two years, then sacrificed.

TABLE 3.2—ARRANGEMENT OF ANIMALS FOR CHRONIC EXPOSURE

Nominal isolevel line	Grid location		Station	Concentrations inferred from instrument readings*	No. of animals Dogs	Burros
$\mu gm/m^2$				$\mu gm/m^2$		
1,000	27	35	1	450	8	0
	27	36	2	450	8	3
	26	36	3	500	8	0
100	35	39	4	80	8	0
	33	41	5	100	8	3
	32	42	6	145	8	0
10	56	45	7	7	8	0
	54	48	8	7	8	3
	52	51	9	7	8	0

*These readings represent a composite of results from the air proportional probe (Model PAC-1G, Eberline Instrument Division, Reynolds Electrical and Engineering Company, Santa Fe, New Mexico) and other monitoring instruments. These meter readings have been correlated with radiochemical analysis. Nominal levels represent the best values available at the time of dog placement.

TABLE 3.3—REMOVAL SCHEDULE FOR CHRONIC-EXPOSURE ANIMALS

Time*	1,000 μgm/m²	100 μgm/m²	10 μgm/m²	Preplaced for acute exposure
		Dogs		
P+4 days	2	2	2	2
P+8 days	2	2	2	2
P+16 days	2	2	2	2
P+32 days	2	2	2	2†
P+64 days	2	2	2	2†
P+96 days	2	2	2	
P+128 days	2	2	2	2†
P+160 days	4	4	4	2
Spares	6	6	6	None
Placed on P+32		4		
Total	24	28	24	14
		Sheep		
Placed on P+32	3	4	3	
		Burros		
P+161 days	3	3	3	

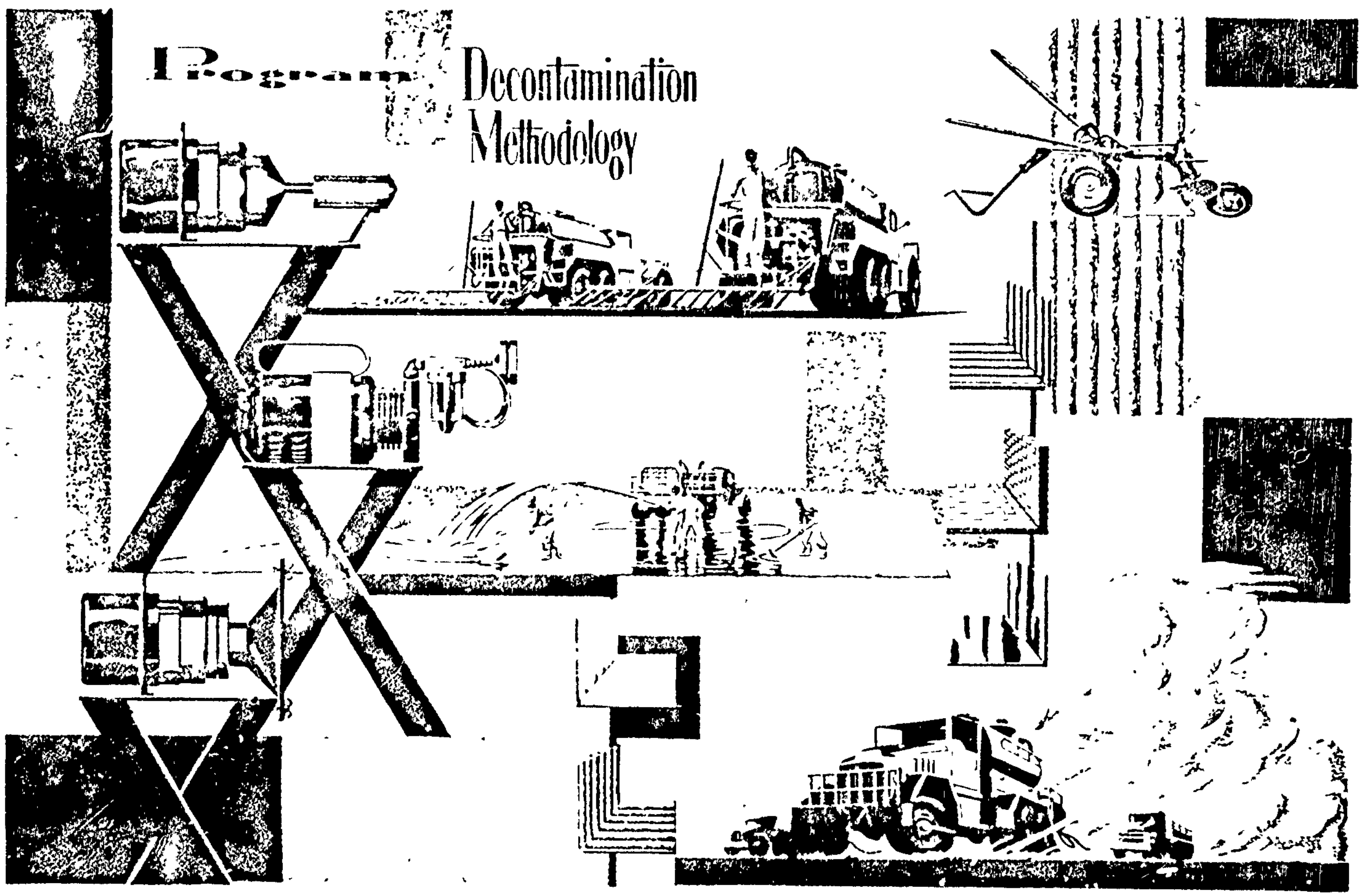
*P = placement time, approximately D+5 days.

†Tentative; may be used for longer term study if early groups show little plutonium in the acute phase.

Tissue assays corresponding to the earlier dog data should provide information on build-up factors, clearing rates, etc. Unfortunately, the tissue concentrations in most cases may be so light that the limits of radiochemical measurements may compromise the results. Even so, the experiment was considered worth pursuing.

REFERENCE

1. J. N. Stannard and others, Biomedical Field Test of Plutonium Inhalation, Sandia Corporation, ITR-1511, November 29, 1957.


Program
Decontamination Methodology

Chapter 4

PROGRAM 73 - DECONTAMINATION AND MONITORING METHODOLOGY

4.1 OBJECTIVES

1. Evaluate various decontamination procedures as to difficulty and efficiency for paving and building materials.
2. Compare the effectiveness of available alpha survey instruments and air samplers.
3. Study fixation and decontamination of plutonium-laden soils and determine contaminant resuspension factors.

4.2 DECONTAMINATION OF PAVING AND BUILDING MATERIALS

4.2.1 Alpha Survey Instruments

Decontamination efficiencies for hard-surface materials have always been partially or wholly determined with alpha meters. Actually, the objective of comparing the worth of different alpha survey instruments for field operation was accomplished before the field phase of TG 57 activities.[1] This fact simplified the choice of field equipment for both Program 73 and 74 (see Chapter 5); both groups purchased, in quantity, Eberline* Model PAC-1G gas-flow proportional counters. The instrument consists of a gas-flow proportional chamber, a transistorized pulse amplifier, and a one-shot multivibrator followed by an integration circuit. The meter read-out has a nominal maximum range of 100,000 counts per minute (cpm). Individual instruments were field calibrated on middle and high ranges by use of large-area (5 x 10 inches) distributed sources of 174 dpm/cm^2 (disintegrations per minute per square centimeter) and 1,790 dpm/cm^2, respectively. The low scale was calibrated against a known point source. All sources used for calibration were prepared by LASL.

4.2.2 Paving Materials

Asphalt and concrete pads, 10 x 10 feet and 24 x 50 feet in size, were constructed within the Program 73 array (Figure 4.1). For concrete, either a wood float or a steel trowel finish was used. Asphalt pads were either sealed or given a highway finish. Obviously, ease of decontamination versus surface finish was to be checked. Numerous 2-x-2-foot pads of asphalt and concrete were tested, as well as the building materials (Figure 4.1).

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*Then Eberline Instrument Division of Reynolds Electrical and Engineering Company, Inc., now simply Eberline Instrument Corporation, Santa Fe, New Mexico.

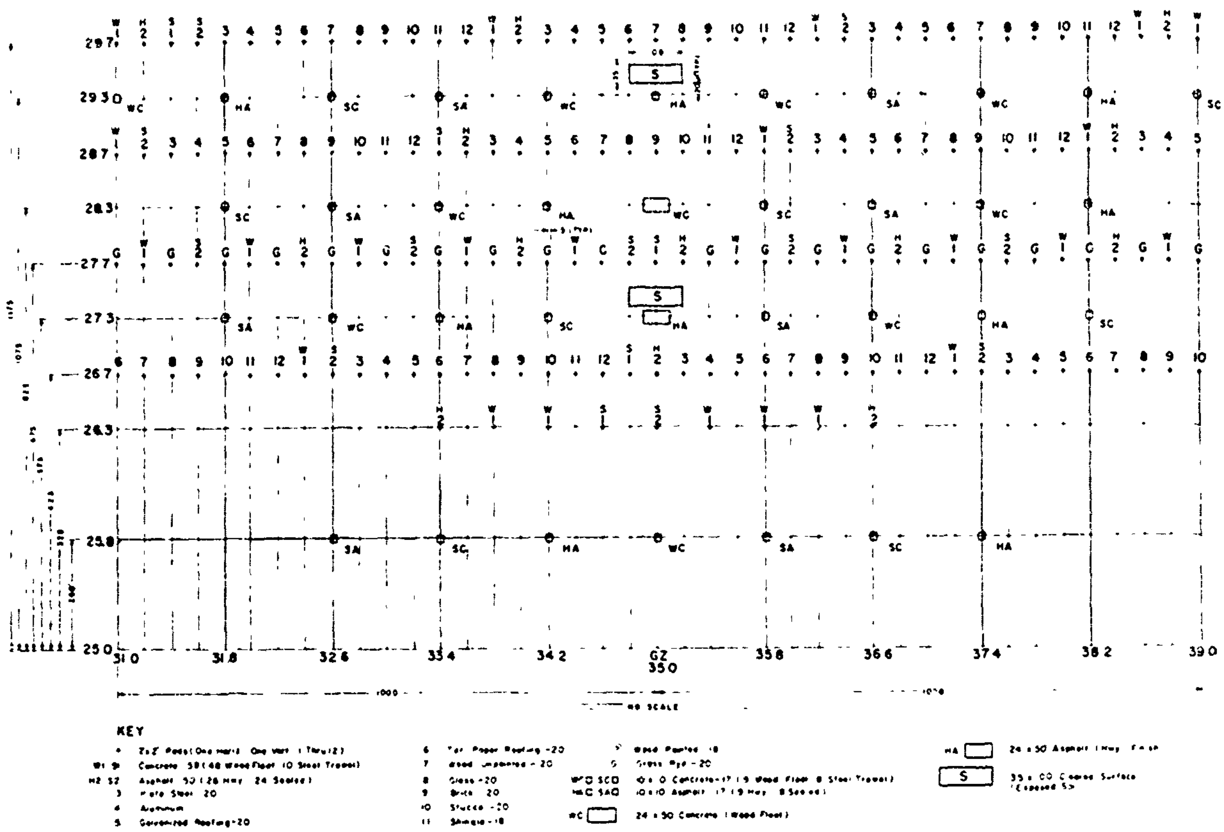


Fig. 4.1—Pad array.

Field decontamination began on D+3. The 10-x-10-foot pads were monitored, decontaminated, and remonitored with the alpha meter. The efficiency of the cleaning method is simply the ratio of monitoring results. Methods tested included vacuuming, water hosing, water scrubbing, water-detergent scrubbing, steam cleaning, and sand blasting.

The same procedure served for the largest paving pads (24 x 50 feet) except that resuspension factors were also checked. Air samplers placed along the long side and on the centerline of the pad were operated while four men stirred up surface dust with brooms. An additional air sampler was set 25 feet downwind from the pad and 5 feet aboveground (the standard height for all samplers used here). The surface was agitated for only about 7 minutes, but all samplers ran 8 minutes longer. After this assessment of resuspendability, the pad was decontaminated, and a second resuspension completed the measure of cleaning efficiency.

4.2.3 Building Materials.

Samples of standard construction material in the form of 2-foot-square pads were positioned as Figure 4.1 denotes. Materials used were concrete, asphalt, plate steel, aluminum, galvanized roofing, tar paper, painted and unpainted wood, glass, brick, stucco, and asbestos shingle. Flats of grass were also exposed. A typical placement is shown in Figure 4.2. Note the vertical sample. While this figure shows horizontal and vertical samples joined, the latter were oriented randomly; few faced the shot in the manner illustrated.

Decontamination was accomplished by the methods stated in Section 4.2.2, the same sequence of monitor, decontaminate, and remonitor being employed. Native soil and brush were monitored to establish the relation of sample contaminations to that of their immediate environs.

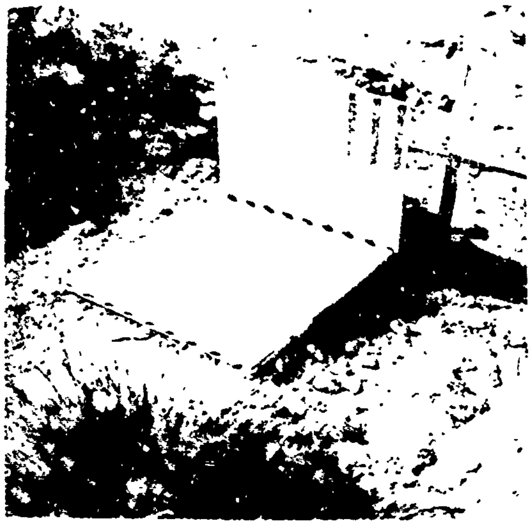


Fig. 4.2—Corrugated roofing samples, 2 feet square.

4.3 DECONTAMINATION OF LAND AREAS

As Figure 4.3 depicts, eleven areas, or test zones, within the pad array were worked for decontamination trials. Most of these were 50-x-100-foot areas, grubbed to eliminate worries with vegetation. A time-study area was designated for later trials.

Before actual decontamination, each area was monitored at six locations, and vertical soil samples were taken at two locations. Four Staplex and two millipore samplers were set up within the test zone and a cascade impactor was placed 30 feet downwind. Each surface was then agitated in a less than 5-knot ambient wind by repeatedly driving a truck back and forth over the area. As before, mechanical resuspension was carried on for 7 minutes; the air samplers were operated for a total of 15 minutes. The area was monitored again and decontaminated by the method selected (Figure 4.3). Each area was monitored still again where such action was applicable, and more vertical soil samples were taken. Finally, the area was subjected to resuspension for a second time to determine the effectiveness of the decontamination method.

In the flooding, water-leaching trials, one area was covered with water to a depth of 0.3 inch and the other to 1 inch to simulate moderate and heavy rainfall. In addition to simple flooding, leaching additives (1 percent, by weight, of Alconox detergent and ferric chloride) were tested for a 0.3-inch flooding level.

Soil mixing (contaminant dilution) was accomplished by a conventional single-bottom farm plow and a four-gang disk. One area was plowed to a 12-inch depth; one was disked to a 4-inch depth (Figure 4.3).

Earth fixation was tried in two areas with Type RC-O road oil, the penetration of which was estimated to be 0.15 inch. A separate area was sprayed with USAF Type 5 charge fire-fighting foam to see how effective this material would be as a temporary fixing agent.

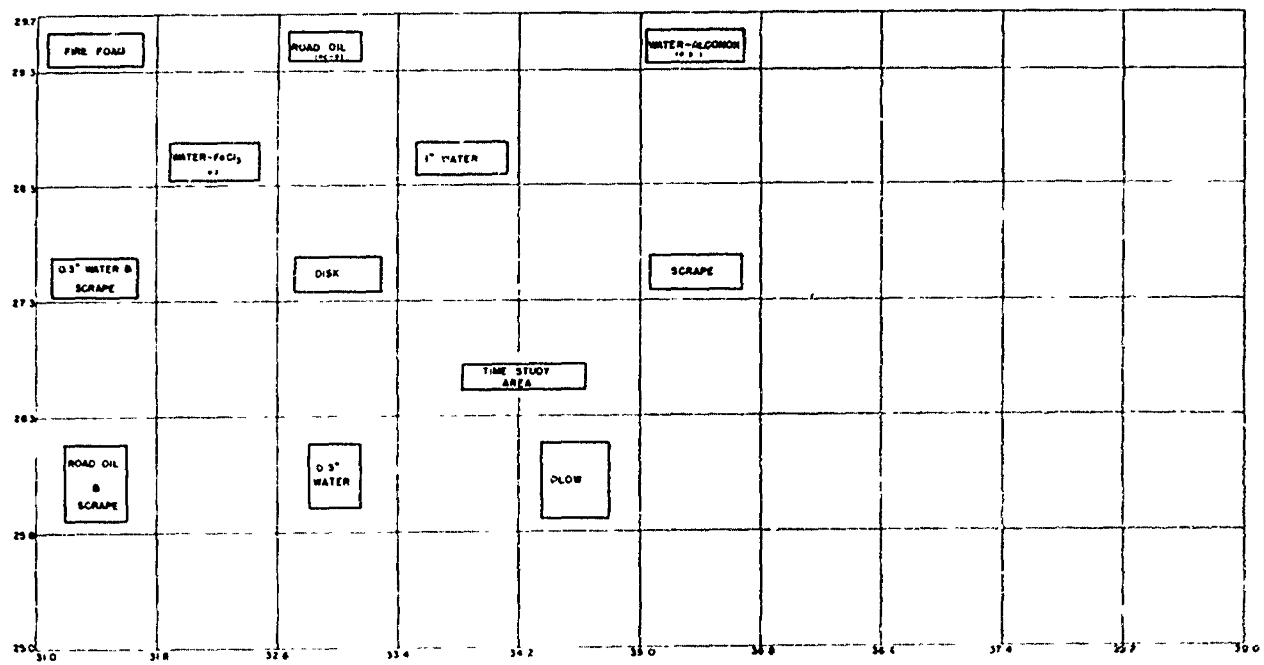


Fig. 4.3—Plot of land decontamination areas.

Removal of the top 3 to 4 inches of soil was attempted for three areas. One had been previously oiled, the second wet with 0.3 inch of water, and the third left undisturbed.

