WT-373 (EX)

EXTRACTED VERSION

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OPERATION JANGLE

Radiochemical Measurements and Sampling Techniques

Armed Forces Special Weapons Project
Washington, D.C.

18 June 1952

Nevada Proving Grounds
October—November 1951

DTL-80/1155

NOTICE

This is an extract of WT-373, Operation JANGLE, "Radiochemical Measurements and Sampling Techniques," which remains classified Confidential as of this date.

Extract version prepared for:
Director
DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

1 October 1979

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HRE-0806

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER WT-373 (EX)	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Operation JANGLE - Radiochemical Measurements and Sampling Techniques - Projects 2.6c-1, 2.6c-2, 2.6c-3 and 2.6a	5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER WT-373 (EX)
7. AUTHOR(s) Charles R. Maxwell et al	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Armed Forces Special Weapons Project Washington, D. C.	10. PROGRAM ELEMENT PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE 18 June 1952 13. NUMBER OF PAGES 263
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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

Operation JANGLE
Nuclear Atmospheric Test
Desert Rock
Residual Radioactivity
Gross Gamma Decay
Gross Beta Decay
Chemical Characteristics
Radiochemical Analysis
Neptumium

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

Chemical analyses of surface soil samples, fallout samples ground air filter samples, and high-air filter samples show definitely that the composition of residual fission products varies greatly with the place and mode of sampling.

This is a consolidation of material in WT-386, Nature and Distribution of Residual Contamination I; WT-397, Nature and Distribution of Residual Contamination II; WT-363, Retrievable Missiles for Remote Ground Sampling; and WT-334, Remotely Controlled Sampling Techniques.

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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.

The material which has been deleted is all currently classified as Restricted Data or Formerly Restricted Data under the provision of the Atomic Energy Act of 1954, (as amended) or is National Security Information.

This report has been reproduced directly from available copies of the original material. The locations from which material has been deleted is generally obvious by the spacings and "holes" in the text. Thus the context of the material deleted identified to assist the reader in the determination of whether the deleted information is germane to his study.

It is the belief of the individuals who have participated in preparing this report by deleting the classified material and of the Defense Nuclear Agency that the report accurately portrays the contents of the original and that the deleted material is of little or no significance to studies into the amounts or types of radiation received by any individuals during the atmospheric nuclear test program.

PROJECT 2.6c-1

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ACKNOWLEDGMENTS

We wish to thank the many persons in the Technical Command for their cooperation and assistance in this investigation. In particular, we wish to acknowledge our indebtedness to:

Dr. W. D. Urry	Air Force Office of Atomic Energy, Washington, D. C.
Dr. L. R. Zumwalt	Tracerlab, Inc., Western Division, San Francisco, California.
Dr. Rod Spence	Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

for their help and advice concerning analytical procedures.

We also appreciate the help of:

Lt. Col. M. B. Forbes	Evans Signal Laboratory, Fort Monmouth, N.J.
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in obtaining samples for analysis.

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ABSTRACT

Chemical analyses of surface soil samples, fall-out samples, ground air filter samples, and high-air filter samples show definitely that the composition of residual fission products varies greatly with the place and mode of sampling. Strontium^{89} and barium^{140} were found to fractionate much more than molydenum^{99}, zirconium^{95} and cerium^{144}.

Gross beta decay curves on surface soil samples are much different from those reported on other operations. This has been interpreted as due to the formation of a relatively large amount of neptumium^{239}. Between fifteen and three hundred hours after the surface shot the beta contribution of neptunium was greater than that of the fission products.

Measurements of gamma decay also show the effect of neptunium. The difference in the observations made with a G-M tube and an ionization chamber indicate the importance of selecting the proper measuring technique.

Analyses of lead and aluminum absorption curves taken as a function of time have been made. These indicate the change in energy and abundance of "effective beta and gamma energies" which describe the observed data.

An estimation of the contribution of induced activity to total activity indicates that the contribution of the induced activity is relatively small.

Experiments on weathering with simulated rain-fall are described. They indicate little transport of residual activity.

The airborne radioactivity at the Nevada Test Site is discussed in Appendix B.

CHAPTER 1

INTRODUCTION

1.1 HISTORICAL

The nature of the residual contamination after an atomic explosion has been found to vary considerably with the physical nature of the test as well as with the nuclear components of the weapon. Measurements made on material from the Almagordo crater exhibited a decay which fell off according to a $t^{-1.2}$ law. At Bikini, measurements indicated that most of the residual contamination following the air burst was due to neutron-induced activity in the sodium of the sea water. In the under water explosion at Bikini most of the activity resulted from fission products and the decay rate followed a $t^{-1.3}$ law.

The general observations above were supplemented and expanded by a specific study[1] made at Eniwetok in 1948. The residual activity from tower shots there exhibited still another picture. The residual activity consisted of various mixtures of fission products, Na^{24} and probably some unidentified activity. The best fit for an equation describing the fission product decay for "X-ray shot" was obtained with $t^{-1.45}$. In all three shots residual activity obtained from the ground and from the air via drone aircraft exhibited different gross decay characteristics. Measurements made on soil samples taken at various distances from ground zero at depths of 2 inches and 4 inches showed considerable activity. The sub-surface activity exhibited the properties of almost pure fission products.

The above study suggested three interesting possibilities, all of practical importance; (1) the presence of an unidentified activity, (2) the possibility of transport of fission products into the ground by rain and (3) the possibility of fractionation of the fission products. The latter is probably the most far reaching in its significance. The interpretation of weapon-performance data and long range detection data will be greatly affected if the composition of fission products is found to vary from sample to sample and to be dependent upon mode, time, and place of sampling as well as upon weapon efficiency[2] and the nuclear components of the weapon.

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[1] H.L. Andrews and R.E. Murphy, "Residual Contamination in the Craters: Operation Sandstone" (January 1949). Restricted data.

[2] R.W. Spence, "Radiochemical Results for Operation Ranger", LA-1242, April 1, 1951. Circulation limited.

1.2 OBJECTIVES

This investigation was undertaken for four reasons:

1. To secure information of theoretical and phenomenological interest along the lines discussed in the Historical Section above.
2. To evaluate the nature and characteristics of the radiation hazard and thus provide information for an estimation of the length of time a given area might be denied to troops.
3. To determine the chemical nature of the residual activity as an aid to the selection of the proper decontamination process if decontamination is desirable.
4. To study the effect of weathering upon the distribution of residual activity.

Specifically, the objectives were to determine:

1. The chemical composition of surface contamination as a function of distance from ground zero.
2. The chemical composition as a function of depth in the crater lip.
3. The chemical composition of air-filter samples.
4. The chemical composition of air samples as a function of particle size.
5. The gross beta and gamma decay of surface samples.
6. The gross beta and gamma effective energies as a function of time.
7. The gross beta and gamma specific activities.
8. The contribution of induced activities.
9. The effect of rainfall upon the distribution of residual activity.

CHAPTER 2

EXPERIMENTAL PROCEDURE

2.1 SAMPLE PROCUREMENT

Soil samples from the surface of the crater lip were secured by Project 2.6a with remotely controlled weasels. Each sample consisted of about two cubic inches of soil scooped from the upper two inches of the crater lip. Wherever possible the location of each scoop was determined by triangulation from the weasel control towers located approximately 90° apart.

Two groups of samples were obtained for each shot. Because of the desire for early samples and the possibility of mechanical failure of the weasels in the loose soil of the lip, the first group of scoops for each shot was taken from a single location.

While attempting to get a pattern of samples from the surface of the crater lip of the surface burst, the second weasel was accidentally directed over the crest of the lip onto a ledge. In order to avoid further mishap with this weasel, the pattern was neglected and all scoops were filled from that portion of the inner surface of the lip.

A pattern of samples from the lip of the crater from the underground burst was taken on D + 1 day.

Samples at various depths within the loose fall-out comprising the crater lips were also obtained by Project 2.6a using weasels. Because of mechanical difficulties and the nature of the crater lip, only one core was obtained for each burst.

For details on surface and core sampling see the report of Project 2.6a "Remotely Controlled Sampling Techniques".

Soil samples for each shot were obtained by retrievable rockets. Only one sample was obtained from the crater of the surface burst and this on D + 3 days after considerable rain. Four samples were retrieved from the crater of the underground burst on D + 2 days.

For details on the retrievable rockets see the report of Project 2.6c, "Retrievable Missiles for Remote Ground Sampling".

Ground air filter samples were supplied by project 2.5a from the Army Chemical Center. These were collected on five inch squares of

Chemical Corps Type VI or "polyfiber" filter papers. Air was drawn through these filters at a rate of four cubic feet per minute for one hour starting at t_0. For details of the sampling see the report of Project 2.5a, "Airborne Particle Studies". The fall-out pattern for the surface burst was such that only one usable filter sample was secured. Three samples were obtained from the underground burst.

Low and high altitude air filter samples were supplied by Air Force Office of Atomic Energy - . These were obtained by aircraft near the cloud at approximately H + 1 hour at altitudes of 1,000 and over 10,000 feet.

Samples for the study of activity as a function of particle size were secured by Project 2.5a with cascade impactors. Air at the rate of 12.5 liters per minute was drawn through a series of five jets with orifices of decreasing diameters. The impactors were run for five minutes. The impactors were started when an ionization chamber indicated that the cloud was overhead. See report of Project 2.5a "Airborne Particle Studies". The air stream from each jet impinged upon the sticky surface of a piece of scotch tape mounted on a glass plate. The first tape opposite the largest orifice collected the largest particles, the tape behind the next largest orifice collected the next largest particles, etc. A molecular filter served as a sixth stage to collect the extremely fine particles.

Pebble samples for induced activity study were selected from the scoop surface samples and core samples. Pebbles between 6 and 12 mm in diameter were selected and only a few taken so as not to materially influence the gross activity of the original sample.

Close-in fall-out samples were supplied by personnel from the Naval Radiological Defense Laboratory working on Project 2.5a. These were collected in shallow metal trays one square foot in area which had been placed downwind prior to the shot. A clock operated mechanism uncovered the tray just before shot time and covered it one hour later. The samples were recovered on D + 2 days.

Samples for studying the effect of weathering will be discussed in detail under section 2.4.

2.2 SAMPLE PREPARATION

Soil samples from the surface of the crater lip, from the core samples of the crater lip, and from retrievable rockets were made homogeneous before division for separate simultaneous measurements.

Each sample was ground to between 50 and 100 mesh in a disc pulverizer, placed in a bottle and mixed before being divided into aliquots. Between the grinding of each sample, the disc pulverizer was "washed" with three grindings of clean soil, opened and blown free of adhering dust with compressed air. It is realized that such a cleaning procedure does not produce a rigorously clean pulverizer, but the amount of activity carried into the next sample is believed to be negligible.

Pebble samples were colored with a red crayon and sand blasted until all visible color was removed. It was hoped that this would remove all adhering fission products and provide a sample which contained only induced activity. The pebbles were then crushed in an iron mortar to approximately 8 mesh, transferred to a mullite mortar, and ground to approximately 100 mesh. Between grindings the mortars were "washed" with two grindings of clean soil, blown free of dust with compressed air, and wiped with damp cleaning tissues.

Air filter samples were returned to NIH for chemical analyses without further preparation.

Cascade impactor samples were covered with a layer of scotch tape and returned to NIH without additional preparation.

A detailed description of all samples studied are listed in numerical order in section 3.1.1.

2.3 CHEMICAL MEASUREMENTS

The details of the chemical separations and radiochemical evaluations of the various isotopes are given in Appendix A.

The chemical symbols Mo, Ag, Ba, Sr, Zr, Ce, and Fe will in this text refer to the specific isotopes Mo^{99}, Ag^{111}, Ba^{140}, Sr^{89}, Zr^{95}, Ce^{144} and Fe^{59} and not to the natural occuring element.

2.3.1 Fission Products

Of the eight or nine fission products which have half lives, yields, and decay schemes of a nature which would allow their use in this investigation, six were selected for study. These were Mo, Ag, Ba, Sr, Zr, and Ce. The inclusion of other isotopes was prohibited by lack of time and personnel, and the belief that their inclusion would have contributed little to the investigation.

These isotopes were selected because of their half lives, the relative ease with which they could be determined, their high fission yields (with the exception of Ag), and the characteristics of the fission chains to which they belong. The nature of the fission chain was of particular importance since it was felt that this would be a large factor in fractionation. The fission chains of the selected

TABLE 2.1

Chain of Beta Decay for Fission Products Studied and Fission Yields for U^{235} and Slow Neutrons[a]

Isotope Determined	Fission Yield	Fission Chain (beta decay)
Mo^{99}	6.2	$Mo \xrightarrow[1.2Mev]{67\ hr} Tc \xrightarrow{10^5 y} Ru$
Ag^{111}	0.18	$Pd \xrightarrow{26\ min} Ag \xrightarrow[1.0Mev]{7.6d} Cd$
Ba^{140}	6.2	$Xe \xrightarrow{16sec} Cs \xrightarrow{66sec} Ba \xrightarrow[1Mev]{12.8d} La \xrightarrow[1.4Mev]{40hr} Ce$
Sr^{89}	4.6	$Kr \xrightarrow{2.6min} Rb \xrightarrow{15.4min} Sr \xrightarrow[1.5Mev]{53d} Y$
Zr^{95}	6.0	$Kr \xrightarrow{short} Rb \xrightarrow{short} Sr \xrightarrow{short} Y \xrightarrow{10.5min} Zr \xrightarrow[0.4Mev]{65d} Nb \xrightarrow{35d} Mo$
Ce^{144}	5.3	$Xe \xrightarrow{(1sec)} Cs \xrightarrow{short} Ba \xrightarrow{short} La \xrightarrow{short} Ce \xrightarrow[0.3Mev]{275d} Pr \xrightarrow[3.1Mev]{17.5min} Nd$

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a. C.D. Coryell and Nathan Sugarman, "Radiochemical Studies: The Fission Products" Book 2, Introduction, McGraw Hill Book Company, Inc., New York (1951).

isotopes are listed in Table 2.1.

Mo is of particular importance because of its previous use in determination of bomb efficiency and because it is the first member of its fission chain. Sr and Ba are of particular interest for two reasons. They have relatively long lived gaseous precursors which may contribute much to fractionation. Biologically they are of particular importance because of their known tendency to concentrate in bone if ingested.

2.3.2 Induced Activity

The only induced activity separated and measured chemically was Fe. The short half lives of the isotopes of Si, Al, Mn, Na, and K made the determination at NIH impractical and it was not felt advisable to attempt to establish a chemical laboratory at the test site. Separation of Ca^{45} at D + 50 days gave activities so low as to be useless in any extrapolation.

2.4 PHYSICAL MEASUREMENTS

All counting done at the test site was performed in a building a considerable distance from the one in which the samples and planchets were prepared. This isolation of the counting equipment decreased contamination and resulted in a background which, in the conventional lead pig, varied between 25 and 40 counts per minute. In a few cases where a routine check of background showed values higher than this, decontamination successfully lowered it to this region. A recording counting rate meter was run continuously as a guard against high backgrounds from sources which might have been brought into the area by other investigators.

All samples were mounted in aluminum planchets either 1 inch or 3/4 inch in diameter. In order to prevent movement or loss of sample, the soil in each planchet was firmly secured with a minute amount of Duco cement. This was accomplished by dampening each sample with a few drops of acetone containing approximately 1% Duco cement. On evaporation of the acetone, the planchet could be inverted and tapped without loss of material.

All measurements of counting rates on soil samples were made with end-window G-M tubes having a window thickness of less than 2 mg/cm^2. All measurements, with the exception of the aluminum absorption curves, were made in conventional lead pig having a 1.5 inch lead wall and an aluminum lining. It was equipped with the common lucite shelf holder which provided window-to-sample distances, in our case, of approximately 0.5, 2.0, 3.6, 5.4, 6.8, and 7.6 cm.

The absolute counting efficiencies of the equipment used at the test site were obtained with Tracerlab standards. The basic efficiencies for betas were taken as the average of measurements made with three Bi^{210} standard sources. After the analysis of the aluminum absorption curves (Section 2.3.4), these efficiencies were adjusted to more closely correspond to the effective beta energies being measured. The calculations are discussed in the results, section 3.3.6.

The determination of the absolute counting efficiencies of the equipment used at the NIH laboratory is discussed in Appendix A.

2.4.1 Gross Beta Decay

Measurements of the gross beta activity as a function of time were begun as soon as the samples were prepared and were continued until 412 hours after the surface detonation and 142 hours after the underground detonation, at which time the laboratory at the test site was closed. Similar measurements were begun at NIH at approximately 70 hours after detonation and continued for approximately three months. The early measurements were made at intervals of 30 to 60 minutes but as the decay rate decreased, the intervals between measurements were correspondingly increased. With rare exceptions, the total count upon which each counting rate was based was greater than 5,000 counts and in most cases greater than 10,000 counts. The individual counting rates were seldom above 20,000 counts per minute and never above 30,000 counts per minute.

Counting rates of the order of 20,000 counts per minute were observed for one milligram samples when the first planchets were placed on the lower shelves in the pig. The period over which the activity of a given sample could be efficiently measured was increased by moving the sample to shelves with higher counting efficiencies as the sample decayed. A factor measuring the change in counting efficiency was determined for each change of each sample by successive counts in the two positions. The ratio of these two counts provided a correction for the change in air absorption as well as the change in physical geometry. Since a knowledge of the absolute counting rate is not required and since the application of constant correction factors to decay data does not change the characteristics of the decay curves, the data presented have only been corrected by the empirical factors for changes in efficiency, and for coincidence loss and background.

Because of the possible heterogeneity in the samples, even after mixing, decay curves were obtained for several aliquots from each sample.

2.4.2 Gross Gamma Decay with G-M Tubes

Measurements of the gross gamma disintegration rate as a function of time were obtained in essentially the same manner as described above for gross beta activity. Because of lower counter efficiencies, considerably larger samples were used and, of course, an absorber was necessary to remove the beta activity. At the test site all measurements of gamma activity were made with an absorber of 1.3 gm/cm^2 of aluminum placed on the first shelf very close to the counter window. This absorbs all the betas having maximum energies less than 2.8 Mev and transmits less than 0.1% of the very few (Sr^{91}, Yt^{92}, Rh^{106}) having energies around 3.2 Mev. Unfortunately, duplicate conditions were not used in the NIH laboratory in extending the decay observations to a longer time. Instead, a 3.8 gm/cm^2 lead absorber was used to remove the beta activity. The implications of this discrepancy are discussed in the results, Section 3.3.3.

2.4.3 Gross Gamma Decay With Ionization Chambers

Since biological hazard is more closely correlated with the concentration of ionization produced than with the flux of incident photons, the gross gamma decay curves obtained with G-M tubes were supplemented with measurements taken with ionization chambers.

An ionization chamber identical to that used in the Beckman MX6 survey meter was used. This chamber is reasonably air-equivalent except for low photon energies. The chamber was operated with a battery-powered electrometer circuit and the output of this circuit was recorded on a Brown continuous recording potentiometer. The instrument was linear and essentially free of drift after an initial two day warm-up. Any change in base line due to drift was routinely measured every few hours.

The sensitivity and range of measurement were increased by changing the sensitivity of the recording potentiometer as the sample decayed. After the sample was in position, the sensitivity of the potentiometer was adjusted for a near full scale deflection of approximately eleven inches. When the deflection decreased to approximately four inches the sensitivity was changed so that a near maximum deflection was again obtained.

A two or three gram aliquot of the prepared soil sample was secured to a shallow metal tray with Duco Cement and placed about two inches below the ionization chamber. The beta activity was absorbed with approximately one cm of wood and the iron shell of the ionization chamber. Sample and chamber were housed in two inches of lead. The background contribution was cancelled by routinely establishing a base line every few hours by removing the sample. Two samples were run simultaneously on the underground burst but no measurements were made on the surface burst.

2.4.4 Effective Beta Energies

The effective beta energies of soil samples as a function of time were determined by analyses of aluminum absorption data taken periodically on the same planchets. The absorption data were obtained with the Tracerlab automatic counting system consisting of (1) SC-1B Autoscaler, (2) SC-5A Tracergraph Printing Interval Timer, (3) SC-9C Shielded Manual Sample Changer and Preamplifier, (4) SC-6A Automatic Sample Changer, and (5) E-25 Aluminum Absorber Kit. The Autoscaler was modified with an SC-4 Eagle Preset Counter and relay so that the total count was not limited by the scale of 4096 but was extended by any desired factor from one to four hundred. The absorber kits contained twenty-five one inch aluminum absorbers graded from 0 to 1600 mg/cm^2. A representative set of absorbers is listed below:

mg/cm^2	mg/cm^2	mg/cm^2
0.00	46.3	375
1.66	67.5	432
3.47	90.9	524
4.80	137	621
7.26	172	734
9.96	214	844
12.8	278	955
19.7	322	1610
29.2		

Since geometry for all measurements was fixed by the automatic equipment, considerable care was necessary in preparing planchets. Initial counting rates, with no absorber, of approximately 20,000 counts per minute but not exceeding 25,000 counts per minute were desired in order to have a planchet which could be measured for a long time but with which the error in coincidence correction was not abnormally large. The rapid decay of the samples and the large amount of data needed necessitated a frequent change in the total count upon which counting rates were based. The total counts were never less than 512, rarely less than 1024, and usually 2048 or more.

Counting rates with no absorber were always determined at the end of an absorption curve so that the data could be corrected for decay during the period in which the absorption data was taken.

2.4.5 Effective Gamma Energies

The effective gamma energies of soil samples as a function of time were determined by analyses of lead absorption data taken periodically on the same planchets. The absorption data were obtained with a conventional lead pig and a thin end-window G-M tube. The beta activity was removed by a 1300 mg/cm² aluminum absorber which was placed on the first shelf of a common lucite shelf holder. The lead absorbers were placed on the second shelf and the planchet on the third shelf. Lead absorbers of the following thicknesses were used:

gm/cm²	gm/cm²
0.000	2.08
.225	3.81
.464	5.89
.910	7.54
	11.26

2.4.6 Gross Beta Specific Activity

The measurements of the gross beta specific activities of soil samples were made after the sample had decayed sufficiently to permit the counting of aliquots weighing approximately ten milligrams. These aliquots could be weighed accurately and were of sufficient size to be fairly representative of the whole sample. However, in most cases, measurements were made on five or six aliquots in order to further decrease the effect of heterogeneity in the sample. The use of larger aliquots was undesirable because of the increased difficulty of making self-absorption corrections.

2.4.7 Gross Gamma Specific Activity

No information was obtained on the gamma specific activity. In view of gamma measurements being made by other projects, the investigators gave this determination low priority and neglected it in favor of the other objectives.

2.4.8 Beta Activity of Air Filter Samples

Beta activity of air filter samples were measured for Project 2.5a with a Nuclear Measurement Corp. Proportional Counter Model PC-1. This counter was equipped with a special cylindrical chamber built to accommodate 5 3/8 inches square filter papers. The filter paper was inserted into a cylindrical metal cup which served as the counting chamber and the chamber fastened so that the paper surrounded the central anode wire. The chamber could be easily disassembled for decontamination.

A limited amount of beta decay data was obtained on some samples from the underground burst.

2.5 EFFECT OF WEATHERING

The effect of rainfall upon the distribution of fall-out was studied by making chemical analyses of samples taken before and after a "simulated rain" and by leaching experiments with distilled water upon a sample of surface soil.

A slow steady rain was simulated by two lawn sprinklers supplied by a tank truck equipped with a centrifugal pump. The oscillating sprinklers were adjusted so that they covered an area of approximately 500 square feet with an almost vertical spray of rain-like drops. Before the shot it was necessary to completely clear the area of vegetation so that the sagebrush would not interfer with the sprinkler pattern and so that additional fall-out would not be washed onto the ground. The amount and distribution of rainfall was measured with a pattern of funnel-topped graduates placed throughout the area. Trial runs showed that two inches of "rain" could be delivered to the area in two hours without surface run-off and that this penetrated the earth to a depth of 8 or 9 inches. Five hours after sprinkling, the plot was dry enough to be sampled. Trial tests showed that the best way to obtain samples at various depths was to scrape soil from the near vertical wall of a hole dug with an ordinary spade. Small corers made of 5/8 inch steel tubing would not work in the compact, rocky soil.

Prior to the underground burst, a pattern of possible test areas were cleared in the north-east quadrant from ground zero. The actual test plot was selected from these on the basis of accessibility, and the fall-out pattern. It was located approximately 6000 feet due north of ground zero.

The experiment was carried out on D + 3 days. This date was a compromise between these conflicting requirements:

1. The desire to work in an area with as much fall-out as possible in order to get sufficient activity for analysis:
2. The necessity of early sampling before the depletion of the short-lived Mo, Ag, and Ba: and
3. The necessity of protecting personnel from over-exposure to radiation.

The following "pre-rain" samples were taken:

32-U-W. The top 1/4 inch of soil taken at random from 10 to 15 locations in the plot. Weight, approximately 1000 grams.

33-U-W. The top 1/4 inch from an area of 100 square inches of the surface. Weight, 105 grams. This was taken to correlate specific activities with the gross radiation field as measured by the monitor accompanying the investigators.

34-U-W. One inch below surface -- approximately 5 grams from each of three holes.

35-U-W. Two inches below the surface — approximately 5 grams from each of three holes.

Unfortunately, in spite of a specific request by the investigators, the contractor furnished a different water truck for the test than for the trial runs and only one inch of "rain" was delivered to the plot. This penetrated to a depth of six inches.

The following "post-rain" samples were taken:

36-U-W. The top 1/4 inch of soil taken at random from 5 to 10 locations in the plot. Weight, approximately 50 grams.

37-U-W
38-U-W
39-U-W
40-U-W
Taken respectively from 1 inch, 2 inches, 4 inches, and 6 inches below the surface. Each sample contained approximately 5 grams from each of three holes.

An aliquot of sample 32-U-W and all of the other samples were dried and pulverized before they were returned to NIH for chemical analysis.

The field tests were supplemented by leaching experiments at NIH on an aliquot from the unpulverized sample 32-U-W. The experiments were performed in the following manner:

A. 108 grams of sample 32-U-W and 1000 cc of water were shaken for one hour. This was allowed to settle for one hour and a 100 cc aliquot of the supernate removed with a pipette. This was centrifuged to remove any suspended matter and the clear supernate (sample 41-U-W) analyzed for dissolved activity.

B. The mixture of water and sample was then stirred for an additional eight hours in a Waring blender and allowed to settle for eleven hours. A 100 cc aliquot was removed, centrifuged, and analyzed (sample 42-U-W).

CHAPTER 3

RESULTS

3.1 GENERAL

The results of this investigation are presented wherever possible in the form of graphs and tables. Because of the small size of the graphs in this format, the authors have often felt that although the graph was necessary to present the general picture, it did not present the data in sufficient detail for its maximum use. For this reason, a graph is often accompanied by a table giving detailed data from which a large scale drawing may be prepared.

Since in decay and absorption curves it is the shape of the curve and not the magnitude of its ordinate which is of interest, the observed counting rates for such curves have usually been adjusted by the use of constant multipliers. Such normalization made possible the most lucid presentation of the maximum amount of data on a given graph. However, the reader should not draw conclusions regarding relative specific activities, etc., from two or more curves.

3.1.1 Description of Samples

A detailed description of each sample studied is given in the numerical listing below. In addition to an identifying number each sample has been given a few simple code letters which briefly describe its principle characteristics. Thus the first code letter "S" or "U" tells whether the sample was taken after the surface or underground burst. The second group of code letters give the general nature of the sample:

S = Scoop samples from the surface of the crater lip

R = Rocket samples from the crater

P = Pebble sample

C = Core sample from the crater lip

F = Fall-out sample

W = Sample taken in connection with the weathering study

GA = Ground air filter sample

LA = Low altitude air filter sample

HA = High altitude air filter sample

CI = Cascade impactor sample

Where the sample was supplied by another project and was accompanied by an identifying number, that number is given in the text of the description. Similarly, original National Institutes of Health numbers are given for those samples from which aliquots were given to other projects for cross-checks.

1-S-S	Composite of five scoop samples from south face of lip of crater from surface burst. See Figure 3.1. Taken at approximately H + 3 hours. Original NIH No. 1.
2-S-S	Composite of six scoop samples from inner face of crater lip from surface burst. See Figure 3.1. Taken at approximately H + 6 hours. Original NIH No. 5.
3-S-S	Soil from platform on weasel. Taken from somewhere on south face of crater lip at H + 3 hours.
4-S-S	Fused glass beads taken from sample No. 2-S-S. Dark green in color. Original NIH No. 11.
5-S-R	From crater of surface burst. Obtained on D + 2 days with retrievable rocket. Exposed to considerable rain before taken.
6-S-P	Selected pebbles from No. 1-S-S.
7-S-P	Pebbles selected from sample No. 3-S-S.
8-S-P	Pebbles from sample No. 12-S-C.
9-S-C	From same core as sample No. 12-S-C; 6 inches from top of core.
10-S-C	From same core as sample No. 12-S-C; 12 inches from top of core.
11-S-C	From same core sample as sample No. 12-S-C; 18 inches from top of core.
12-S-C	From core sample taken near sample No. 1-S-S at approximately H + 4 hours; 24 inches from top of core.

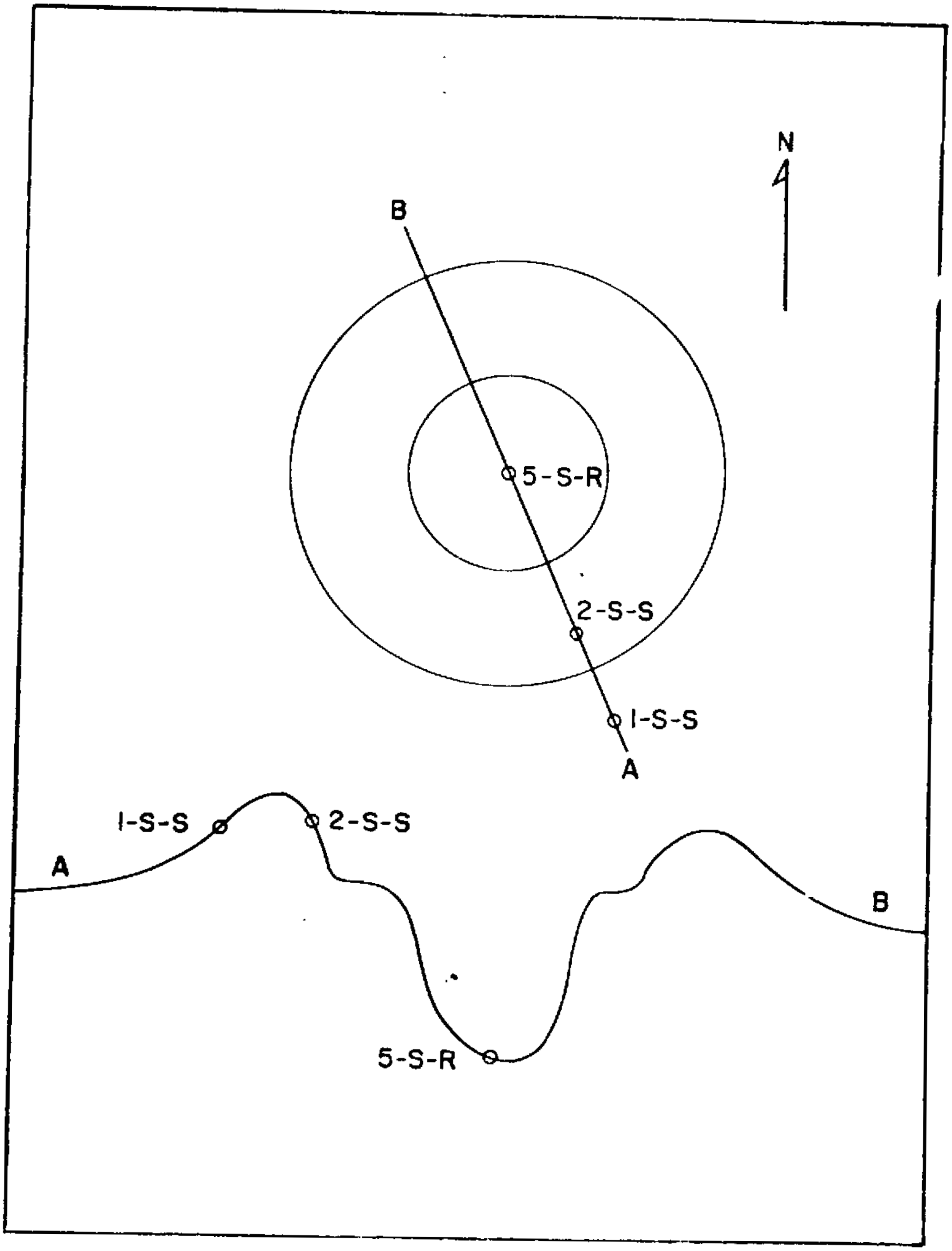

Figure 3.1. Location of Surface Samples on Crater of Surface Burst

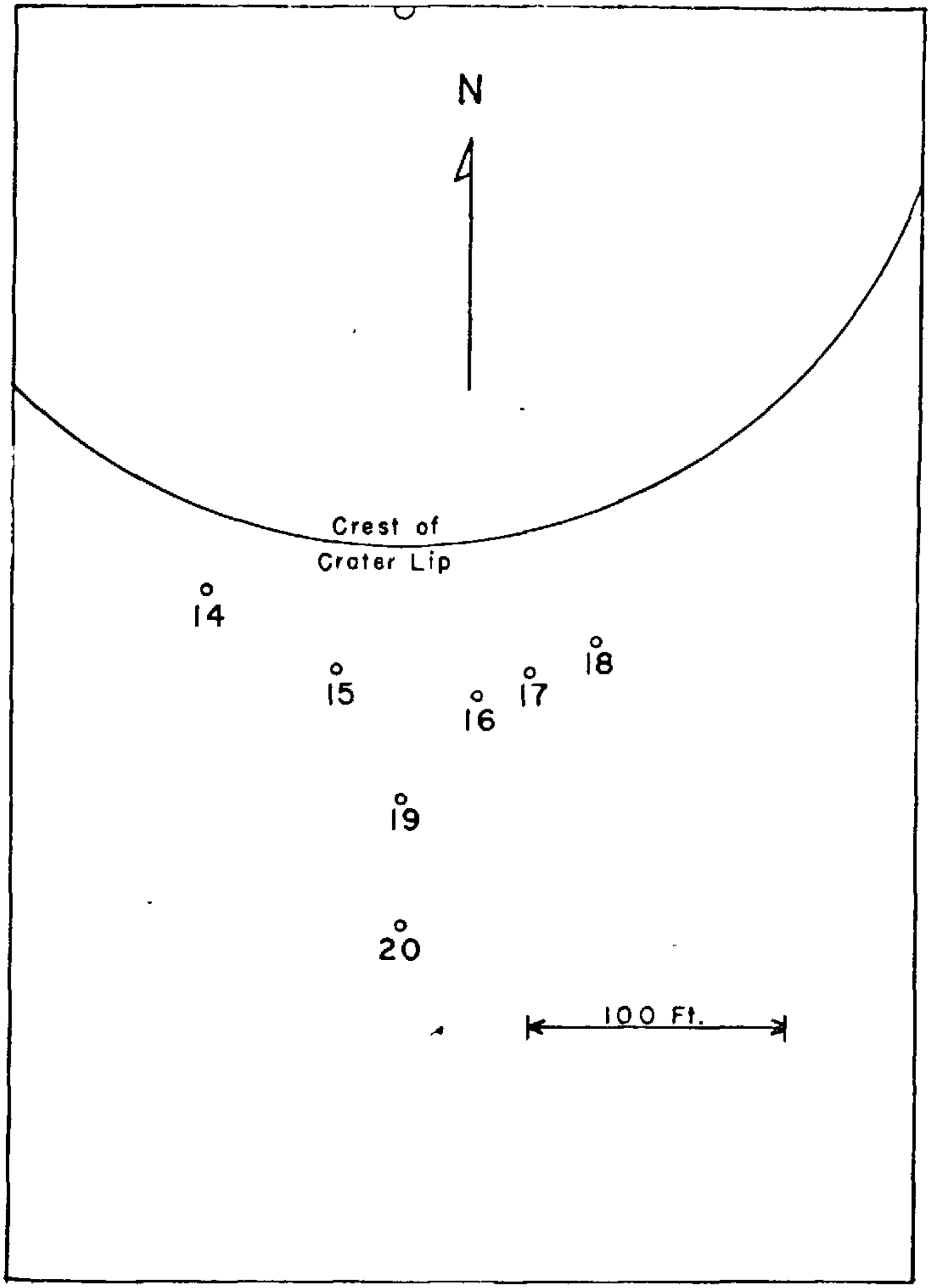

Figure 3.2. Location of Surface Scoop Samples on Crater Lip of Underground Burst

13-U-S	Composite of seven scoops from south face of crater lip from underground burst. Taken at approximately H + 1 1/2 hours. Original NIH No. 18.
14-U-S 15-U-S 16-U-S 17-U-S 18-U-S 19-U-S 20-U-S	Individual scoop samples from south face of crater lip from underground shot. See Figure 3.2. Taken at approximately H + 20 hours.
21-U-R	Composite of four samples taken by retrievable rocket on D + 2 days. Sample mostly shattered rock.
22-U-P	Pebbles from Sample No. 13-U-S
23-U-P	Pebbles from sample No. 27-U-C.
24-U-P	Pebbles from sample No. 25-U-C.
25-U-C	From core taken near sample No. 13-U-S at approximately H + 5 hours. One inch from top of core.
26-U-C	From same core as No. 25-U-C; 7 inches from top.
27-U-C	From same core as No. 25-U-C; from bottom of core; 12 inches from top.
28-U-F	Fall-out tray; NRDL No. M-G-6; 900 yards east, 600 yards north of ground zero.
29-U-F	Fall-out tray; NRDL No. M-H-4; 600 yards east, 900 yards north of ground zero.
30-U-F	Fall-out tray; NRDL No. M-NE-5; 2000 yards northeast of ground zero.
31-U-F	Fall-out tray; NRDL No. M-G-2; 300 yards east, 600 yards north of ground zero.
32-U-W 33-U-W 34-U-W 35-U-W 36-U-W	Samples taken in connection with study on effect of weathering. See section 2.4.

37-U-W 38-U-W 39-U-W 40-U-W 41-U-W 42-U-W	Samples taken in connection with study on effect of weathering. See section 2.4.
43-S-GA	Ground air filter sample from surface burst; ACC No. S-15 $A_1$1. 3000 feet northeast of ground zero. First sheet in pack of filter paper; Chemical Corp. Type VI.
44-S-LA	Low altitude air filter sample from surface burst; No. J1-I-1A. Close-in; approximately 1000 feet at approximately H + 1 hour.
45-S-HA	High altitude air filter sample from surface burst; No. J1-I-16A. Close-in; above 10,000 feet at approximately H + 1 hour.
46-U-GA	Ground air filter sample from underground burst; ACC No. U-114 A1. 4000 feet north of ground zero. First sheet of filter paper in pack; of "polyfiber" filter paper.
47-U-GA	Ground air filter sample from underground burst; ACC No. U-114 A2. Second sheet of filter paper in pack used in No. 46-U-GA.
48-U-GA	Ground air filter sample from underground burst; ACC No. U-114$A_1$1. Duplicate of 46-U-GA.
49-U-GA	Ground air filter sample from underground burst; ACC No. U-114 $A_1$2. Duplicate of 47-U-GA.
50-U-GA	Ground air filter sample from underground burst. ACC No. U-115 A1. 3000 feet northeast of ground zero. First sheet in pack of "polyfiber" filter paper.
51-U-GA	Ground air filter sample from underground burst. ACC No. U-115 $A_1$1. Duplicate of No. 50-U-GA.
52-U-LA	Low altitude air filter sample from underground burst; No. J2-I-2A close-in, approximately 1000 feet at approximately H + 1 hour.

53-U-HA	High altitude air filter sample from underground burst; No. J2-I-11A close-in, above 10,000 feet at approximately H + 1 hour.
54-S-CI	Cascade impactor sample from surface burst; ACC No. SL; 20,000 feet from ground zero on north northeast line.
55-S-CI	Cascade impactor sample from surface burst; ACC No. SM; 4000 feet from ground zero on north line.
56-S-CI	Cascade impactor sample from surface burst; ACC No. SN; 4000 feet from ground zero on north line.
57-U-CI	Three molecular filters used as final stages in samples No. 54, No. 55 and No. 56.
58-U-CI	Cascade impactor sample from underground burst; ACC No. UL; 20,000 feet from ground zero on northeast line.
59-U-CI	Cascade impactor sample from underground burst; ACC No. UM; 4000 feet from ground zero on north line.
60-U-CI	Cascade impactor sample from underground burst; ACC No. UN; 4000 feet from ground zero on north line.
61-U-CI	Three molecular filters used as final stages in samples No. 58, No. 59 and No. 60.

3.1.2 Reliability of Data

The reliability of all the data is, of course, not the same. Where the data does not by its nature or self consistency provide the reader with a measure of reliability, the authors have attempted to do so.

The spread of reliabilities is very large in the data on chemical analysis presented in the accompanying tables. Some values are the average of as many as fourteen separate determinations with counting rates between 1,000 and 20,000 counts per minute above background, and with average deviations of 5%. Others are single values or the average of two or three values with counting rates two or three counts per minute above background and with average deviations of 200-300%.

The assignment of a probable error to each determination would have been laborious and in many cases without meaning. Therefore, four general categories of reliability have been selected and each measurement placed in one of these. The superscript in the tables designates the category to which the given datum has been assigned. The characteristics of the four categories of reliability are as follows:

First Category: Data in this group are reliable to better than 10%. In general, a datum is based on counting rates of over 1,000 counts per minute above background and three or more determinations with an average deviation of less than 10%.