4.4 AIR SAMPLING

Patently, air sampling was an important adjunct to many of the decontamination evaluations. Yet Objective 2 of the program makes clear the further desire to compare air samplers of different types. A concentrated array of samplers located according to the plot of Figure 4.4 was operated for this purpose. Of the six impactors mentioned, five were the cascade type described earlier (Section 2.3.2); the sixth was a Battelle impactor (27.7-35),[2] a multistage device too complex to be explained here. The standard Staplex sampler is shown in Figure 4.5; a Staplex fitted with an annular impactor head, in Figure 4.6. The three millipores called for are nearly identical to those used by Program 71.

Unlike those of Programs 71 and 74, participants in Program 73 remained in the field for a full month after the shot. During this time, wind direction and speed were recorded continuously and standard Staplex samplers (facing south) were run at 26.9-34.4 and 26.9-35. Precipitation accumulating through each 24-hour period was tabulated.

Figure 4.4 also shows microscope-slide locations. These slides were supplied and placed by the Naval Radiological Defense Laboratory (NRDL) to further chances of information on particulates (size, activity, etc.) from electron microscopy and comparative autoradiography.

4.5 SOIL SAMPLING

The method of obtaining soil, sampled as a preliminary to land-area decontamination, needs to be described. Standard soil sampling techniques are standard only to those who employ them; no universally acceptable method exists.

The Program 74 sampling was achieved by pressing a 1-foot-square thin-walled metal frame into the ground. One 1/4-inch and two 1/2- and 1-inch layers of soil were then successively removed from within the frame, beginning at the top and progressing downward to a depth of 3-1/4 inches. In addition, shallow soil samples were taken in units 1 foot square and 1/2 inch deep.

4.6 LONG-TERM PROGRAM

At 3 and 6 months postshot, resuspension experiments and soil samplings were made in attempts to determine: (a) What amount of material remained available for resuspension, (b) how much had been transported in the intervening times by high winds, and (c) to what degree plutonium had migrated into the soil. Much of this parallels and cross-checks work of Program 71. Extensive alpha monitoring was also done within the 73 array.

Experiments performed at LASL have shown that plutonium in soluble form has little tendency to migrate and has rather a surprising ability to retain its initial position in the soil. Not so much is known concerning plutonium in its insoluble form. It was hoped that soil sampling by both Programs 71 and 74 would lead to better information concerning this characteristic of plutonium and uranium oxides, both of which are virtually insoluble in water. Disappointingly, the uranium background of approximately 1 part per million negated most tries at tracing uranium with the precision required.

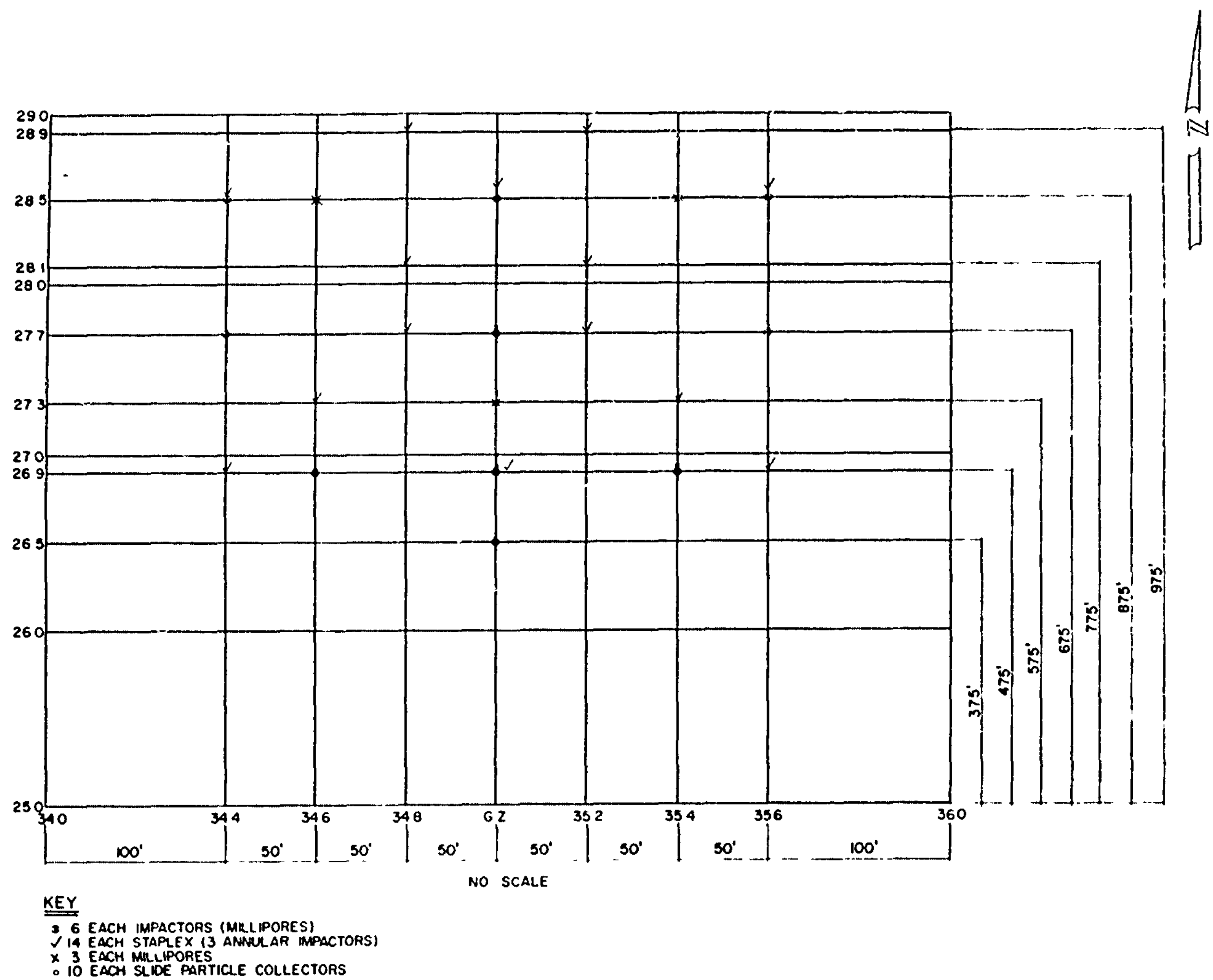


Fig. 4.4—Plot of air sampler array.

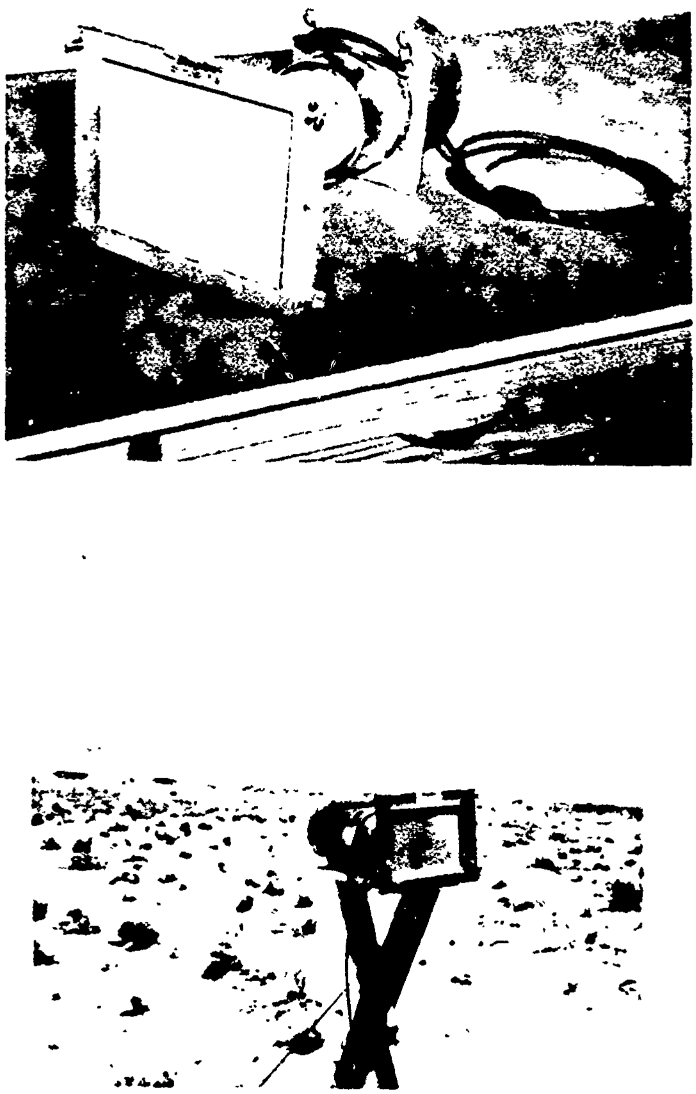


Fig. 4.5—Staplex air sampler with adapter head.

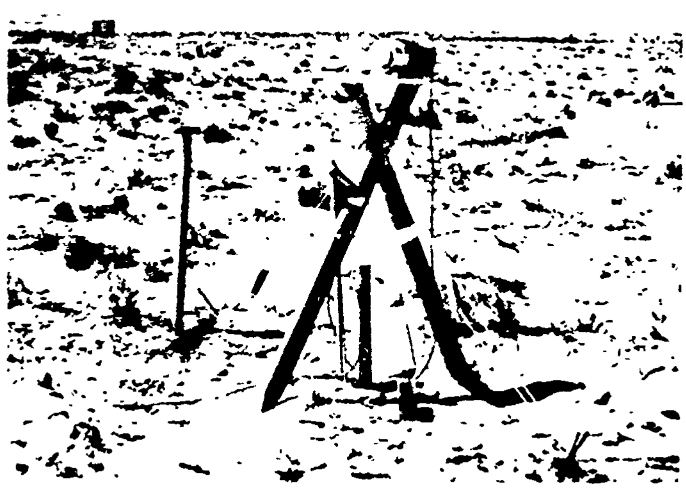


Fig. 4.6—Staplex air sampler with annular impactor.

4.7 ANNIVERSARY MEASUREMENTS

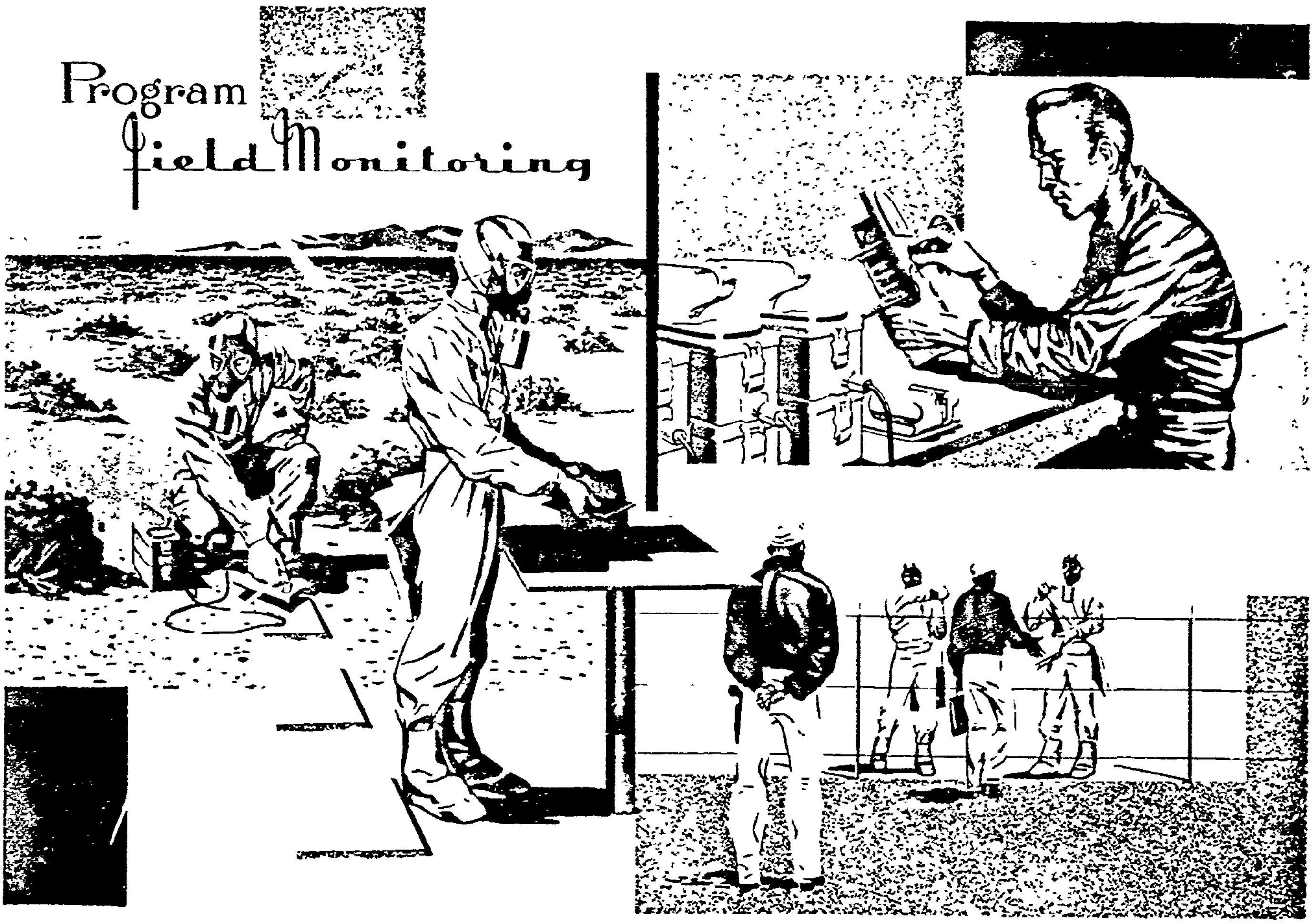
The Program 73 task in the restudy of Area 13 approximately 1 year after the shot was this:

1. Continue resuspension experiments, alpha monitoring, and soil sampling. Take soil specimens both by previous techniques and by the method developed by Program 71.
2. Operate Staplex air samplers in a cluster with four facings—north, east, south, and west—to learn more of directional sensitivity of the instrument. The cluster will be set at the location (26.9-35) used for Staplex air sampling for 30 days following the shot (April 24, 1957).
3. Record winds continuously for the period of observation.
4. Set slides, in cooperation with NRDL, to collect particulates for subsequent electron microscopy and autoradiography.

REFERENCES

1. Capt. Richard F. Merian and 2nd Lt. John B. O'Loughlin, USAF, Evaluation of Portable Alpha Survey Instruments, Hq. Air Force Special Weapons Center, AFSWC-TR-57-40, Kirtland Air Force Base, New Mexico.
2. E. A. Pinson, R. F. Merian, B. B. Boecker, J. L. Dick, Monitoring and Decontamination Techniques for Plutonium Fallout on Large-Area Surfaces, Sandia Corporation ITR-1512, December 9, 1957.

Program Field Monitoring



Chapter 5

PROGRAM 74 - SURFACE ALPHA MONITORING AND MONITOR FIELD TRAINING

5.1 OBJECTIVES

2. Normalize instrument survey results to contamination measurements with more absolute methods and estimate the worth of alpha meters for quick quantification of surface alpha activity.
3. Train and employ for field measurements AEC and military personnel destined to serve with emergency teams for accidents involving plutonium-bearing weapons.

5.2 THE ALPHA SURVEY

5.2.1 Choice of a Standard Surface

An accidental detonation in an urban area is of much greater immediate concern than one in a rural area. Because smooth surfaces such as sidewalks, curbing, pavements, and automobiles are generally present in urban areas and because best correlation between survey readings and actual contamination can be expected from monitoring such surfaces,* broom-finish concrete was chosen as a monitoring surface standard in this program.

About 1,400 blocks (10 x 10 x 1 inches) were fabricated and arrayed in the test field before the shot. Zone A contained 24 blocks, centered in the 50-foot squares. Zone B contained 4 blocks at every other grid intersection and one at each of the intervening points. In Zone C, placement was variable and not important to define here, since the monitoring locations will be clear in the chart of results shown in Chapter 7. In all areas but Zone A, where no sticky pans were placed, the blocks were set adjacent to the fallout-collector stands.

5.2.2 The Survey Instrument

As in Program 73, all instruments used were Eberline Instrument Division, Model PAC-1G, survey meters. One unusual feature in Program 74's use of the probe connected

*Alpha particles as energetic as emanations from Pu^{239}, about 5 mev, are so rapidly attenuated even in air that smoothness of surface can affect measurements markedly.

to this instrument is indicated in Figure 5.1. Special 1/4-inch-high standoff clips on the probe allowed the operator to set the instrument on the concrete slab and always have the same instrument-face-to-block distance. A spot source of uranium (another alpha emitter), incorporated in one of the clips, permitted continual check of instrument calibration between field measurements. These clips, plus enclosure of each counter in a plastic bag, practically eliminated instrument contamination during the field operation.

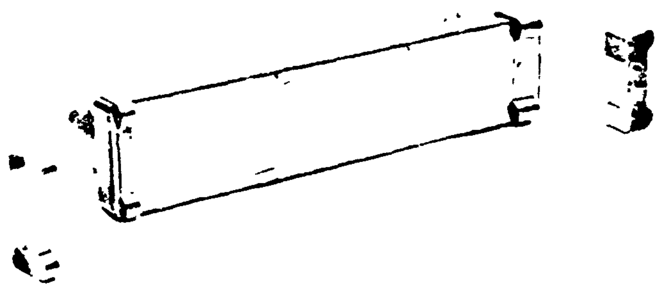


Fig. 5.1—Monitoring probe with standoff clips. Uranium spot source is visible in right clip.

5.2.3 Instrument Calibration

The primary alpha standard employed in the experiment was a sheet of stainless steel with a very thin coating of plutonium on one side. Furnished to Program 73 by LASL, it was made available to Program 74. As of March 4, 1957, the source was reported to disintegrate at the rate of 58,000 dpm ±10 percent. Approximately 5 x 10 inches in area, it had a usable surface of some 324 cm^2.

The secondary alpha standard was a jig-mounted disk coated with U^{235}. The jig enabled each probe to be fixed in the same position relative to the source. The spot uranium source, the tertiary standard, already pictured in one probe clip, was normalized to the secondary standard at the beginning of each day of use.

5.2.4 Field Monitoring Procedure

On each 10-x-10-inch concrete slab, three probe positions were read. Each reading was tabulated separately; the average of three was taken at a later time. Figure 5.2 shows a monitor taking measurements and emphasizes the extensive protective equipment required for this operation. Such protective equipment was worn by all who had duties in the field postshot. The only variation was the relaxed standard of a partial face mask ("Comfo") for outlying areas which were "cooler."

Fig. 5.2—Zone B monitor.

5.2.5 Data Handling

Cards on which original data were tabulated were handed across the hot-cold boundary at the edge of the field. A man on the cold side accepted the card between transparent plastic sheets whose edges were then taped together so that the original data could be handled without personnel contamination. These data cards, taken to the Field Control Point, permitted a running plot of estimated isoconcentration contours. This early information on fallout enabled the chronic-dog locations to be chosen.

5.3 MONITOR TRAINING

Important for Program 74 was the fact that the Division of Military Applications, AEC, had directed that AEC shipment would not be undertaken until the AEC had established emergency teams capable of protecting the public welfare in event of accidental detonation during transport.

Few people in the country were experienced in alpha field monitoring. In fact, at the time LASL reportedly had the only emergency team in the continental USA. Accordingly, a training program was set up as an integral part of Program 74. Thirty-three people from the AEC and the DOD and fifteen from Sandia Corporation were assigned as trainees and participants; six more Sandia Corporation personnel acted as staff, bringing the total number of active participants to fifty-four. An extensive training program—consisting of lectures, field work, study assignments, and problem sessions—was given to all participants.[1]

5.4 LONG-TERM ASPECTS

At approximately 12 and 24 weeks postshot, a resurvey was made with alpha meters to document the virtual shift in principal isoconcentration contours; namely, 10, 100, and 1,000 $\mu gm/m^2$.

5.5 ANNIVERSARY MEASUREMENTS

Program 74 is scheduled to participate in the anniversary effort in the following specific ways:

1. Make a 1-year resurvey with alpha instruments to identify virtual locations of the principal contour lines.
2. Train additional AEC and DOD personnel for emergency team assignment.

It is predicted that more than 40 new trainees will participate in this program. With the completion of the anniversary program, nearly 100 men will have received Program 74 training.

REFERENCE

1. R. E. Butler, Surface Alpha Monitoring as a Method of Measuring Plutonium Fallout, Sandia Corporation ITR-1513, May 1957.

Chapter 6

OPERATIONS

At the January 18, 1957, general meeting of Test Group 57 personnel, April 3 was chosen as a target D-day for the shot. In the week or two preceding this date, it became clear that operational readiness could not be reached until the night of April 10, so prospective shot time was changed to that date. Weather briefing on April 9 led to the belief that the night of April 10 held promise as a shot time. Everything was ready that could be readied; weather-balloon runs and resultant data through the night of April 9 and the daylight hours of April 10 confirmed the good chance for a shot. However, heavy winds persisted to make a 2100 to 2300 firing operationally untenable; the complicated balloon array described earlier was started but by shot time had not been completed. Wind data and the forecast of the following several hours were not nearly so ideal as hoped for, so the shot was canceled.

6.1 WEATHER OBSERVATIONS

As reported by the U.S. Weather Bureau, weather observed during attempted operations is summarized as follows:

April 10, 1957. Hodographs during the period 2100 to 2330 PST showed that satisfactory conditions existed at 2100 PST, but a recommendation for cancellation was made after the wind shifted to northwest on the 2300 PST soundings.

April 16, 1957. Satisfactory wind conditions existed at 0441 PST,* but the morning inversion broke more quickly than expected. By 0530 PST, winds were too strong and the shear had disappeared, forcing cancellation.

April 20, 1957. Intermittent light showers began at 2330 PST on the 19th and continued through the remainder of the night and following morning. Hodographs indicated that satisfactory winds existed during this period, but moisture on the instrumentation forced cancellation.

April 24, 1957. Scattered middle clouds were observed and a moderate dew formed during the night. The sequence of wind changes from 0415 to 0756 is shown by the hodographs in Figures 6.1, 6.2, 6.3, and 6.4. Note that two observation stations, 25.5-31 to 71-27, were operated. The shot was fired at 0627 PST.

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*First planning looked to a shot time between 2100 and 2300. Persistence of afternoon winds prevented the start of balloon operations so consistently that shot time was moved to early morning hours. More and better technical photography was assured by the change as well.

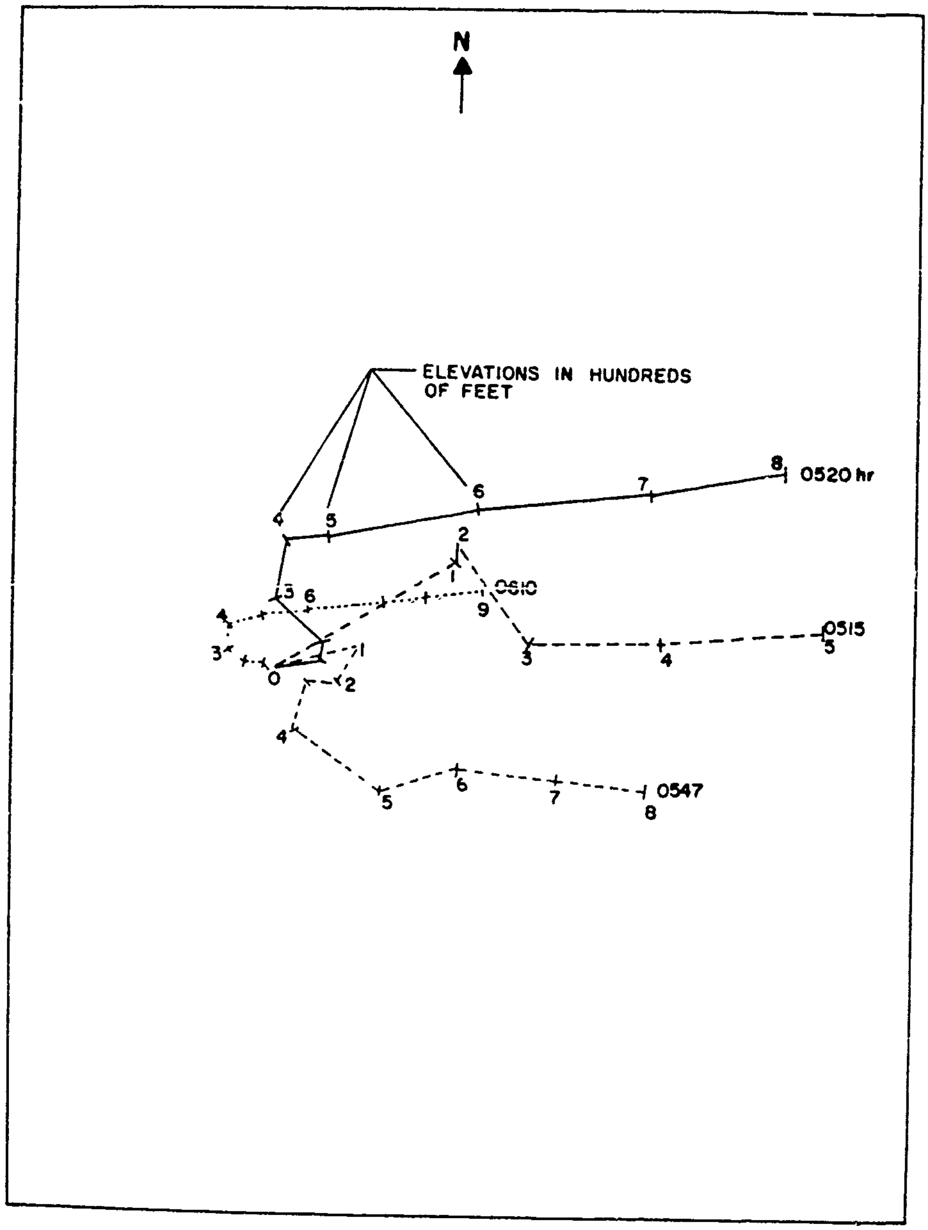

Fig. 6.1—Adjusted hodographs prior to operation on April 24, 1957, Station 23.5-31.

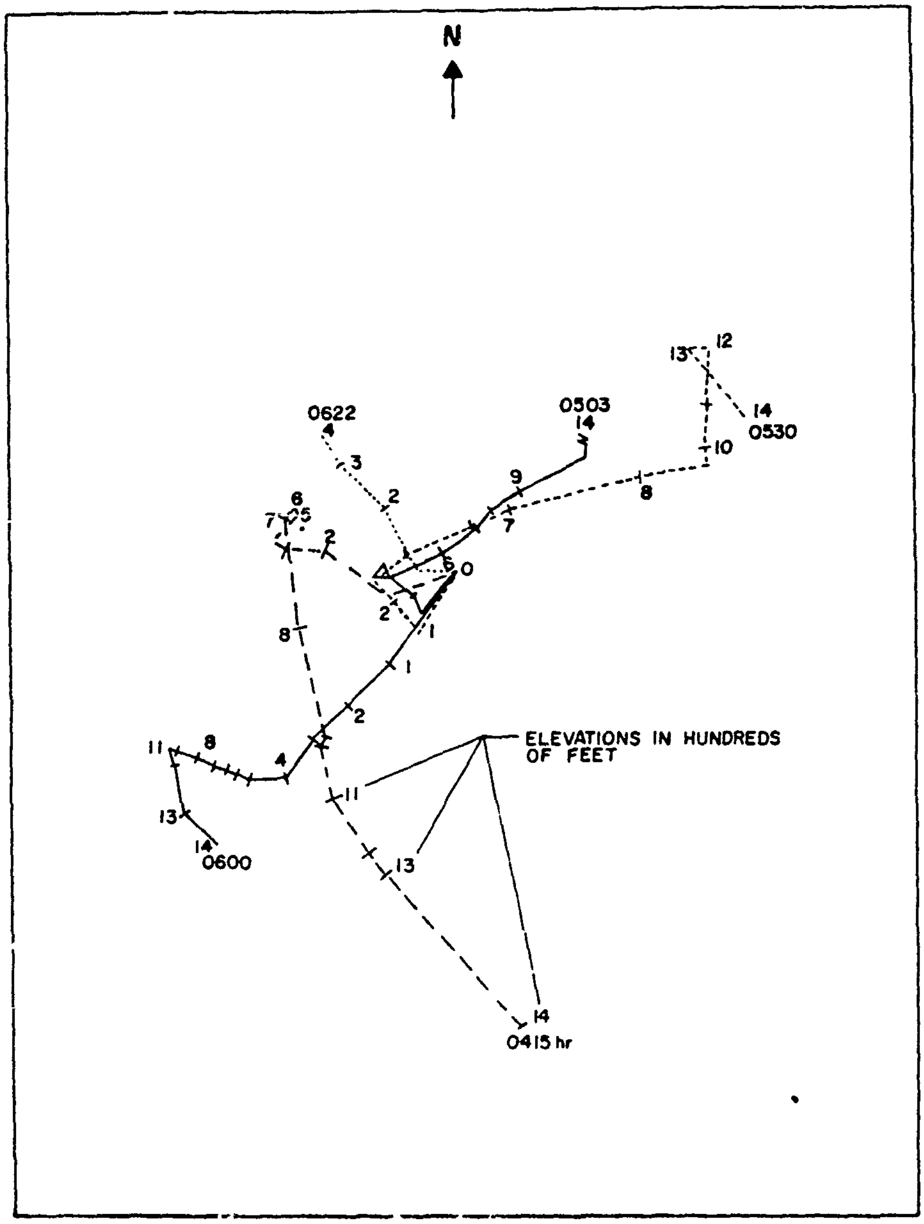

Fig. 6.2—Adjusted hodographs prior to operation on April 24, 1957, Station 71-27

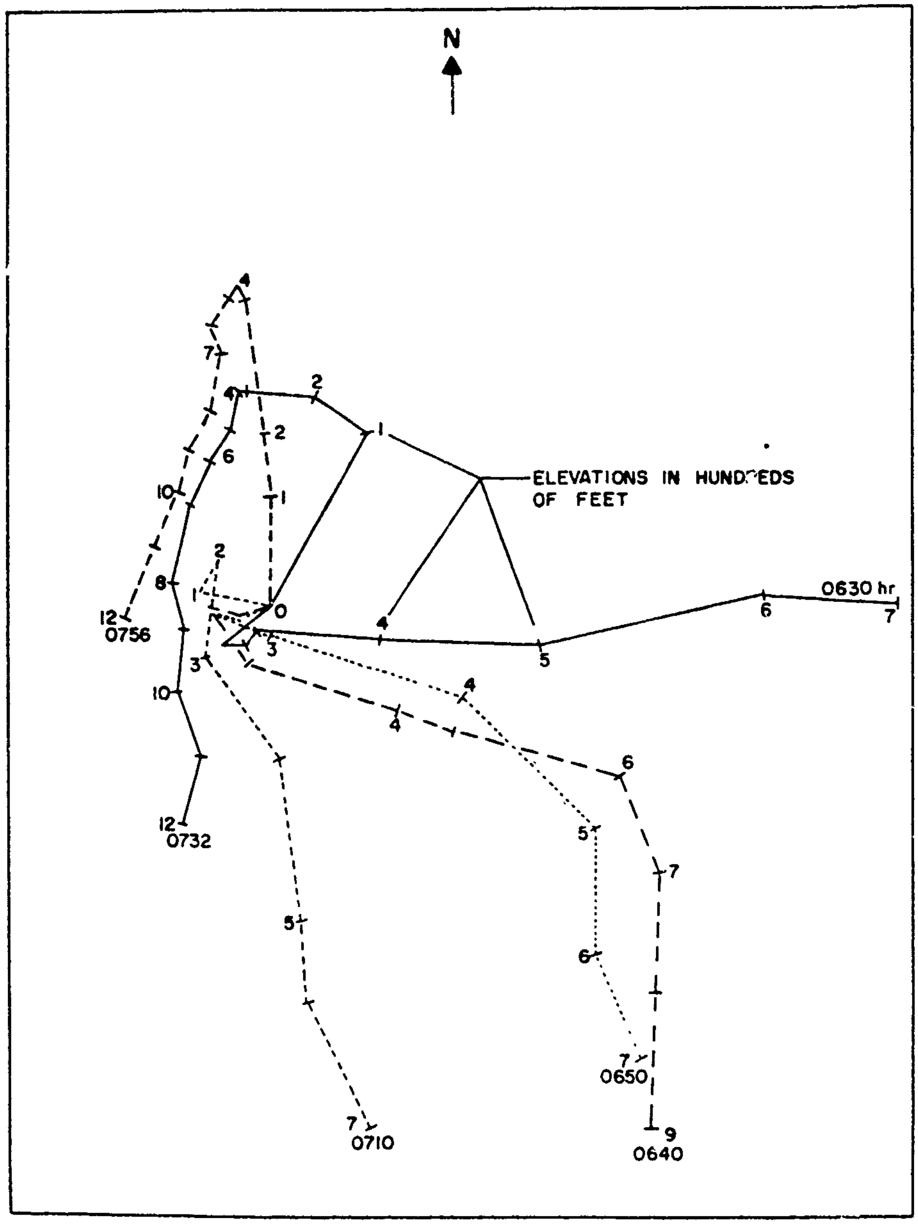

Fig. 6.3—Adjusted hodographs during fallout, April 24, 1957, Station 25.5-31.

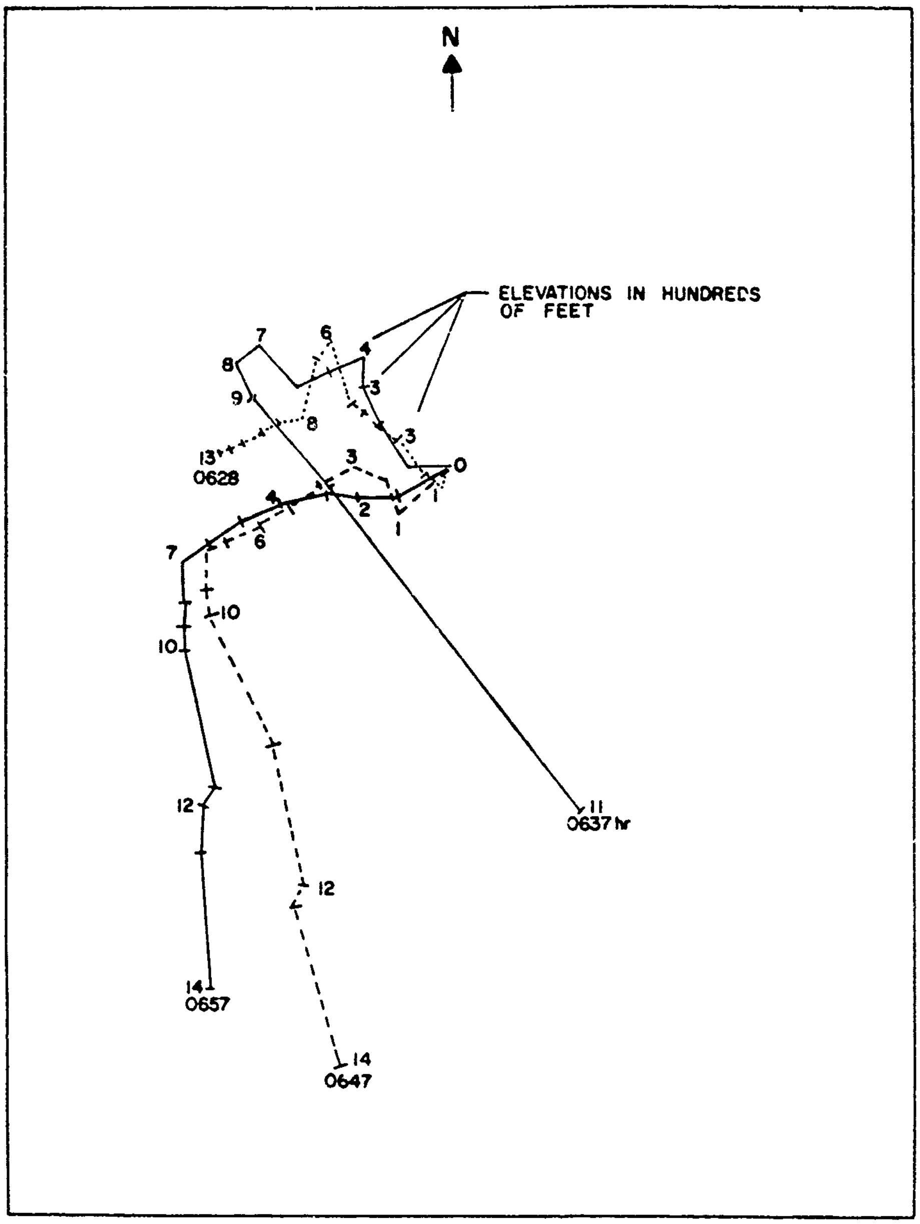

Fig. 6.4—Adjusted hodographs during fallout, April 24, 1957, Station 71-27.