Second Category: Data in this group are reliable to between 10% and 20%. In general, a datum is based on counting rates of over 200 counts per minute above background and on at least three determinations with an average deviation of less than 30%.

Third Category: Data in this group are reliable to between 20% and 50%. In general, a datum is based on counting rates of over 50 counts per minute above background and at least two determinations with an average deviation of less than 50%.

Fourth Category: Data in this group are reliable to less than 50%. In general, a datum is based on a counting rate of less than 50 counts per minute above background and on only one or two determinations which deviate more than 50%.

Because of the continuous nature of the data, the limited amount of data and the broadness of the categories, a given datum could often have been placed in either of two adjacent categories. The actual placement was often influenced by the investigator's "feel" for the particular determination as much as by the limited statistics. However, cases of doubtful reliability have been placed in the category of lesser reliability.

3.2 CHEMICAL CHARACTERISTICS OF RESIDUAL RADIOACTIVITY

3.2.1 Surface Soil Samples

Tables 3.1 and 3.2 show the abundance of specific radioactive isotopes in soil samples taken either from the surface of the ground or the surface of the crater. These tables present exactly the same data but in different units. In both, the analytical results have been extrapolated by exponential decay laws to "t_0". These values present the relative yields of isotopes and the most convenient values for calculating relative composition at later times after the completion of the initial fission chains.

Table 3.1 gives the composition in atoms of isotope per gram of soil. Table 3.2 gives the activity of each isotope in millicuries per gram of soil. Table 3.3 presents information concerning fractionation of these fission products. It compares the observed abundances in Table 3.1 with the fission yields from U^{235} and slow neutrons. The values of fission yields used for the comparison were[1]

"R" Factors similar to those used by the Air Force Office of Atomic Energy (AFOAT-) have been calculated and listed.

These Factors have the following definition:

$$R \text{ for } x/y = \frac{\text{observed abundance of } x}{\text{observed abundance of } y} \div \frac{\text{fission yield of } x}{\text{fission yield of } y} \qquad (3.1)$$

For Sample 1 from Table 3.1:

$$R \text{ for Sr/Mo} = \frac{14.9}{229} \div \frac{4.6}{6.2} = 0.09$$

3.2.2 Chemical Composition vs Depth in Crater Lip

Table 3.4 gives the abundance of certain radioactive isotopes as a function of depth in the loose soil comprising the crater lips. The actual depth for each sample is in doubt. The corer was driven to a depth of three feet in each case, but was only partially filled with soil. Whether the core obtained represented a compressed three foot core, or the upper part of three foot core, or a combination is not known. The depths indicated in the table are the depths below the surface of the soil in the core.

Table 3.5 presents "R" factors as a measure of fractionation as a function of depth. The core of the surface lip was taken near sample 1-S-S. The core of the underground lip was taken near sample 13-U-S.

3.2.3 Chemical Composition of Air Filter Samples

Table 3.6 gives the abundance of certain radioactive isotopes in air filter samples. The abundances are expressed in atoms per sample. No attempt has been made to determine abundance or activity as a function of either volume of air filtered or mass of sample.

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[1] C.D. Coryell and Nathan Sugarman, "Radiochemical Studies: The Fission Products" Book 2, Introduction, McGraw Hill Book Company, Inc., New York (1951)

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These analyses were made to determine relative composition for comparison with other samples. Table 3.7 presents the "R" factors as a measure of fractionation.

The very small amount of activity available on a filter for analysis makes the reliability of any particular value less than for those reported in the previous tables for soil samples.

3.2.4 Chemical Composition as a Function of Particle Size

The amount of activity on a single stage of the cascade impactor was so small that the values reported in Table 3.8 must be considered as only approximate. It is impossible to say how much of the fractionation indicated by the "R" factors in Table 3.9 is real, how much is due to experimental error, and how much is due to the fact that the minute amount of material on any stage is probably not representative of the whole. The data are given more as a guide to future work than for any intrinsic value it may have.

3.2.5 Pebble Samples

The chemical composition of the pebble samples is shown in Table 3.10. The presence of Mo, Ag, Ba, Sr, Zr, and Ce shows that the sand blasting did not completely remove the fission products and that the specific activities determined on these samples are not a correct measure of induced activity.

3.3 GROSS CHARACTERISTICS OF RESIDUAL RADIOACTIVITY

3.3.1 Gross Beta Decay of Crater Lip Samples

The decay characteristics of the beta activity of the crater lip samples from the surface and underground burst are similar. They markedly depart from the usual type of fission product decay described by the expression:[8]

$$A=kt^{-1.2} \tag{3.2}$$

As can be seen in Figure 3.3, describing the decay, both log-log curves exhibit an initial slow rate of decay which steadily increases to a maximum and then decreases again. The slopes of the plot of the data varies from initial values of -0.7 and -0.8 to maxima of approximately -2.3.

Although qualitatively similar, quantitatively the decay curves are quite different. The type of expression which describes very accurately the decay curves of aliquots of samples from the surface burst will not describe similar data from the underground burst.

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3.3.2 Beta Decay of Air Filter Samples

A limited amount of data on beta decay of air filter samples from the underground burst is shown in Figure 3.7. The curves are numbered according to ACC nomenclature, see report of Project 2.5a "Airborne Particle Studies".

3.3.3 Gross Gamma Decay of Crater Lip Samples

Decay with G-M Tubes: The gross gamma decay characteristics of crater lip samples from the underground and surface bursts were found to be different. Since no analytical expression which would describe the decay has been found, empirical data are presented in Figure 3.8 and Tables 3.13, 3.14, and 3.15. The tables present in detail the average data from which the figures were plotted.

The early decay measurements were made at the test site and the later measurements at the National Institutes of Health with a considerable time overlap. These data have been adjusted to form continuous decay curves. Different absorbers for the removal of beta particles were used at the two laboratories and the adjustment is not without criticism. The early measurements were made using a 1.3 gm/cm^2 filter of aluminum, while the later ones were made with a 3.7 gm/cm^2 lead filter. Both filters effectively removed the beta particles, but the lead removed, in addition, approximately 40% of the gammas. Since the gamma spectrum of the residual activity is changing with time (Figures 3.14 and 3.15), the decay curves obtained with the two filters are not identical.

Fortunately, an estimate of the magnitude of the discrepancy can be made, since lead absorption curves as a function of time were determined on the planchets used for obtaining the early decay curves. A comparison of the decay curves obtained with 1.3 gm/cm^2 of Al, and with 1.3 gm/cm^2 of Al plus 3.8 gm/cm^2 of Pb over the early portion of the decay indicates this magnitude.

The decay curves for two samples from the surface burst are shown. Sample 1-S-S was from the outer surface of the crater lip, and sample 2-S-S was from the inner surface of the crater lip. Each curve is the average of two or more curves obtained on separate aliquots

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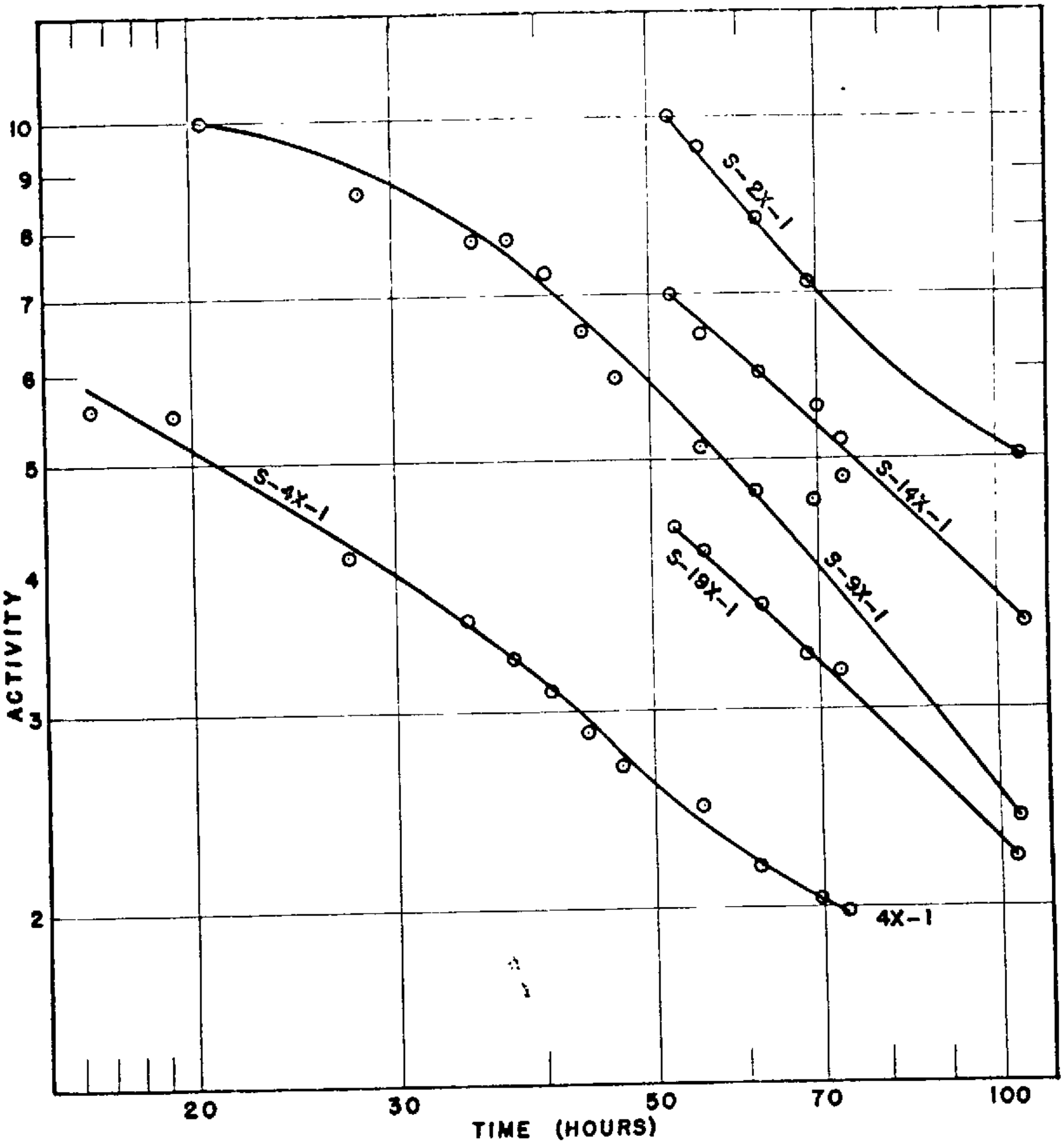

Figure 3.7. Beta Decay of Ground-Air Filter Samples

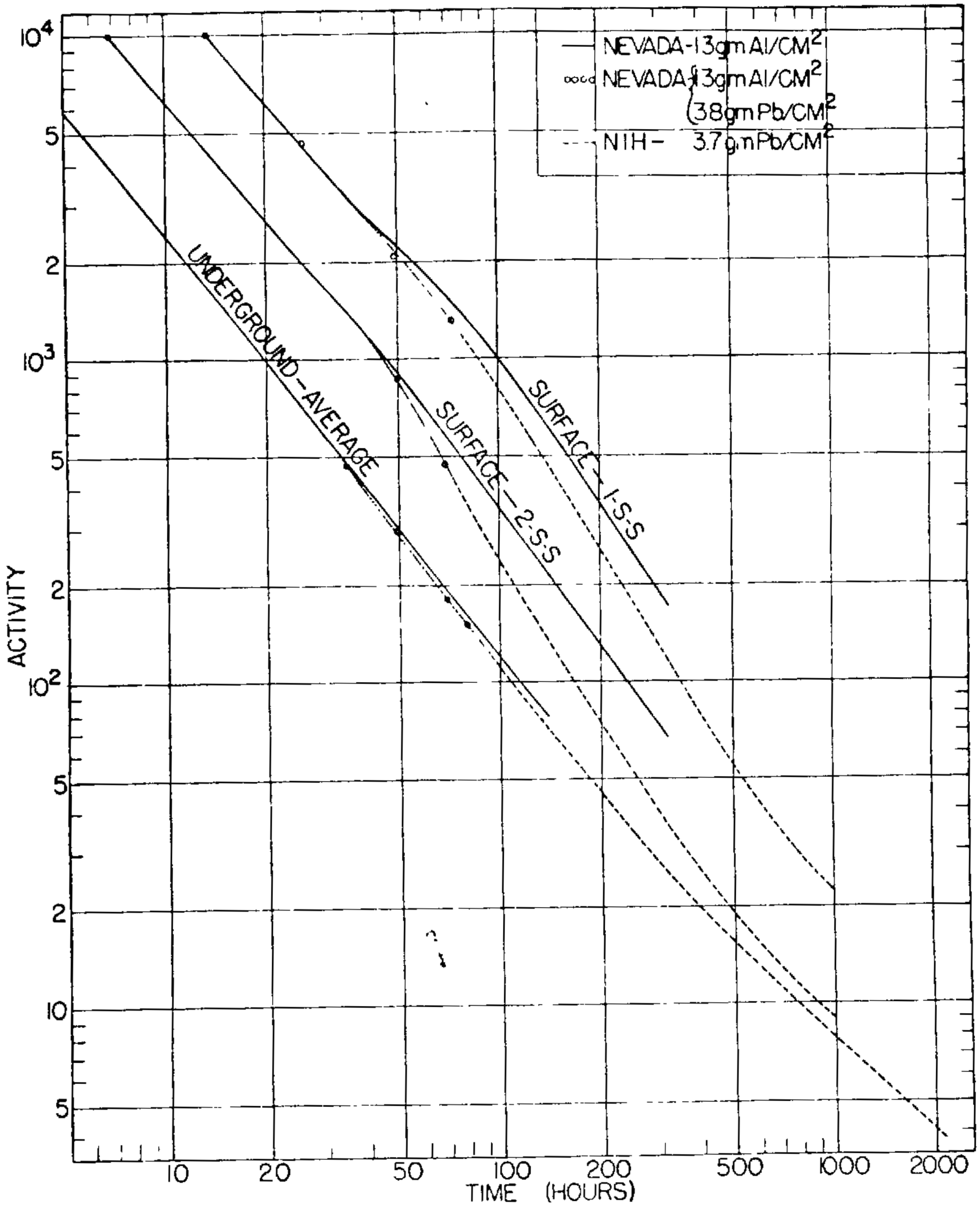

Figure 3.8. Geiger-Muller Tube Measurements of Gamma Decay of Surface Soil Samples.

TABLE 3.13

Gamma Decay of Crater Lip from Surface Burst

Time (Hours)	Absorber Thickness		
	1.3gm Al	1.3gm Al 3.8gm Pb	3.7gm Pb
7	10,000	10,000	-
8	8,462	-	-
9	7,308	-	-
10	6,442	-	-
12.5	4,904	-	-
15	3,894	-	-
17.5	3,221	-	-
20	2,740	-	-
25	2,077	2,077	-
30	1,663	-	-
35	1,510	-	-
40	1,202	-	-
45	1,058	-	-
50	942	865	-
60	721	-	-
70	577	471	471
80	476	-	364
90	401	-	287
100	346	-	236
115	288	-	188
130	240	-	155
150	197	-	123
175	159	-	94
200	130	-	76
250	96	-	53
320	67	-	35.2
400	-	-	26.2
500	-	-	19.2
700	-	-	12.7
900	-	-	9.8
1000	-	-	9.0

<u>Note</u>: Sample 1-S-S measured with G-M tube.

PROJECT 2.6c-1

TABLE 3.14

Gamma Decay of Crater Lip from Surface Burst

Time (Hours)	Absorber Thickness		
	1.3gm Al	1.3gm Al 3.8gm Pb	3.7gm Pb
13.6	10,000	10,000	-
14.8	9,151	-	-
19.1	6,492	-	-
22.0	5,548	-	-
24.3	4,880	-	-
26.1	4,570	4,634	-
30.3	3,824	-	-
42.2	2,639	-	-
48.9	2,310	2,067	-
54.7	1,991	-	-
62.2	1,802	-	-
73.2	1,514	1,303	-
78.6	-	-	1,170
83.8	1,265	-	-
84.5	-	-	1,039
96.2	1,034	-	847
102.3	967	-	-
108	-	-	712
120	796	-	591
144	-	-	452
146	606	-	-
154	540	-	-
168	482	-	-
171	-	-	344
183	447	-	-
196	-	-	277
216	320	-	-
223	-	-	219
267	234	-	159
291	203	-	139
325	171	-	-
336	-	-	104
367	-	-	91.8
413	-	-	75.4
461	-	-	63.2
506	-	-	54.8
700	-	-	32.7
916	-	-	24.7
965	-	-	22.6

Note: Sample 2-S-S measured with G-M tube.

PROJECT 2.6o-1

TABLE 3.15

Gamma Decay of Crater Lip from Underground Burst

Time After Burst (Hours)	Beta Absorber		
	1.3gm Al	1.3gm Al 3.8gm Pb	3.7gm Pb
5	6,000	-	-
10	2,400	-	-
30	588	-	-
35	470	470	-
50	300	294	-
70	192	180	207
80	162	150	-
100	120	-	112
140	76.8	-	72
200	-	-	45
300	-	-	27
600	-	-	12.8
800	-	-	9.7
1000	-	-	7.8
1500	-	-	5.4
2000	-	-	4.0
2124	-	-	3.8

<u>Note</u>: Average curve; measured with G-M tube.

of the samples. Sample 1-S-S is probably more typical of the close-in fall-out, since sample 2-S-S contained several very large fused glass beads not found elsewhere.

The decay characteristics of samples from the underground burst were more consistent than were the decay curves from the various samples from the surface burst. Therefore, it was possible to present an average decay curve in Figure 3.8. This curve represents the average of eleven decay curves taken on aliquots of samples distributed over the crater lip. It will be noted that for the period from 5 hours to 300 hours the curve can be described analytically by the expression

$$A = kt^{-1.3} \tag{3.8}$$

Gamma Decay With Ionization Chamber: The data for the decay of gamma activity as measured with an ionization chamber are shown in Figure 3.9. Both curves were obtained with aliquots of sample 13-U-S from the surface of the lip of the underground crater. A portion of the decay curve measured with a G-M tube is shown for comparison.

The difference in the two measurements is undoubtedly due to the contribution of the low energy gammas from Np^{239}. The low efficiency of the G-M tube for low energy photons results in a relatively small contribution to the activity as measured by a G-M tube. Conversly, the relative contribution of Np^{239} to the ionization chamber is large. Note the great change in slope at around t_0 + 100 hours when, according to Figure 3.3, the relative abundance of Np^{239} is beginning to decrease rapidly.

No measurements were made on the surface burst.

3.3.4 Effective Beta Energies As A Function Of Time

The gross characteristics of the beta energies as a function of time have been determined by analysis of families of aluminum absorption curves for the same planchets. A typical family of curves on an aliquot from sample 13-U-S is shown in Figure 3.10. Although these curves were obtained with the same geometry, no inference as to gross decay should be drawn. The data have been normalized so that the entire group could be plotted on the same graph.

Three "effective" components could be distinguished in each of the absorption curves. Table 3.16 lists the characteristics of the three components found for the individual curves. The energies

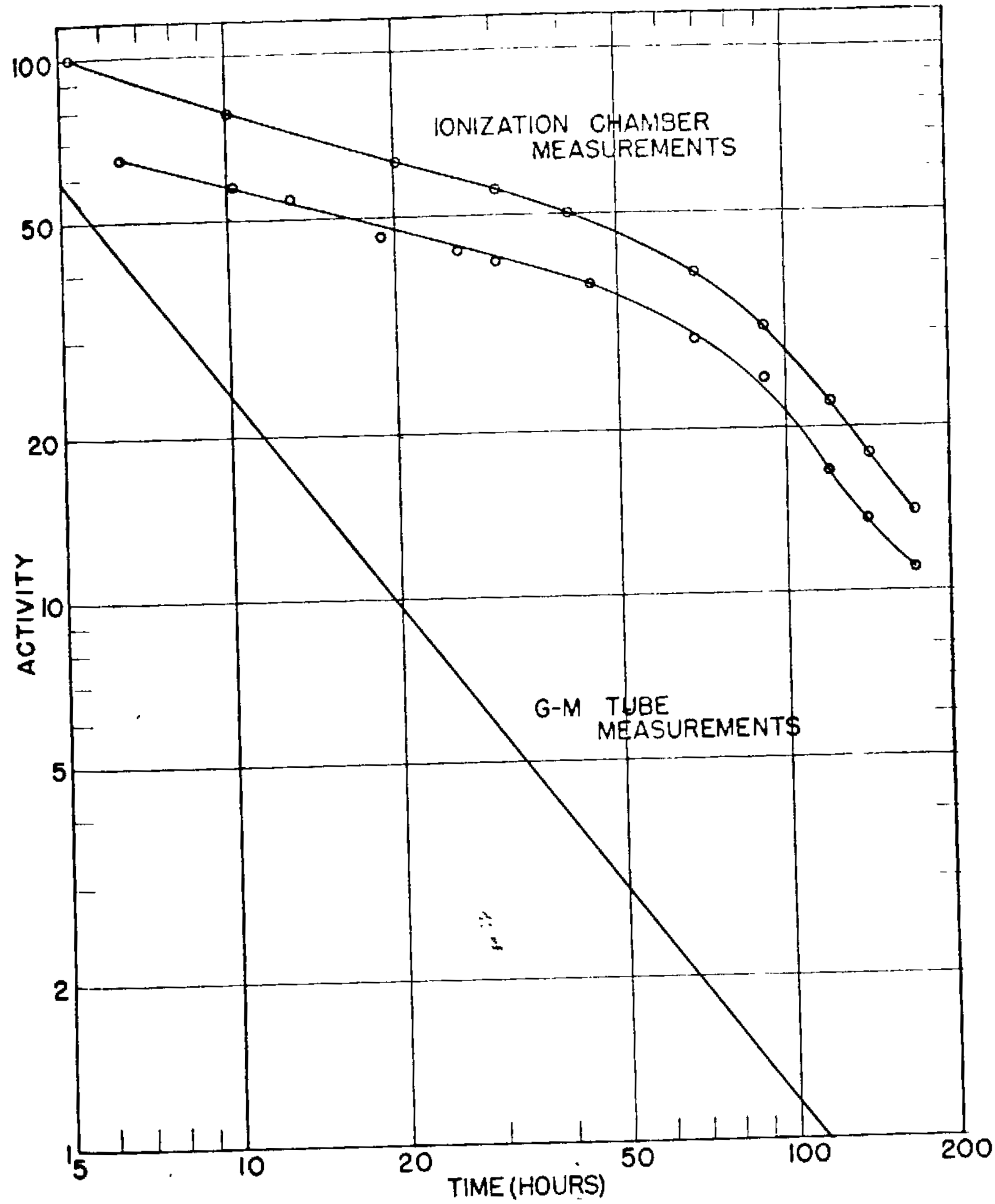

Figure 3.9. Ionization Chamber Measurements of Gamma Decay of Surface Soil Samples from Underground Burst

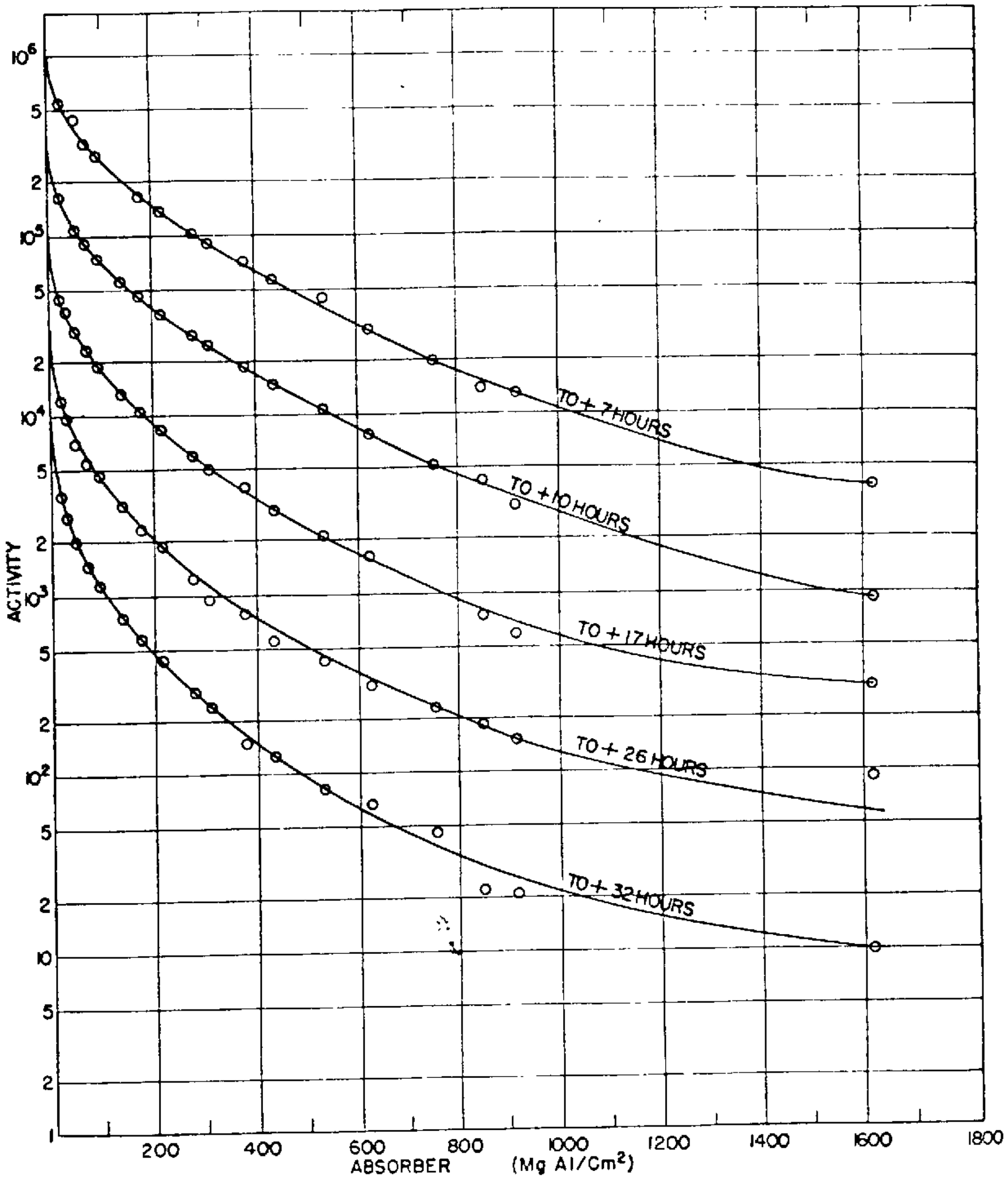

Figure 3.10. Typical Family of Aluminum Absorption Curves for Surface Soil Sample

TABLE 3.16

Beta Energies of Soil Samples Versus Time

Sample	Time (hours)	Energy (Mev)			Abundance (%)		
		E_1	E_2	E_3	A_1	A_2	A_3
1-S1S	7	3.8	0.68	0.18	30	44	27
	10	3.9	0.82	0.17	24	46	30
	13	3.4	1.17	0.30	11	32	48
	24	3.5	0.96	0.25	11	31	59
	34	2.6	0.54	0.26	11	26	58
	60	2.4	0.78	0.26	6	25	56
	107	2.2	0.52	0.18	5	67	28
	126	2.1	0.50	0.05	6	59	35
1-S-S	226	1.6	0.41	0.12	12	65	24
	333	1.8	0.57	0.19	13	44	43
4-S-S	10	3.9	2.23	0.41	5	19	60
4-S-S	24	3.6	1.31	0.40	12	24	46
	32	2.6	0.89	0.32	16	18	54
	58	2.0	0.69	0.31	12	23	59
	100	1.6	0.51	0.22	11	45	40
	126	1.6	0.52	0.27	11	46	43
12-S-C	12	3.4	0.97	0.35	25	26	45
	14	3.3	0.61	0.29	23	40	35
	21	3.5	1.27	0.37	9	25	61
	55	2.6	0.99	0.35	7	22	70
	101	2.0	0.72	0.40	6	13	72
	129	-	1.63	0.37	-	19	76
6-S-P	8	3.9	1.26	0.41	32	53	14
6-S-P	8	3.9	1.19	0.25	36	51	11
	12	3.6	1.19	0.21	30	50	17
	24	3.1	1.09	0.24	30	48	21
	34	4.5	0.66	0.36	11	60	28
8-S-P	15	3.5	1.56	0.32	45	30	22
	26	3.5	1.17	0.36	34	38	25
	55	2.6	0.77	0.25	32	33	35

TABLE 3.16 (Continued)

Beta Energies of Soil Samples Versus Time

Sample	Time (hours)	Energy (Mev)			Abundance (%)		
		E_1	E_2	E_3	A_1	A_2	A_3
13-U-S	7	4.2	0.94	0.10	31	44	25
	10	4.3	0.92	0.26	27	41	25
	17	3.2	0.77	0.24	25	37	36
	26	3.3	0.71	0.21	17	48	45
	32	3.0	0.72	0.32	11	41	43
13-U-S	21	3.2	0.77	0.22	21	41	38
	27	2.5	0.65	0.25	23	33	43
	34	2.6	0.68	0.27	18	34	47
	80	2.0	0.49	0.17	6	30	65
25-U-C	10	4.0	0.84	0.20	33	40	27
	15	4.0	1.19	0.37	24	27	49
	28	3.1	1.08	0.35	17	23	59
	35	3.3	1.15	0.35	12	24	65
	80	2.1	0.54	0.23	12	58	30
26-U-C	9	4.7	1.63	0.62	34	21	40
	11	3.8	2.06	0.54	37	19	40
	23	3.9	1.24	0.40	24	41	33
	31	3.5	1.22	0.28	20	45	32
	46	3.0	0.81	0.22	23	56	20
27-U-C	9	4.5	1.12	0.23	32	37	30
	13	4.1	1.03	0.18	42	31	27
	26	3.0	0.90	0.29	19	35	38
	34	2.6	0.58	0.16	22	52	27
	79	2.1	0.53	0.19	13	52	35
22-U-P	8	3.4	1.17	0.32	28	59	21
	12	3.3	1.12	0.25	28	65	12
	25	2.8	0.90	0.14	26	62	11
	32	2.4	0.98	0.26	30	47	22

PROJECT 2.6a-1

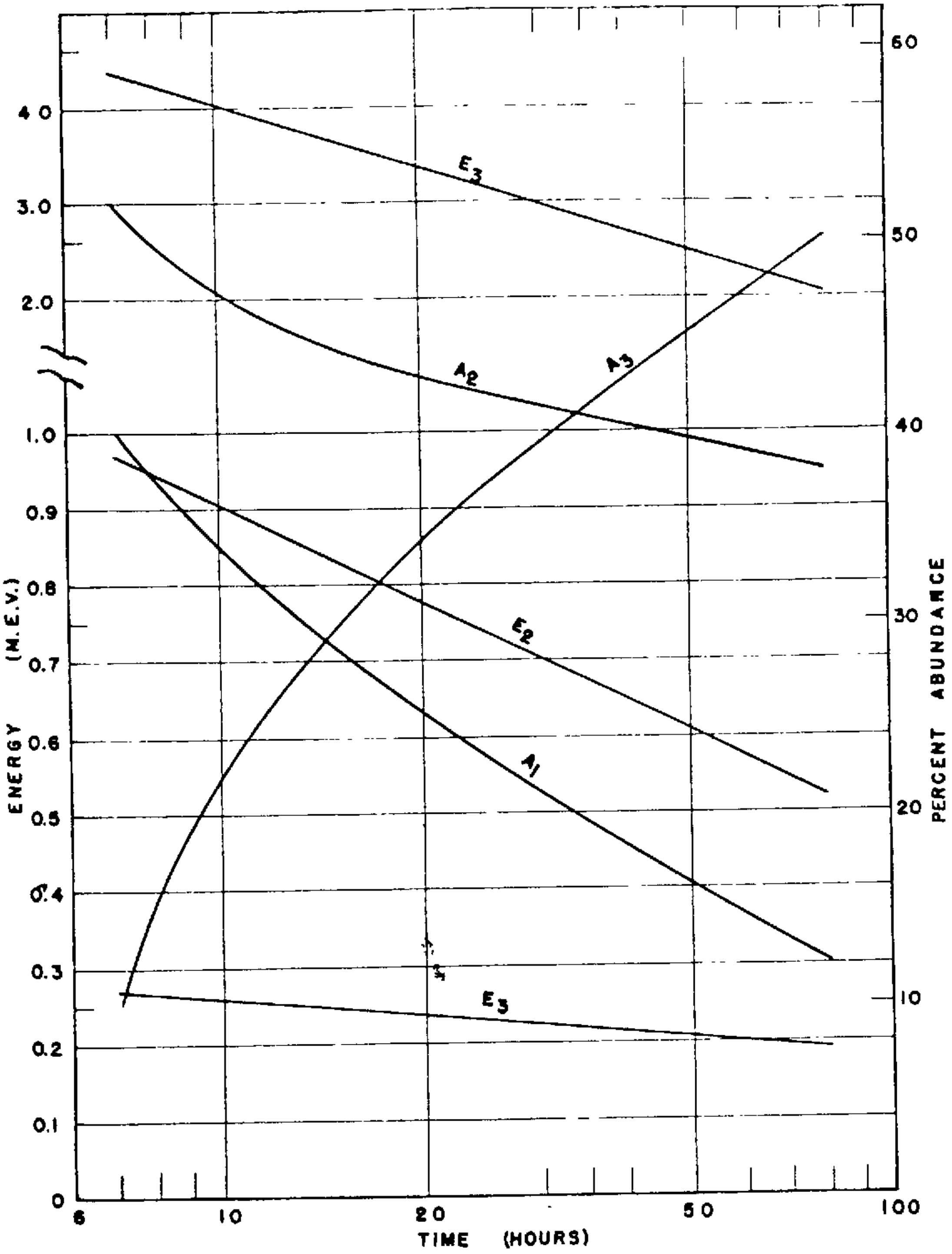

Figure 3.11. Effective Beta Energies of Surface Soil Samples from Surface Burst

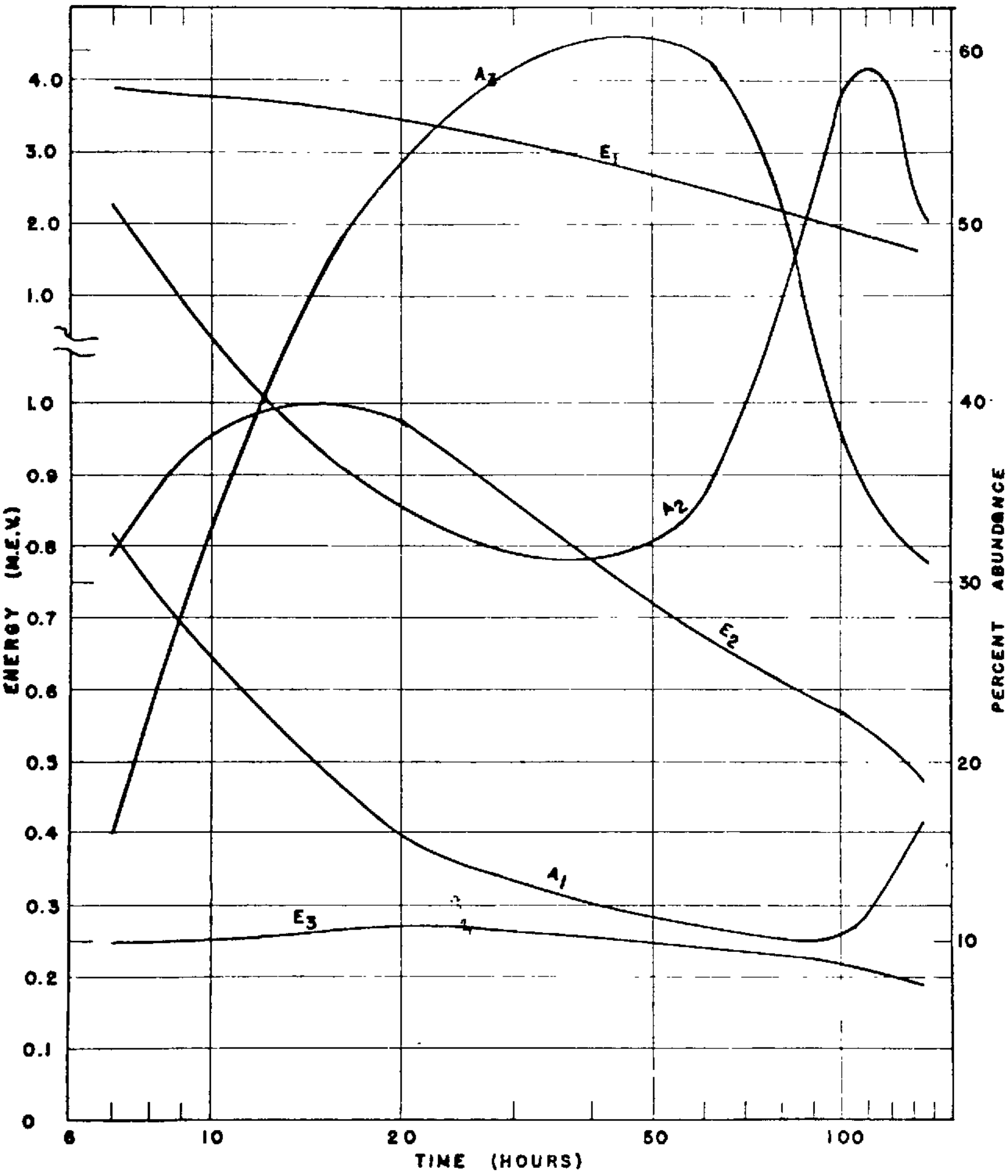

Figure 3.12. Effective Beta Energies of Surface Soil Samples from Underground Burst

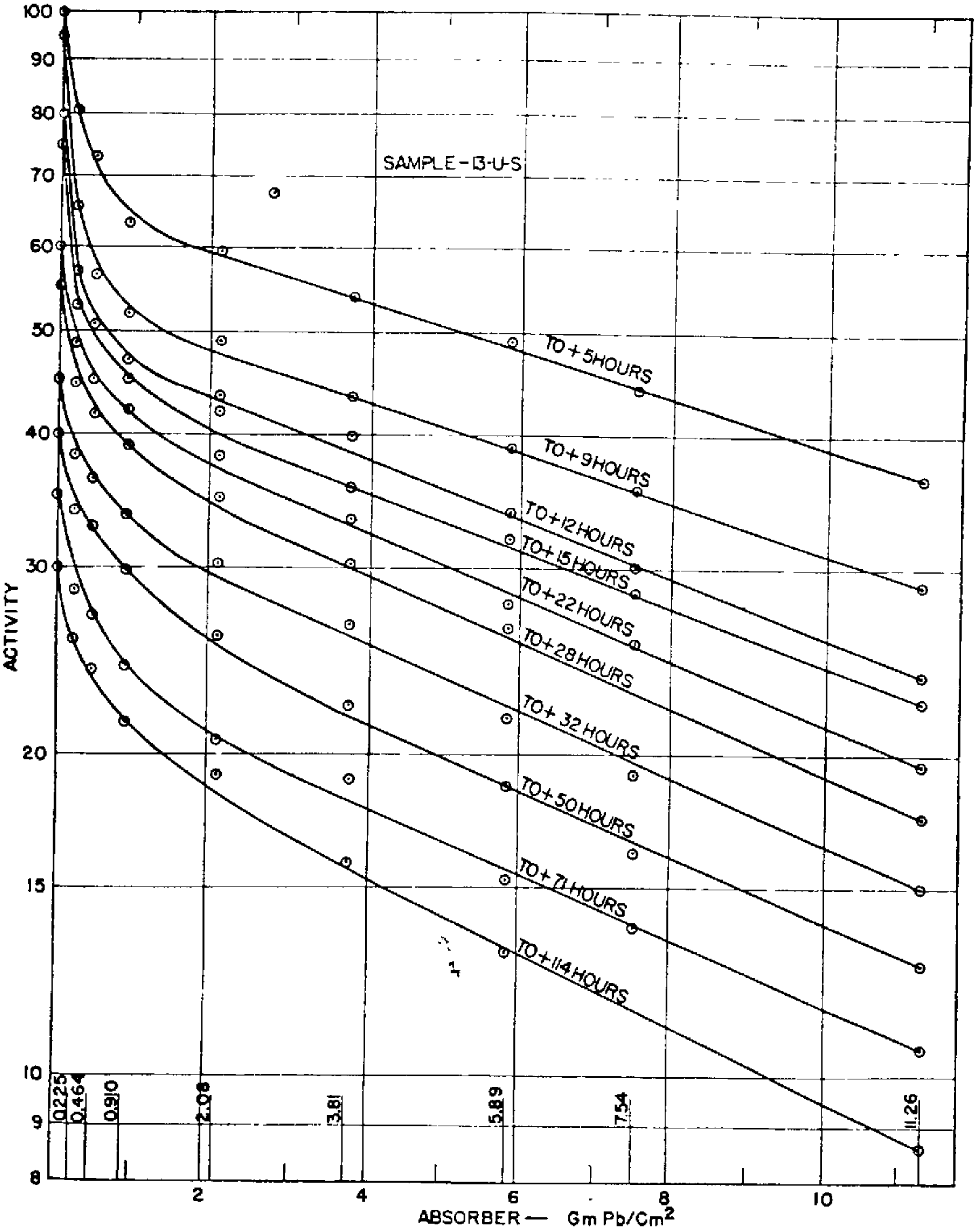

Figure 3.13. Typical Family of Lead Absorption Curves for Surface Soil Sample

of the components were calculated by the formulae[1]

$$E = 1.92\ R^{0.725} \qquad \text{for } R < 0.3\ \text{gm/cm}^2 \qquad (3.9)$$

$$E = 1.85\ R + 0.245 \qquad \text{for } R > 0.3\ \text{gm/cm}^2 \qquad (3.10)$$

and ranges (R) obtained by a simplified Feather analysis. The range was obtained by the linear ratio of the observed value of absorbers for 90% reduction of initial activity of the unknown, the observed value of absorber for the 90% reduction of a Bi^{210} standard and the literature[2] value of 476 mg/cm^2 for the range of Bi^{210}.

The relative abundances listed in columns 6, 7, and 8 have been corrected for backscattering and for air and window absorption. The backscattering correction was taken from a graph by Burtt[3] and the absorption correction was calculated by the equations[4]

$$F = e^{-\mu t} \qquad (3.11)$$

$$\mu = 0.017E^{-1.43} \qquad (3.12)$$

The trend of this data is shown in Figures 3.11 and 3.12.

3.3.5 Effective Gamma Energies As A Function of Time

The gross characteristics of the gamma energies as a function of time have been determined by analyzing families of lead absorption curves for the same planchets. A typical family of curves on an aliquot from sample 13-U-S is shown in Figure 3.13. Although these curves were obtained with the same planchet and geometry, no inference as to activity as a function of time should be drawn. The data for each curve have been normalized with a constant multiplier so that the entire group could be plotted clearly on one graph.

Each of the absorption curves could, with a fair degree of accuracy, be considered as the absorption curve of a two component mixture. Table 3.17 lists the characteristics of the two components found by analysis of individual curves. In columns 3 and 4 are listed

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1. R.E. Lapp and H.L. Andrews, Nuclear Radiation Physics, page 180, Prentice-Hall, Inc., New York, (1948).
2. G. Friedlander and J.W. Kennedy, Introduction to Radiochemistry, page 161, John Wiley and Sons, Inc., New York, (1949).
3. B.P. Burtt, "Absolute Beta Counting", NUCLEONICS 5, 28, (August 1949).
4. G.I. Gleason, J.D. Taylor and D.L. Tabern, "Absolute Beta Counting at Defined Geometries", NUCLEONICS 8, 12, (May 1951).

PROJECT 2.6c-1

TABLE 3.17

Gamma Energy of Soil Samples Versus Time

Sample	Time after burst (hours)	Absorption Coefficients (cm^2/mg) Pb		Energy (Mev)		Relative Abundance %	
		μ_1	μ_2	E_1	E_2	A_1	A_2
1-S-S	7.3	0.74	49.5	1.36	0.113	13	87
	12	0.84	51.4	1.14	0.111	14	86
	25	0.96	43.1	1.00	0.122	23	77
	48	1.08	31.1	0.89	0.145	26	74
	72	1.24	23.5	0.78	0.172	28	72
2-S-S	14	0.76	37.8	1.31	0.142	16	84
	26	0.92	29.9	1.03	0.149	23	77
	49	0.96	24.3	1.00	0.167	21	79
	73	1.12	26.0	0.85	0.162	24	76
5-S-R	60	1.10	29.0	0.87	0.154	29	71
	71	1.18	26.7	0.82	0.160	32	68
	96	1.12	29.8	0.85	0.149	25	75
12-S-C	7.9	0.59	42.7	1.87	0.121	25	75
	13	0.57	35.2	1.96	0.136	25	75
	25	0.58	31.6	1.90	0.144	30	70
	48	0.62	19.2	1.82	0.190	30	70
	73	0.70	16.9	1.45	0.202	31	69
13-U-S	25	0.84	41.0	1.15	0.126	25	75
	30	0.81	36.7	1.20	0.134	26	74
	34	0.98	40.1	0.96	0.127	40	60
	52	0.94	67.8	1.01	0.098	15	85
	77	0.79	29.9	1.25	0.151	26	74
13-U-S	5	0.62	39.1	1.71	0.127	13	87
	8.7	0.66	57.6	1.67	0.112	7	93
	12	0.41	71.3	3.17	0.094	5	95
	15	0.40	54.2	3.34	0.109	5	95
	22	0.81	47.1	1.21	0.115	21	79
	28	0.83	41.2	1.19	0.123	22	78
	32	0.94	45.4	1.02	0.118	32	68
	50	0.95	30.5	1.00	0.147	33	67
	71	0.82	29.2	1.20	0.149	21	79
	114	0.94	26.0	1.02	0.160	29	71

TABLE 3.17 (Continued)

Gamma Energy of Soil Samples Versus Time

Sample	Time after burst (hours)	Absorption Coefficients (cm²/mg) Pb		Energy (Mev)		Relative Abundance %	
		μ_1	μ_2	E_1	E_2	A_1	A_2
13-U-S	6	0.63	57.6	1.67	0.105	10	90
	9	0.73	43.7	1.40	0.120	11	89
	13	0.69	52.0	1.49	0.118	10	90
	16	0.80	40.7	1.22	0.126	16	84
	23	0.87	67.0	1.10	0.098	15	85
	29	0.93	65.3	1.04	0.100	20	80
	33	0.91	86.2	1.06	0.086	18	82
	51	0.92	80.6	1.04	0.090	15	85
14-U-S	30	0.84	35.0	1.16	0.137	29	71
	34	0.85	29.4	1.14	0.152	32	68
	53	0.93	26.4	1.02	0.160	34	66
	80	0.89	26.6	1.09	0.160	25	75
15-U-S	30	0.86	43.3	1.12	0.121	27	73
	34	0.87	32.2	1.10	0.144	33	67
	53	1.00	26.6	0.95	0.160	39	61
	80	0.87	27.5	1.10	0.158	23	73
16-U-S	35	0.91	32.6	1.05	0.142	34	66
	54	0.85	21.1	1.14	0.182	33	67
	77	0.91	26.4	1.05	0.160	27	73
17-U-S	35	0.92	34.1	1.04	0.140	35	65
	54	0.97	22.8	0.99	0.174	38	62
	79	0.97	32.6	0.99	0.142	27	73
18-U-S	35	0.99	43.5	0.96	0.121	36	64
	55	0.97	25.0	0.99	0.165	37	63
	81	0.97	32.2	0.99	0.144	28	72
19-U-S	35	0.94	35.0	1.02	0.137	39	61
	55	0.91	24.5	1.06	0.167	33	67
	81	0.93	26.6	1.03	0.160	30	71

TABLE 3.17 (Continued)

Gamma Energy of Soil Samples Versus Time

Sample	Time after burst (hours)	Absorption Coefficients (cm^2/mg) Pb		Energy (Mev)		Relative Abundance %	
		μ_1	μ_2	E_1	E_2	A_1	A_2
27-U-C	7.5	0.76	66.8	1.30	0.099	13	87
	9.2	0.80	72.9	1.23	0.094	12	88
	13	0.79	68.2	1.26	0.098	12	88
	16	0.86	50.7	1.12	0.113	19	81
	23	0.97	75.9	1.00	0.093	24	76
	29	0.99	44.3	0.97	0.120	36	64
	34	1.05	59.9	0.91	0.104	36	64
	51	0.89	68.5	1.09	0.097	28	72
	73	1.05	57.6	0.91	0.106	26	74

the mass absorption coefficient of the two components for lead. In columns 5 and 6 are listed the corresponding energies in Mev. These values were obtained from a plot of the data on mass absorption coefficient vs energy from the 33rd edition of the Chemical Rubber Company Handbook of Chemistry and Physics.

Because of the Kα absorption edge of Pb this plot was discontinuous and double-valued for some of the μ values obtained for the soft component. Where two possible energy values were indicated by the plot, the higher has been listed. This value was selected because it was consistent with those energy values obtained with μ values outside the double-valued region of the plot.

The relative amounts of the two components are listed in columns 7 and 8. These values have been corrected for the change in the tube efficiency with gamma energy. Since the efficiency of a G-M tube made of low atomic weight elements is roughly proportional to the gamma energy[1] this correction was made by dividing the observed counting rate by the energy in Mev of the component in question.

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1. S.C. Brown, "Theory and Operation of Geiger-Muller Counters-II", NUCLEONICS 3, 50, (August 1948).
   C.D. Coryell and Nathan Sugarman, Radiochemical Studies: The Fission Products, Book 1, page 22, McGraw Hill Book Company, Inc., New York, (1951).

The trend of this data is shown in Figures 3.14 and 3.15.

3.3.6 Beta Specific Activity

The data for beta specific activities are listed in Table 3.18 in millicuries/gram at H + 10 hours. These values include corrections for geometry, backscattering, self-absorption, mass absorption

[redacted]

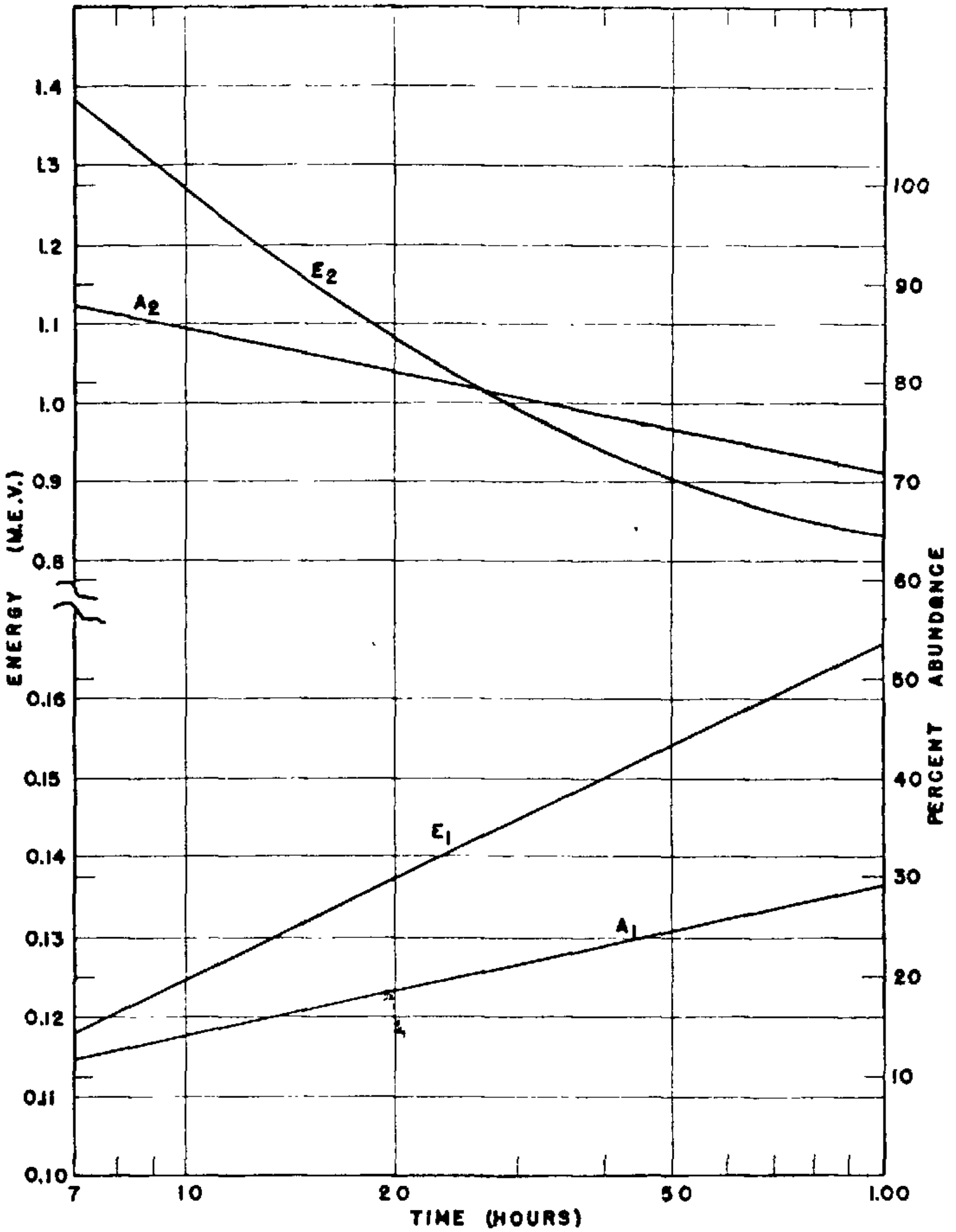

Figure 3.14. Effective Gamma Energies of Surface Soil Samples from Surface Burst

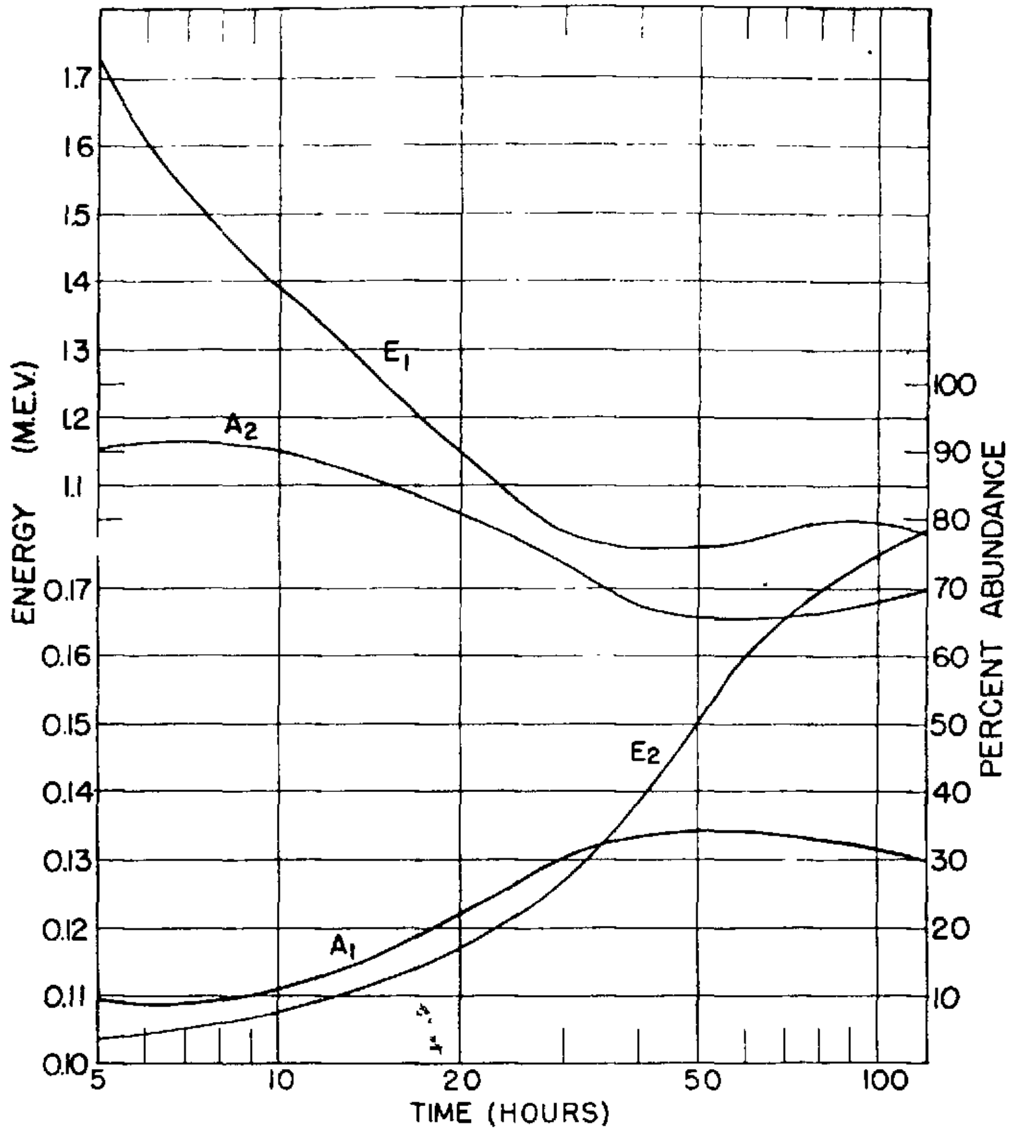

Figure 3.15. Effective Gamma Energies of Surface Soil Samples from Underground Burst

TABLE 3.18

Gross Beta Specific Activities

Sample	μc/gm at t_o + 10 hrs
1-S-S	2,100
2-S-S	4,300
3-S-S	1,050
4-S-S	10,000
6-S-P	2.1
7-S-P	0.2
8-S-P	2
22-U-P	4.2
23-U-P	0.1
24-U-P	0.4
9-S-C	120
10-S-C	120
11-S-C	170
12-S-C	63
25-U-C	250
26-U-C	6
27-U-C	200

Sample	μc/gm at t_o + 10 hrs
13-U-S	5,000
14-U-S	4,500
15-U-S	9,000
16-U-S	5,500
17-U-S	5,600
18-U-S	4,000
19-U-S	3,900
20-U-S	1,700
21-U-R	3,800
33-U-W	560
34-U-W	8
35-U-W	0.5
36-U-W	570
37-U-W	1.5
38-U-W	2.5
39-U-W	14
40-U-W	1.8

The correction factors for mass absorption were calculated for the same mixtures with equations 3.11 and 3.12.

The corrections for decay were made to $t_0 + 10$ hours by empirical data on other aliquots of the particular sample or by the curves in Figure 3.3. Corrections to an earlier time would have required extrapolations beyond the measured decay curves.

3.4 EFFECT OF WEATHERING

The results of the chemical analysis of samples taken in connection with the weathering study are listed in Table 3.19. The presence of small amounts of fission products one and two inches below the surface (samples 34-U-W and 35-U-W) before weathering is most logically interpreted as contamination introduced during sampling although it could be the result of weathering and/or disturbance of the fall-out from the surface shot. Such an interpretation throws much doubt as to the meaning of similar amounts of activity found in sub-surface samples after "rainfall" but it is probably due to contamination during sampling. In any event the conclusion that at most only small amounts of activity is carried into the soil by leaching seems evident. This conclusion is supported by samples 41-U-W and 42-U-W which were water extracts of a large sample of surface soil. The results of these analyses show that only about one per cent of the activity is soluble in distilled water.

TABLE 3.20

Solubility of Residual Activity

Element	% Dissolved	
	1 hr.	8 hrs.
Mo	0.6	0.1
Ag	8.8	11.0
Ba	0.6	0.1
Zr	0.6	0.2
Ce	-	1.5

p. 64 Deleted

CHAPTER 4

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

4.1 FRACTIONATION OF FISSION PRODUCTS

The R factors in Table 3.3, 3.5 and 3.7 show rather conclusively that there is considerable fractionation of the fission products. The trend of these data is summarized in Table 4.1. From these data we see that the relative amount of Sr is the most dependent upon location of sample and that Ba is the next most susceptible to fractionation. The relative amounts of Zr, Ce and Mo are comparatively constant. The high R values of Ag are difficult to interpret since the fission yield of Ag is known to be more dependent upon the nuclear components of the weapon than are the other isotopes determined.

TABLE 4.1

The relative amounts of Sr and Ba increase with altitude or distance from ground zero. Fundamentally this can be considered a measure of the time of sampling. The explanation for this change in composition must lie, at least in part, in the gaseous precursors of Ba and Sr and in the washing or scrubbing action of the large amount of soil blown into the cloud and fire ball. Other work[1] has shown that the fission products are removed from the fire ball as small particles of condensed minerals. The diameter of these particles vary from a fraction of a micron to, in rare cases, several millimeters. They may be apparently homogenous beads condensed from molten material or semi-fused particles of earth with occlusions of fused particles of fission products. In any event their composition must, on the average, represent the composition of the fire ball or cloud at the time they were formed. A consideration of the fission chains (see Figure 2.1 for examples) initiated by the detonation shows that the isotopic composition of the cloud is changing quite rapidly at first. The fission products removed early by the scrubbing action of soil blown into the cloud or the condensation of relatively large particles from the high concentration of vaporized material would be expected to contain relatively small amounts of Ba and Sr since they exist at this time largely in the form of their rare gas precursors. The early removal of a large amount of activity would of course make the relative contribution of Ba and Sr to the remaining activity quite large. Note that the distribution of Sr, whose gaseous precursor has a 2.6 minute half life, varies much more than does the distribution of Ba, whose gaseous precursor has a 16 second half life.

The samples from cascade impactors, for the study of chemical composition as a function of particle size, had such low activities that the data obtained are inconclusive.

4.2 DISTRIBUTION OF RESIDUAL ACTIVITY

The residual activity near the bomb crater seems to lie almost entirely on the surface. Table 3.4 indicates very little activity in the core samples and some of this may have been due to unavoidable contamination arising from the method of sampling. Table 3.18, giving beta specific activities, indicates considerable variation over the surface of the crater lip from the underground burst. However, this is not so noticeable in Table 3.1 which gives the abundance of separate isotopes for these samples. This difference is probably due to inhomogeneity in the samples and would be much more conspicuous in the small aliquots taken for specific activity than for the larger aliquots used for chemical analysis. This inhomogeneous nature of soil samples was very noticeable in the small aliquots used for determination of early beta decay.

It should be pointed out that great caution should be exercised in drawing conclusions from small soil samples. This applies not only to specific activity measurements but also to the determination of the

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[1] Report Project 2.5a-1 "Airborne Particle Studies", Army Chemical Center.
Report Project 2.5a-2 "Radiochemical Studies of Large Particles", Army Medical Center.

composition of the residual activities. Table 3.11 shows very clearly the variation in the relative abundance of neptunium and the fission products with small aliquots.

Distribution of activity as a function of distance from ground zero cannot be obtained from the data in this report because of the method of sampling which included an undetermined amount of sub-surface soil. A correlation between the specific activity per unit of area is given by sample 33-U-W and the intensity of the radiation field at a height of 3 feet on the morning of D + 3 at a position 6000 feet north of ground zero. A specific activity of 10.5 mc/ft^2 corresponded to a reading of 3.7 r/hr. obtained by a monitor with a survey meter.

4.3 CONTRIBUTION OF NEPTUNIUM

The theoretical aspects of the contribution of neptunium to the residual activity from this type of bomb has been discussed in another report.[1] The actual neptunium contribution on these tests is shown in Figures 3.3 and 3.4 and in Table 3.11. Equation 3.7, which describes the beta decay for crater lip samples from the surface shot, indicates that between 15 and 300 hours the beta contribution from neptunium is greater than that from the fission products. Between 90 and 120 hours the contribution of neptunium is more than three times that of the fission products.

Similar analyses could not be made of samples from the underground burst but the general similarity of the decay curves indicate a neptunium contribution of about the same magnitude.

4.4 CONTRIBUTION OF INDUCED ACTIVITY

The contribution of activity induced in the soil is believed to be small, but is somewhat greater in the underground than in the surface burst. However, this conclusion is somewhat subjective and is based upon the low specific activity of all of the pebble samples, and on the shape of the beta decay curves.

The fact that the beta activity of soil samples from the surface burst could be represented by an equation describing only the decay of fission products and neptunium indicates a relatively small contribution of other activities. This observation, of course, neglects the possible effect of fractionation on the shape of the normal fission product decay curve.

The fact that the same type of equation gave a poor description of

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[1] G.W. Johnson, "The Contribution of the Neptunium^{239} Activity to the Total Fission Product Activity", AFSWP-101, 18 September 1951.

the decay of samples from the underground burst indicates a larger contribution of induced activity since this lack of correspondence was most pronounced in the early stages of decay, at the time when this induced activity would be expected to be most prominent.

No conclusions can be drawn from the iron determinations. The inclusion of a large amount of structural steel near the weapon and the presence of some iron in the weapon itself makes interpretation impossible. This iron was not distributed and therefore did not receive the same neutron flux as did the surrounding soil.

4.5 GROSS BETA DECAY

The gross beta decay is much different from that observed for other bursts. The characteristics of the decay are most accurately summarized by referring to Figure 3.3. The departure from normal is almost certainly due to the contribution of neptunium.

4.6 GROSS GAMMA DECAY

The trend in gamma decay is best seen by referring to Figures 3.8 and 3.9. It will be observed that the two curves vary considerably with the measuring instrument used. The initial slow rate of decay followed by a very rapid rate, as observed with the ionization chamber, is probably due to the soft gamma contribution arising from neptunium. The low efficiency of G-M tubes for detection of soft gamma radiation minimizes the contribution of neptunium in data obtained with this type of counter.

4.7 GAMMA AND BETA EFFECTIVE ENERGIES

The gamma and beta effective energies of the residual activity change with time. There is a change both in the average energies of the various components and in the relative contributions of their energies. The general trend is best seen by referring to Figures 3.11, 3.12, 3.14 and 3.15.

4.8 EFFECT OF WEATHERING

Any effect produced by weathering in the atypical soil of the Southwest will almost certainly be the result of physical movement of the soil. The field test showed no transport of activity by a slow rain. Laboratory tests indicated that the activities were essentially insoluble in rain water. Rain will probably reduce the inhalation hazard but will almost certainly not reduce the strength of the radiation field.

The absence of appreciable amounts of fission product activity below the surface after "rain" is in disagreement with the observations[1] made at Einwetok on operation Sandstone. However, the coral sand there is just as atypical as the hard-packed sand of the Nevada flats.

4.9 RECOMMENDATIONS

4.9.1 Fractionation

Additional study on fractionation seems to be in order, but to be of much value it would require a large effort. In addition to determinations of the type reported here an attempt should be made to correlate the individual activities with the unfissioned bomb material.

Chemical composition as a function of particle size is of great interest but a method of sampling other than cascade jet impactors should be used. To be of maximum value the investigation of this phenomenon should include a study of the effect of distance (time and/or space) from the detonation.

An investigation of the chemical composition of individual particles or of small samples taken under as near as possible identical conditions should be of particular interest. Information on this subject might throw considerable light on the nature of particle formation and the physical conditions of mixing etc. in the fire ball and cloud.

4.9.2 Induced Activity

Although this investigation indicates a relatively small contribution of induced activity to the total radiation hazard associated with these types of burst, the exact magnitude of that contribution has not been established. If more exact information be desired it is recommended that the chemical determination be done in a well-equipped, well-staffed laboratory at the test site. In this manner measurements on the short lived isotopes could be made.

4.9.3 Effective Beta and Gamma Energies

Although some measurements of the effective energies of the beta and gamma radiation were made on this project, the method used is not the method of choice. If more exact information is desired it should be obtained with different techniques or, if by the technique used here, be the major effort of a special group.

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[1] H.L. Andrews and R.E. Murphy, "Residual Contamination in the Craters: Operation Sandstone" January 1949.

4.9.4 Sampling

Efforts to obtain samples at an earlier time than used in this investigation (three to six hours) seems unwarranted for chemical measurements but not necessarily so for physical measurements. For surface samples the retrievable rocket and its modifications[1] would probably be adequate. However, the retrievable rocket would not obtain the core samples secured in this operation by remotely controlled weasels.

4.9.5 Weathering

Further study of weathering by rainfall seems to be unwarranted in view of the atypical nature of the Nevada terrain.

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[1] Report Project 2.6c-3 "Retrievable Missiles for Remote Ground Sampling.

APPENDIX A

RADIOCHEMICAL ANALYSIS

A.1 GENERAL

The samples analyzed at the laboratories of the National Institutes of Health fell into four categories:

a. Earth (or other siliceous material) pulverized to approximately 100 mesh.

b. Filter papers, from air sampling devices, containing earth particles.

c. Fall-out material.

d. Earth particles impacted on cellophane tape.

There were three principal steps involved in the analysis:

a. Dissolving of material.

b. Chemical separation.

c. Mounting and counting.

Detailed methods used are included among the procedures in A.7. The following isotopes were determined: molybdenum, silver, barium, strontium, zirconium, cerium, and iron.

A.2 LABORATORY PROCEDURE

The analytical procedures used were based on procedures furnished by Dr. Lloyd Zumwalt[1] and Dr. Rod Spence.[2] These were substantially the same as those in the National Nuclear Energy Series.[3,4] However, it was

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1. Tracerlab, Inc., Western Division, San Francisco, California.
2. Los Alamos Scientific Laboratory, Los Alamos, New Mexico.
3. C.D. Coryell and Nathan Sugarman, Radiochemical Studies: The Fission Products, Book 1, Book 2 and Book 3, McGraw-Hill Book Company, Inc., New York, (1951).
4. C.J. Rodden, Analytical Chemistry of the Manhattan Project, McGraw-Hill Book Company, Inc., New York, (1950).

necessary to adapt these procedures for use with soil solutions since they were designed for work on clean target solutions of air filter samples containing very small amounts of earth.

In order to prepare a maximum amount of data in a limited time, the laboratory was organized as an "assembly line". Large groups of samples were analyzed for a particular isotope at the same time and each chemist was assigned a portion of the procedure. One man did all the weighing, another the fusion, still another operated a battery of centrifuges, etc. Each sample was accompanied with a check list which provided a running record of its progress in the procedure.

The analyses were run in the following order:

Mo, Ag, Ba on soil from surface burst
Mo, Ag, Ba on air filter samples from surface burst
Mo, Ag, Ba on weathering samples from surface burst
Mo, Ag, Ba on all samples from underground burst
Sr on all samples from both bursts
Fe on all samples from both bursts
Ca on all samples from both bursts
Zr on all samples from both bursts
Ce on all samples from both bursts

This routine type of analysis produced the most results and reduced errors to a minimum during the extremely long hours worked on the analysis of the short lived isotopes.

A.3 SAMPLING PROCEDURE

Where the mass of the sample permitted, three aliquots of each soil sample were put into solution and stored in polyethyleneglycol bottles. Duplicate determinations were made for each isotope on aliquots from these solutions. This procedure provided six determinations of each isotope on each soil sample.

Each air filter sample and cascade impactor sample was dissolved as a unit and stored in the plastic bottles. Duplicate determinations for each isotope were made on each sample.

A.4 CHEMICAL YIELDS

Chemical yields as determined by the weight of the individual carrier precipitate averaged as a whole 62%. The average chemical yields for the individual isotopes were 80% for Ag, 79% for Sr, 72% for Ba, 57% for Ce, 53% for Mo, and 31% for Zr. Approximately 80% of the yields were within 20% of these average values.

The effectiveness of the chemical separation was checked by decay curves or aluminum absorption curves on several samples from each batch carried through the assembly line. Absorption curves were run on Ce and Sr and decay curves on all isotopes except Ce. In every case the curves had the expected slopes and indicated a clean chemical separation.

A.5 PLANCHET PREPARATION

The final precipitates were all counted in the same manner. The final solutions were filtered with suction through a two-piece, gold-plated Buchner type filter which gave a precipitate of defined geometry (Figure A.1).

The precipitate was dried and weighed for the determination of chemical yield and mounted on an aluminum planchet. (Figure A.1). The precipitate and filter paper were firmly secured to the planchet by an overlying sheet of thin plastic which was held in position by the tightly fitting outer ring. This plastic cover prevented loss of precipitate, change in geometry, and contamination of counting equipment. Its effect upon the counting efficiency was determined empirically (Section A.6.1). Saran FR1005 plastic, with a thickness of 2 mg/cm^2, was used.

A.6 COUNTING TECHNIQUES

Counting rates were measured in conventional lead pigs with G-M tubes having end windows less than 2 mg/cm^2 thick. The absorption curves were determined with Tracerlab automatic equipment and E-25 aluminum absorber kit (Section 2.3.4).

For the most part, observed counting rates are based on 10,000 or more total counts, and in no case on less than 5,000 total counts. The observed counting rates were corrected for coincidence and background, and then normalized to one shelf in a particular pig. Normalizing factors were obtained by counting a single sample of the isotope being determined at all the geometries used.

The normalized counting rate for each planchet was converted to absolute disintegration rates at t_0 by the application of correction factors for (a) decay, (b) self-absorption, (c) air and window absorption, and (d) counter efficiency.

The decay factors were obtained from the time of counting and the exponential decay constant for each isotope.

The self-absorption factors were taken from graphs of counting rate vs precipitate weight prepared with constant aliquots from solutions of each isotope and different amounts of carrier.

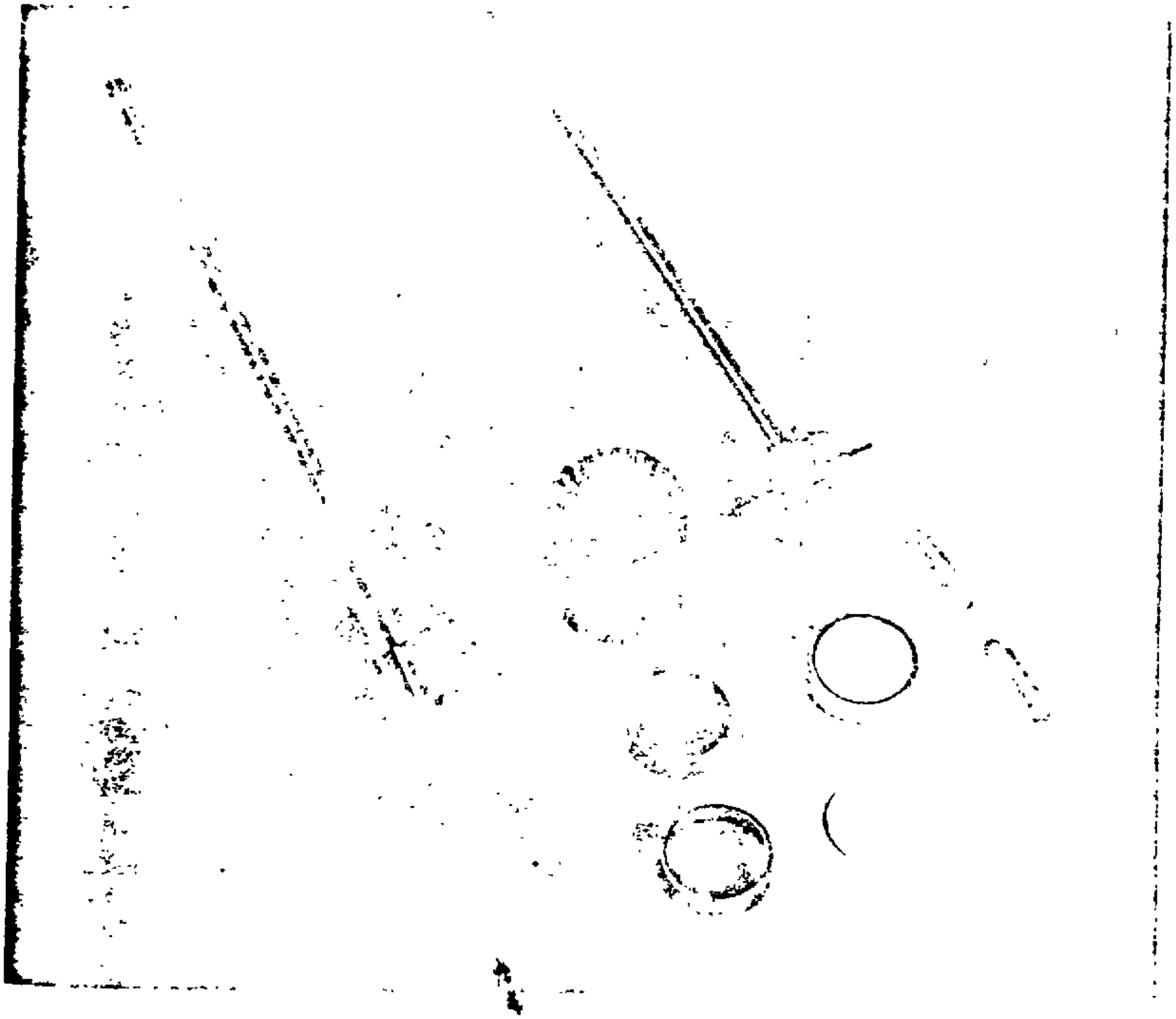

Figure A.1 Equipment for Preparing Planchets

The air and window absorption factors were calculated using the formulae[1]

$$F_w = e^{-\mu t} \qquad (A.1)$$

$$\mu = 0.017E^{-1.43} \qquad (A.2)$$

where t equals absorber thickness in mg/cm^2 and E is the maximum energy of the beta particle in Mev.

The method by which the absolute counting efficiencies were evaluated is described in Section A.6.1.

A.6.1 Absolute Counting Efficiency

The absolute counting efficiency of the counting equipment was obtained by determining the counting rates of precipitates of AgCl prepared from aliquotes of $AgNO_3$ solution of known specific activity.

The $AgNO_3$ solution was prepared from a neutron-bombarded palladium foil obtained from Oak Ridge. The specific activity of the solution was determined by a method described by Gleason, Taylor, and Tabern[1]. Aliquots of the solution were evaporated as point sources (less than 3mm diameter) on thin sheets of Saran plastic and counted in the conventional lead pig with thin end-window G-M tubes.

The physical geometry was accurately defined by a metal diaphram placed between the point source and the G-M tube. Air and window absorption were calculated by the method described above.

Self-absorption in the essentially weightless sample, backscattering from the 2 mg/cm^2 plastic backing, and forward scattering by the air were small and considered to be zero.

The specific activity of the solution was calculated from the aliquot volume, physical geometry, air and window absorption and observed counting rates.

The absolute counting efficiency of our equipment for Ag was determined from observed counting rates of precipitates of AgCl prepared in the usual manner from aliquots of the standardized solution. The observed counting rates were corrected for chemical yields, self-absorption, and air and window absorption. The physical geometry, the backscattering from the filter paper and the aluminum planchet, and the absorption and forward scattering of the Saran film were lumped into one factor termed counting efficiency.

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[1] G.I. Gleason, J.D. Taylor and D.L. Tabern, "Absolute Beta Counting at Defined Geometries", Nucleonics, Vol. 8, No. 5, 12-12, (May 1951).

The factor for the counting efficiency of Ag determined above was used as the factor for all isotopes determined. This is recognized as in error but it is believed to be sufficiently accurate for the purpose of this investigation. The physical geometry was the same for all isotopes. The error in assuming constant backscattering is certainly small since it is independent of beta energy above one Mev and has a maximum value for paper and aluminum of approximately 15%[1]. The error in neglecting absorption of the plastic covering is believed to be small because it was largely compensated for by forward scattering. Experimental counting rates measured with the plastic cover were often greater than those measured without the cover.

A.6.2 Special Techniques

Cerium: The determination of the disintegration rate of Ce^{144} was complicated by the presence of Ce^{141} and Pr^{144}. The latter is the daughter of Ce^{144} and has a half life of 17.5 minutes which makes it impossible to prepare and count a planchet before an appreciable amount of the isotope has grown in. Ce^{144} is present because it is a fission product and cannot be removed by chemical purification. Its half life of 30 days prohibits waiting for its removal by decay. The difficulty was overcome by waiting for at least two hours for equilibrium between Pr^{144} and Ce^{144} and counting the mixture with a 112 mg/cm^2 aluminum absorber. Several absorption curves of the equilibrium mixture showed that this absorber completely removed the 0.6 Mev beta from Ce^{141}, the 0.4 Mev beta from Ce^{144}, and transmitted 70% of the 3.1 Mev betas from Pr^{144}. The disintegration rate of Pr^{144} calculated with this 70% transmission factor and the usual counter correction factors corresponds to the disintegration rate of Ce^{144} at the time of measurement.

Barium: It was necessary to count Ba^{140} as soon as possible after the purification in order to avoid contribution by the daughter La^{140} which has a half life of 40 hours. Measurements were made within two hours after the last purification step. The La^{140} contribution at that time is approximately 3%.

A.7 SPECIFIC ANALYTICAL PROCEDURES

A.7.1 Method for Dissolving Soil Samples

1. To a 2 gm soil sample in a 100 ml platinum evaporating dish, add 5 ml HF (48%). Digest on hot plate, evaporate to dryness.

2. Repeat step 1 four times.

---

[1] B.P. Burtt, "Absolute Beta Counting", Nucleonics, Vol. 5, No. 2, 28-43, (August 1949).

3. To residue in dish, add 5 ml $HClO_4$ (68-70%) and evaporate to dryness.

4. Repeat step 3 twice.

5. To residue in dish add 30 ml conc. HNO_3, heat, and add 50 ml H_2O.

6. Transfer to 100 ml volumetric flask and make up to volume with H_2O.

A.7.2 Method for Dissolving Air Filter and Impactor Samples

1. Place filter or impactor sample in 400 ml beaker, add 50 ml fuming HNO_3, heat on hot plate and evaporate almost to dryness. Repeat if necessary.

2. Add 10 ml $HClO_4$, 10 ml conc. HNO_3, evaporate almost to dryness.

3. Add 10 ml H_2O, transfer to 100 ml platinum dish, wash sparingly. Add 10 ml HF, evaporate to dryness. Repeat HF treatment.

4. Add 25 ml H_2O and a few ml HNO_3 to dissolve residue. Transfer to 50 ml volumetric flask and make up to volume.

A.7.3 Filter Paper Preparation

Filter papers as specified in the various procedures are prepared as follows:

1. Mount on gold filter apparatus without funnel head.

2. Turn suction on.

3. Wash with 3-5 ml portions H_2O.

4. Wash with 3-5 ml portions ethyl or methyl alcohol as called for in procedures.

5. Suck dry and turn suction off.

6. Remove paper and place in drying oven, on porcelain plate, at temperature specified in procedure, for 30 minutes.

7. Cool in dessicator for 10 minutes.

8. Bring to constant weight by redrying and reweighing until within 0.1 mg.

A.7.4 Procedure for Molybedenum Analysis

Carrier Solution: 10 mg Mo/ml., $(NH_4)_6Mo_7O_{24}$ in H_2O.