6.2 THE SHOTS

At 0350 PST, April 24, a surface charge of 110 pounds of stick dynamite was fired 1,000 feet east of Zone C (as position 42-61) to verify predictions of cloud height. Manned transits at 42-50 and 27-60 triangulated the cloud apex for an approximate cloud-height measure.

The W-25 was actually fired at 0627 PST, April 24, in Area 13. There are some important apparent differences in measurements of wind patterns during the fallout period. Many of those reported show a net wind to the south. The pattern of fallout which will be reported later indicates that there must have been a slight north-carrying component to the hodograph. One must admit the difficulty of obtaining precise hodographs over this short height range under conditions of high shear and light winds, with a remote manned theodolite system; the hodographs of Figures 6.1, 6.2, 6.3, and 6.4 should, therefore, be taken in an indicative rather than an absolute sense. The best remaining means of arriving at actual wind conditions was the dual photography of the cloud, looking north and east through GZ with separate cameras. Also, the aerial photograph of the progress of the cloud does hold some evidence. Finally, the fallout pattern itself can be used as a base from which to infer the actual wind structure which may not be, and very probably was not, persistent or uniform over the principal fallout area.

The way it turned out, the east-facing camera, because of the hour (0627), looked into the sun just clearing the mountains and gave little cloud information. However, combination of the data on north-facing camera film and aerial photographs allowed the construction of Figure 6.5, which portrays probably the best description of mean wind structure for the first hour following zero time.

6.3 THE WEAPON

handled, placed, and armed the weapon,
The instant of firing was not critical,
since time-correlated instrumentation was practically nonexistent. Timing and firing circuits were the ultimate in simplicity; the weapon was hand fired by EG&G at the Test Group Director's instruction.

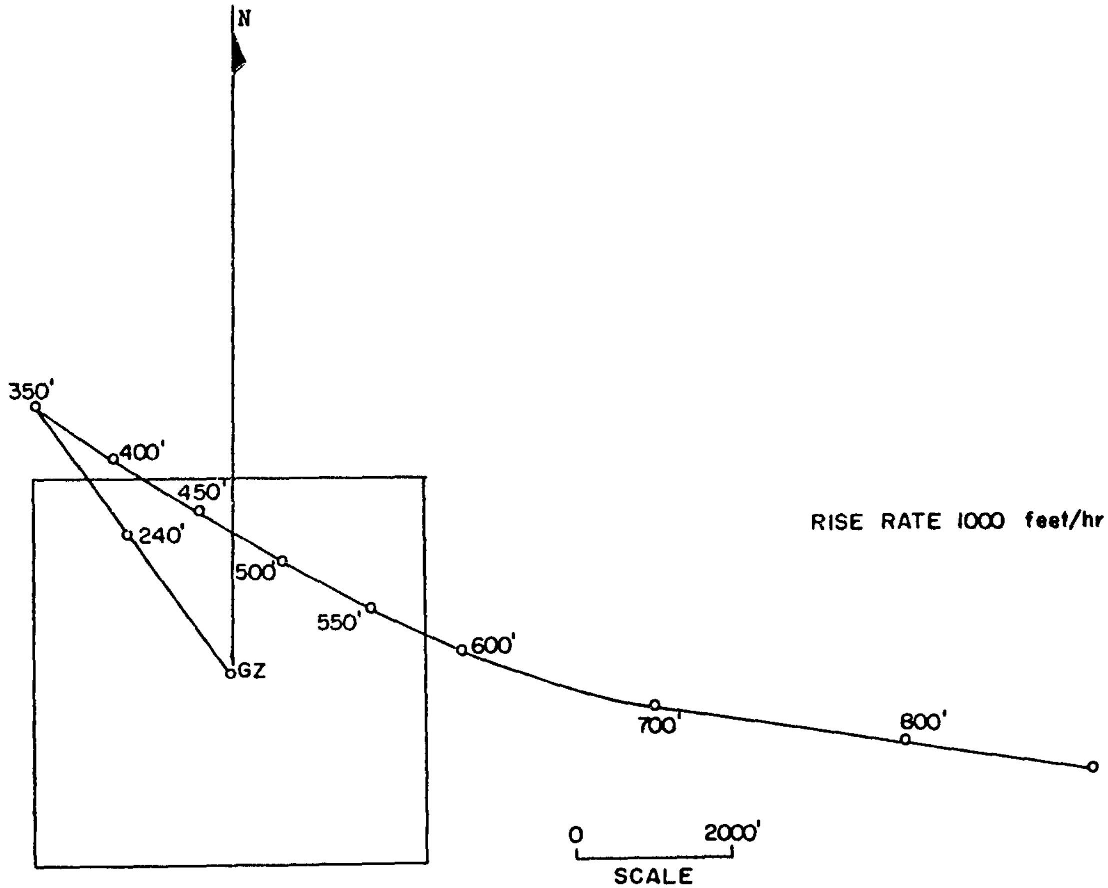

Fig. 6.5—Mean first hour wind pattern.

Chapter 7

RESULTS

In light of a shot date of April 24, one might expect that considerable data had accrued and been interpreted by the close of Operation Plumbbob, and to some extent this is true. However, when one realizes that about 15,000 radiochemical analyses for plutonium and uranium will ultimately be necessary to report the full operation and that all programs had a long-term schedule carrying them to mid-October 1957, it is apparent that considerable data remain to come. The scale of the analysis and the time for careful analysis of the separate program results prevent final reports from being issued until September 1958.

7.1 ISOCONCENTRATION LINES

The pattern of plutonium deposition throughout the field was a principal objective of Test Group 57. It was practically the singular objective of Program 74 and constituted a large percentage of the Program 71 effort. Determinations by Program 74 were made, of course, with alpha survey instruments, while Program 71 employed sticky-pan fallout collectors. Since contours were first determined by the alpha-survey method, Program 74 results will be given first.

7.1.1 Data from Alpha Survey Instruments

In any alpha-survey effort with instruments, there is always difficulty in arriving at a normalization scheme for the actual counts per minute registered by the meter. The limited range of alpha particles, the form of the plutonium oxide (plated on a scavenging agent, or manifest as solid plutonium oxide particulate), shielding by nonplutonium-bearing particles, and differences in the surfaces on which the contaminant falls make it almost impossible to judge what degree of deviation from an ideal source really exists. The over-all intent of TG 57 was the correlation of survey readings with the chemical analysis of sticky pans and soil samples. However, because many programs, as well as many agencies interested in the problem, wanted some guiding contours as soon as possible after the shot, another method of tying actual numbers to the isoconcentration lines had to be chosen. Advice was sought from M. Cowan, Sandia Corporation, who had conducted analyses of seven experiments in a fallout program at Sandia[1] in which uranium was used as a stand-in for plutonium

By weighting fallout from the uranium shot with wind conditions judged most similar to those on the TG 57 shot and by scaling actual differences, it was calculated that the contour line which enclosed or accounted for, roughly

the plutonium should be called 10 $\mu gm/m^2$. With this as a tie point, Program 74 made calculations which resulted in the preliminary contours shown in Figure 7.1; computed ground concentration for individual survey points in Zone C are also included.

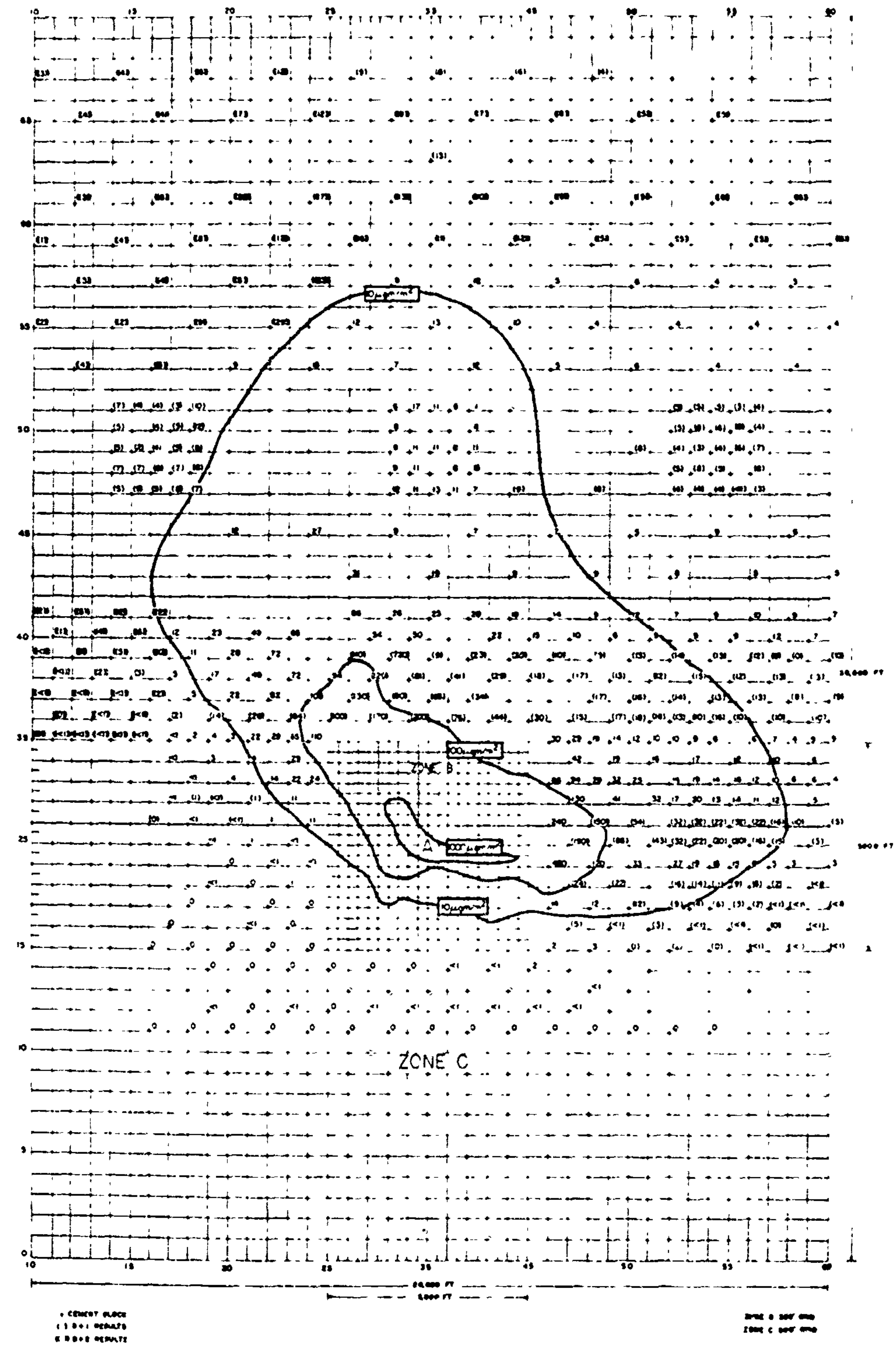

Fig. 7.1—Preliminary isoconcentration contours from alpha survey with point results in $\mu gm/m^2$.

The areas, in square miles, enclosed by the three tentative contours for early planning were:

Concentration (μgm/m^2)	Area (sq mi)
1,000	0.06
100	0.77
10	5.3

Since the complete survey could not be accomplished in a single day, recognition of the degradation that had occurred from D-day to D+1 and D+2 was necessary. Remonitoring of blocks—selected from those read on D-day, on D+1, and on D+2—showed that the virtual degradation was considerable. In a valley with the Area 13 topography, it was difficult to decide whether or not weathering was uniform over the entire area instrumented, especially since late afternoon of D-day brought rain squalls and gusty winds. Even so, re-read blocks extending from, roughly, 2,500 feet south to 12,000 feet north of GZ indicated that degradation in 24 hours was, roughly, a factor of 1-1/2; in 48 hours, a factor of 2. Wherever possible, in the isoconcentration contours shown in Figure 7.1, D-day measurements were employed. Data gathered on D+1 and D+2 are identified by single and double parentheses, respectively.

7.1.2 Survey Data Renormalized

Survey data were re-examined after enough sticky-pan data had accumulated to delineate complete 1,000-, 100-, and 10-μgm/m^2 contours. The comparison uncovered differences of a factor of 2 in enclosed areas.

The conversion factor of 140 cpm per μgm/m^2 utilized for preliminary ground concentration calculations was simply enlarged by $\sqrt{2}$; for ease in arithmetic, conversion was actually rounded off to 200. Recomputation produced contours which agreed satisfactorily with those from chemical data. An areal comparison is given later (Table 7.10), but the final alpha survey contours are shown in Figures 7.2 and 7.3. Best Zone A interpretation is that of Figure 7.4.

7.1.3 Sticky-Pan Data

Of the 4,000 sticky pans placed before the shot, some 3,500 were picked up, covered, packaged, and shipped to Albuquerque for radiochemical analysis. Of these, about 2,800 have been analyzed to date. Figures 7.5 and 7.6 give the resulting data. Contours for 1,000, 100, and 10 μgm/m^2 have been superimposed on the figures to facilitate interpretation of the radiochemical results. Comparison of these contours with those shown for alpha survey monitoring validate instrument-survey results. Grid lines have been deleted from Figures 7.5 and 7.6 to reduce cluttering; however, they can be appreciated from the distance scale contained and the fact that the decimal point in each plutonium value is a grid intersection.

The most interesting contours, 100 and 1,000 μgm/m^2, enclosed, respectively, 0.46 and 0.03 square mile. In time, all data will be available, and corrections, probably minor, will be made. A simplified contour representation appears as Figure 7.7, on which the hodograph is superimposed to exhibit the cause-and-effect relation of fallout.

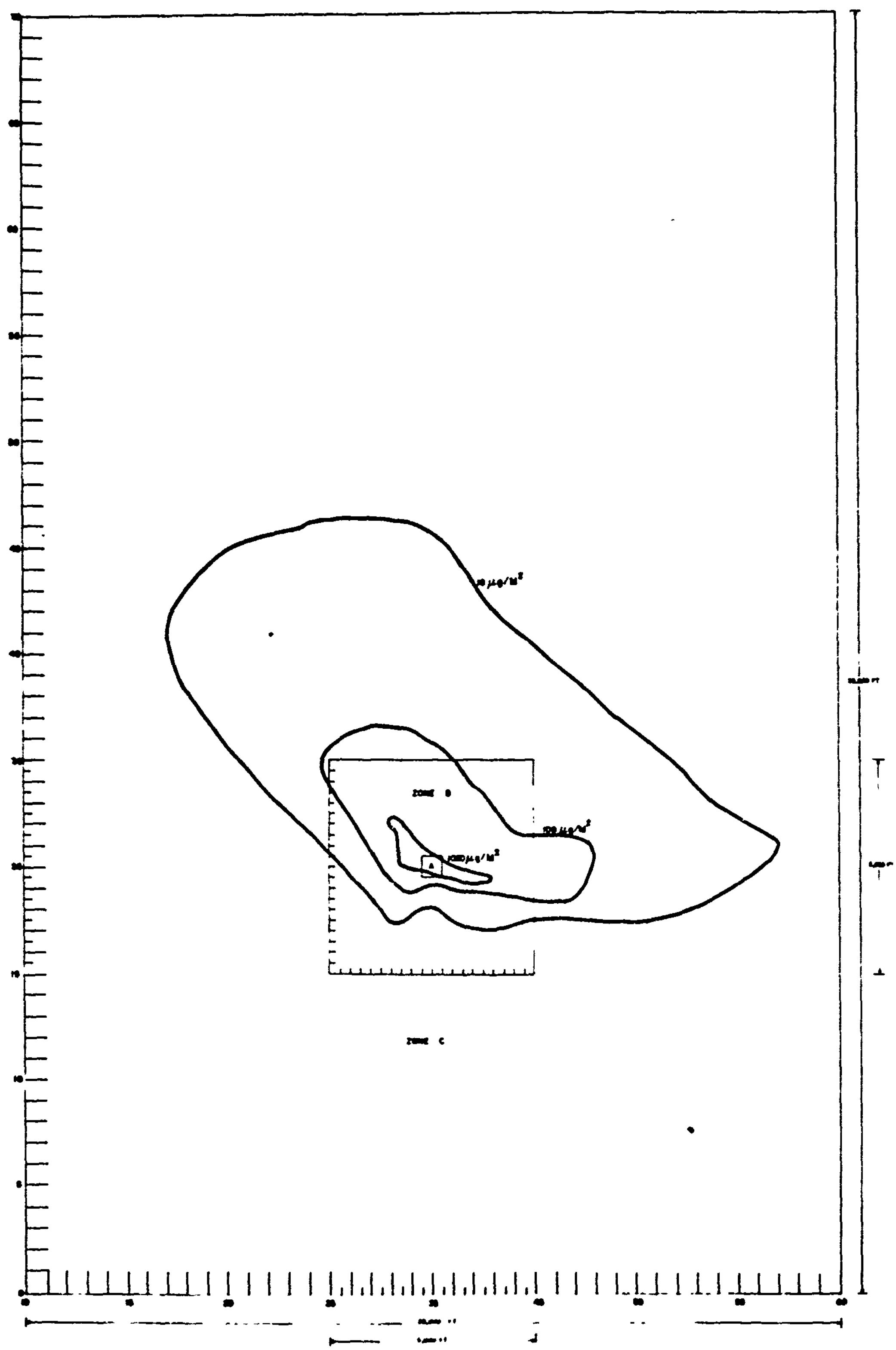

Fig. 7.2—Normalized Zones B and C alpha survey contours.