Weighed and counted as: $PbMoO_4$.

Standard precipitate thickness: 13.4 mg/cm^2

Reagents:

Conc. HNO_3
Saturated oxalic acid.
2% Cupron (α benzoin oxime) in ethyl alcohol.
1 N HNO_3
$HClO_4$ (70-72%)
Conc. NH_4OH
$FeCl_3$ in H_2O, 10 mg. Fe+++/ml.
Methyl red indicator
0.1M $Pb(NO_3)_2$
10% Sodium acetate

1. To 5 ml soil solution containing the activity add 10 mg.Mo carrier.

2. Add 2 ml conc. HNO_3, dilute to 20 ml with water. Add 1 ml saturated oxalic acid,[1] stir, add 6 ml 2% Cupron, stir.

3. Centrifuge; decant, discard supernate.[2]

4. Wash twice with 20 ml 1N HNO_3. Discard supernates.

5. Add 3 ml conc. HNO_3, 2 ml 70-72% $HClO_4$, warm carefully in a water bath 3-4 minutes, transfer to 125 ml Erlenmeyer flask, wash tube with 3 ml conc. HNO_3 (warm if necessary) then with 2-4 ml water, transferring washings to flask.

---

1. Oxalic acid complexes Niobium.
2. Because of the size and gelatinous nature of this precipitate, it is best to centrifuge for a short while, then break up the precipitate and recentrifuge.

6. Place flask on hot plate at low setting until vigorous boiling ceases. Then heat on hot plate at high setting until residue is nearly dry. Heat carefully at end during exothermic phase.

7. Cool flask, dissolve residue in 3-4 ml conc. NH_4OH added slowly, transfer to a clean tube. Wash flask with water and add washings to tube until volume is 20 ml.

8. Add 10 mg. Fe carrier, stir.

9. Centrifuge.

10. Add 6 ml conc. HNO_3 to a clean tube, transfer supernate to this tube.

11. Cool 3-4 minutes in an ice bath, add 1 ml sat. oxalic acid, stir, add 8 ml 2% Cupron, stir.

12. Centrifuge, decant, discard supernate.

13. Wash twice with 20 ml 1N HNO_3, discard supernates.

14. Repeat steps 5 through 9.

15. Transfer supernate to clean tube, add 1 drop Methyl red indicator and conc. HNO_3 dropwise until acidic.[1]

16. Add 1 ml 6N HNO_3, heat to boiling.

17. Add 3 ml 0.1M $Pb(NO_3)_2$, stir and boil for 1 minute.

18. Add 5 ml 10% sodium acetate, boil, cool in ice bath for three minutes.

19. Filter through gold filter through previously prepared No. 5 paper with very little suction.

20. Wash 3 times with 5 ml water, three times with 5 ml 95% ethyl alcohol. Dry 15 minutes at 110°C. Cool in dessicator, weigh to constant weight.

21. Mount and count.

---

[1] Best yields are obtained by doing the stirring continuously on a mechanical stirrer throughout steps 15-18.

A.7.5 Procedure for Silver Analysis

Carrier Solution: 10 mg Ag/ml, $AgNO_3$ in H_2O.

Weighed and counted as: AgCl.

Standard precipitate thickness: 6 mg/cm^2.

Reagents:

6N HCl
Conc. NH_4OH
$FeCl_3$ in H_2O, 10 mg. Fe+++/ml.
$(NH_4)_2$ S, light yellow
Conc. HNO_3
Phenolphthalein indicator.
6N NH_4OH
Filter aid (C.P. diatomaceous earth).
6N HNO_3
1% Aerosol solution

1. To 5 ml soil solution containing the activity add 20 mg. Ag^+ carrier, make up to 10 ml.
2. Add 1 drop of 1% aerosol, heat to boiling, add 1 ml 6N HCl, stir until AgCl coagulates.
3. Centrifuge, decant, discard supernate.
4. Wash with 5 ml water, discard wash.
5. Dissolve AgCl in 2 ml conc. NH_4OH, heat if necessary.
6. Dilute to 5 ml, add 10 mg. Fe carrier dropwise while stirring.
7. Add 2-3 drops aerosol, centrifuge and decant into a clean tube.
8. Wash $Fe(OH)_3$ with 2-3 ml water containing a few drops of NH_4OH.
9. Centrifuge, combine wash with supernate in step 7.
10. Add 4 drops aerosol and 2 ml $(NH_4)_2S$.
11. Continue stirring until Ag_2S coagulates.

12. Centrifuge, decant, and discard supernate.

13. Wash with 5 ml water, discard wash.

14. Add 4 ml conc. HNO_3, heat to boiling, stir 10 minutes to dissolve Ag_2S.

15. Place tube in ice bath under stirrer, add 5 ml. conc. NH_4OH cautiously, then 2 drops phenolphthalein, then NH_4OH dropwise until alkaline.

16. Add 10 mg. Fe carrier dropwise while stirring.

17. Add 2-3 drops aerosol, stir.

18. Centrifuge and decant into a clean tube.

19. Wash $Fe(OH)_3$ with 2-3 ml water containing 3 drops NH_4OH.

20. Centrifuge, combine wash with supernate in step 18.

21. Repeat steps 10 through 20 using filter aid to flocculate Fe precipitate.

22. Quickly add 4 drops aerosol, 1 ml 6N HCl and 2 ml 6N HNO_3, stir.

23. Filter immediately on previously prepared No. 42 paper.[1]

24. Wash with 3-5 ml portions H_2O, then 3-5 ml portions ethyl alcohol.

25. Dry at 90 - 100° C for 10 minutes, cool and weigh to constant weight.

26. Mount and count.

A.7.6 Procedure for Barium Analysis

Carrier Solution: 10 mg Ba/ml, $Ba(NO_3)_2$ in H_2O.

Weighed and Counted as: $BaSO_4$.

Standard precipitate thickness: 6 mg/cm².

---

[1] If not filtered immediately, large particles of coagulated AgCl cause uneven distribution, introducing a counting error due to self-absorption.

PROJECT 2.6c-1

Reagents:

$Sr(NO_3)_2$ in H_2O, 10 mg Sr^{++}/ml
Fuming HNO_3
$FeCl_3$ in H_2O, 10 mg. Fe^{+++}/ml.
6 N NH_4OH
5% NH_4NO_3
Conc. NH_4OH
6 N HNO_3
6 N Acetic acid
6 N Ammonium acetate
6 N HCl
3 N H_2SO_4
1.5 M K_2CrO_4
Fresh cold ether-HCl reagent (5 pts. conc. HCl, 1 pt. ether).

1% Aerosol solution.

1. To 5 ml sulphate-free soil solution, containing the activity, add 20 mg. Ba^{++} and 20 mg. Sr^{++}.

2. Stir thoroughly, let stand 5 minutes.

3. Add 30 ml. fuming HNO_3, to precipitate $Ba(NO_3)_2$,[1] stir and cool in ice bath for 5 minutes.

4. Centrifuge, decant and discard supernate.

5. Dissolve ppt. in 2 ml H_2O, if necessary add several more drops. Warming hastens the solution.

6. Add 10 ml fuming HNO_3, to reprecipitate $Ba(NO_3)_2$, stir and cool in ice bath.

7. Centrifuge, decant and discard supernate.

8. Dissolve ppt.* in 7 ml. H_2O.

9. Add 5 mg. Fe^{+++} carrier and 2 drops aerosol to prevent creeping.

10. Add 2 ml 6N NH_4OH while stirring.

11. Centrifuge and transfer supernate to clean tube.

---

[1] For quantitative results, fuming nitric acid at least 3 times the volume of the solution must be added. It should be added rapidly.

12. Wash ppt. by slurrying in 7 ml 5% NH_4NO_3 containing 2 drops conc. NH_4OH.

13. Centrifuge and combine supernate with 11. Discard $Fe(OH)_3$ precipitate.

14. Neutralize supernate with 6-8 drops 6N HNO_3 using 1 drop phenolpthalein indicator.

15. Add 1 ml 6N acetic acid and 2 ml 6N ammonium acetate.

16. Heat to boiling and add 1 ml 1.5 M K_2CrO_4 dropwise with stirring, stir 1 minute.[1]

17. Centrifuge, decant supernate into clean tube and save for Sr analysis.

18. Wash ppt. with 10 ml hot water.

19. Centrifuge and combine supernate from 18 with supernate from 17.

20. Do not go further unless procedure can be completed in 2 hours.[2] Dissolve $BaCrO_4$ ppt. in 2 ml 6N HCl. If white ppt. appears add 0.5 ml H_2O.

21. Add 15 ml fresh cold ether-HCl reagent and stir for 2 minutes. To coagulate $BaCl_2$ let stand 5 minutes in the ice bath.

22. Centrifuge, decant and discard supernate.

23. Dissolve $BaCl_2$ in a few drops H_2O and reprecipitate $BaCl_2$ with 15 ml ether-HCl reagent.

24. Stir 2 minutes and cool in ice bath for 5 minutes.

25. Centrifuge, decant and discard supernate.

26. Dissolve $BaCl_2$ in 10 ml H_2O, heat nearly to boiling,[3] add 5 drops 3N H_2SO_4.

27. Continue heating 3 minutes to coagulate ppt.

---

[1] This is best accomplished using a mechanical stirrer.

[2] The counting error due to the growth of the La^{140} daughter will become appreciable after two hours.

[3] A water bath serves well for this.

28. Filter in gold filter with previously prepared No. 42 paper.

29. Wash 3 times with 3 ml H_2O and then 3 times with 3 ml ethyl alcohol.

30. Dry at 90-100° C and cool in desicator.

31. Weigh to constant weight. (± 0.1 mg.).

32. Mount and count.

A.7.7 Procedure for Strontium Analysis

Carrier Solution: 19 mg Sr/ml, $Sr(NO_3)_2$ in H_2O.

Weighed and counted as: $SrCO_3$.

Standard precipitate thickness: 6 mg/cm^2.

Reagents:

Same as for barium analysis with the addition of saturated Na_2Co_3.

1. To supernate from barium step No. 19, add 6 ml saturated Na_2Co_3 slowly with stirring.

2. Heat on water bath for 15 minutes.

3. Filter on gold filter with previously prepared No. 42 filter paper.

4. Wash with 3-5 ml portions of water and 3-5 ml portions of alcohol.

5. Dry in oven at 110° C. to constant weight.

6. Mount and count.

A.7.8 Procedure for Zirconium Analysis

Carrier Solution: 10 mg Zr/ml, $ZrO(NO_3)_2$in
3N HNO_3.[1]

---

[1] Commercially available zirconium salts vary considerably as to purity. Best procedure is to dissolve, filter, precipitate as hydroxide, filter, wash, and redissolve in 3N HNO_3.

PROJECT 2.6o-1

Weighed and counted as: ZrO_2.

Standard precipitate weight: 5 mg/cm^2.

Reagents:

NH_2OH-HCl
HF (48%)
$La(NO_3)_3$ in H_2O, 10 mg La^{+++}/ml.
$Ba(NO_3)_2$ in H_2O, 50 mg Ba^{++}/ml.
Saturated H_3BO_3
Conc. HCl.
Conc. H_2SO_4.
Conc. NH_4OH.
6% Cupferron, freshly made. Keep under refrigeration.
1N HCl cold.
CH_3OH, anhydrous, cold.
Aerosol 1%.

1. To 5 ml sulfate-free soil solution containing the activity in a 50 ml lusteroid tube, add 20 mg. Zr carrier.

2. Dilute to 12 ml.

3. Add 0.3 g. solid NH_2OH-HCl and 2 cc HF and let stand 1 minute.

4. Add 5 mg. La^{+++} carrier and centrifuge briefly, add another 5 mg. La^{+++} carrier and 3 drops 1% aerosol and centrifuge thoroughly.

5. Decant supernate into clean lusteroid tube, discard ppt. and repeat step 4 on supernate. Decant supernate into clean lusteroid tube. Discard precipitate.

6. Add 150 mg. Ba^{++} carrier and let stand 1 minute. Centrifuge, decant and discard supernate.

7. Add 4 ml saturated H_3BO_3 and slurry well. Add 2 ml. conc. HNO_3 and slurry well again.

8. Add 10 - 12 ml H_2O and stir.

---

1. Best results were obtained by dissolving the cupferron in hot ethyl alcohol, filtering hot, then recrystallizing the cupferron. Commercial cupferron contained decomposition products and other impurities. The above method produces clean crystals.

9. If ppt. does not dissolve completely, centrifuge, decant supernate into another lusteroid tube and discard ppt.

10. Add 100 mg. Ba^{++} carrier and 2 ml HF. Centrifuge, decant and discard supernate.

11. Repeat steps 7, 8, 9 and 10.

12. Dissolve ppt. in 4 ml sat. H_3BO_3 and 4 ml. conc. HCl and then add 15 ml H_2O. Add 3 drops conc. H_2SO_4, stir and let stand 15 minutes.

13. Centrifuge, decant supernate into glass tube and discard ppt.

14. Add NH_4OH (conc.) until basic, (white precipitate). Centrifuge, decant and discard supernate.

15. Dissolve precipitate in 2 ml conc. HCl, 4 ml sat. H_3BO_3 and then add 10 ml H_2O. Centrifuge any undissolved materials and discard these materials.

16. Precipitate with NH_4OH. Centrifuge, decant and discard supernate.

17. Dissolve in 2 ml conc. HCl, 4 ml H_3BO_3, and then add 10 ml H_2O.

18. Precipitate with NH_4OH. Centrifuge, decant and discard supernate.

19. Dissolve ppt. in 4 ml HCl and 15 ml H_2O. Cool in ice bath and add 5 ml cold freshly made cupferron (6%), centrifuge immediately. Decant and discard supernate.

20. Add 10 ml cold 1N HCl and slurry. Centrifuge, decant and discard supernate.

21. Add 30 ml. cold CH_3OH and slurry. Centrifuge, decant and discard supernate.

22. Slurry with 3-4 ml cold CH_3OH and filter on gold suction filter using No. 42 paper with small portions of cold CH_3OH for washing.

23. In a porcelain crucible with lid, ignite ppt. very carefully over a Meeker burner. Place in a muffle for 1 hour between 600 and 800°C.

24. Slurry ZrO_2 with 5 ml. CH_3OH. Filter on gold filter with previously prepared No. 42 paper using small portions of CH_3OH for washings.

25. Dry at 110°C. to constant weight.

26. Mount and count. (Wet the precipitate with a solution of 5 drops Duco Cement in 50 ml ethyl acetate, and allow to dry before mounting. This will eliminate losses during the mounting procedure).

A.7.9 Procedure for Cerium Analysis

Carrier Solution: 10 mg Ce/ml, $Ce(HSO_4)_4$ in 3N H_2SO_4.

Weighed and counted as: CeO_2.

Standard precipitate weight: 8 mg./cm^2.

Reagents:

Conc. HNO_3
Saturated H_3BO_3
Saturated $NaBrO_3$
0.35 M HIO_3
1% HIO_3
H_2O_2 - 30%
Conc. HCl
$ZrO(NO_3)_2$ in 3N HNO_3, 10 mg. Zr^{+++}/ml.
Saturated NaOH
Solid $NaHSO_3$
Conc. NH_4OH
6N HCl
Saturated oxalic acid.

1. To 5 ml soil solution containing the activity in a 50 ml. lusteroid tube add 20 mg Ce carrier and make up to 12 ml with water.

2. Add 3 ml HNO_3, stir and let stand for 10 minutes.

3. Add 2 ml. HF, stir and let stand 5 minutes.

4. Centrifuge, decant, discard supernate.

5. Wash with 10 ml water, centrifuge, discard washing.

6. Add 1-2 ml saturated boric acid, stir.

7. Add 8 ml conc. HNO_3, stir until dissolved.

8. Transfer solution to 40 ml glass tube, wash sparingly.

9. Add 1 ml saturated $NaBrO_3$ (color change).

10. Add 20 ml 0.35M HIO_3, stir.

11. Cool 5 minutes in ice bath.

12. Centrifuge, decant, discard supernate.

13. Wash with 20 ml 1% HIO_3, centrifuge, decant, discard supernate.

14. Add 8 ml conc. HNO_3, stir, heat to boiling and add 2-3 drops 30% H_2O_2 and one drop conc. HCl.

15. Stir and add more H_2O_2 dropwise until precipitate is dissolved.

16. Heat until I_2 vapor goes off and solution clears.

17. Boil 2 minutes to get rid of excess H_2O_2.

18. Cool in ice bath and add, while in ice bath, 3 ml. sat. $NaBrO_3$ (color change).

19. Ppt. cerium by adding 20 ml 0.35 M HIO_3, stir and let stand 5 minutes in ice bath.

20. Centrifuge, decant, discard supernate.

21. Wash with 20 ml 1% HIO_3, centrifuge, decant, discard supernate.

22. Repeat steps 14 through 21.

23. Repeat steps 14 through 17.

24. Cool in ice bath. (Three hours needed to complete procedure. Do not continue unless procedure can be completed).

25. Add 10 mg. Zr carrier, add 20 ml 0.35M HIO_3, let stand 5 minutes in ice bath.

26. Centrifuge, decant supernate into a clean tube.

27. Add 10 ml saturated NaOH, stir well.

28. Centrifuge, decant, discard supernate.

29. Wash twice with 10 ml water, discard washings.

30. Add 1 ml conc. HCl, stir until dissolved and dilute to 10 ml.

31. Heat to boiling, add one drop 1% aerosol, add solid $NaHSO_3$ slowly until solution is clear and colorless.

32. Add conc. NH_4OH until $Ce(OH)_3$ ppts.

33. Centrifuge, decant, discard supernate.

34. Wash twice with 10 ml water, discard washings.

35. Dissolve in 1 ml 6N HCl.

36. Add 16 ml water, heat to boiling.

37. Add 15 ml saturated oxalic acid. If no ppt, add NH_4OH dropwise until it appears. Do not make alkaline.

38. Filter on gold filter using No. 42 paper. Wash with H_2O, then ethyl alcohol.

39. Transfer filter paper to crucible, ignite at 700° C.

40. Slurry CeO_2 with 5 ml ethyl alcohol, filter on gold filter, using previously prepared No. 42 paper. Use small portions of alcohol for washing.

41. Dry at 110° C to constant weight.

42. Mount and count.

A.7.10 Procedure for Iron Analysis

Carrier Solution:	No carrier added. Standard volumetric iron analysis run on each sample to determine amount of iron present.

Weighed and counted as: Fe_2O_3.

Standard precipitate weight: Approximately 0.8 mg/cm^2.

Reagents:

Solid tartaric acid
Conc. NH_4OH.
Conc. H_2SO_4
H_2S (gas)
10% H_2SO_4
6% Cupferron in H_2O, freshly made (See Zr procedure).
6 N NH_4OH

1. To 5 ml soil solution containing the activity add 0.1 gm tartaric acid.
2. Neutralize with conc. NH_4OH.
3. Add 3 ml conc. H_2SO_4.
4. Centrifuge, decant supernate into clean tube. Wash precipitate with 3 ml H_2O and combine wash with previous supernate. Discard precipitate.
5. Pass H_2S through solution until saturated.
6. Add NH_4OH to excess.
7. Repeat step 5.
8. Centrifuge, decant, discard supernate.
9. Dissolve precipitate in 10 ml 10% H_2SO_4.
10. If precipitate remains, centrifuge, decant supernate into clean tube, wash with 3 ml H_2O and combine wash with previous supernate. Discard precipitate.
11. Add 5 ml cold 6% cupferron.
12. Centrifuge, decant, discard supernate.
13. Wash twice with 3 ml cold H_2O. Discard washes.
14. Wash with 3 ml 6N NH_4OH. Centrifuge, decant, discard supernate.

15. Using cold H_2O, filter on No. 42 paper.

16. Ignite to Fe_2O_3 at 800°C., in porcelain crucible.

17. Slurry with 5 ml ethyl alcohol and filter on previously prepared No. 42 paper.

18. Dry at 100-110°C., weigh to constant weight.

19. Mount and count.

APPENDIX B

AIRBORNE RADIOACTIVITY AT THE NEVADA TEST SITE

Air filter samplers at the Nevada test site pick up considerable alpha and beta activity. Analysis of the decay curves of the alpha activity shows that it arises from natural sources in the vicinity and is not the result of long-lived alpha emitting bomb debris. The source and nature of the beta activity has not been established. It probably arises, to a large extent at least, from fission products and induced activities resulting from atomic bursts. The magnitude of this activity is much larger than can be accounted for by the beta emitters associated with the natural occuring alpha emitters. It has also been noted that the relative abundance and the decay characteristics of the beta activity are not constant.

Figure B.1 shows the alpha and beta decay of an air filter sample taken in the Quonset area of Camp No. 3 on October 30, 1951. The sample was collected by Project 2.5a using Chemical Corps Type VI filter paper with a filter area of 100 cm^2. The sampler was run from morning until night, approximately 10 hours, and filtered air at the rate of approximately 3 cu ft/min. The sampler was exposed to the dust, etc, resulting from the normal traffic in the area. Measurements of the activity were begun twenty minutes after the sampler was shut off. Measurements were made with a special gas flow, proportional counter. See Section 2.4.8 for description.

Analysis of the decay curves shows that the alpha activity consists of two components decaying with half lives of 33 minutes and 10.6 hours. The straight lines in Figure B.1 represent decay curves of these two components and the curved line is the sum of these two lines. The agreement between the curve and the experimental points is good. However, no known alpha emitters have half lives corresponding to these observed values!

The identity of the alpha activity is established by considering the decay schemes of U^{238} and Th^{232}, both present in the minerals of this area. Both of these elements have radioactive rare gas daughters, radon (Rn^{222}) and thoron (Rn^{220}), which escape from the mineral deposits. These gases decay to produce a suspension of very fine airborne radioactive isotopes in more or less equilibrium. The pertinent parts of the decay schemes are shown in Figure B.2.

In the Th^{232} decay scheme the two alpha emitters ThC and ThC' have half lives considerably less than their precursor ThB and hence in

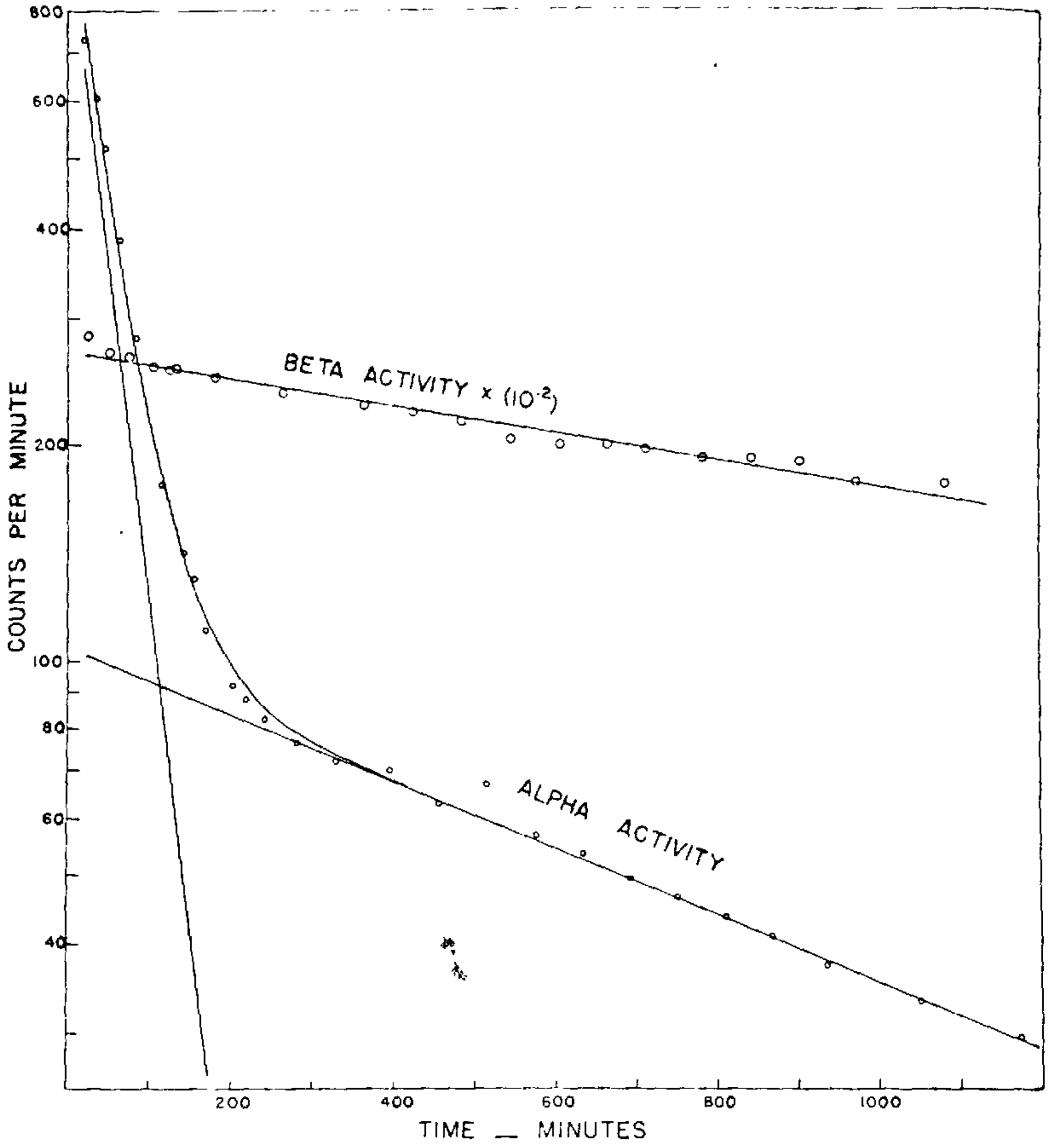

Figure B.1 Decay Curves of Airborne Radioactivity at Test Site a case of transient equilibrium would decay with an apparent half life identical with the half life of this precursor. Since the sample was collected for a long period of time and since even before sampling equilibrium is being established in the air, conditions of equilibrium or near equilibrium are to be expected. Thus the long lived alpha emitter is identified as a mixture of ThC and ThC' decaying at a rate determined by the 10.6 hour half life of their precursor ThB.

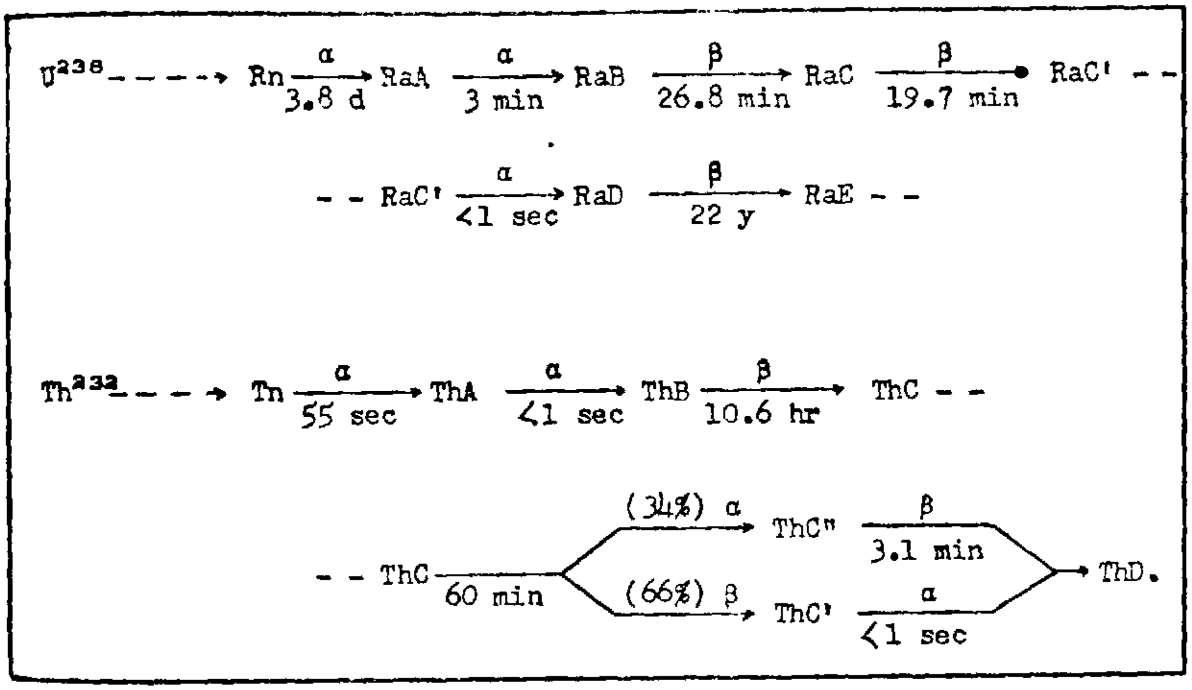

Figure B.2. Decay Schemes of Uranium^{238} and Thorium^{232}

Similarly in the decay scheme of U^{238}, RaC' is an alpha emitter whose decay rate at equilibrium is determined by its grand-parent RaB, a beta emitter with a half life of 26.8 minutes. The lack of agreement between the observed apparent half life of 33 munites and this 26.8 minute half life is probably the result of a perturbation produced by the relatively long lived (19.7 min) intermediate RaC. Lack of complete equilibrium at the start of the decay observations would result in an average half life larger than that of the grand-parent RaB. Close scrutiny of the single set of observed values for the short-lived component shows a slight downward concavity in the early portion of the curve, in complete agreement with this explanation. Thus it seems that the identity of the shorter lived component has been established as RaC' decaying at a rate determined by RaB.

U^{235} has a correspondingly alpha emitting daughter AcC' whose decay rate is similarly controlled by AcB with a half life of 36.1 minutes. The relative contribution of this isotope would be expected to be negligible and no activity with this half life has been identified in our samples.

The beta activity of this sample had an apparent half life of 28 hours. The data are shown also in Figure B.1.

A similar sample collected the same day in the field north of the Buster area gave essentially the same results on alpha activity but different results on the beta activity. This sample was collected for four hours from 7 AM until 11 AM but because of logistics was not counted until 5 PM. Activity measurements over a period of 20 hours indicated a half life of 10.5 ± 0.2 hours for the alpha activity. The shorter-lived component had completely decayed before the measurements were begun. The beta activity on this sample had a half life of 14 ± 0.4 hours.

The ratio between the beta and alpha activities on the two samples were of the same order of magnitude. A comparison of the activities measured six hours after the completion of the sampling is

for the field sample $\frac{16,400}{45} = 360$ and

for the Camp No. 3 sample $\frac{23,000}{70} = 330$

On November 11 a series of samples were collected in the field by Project 2.5a in order to determine the order of magnitude of the "background" activity which would be superimposed on their air filter samples collected for the JANGLE tests. This data is shown in Table B.1. The values given are good to approximately 20%. The purpose of the experiment did not seem to justify the longer counting times required for greater accuracy.

TABLE B.1

Airborne Contamination Observed on November 11, 1951

Station ACC No.	Time of Collection		Cubic Feet Air Sampled	Activity,[a] counts/min	
	Start	Finish		α	β
2	1527	1630	196	9	-[b]
	1322	1522	375	15	150
	0918	1315	740	25	-[b]
	0928	1528	1175	40	500
23	1610	1710	185	10	-[b]
	1406	1606	370	15	130
	1001	1401	740	24	-[b]
	1007	1607	1110	34	350
14	1550	1650	202	11	-[b]
	1349	1549	305	13	-[b]
	0944	1344	610	20	200
	0944	1544	915	36	-[b]

a. Measured five hours after completion of sampling.
b. Not measured.

OPERATION JANGLE

WT-397

PROJECT 2.6c-2

NATURE AND DISTRIBUTION OF RESIDUAL CONTAMINATION II

By

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30 June 1952

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ACKNOWLEDGMENTS

The authors thank the following contributors for their help in the accomplishment of this work.

- E.M. Scadden
- E.C. Freiling
- S.E. Turner
- A.E. Groendale
- M.H. Rowell
- H.J. Crosby
- J. Silverman
- D.F. Covell
- K.F. Sinclair
- R.H. Sorenson
- H.A. Zagorites
- J.A. Seiler
- W. Simon
- J.C. Sheppard
- J.N. Pascual
- W.H. Shipman
- M. Honma
- J.D. O'Connor
- S.C. Foti
- L. Wish
- E.W. Roberts

The editorial guidance provided by Jarvis Todd, Publications Editor, Chemical Technology Division, is gratefully acknowledged.

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CHAPTER 3 EXPERIMENTAL RESULTS

PROJECT 2.6c-2

ABSTRACT

The importance of neutron induced radionuclides has been investigated in several samples from Operation JANGLE. Np^{239}, which is produced from the bomb materials, is the only neutron induced activity of major importance.

The extent of fractionation of fission products at Operation JANGLE was shown to be quite great.

Gross decay and energy measurements were carried out on a number of samples from Operation JANGLE. These measurements included a few samples as soon as six hours after detonation.

Leaching was shown to have doubtful value as a method of soil reclamation after an underground burst under the conditions of this test.

CHAPTER 1

INTRODUCTION

The purpose of this portion of Project 2.6 is to determine the following characteristics of various radioactive soil samples:

(a) The relative amounts of neutron induced and fission product radionuclides,
(b) Gross decay rates and beta and gamma-ray energies,
(c) The leaching behavior of radioactive elements present in the soil.

This information is useful in guiding hazard evaluation studies, development of contaminant simulants, and various contamination-decontamination investigations. Thus, determinations of radiochemical composition indicate the radioelements to be considered in contamination-decontamination investigations and in formulations of contaminant simulants, and they indicate the importance to the radiation hazard of the neutron-induced radionuclides; measurements of gross decay rates and beta and gamma-ray energies are usefully applied to radiation hazard studies as they show the rate at which the radiation field is decreasing and the types and intensities of radiations which must be dealt with; determinations of leaching characteristics are of value in estimating: (1) the feasibility of leaching as a method of soil reclamation, (2) the relative merits of the various solutions with respect to soil reclamation and decontamination, (3) the correlation of laboratory experiments with field operations, and (4) the behavior of radioactive species in soil with respect to uncontrolled disturbances such as rainfall.

Four different types of soil samples were studied: scoop, core, differential fall-out, and size-separated fall-out samples. The scoop and core samples were collected for the National Institute of Health by the Evans Signal Laboratory's remotely controlled "weasel". They were obtained from the crater lip by scooping up the surface soil and by driving a coring pipe into the soil. The differential fall-out samples were collected as part of the U. S. Naval Radiological Defense Laboratory's participation in Project 2.5a; a description of the differential fall-out collectors is given in the report of that project. The size-separated fall-out samples were collected as part of the USNRDL participation in Program 6; a description of the stations is given in the report of that project. The fall-out samples were separated into fifteen size fractions by sieving.

For the determinations under (a), radiochemical analyses were run at the site for Mn^{56}, Si^{31}, and Mo^{99}. At USNRDL, the following elements were determined radiochemically: Na^{24}, P^{32}, K^{42}, Ca^{45}, Fe^{59}, Ga^{72}, Sr^{89}, Mo^{99}, Ba^{140}, Ce^{144}, Zr^{95}, Ag^{111}, Ru^{103}, Ru^{106}, Cd^{115}, and Np^{239}.

For (b), all samples available before H + 8 hr were counted at the site on a scintillation spectrometer and proportional counters utilizing automatic absorber changers. The scintillation spectrometer was a conventional one in which a 5819 photomultiplier drove a Bell and Jordan A-1 linear amplifier followed by a differential pulse analyzer coupled to a two decade scaler. Provision was also made to scale total count. Automatic scanning was accomplished by a synchronous motor driving the helipot that controlled the lower discrimination level in the analyzer so the entire pulse height spectrum could be examined continuously and be recorded automatically with a Brown potentiometer. A diphenylacetlyene crystal was used in the spectrometer for beta detection and a thallium-activated sodium iodide one for gamma detection.

The remaining and some duplicate samples were counted at USNRDL on side-window, argon-carbon dioxide gas-flow detectors connected to proportional counters. Aluminum and lead absorption curves were taken at periodic intervals to obtain average beta and gamma-ray energies as a function of time after detonation.

For (c), scoop and core samples ground to pass a 100 mesh screen were obtained from the surface burst, and an untreated scoop sample was obtained from the underground burst. They were all returned to USNRDL for the leaching experiments.

CHAPTER 2

EXPERIMENTAL PROCEDURE

2.1 DETERMINATION OF RADIOCHEMICAL COMPOSITION OF SCOOP, CORE, DIFFERENTIAL FALL-OUT, AND SIZE-SEPARATED FALL-OUT SAMPLES

Radiochemical analyses were made of the following: scoop samples, numbers 1 and 5 from the surface burst and number 18 from the underground burst; core sample from the surface burst; differential fall-out samples, numbers 33-8 and 29-12 from the surface burst and numbers 102-10, 103-15, 108-2, 108-6, 108-10, 108-15, and 108-19 from the underground burst; and size separated fall-out samples, numbers G-1-6, G-1-8, G-1-9, G-1-12, G-1-15, I-1-7, I-1-10, I-1-11, I-1-12, I-1-15, N-1-12, N-1-15, N-5-9 and N-5-10 combined, N-5-11, and N-5-15 from the underground burst. The locations of the differential fall-out collector stations and the times relative to zero time that the pertinent sectors were exposed are listed in Table 2.1. The locations of the fall-out stations pertinent to the size-separated samples are listed in Table 2.2. The various screen sizes used to make the size separations are listed with the experimental results in Chapter 3. These screens were used in a "Ro-Top" sieve shaker to separate the fractions.

The scoop and size-separated samples had been ground to pass a 100-mesh screen before portions were taken for analysis. The differential fall-out (DFO) samples, which had been collected on 1.25-mil aluminum foil covered with a water soluble grease (carbowax 1500), were simply rinsed into a platinum dish and evaporated to dryness.

Known weights of scoop, core, and size-separated fall-out samples and total differential fall-out samples were fused in platinum crucibles with a carbonate, carbonate-borate, or carbonate-fluoride flux, the particular flux used being dependent on the analysis to be performed. The melts from the fusions were dissolved in 1:1 HCl or 1:2 HNO_3.

TABLE 2.1

Locations and Exposures for D.O Collection

Locations of D.O Stations			
Station No.	Direction from Zero Point	Distance from Zero Point (ft)	Altitude above Zero Point (ft)
19 (S)	N 30° W	6,000	20
29 (S)	N 10° E	14,000	1/2
33 (S)	N 10° E	20,000	180
102 (U)	N 5° W	2,000	20
103 (U)	N 35° E	2,000	20
108 (U)	N 5° W	3,000	30
119 (U)	N 45° W	3,000	20
125 (U)	N 45° W	9,000	205

Time of Exposure of DSO Sectors		
Sample No.	Time (from zero) Exposure Started (min)	Length of Exposure
29-12 (S)	H + 72	6 min
33-8 (S)	H + 6	6 min
102-10 (U)	H + 2½	1 min
103-15 (U)	H + 20	2 days
103-2 (U)	H + 20	2 days
108-6 (U)	H + 3½	1 min
108-10 (U)	H + 7½	1 min
108-15 (U)	H + 12½	1 min
108-19 (U)	H + 16½	1 min

Posit[illegible] Separated
[illegible]

Station No.	Position Relative to Ground Zero (yd)	
F-3	300 N	300 W
G-3	600 N	300 W
H-3	900 N	300 W
I-3(a)	1,200 N	300 W
D-1	300 S	
G-1	600 N	
I-1	1,200 N	
E-1	4,000 N	
M-3	3,000 N	
M-5	2,000 N	

(a) I-3 was located in the same position, relative to ground zero, for both bursts.

The radiochemical determinations followed the procedures from Atomic Energy Commission reports[1] with some modifications. (See Appendix A.) The procedures for silicon, sodium, potassium, manganese, iron, and phosphorus were developed at USNRDL, because those available were not suitable for the present work. Samples were prepared for counting by filtering the final precipitate on a 2.3 cm diameter filter paper, placing it in the center of an aluminum card, 1/16 in. thick and 2 1/2 in. by 3 1/4 in, and covering it with 1 mg/sq cm strip of pliofilm. Counting was done either with an end-window Geiger-tube or a side-window, gas-flow proportional counting tube.

---

[1] D.N. Hume, N.E. Ballou, and L.E. Glendenin, "A Manual of the Radiochemical Determination of Fission Products Activities", CN-2815 (no date).

C.D. Coryell, "Development of Methods for the Determination of Fission Product Activities in Plant Process Solutions", CN-1312, May 23, 1945.

W. Wayne Meinke, "Chemical Procedures used in Bombardment Work at Berkeley", UCRL-432, Aug. 30, 1949.

2.2 DETERMINATION OF GROSS DECAY RATES AND AVERAGE BETA AND GAMMA-RAY ENERGIES

Proportional counters were used in determining activities of all samples. The counting with lead absorbers was performed on a proportional counter utilizing a large detector (5 in. x 12 in. x 1 1/4 in.) filled with 90 per cent A--10 per cent CO_2. Aluminum foil (2.4 mg/sq cm) served as window material for this detector. The counting with aluminum absorbers was performed on a proportional counter utilizing a smaller detector (1 1/2 in. diameter x 4 1/2 in) filled with 90 per cent A--10 per cent CO_2. Aluminum foil (4.25 mg/sq cm) served as window material for this smaller detector.

The differential fall-out samples were on thin cover glasses 7/8 in. square. These were mounted on aluminum cards (2 1/2 in. x 3 1/4 in. x 1/16 in). The other samples were also mounted on the same size aluminum cards, but were uniformly spread over a circular area of 7/8 in. diameter on the center of the card. Each sample was covered with a sheet (1 mg/sq cm) of pliofilm held in place by a pressure sensitive tape.