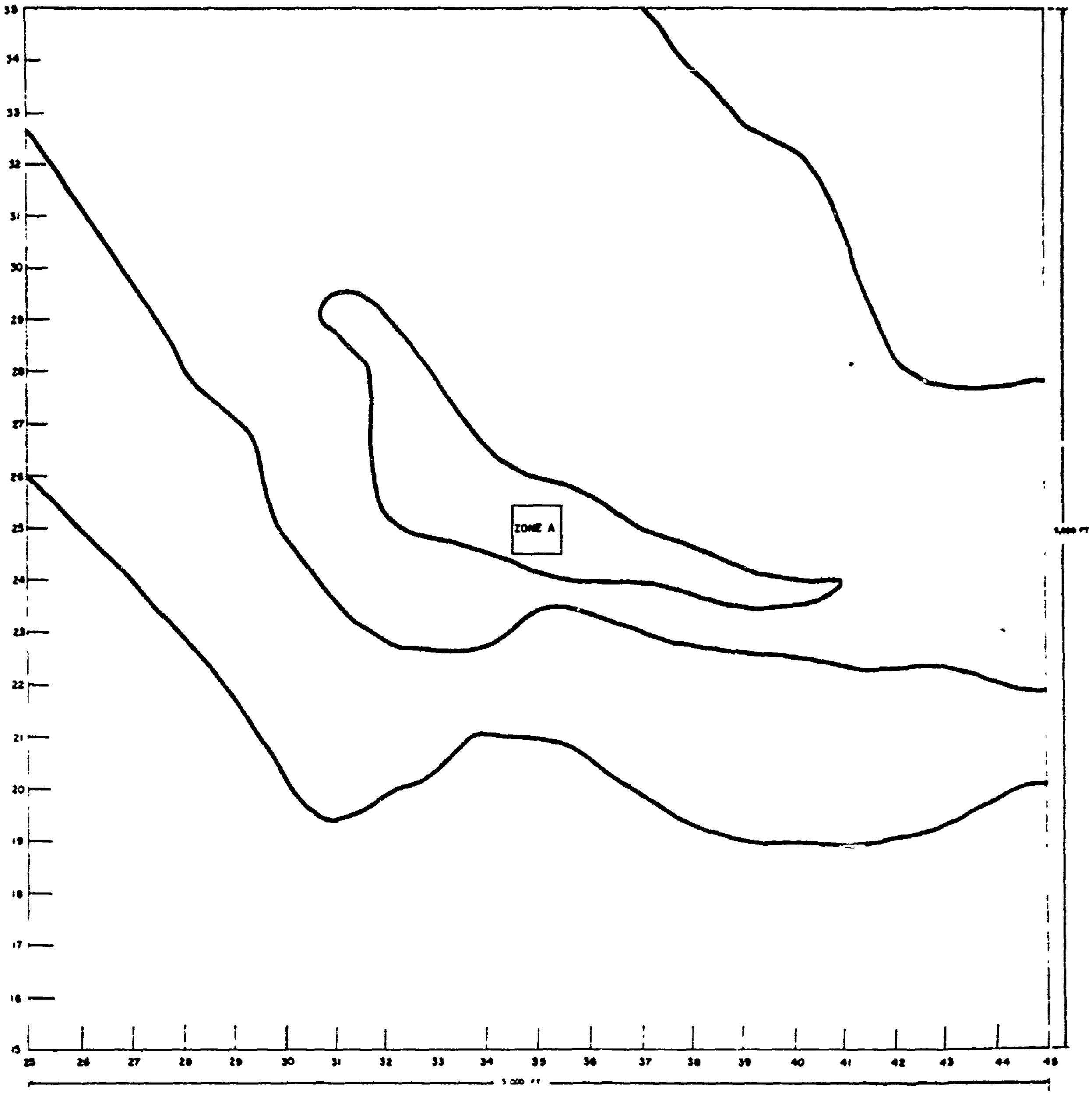

Fig. 7.3—Normalized Zone B alpha survey contours.

ZONE A

E 8400 440 610	J 3700 380 290	O 3200 240 290	T 2000 250 160	Y 3400 120 92
D 9800 870 1200	I 8400 410 440	N 7700 800 1000	S 4400 360 350	X 2500 200 160
C 6800 620 460	H 9800 740 480	G.Z.	R 6600 290 300	W 6600 330 280
B 4800 460 390	G 8400 1100 650	L 21000 1300 920	Q 4100 260 230	V 7000 370 290
A 7700 510 410	F 7700 960 880	K 7000 550 430	P 2800 140 110	U 3200 230 240

KEY

APRIL 1957
JULY 1957
OCT 1957

Fig. 7.4—Normalized Zone A survey data.

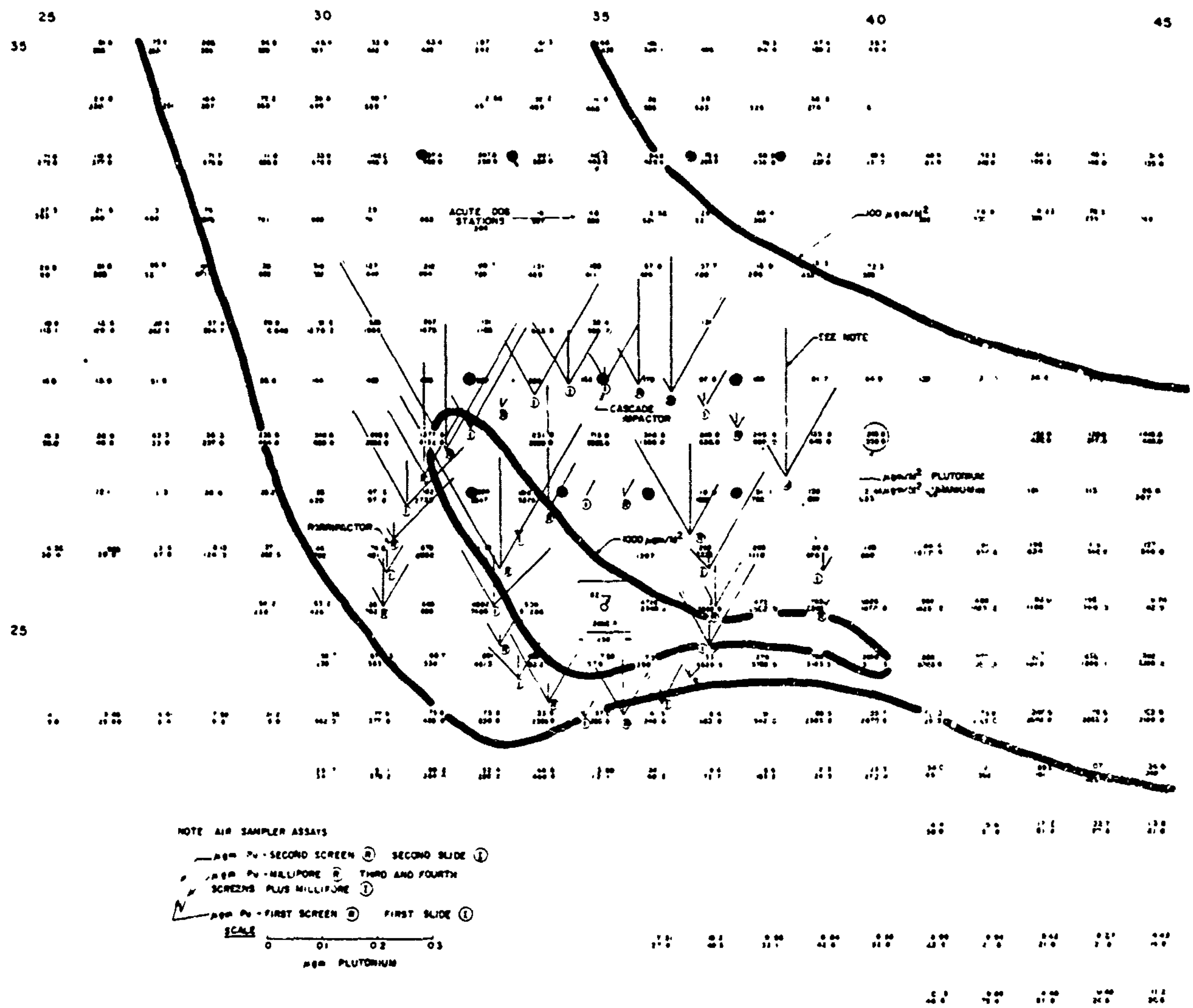

Fig. 7.5—Sticky-pan and acute air-sampler assays, plutonium isoconcentration lines and acute dog stations in Zone B.

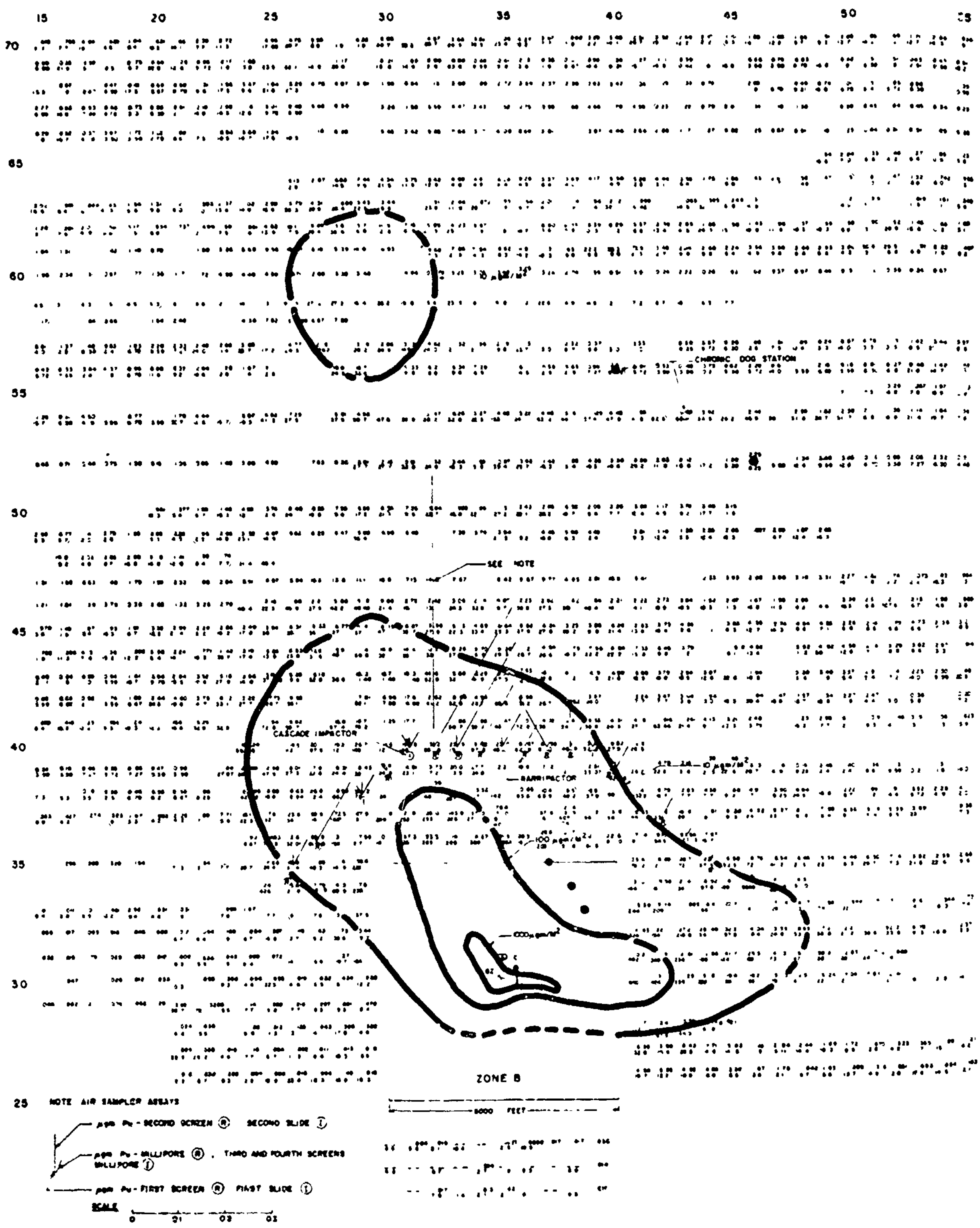

Fig. 7.6—Sticky-pan and acute air-sampler assays, plutonium iso-concentration lines and chronic-dog stations in Zones B and C.

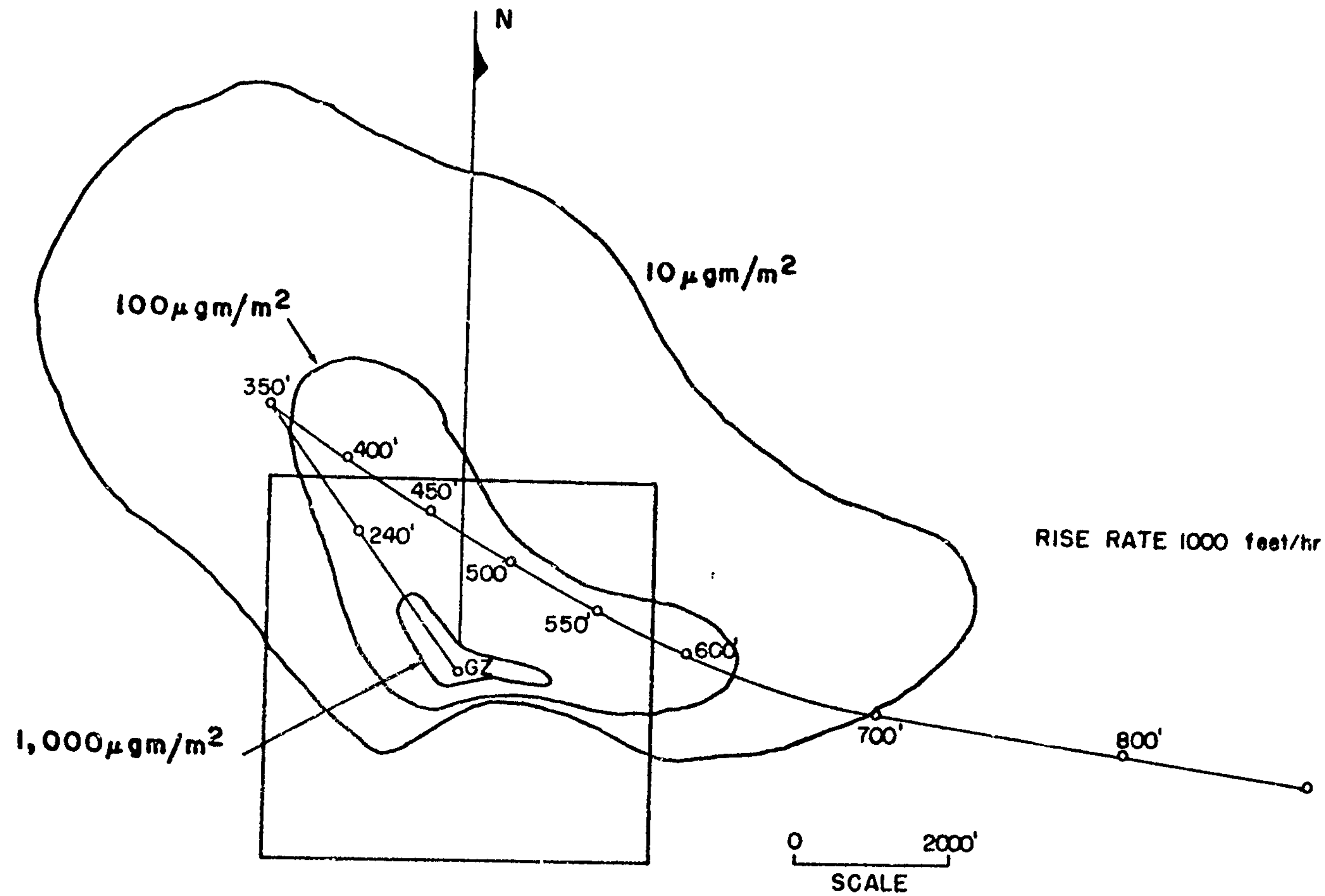

Fig. 7.7—Major isoconcentration lines and mean wind hodograph.

7.2 AIR SAMPLING DURING THE FALLOUT PERIOD

7.2.1 Program 71 Data

Figures 7.5 and 7.6 also give data from the most significant of Program 71 air-sampling stations run during the acute-hazard period. Results are shown in the form of line segments, the lengths of which represent micrograms of plutonium according to the key. Legends on the figures indicate what their rough interpretation as to particle size should be. All these air samplers operated for approximately 3 hours after the shot, and the amount of plutonium graphed was collected over that 3-hour period. The results were not averaged because 80 to 90 percent of the material collected very likely reached all stations reported here within the first hour.

Most significant, at first glance, is the fact that air concentrations, especially in the vertical and right leaning lines (roughly, the respirable particle sizes present), increase along the hot line out to 5,000 feet. Consequently, it cannot be said that maximum air concentration occurred between 1,000 and 5,000 feet or that it occurred beyond the 5,000-foot stations, one of which had the highest plutonium collection made. It is certain, however, from the pattern of air concentration at 5,000 feet, that the width of the area over which high air concentrations occurred beyond 5,000 feet must have narrowed quickly to virtual insignificance. This is obvious from the rapid fall-off in air collections east and west of the highest sample.

A remaining characteristic that seems physically correct is implicit in the differences in relative line lengths with distance. As one moves from the 500-foot to the 5,000-foot circle, particularly along the major hot line of fallout, the coarse-particle line essentially disappears, but the medium and very small particle lines grow over the full distance.

7.2.2 Program 73 Data

Predicated upon the outcome of Project 56, the Program 73 acute air-sampling experiment was tailored to evaluate close-in air concentrations and the nature of particulates producing them. The variety of sampler types will ultimately allow a study of their differing particle discrimination, compatibility with optical microscopy, quick answers by counting, etc. Comparison of gross collections and over-all figures of merit for the separate techniques is equally important. Clearly, the broad description of airborne contaminants throughout the large field was not the intent. Thus, the endeavors of Programs 71 and 73 complement each other in many respects but overlap in the difficult problem of particulate definition where no uniquely suitable approach exists.

The Staplex instruments are the sole source of data so far, and these by counting only. They all average about 35,000 dpm/m^3 for the fallout collection period of 3 hours. Corresponding chemical measurements have not been reported as yet. The same is true for the Casella, Battelle, and annular impactors. Millipore filter paper becomes transparent when moistened with oil, so samples taken in this way are being examined by optical microscopy and will finally be assayed radiochemically for gross plutonium. Although the work with air samplers, which is being done on USAF contract with Columbia University, is about complete, it cannot yet be reported.

7.3 AIR CONCENTRATIONS VERSUS TIME

The two Staplex samplers at grid locations 26.9-34.4 and 26.9-35.0, respectively, operated continuously for 28 days after the shot. Appropriate recycling and counting of individual filters 5 days after removal (to allow decay of the principal natural-occurring alpha emitters) produced similar results for the two stations. Data from the two stations are given in Figures 7.8 and 7.9. The fluctuations caused by periods of high wind and quiet are obvious. Rainfall during each sampling cycle is also noted in Figure 7.8.

Air concentrations decreased very rapidly; they were down by a factor of 100 by H+7 and by an estimated factor of 500 at the end of the 28 days (see the smooth curve fitted to the data in Figure 7.9).