The sample was placed 0.8 in. from the detector when aluminum absorbers were used and 2 5/16 in. from the detector when lead absorbers were used. The lead absorbers were always placed within 7/8 in. of the detector and the aluminum absorbers were placed as close to the detector as possible. Counts were taken at regular intervals with no added absorber and with 0.0035, 0.0538, 0.141, 0.279, 0.454, 0.693, 1.38, 2.08, and 2.75 g/sq cm of aluminum and 2.0, 5.9, 9.85, 18.65, and 24.55 g/sq cm of lead.

Counts of a standard source were taken periodically to check the stability of the counters, and background determinations were made each day. Coincidence corrections were determined for each of the counters by the use of a series of sources prepared by dilution, giving a measure of linearity of counting rate with activity.

2.3 COUNTING CALIBRATION PROCEDURE

Because of the special counting arrangement used, beta and gamma-ray absorption curves of radionuclides of known radiation characteristics were taken for calibration and comparison purposes. The samples were prepared in the same manner as the gross decay samples, and the counting arrangements for the aluminum and lead absorption curves were identical with those used in the measurements of activities of the gross decay samples with aluminum and lead absorbers. The aluminum absorption curves of Sr^{90}, Tl^{204}, P^{32}, Y^{90}, Rh^{106}, Zr^{95}, and Nb^{95} were taken in order to establish the relationship between [illegible] gamma-ray energy and half-thickness for the particular counting setup used. In addition, [illegible] of Co^{60}, and an equilibrium mixture of Zr^{95} and Nb^{95} were taken for the purpose of checking the gamma-ray half-thickness [illegible] relationship as obtained in the experimental counting [illegible].

2.4 INTERACTION OF [illegible] OF RADIOACTIVE ELEMENTS IN THE SOIL SAMPLES

2.4.1 Soil Sample from the Surface Burst

The three soil samples (30 to 40 g each) which were obtained from the surface burst had been ground at the site to pass a 100-mesh screen. From each of these samples, six portions approximately equal were weighed out and placed in separate Cellophane dialysis bags; a seventh sample, weighing about 10 mg, was spread upon an aluminum card for obtaining a measure of the specific soil activity and its decay characteristics. The first six portions were then treated with the following six solutions in the manner described below:

1. Distilled water;
2. Sea water;
3. 0.8 per cent "Duponol C";
4. 0.8 per cent "Tide";
5. 0.8 per cent Tetrasodium ethylenediaminetetraacetate, hereafter referred to as EDTA;
6. 10 per cent Trisodium citrate.

These solutions had been freshly filtered in order to minimize the uncertainties arising from radiocolloid formation.

Ten ml of a given solution were introduced into the dialysis bag with the soil and the bag was then suspended in another 60 ml of the same solution. This outer solution was contained in a Lusteroid centrifuge tube. The progress of the system toward equilibrium was followed by withdrawing 500 λ (microliter) aliquots from inside and outside the bag.

When the system had been standing for about 24 hr, 3 ml aliquots of dialysate were withdrawn and introduced into another set of Lusteroid tubes, each containing approximately 1 g of uncontaminated surface soil which had been previously obtained from the site. This soil had been pretreated by placing it on a 200-mesh sieve and washing it thoroughly to remove particles of colloidal size. The samples were shaken from time to time and the rate of ion-exchange between the solution and soil was followed by allowing the soil to settle at appropriate intervals and sampling the clear supernantant liquid thus obtained. About 15 per cent of the soil was lost in the sieving operation, but, since no ultrafiltration apparatus was available, this device was considered more expedient than waiting for a second set of dialyses to equilibrate.

The various leachings were compared with one another and with the original soil by measuring their beta activities under as identical conditions as the form and activity of the sample would permit.

2.4.2 Soil Sample from the Underground Burst

The scoop soil sample obtained from the underground burst for this study consisted of about 30 g of extremely heterogeneous material, ranging in particle size from 3/4 in. on down. Obvious difficulties in sampling were circumvented by choosing only that portion of the sample for experimentation which passed through a 20-mesh screen. This portion of the gross sample was divided into eight representative and approximately equal fractions and the weight of each fraction was determined. Two of these fractions were combined and ground and used to obtain the specific activity of the untreated soil. The other six fractions were treated separately with the same six solutions that were used on the samples from the surface burst.

A procedure modified somewhat from that for the surface burst was used. Approximately 1.2 g of soil, together with 10 ml of leaching solution, were introduced into a Lusteroid centrifuge tube and allowed to remain in contact for one hour. While in contact, the contents of the tube were thoroughly agitated every 5 min. At the end of the hour the contents of the tube were centrifuged and 5 ml of the supernatant liquid were withdrawn. Three 500 λ aliquots of the supernatant were used to determine the combined activity in ionic and colloidal states removed in the leaching process while the remainder was separated into ionic and colloidal fractions by dialysis.

Dialysis was carried out, as before, in Cellophane bags which were immersed in 60 ml of fresh decontaminating solution. About 24 hr after dialysis had begun, samples were withdrawn in the usual manner to determine the activity of the ionic fraction. At the same time, 3 ml of dialysate were withdrawn for investigating the ion-exchange properties of uncontaminated soil. After another 48 hr, dialysate aliquots were again withdrawn in order that the degree of equilibrium attained at the time the first aliquots were taken might be determined.

The study of the ion-exchange properties of the soil again consisted simply in allowing the ionic fraction of the leach to remain in contact with fresh soil and sampling the supernatant liquid from time to time.

Since the amount of soil originally obtained was insufficient to permit duplicate determinations to be made, an estimate of the reproducibility of the experimental procedure was obtained by leaching four different samples of active soil with water and comparing the results obtained with each other. Since the particle size of these samples was necessarily greater than 20 mesh, sampling was less reliable and the results should be taken as an upper limit of irreproducibility.

It was considered more practicable to carry out several group separations rather than perform a complete radiochemical analysis of each ionic fraction obtained in the leachings. Standard radiochemical analytical procedures were then employed to carry out subsequent separations and purifications as the activity of the group and the ease of further separation warranted. Individual isotopes were identified by means of absorption and decay characteristics. The groups chosen and the methods of separation are summarized in the following separation schemes:

Cation Analysis

To 25 ml aliquot of dialysate, 20 mg each of the following carriers were added: Cs(I), Sr(II), Ca(II), La(III), Y(III). Organic material was destroyed by boiling in concentrated HNO_3. The residue was taken up in a 20 per cent $(NH_4)_2CO_3$ concentrated NH_4OH solution.

- Supernatant: Alkali metal activities and Cs(I) carrier
- Residue: Treated with N/2 H_2SO_4.
  - Residue: $SrSO_4$, $BaSO_4$, and associated activities
  - Supernatant: Complexed rare earths by making 1 per cent in EDTA and added saturated $(NH_4)_2C_2O_4$ solution.
    - Residue: CaC_2O_4
    - Supernatant: Rare earth activities and La(III) and Y(III) carriers.

Anion Analysis

To 10 ml aliquot of dialysate were added 20 mg iodide-ion carrier and a standard radiochemical analysis was made.

CHAPTER 3

EXPERIMENTAL RESULTS

3.1 RADIOCHEMICAL COMPOSITION OF SAMPLES

The results of the radiochemical determinations are presented in Tables 3.1 through 3.13 and are reported in terms of relative fission yields, relative neutron capture cross sections, R-values, and percentage contribution to the gross activity at certain times after the atomic bomb detonations.

The yields of all radionuclides are compared to Mo^{99} yield set at 6.0 per cent, except in the case of the size separated fall-out samples in which they are compared to the Ce^{144} yield set at 5.3 per cent. For each radionuclide, the disintegration rate per minute at zero time per milligram of soil, in the case of the soil samples, and per total sample, in the case of the differential fall-out samples, was calculated from its measured activity. Corrections for the following were applied to the measured activities: (1) volume of aliquot or weight of soil, (2) geometry factor of counter as determined by a UX_2 standard, (3) chemical yield, (4) absorption of beta particles by counter window, air gap between sample and window, and sample covering, and for energies of less than 0.5 Mev, by the sample itself, (5) daughter growth when occurring, (6) decay of radionuclide from the time of detonation to the time of count. For beta-rays with maximum energy above 0.6 Mev, the constant correction factor for saturation backscattering from the 1/16 in. thick aluminum mounting cards[1] did not have to be applied in the determination of relative fission yields.

For the percentage contribution to gross activity calculations, all the above corrections were applied except that the measured activities were corrected to an absorption of 7.65 mg aluminum - the calculated amount of absorber through which the gross activity measurements were made.

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[1] B.P. Burtt, "Absolute Beta Counting", Nucleonics 5, (1949), 28.

The R-values are defined by:

$$R = \frac{Y_1 / Y_2}{Y_1^{235} / Y_2^{235}} , \qquad (1)$$

where Y_1 and Y_2 are the observed relative fission yields for two given radionuclides, and Y_1^{235} and Y_2^{235} are the fission yields for the same radionuclides in the thermal neutron fission of U^{235}.

Neutron capture cross-sections were calculated relative to that of Na^{23} arbitrarily set at 10 millibarns. Since the capture cross-sections depend on the neutron energies and the latter undoubtedly change markedly as the neutrons diffuse outward from their point of origin, the observed neutron capture cross-sections are expected to vary from sample to sample. Possible n,p reactions, on other elements present, may make some contribution to the amount of radionuclide produced by the neutron capture reaction of interest. Consequently, the relative neutron capture cross-sections are observed not to be constant, but their orders of magnitude and the extent of variation from sample to sample are of interest. The table listing the cross-sections also notes the quantitative analytical data and the possible n,p reactions.

Approximately half the radiochemical analyses were done in duplicate, the remainder were single determinations. Of the duplicate results, 83 per cent had a mean deviation of 10 per cent or less, 8 per cent (six analyses) had a mean deviation greater than 15 per cent.

It was shown that even sampling procedures normally regarded as satisfactory failed to give homogeneous results from the scoop and core samples. For this reason, the over-all accuracy of the relative fission yield data is considered to be ± 10 per cent for data on the differential fall-out samples, and ± 15 per cent for the data on the scoop and core samples. The values given for percentage contribution at various times following detonation are considered to have an over-all accuracy of ± 20 per cent.

TABLE 3.3

Gross Activities[a] of Size-Separated Fall-Out Samples in the Surface Burst

Size Fraction No.	Size Range (μ)	F-3	G-3	H-3	I-3
1	> 5600	-[b]	-	-	-
2	4760 - 5600	21	-	-	-
3	3327 - 4760	229	368	422	1,775
4	2362 - 3327	1,291	1,422	3,360	1,910
5	1651 - 2362	943	1,943	2,820	2,262
6	1190 - 1651	1,519	2,196	2,820	3,770
7	840 - 1190	1,920	2,268	4,270	4,080
8	589 - 840	2,973	2,115	497	1,095
9	417 - 589	1,287	630	6,560	1,140
10	295 - 417	47	23	4,210	2,300
11	208 - 295	158	74	1,590	570
12	147 - 208	27	3.4	183	677
13	104 - 147	20	0.9	93	543
14	74 - 104	34	4.2	71	611
15	< 74	17	8.1	81	196

(a) Activities (counts/min/mg) measured 161 days after burst. Counts taken on top shelf and corrected to 10 per cent geometry; no absorption corrections were made.

(b) A blank indicates sample, if any, was combined with next smaller particle size range.

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TABLE 3.4

Gross Activities[a] of Size-Separated Fall-Out Samples in the Underground Burst

Size Fraction No.	Size Range (u)	D-1	G-1	I-1	I-3	N-1	N-3	N-5
1	5600	-[b]	-	-	-	-	-	-
2	4760 - 5600	-	-	-	-	-	-	-
3	3327 - 4760	-	2	-	13	9	-	-
4	2362 - 3327	-	173	-	12	-	-	-
5	1651 - 2362	-	1,298	7	63	-	-	-
6	1190 - 1651	-	403	1,243	607	431	-	-
7	840 - 1190	-	349	1,010	1,142	288	-	-
8	589 - 840	-	611	795	1,052	16	-	381
9	417 - 589	-	452	733	703	-	2	872
10	295 - 417	-	861	664	535	130	198	856
11	208 - 295	30	586	709	774	-	766	953
12	147 - 208	35	427	830	700	992	834	820
13	104 - 147	30	171	716	612	708	733	757
14	74 - 104	26	119	523	433	609	597	520
15	74	42	135	436	411	396	450	383

(a) Activities (counts/min/mg) measured 151 days after burst. Counts taken on top shelf and corrected to 10 per cent geometry; no absorption corrections were made.

(b) A blank indicates sample, if any, was combined with next smaller particle size range.

3.2 GROSS DECAY RATES OF SAMPLES, AND EFFECTIVE GAMMA-RAY ENERGIES

The gross decay rate [illegible]:

$$A = kt^{-n} \qquad (2)$$

where A is the activity present at time t, t is the time after detonation, k is a proportionality constant, and the exponent n has a constant value over certain time intervals. Decay data were taken as long as there was sufficient activity for counting. Decay curves of the various samples were plotted on log-log paper and the values of n for these samples were obtained directly from the slopes of the curves.

The very large amount of data obtained has necessarily been presented in a condensed form in Tables 3.15 and 3.16. Scoop-1, Scoop-5, and Core refer to the samples taken from the crater formed by JANGLE Surface Burst. U-1S refers to a composite scoop sample taken from the crater formed by JANGLE Underground Burst. The locations of the DuO samples with respect to the crater are given in Table 2.1 of this report.

Since the slope of the decay curves varied with the amount of absorber placed over the sample and with time after detonation, Tables 3.15 and 3.16 present the decay exponent for the given absorber used over a number of time intervals where the slope appeared to be reasonably constant.

From the decay curves obtained with various absorbers, it is possible to construct beta and gamma-ray absorption curves of the radiations at any time within the interval covered by the curves. Such curves were constructed from the decay data at various intervals after the bomb detonations.

Analyses of the aluminum and lead absorption curves showed that they could each be approximated fairly well by two components of various relative abundances. The absorption coefficients of the components varied with sample and with time. Several lead absorption curves showed the presence of a third low energy component, and where possible, the lead absorption curves were resolved into three apparent components.

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In order to obtain information on the energies of the various beta-ray components, a calibration curve of maximum beta-ray energy[2] versus half-thickness was constructed from the data of the absorption curves of Sr^{90}, Tl^{204}, P^{32}, Y^{90}, Zr^{95}, and Nb^{95}. These radionuclides all gave straight line curves out to approximately two-thirds of their maximum beta-ray range in plots of logarithm of activity versus thickness of added aluminum absorber.

The half-thickness of each of the components in the aluminum absorption curves was calculated, and from this the corresponding maximum beta-ray energy was obtained directly from the calibration curve. The average energy of the beta-ray spectrum associated with each beta-ray component[3] of given maximum energy was calculated from the data given by Marinelli. The average beta-ray energies of the various samples at each of the selected times were computed from the relative abundances of the components and their average energies. All of these data for beta-rays are listed in Tables 3.17 and 3.18.

For the gamma-ray energy studies, calibration absorption measurements were made. Half-thickness values of 12.3 and 7.2 g/sq cm of lead were determined for Co^{60} and the pair Zr^{95}-Nb^{95} from their respective lead absorption curves as taken in the counting arrangement used for the gross decay samples. According to the theoretical relationship of gamma-ray energy to half-thickness, these values correspond to energies of 1.30 and 0.74 Mev; the reported gamma-ray energies are 1.17 and 1.33 for Co^{60}, 0.71 for Zr^{95}, and 0.76 for Nb^{95}. This agreement in gamma-ray energies as reported in the literature and as determined by lead absorption measurements in the special counting set-up used for the gross decay samples demonstrates that the absorption curve technique used here is satisfactory for determining gamma-ray energies.

In the majority of cases, the gamma-ray absorption curves constructed from the gross decay curves were resolved into two components. The energies of the components were obtained from their half-thickness values by reference to the theoretical relationship between energy and half-thickness. Average gamma-ray energies for each of the samples at the different selected times were computed from the relative abun-

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[2] The maximum beta-ray energy values of these nuclides were taken from The National Bureau of Standards Circular 499.

[3] L.D. Marinelli, R.F. Brinckerhoff, and G.J. Hine, "Average Energy of Beta-Rays Emitted by Radioactive Isotopes", Rev. Mod. Phys. 19 (1947), 25.

dances and energies of the components. These data are summarized in Tables 3.19, 3.20, and 3.21.

Apparent energies obtained from the resolution of lead absorption curves taken on a scintillation counter are listed in Table 3.20. Pulse height analysis data where obtainable on the scintillation detector are also listed in Table 3.20.

TABLE 3.14

Physical Appearance of Samples

Sample	Physical Appearance
Scoop 1	Finely ground soil
Scoop 5	Finely ground soil
Core	Finely ground soil
DFO-19	Fine dust
DFO-125	Fine dust
DFO-102	Sand particles, some dust
DFO-103	Heavy layer of fine sand
DFO-108	Sand particles, some dust
U-18	Finely ground soil

TABLE 3.15

Gross Decay for the Surface Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
DFO-19	The gross decay at 0 added absorber for this sample, between the period of 4.5 hr and 55 hr after the detonation, was resolved into two apparently predominant activities with half lives of 3.1 hr and 20.8 hr.		
	(mg/cm^2 Al)		
	0 and 3.45	0.64	1.3 - 3
	0 and 3.45	1.8	3 - 9
	0 and 3.45	3.1	9 - 40
	53.8	1.4	1.3 - 5
	141	1.7	1.3 - 13
	279	1.8	1.3 - 10
Scoop 1	(mg/cm^2 Al)		
	0 and 3.45	0.55	1.1 - 2
	0 and 3.45	1.2	2 - 6
	0 and 3.45	2.5	6 - 20
	0 and 3.45	1.6	20 - 55
	0 and 3.45	1.3	55 - 120
	53.8	1.2	1.2 - 3
	53.8	1.4	3 - 50
	53.8	1.15	50 - 120
	56.7	1.25	0.5 - 1.04
	56.7	1.70	1.04 - 15
	56.7	1.0	15 - 108
	141	1.6	1.1 - 20
	141	0.83	20 - 120
	221	1.65	0.5 - 1
	221	1.9	1 - 2.7
	221	1.5	2.7 - 10.8
	221	1.00	10.8 - 29.2
	221	0.65	29.2 - 108
	279	1.7	1.1 - 20
	279	0.62	20 - 120
	454	1.7	1.1 - 10
	580	1.7	0.5 - 2.08
	580	1.22	2.08 - 22.5
	580	0.64	22.5 - 108
	693	1.4	1.1 - 10

TABLE 3.15 (Continued)

Gross Decay for the Surface Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
Scoop 1 (Cont'd)	(g/cm^2 Al)		
	1.57 and 2.34	1.4	0.5 - 5.8
	1.57 and 2.34	0.98	5.8 - 83
	2.750	0.8	1.1 - 3
	2.750	1.4	3 - 10
	(g/cm^2 Pb)		
	2.00	1.2	1.2 - 7
	2.00	1.8	7 - 20
	2.00	0.9	20 - 110
	5.7	1.34	0.5 - 7.5
	5.7	1.04	7.5 - 108
	5.9	1.2	1.2 - 8
	5.9	1.3	8 - 50
	5.9	1.0	50 - 120
	9.85, 14.7, 18.65, and 24.55	1.2	1.2 - 120
	14.45	1.42	0.5 - 5
	14.45	1.09	5 - 108
Scoop 5	(mg/cm^2 Al)		
	0 and 3.45	0.47	1.1 - 2
	0 and 3.45	0.96	2 - 6
	0 and 3.45	2.6	6 - 20
	0 and 3.45	1.5	20 - 120
	53.8	1.4	1.1 - 60
	53.8	0.93	60 - 120
	56.7	0.85	0.54 - 1.0
	56.7	1.62	1.0 - 9.6
	56.7	1.37	9.6 - 37.5
	56.7	1.02	37.5 - 108
	141	1.6	1.1 - 18
	141	0.88	18 - 50
	141	0.67	50 - 120
	221	1.86	0.54 - 3.8
	221	1.39	3.8 - 23
	221	0.60	23 - 108

TABLE 3.15 (Continued)

Gross Decay for the Surface Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
Scoop 5 (Cont'd)	(mg/cm^2 Al)		
	454	1.3	1.1 - 5
	454	1.9	5 - 15
	454	0.74	15 - 50
	454	0.48	50 - 120
	580	1.43	0.54 - 27
	580	0.65	27 - 108
	692	1.2	1.1 - 5
	692	2.0	5 - 18
	692	0.94	18 - 50
	692	0.65	50 - 120
	(g/cm^2 Al)		
	2.75	0.86	1.1 - 4
	2.75	1.9	4 - 18
	2.75	1.1	18 - 86
	(g/cm^2 Pb)		
	2.0	1.02	1.2 - 7
	2.0	1.8	7 - 24
	2.0	1.0	24 - 106
	5.7	0.94	0.54 - 1.3
	5.7	1.28	1.3 - 7.9
	5.7	1.09	7.9 - 108
	5.90	1.2	1.2 - 8
	5.90	1.3	8 - 50
	5.90	1.0	50 - 120
	9.85, 14.7, 18.65, and 24.55	1.2	0.54 - 120
Core	(mg/cm^2 Al)		
	0 and 3.45	0.8	0.25 - 1.1
	0 and 3.45	1.0	1.1 - 4
	0 and 3.45	2.1	4 - 25
	0 and 3.45	1.3	25 - 120
	53.8	1.6	1.1 - 2.5
	53.8	2.1	2.5 - 15
	53.8	1.1	15 - 120
	56.7	1.10	0.28 - 0.67
	56.7	1.32	0.67 - 1.8
	56.7	2.61	1.8 - 5.8

TABLE 3.15 (Continued)

Gross Decay for the Surface Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
Core (Cont'd)	(mg/cm^2 Al)		
	141	1.5	1.1 - 2.5
	141	3.0	2.5 - 6
	141	1.7	6 - 20
	141	0.83	20 - 120
	221	0.97	0.28 - 1.0
	221	1.79	1.0 - 2.2
	221	3.04	2.2 - 5.4
	279	1.8	1.1 - 2.5
	279	3.0	2.5 - 7
	279	1.7	7 - 20
	454	1.6	1.1 - 2.5
	454	3.1	2.5 - 6
	454	2.0	6 - 15
	580	0.87	0.28 - 0.75
	580	1.46	0.75 - 1.9
	580	2.92	1.9 - 5
	693	1.4	1.1 - 2.5
	693	3.0	2.5 - 7
	(g/cm^2 Al)		
	1.57 and 2.35	0.81	0.28 - 0.75
	1.57 and 2.35	1.25	0.75 - 1.8
	1.57 and 2.35	2.87	1.8 - 5
	2.75	1.3	1.1 - 2.2
	2.75	3.0	2.2 - 6
	(g/cm^2 Pb)		
	2.0	1.3	1.1 - 2
	2.0	3.1	2 - 7
	2.0	1.5	7 - 30
	5.7	0.71	0.28 - 0.67
	5.7	1.25	0.67 - 1.8
	5.7	3.54	1.8 - 5
	5.9	1.6	1.2 - 2
	5.9	3.5	2 - 7
	5.9	1.7	7 - 14
	9.85	1.6	1.2 - 2
	9.85	3.4	2 - 6
	9.85	1.5	6 - 20

TABLE 3.15 (Concluded)

Gross Decay for the Surface Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
Core (Cont'd)	(g/cm^2 Pb)		
	14.45	0.67	0.28 - 0.67
	14.45	1.25	0.67 - 1.8
	14.45	3.54	1.8 - 5
	14.7	1.7	1.2 - 2
	14.7	3.4	2 - 6
	18.65	1.8	1.2 - 2
	18.65	3.4	2 - 6
	24.55	1.7	1.2 - 2
	24.55	3.4	2 - 6
Scoop 1	(mg/cm^2 Al)		
	0.0 and 3.45	1.3	120 - 186
	53.8	1.1	120 - 186
	141	0.85	120 - 186
	(g/cm^2 Pb)		
	2.00	1.6	110 - 186
	5.90	1.4	120 - 186
	9.85	1.3	120 - 186
	14.7	1.6	120 - 186
Scoop 5	(mg/cm^2 Al)		
	0.0 and 3.45	1.3	120 - 186
	53.8	0.9	120 - 186
	141	0.65	120 - 186
	454	0.48	120 - 186
	(g/cm^2 Pb)		
	2.00	1.5	106 - 186
	5.90	1.3	120 - 186
	9.85	1.2	120 - 186
Core	(mg/cm^2 Al)		
	0.0 and 3.45	1.1	120 - 186
	53.8	1.1	120 - 186
	141	1.4	120 - 186

TABLE 3.16

Gross Decay for the Underground Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
U-16	(mg/cm^2 Al)		
	0.0 and 3.45	0.77	0.23 - 0.8
	0.0 and 3.45	1.0	0.8 - 5
	0.0 and 3.45	1.5	5 - 40
	0.0 and 3.45	1.4	40 - 120
	53.8	1.4	0.8 - 12
	53.8	1.2	12 - 40
	53.8	1.3	40 - 65
	53.8	1.03	65 - 120
	56.7	1.05	0.25 - 0.5
	56.7	1.49	0.5 - 11.7
	56.7	1.09	11.7 - 88
	141	1.7	0.8 - 7
	141	0.94	7 - 40
	141	1.03	40 - 120
	221	1.09	0.25 - 0.75
	221	1.92	0.75 - 9.6
	221	0.59	9.6 - 69
	279	1.9	0.8 - 6
	279	0.76	6 - 40
	279	0.60	40 - 120
	454	2.3	0.8 - 4
	454	1.2	4 - 30
	580	0.84	0.25 - 0.56
	580	1.90	0.56 - 3
	580	1.29	3 - 9.6
	693	2.0	0.8 - 4
	693	1.1	4 - 20
	(g/cm^2 Al)		
	1.57	1.03	0.25 - 4
	1.57	1.31	4 - 9.6
	2.35	0.88	0.27 - 1.9
	2.35	1.24	1.9 - 8.3
	(g/cm^2 Pb)		
	2.0	0.97	0.79 - 1.2
	2.0	1.4	1.2 - 5.8
	2.0	1.0	5.8 - 110
	5.7	1.36	0.25 - 9.6
	5.90	1.4	0.79 - 5.8
	5.90	0.95	5.8 - 110

TABLE 3.16 .(Continued)

Gross Decay for the Underground Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
U-18 (Cont'd)	(g/cm^2 Pb)		
	9.85	1.4	0.79 - 5.8
	9.85	0.98	5.8 - 110
	14.45	1.36	0.25 - 9.6
	18.65	1.4	0.79 - 5.8
	18.65	0.91	5.8 - 11
	18.65	0.98	11 - 97
	24.55	1.3	0.79 - 5.8
	24.55	0.89	5.8 - 11
	24.55	1.0	11 - 40
DFO-102	(mg/cm^2 Al)		
	0 and 3.45	0.93	2.1 - 5
	0 and 3.45	1.5	5 - 30
	0 and 3.45	1.2	30 - 96
	53.8	1.6	2.1 - 10
	53.8	1.3	10 - 30
	59.8	1.1	30 - 96
	56.7	1.57	1 - 11.3
	56.7	1.16	11.3 - 96
	141	1.8	2.1 - 4
	141	1.3	4 - 10
	141	1.1	10 - 30
	141	0.75	30 - 120
	221	1.94	1 - 4.6
	221	1.35	4.6 - 20.8
	279	1.7	2.1 - 5
	279	1.2	5 - 12
	279	0.83	12 - 30
	279	0.55	30 - 96
	454	1.4	2.1 - 6
	454	1.2	6 - 30
	454	0.53	30 - 120
	580	1.51	1 - 25
	580	0.62	25 - 96
	692	1.2	2.1 - 30
	692	0.74	30 - 120

TABLE 3.16 (Continued)

Gross Decay for the Underground Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
DFO-102 (Cont'd)	(g/cm^2 Al)		
	1.57 and 2.35	0.92	1 - 3.96
	1.57 and 2.35	1.55	3.96 - 35.4
	1.57 and 2.35	0.76	35.4 - 96
	2.75	0.97	2.1 - 4
	2.75	1.4	4 - 30
	2.75	1.15	30 - 120
	(g/cm^2 Pb)		
	2.0	1.3	2.9 - 36
	2.0	0.70	36 - 97
	5.7	1.38	1 - 5.4
	5.7	0.95	5.4 - 50
	5.9	1.1	2.9 - 36
	5.9	0.85	36 - 82
	9.85	1.0	2.9 - 36
	14.45	1.43	1 - 4.2
	14.45	1.03	4.2 - 33
	14.7	1.0	2.9 - 10
	14.7	0.92	10 - 36
	18.65	0.90	2.9 - 36
	24.55	1.0	2.9 - 13
	24.55	0.94	13 - 36
DFO-103	(mg/cm^2 Al)		
	0 and 3.45	0.84	2.2 - 4
	0 and 3.45	1.5	4 - 34
	0 and 3.45	1.3	34 - 110
	53.8	1.5	2.2 - 10
	53.8	1.4	10 - 34
	53.8	1.15	34 - 110
	141	1.7	2.2 - 10
	141	1.1	10 - 34
	141	0.80	34 - 110
	279	1.7	2.2 - 5
	279	1.0	5 - 13
	279	0.82	13 - 34
	279	0.68	34 - 97
	454	1.6	2.2 - 5
	454	1.0	5 - 34
	454	0.53	34 - 110

TABLE 3.16 (Continued)

Gross Decay for the Underground Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
DFO-103 (Cont'd)	(mg/cm^2 Al)		
	693	1.2	2.2 - 34
	693	0.70	34 - 110
	(g/cm^2 Al)		
	2.75	1.2	2.2 - 110
	(g/cm^2 Pb)		
	2.0	1.1	2.2 - 6
	2.0	1.2	6 - 36
	2.0	0.98	36 - 90
	5.9	1.1	2.2 - 40
	5.9	0.75	40 - 110
	9.85	1.1	2.2 - 6
	9.85	0.99	6 - 36
	14.7	1.1	2.2 - 6
	14.7	0.84	6 - 22
	18.65	1.05	2.2 - 6
	18.65	0.85	6 - 22
	24.55	1.0	2.2 - 6
	24.55	0.80	6 - 20
DFO-108	(mg/cm^2 Al)		
	0 and 3.45	0.44	2.1 - 4.5
	0 and 3.45	1.2	4.5 - 9
	0 and 3.45	2.2	9 - 20
	0 and 3.45	1.5	20 - 34
	0 and 3.45	1.2	34 - 110
	53.8	1.5	2.1 - 34
	53.8	1.15	34 - 110
	56.7	1.54	0.96 - 13.8
	56.7	1.11	13.8 - 96
	141	1.8	2.1 - 9
	141	1.1	9 - 34
	141	0.88	34 - 110
	221	1.85	0.96 - 5.8
	221	1.27	5.8 - 25
	221	0.64	25 - 96
	279	1.8	2.1 - 6
	279	1.1	6 - 34
	279	0.90	34 - 96

TABLE 3.16 (Continued)

Gross Decay for the Underground Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
DFO-108 (Cont'd)	(mg/cm^2 Al)		
	454	1.9	2.1 - 4
	454	1.2	4 - 34
	454	0.53	34 - 96
	580	1.48	0.96 - 27
	580	0.64	27 - 96
	692	1.4	2.1 - 34
	692	0.76	34 - 110
	(g/cm^2 Al)		
	1.57 and 2.35	0.85	0.96 - 2.2
	1.57 and 2.35	1.25	2.2 - 6.7
	1.57 and 2.35	1.86	6.7 - 22
	1.57 and 2.35	1.03	22 - 46
	2.75	1.1	2.1 - 9
	2.75	1.7	9 - 34
	2.75	1.15	34 - 96
	(g/cm^2 Pb)		
	2.0	1.3	2.1 - 7
	2.0	1.6	7 - 20
	2.0	1.1	20 - 36
	2.0	1.4	36 - 110
	5.7	1.38	0.96 - 7.1
	5.7	0.92	7.1 - 33
	5.9	1.3	2.1 - 36
	5.9	0.93	36 - 96
	9.85	1.3	2.1 - 10
	9.85	1.1	10 - 36
	14.45	1.47	0.96 - 5.4
	14.45	0.86	5.4 - 30
	14.7	1.2	2.1 - 36
	18.65	1.3	2.1 - 10
	18.65	1.2	10 - 36
	24.55	1.2	2.1 - 36

TABLE 3.16 (Continued)

Gross Decay for the Underground Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
DFO-120	(mg/cm^2 Al)		
	0	0.95	1 - 3.1
	0	1.49	3.1 - 5.4
	0	1.16	5.4 - 35
	56.7	1.45	1 - 8.3
	221	1.84	1 - 4.0
	221	1.47	4.0 - 8.3
	580	1.70	1 - 3.3
	580	1.21	3.3 - 8.3
	1570 and 2350	0.95	1 - 3.1
	1570 and 2350	1.13	3.1 - 8.3
	(g/cm^2 Pb)		
	5.7	1.33	1 - 2.7
	5.7	1.09	2.7 - 8.3
U-18	(mg/cm^2 Al)		
	0.0 and 3.45	1.4	120 - 176
	53.8	0.96	120 - 176
	141	0.36	120 - 176
	(g/cm^2 Pb)		
	2.0	0.87	110 - 176
	2.0	1.05	110 - 176
DFO-102	(mg/cm^2 Al)		
	0.0 and 3.45	1.2	96 - 176
	53.8	0.9	96 - 176
	141	0.7	120 - 176
	279	0.7	96 - 176
	454	0.5	120 - 176
	692	0.6	120 - 176
	(g/cm^2 Al)		
	2.75	1.2	120 - 176
	(g/cm^2 Pb)		
	2.0	1.7	97 - 162

TABLE 3.16 (Concluded)

Gross Decay for the Underground Burst

Sample	Added Absorber	Decay Exponent	Time Interval (days)
DFO-103	(mg/cm² Al)		
	0.0 and 3.45	1.4	110 - 176
	53.3	1.1	110 - 176
	141	1.0	110 - 176
	279	0.60	97 - 176
	454	0.70	110 - 176
	693	0.70	110 - 176
	(g/cm² Al)		
	2.75	1.6	110 - 176
DFO-103	(mg/cm² Al)		
	0.0 and 3.45	1.2	110 - 176
	53.3	1.0	110 - 176
	141	0.75	110 - 176
	279	0.85	96 - 176
	454	0.60	96 - 176
	692	0.75	110 - 176
	(g/cm² Al)		
	2.75	1.7	96 - 176
	(g/cm² Pb)		
	5.9	1.2	96 - 148

TABLE 3.17

Beta-Ray Energies for the Surface Burst

Sample	Time After Detonation (days)	Max.Energy (Mev)		Average Energy		Ratio Soft/ Hard	Average Energy
		Soft	Hard	Soft	Hard		
DFO-19	0.17	0.31	2.30	0.10	0.92	2.1	0.36
Scoop 1	1.06	0.45	2.5	0.13	1.1	7.3	0.25
	4.1	0.43	1.6	0.14	0.59	2.31	0.28
	6.3	0.49	2.3	0.16	0.92	42	0.18
	10.0	0.50	1.8	0.18	0.75	10.0	0.23
	31.0	0.72	2.1	0.26	0.89	3.4	0.40

TABLE 3.17 (Continued)

Beta-Ray Energies for the Surface Burst

Sample	Time After Detonation (days)	Max. Energy (Mev)		Average Energy		Ratio Soft/ Hard	Average Energy
		Soft	Hard	Soft	Hard		
Scoop 1 (Cont'd)	59	0.49	2.0	0.16	0.78	1.9	0.42
	92	0.41	2.2	0.13	0.88	1.5	0.43
Scoop 5	1.1	0.69	2.2	0.25	0.94	5.3	0.36
	2.3	0.85	1.75	0.28	0.66	2.2	0.40
	3.6	0.68	1.38	0.23	0.50	2.04	0.32
	4.1	0.69	1.48	0.23	0.53	2.7	0.31
	5.08	0.71	1.48	0.23	0.53	2.8	0.31
	6.30	0.68	1.48	0.23	0.53	3.7	0.29
	7	0.64	1.47	0.21	0.53	3.2	0.29
	10	0.50	1.79	0.16	0.68	6.9	0.23
	12	0.75	2.2	0.25	0.87	6.8	0.33
	31	0.69	2.4	0.25	1.04	4.8	0.39
	92	0.51	2.3	0.16	0.92	1.6	0.48
Core	0.28	0.92	2.1	0.31	0.83	1.18	0.55
	1.2	0.63	1.9	0.22	0.82	2.4	0.40
	2.3	1.04	2.3	0.36	0.92	4.12	0.47
	3.6	0.77	2.2	0.23	0.87	13.6	0.27
	4.1	0.77	1.70	0.23	0.64	5.8	0.29
	5.1	0.88	2.00	0.27	0.78	29.3	0.29
	6.3	0.77*	2.00	0.26	0.78	16.2	0.29
	9	0.58	2.4	0.20	0.98	16.0	0.25
	10	0.41	1.8	0.12	0.75	13.0	0.17
	31	0.69	2.2	0.25	0.94	2.9	0.43
Scoop 1	186	0.28	2.4	0.09	0.97	0.79	0.58
Scoop 5	186	0.43	2.6	0.14	1.08	0.78	0.67

TABLE 3.13

Beta-Ray Energies for the Underground Burst

Sample	Time After Detonation (days)	Max. Energy (Mev)		Average Energy		Ratio Soft/ Hard	Average Energy
		Soft	Hard	Soft	Hard		
DFO-125	1.1	0.57	1.9	0.20	0.52	2.2	0.39
U-18	1.1	0.63	2.4	0.25	1.04	2.6	0.47
	5	0.67	2.70	0.22	1.13	22.3	0.26
	10	0.43	1.4	0.13	0.59	3.5	0.23
	30	0.73	2.0	0.27	0.87	4.2	0.39
	90	0.56	2.5	0.18	1.03	1.6	0.51
DFO-102	2.3	0.83	2.0	0.30	0.87	4.2	0.41
	5	0.77	2.6	0.26	1.03	15.7	0.31
	9.5	0.51	1.8	0.17	0.75	5.8	0.26
	30	0.90	2.3	0.34	0.99	4.6	0.46
	89	0.55	2.1	0.16	0.83	0.61	0.58
DFO-103	2.2	0.79	1.9	0.29	0.82	4.8	0.38
	9.5	0.53	1.8	0.20	0.75	7.8	0.26
	30	0.86	2.4	0.30	1.04	5.9	0.41
	89	0.57	2.1	0.18	0.80	0.80	0.52
DFO-108	2.1	0.91	1.8	0.34	0.75	1.2	0.53
	4.9	0.65	2.35	0.21	0.95	18.4	0.25
	9.4	0.65	2.0	0.23	0.87	14.0	0.27
	30	0.79	2.0	0.26	0.87	4.0	0.41
	89	0.57	2.5	0.18	1.03	1.34	0.54
U-18	176	0.25	2.5	0.08	1.09	0.68	0.64
DFO-102	176	0.34	2.5	0.11	1.03	0.32	0.81
DFO-103	176	0.31	2.3	0.10	0.92	0.42	0.68
DFO-108	176	0.31	2.4	0.10	0.97	0.43	0.72

TABLE 3.19

Gamma-Ray Energies for the Surface Burst

Sample	Time After Detonation (days)	Energies (Mev)		Ratio of Abundance of Soft Component to that of Hard Component at Zero Absorber	Average Gamma-Ray Energy of Sample (Mev)
		Soft Component	Hard Component		
Scoop 1	1.2	0.26	0.84	1.3	0.51
	10.2	0.26	0.96	1.8	0.51
	31.0	0.37	0.92	0.46	0.75
	92	0.56	0.81	0.31	0.75
Scoop 5	1.2	0.31	0.87	1.3	0.56
	10.2	0.31	0.95	1.7	0.55
	31.0	0.37	1.01	0.61	0.77
	92	0.35	0.82	0.32	0.71
Core	1.3	0.38	1.9	0.21	1.6
	10.1	0.35	0.82	0.88	0.60
Scoop 1	186		0.69		0.69
Scoop 5	186		0.76		0.76

TABLE 3.20

Gamma-Ray Energies for the Surface Burst
(From the Scintillation Counter)

Sample	Time After Detonation (days)	Energies (Mev)					
		Absorption			Spectrometer		
Core	2.3		-	~3.5	0.1	0.25	
	3.6		0.34	2.0			
	4.1		0.26	1.77			
	5.1		-	1.6			
	6.3		-	1.4			
Scoop 1	2.3		0.32	0.94	0.1	0.37	0.6
	3.6		0.30	0.8			
	4.1		0.30	0.9			
	5.1		0.32	1.03			
	11		0.26	1.03			
	39		-	0.91			

TABLE 3.20 (Continued)

Gamma-Ray Energies for the Surface Burst
(From the Scintillation Counter)

Sample	Time After Detonation (days)	Energies (Mev)						
		Absorption				Spectrometer		
Scoop 5	2.3			0.24	0.93	0.1	0.4	0.6
	3.6			0.26	0.92			
	4.1			0.20	0.96			
	5.1			0.28	0.97			
	6.3			0.27	0.95			
	7			0.29	1.0			
	9		0.13	0.25	1.1			
	12		0.16	0.29	1.1			
	38		-	-	0.92			

TABLE 3.21

Gamma-Ray Energies for the Underground Burst

Sample	Time After Detonation (days)	Energies (Mev)		Ratio of Abundance of Soft Component to that of Hard Component at Zero Absorber	Average Gamma-Ray Energy of Sample (Mev)
		Soft Component	Hard Component		
U-18	0.79	0.39	0.90	0.59	0.71
	5	0.13 0.28	1.3	1.21:0.63:1	0.57
	9.4	0.35	1.08	1.1	0.69
	29	0.30	0.92	0.42	0.74
	90	-	0.74	-	0.74
DFO-102	2.8	0.29	0.85	1.6	0.51
	5	0.14 0.26	0.98	1.63:0.84:1	0.44
	9.5	0.31	0.88	1.2	0.57
	27	0.39	0.94	0.43	0.78
DFO-103	2.2	0.31	0.90	1.1	0.60
	9.4	0.31	1.01	1.0	0.66
	29	0.25	1.06	1.0	0.66

TABLE 3.21 (Continued)

Gamma-Ray Energies for the Underground Burst

Sample	Time After Detonation (days)	Energies (Mev)		Ratio of Abundance of Soft Component to that of Hard Component at Zero Absorber	Average Gamma-Ray Energy of Sample (Mev)
		Soft Component	Hard Component		
UO-108	2.1	0.30	0.84	1.3	0.54
	5	0.11 0.29	1.03	1.94:0.63:1	0.39
	9.4	0.34	0.92	1.1	0.62
	29	0.33	1.2	0.56	0.88
	90	-	0.88	-	0.88

3.3 LEACHING BEHAVIOR OF SOIL SAMPLES

Some examples of the percentages of total activity removed from the scoop and core samples from the surface burst by the decontaminating solutions are shown in Table 3.22A. For each solution except sea water, the activity is broken down into the percentage appearing in the ionic state and that in the colloidal state. Such a breakdown for sea water was precluded by the formation of colloidal material (possibly algae) in the dialysate. Unless otherwise indicated, these values refer to 171 hr after detonation and 134 hr of contact between soil and decontaminant.

Some results of the ion-exchange experiments are presented in Table 3.22B. The values shown were calculated from the relationship

$$\frac{A_o(t) - A_s(t)}{WA_o(t)} \qquad (3)$$

where $A_o(t)$ is the activity of the original dialysate at time t, $A_s(t)$ is the activity of the supernatant liquid from the soil mixture at the same time t, both activities referring to 500 λ aliquots, and W is the weight of the soil in grams. It should be noted that t, here, refers to the time at which the activities were measured and not to the duration of contact between soil and dialysate when the aliquots were taken. This latter time was 24 hr.

TABLE 3.22

Examples of Results Obtained with Soil Samples from the Surface Burst

A. Percentage of Total Activity Removed by Leaching

Sample	Physical State of Activity	Distilled Water	Sea Water(a)	0.8% "Duponol C"	0.8% "Tide"	0.8% EDTA	10% Sodium Citrate(b)
Core	Ionic	1.8	2.5	1.5	3.9	16.6	23.9
	Colloidal	0.58		1.65	1.04	1.37	0.37
Scoop 1	Ionic	3.1	2.5	4.6	7.0	22.7	14.9
	Colloidal	0.19		0.70	0.73	1.10	0.03
Scoop 5	Ionic	0.9(c)	2.1	1.6(c)	6.5	5(c)	~11
	Colloidal	0.14(c)		0.3(c)	0.56	0.5(c)	~ 0.2

B. Relative Decrease in Ionic Activity per Gram of Fresh Soil

Sample	Distilled Water	Sea Water	0.8% "Duponol C"	0.8% "Tide"	0.8% EDTA	10% Sodium Citrate
Core	0.22	-	0.25	0.30	0.07	0.00
Scoop 1	0.20	0.04	0.23	0.45	0.22	0.09
Scoop 5	0.21	0.25	0.12	0.15	0.13	0.04

(a) Only the total percentage of leached activity is given for sea water.

(b) The values for sodium citrate are of uncertain reliability due to mold growth in the solution.

(c) These values refer to 96 hr after detonation and are based on an extrapolated decay curve.

The percentages of total activity removed from the underground burst sample are broken down according to their physical state and presented in Table 3.23A. In order to check the selectivity of the solutions, the variation of these percentages with time has been determined from the decay curves of the aliquots and of the original sample. Both the earliest values obtained and values for a substantially greater period of decay time are presented for comparison. By comparing the activities of the first set of aliquots with the activities of another set taken 48 hr later, it was established within the error of the experiment that these values refer to equilibrium conditions.

In Table 3.23B, the results of the ion-exchange experiment are summarized by means of the same function used in the previous section. Here, however, the values presented for the different periods of contact were obtained from separate sets of aliquots and the increase of the values with time is due to the slow attainment of equilibrium.

An absorption curve of the ground 20 mesh fraction of the original sample was taken and compared to the absorption curve of a thoroughly pulverized and mixed portion of the original scoop sample. The identity of the curves established the fact that discarding the larger size particles did not produce any significant fractionation of the contaminating activity.

The upper limit of irreproducibility, as determined from the standard error of four identical water leaches on four representative samples of particle size somewhat greater than 20 mesh, was ± 15 per cent.

The results of the analytical procedure are summarized in Table 3.24. For any given source of radiation, the tabulated data represent the activity in 1 ml of dialysate due to that source. By means of the known decay characteristics, all data have been computed for 43 days after detonation. The relative amount of dialysate activity accounted for can be readily seen by comparing total amount of activity obtained from the sources listed for any given solution with the activity of 1 ml of that solution as shown at the bottom of the table.

The Cs^{137} activities in sea water, "Tide", and sodium citrate dialysates were found to be anomalously high and have not been reported. This anomaly is believed to be due to the concentration of alkali metals in algae, sediment, and mold, respectively, over prolonged periods of standing and to the introduction of these concentrates into the aliquots chosen for analysis.

TABLE 3.23

Summary of the Results Obtained with Contaminated Soil from the Underground Burst

A. Percentage of Total Activity Removed by Leaching

Time After Detonation (hr)	Physical State of Activity	Distilled Water	Sea Water	0.8% "Duponol C"	0.8% "Tide"	0.8% EDTA	10% Sodium Citrate
51	Ionic	0.35	0.34	0.42	0.58	[illegible]	0.69
51	Colloidal	0.90	0.50	1.35	1.54	1.60	0.76
288	Ionic	0.15	0.36	0.24	0.55	0.93	0.69
261	Colloidal	0.57	0.30	1.13	1.37	1.37	0.67

B. Relative Decrease in Ionic Activity per Gram of Fresh Soil

Time After Mixing (hr)	Distilled Water	Sea Water	0.8% "Duponol C"	0.8% "Tide"	0.8% EDTA	10% Sodium Citrate
45	0.48	0.38	0.31	0.32	0.22	0.16
144	0.54	0.49	0.52	0.59	0.46	0.16

TABLE 3.24

Analysis of Leach Dialysates from the Underground Burst

Source of Activity	Means of identification	Activity in 1 ml dialysate due to source 43 days after detonation					
		Distilled Water	Sea Water	0.8% "Duponol C"	0.8% "Tide"	0.8% EDTA	10% Sodium Citrate
Cs^{137}	Absorption	0.06	-	0.30	-	0.42	-
Ca	-	n.d.(a)	n.d.	n.d.	n.d.	n.d.	n.d.
Sr^{89}	Absorption and decay	0.02	0.20-0.21	0.13	0.15	0.26	0.26
Ba^{140}	Absorption and decay	0.01	0.20-0.28	0.03	0.07	0.18	0.21
La^{140}	Calculated from Ba^{140}	0.01	0.17-0.24	0.03	0.06	0.15	0.18
Y^{91}(b)	Absorption and decay	0.02	0.03	0.08	0.89	1.29	1.44
I^{131}	Absorption and decay	0.09	0.13	0.14	0.14	0.18	0.14
I^{133}	Absorption and decay	n.d.	n.d.	n.d.	$\sim 10^{-7}$	$\sim 10^{-7}$	n.d.
Total		0.21	-	0.71	-	2.48	-
1 ml dialysate		0.20	1.52	0.82	2.50	3.28	3.20

(a) Not detected.

(b) Values are based upon the assumption of equivalent yields of La and Y carriers.

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An inadvertent contamination of alkaline earth activities during analysis has made the presentation of exact values for Sr^{89}, Ba^{140}, and La^{140} in sea water impossible. It has been possible, however, to calculate a fairly narrow range of limits for these activities and these values have been offered along with the more reliable data.

CHAPTER 4

DISCUSSION

4.1 RADIOCHEMICAL COMPOSITION OF SAMPLES

The radiochemical investigations of samples collected at Operation JANGLE give information on (1) the shape of the fission yield curve of products of a bomb fission process, (2) the extent of production of several neutron induced radionuclides, (3) the existence of fractionation of several radionuclides, and (4) the contribution of several induced radionuclides and fission products to the measured gross beta-activity as a function of time after detonation.

In the thermal neutron fission process, the ratio of fission yields of radionuclides at the maxima of the fission yield curve to those at the minimum is about six hundred to one. Although the curves obtained in these studies are not clearly defined because of fractionation effects, the ratio seems smaller in the bomb fission process. In the surface burst, the ratio is about one hundred to one for the scoop and core samples and about three hundred to one for some of the differential fall-out samples. In the underground burst, the ratio is about six hundred to one for both the scoop sample and the differential fall-out samples.

4.2 GROSS DECAY RATES AND BETA AND GAMMA-RAY ENERGIES

In the tables, the values for the ratio of abundance of the soft radiation component to that of the hard radiation component varied appreciably, since the values were determined from intercepts of slopes of half-thickness curves with the zero added absorber axis. A small change in half-thickness of the soft component would make an appreciable change in ratio of soft to hard radiation. Similarly, the scatter of experimental points made it difficult to define the slope of the curves accurately. The combination of these errors contributed a maximum error of about ± 0.04 Mev to the average energies. The total error in average beta and gamma-ray energy is estimated to be approximately ± 0.1 Mev.

Average beta-ray energies range from 0.17 to 0.52 Mev for the surface burst and from 0.23 to 0.58 for the underground burst. In both cases, the average energy showed a general decrease with time at early times, and a gradual tendency to increase at later times; the minimum occurred at about 10 days. Average gamma-ray energies range from 0.51 to 0.77 Mev for scoop samples and from 0.6 to 1.6 Mev for the core sample from the surface burst and from 0.51 to 0.88 Mev for the scoop sample from the underground burst. These average energies are not corrected for the counting efficiency of the detector used. Pulse height analysis data and several lead absorption curves (taken through relatively thin lead absorbers) showed the presence of a 0.1 Mev component, in addition to the two components usually observed.

Except for the core sample, the average gamma-ray energies were observed to be relatively constant over the period observed, with a slight tendency to increase with time. The core sample showed stronger average gamma-ray energies at early times than any other sample observed. The high energy component showed a continual decrease in energy with time from about 2 Mev at approximately 1 day to about 0.8 Mev at 10 days. The decay curve and radiochemical analyses of this sample indicate that it had more induced activity than the other samples. Si^{31} (no γ); Mn^{56} (E_γ = 0.8, 1.8, 2.1, and 2.7); K^{42} (E_γ = 1.51); and Na^{24} (E_γ = 2.76 and 1.38) comprise about 20 per cent of the gross activity 8 hr after detonation. The observed slopes of the log-log plots of the beta-gamma-ray decay of the gross radiations range from 0.47 to 3.1 for the surface burst and from 0.44 to 2.3 for the underground burst. The slopes for the core sample were generally much greater than those of any other sample. The observed slopes of the log-log plots of the gamma-ray decay range from 0.87 to 1.3 for scoop and 1.3 to 3.5 for core samples for the surface burst and from 0.80 to 1.4 for the underground burst.

As is apparent from the great difference in slope of log-log plots of beta and gamma-ray decay and the great difference between the average energies of radiations of the various samples, it is evident that the contamination in the soil is of variable composition and consists of induced activities and fission products fractionated to differing extents. The semi-log plot of the decay of the radiations from NYO-19, at early times, was resolved into two components of half-lives 3.1 hr and 21 hr. A similar plot of the decay of the core sample yielded components of half-lives of 3.2 hr and 16 hr.

4.3 LEACHING BEHAVIOR OF SOIL SAMPLES

It should be pointed out that the value of the results obtained in the leaching experiments on samples from the surface burst are questionable for two reasons: first, the use of ground soil presented an unrealistically large surface area from which neutron induced activity and occluded fission products could be leached, and, secondly, the experimental arrangement was such that activity was continually passing from the soil to the solution so that the values given are not for equilibrium conditions. These two defects were remedied in the treatment of the scoop sample from the underground burst so that the resulting data are more meaningful.

Regarding the ion-exchange experiment with the surface burst material, it is interesting to note that while the ability of citrate ion to form complex ions shows up markedly in the low values of the relative activity decrease for the citrate solutions, there is a strong tendency for all other values of Table 3.22B to cluster about 0.2.

According to the results (shown in Table 3.23A) of the studies on the scoop sample from the underground burst, at most only about 2 per cent of the total activity is leached out of a gram of soil with 10 ml of solution; thus, leaching does not seem to be a very practical method of soil reclamation. Similarly, unless large amounts of material are mechanically transported over considerable distances, the effect of rainfall on the radiation characteristics of a contaminated area may be expected to be slight.

As was expected, the effect of grinding the soil sample from the surface burst was to increase greatly the amount of ionic activity in the leach without appreciably effecting the magnitude of the colloidal fraction.

In all cases except one, the largest fractions of ionic activity appeared in the EDTA and sodium citrate solutions. Similarly, the largest colloidal percentages consistently appear in "Duponol C", EDTA, and "Tide"; only the relatively high efficiency of EDTA for removing colloidal activity was not anticipated. These results indicate, therefore, that EDTA and sodium citrate should be of value in removing contamination of an ionic nature. "Tide", "Duponol C", and EDTA should be superior in removing contamination which is primarily colloidal.

Again in Table 3.23B, low values of the relative activity decrease are obtained for sodium citrate. Here, also, the ability of EDTA to form complexes is more apparent than in Table 3.22B. Again, too, there seems to be little, if any, difference among the remaining solutions.

The analyses of the ionic fractions of the leaches lend themselves fairly well to theoretical explanation on the basis of three factors: solubility, exchange, and complexing action. Thus, the appearance of ionic activity in distilled water should be principally due to the solubility of the source of activity. Taking distilled water as a point of reference, then, the greater alkali metal activity in the other solutions and the greater activity due to Ba and Sr and I in sea water may well have been brought about through exchange. The complexing action of EDTA and citrate ion is probably responsible for the relatively large amounts of activity associated with Ba, Sr, and the rare earths found in these solutions.

The equivalence of all solutions for removing iodine activity and close parallelism in the results of analyses of EDTA and citrate dialysates are also worthy of mention.

CHAPTER 5

SUMMARY

The following conclusions may be made from our studies of samples obtained in Operation JANGLE.

Np^{239} is the major neutron induced radionuclide produced. Measurable amounts of other neutron induced radionuclides were found. Na^{24}, K^{42}, and Mn^{56} may be important contributors to the gross activity at early times under the conditions of these tests.

Neutron induced radionuclides other than Np^{239} do not contribute more than a few per cent to the gross radioactivity remaining from a surface or underground burst in the period 1 to 90 days after detonation, except in places which, although subject to the neutron flux of the bomb, are not significantly contaminated by the fission products (e.g., a few inches below the surface of the soil at the lip of the surface burst crater).

Fractionation of the fission products occurs much more extensively in the bomb debris from a surface or underground burst than it does from an air burst.

The observed slopes of the log-log plots of the decay of gross radiations vary from 0.5 to 3.1 with most values for the period 1 to 90 days lying between 0.9 and 1.5.

Average beta-ray energies range from 0.17 to 0.55 Mev, and lie mainly between 0.25 and 0.45 Mev.

Average gamma-ray energies lie mainly between 0.4 and 0.9 Mev. The softer component of the gamma-rays has an average energy close to 0.3 Mev, while the harder component has an average energy of about 1.0 Mev at most times from 1 to 90 days after detonation.

Leaching contaminated soil with water or decontaminating solutions (detergents or chemical complexing agents) does not seem to be a feasible method of soil reclamation. Only about 3 per cent of the gross activity is removed by such treatment.

APPENDIX A

RADIOCHEMICAL PROCEDURES

The following outline of the radiochemical procedures supplements Section 2.1.

Ruthenium - Ruthenium was separated from the other elements by distillation as ruthenium tetroxide, precipitation with ethyl alcohol from a sodium hydroxide solution, and reduction to the metal with magnesium as described by Hume.[1]

Barium - The barium procedure followed that of Hume except that a fuming nitric acid precipitation preceded the barium chloride precipitation.

Silver - Silver was purified according to the procedure described by Hume by silver chloride precipitation, ferric hydroxide scavenging precipitations, silver sulfide precipitation, and final silver chloride precipitation.

Cadmium - Cadmium was separated as described by Hume with cadmium sulfide precipitations, ferric hydroxide and palladium sulfide scavenging precipitations, and final precipitations as cadmium ammonium phosphate.

Cerium - Cerium was separated by a fluoride precipitation, purified with iodate and oxalate precipitations and zirconium iodate scavengings, as in the work already cited.

Zirconium - The procedure described by Hume was followed, i.e., lanthanum fluoride scavenging precipitations, barium fluozirconate precipitations, barium sulfate and zirconium cupferrate precipitations, followed by ignition to zirconium oxide.

Molybdenum - The molybdenum determination followed the procedure given by Hume, i.e., precipitations as molybdenum alpha-benzoin oximate, a ferric hydroxide scavenging precipitation, and final precipitation as lead molybdate or as molybdenum alpha-benzoin

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[1] D.N. Hume, N.E. Ballou, and L.E. Glendenin, "A Manual of the Radiochemical Determination of Fission Products Activities", CN-2815 (no date).

oxinate, which was then ignited to molybdenum oxide. In some cases, the first two molybdenum oxinate precipitates were dissolved in fuming nitric acid and reprecipitated by dilution, neutralization with ammonium hydroxide and addition of more reagent; the third and last oxinate precipitate was destroyed by perchloric acid.

Neptunium - The separation of neptunium followed the procedure discussed by Hudgens,[2] i.e., reducing the neptunium, carrying it on lanthanum fluoride, oxidizing the neptunium, precipitating and discarding the lanthanum fluoride, reducing the neptunium and mounting it with a lanthanum fluoride slurry on a metal disc. Chemical yield was determined by adding a known amount of Np^{237} tracer to the original solution and counting the alpha particles in the final mounted sample.

Gallium - The gallium procedure followed that described by Meinke,[3] which included extractions of gallium with ethyl ether from 6N hydrochloric, bismuth sulfide, ferric hydroxide and barium carbonate scavenging precipitations, evaporations to dryness with hydrobromic acid, and final precipitation as the 8-hydroxyquinolate.

Phosphorous - Phosphorous was separated by ammonium-phosphomolybdate precipitations in the presence of lanthanum hold back carrier, ferric hydroxide scavenging precipitations, and final precipitation as magnesium ammonium phosphate, followed by ignition to magnesium pyrophosphate.

Manganese - Manganese was purified by precipitations of MnO_2 (produced by sodium chlorate-nitric acid oxidation of manganous ion) in the presence of lanthanum, cadmium, iron, zirconium and calcium hold back carriers, basic ferric acetate, ferric hydroxide and cerium oxalate scavenging precipitations, and final precipitation as manganese ammonium phosphate, followed by ignition to manganese pyrophosphate.

Iron - Iron was purified by isopropyl ether extractions from 6N hydrochloric acid, barium sulfate, antimony and tellurium sulfide and cerium fluoride scavenging precipitations, and final precipitation as ferric hydroxide, followed by ignition to ferric oxide.

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[2] J.E. Hudgens, and J.E. Sattizahn, "Development of a Method for the Determination of Np Activity in Process Solution", MON N-13, Sept. 24, 1945.

[3] W. Wayne Meinke, "Chemical Procedures used in Bombardment Work at Berkeley", UCRL-432, Aug. 30, 1949.

Silicon - Silicon was determined by precipitation of silicon dioxide by fuming perchloric acid, dehydration and ignition, followed by distillation of silicon tetrafluoride in a copper still, and precipitation as potassium fluosilicate.

Calcium - Calcium was purified by ruthenium, iron, and bismuth sulfide, iron, lanthanum, and yttrium hydroxide, and strontium and barium nitrate, scavenging precipitations, and final precipitation as calcium oxalate.

Sodium - Sodium was purified by ferric hydroxide, lanthanum fluoride, barium carbonate and lead sulfide scavenging precipitations, separated from potassium by extraction of sodium perchlorate with ethyl acetate, and finally precipitated as sodium chloride.

Potassium - Potassium was purified by the same scavenging precipitates used in the sodium procedure, and separated from sodium by precipitation of potassium perchlorate.

Strontium - Strontium was isolated by a fuming nitric acid precipitation, purified by barium chromate and ferric hydroxide scavenging precipitations, and finally precipitated as strontium oxalate.

OPERATION JANGLE

WT-363

PROJECT 2.6c-3

RETRIEVABLE MISSILES FOR REMOTE GROUND SAMPLING

By

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June 9, 1952

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PROJECT 2.6c-3

PREFACE

The purpose of this investigation was to develop and field-test a cheap, simple method for obtaining surface soil samples from areas which cannot be entered by personnel. It was desirable that the method selected use material which was readily available and which did not require extensive basic research. The method should not require the training of a group of specialists.

The use of a retrievable missile seemed to be an obvious method of attack. If successfully developed it would not only be of use in future atomic weapons tests but would also be of potential value in evaluating the hazards associated with an explosion delivered by an enemy.

ACKNOWLEDGMENTS

The investigators wish to express their indebtedness to the personnel of Aberdeen Proving Grounds for assistance in conducting the firings in the pre-test development program. In particular we are indebted to Mr. S. W. Swim, Rocket Branch Office, Chief of Ordnance for his advice and for making the arrangements with Aberdeen Proving Grounds. Mr. Walter Ramsey, Mr. H. T. Smith, and Mr. Rush of "C" Field were extremely cooperative throughout the whole firing program.

The Kilgore Manufacturing Company, Westerville, Ohio, was very cooperative in filling orders on very short notice and in giving technical advice.

The Columbian Rope Company, Auburn, New York went to considerable trouble to prepare special coils of nylon shot line for these tests.

Capt. Marius De Martino, U.S. Coast Guard, Washington, D. C., was very generous with advice and loan of equipment in the early phases of this project.

PROJECT 2.6c-3

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PROJECT 2.6c-3

ABSTRACT

Field tests, described in this report, show that a retrievable missile may be used to obtain surface soil samples. This report describes the selection of the missile, its pre-test development, its performance and its limitations. The missile selected was a small line-towing rocket manufactured by the Kilgore Manufacturing Company, Westerville, Ohio. It is inexpensive, readily available and easy to use. It has a range of 1100 feet and a probable impact area approximately 75 feet in diameter.

Recommendations are given for improvements which will greatly expand its possibilities.

CHAPTER 1

SELECTION OF TOWING MISSILE

1.1 INTRODUCTION

Five types of line-towing missiles are readily available. Four of these were eliminated without experimentation.

1.1.1 The Shoulder Line-Throwing Gun

The shoulder line-throwing gun used by the Navy and the Coast Guard is too small and has a range of only 400 feet when towing a very light flax line with a breaking strength of approximately 200 pounds.

1.1.2 The Lyle Gun

The Lyle Gun ("Report on Life Saving Ordnance", Lt. D. A. Lyle, Ordnance Department, U.S. Army, Government Printing Office, 1878) used by the Coast Guard for shore to ship contact, was eliminated after discussing its characteristics with an officer of the U.S. Coast Guard. This gun is a 2-1/2 inch bore muzzle-loading mortar of variable range. The range is controlled by the amount of charge and the elevation. A maximum range of 1000 to 1200 feet may be normally obtained with a 7/32 inch manila line. The missile is a 19 pound solid slug of metal, loaded nose first into the mortar. This slug, which is approximately 16 inches long, extends beyond the mouth of the mortar and the line is attached to the protruding end. The missile tumbles in flight, thereby furnishing a low probability that an attached sampling device will strike the ground with a suitable orientation. A further disadvantage of the Lyle Gun is its large recoil, which eliminates the possibility of firing it from a vehicle.

1.1.3 JATO Motors

The use of JATO motors was discussed by Walter Ramsey of Aberdeen Proving Ground. JATO motors have been used for towing long lengths of very heavy line, but the motors now available are either too large or too small for the sampling device and line required for this project.

1.1.4 Standard Military Rockets

The possibility of using a standard military rocket was considered. Dr. Weil[1] and Dr. Anderson[2], with Mr. Wadsworth Mount[3] as a consultant, developed a remote sampling device using a military rocket for sampling the crater during the first atomic test in New Mexico. The present investigators were unable to locate the report on these developments in the literature of the Manhattan Project. However, discussions with Dr. Weil and with Mr. Mount convinced the investigators that the military rocket was not the missile of choice for this development.

The equipment used by Dr. Weil consisted of a 3 inch to 4 inch army rocket weighing approximately 40 pounds and a special reel of 1/8 inch steel cable. The rocket which was fired from a conventional military launcher at an angle of 45°, used a high pressure motor which accelerated the rocket very rapidly to maximum velocity in approximately 0.1 seconds. The rocket, with cable attached at the center of gravity, was stabilized in flight by a standard airfoil assembly. It fell almost vertically at a range of 1500 feet and drove the sampling head so firmly into the ground that the force necessary to retrieve the sample quite often snapped the 1/8 inch steel cable.

The specially wound reels of cable supplied to Dr. Weil by the Intertype Corporation, (New York City) are not now being produced. The special production of the limited number of cables required by Project 2.6c would force the cost of each cable up to approximately $1000 each. Such an expenditure was prohibited by the project budget and diametrically opposed to one of the aims of the project, namely to develop a cheap simple sampling device.

1.1.5 The Line-Towing Rocket

The elimination of the above missiles left the investigators with the line-towing rocket manufactured by the Kilgore Manufacturing Company for ship use by the Merchant Marine. Except for its limited range this missile seemed to satisfy all requirements.

This simple 8-1/2 pound rocket has been specifically designed as a portable line-towing device which will tow a 7/32 inch manila line 1000 to 1100 feet. The components as purchased are shown in Figure 1.1. "A" is the rocket motor which is powered by 2-1/4 pounds of slow-burning solid propellent of the nature of black gunpowder. It "pulls" for approximately three seconds thereby greatly reducing the stress on the towing line by its acceleration. The cost of the motor is $15. "B" is the harness used to fasten the line to the motor. The harness

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1. Dr. George L. Weil, Atomic Energy Commission, Washington, D. C.
2. Dr. Herbert L. Anderson, Institute of Physics, University of Chicago, Chicago, Illinois.
3. Mr. Wadsworth Mount, 51 High Street, Summit, New Jersey.

consists of a yoke which allows the motor to be placed in the launcher and to which is attached 10 feet of 1/8 inch steel cable for the purpose of removing the manila line from the searing blast of the rocket exhaust. This construction places the center of drag well behind the center of thrust, thereby producing a stable rocket without the use of airfoils. The harness costs $5. "C" is an assembled rocket and harness with the standard nose instead of the ground sampling nose shown in "B". "D" is the rocket launcher. It consists of a modified Very pistol, with a shield to protect the operator from the rocket exhaust. The rocket launcher weighs 15 pounds and according to the manufacturer can be handfired with a recoil approximately that of a 10 gauge shotgun. The cost of the complete rocket launcher is $122. "E" is the primer-ejector which simultaneously ejects the rocket from the launcher and ignites the rocket motor. The cost of the primer-ejector is $0.50. The bucket containing the 7/32 inch manila shot line is shown in Figure 1.2. The cost is $28 for a 1700 foot length weighing 30 pounds.

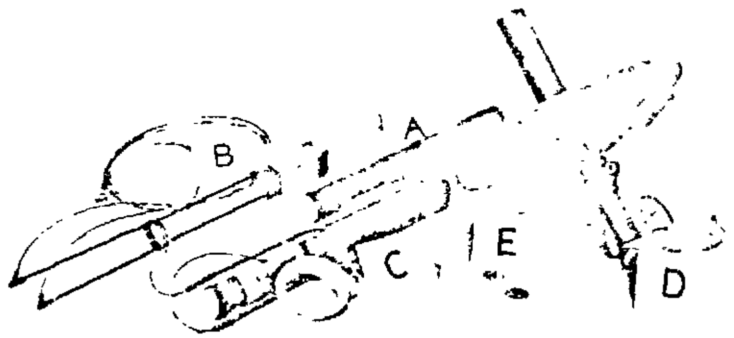

Figure 1.1 Component parts of sampling device

The investigators have never fired the rocket from the hand-held firing position recommended by the manufacturer but have built a mechanical support for more accurate control of the elevation and direction. (See Figure 1.3).

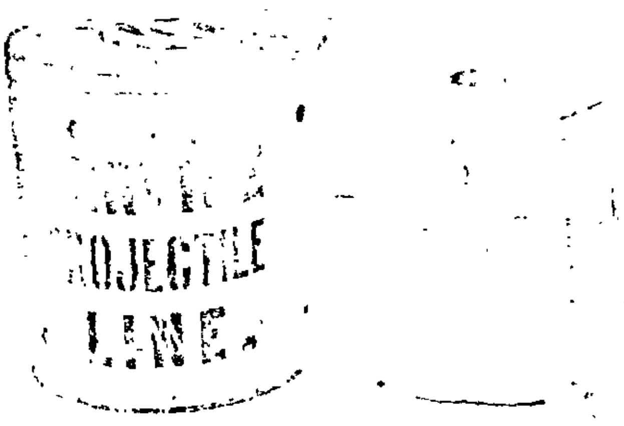

Figure 1.2 Coils of manila shot line and nylon shot line as received

Figure 1.3 Loading rocket into launcher on firing mount

CHAPTER 2

PRE-TEST DEVELOPMENT

2.1 OBJECTIVES

The objectives of the pre-test development program were: (1) to become familiar with the operation and characteristics of the equipment selected, (2) to design and build a sampling device to be attached to the rocket and to determine the effect of the device upon the flight characteristics of the rocket, (3) to increase the range of the rocket by the use of lines other than the recommended 7/32 inch manila line, and (4) to build and test a light mount for use in firing the rocket from a vehicle.

2.2 EXPERIMENTAL

The pre-test firings were conducted at the Aberdeen Proving Grounds by the personnel of "C" Field through arrangements made by Mr. S. W. Swipp, Rocket Branch Office, Chief of Ordnance.

The number of firings was kept to a minimum. Most of the effort was directed toward studying the effect of different lines upon the range and flight characteristics of the rocket. The testing of the launching mount and the sampling device were incorporated into these tests. All firings were made at an elevation of 25 to 30° as recommended by the manufacturer.

No tests were made on recovery because the hard black loam and heavy grass and underbrush which comprised the firing field did not approximate the expected field conditions and because we did not wish to tie the "C" Field personnel up any longer than necessary.

2.3 APPARATUS

2.3.1 Rocket

The rocket, standard harness, and rocket launching appliance, as secured from the Kilgore Manufacturing Company, has been described earlier (Chapter 1) and is shown in Figure 1.1.

2.3.2 Sampling Head

The two sampling heads developed are shown in Figures 2.1, 2.2, and 2.3. The door is opened by impact as the kinetic energy of the rocket drives the sampling device into the ground. The heavy leading edges protect the hinges and spring which operate the door and serve as stops when the door is closed. If the soil packs so tightly that the coil spring cannot close the door, a large sample is collected. If the soil is packed loosely into the device and the spring closes the door a smaller sample is collected. The 45° plates on the sampling device in Figure 2.3 are designed to prevent the rocket from penetrating too deeply into the earth and to blast a crater, rather than a clean narrow hole, by diverting part of the kinetic energy into side thrust.

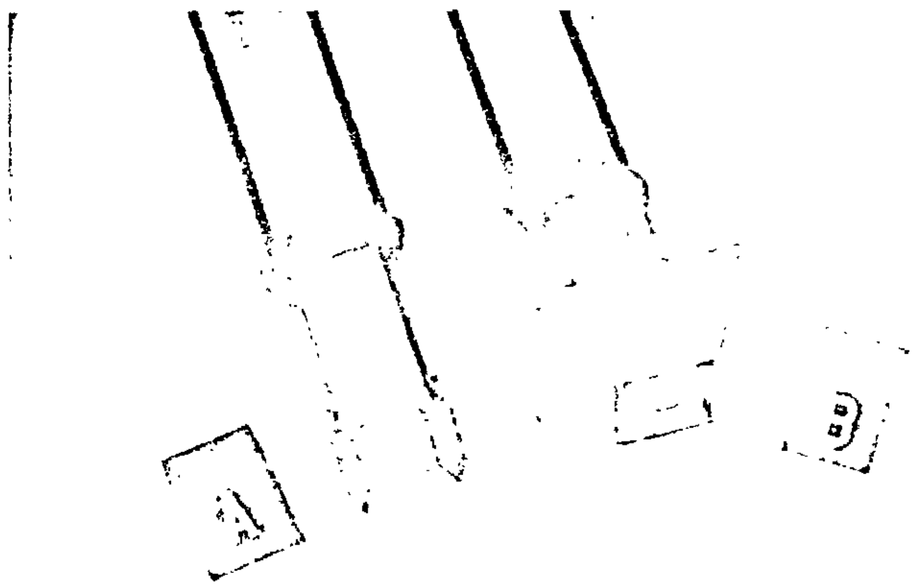

Figure 2.1 Sampling Heads

2.3.3 Lines

The characteristics of the various lines tested are listed

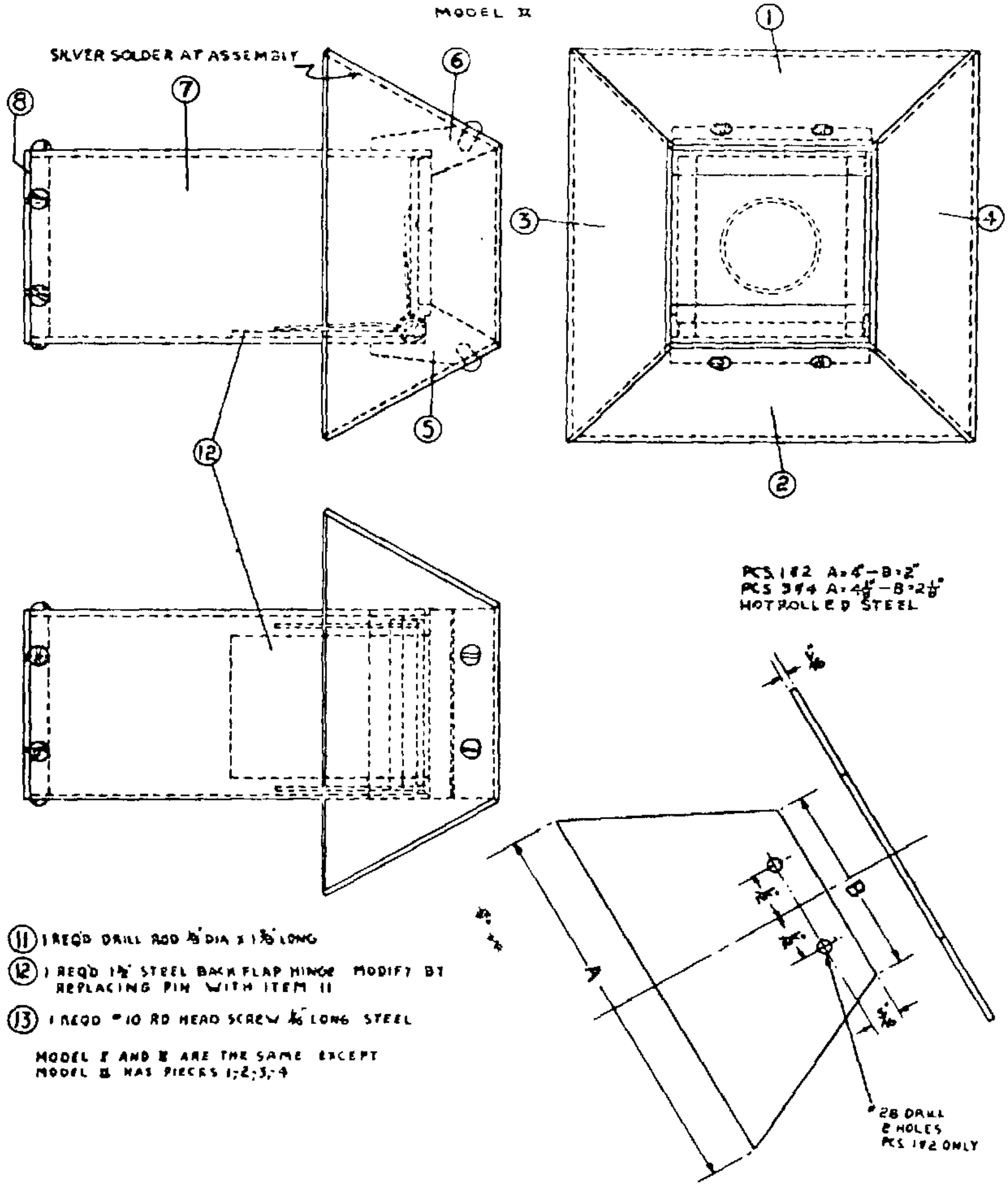

Figure 2.2 Details of sampling head

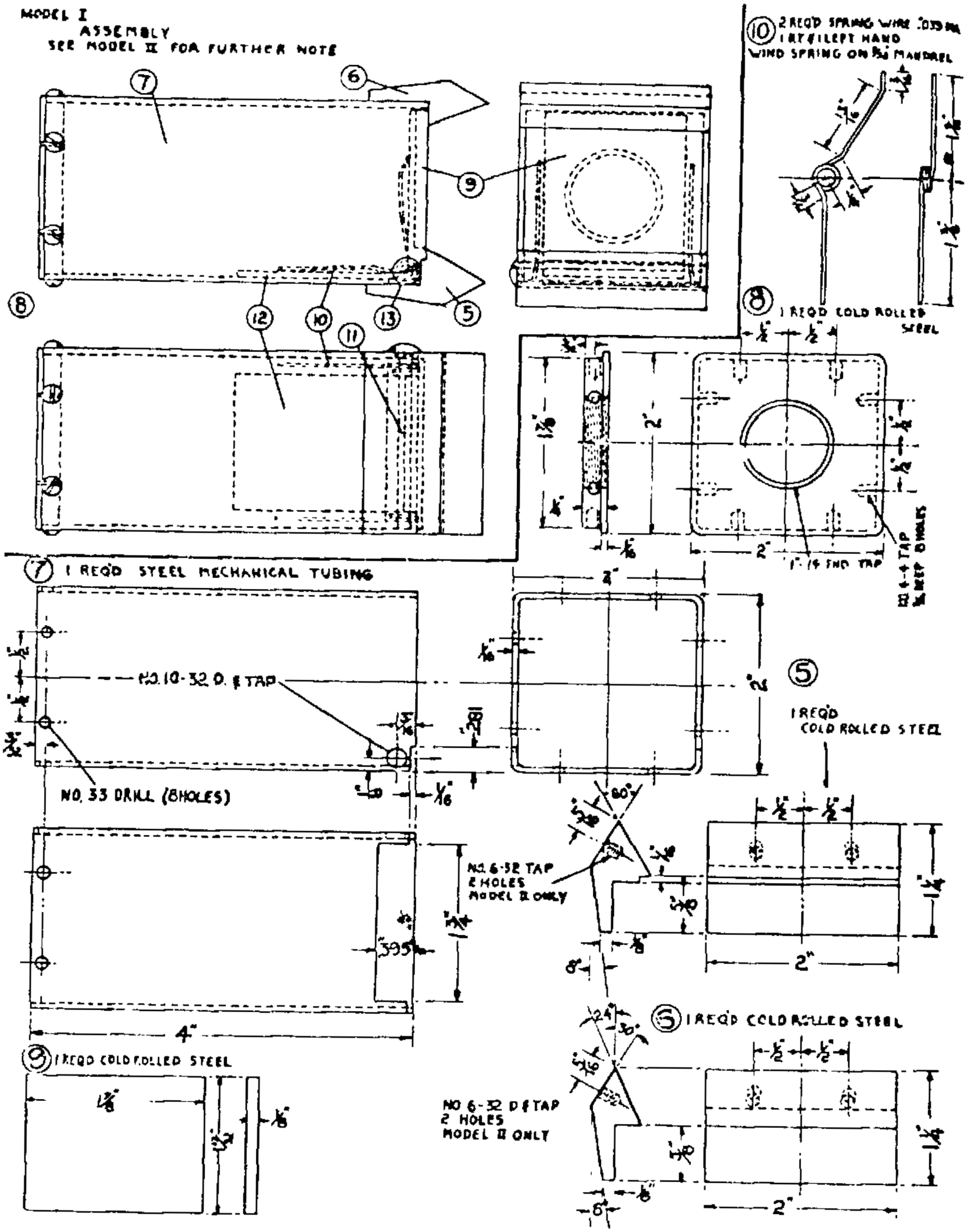

Figure 2.3 Details of sampling head

below:

- a. 7/32 inch Manila shot line
  - (a) breaking load - 450 pounds
  - (b) weight - 18 pounds/1000 feet
  - (c) cost - $28/tub of 1200 feet
  - (d) source - R.J. Taylor Co. 39 S. Gay St., Baltimore, Md.
  - (e) remarks - received ready for use
- b. 1/8 inch nylon trawl line
  - (a) breaking load - 420 pounds
  - (b) weight-2.1 pounds/1000 feet
  - (c) cost - $12 for spool of 2000 feet
  - (d) source - Plymouth Cordage Co., Plymouth, Mass.
  - (e) remarks - a very soft laid, very flexible line. Must be rewound before use
- c. 5/32 inch hard laid nylon line
  - (a) breaking load - 800 pounds
  - (b) weight - 7.5 pounds/1000 feet
  - (c) cost - $46 for coil of 2240 feet
  - (d) source - Columbian Rope Co., Auburn, N. Y.
  - (e) remarks - received in coil which had to be placed in tub before firing
- d. 1/16, 1 x 19 stainless steel cable
  - (a) breaking load - 500 pounds
  - (b) weight - 8 pounds/1000 feet
  - (c) cost - approximately $70/1000 feet
  - (d) remarks - must be wound on special reel before use
- e. 1/8 inch, 6 x 7 stainless steel cable
  - (a) breaking load - 1500 pounds
  - (b) weight - 25 pounds/1000 feet
  - (c) cost - approximately $200/1000 feet
  - (d) remarks - must be wound on special reel before use

2.3.4 Line Dispensing Apparatus

The rapid acceleration of the rocket makes it necessary for the line to be paid out in a manner which does not require the initial acceleration of an entire reel or other holding device. This was accomplished with the various ropes by pulling the line from the inside of a hollow coil. The manila shot lines used came in such a hollow close-wound coil, protected in an open end bucket. The 5/32 inch nylon line came wound in a similar coil but without the protecting bucket. A bucket similar to the one on the manila lines had to be constructed to support the coil before the binding ropes could be cut and the line paid out. Figure 1.2 shows a coil of each line as received.