7.3.1 Extrapolations to Inhalation by Man

Program 73 data in present form are measurements at essentially one point in a large test field. There have been no corrections or refinements to account for the influence of wind speed and direction on air concentrations—differing mean concentrations and concentration gradients are traversed as wind shifts direction. Additional attention needs to be given the directional sensitivity of air samplers. That fixed Staplex units sample equitably as winds change is highly improbable. Results of anniversary measurements should provide evaluation of this factor eventually.

Meanwhile one can boldly speculate from the raw data. What follows is the scheme employed by Program 73 together with editorial notes of caution in which assumptions should be couched.

1. Examine the raw data from Figures 7.8 and 7.9 where indicated 24-hour accumulations of precipitation and wind speed guide considerations. Note sensitivity to wind speed.

2. Accept the smoothed data approximation of the curve shown in Figure 7.9. Realize the wind-averaging implications of this.

3. Note the fortuitous one-to-one correspondence at one position of initial air and ground concentrations after cloud passage, dpm to $\mu gm/m^2$; assume that this singular experience can be generalized to all ground concentration levels. This ignores the role of wind and the distance traveled by measured contamination.

4. Consider all material from air sampling respirable and an acceptable input to the standard respiration model* which assumes that 15 percent of respirable activity becomes lung burden with a half life of 180 to 365 days. Of course, particle size is hereby disregarded.

5. Assume that man enters at 0.1 day postshot and calculate full-time occupancy required to produce the maximum permissible lung burden, using 1 $\mu gm/m^2$ on the ground equivalent to 1 dpm/m^3 in the air to determine initial air concentration and using the fitted curve of Figure 7.9 to approximate air concentration versus time. The interesting result is Figure 7.10. Points from this curve make up Table 7.1. Normal activity for this period is an important stipulation; i.e., weather is the sole resuspension force.

The results from these computations disagree startlingly with LASL predictions from Project 56 data.[2] Further discussion of the results appears in the final chapter where they can be weighed against experience from biomedical experiments and decontamination measurements.

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*Now in common use for virtually all air pollution problems is a computational lung model.[2] A variation of this model described in LA-2079[3] is used here.

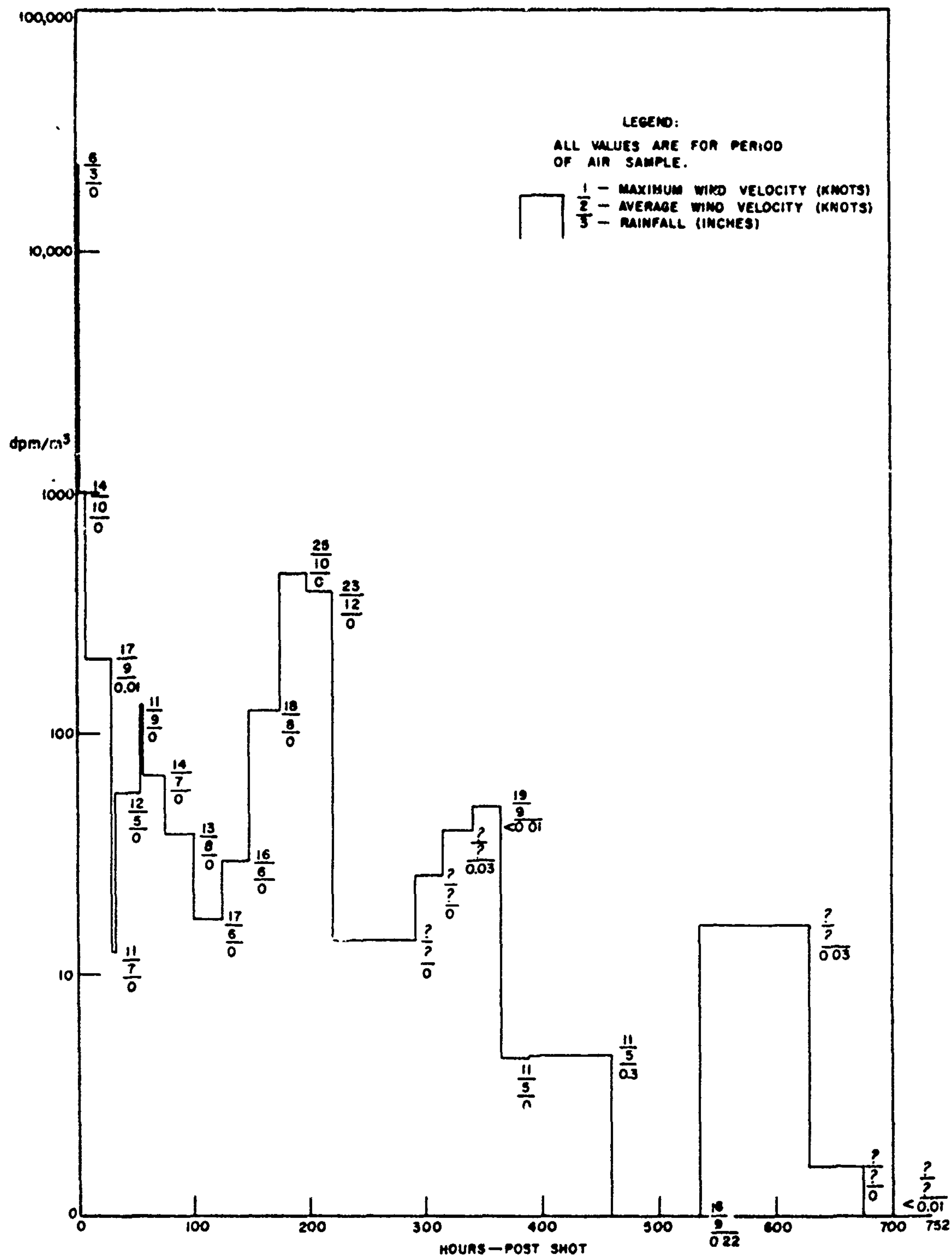

Fig. 7.8—Air concentration, maximum wind, average wind, and rainfall as a function of time - Station 26.9-35.0.

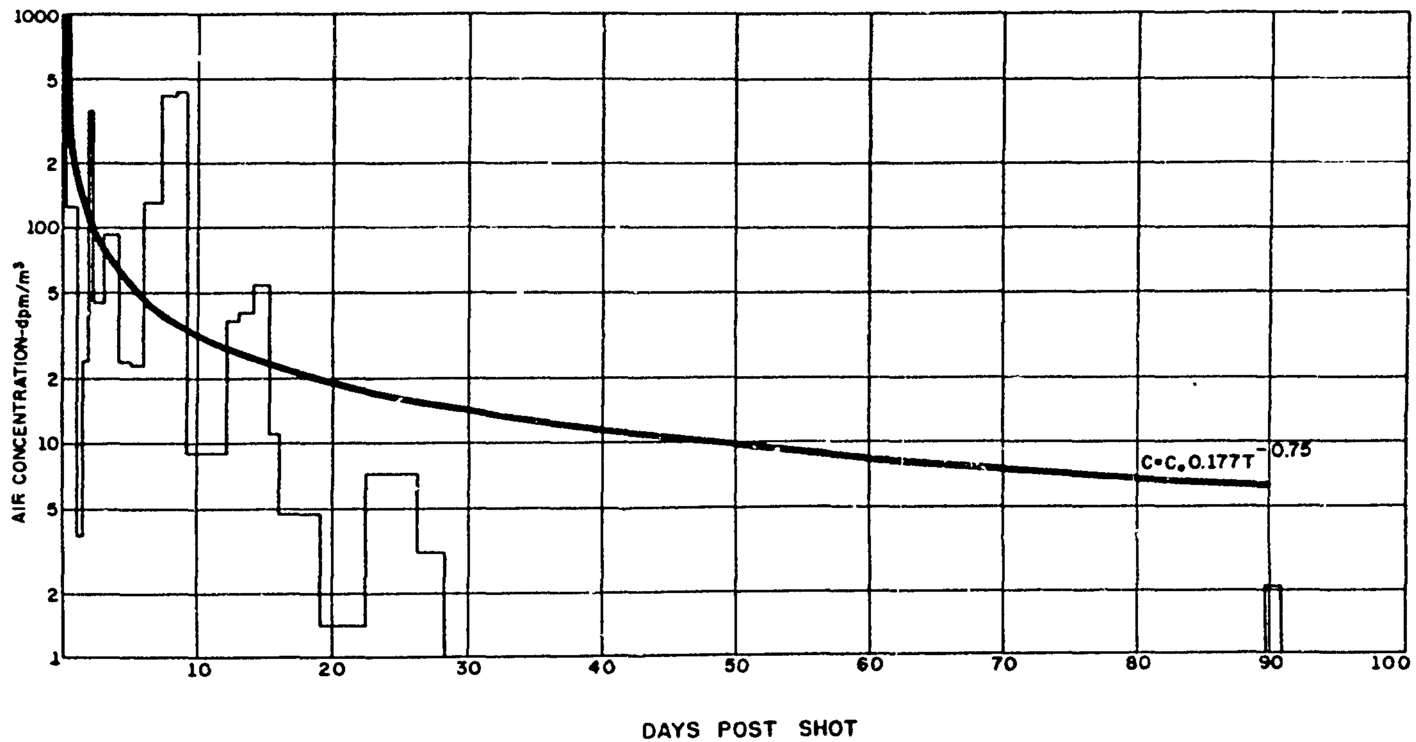

Fig. 7.9—Air concentration vs time post shot

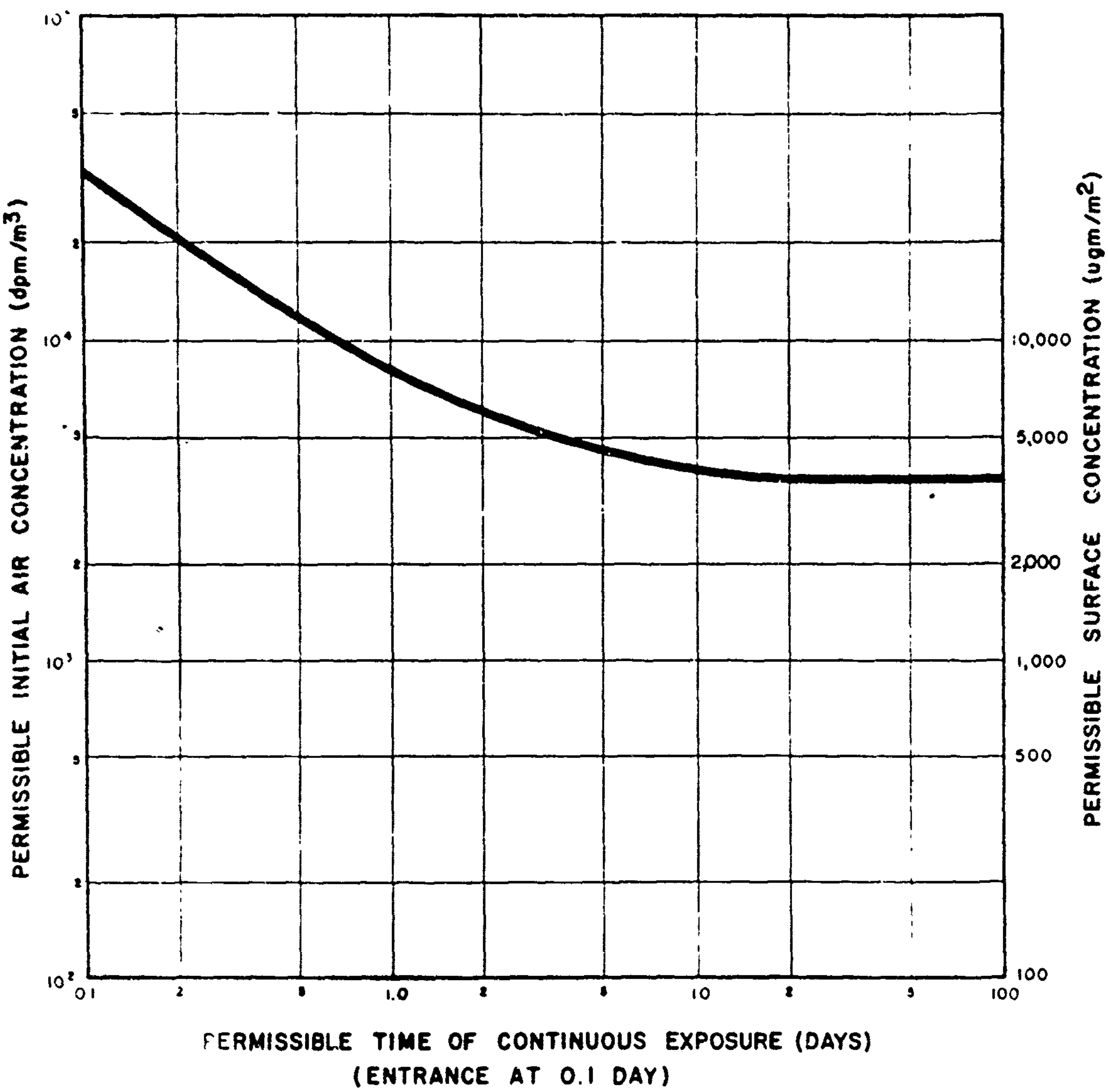

Fig. 7.10—Occupancy required to produce MPL (lung) in man.

TABLE 7.1—TIME OF PERMISSIBLE OCCUPANCY

Ground concentration ($\mu gm/m^2$)	Area (mi^2)	Time of occupancy
100	0.27	Lifetime
350	0.042	Lifetime
400	0.035	Lifetime
500	0.025	Lifetime
1000	0.009	Lifetime
3500	0.0014	Lifetime
4000	0.0012	8 Days
5000	.0.00084	3.6 Days

7.4 SURFACE MONITORING AS A FUNCTION OF TIME

Surface alpha monitoring was conducted throughout the Program 73 array from D-day to D+26. Initial count rates within the array ranged from 15,000 cpm to more than 100,000 cpm on horizontal surfaces. By comparison, pads placed in a vertical position were, in general, contaminated less by a factor of 100. Repeated surveys at selected points indicated a decrease in survey readings with time; the magnitude of decrease was a function of the type of surface involved. If surfaces are divided into three groups—smooth, rough or porous, and soil—the "apparent" surface contamination level on smooth materials such as glass, plate steel, etc., decreased by a factor of 10 by D+7 and of 100 by D+24. Rough surfaces decreased by only a factor of 2 by D+7 and of 5 by D+24. Soil monitored was down by a factor of 15 by D+7 and of a factor of 40 by D+24. The word "apparent" is used here to describe a reduction in the contamination level as determined by surface monitoring. Degradations may have been caused by removal by wind or rain or simply by the addition of material (dust) which increased self-shielding. Certainly, plutonium, with a 24,000-year half life, has not sensibly decayed. This and corroborative evidence furnished by Program 74 appears as Figure 7.11.

7.5 AIR CONCENTRATIONS DOWNWIND FROM A RESUSPENSION

To determine air concentration as a function of distance downwind (wind <5 knots) from a resuspension activity (dust raised by vehicles), Staplex air samplers were located at 50-foot intervals for a total distance of 200 feet downwind. Levels of airborne concentration decreased very rapidly. At 200 feet, the measurements were 1/2,000 of those recorded adjacent to resuspension activities. Decrease in air concentration with distance is plotted in Figure 7.12.

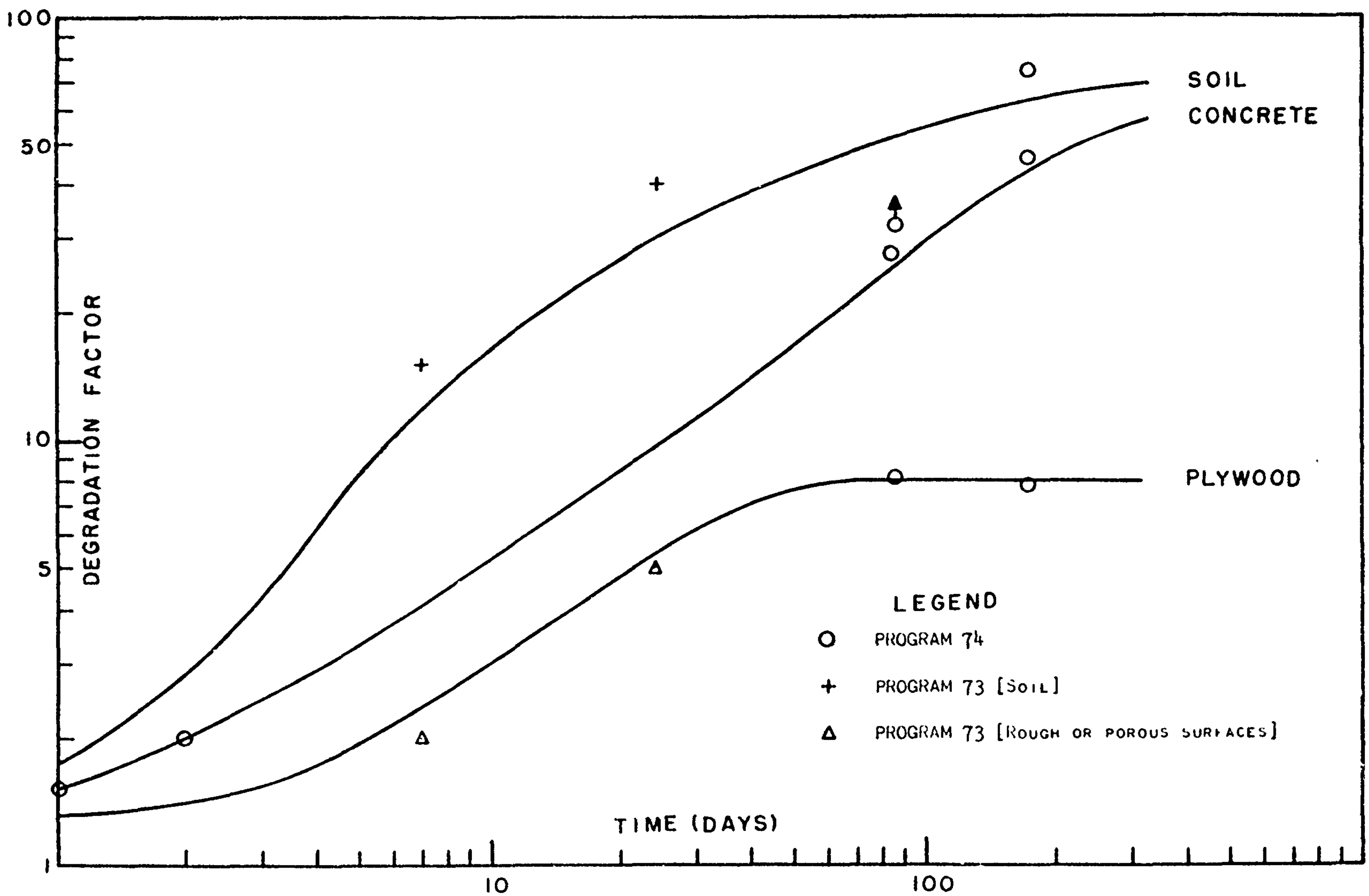

Fig. 7.11—Activity degradations apparent to alpha survey instruments.