The 1/8 inch nylon line had to be rewound before it could be used. For this purpose a winding machine was constructed similar to the line winding machines used by the Coast Guard for both the 7/32 inch manila line they use with the Lyle gun and the smaller line they use with the shoulder line-throwing gun. This machine winds the line into a coil which is self supporting. Figure 2.4 shows the rewinding machine and the start of a self supporting coil. Note the pattern of the winding upon the removable tapered center.

The investigators were assured by Mr. Mount that stiff springy steel cable could not be paid out from such coils. Consequently two wooden reels were devised for use with the steel cables. The first consisted of a large wooden drum four feet in diameter upon which the cable was wound in a single layer. The rocket pulled the cable over the end of the drum and since the coil of cable was only one layer deep there was no possibility of kinking on pay out. However, a special winding technique had to be used to prevent the cable from kinking as the result of the twists introduced in the cable as the turns were pulled off the drum. As each turn was wound onto the drum, a twist was introduced in the cable in such a manner as to neutralize the twist introduced later as the turn was pulled off the end of the drum.

The second reel consisted of two 18-inch drums placed 36 inches between centers. The cable was wound in a single layer on these two drums in a figure eight pattern. When pulled from the reel the clockwise twist introduced by one drum was neutralized by the counter-clock-wise twist introduced by the second drum.

Since the completion of the test it has come to the author's attention that drums of steel cable for use as shot line can be purchased from Wellcome Devices Manufacturing Corporation, 290 Manville Road, Pleasantville, New York. The cable is available in a variety of sizes and in lengths up to several thousand feet and is wound in a manner which eliminates twist. The cost is not known.

2.3.5 Firing Mount

The simple firing mount used in this test is shown in Figure 2.5. The rope and remote firing were a requirement of the safety personnel at "C" Field and was used in all firings in spite of the fact that the launcher was designed for hand held firing.

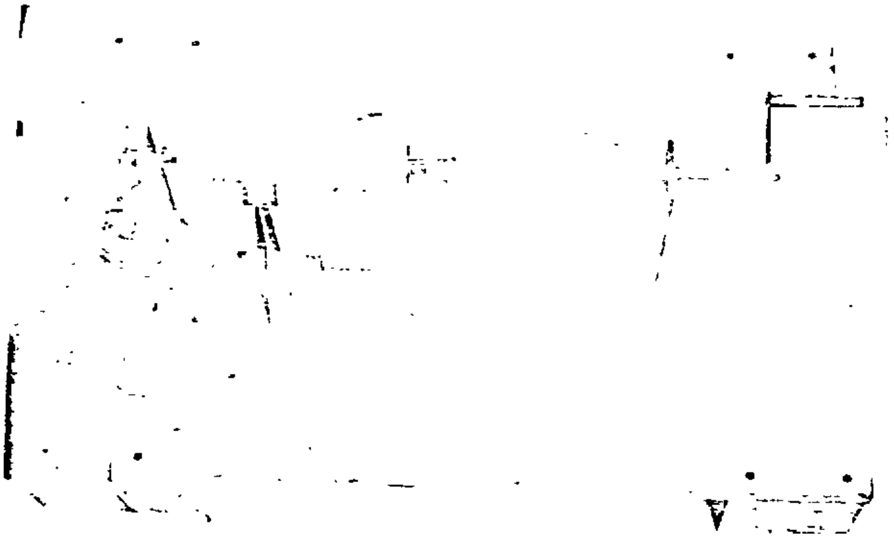

Figure 2.4 Line winding machine

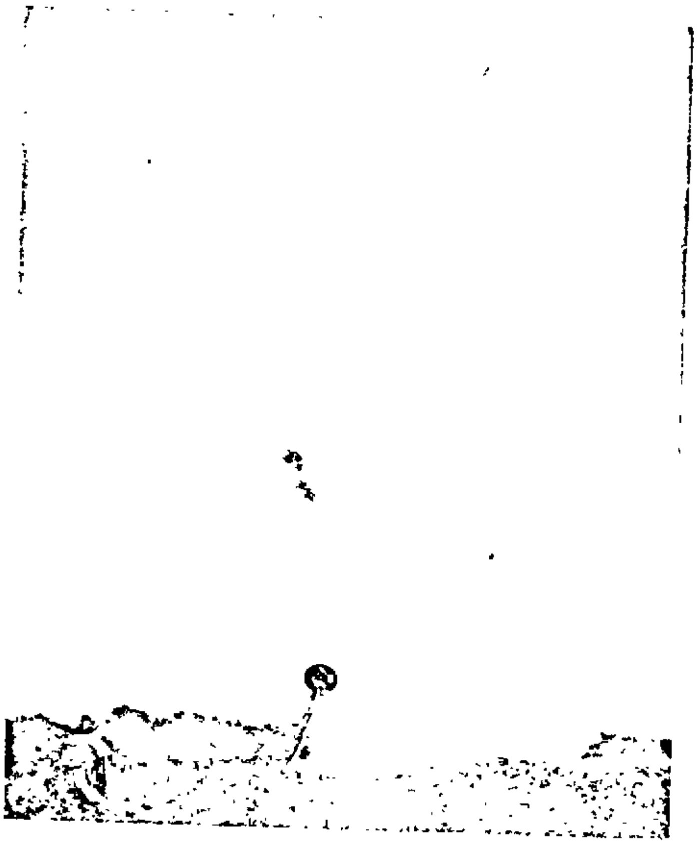

Figure 2.5 Rocket in flight with nylon line. Note kinks

2.4 RESULTS

The details of the results of the pre-test firings are given in the following sections.

2.4.1 Manila Line

Firings with the 7/32 inch manila line and the standard rocket showed that this combination gave a steady, well stabilized flight. The rockets landed at about a 45° angle and penetrated the hard soil 7 to 9 inches. The rocket had a range of 1000 to 1100 feet and a deflection of less than 50 feet.

One firing with a 7/32 inch manila line and with the sampling device, Figure 2.2, had a steady stabilized flight. The range was 1000 feet with a deflection of 50 feet. The sampling head penetrated the ground 6 inches.

2.4.2 Steel Cable

One standard rocket was fired with the 1/8 inch steel cable and the large four foot drum. The rocket had an erratic "cork screw" flight with a range of 600 feet and a deflection of 20 feet.

One standard rocket was fired with the 1/16 inch steel cable and the four-foot drum. The rocket had a very high erratic "cork screw" flight with a range of 1000 feet and a deflection of 200 feet.

One standard rocket was fired with the 1/16 inch steel cable and the "figure eight" reel. The rocket had a high "cork screw" flight with a range of 1050 feet and a deflection of 300 feet.

2.4.3 Nylon Line

Three standard rockets were fired with the 1/8 inch nylon line with the coil in a bucket similar to the ones used with the manila line. Except in one experiment reported below, a leader of 50 feet of manila line was used with the 1/8 inch nylon line to protect the thermosensitive nylon from direct blast of the rocket exhaust. In all cases approximately 1000 feet of line were paid out but the line broke in the air two or three hundred feet behind the rocket. In all cases the line had large kinks and knots and was broken at the forward edge of a kink. The trailing edge of the line attached to the rocket appeared to have been fused or melted. Many of the kinks and some open line showed positive evidence of fusion and thermal damage. The rockets had fairly stable flights and ranges of 1500, 1600 and 2600 feet.

One standard rocket was fired with only the manila line and two attached handkerchiefs for establishing drag. Two coils of nylon line in protecting buckets were placed in the normal position under the rocket launcher to see if the kinking and fusing of the line might be the result of hot cinders falling from the rocket exhaust into the bucket during the initial stages of burning when the rocket was traveling comparatively slowly. No cinders or fused places were found on the nylon coils but several cinders were found imbedded in the handkerchiefs attached to the end of the manila line. In addition, several holes had burned in the handkerchiefs.

One rocket was fired with the 1/8 inch nylon line in a bucket but without a manila leader. Even with this light drag the rocket had a stable flight. The line was kinked and knotted and was broken in the air about 300 feet behind the rocket. There was no excessive thermal damage in the first 50 feet of line.

The large increase in range obtained with the 1/8 inch nylon line indicated further experiments with it in spite of the breaking and thermal damage observed. The investigators felt that both the breaking and the thermal damage might be eliminated if the line could be paid out without knots and kinks. Since comparatively stiff hard laid manila line does not kink when paid out from this type of coil by the Coast Guard, a treatment was developed which gave the very soft nylon line physical characteristics approximating those of the manila line. This treatment consisted of soaking the line in a mixture of 1/2 gallon of Duco Cement and one gallon of acetone, wiping the excess solution from the line and air-drying it. The incorporated Duco Cement increased the weight of the nylon line 7 pounds. Coils of line prepared with treated line were easier to make, much firmer, and easier to handle than coils prepared with untreated line.

Two firings with treated 1/8 inch nylon line in protecting buckets resulted in two lines breaking in the air as before. The knotting and kinking was some less than with untreated line but the general flight characteristics were the same.

Six firings were made with the coil of treated 1/8 inch nylon line lying on the ground without a protecting bucket. Two lines paid out without breaking and four lines broke in flight as before. One of the intact lines was almost free of kinks but had some thermal damage. Approximately 1950 feet of line were paid out and the rocket had a range of 1550 feet. The other intact line was heavily kinked and also showed thermal damage. Approximately 1900 feet of line were paid out and the rocket had a range of 1400 feet.

Four firings were made with 5/32 inch hard laid nylon line wound for use as a shot line by the Columbian Rope Company. All lines broke in flight and there was much kinking and thermal damage. Figure

2.5 shows the rocket being fired with 5/32 inch nylon line. Note the kinking in the line.

2.5 CONCLUSIONS

The investigatos concluded from the above results that:

a. The Kilgore line towing rocket has a stable well directed flight with any of the ropes tested.

b. The range of the rocket decreases with an increase in the weight of the rope.

c. Steel cables when paid out from the two reels tested produce erratic flights and are not practical for field use.

d. Nylon line cannot be used without further experimentation with line dispensing techniques.

e. The sampling devices do not materially effect the flight characteristics of the rocket.

f. The launching frame is stable when used on the ground.

g. In spite of the investigators' inability to increase the range of the rocket by the use of other lines, the retrievable rocket seemed worthy of field testing with the 7/32 inch manila, the line of choice. The practicability of the method was determined on comparatively cold craters and at a short range during the Jangle operation.

CHAPTER 3

FIELD TESTING

3.1 GENERAL

The sampling equipment selected as the result of the pre-test development discussed in Chapter 2 was further tested at the test-site in order to determine its behavior and performance under field conditions.

3.2 PRE-TEST FIRING

The functioning of the assembled equipment and the recovery procedure were tested by firing five rockets. The equipment was mounted on a 2-1/2 ton 6 x 6 truck so that the rocket launcher pointed to the rear. The truck was driven toward a simulated target, turned around and the rocket fired. The rocket mount was aimed by movement of the truck. Recovery of the rocket was made by attaching the shot line to the truck and driving slowly from the area.

Two rockets were fired slow fire and recovered individually. They had ranges of 1075 and 1085 feet; one was on line of sight and the other went 20 feet to the left. The rockets did not penetrate the hard-packed desert sand but were found lying on the surface. Each sampling head contained approximately two grams of sand from a small crater about one inch deep made by impact. Both rockets were successfully recovered. The heavy sage brush and vegetation were not enough to snarl and break the line. A dynamometer inserted in the line indicated that a maximum force of 150 pounds was required for recovery.

Three rockets were then fired rapid fire under simulated field conditions to determine the time required for multiple sampling. The rocket launcher was swabbed between firings to prevent accidents and possible pre-firing by ignition from residual powder embers but the line of sight was not checked. The firing was completed, the lines were attached to the truck and the truck got underway in two minutes and forty-five seconds. All rockets were successfully recovered.

The three rockets had a range of 1080 ± 15 feet and deflections of 100, 120 and 150 feet to the left. Whether these large deflections were the results of erratic rocket flights or a shift in line of sight of the rocket launcher during the test is not known.

3.3 SAMPLING OF SURFACE CRATER

The field performance of the sampling device was studied by sampling the crater from the surface burst. On the afternoon of D + 2 days the truck with rocket launcher was driven along the weasel-approach road to a marked spot 1050 feet from ground zero. The radiation level was only 100 mr/hr at this time and the test could be conducted slowly and carefully. An observing party proceeded to a point on a line of sight making an angle of approximately 70 degrees with the line of fire. Seven rockets were fired. Corrections for deflection and range were made on the first two shots and the balance were fired from the same position. There was a very strong cross wind which carried the line far to the right into the wrecked remains of a Bailey bridge and a jeep. Two rockets were lost during recovery by becoming so firmly entangled in this debris that the manila lines were broken. The results of individual firings are given below:

1) 200 feet to left; slightly over target. Line broke with a load of 450 pounds when rocket became entangled in jeep. Line of sight adjusted; too much allowance had been made for windage.

2) Erratic flight; on line of sight; over crater. Rocket recovered; maximum pull required, 200 pounds. Launching site moved to 1100 feet from ground zero.

3) 150 feet to right; range good. No recovery attempted. No adjustments made.

4) On dead center; successful recovery. Sampling head was unscrewed from rocket with long wrenches and sample removed by pouring from hole in rear. Approximately 100 grams of sandy soil in sample.

5) 125 feet to right; range good. No recovery attempted.

6) In crater. Rocket was recovered but sampling head had become unscrewed and lost.

7) In crater. Rocket lost on recovery when it became entangled in remains of Bailey bridge.

3.4 SAMPLING OF UNDERGROUND CRATER

On the afternoon of D + 2 days the sampling techniques were further tested by firing into the crater from the underground burst. Five rockets were fired with slightly different ranges and lines of sight in order to obtain a pattern of samples from the large crater. Four of the rockets landed in the crater; the other had an erratic flight and landed 50 feet short. All rockets were recovered.

3.5 USE OF ROCKETS FOR PLACING AND RECOVERING FILM DOSIMETERS

An extemporaneous attempt to determine the radiation field intensity in the crater was made on D + 3 days. A standard packet of film, similar to that used throughout the project for dosimetry, was loaded into the sampling head of the rocket. The rocket was fired into the crater and left there for a measured time before recovery. The intensity of the radiation field was determined from the exposure of the calibrated film. The film packet inside the sampling head was supplemented by Land film dosimeters taped to the outside of the sampling head.

At the time the experiment was conceived only three rockets and one bucket of shot line remained. The measurements were not too successful. Too large an allowance was made for the effect of the additional weight in the sampling head and the first rocket landed just on the far edge of the crater. The truck, with attached line, was immediately moved to a position which the investigators estimated would drag the attached rocket to the center of the crater. Recovery was completed 10 minutes later.

Two more attempts were made with improvised lines, neither attempts being successful. Both rockets fell short as the result of excessive drag due to tangled lines.

The field intensities indicated by the films were very low. Both the Land film and the film packet indicated a field intensity of approximately 10 r/hr. This was true for both the rocket which was thought to be in the crater and for the rockets which fell short onto the crater lip. Whether the low readings are real or whether they are to be attributed to shielding of the dosimeter by burial in the ground, is not known.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

These experiments have shown that the retrievable missile tested is a practical, cheap, simple method for obtaining soil samples from an area 100 feet in diameter at a range of 1100 feet. However, more than one firing is necessary to be sure of hitting this area. Samples obtained by this method should be adequate for chemical study of the composition of close-in contamination. It may not furnish an exact method for determining the concentration of surface contamination as a function of area but should be better in this respect than the scoop samples obtained with the remotely controlled weasels.

If the method is to be used in future tests certain changes and improvements are recommended.

4.2 INCREASE IN RANGE

It is recommended that an increase in range be obtained by the use of a larger rocket. The scientific personnel of the Kilgore Manufacturing Company have assured the present investigators that the development of such a rocket would be very simple. A rocket of approximately twice the mass would have a range of between 2500 and 3000 feet. Such a development was prohibited both by time and budget in the present investigation.

4.3 LINE

The available 7/32 inch manila shot line will probably continue to be the line of choice although the steel cable supplied by the Wellcome Devices Manufacturing Corporation, 290 Manville Road, Pleasantville, New York, might be considered. The cost of the steel cable will probably be relatively high.

The additional line required for a rocket of greater range could be supplied by use of two or more manila lines tied in series.

4.4 FIRING MOUNT

The firing mount should be considerably improved. It should be a multiple launcher so that no time would be required for loading while in a radiation field. It should fire at constant elevation but should have provision for a small adjustment in azimuth. It should probably fire to the rear of the truck as in this test.

4.5 SAMPLING HEAD

The sampling head shown in Figure 2.2 is adequate for sampling loam or loose earth. The deflector plates shown in Figure 2.3 are not necessary with the present rocket. They may be necessary with a heavier, more penetrating missile. For hard-packed earth a similar head but with smaller cross-section is recommended.

4.6 OPERATION

The recovery of samples by this method will be greatly facilitated if an access road from the prevailing up wind direction is prepared in advance. This road should be well marked with range stakes in the region from which the rockets will be fired. Both sides of the road should be free of construction and other test equipment in order to prevent the entanglement of the recovery lines. Corrections in azimuth can be easily made from the truck with the new mount. Corrections in range will probably be unnecessary if adequate pre-test firings are made but radio contact with a flank observing party well out of the contaminated area is recommended.

With all of the above mentioned improvements a party of two or three should be able to obtain from 5 to 10 samples and not be in the most advanced position for more than 2 or 3 minutes. With the sharp gradients in radiation field intensities generally observed a party should be able to take samples when the launching vehicle at the most advanced position is in a field of 40 to 50 r/hr.

4.7 LOCATION OF SAMPLE

If desired, the accurate location of a sample can be determined by triangulation with high power theodolites on fixed towers outside the radiation field. For accurate observation some type of smoke signal on the rocket is suggested. This signal may be supplied in one of the following ways.

The simplest method consists in fastening one or two "Coston Hand-held Distress Signal Flares" to the exterior of the rocket and manually igniting them before launching the rocket. These flares burn with a deep orange smoke for a little over a minute which should be more than ample for accurate triangulation. These are also supplied by the Kilgore Manufacturing Company.

A better but more expensive method would be to build a smoke candle into the forward end of the rocket motor. The spent rocket motor and tube would act as a smoke stack for this candle which would be ignited by the rocket motor when it burns to the end of its charge. This method has been discussed with the engineers of the Kilgore Manufacturing Company and is considered very feasible.

4.8 USE FOR FILM DOSIMETRY

The present rocket may not be the missile of choice for delivering packets of film to a contaminated area. The military rocket used by Dr. Weil and Dr. Anderson will probably be better. With this rocket, which is stabilized by an air foil and not the drag of the line, a long nose which would support the film packet above the ground could be designed. The penetrating force of this rocket would not be detrimental since it would not be necessary to recover the entire nose but only that part containing the film packet. The heat of the rocket motor and exhaust makes the fastening of the film to the line or rocket motor impracticable.

4.9 OTHER USES FOR ROCKETS

Incremental measurements of accumulated dose in regions of high radiation-field intensity could be easily obtained with an adaptation of the military type rocket. These rockets could be placed in sub-surface launching tubes and equipped with long nose rods which hold film packets above the ground. They could be fired either automatically or manually by remote control wires at any time after the atomic explosion. The accuracy of the military rocket and careful emplacement of the buried launcher should make the location of these rockets very simple.

It should also be possible to design a small fall-out tray which could be attached to the long nose of one of these buried rockets. It would take only a very small amount of the highly radioactive early fall-out to make several interesting chemical and physical measurements.

WT-334

OPERATION JANGLE

PROJECT 2.6a

REMOTELY CONTROLLED SAMPLING TECHNIQUES

by

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18 February 1952

SIGNAL CORPS ENGINEERING LABORATORIES

FORT MONMOUTH, N. J.

ACKNOWLEDGEMENTS

The authors take pleasure in acknowledging the help and fine cooperative spirit of the various groups within the Signal Corps Engineering Laboratories which greatly aided in the successful attainment of the project objectives.

Evans Signal Laboratory

Nucleonics Branch Weapons Test Section	Specifications and Drafting Branch Mechanical Engineering Section
E. Ellstrom	V. Stine
J. Moulden	S. Adler
M. Berdan	S. Micale

Coles Signal Laboratory

Radio Communications Branch Radio Research Section	Wire Branch Televisual Equipment Section
T. Sueta	J. Rice
E. Moyes	J. Jones

Thanks are also expressed to Lt. W. Gilbanks, Ordnance Corps, Development and Proof Services, Automotive Division, Aberdeen Proving Grounds for his fine work and spirit of cooperation shown in directing the modification and preparation of the weasels for remote operation. Finally, the project is deeply indebted to the many Signal Corps Engineering Laboratories and Aberdeen Proving Grounds personnel at the test site without whom this operation would not have been possible.

PROJECT 2.6a

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PROJECT 2.6a

ABSTRACT

Radiological samples were collected from highly contaminated areas during Operation JANGLE. Both surface and core samples were obtained around the lip and crater area resulting from a surface and a subsurface detonation of an atomic weapon. The samples were obtained utilizing remotely controlled weasels equipped with remotely controlled instrumentation, viz:

a. One surface sampler on each of two weasels, capable of picking up ten two-cubic inch samples.

b. One earth corer on each of two weasels, capable of taking an earth core three feet six inches deep and two inches in diameter, with six to eight sampling points.

c. An ionization chamber probe to measure the gamma rate in the area where samples were taken. This rate was telemetered back to the control point by a radio link.

d. Television cameras on the surface and earth core sampling weasels to observe the surface sampling and coring operations and also to aid in guiding the coring weasels and surface sampling weasels into the lip and crater area.

After samples were obtained by the weasels they were removed from the weasels and placed in lead containers for immediate delivery to site laboratories.

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The major objective of this project was to obtain surface samples and deep core samples of the earth around the lip and crater area resulting from the detonation of atomic weapons at the surface and buried seventeen feet underground. Surface samples were taken in the lip and crater area for the surface and underground shots as well as over a pattern from which estimates may be made of the distribution of ground contamination in the crater area. Valuable information was obtained concerning the efficacy of utilizing remotely controlled weasels equipped with sampling instrumentation on atomic weapons tests.

1.2 HISTORICAL AND THEORETICAL

The nature, amount and distribution of residual contamination in the lip and crater area are of direct military importance since they indicate the radiation hazard, as a function of time, associated with each type of burst. Such an indication is necessary in order to estimate the length of time a given area will be denied to troops in the eventuality of surface or subsurface nuclear detonations. The chemical nature of the residual contamination as a function of distribution and of particle size furnishes information for the selection of decontamination processes and provides fundamental data for interpreting and understanding the phenomenology of each burst.

The only previous work in the field of radioactive contaminated sample collection by means of remotely controlled vehicles using tanks was performed at Operation SANDSTONE. The use of remotely controlled weasels represents a major effort in providing an improved method for sample collection in highly contaminated areas.

1.3 PHYSICAL FACILITIES

Preliminary installations, testing and repairs were performed in the JANGLE test area at the electronics repair shop and weasel shed as shown in Figure 1.1. The electronics repair shop incorporated facilities for storing and repairing major components used in conjunction

PROJECT 2.6a

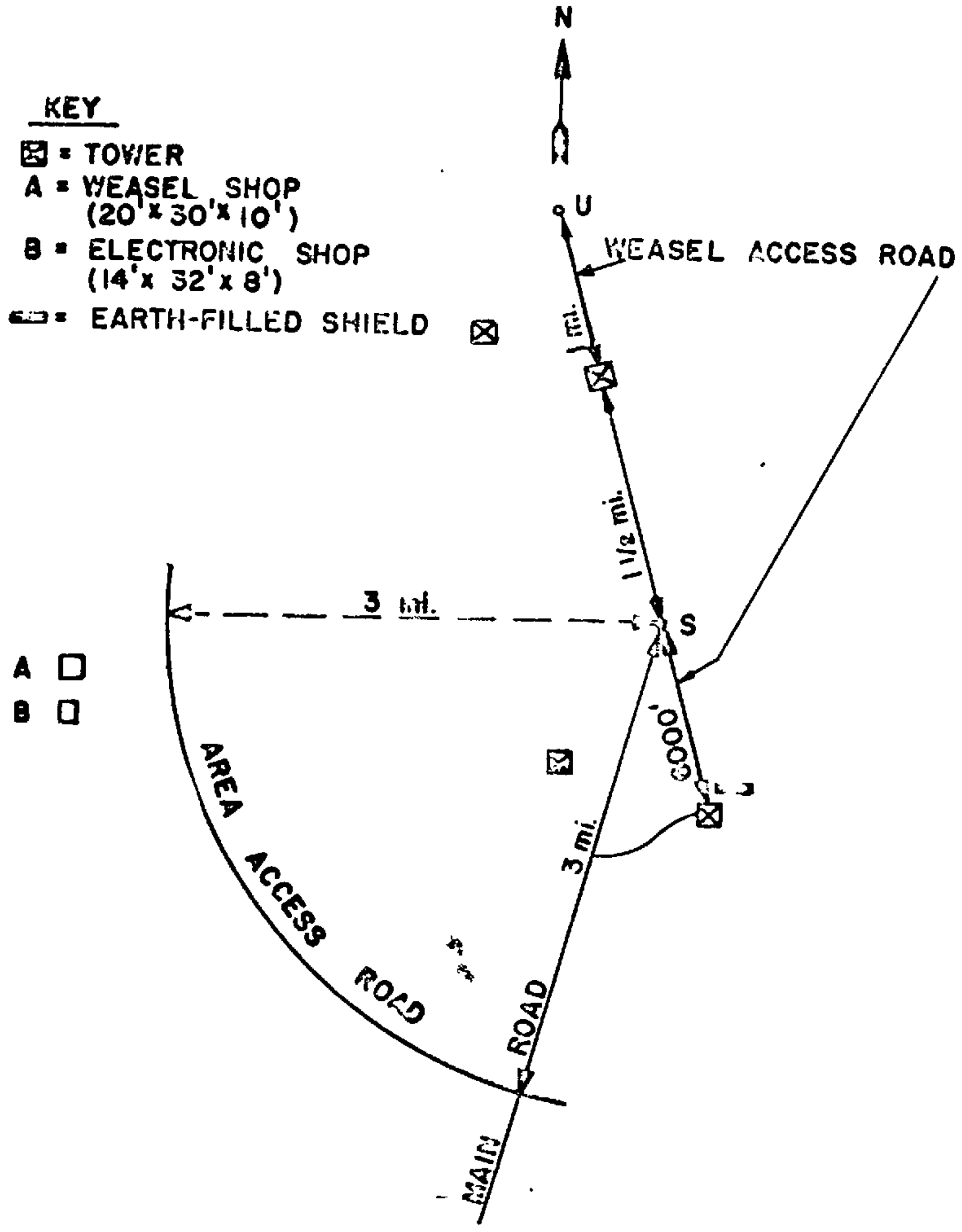


Fig. 1.1 Shop and Tower Layout

with the remotely controlled weasels. Included, were the various radio, television and sampling components. This also served as the central working area in conducting all preliminary tests, in serviceing the weasels and in serving as the field base of all preliminary operations. The weasel shed accommodated the four weasels concerned. Repair and calibration facilities were available in the Camp 3 area. Some minor shop work was done at the machine shop in the control point area. Towers used in the operation were distributed as shown in Figure 1.1.

CHAPTER 2

INSTRUMENTATION

2.1 GENERAL

The system was comprised of:

a. Four weasels, (M-29), two of which were equipped with surface samplers, radio and television and two with deep corers, radio and television.

b. Two identical mobile control stations in two and one-half ton, M-53 trucks together with a semi-portable 24 ft. tower used to control the sampling weasels. One mobile control station served as a spare.

c. A second 24 ft. tower used for lateral location of the weasel utilizing a battalion Commander's scope.

d. A jeep equipped with a mobile control transmitter.

e. A radiological detector probe on each weasel to measure gamma rate at the sampling points.

f. A semi-portable earth-filled shield and a remote sample removing instrumentation system.

2.2 MOBILE CONTROL STATION

The mobile control station was installed in a two and one-half ton M-53 truck which towed its own PE-95 power unit and was equipped with an AC-DC converter and a bank of storage batteries as shown in Figure 2.1. Figure 2.2 shows the interior of the mobile control station.

2.2.1 Radio Equipment

The mobile control station contained a 50 watt FM transmitter operating on 162.120, 162.240, or 162.360 mcs. for controlling one weasel, while a second transmitter of the same type con-

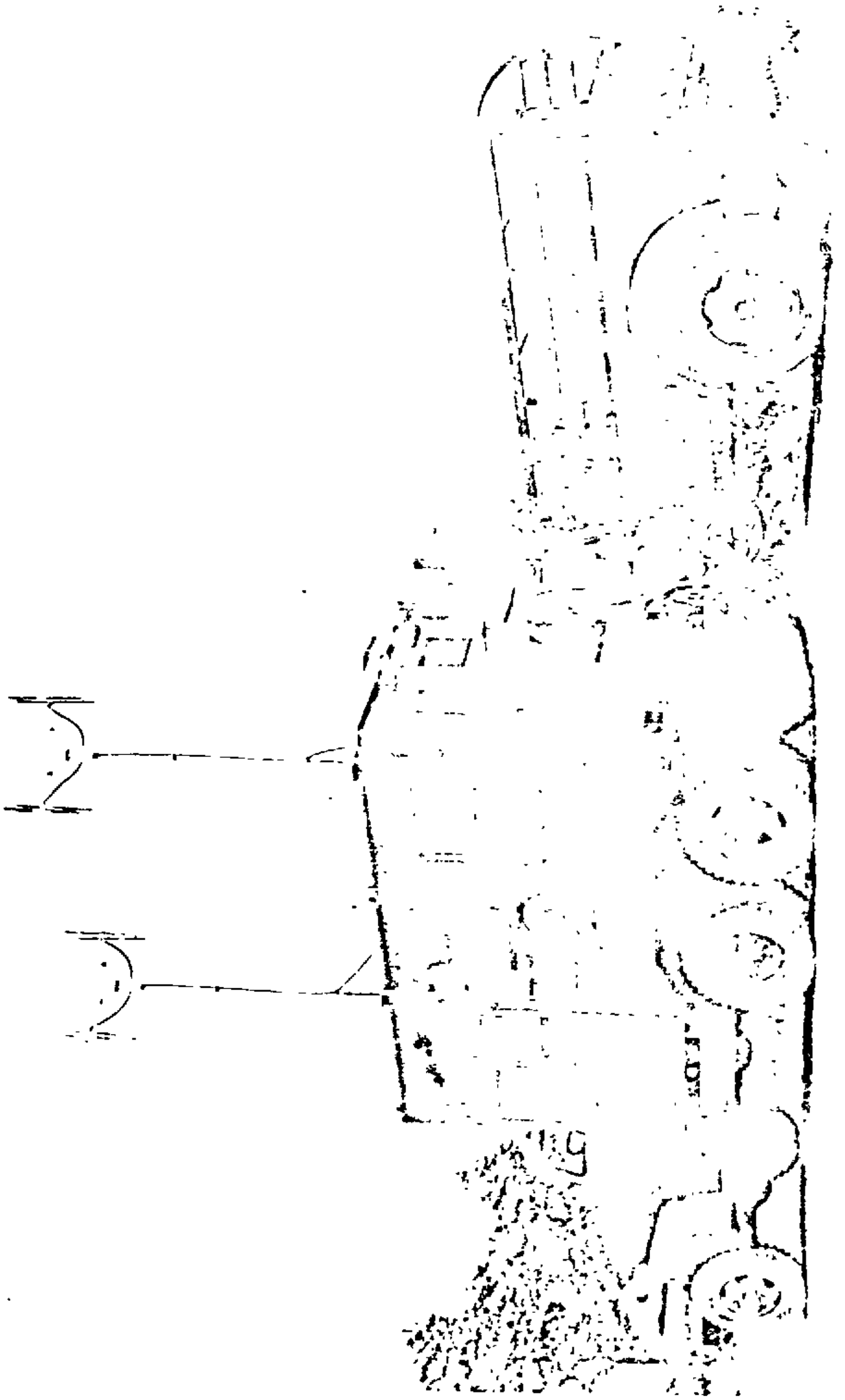


Figure 2.1 Mobile Control Station, Exterior

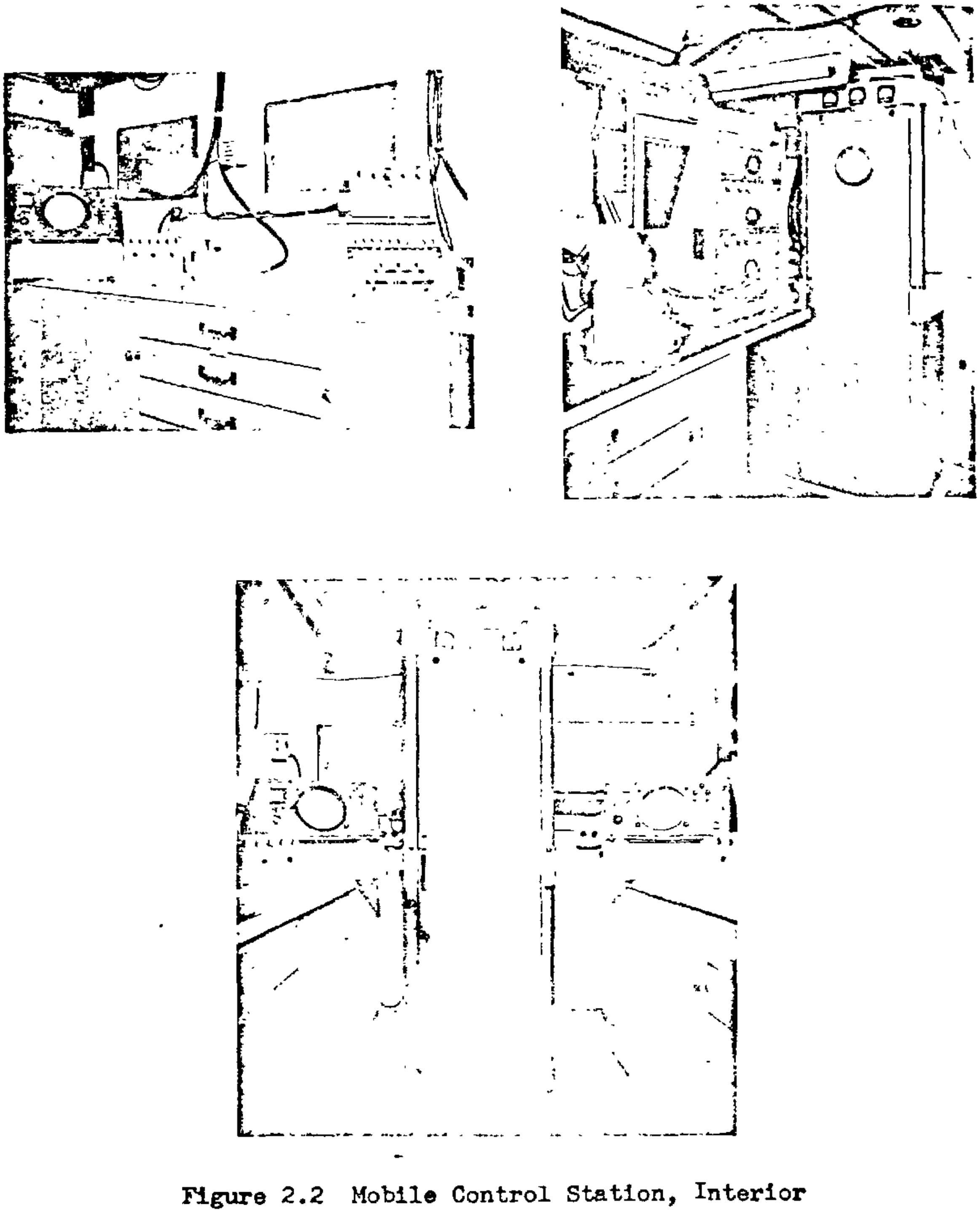


Figure 2.2 Mobile Control Station, Interior

trolled a second weasel on 162.480, 162.600, or 162.720 mcs. The additional two frequencies on each transmitter could be switched in immediately for operation of the appropriately tuned weasel if required.

Each control transmitter contained means for modulating its carrier in such a way that twenty-eight different pairs of audio tones could be transmitted thus activating twenty-eight relay controlled functions in the weasel. The transmitted functions were produced by pressing controls on three separate consoles. One console controlled the Master System Control function as well as the eight vehicular functions listed in 2.3.1.

The second console controlled the TV equipment in the weasel using the following fourteen functions:

(1) On
(2) Off
(3) Camera Right
(4) Camera Left
(5) Camera Up
(6) Camera Down
(7) Contrast Advance
(8) Contrast Retard
(9) Iris Open
(10) Iris Close
(11) Beam Control Advance
(12) Beam Control Retard
(13) Target Focus Advance
(14) Target Focus Retard.

The third console provided controls for operating shallow samplers, earth corers, and also caused the remote weasel to send back either engine speed information by means of a microphone in the engine compartment or gamma radiation rate data from a specially designed radiation probe on the front of each weasel. A loudspeaker for monitoring engine speed and an Esterline Angus recorder for recording the gamma rate were provided. A duplicate set of three consoles was available for tower top operation. Antennae for these transmitters were skirt type of vertical dipole antennas located at the top of the 24 ft. tower. The maximum operating range was estimated to be ten miles.

The control station was also equipped with a rack of receivers. Two of these received gamma rate data or engine noise, as desired, from the corresponding two weasels, while the third acted as an immediately available spare in case of failure. The first receiver could be switched to 172.120, 172.240, or 172,360 mcs., the frequencies used by one group of weasel transmitters. The second receiver could be switched to 172.480, 172.600, or 172.720 mcs., the frequencies used by the second group of weasels. The third receiver could be preset to any of the above frequencies. Antennae were skirt type vertical dipoles located just above the transmitting antennae on the tower described above.

2.2.2 Television Equipment

The mobile control station contained two television receivers. One television receiver demonstrated the picture obtained by the shallow sampling weasel and the other the deep sampling weasel. When used in conjunction with the remote vehicular control boxes, the two television receivers proved invaluable in safely guiding the weasels around various obstacles to the desired locations, in satisfactorily choosing good sampling locations and in viewing the actual sampling operations. The consoles controlling the TV equipment in the weasels were mounted alongside of the appropriate TV receivers. The two television channels used were 258-270 mcs. and 294-306 mcs. with central frequencies of 264 mcs. and 300 mcs. A list of all frequencies used appears in Table 2.1. Spare TV receivers were available for immediate use in case of failure. The mobile control station antennae consisted of a pair of directional three-element vertically polarized Yagi antennae for TV reception from each weasel.

2.2.3 Power Supply

All control station equipment operated from 110 volts AC except the TV equipment which was designed for vehicular operation and required 24 volts DC which was provided by AC-DC converters. A total of 10 KW was required for the control station. Drawers and cabinets were used for storage of special spares and tools.

2.3 Vehicular Equipment

All vehicular equipment was installed in four weasels (M-29), which were specially modified for remote control usage in this operation. The vehicular functions as described in 2.2.1. were activated from the mobile control station. Figure 2.3 and Figure 2.4 show a surface sampling weasel and a core sampling weasel respectively.