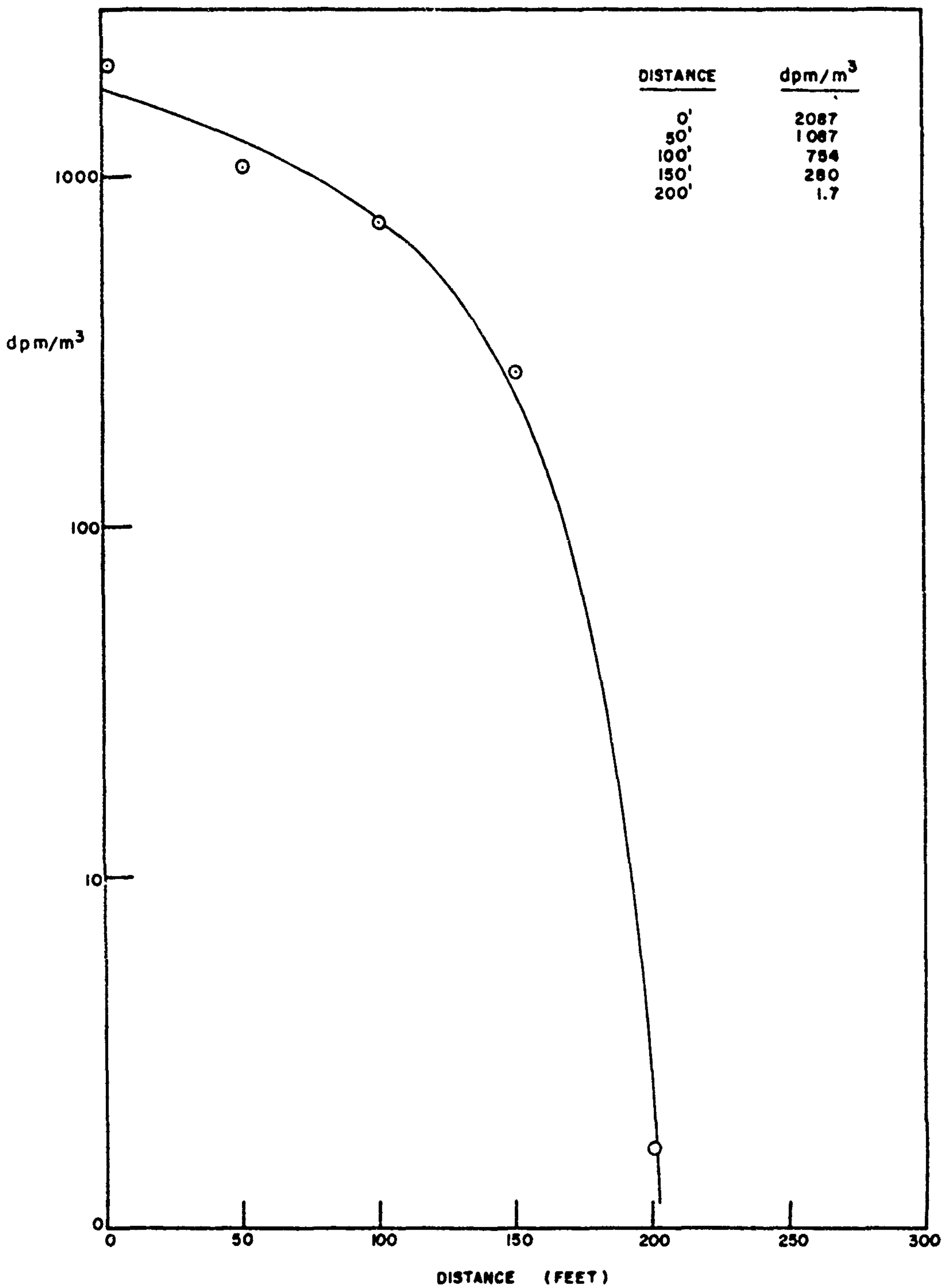

Fig. 7.12—Air concentration downwind from a resuspension activity.

7.6 ANIMAL UPTAKE OF PLUTONIUM

7.6.1 Acute Exposures

Table 7.2 gives results of radiochemical analysis in terms of dpm per tissue for all animals placed in the field before the shot (500, 1,000, and 2,000 feet from GZ). Results are included for dogs who lived through not only the acute phase of exposure but part of the chronic phase as well. One microgram of plutonium produces 140,000 dpm, and the maximum permissible level per whole lung in man is 0.02 microcurie or about 45,000 dpm. Obviously, one also needs to know the factor which relates dog to man. This is estimated by University of Rochester personnel as 3; i.e., all entries should be multiplied by 3 before comparing tissue burdens with maximum permissible levels for man.*

7.6.2 Chronic Exposures

The results of tissue assays for animals given chronic exposure only are shown in Tables 7.3 and 7.4. Attention is usually first directed to data for the lungs of the various animals, since the lung is a retention center for material likely to do eventual biological damage. It is natural to look for the maximum value, scale to man, and compare the outcome with the whole-lung MPL. The highest uptake was 908 dpm in the lung of a dog on the 1,000-foot line (acute exposure). For man this means approximately 3,000 dpm. From Figure 7.5, the environment of the 908-dpm dog as recorded by nearby air sampler uptake (medium and small particle sum) was about 0.45 μgm of plutonium, or 63,000 dpm. Thus, one concludes that a man would have received only 1/5 of his expected uptake.[2] Of course, the location of the 908-dpm dog was not the site of the maximum air concentration. Figures 7.5 and 7.6 indicate that the highest air sample for the acute-exposure period was about 0.9 μgm at a 5,000-foot station. At this location, a man, by simplest reasoning, would have accumulated a lung burden of 2 x 3,000 dpm, or about 13 percent of the MPL for the lung.

Actually the whole-lung result is not definitive by itself, because particles captured in the upper respiratory region clear by ciliary action, with a half life of several days. Particles attaining the deeper recesses and the alveolar chambers have an estimated clearing rate (phagocytosis) of 180 to 365 days. To this point, most researchers in the field agree. They disagree on how blood or systemic burdens can arise from inhaled insoluble particulates. Handbook 52 (U.S. radiological standards) implies it cannot happen. In University of Rocheste animal inhalation experiments with 1-micron uranium oxide, only trace amounts (<0.01 percen transferred to liver, spleen, or bone. LASL Report No. 2079 asserts that 10 of 25 particles (1-to-3-micron range†) reaching alveolar surfaces pass through the alveolar walls into the blood stream. The conflict among these opinions is strong.

There must be heavy reliance upon particulate size. Chemical solubility rates are dependent upon surface area/unit mass. Too, a ticulates decrease in size, permeability of membranes must increase. Some current expei. ientation at the University of Rochester with 0.1-micron plutonium oxide may bring some understanding of the alveolar wall to blood transfer and its dependence upon particulate dimensions. This or some alternate mechanism surely exists, for TG 57 animals developed contaminated liver and bone tissues.

*Factors relating man to burro, sheep, and rat should be used with less confidence. They are, respectively, 0.4, 2, and 200. Animal tissue burden times the factor gives approximate corresponding tissue content in man.

†Verbal information from W. H. Langham, LASL.

TABLE 7.2—TISSUE ASSAYS FOR ANIMALS EXPOSED TO THE CLOUD

Dogs

Time of sacrifice	Distance north of GZ(ft)	Location*	Radioactivity (dpm) Spleen	GI Tract	Liver	Hilar LN	Med. LN	Lung	Trachea	Nas. Muc.	Femur	Rib
H+4	500	600 W	9	8725		2.7	1.5	64		3.6	8	3
H+4		600 E	92	13750	27	0	4	129		1.4	69	1
D+2		200 W	0	108658	0	1	0.5	48	25	9.3	0.3	0.3
D+2		200 E		0	107	1.8	2	0	4.8	177	10	3
D+9		600 W	0	1184	8	0.8		77	0.4	8.6	9.5	2.5
D+11		200 W	0	2076	6	0.39	0.7	46	0	1	6	3
D+12		200 E	4	2742	1	4	28	47	4	0.5		0
D+21		600 E	0			0.35	1.0	1.4		0.7	0.3	2.5
H+4	1,000	0	0	72109	2.6	0.8	7	170	3	1.7	1	0
D+2		0	0	89953	0	0.7	1.5	908	424	22	0.3	3
D+13		600 E	0	4210	14	0.5	1	20	0.7	0	3.6	2
D+21		600 W	0.35			0	6.7	0		13	2.1	
H+4	2,000	800 W	0	45976	3	3.5	0	41	0.7	33	1	1.3
H+4		800 W	8.8	8950	7	0	0.4	35	0.9	0	1.6	2
H+4		800 E	1.5	79291	0.7	2	0.8	134	6	1.7	0	
H+4		0	0		2.6			34	0.5	2.3	0	2.5
H+4		800 E		91812	2	4	1	27	0.9	82	1.4	0.5
D+2		0		50161	10.5	2.7	4	207	3	90	3	3
D+8		400 E	3	15017	1797		1	475	67	70	25.1	1.3
D+13		400 W	2.3	844	0	0.8	8	155	0.7	0	2	0.8
D+36		400 W	0	16380	3.8	0		68	2.6	1.4	1.5	
D+36		400 E	0	286	2.4	2	0.3	277	0	0	0	0

*Location with respect to north-south centerline of test field; thus, 600 W is 600 ft west of centerline, etc. See Table 3.1.

Rats
(all sacrificed at H+2 to H+4 hours)

Distance from GZ	Location	dpm per lung Rat 1	Rat 2	Rat 3	Rat 4
500 ft	FW	0	48	1.1	13
	NW	14	0	1.5	0
	NE	45	7.4	0.8	0.4
	FE	0	-	21	1.5
1,000 ft	C	0	0	2	4.5
2,000 ft	FW	0	2	3	388
	C	0	5	36	0
	FE	2	0		

TABLE 7.3—TISSUE ASSAYS FOR ANIMALS PLACED POSTSHOT

Time of sacrifice	Grid location	Radioactivity (dpm) Spleen	GI tract	Liver	Hilar LN	Med. LN	Lung	Trachea	Nas. Muc.	Femur	Rib
Dogs on 10-µg line											
P+4	54-48			0.4	0	2	27	0	0.5	4.6	0.8
P+4	56-45	0	348	0	0	0.4	0(sp)*	1	0.4	5	2
P+8	56-45	0	748	3.7	2	1	2.5	0.9	0	6.8	0.9
P+8	52-51	1.5	112	2	0.8	1.5	19	1.1	2.0	2	3
P+16	52-51	0.4	352		0	2	5(sp)*	0	2	2	0.4
P+16	54-48	1.4	5.0	123	4.5	0.2	0.5	1.8	0.5	17	0.7
P+32	56-45	0.7	1088	4.8	0.3	1.0	2.4	0.3	0	19.4	0.7
P+32	52-51	0	0	1.8	6.7	405	0	16	0	174	
P+64	56-45	0	44(sp)*	0.4	12	0	34	0	18	5.7	15
P+64	52-51	0	653	1.2	0.36	0	763	2	0	2	0
P+96	52-51	0	229	5.7	4.2	23	3.1	0.5	0	2.3	6.9
P+96	56-45	1.8	36	3.9	1.6	0.2	2.5	2.1	0.9	0.5	0.8
P+128	52-51		426		2	4	14	0.7	0.9	6	0.8
P+128	56-45	0	37	0		1	0	0	1	0	0.4
P+160	54-48	0	159	3		0.8	0	0.4	3.5	2	1.4
P+160	52-51	2	16	0	2	1	0	0		4.4	1.4
P+160	56-45	5	14	0.7		2	33	0	4.4	2	
P+160	54-48	0	63	0.7	0.8	1	0.7	0	0.5	37	0.7
Dogs on 100-µg line											
P+4	33-41	1.1	485(sp)*	11	0	1	0	1	0.8	0.8	5
P+4	31-42		2523	5.0	0	0.8	10(sp)*	0	0	1.1	0.5
P+8	35-39	3		1.7	0	2.6	1.1	0.5	0.5	4.3	1
P+8	35-39	3	1100	0	2	2.6	1.6	3.4	0.7	0.7	8
P+16	33-41		352	2	2	0.8	5.5	0.4	4	10	2
P+16	33-41	0	238			10.6		3.2	0	0.7	0
P+32	31-42	42	623	24	20	28	0	19	23	31	61
P+32	35-39		1909	1.5	6	2	0	0.7	3	0.4	
P+64	35-39	0		3.5		5	6	11	2	3	2
P+64	35-39			0.4	0	0	0.4	3.2	1.0	1.2	241
P+96	33-41	0.5	Lost	Lost	1.8	1.8	1.1	1.1	1.4	2.3	1.4
P+96	33-41	2	164	0.2	4.3	0.7	1.6	1.8	0.7	0	6.4
P+128	35-39	0.7		0	0.8	3	18	0.7	5	4	0.8
P+128	33-41	0.7		1	0.8	4	2		4	42	1.3
P+160	35-39	0	496	2	0.8	1.5	35	0	1	1.3	2
P+160	31-42	1.1	74	2.6	0	2	0	6	2	2	1.5
P+160	31-42	0	2583	1	4		10.7	2	0	2.6	0
P+160	31-42	0	1066	4.5	7		15	0	13		1
Dogs on 1,000-µg line											
P+4	27-35		13198	5	0.8	1.5	22	10	1	1	1.4
P+4	26-36	3.0	Lost	Lost		0.7	30	0	0.7	3	0
P+8	27-36	0	54545	20		0.7	57	3.8	1.6	4	1
P+8	26-36	1.1	16757	1.5	0.8	3	57	2	1.4	2	45
P+16	27-35	121		0.7	0.7	0		19.9	0	1.0	0.3
P+16	26-36	0.85	6862	2	0	2.6	27.7	5	0.5	0	7.8
P+32	26-36	0	2660	3.5	2.1	2	1.6	14	4.2	2	2
P+32	27-35	0.7	Lost	5.7	3.2	8.9	45	0	0	7.5	0.9
P+64	27-36	0	21301	0	4	1	51	0	0.4	[illegible]	3
P+64	27-35	1.6	3.7	0	5.4	0		0	4.4	1.7	1.4
P+96	27-35	0	3.0	0	1.4	2	36	0	0.2	3.0	1.8
P+96	27-35	0	Lost	30900	0.2	0		2.7	0.9	3.7	1.8
P+128	27-36	0	2475		0.4	0.8	61	3	0	0.7	3
P+128	26-36	0		2.6	1	0	29	0.4	0.4	2	3
P+160	26-36	0	818	4.5	1.6		35.5	0.7	1	3.5	
P+160	27-36	0	1314	2		5	99	0	1.4	1	2.5
P+160	27-36	26	1347	3.7	0.8	2	21	0	0.4	3.5	2
P+160	26-36	0	326	9	0	5	173	2	1.4	2	0

Time of sacrifice	Grid location	Radioactivity (dpm) Lung	Hilar LN	Rib	Fetus
Burros on 10-µg line					
P+160	54-48	2	1.7	3	
P+160	54-48	7.7	0.8	9	
P+160	54-48	46	21	19	
Burros on 100-µg line					
P+160	33-41	15	3	0.8	
P+160	33-41	9	1.4	7	
P+160	33-41	6	1	18	5
Burros on 1,000-µg line					
P+160	27-36	25	1	3.8	1
P+160	27-36	158	1.6	2.6	
P+160	27-36	33	3	6	2.6

*(sp) = Chemical spill and likely compromise of the result.

TABLE 7.4—TISSUE ASSAYS FOR LATE-CHRONIC ANIMALS

Animals Placed at P+32 and Sacrificed at P+160

Animal	Nominal isolevel line	Lung	Radioactivity (dpm) Hilar LN	Rib
Sheep	1,000 μg	30	17	9
Sheep		37	1.7	-
Sheep		34	2.5	1
Sheep	100 μg	7	2.4	2
Sheep		8	3	0.8
Sheep		7	3.5	1
Dog		0	2	2.5
Dog		1.8	3.5	0.9
Dog		0	0	3.5
Dog		1.1	1	2
Sheep	10 μg	1	3	6
Sheep		0 (sp)*	3	4.5
Sheep		10	0	7

*(sp) = Chemical spill and likely compromise of the result.

Apparently following initial blood uptake, most of the insoluble particulate is filtered out principally in the liver where it resides until trace solubility allows gradual assimilation by the bone. Unlike the case of alveolar contamination, no natural body process appears to recognize plutonium in the bone as unwanted; it is permanently retained so far as is known. Even in the face of concerted attempts to perturb body chemistry and selectively induce plutonium excretion, bone-borne plutonium has stayed in place. Thus, a high lung assay without high liver and bone assays for the same animal leads one to suspect upper respiratory or larger particulate retention and a much smaller hazard. The 908-dpm dog had a 424-dpm trachea, a zero liver, and only trace bone contamination. Contrast this with the dog removed on D+8 from the 400E, 2,000-foot station. His lung showed only 475 dpm, but the liver showed 1,797 dpm, femur 25.1 dpm, and the trachea only 67 dpm. This spells a much more serious situation. This line of argument merely seeks to emphasize the need for caution and understanding when interpretation of animal data is attempted.

In rat data in Table 7.2, the greatest impact is produced by one lung datum, 388 dpm, and the realization that 200 is the scale factor to man. Again, the obvious may not be the answer. Unfortunately, the additional tissue analyses required to define the impounding lung site better were not made. Many rat organs are so small that like specimens of 10 or more animals are often combined for a single analysis. If this is not done, the resolution of radiochemistry makes data unreliable.

7.6.3 Animal Data Summary

The fund of data from all tissue assays is overwhelming unless it is carefully and slowly studied. In an effort to simplify by summarization, Table 7.5 was prepared. Median values for dog and burro tissues and reduction to irradiation per unit-tissue-mass greatly narrow considerations, since the standard of 0.3 rem per week puts the same criterion on all results. An assumption of 10 for the relative biological effectiveness (RBE) sets the MPL for all entries at 34.6 dpm/gm.

Most interesting in Table 7.5 is the clear and orderly, nonlinear, decrease in median lung burden with ground concentration, while the long-bone deposition tendency is exactly opposite. First implications are obvious, but so many parameters enter that all conclusions must be critically and repeatedly reweighed.

TABLE 7.5—SUMMARY OF MEDIAN VALUES REDUCED TO IRRADIATIONS PER UNIT TISSUE MASS

Dogs

Exposure condition	GI tract	Hilar LN	Med. LN	Lung	Femur
Acute	25.05	2.05	3.45	0.71	0.046
1,000 μg	4.51	2.05	6.90	0.45	0.057
100 μg	1.14	3.33	6.90	0.020	0.057
10 μg	0.25	3.08	3.45	0.031	0.13

Burros

Exposure condition	Lung	Hilar LN	Rib
1,000 μg	0.15	0.62	0.083
100 μg	0.032	0.50	0.15
10 μg	0.02	0.65	0.18

Radioactivity in disintegrations per minute per gram of wet tissue
(All values expressed as medians)

7.7 DECONTAMINATION TRIALS

7.7.1 General Results for 2-x-2-Foot and 10-x-10-Foot Pads

Results of pad decontamination are given in Table 7.6. The effectiveness of decontamination is a function of cleaning technique rather than type of surface. For example, a method that was equal or superior to other methods on one type of surface ranked equally well on other surfaces. Therefore, methods may be ranked by average percent of effectiveness, as in Table 7.7.

7.7.2 Decontamination of 24-x-50-Foot Pads

The large pads of highway asphalt and wood-float-finish concrete were decontaminated on D+23 by water-detergent hosing. Hosing was started at one end and progressed along the length of the pad. Subsequent monitoring revealed no trend toward build-up of contamination

TABLE 7.6—HARD-SURFACE DECONTAMINATION EFFICIENCIES
(percent)

Material	Vacuum (D+2)	High-pressure water (D+3)	High-pressure water with scrub (D+12)	High-pressure water and detergent (D+4)	High-pressure water and detergent with scrub (D+5)	Sandblasting (D+9)	Steam cleaning (D+14)
Glass	98.95	98.85	97.79	100.00	99.76	100.00	97.86
Stucco	48.00	97.94	95.22	100.00	99.59	100.00	27.00
Painted wood	99.[illegible]3	98.43	96.77	99.69	99.97	100.00	91.61
Unpainted wood	36.00	85.00	93.18	99.54	95.54	99.90	85.00
Aluminum	89.00	99.45	97.33	99.62	100.00	98.49	84.00
Plate steel	93.04	97.26	94.19	100.00	98.83	99.72	91.46
Asbestos shingles	61.00	99.97	98.91	96.89	99.36	100.00	63.00
Unpainted wood shingles	61.00	97.16	90.49	95.01	97.93	99.82	71.00
Brick	29.00	99.46	99.32	99.14	99.56	99.92	97.50
Tar paper	55.00	98.66	95.04	>95.32	96.83	99.51	52.00
Corrugated galvanized roofing	89.00	99.36	97.19	99.73	99.86	100.00	85.00
Highway asphalt	32.00	99.90	96.25	>99.82	99.48	99.90	44.00
Highway asphalt (10 x 10 ft)	72.00	92.45	94.95	98.85	96.34	92.73	22.00
Sealed asphalt	71.00	98.67	90.00	100.00	99.72	99.61	84.00
Sealed asphalt (10 x 10 ft)	64.00	90.00	82.00	96.31	97.54	>90.42	48.00
Steel trowel concrete	74.00	98.94	-	96.91	99.53	100.00	
Steel trowel concrete (10 x 10 ft)	-	78.00	97.34	-	98.58	98.96	27.0[illegible]
Wood float concrete	-	>98.00	92.03	100.00	97.47	100.00	65.[illegible]
Wood float concrete (10 x 10 ft)	56.00	97.84	-	98.09	>98.28	98.78	85.[illegible]
Average of all surfaces	66.40	96.12	94.59	98.61	98.64	98.83	67.[illegible]

TABLE 7.7—EFFECTIVENESS OF VARIOUS DECONTAMINATION METHODS

Method	Effectiveness (percent)
Sandblasting	98.83
Water-detergent scrubbing	98.64
Water-detergent hosing	98.61
Water hosing	96.12
Water scrubbing	94.59
Steam cleaning	67.80
Vacuum	66.40

at the far end. The effectiveness of this method for the two surfaces tried is shown in Table 7.8. Because of the rain which fell before decontamination, the listed efficiencies are lower than would be expected from fresh contaminants.

TABLE 7.8—DECONTAMINATION OF 24-x-50-FT PADS

	Average initial dpm/m^3	Average final dpm/m^3	Efficiency (percent)
Highway asphalt	87.8	3.9	95.6
Wood float concrete	43.8	6.1	86.1

7.7.3 Decontamination or Fixation of Land Areas

The one temporary measure tried, spraying with USAF fire foam, worked well as a temporary fixing agent, but its usefulness was exhausted within an hour because high desert temperatures produced rapid evaporation of the foam. During the period of its usefulness, however, air concentrations produced by resuspension action were reduced from 44,234 dpm/m^2 to 2,208 dpm/m^2 for a 95 percent efficiency.

7.7.4 Permanent Measures

The efficiencies of the various land-fixation or decontamination methods tried are listed in Table 7.9. Since the methods rated in the table have been previously described and heading make the entries self-explanatory, no further comment is necessary except to state that plowing or scraping is an effective method of removing contamination from the surface and that the method chosen depends largely on availability of equipment. There is one inconsistency apparent when the effects of leaching with 0.3 inch of water and with the water-Alconox solution are compared. The latter should be at least as effective as plain water. The reason for its lesser effect is probably the result of its use on a plot of ground which had previously been scraped and allowed to weather for a month. A tough top layer, which was apparently formed, probably hindered penetration of the solution into the soil.

TABLE 7.9—PERMANENT LAND DECONTAMINATION EFFICIENCIES

	Mean initial dpm/m^3	Mean final dpm/m^3	Decon factor	Efficienc (percent)
Plowing	8,193	141	58.1	98.3
Oiling and scraping	4,221	78	54.1	98.2
Scraping	581	25	23.2	95.6
0.3-inch water-leaching and scraping	1,400	95	14.7	93.2
Oiling (RC-O road oil)	1,045	109	9.59	89.0
1.0-inch water-leaching	1,598	227	7.04	85.0
0.3-inch water-$FeCl_3$-leaching	4,020	631	6.37	84.0
Disking	3,050	732	4.17	76.0
0.3-inch water-leaching	13,210	8,832	1.5	33.0
0.3-inch water-Alconox-leaching	357	347	1.03	3.0

7.7.5 Decontamination of Equipment

In any decontamination done in an actual accident situation, attention must be given to reclamation of vehicles from the contaminated area. In TG 57, it was found that vehicles driven daily in heavily contaminated portions of the test area were simply and easily decontaminated by water hosing. In fact, one thorough washing appeared to be sufficient. One notable exception was the road-oil-distributing truck, on which contamination was imbedded in spots of road oil. Although in this fixed condition no hazard was apparent, considerable time and effort were expended to remove it by scrubbing and steam cleaning. One additional caution in decontaminating motor vehicles should be stated: All engine air cleaners should be decontaminated or replaced, since they accumulate a large amount of contamination by the very nature of their operation.

Miscellaneous pieces of equipment—such as air samplers, survey instruments, and wind measuring equipment—were readily decontaminated either by washing with water and detergent or by vacuuming.

7.8 CONTROVERSY OF GROUND CONCENTRATIONS

As mentioned previously, normalization of alpha survey readings is a step basic to any use of an alpha instrument. Further, in field work where no surface is ideal, conversion factors are moot. Such was the case when Programs 73 and 74 compared results. The disagreement as to instrument reading interpretation was made firmer by chemical analysis of about 100 soil samples taken by Program 73. These soil data corroborated the Program 73 translations of meter cpm to ground concentrations, while Program 74 readings were normalized to the sticky-pan analysis. The variances are defined in terms of areas within major contours by Table 7.10.

TABLE 7.10—AREAS WITHIN GROUND CONCENTRATION CONTOURS

GROUND CONCENTRATION $\mu gm/m^2$	REPORTED AREAS (mi^2)		
	Sticky pans (Program 71)	Meter survey and shallow soil samples (Program 73)	Meter survey and sticky pans (Program 74)
1000	0.03	0.01	0.035
100	0.46	0.27	0.51
10	2.30		3.00

A few soil data just received by Program 71 corroborate sticky-pan data reasonably well (Table 7.11). But the discrepancy still remains! Perhaps anniversary measurements where the Program 71 technique was also employed by Program 73 for its 1-year soil sample will help to resolve existing differences.

TABLE 7.11—Earliest Program 71 Soil Sample Data

Ground Concentration in $\mu gm/m^2$ for Data Indicated

Location	Depth*	May 4, 1957				June 25, 1957				July 25, 1957				Oct 19, 1957			
		A	B	C	Avg	A	B	C	Avg	A	B	C	Avg	A	B	C	Avg
45-24	1	0.961				3.49	3.10	4.56	3.72					4.84	3.26	3.71	3.94
	2					1.24	0.734	0.461	0.812					1.06	1.33	1.74	1.38
29-31	1	35.6	44.6			120.5	117.5	191.7	143.2	71.4	40.0	159.7	90.4	29.9	93.6	123.2	82.2
	2					57.5	35.0	15.9	36.1		39.7	18.6	29.1	70.1	10.3	13.6	31.3
26-44	1	510.6				626.3		748.6	687.4	1214.2	86.2	759.8	693.4	999.0	1122.0	60.8	727.2
	2					80.0		62.0		185.5	9.36	92.1	95.7	36.6	143.9	825.4	87.7
33-28	1					34.5	28.3			51.6	40.1	48.0	46.6	53.3	38.0	4.13	31.8
	2					3.11	4.38			1.63	9.27	1.89	4.26	4.56	5.92	3.21	4.56
39-27	1	71.5	29.8	9.73	37.0	11.1	9.36	280.9	100.5	7.07	4.09	2.69	4.62	14.5	1.36	7.68	11.9
	2					1.98	2.63	3.77	2.79		2.52	1.42		1.76	1.75	1.98	1.83
45-27	1									1.40	3.81	4.85	3.35				
	2									1.39	0.746	0.978	1.04				
32-28	1							58.0									
	2							2.03									
67-27	1					2.22	2.78	2.50	2.50		1.24	2.23					
	2					1.98	1.00	1.84	1.61		0.509	1.08					
57-27	1									1.42							
	2									2.37							

* 1 = Top 1/4 inch, 2 = second 1/4 inch

NOTE: A, B, and C are separate samples from same location

7.9 PLUTONIUM IN SOIL VERSUS TIME

Although Table 7.11 data are a very recent acquisition and there are too few to permit definite conclusions, several features deserve mention.

1. There are few instances of plutonium depletion with time.
2. There is little tendency for the plutonium to change position (depth) in soil with time.

REFERENCES

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2. U.S. Department of Commerce, National Bureau of Standards, Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water, Handbook 52, March 20, 1953. British Journal of Radiology, published by the British Institute of Radiology, Recommendation of International Commission on Radiological Protection, December 1, 1954.
3. P. S. Harris and others, Contamination Hazard From Accidental Non-Critical Detonation of Small Atomic Devices, Los Alamos Scientific Laboratory, LA-2079, September 1956.

Chapter 8

CONCLUSIONS

8.1 PLUTONIUM ON THE GROUND

Isoconcentration contours have been inferred both from partially complete sticky-pan analyses and alpha survey instruments. The sticky-pan contours are good enough for planning against accident situations. The discrepancy that exists between soil-sample assays done by Columbia University for Program 73 and the sticky-pan analyses of Program 71 must be resolved, either by relating the chemical procedures employed by the separate analytical groups or by explaining differences in terms of the two methods of sampling. From cross checks already performed, the difference in soil sampling techniques is the more suspect.

It must be emphasized that wind structure is the important factor. The contours reported here obviously manifest fallout from a burst on the ground and in the open, in a specific type of soil. Success, informationwise, can be claimed for the basic experiment only when data interpretation can lead to the inference of a fallout model that will permit computation of plutonium distribution for any chosen or experienced wind situation. Although a preliminary fallout model has been constructed, a more detailed one is still in process. Upon its completion, a range of wind conditions will be computed and reported.

8.2 PLUTONIUM IN THE AIR

8.2.1 During Fallout

While much information on air concentration—undefined by previous experiments, such as Project 56—has resulted from the TG 57 investigation, the actual maximum air concentration existing for the TG 57 shot conditions was not determined. Guesses from the fragmentary data of Project 56 led TG 57 planners to believe that the 5,000-foot array of air samplers would be situated well beyond maximum air concentration levels. This may or may not have been the case. All that can be said is that the maximum air concentration measured was at a 5,000-foot station. It is important to note, however, that at this 5,000-foot distance the width of the area over which higher concentrations could be expected was rapidly disappearing, and only a narrow spikelike area could have received significant air concentration beyond 5,000 feet. While samplers were in the field beyond this distance, their spacing was such as to miss the hot line.

8.2.2 Plutonium Resuspended

Although the Program 73 evaluation of the resuspension of plutonium by natural forces and the resulting hazard to man is a severe extrapolation, it is nonetheless interesting. When considered against the less-than-expected (from the lung model) animal uptake, their calculational safety factors of calling 75 percent of gross air samples respirable, and the assumption of continuous exposure, it is likely that the uncertainties will add in the conservative direction. If to these considerations, one adds a requirement of decontamination to the 1,000-μgm/m^2 line at the site of any weapon accident, safety criteria based on the Program 73 computation become more reasonable. Certainly, all the factors of wind, moisture, directional sensitivity of samplers, etc., must be studied in detail before such answers can be confidently supported.

8.3 PLUTONIUM IN THE DOGS

A sweeping consideration of dog-tissue burdens of plutonium leads one to conclude that exposure is more hazardous than long-term exposure in a dusty desert area such as . This conclusion, however, stands short of real defense in that air samples taken during the entire chronic exposure have not been measured as yet, nor have wind velocities versus time been reduced to interpretable form. The chronic dog stations were chosen to lie along a southwest wind line; i.e., they were situated at a bearing of some 30 degrees with respect to GZ, since it was believed that most probable winds were southwesterly. If, for the specific period of exposure, this assumption were incorrect, there may well have been other positions in the field at which larger inhaled quantities of plutonium could have resulted.

The lung model now used for computing inhalation hazards can be critically evaluated by the rather extensive dog data that have accrued. It is believed that the combination of Casella cascade impactor sampling (with its particle-size discrimination) and animal uptake will allow more detailed lung-model evaluation than was originally hoped.

Then, too, the 24 dogs being held for the 2-year period should enlarge understanding of clearance mechanisms or biological recovery processes. Unfortunately, starting tissue burdens are so low in these animals that levels 2 years hence may be too low to permit resolution of difference. On the other hand, build-up within any tissue, especially lymph nodes, should be easily detected.

Finally, if the extensive endeavors in autoradiography are fruitful, some evidence as to intratissue preferences by plutonium can result.

8.4 PLUTONIUM REMOVAL AND FIXATION

Natural influence caused rather rapid "apparent" decreases in contamination levels. Repeated surface monitoring indicated that smooth surfaces dropped by a factor of 10 by D+7 and of 100 by D+24. Rough or porous surfaces decreased by a factor of 2 by D+7 and of 5 by D+24. Soil decreased by a factor of 15 by D+7 and of 40 by D+24.

Air-sampling stations 500 feet north of GZ indicated, on the average, a concentration of the order of 35,000 dpm/m^3 for the 3-hour period immediately following the detonation. Succeeding air samples show airborne contaminants down by as much as a factor of 100 by H+7.

General efficiencies in percent for pad decontamination are as follows: sand blasting - 98.8; water-detergent scrubbing - 98.6; water-detergent hosing - 98.6; water hosing - 96.1; water scrubbing 94.6; steam cleaning - 68; and vacuuming - 66.

General efficiencies in percent for large-area earth decontamination or fixation are as follows: plowing - 98.3; oiling and scraping - 98.2; scraping 95.6; leaching with 0.3 inch of water and scraping - 93.2; oiling (CRG-O road oil) - 89; leaching with 1 inch of water - 85; leaching with 0.3 inch of water $FeCl_3$ solution - 33; and leaching with 0.3 inch of water Alconox solution - 3.

As a temporary measure, covering the area with fire-fighting foam was found to be 95 percent efficient for a period of 1 hour or less.

8.5 OTHER DATA

Many data are now in hand. Still more will become available in the next 4 months. Some classes of data are completely absent. No diffusion-tray results have been reported. Few soil samples from Programs 71 and 73 are available.

Attempts have been made to cite gross conclusions indicated by data available. Consideration of all data by each of the programs separately, interrelation of the work of the programs into a complete entity, plus refinement of the fallout model, should provide an excellent assessment of plutonium contamination from an accidental detonation.

8.6 A NEW PROGRAM

The idea of an entirely separate program on ecology in Area 13 had occurred to many in the summer of 1957, but the AEP/UCLA logical group to undertake the investigation was too committed on Operation Plumbbob to consider undertaking the responsibility. Recently, a full study has been detailed by the Environmental Radiation Division of AEP/UCLA. Field work should start about mid-June and continue thereafter for 4 to 6 weeks. Included will be:

1. Five to seven animal-trapping locations (Program 72 dog sites, GZ, and out along hot line to 10 or 20 miles).
2. Vegetation sampling adjacent to animal-trapping locations.
3. Radiochemical assays of lung, liver, whole skeleton, GI tract contents, and possibly blood will be done on composite samples taken from a minimum of 10 animals.
4. At each animal-trapping site, Hi-vol air sampling, soil sampling, and ground level fallout collection will be done. Further, particulate size will be measured on collected fallout material.

Finally, Dr. Kermit Larson agreed to exploit an idea which grew out of discussions among participants in the anniversary measurements—earthworms. Compton's Encyclopedia reports that the renowned Charles Darwin studied an acre of garden in which he claimed 53,000 hard-working earthworms moved 18 tons of soil. Translocation of soil, the possibility that earthworm body chemistry may vary plutonium form, etc., could turn out to be significant influences, intentional or unintentional, in the rehabilitation of a weapon-accident environment.