2.3.1 Servo-Mechanisms

The weasels were all modified and equipped with servo-mechanism which when remotely activated performed the following vehicular operations:

Engine Start
Left Steer
Right Steer
Throttle Advance
Throttle Retard
Clutch
Shift Lever Forward
Shift Lever Reverse

TABLE 2.1

Frequency Requirements

Television	Channel 1	258-270 mcs
	Channel 2	294-306 mcs
	Power: 24-30 Watts RF Peak	
	Control: LC (balanced line)	
Radio (Control Station to Mobile Station)	Transmitter #1	162.120 mcs
		162.240 mcs
		162.360 mcs
	Transmitter #2	162.480 mcs
		162.600 mcs
		162.720 mcs
	Power: 50-60 Watts RF	
	Control: Single Crystal controlled frequencies	
Radio (Mobile Station to Control Station)	Transmitter #1	173.120 mcs
	Transmitter #2	173.240 mcs
	Transmitter #3	173.360 mcs
	Transmitter #4	173.480 mcs
	Transmitter #5	173.600 mcs
	Transmitter #6	173.720 mcs
	Power: 30 Watts RF	
	Control: Single Crystal controlled Frequencies	

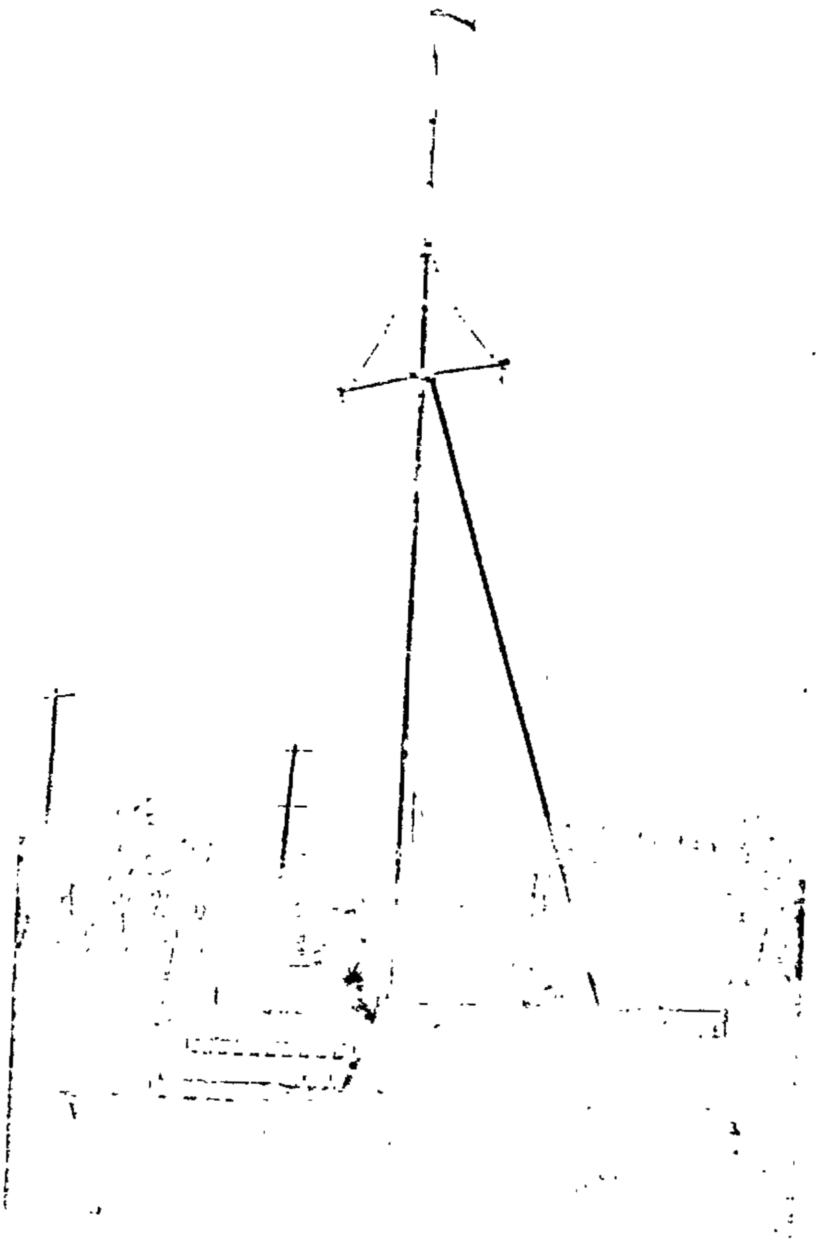


Figure 2.3 Weasel, Surface Sampling

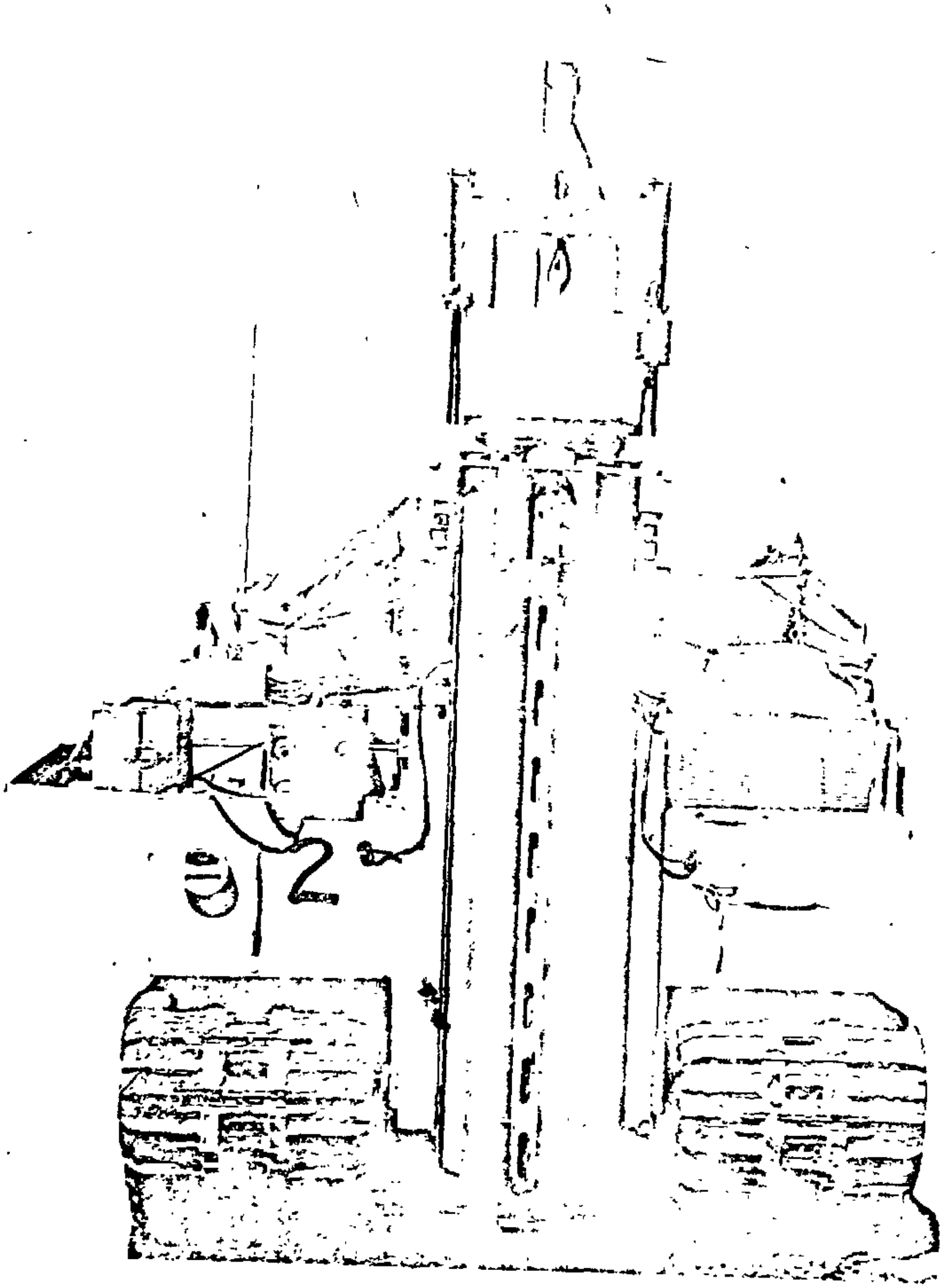


Figure 2.4 Weasel, Deep Sampling

2.3.2 Weasel, Radio and Television Equipment

The four weasels were equipped with radio receivers and transmitters, and television cameras and transmitters. The radio control equipment consisted of three units operated from the 24 volt DC power supply of the weasel.

Unit "A" consisted of a 30 watt crystal controlled FM transmitter for transmitting gamma rate and engine speed data to the control station and a receiver for bringing in the tone-modulated controlling carrier. Units "B" and "C" demodulated the vehicular, sampling and TV control signals thereby producing relay operating currents. These relays controlled the servo-mechanisms for vehicular control, the motor operated potentiometers for TV control and also actuated motor turn-on relays for sampling operations. Antennae for the radio and television equipment consisted of vertical skirt type dipoles and vertical dipoles respectively. Figures 2.5 and 2.6 show the weasel's radio and TV equipment respectively.

2.3.3 Core Sampler

The core sampler, Figure 2.7, consisted of a remotely actuated pile driver mechanism using a 150 lb. weight to drive a steel tube into the ground. The steel tube was five feet long, two inches in diameter and contained eight evenly spaced slotted openings each four inches long and six inches apart. A second rotatable tube, identically slotted was concentrically held within the first tube. In the operating position, the slots in the inner tube were peripherally displaced from those in the outer tube. For sample removal, the slots were lined up thus exposing the contents of the steel coring tube.

A one second duration signal from the mobile control station initiated the coring operation. Simultaneously, a timing motor adjusted for a running time of five minutes and the cable drum motor were activated causing the tube withdrawer to be lowered to the base plate of the steel tube guide. Upon reaching this point a limit switch was tripped which caused the operation of the hammer motor. The hammer motor arm, rotated at approximately 6 rpm, effected the cycle raising and free fall of the 150 lb. hammer thereby driving the sampling tube into the ground. When the steel tube had been driven to the predetermined four-foot depth a micro-switch was actuated causing the stoppage of the hammer motor and the starting of the operation of the cable drum motor which automatically withdrew the sampling tube from the ground. Another limit switch stopped the cable drum motor when the

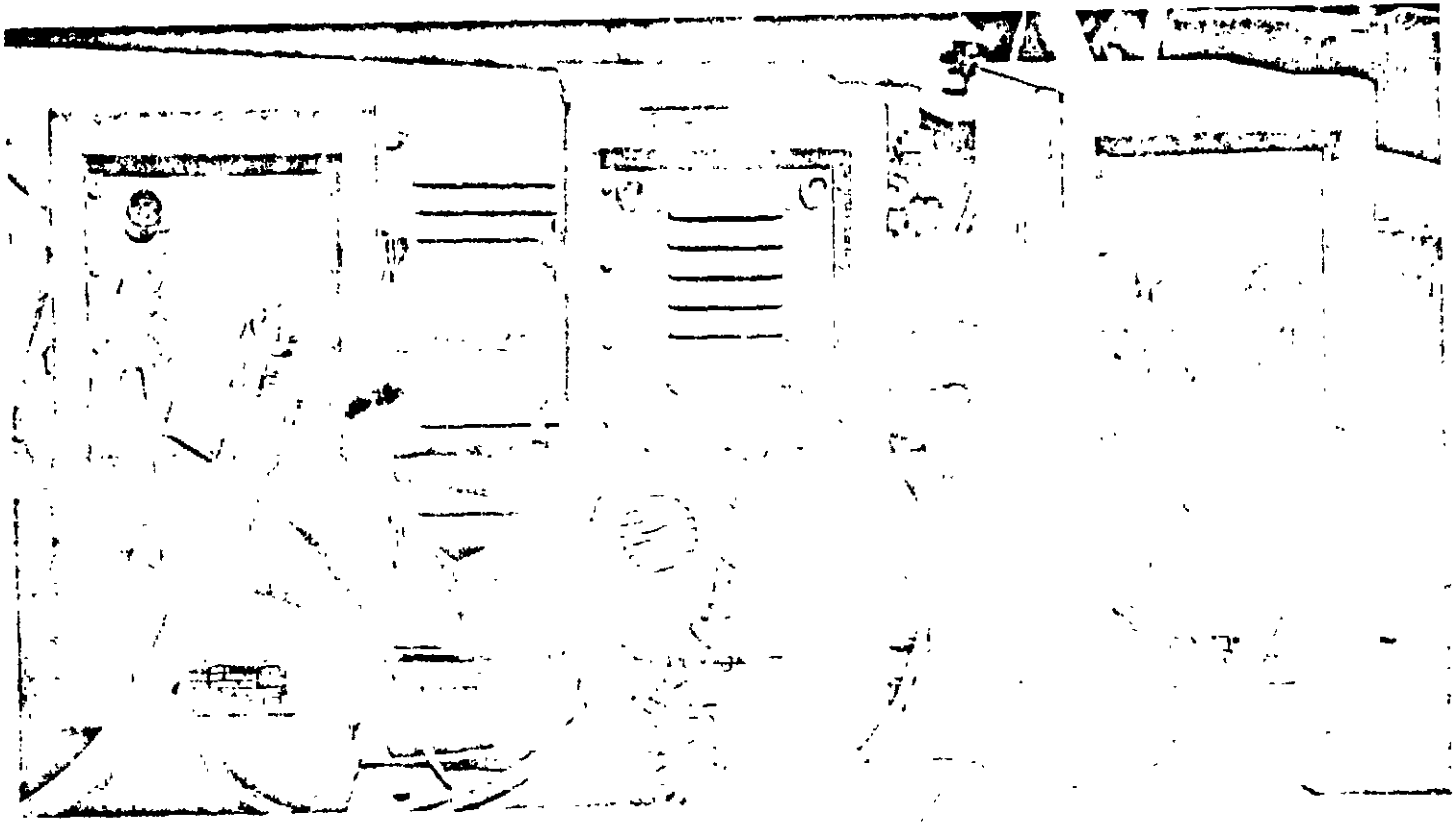


Figure 2.5 Weasel, Radio Equipment

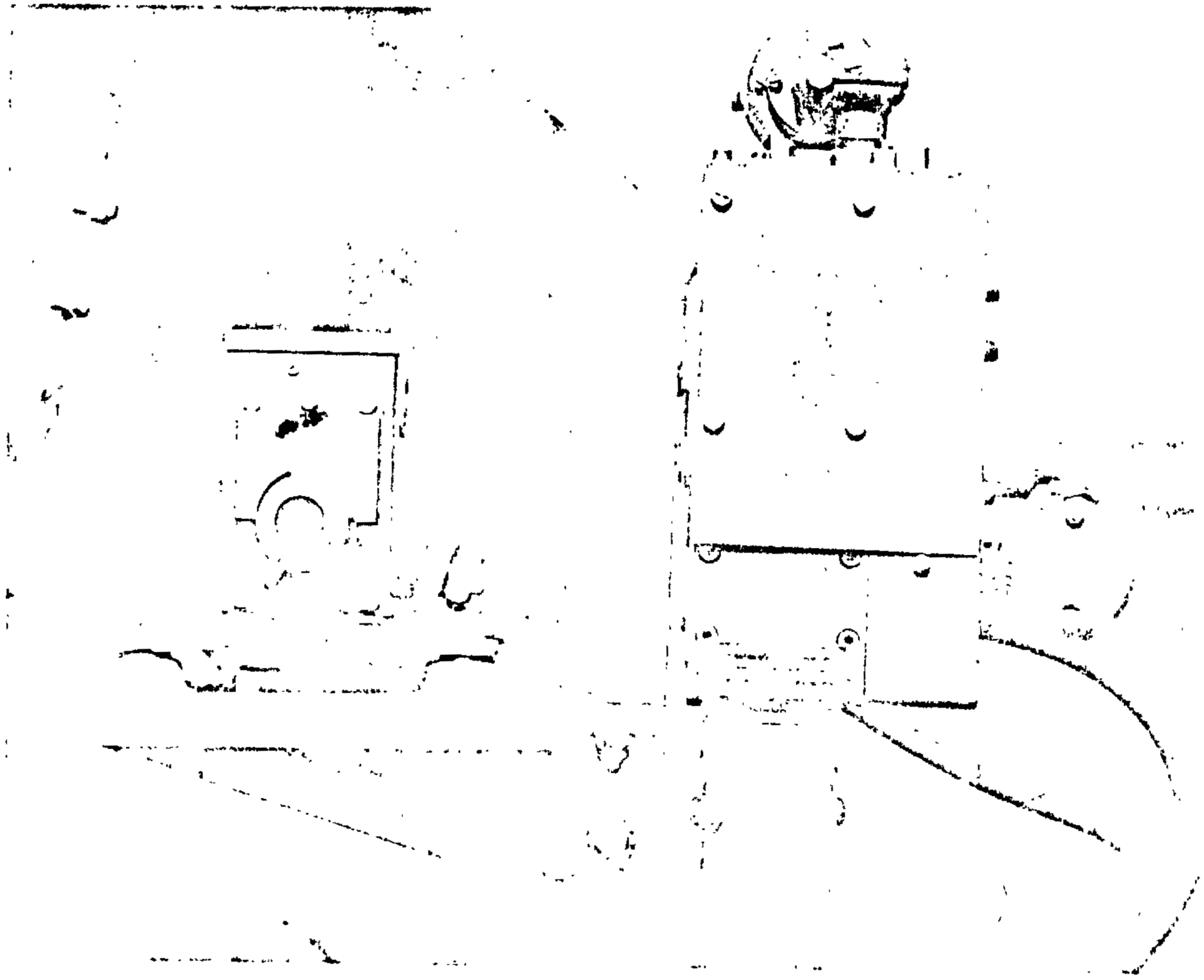


Figure 2.6 Weasel, TV Equipment

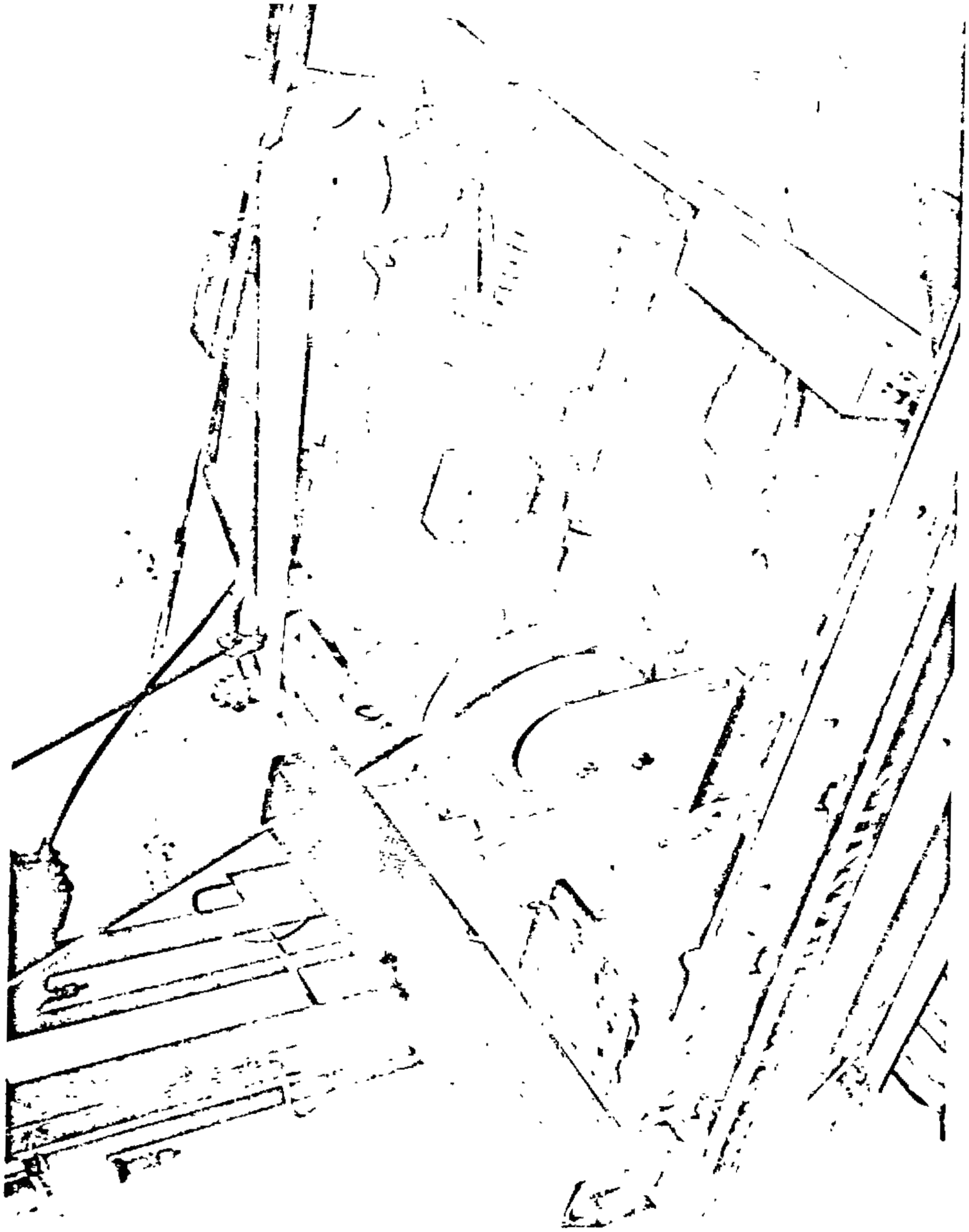


Figure 2.7 Deep Soil Sampling Equipment

steel tube had been completely withdrawn. A spring-loaded flap valve sealed the bottom of the tube thereby completing the deep soil sampling cycle. A complete schematic of the core sampling instrumentation appears in Figure 2.8.

The five minute time limit was imposed on the pile driving mechanism so that if impervious earth were encountered, the tube was automatically removed at the end of this time. An additional electronic feature was the use of a remote control function in the mobile control station which enabled withdrawal of the sampling tube at any earlier time.

The sampling tube was held in place by an easily removable pin which, however, could not be jarred loose by mechanical vibrations of the weasel. Tubes were readily interchangeable enabling repeated use of the same weasel.

2.3.4 Shallow Surface Sampler

The shallow surface sampling equipment, Figure 2.9, consisted of ten identical scoops for sample collection, and a vehicular sampling selector box which cycled any individual scoop. A scoop selector in the mobile control station automatically selected the desired scoop upon throwing the appropriately numbered switch. This caused the transmitter to be pulsed the desired number of times which in turn operated the proper relay in the radio equipment on the weasel. The make and break of this relay was followed by a stopping relay in the vehicular sampling selector box. A small DC timing motor mounted in the vehicular sampling selector box insured a long enough time delay so that none of the scoops might be prematurely activated. The time required per pulse was approximately two seconds so that a total time delay of twenty-five seconds was adequate to insure proper operation were the tenth scoop selected. For example, a time delay of only fifteen seconds would not permit selection of the eighth, ninth or tenth scoops but would activate the seventh scoop instead. At the end of the delay period the stopping relay caused the chosen scoop to start its cycle. The linear actuator motor was activated causing the scoop sampling arm to be lowered to a height above the ground determined by a micro-switch feeler attachment. The rotary actuator on the scoop sampling arm then caused the scoop to undergo a rotary motion resulting in a shallow sample collection about 2 inches deep at the earth's surface and the automatic closing of a cover which prevented spillage. A micro-switch was then tripped causing completion of the rotary motion and reversal of the linear actuator until the arm was returned to its original raised position. This completed the cycle and the stopping relay was returned to its home position preparatory to activation of a different scoop.

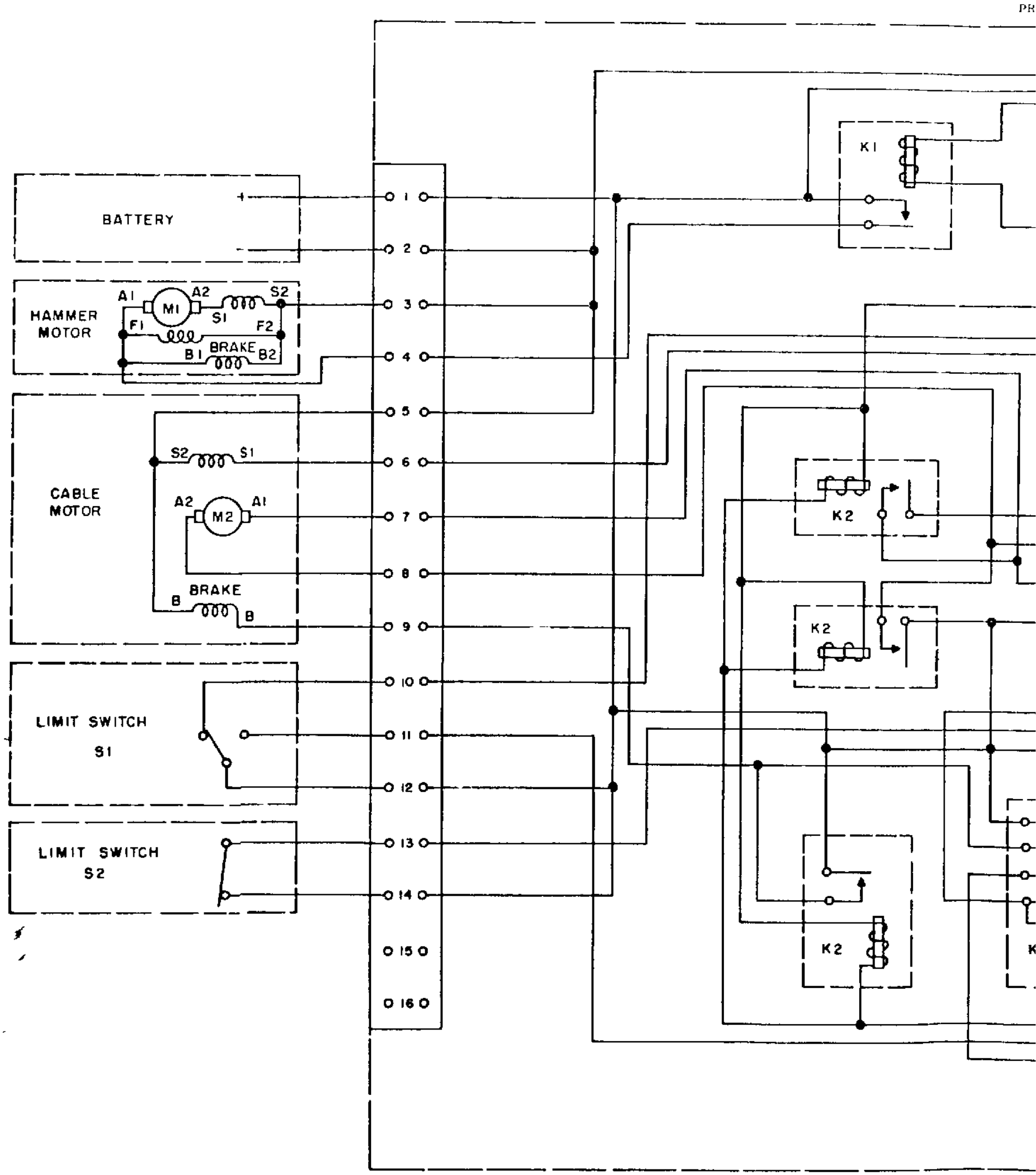
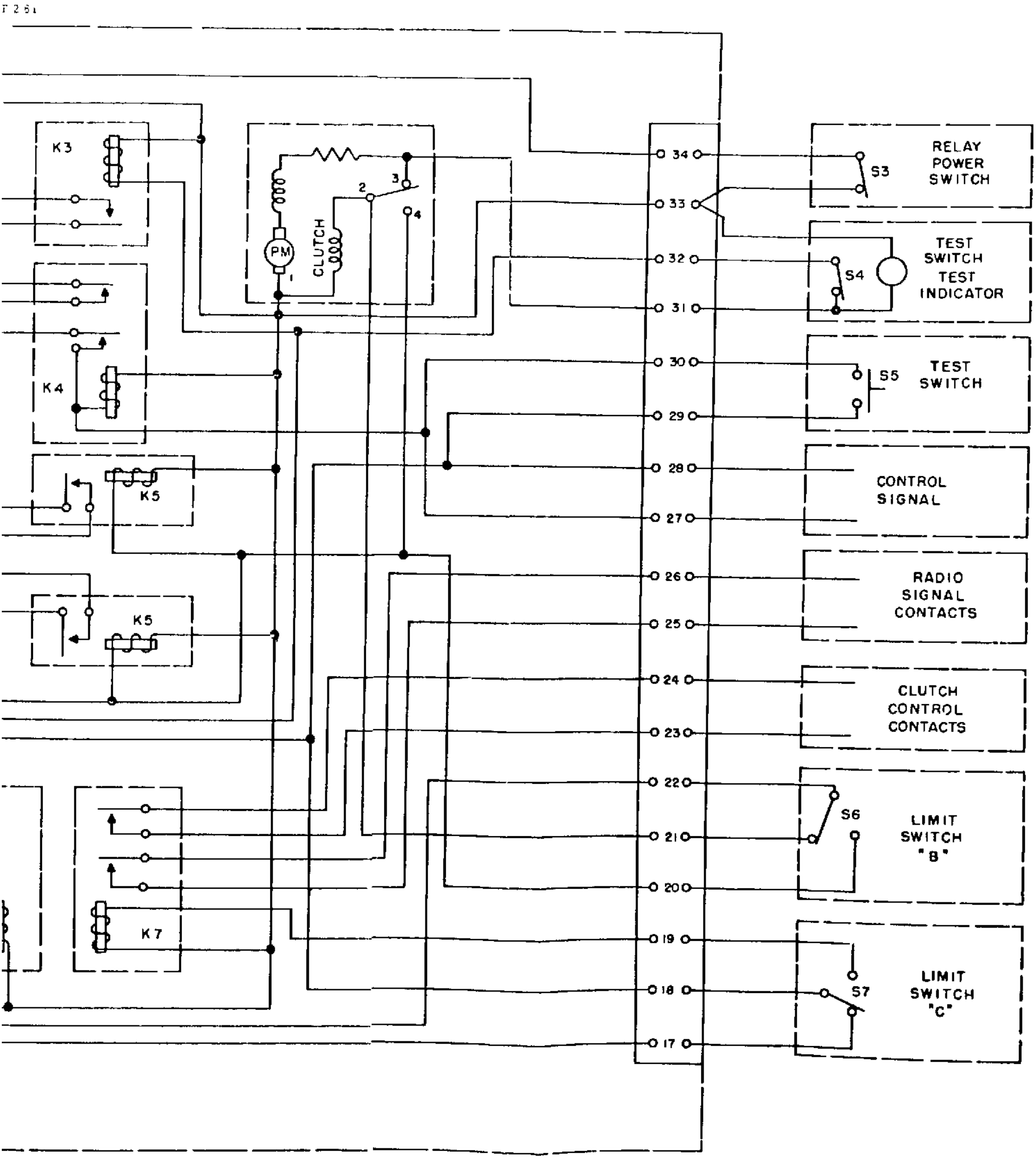


Figure 2.8 Schema



eep Soil Sampler

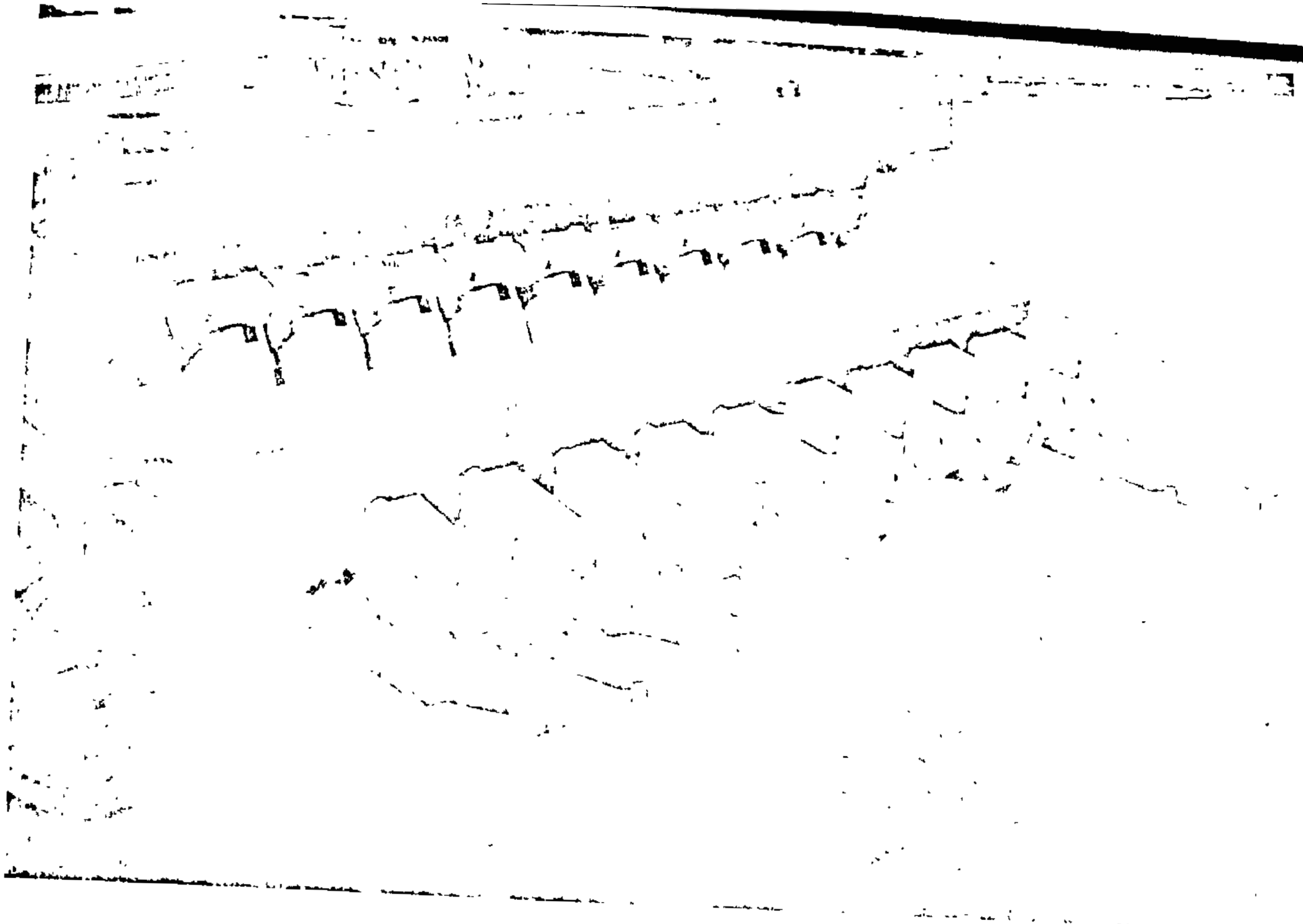


Figure 2.9 Shallow Soil Sampling Equipment

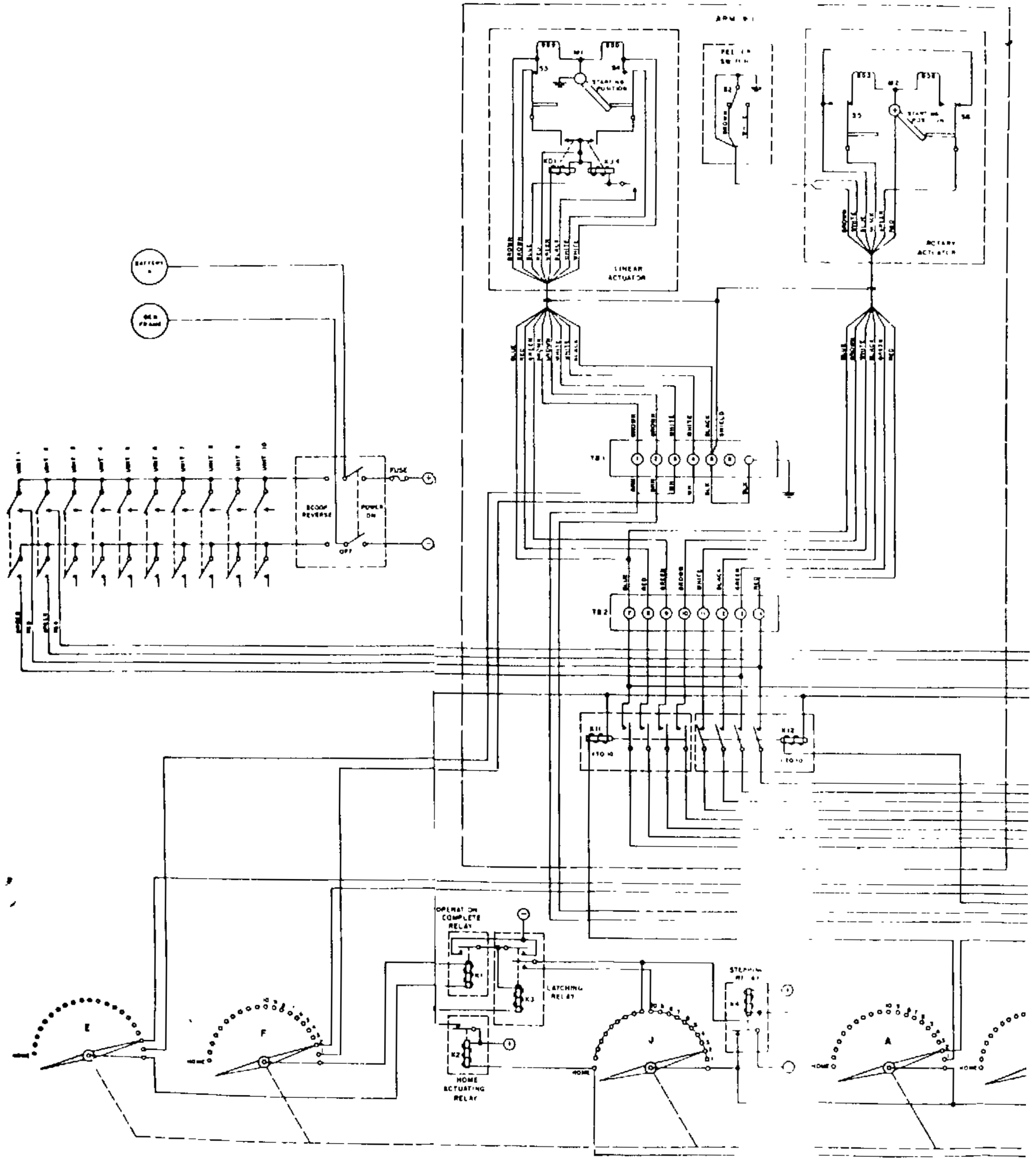
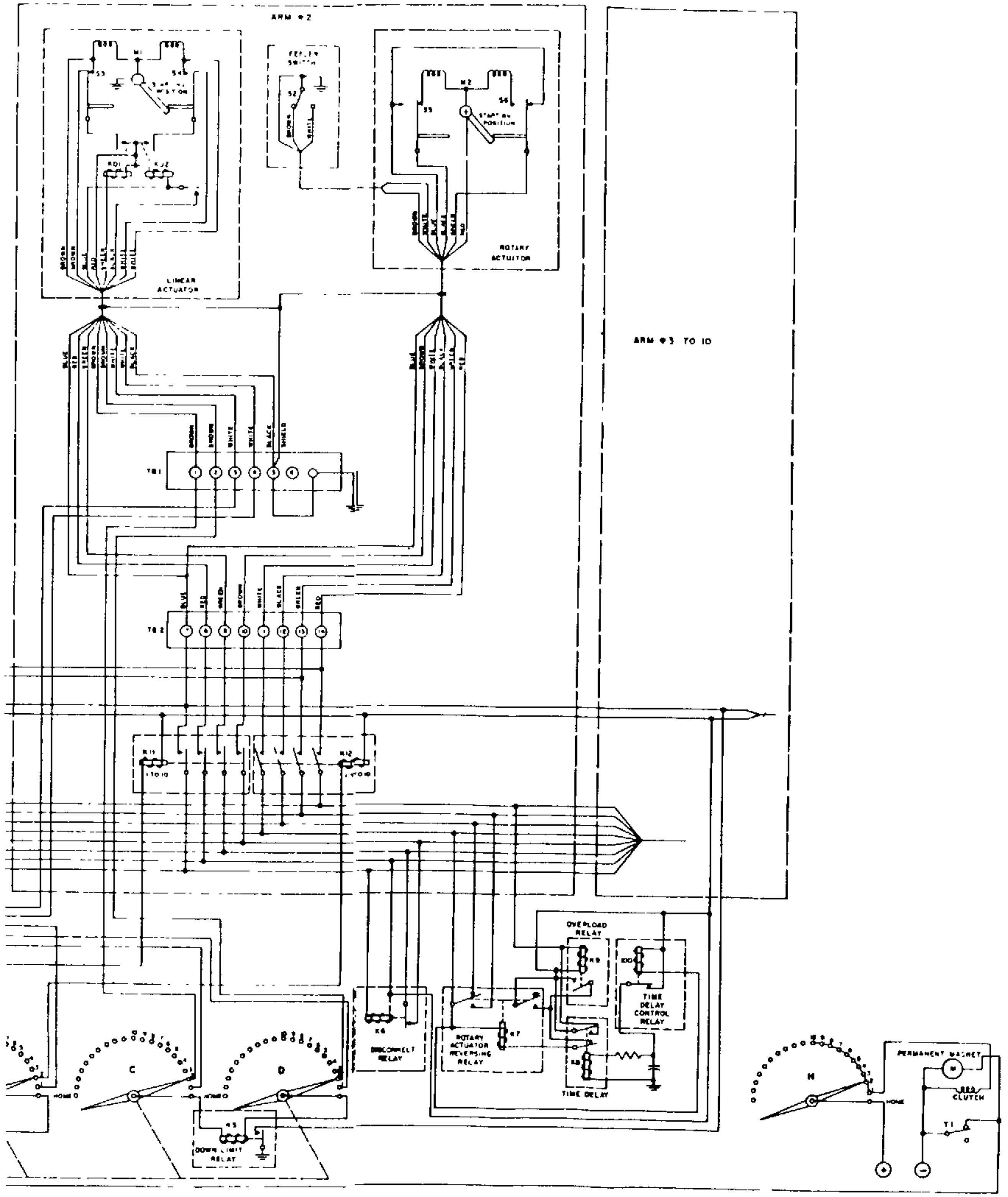


Figure 2.10 Schematic,

.6a



allow Soil Sampler

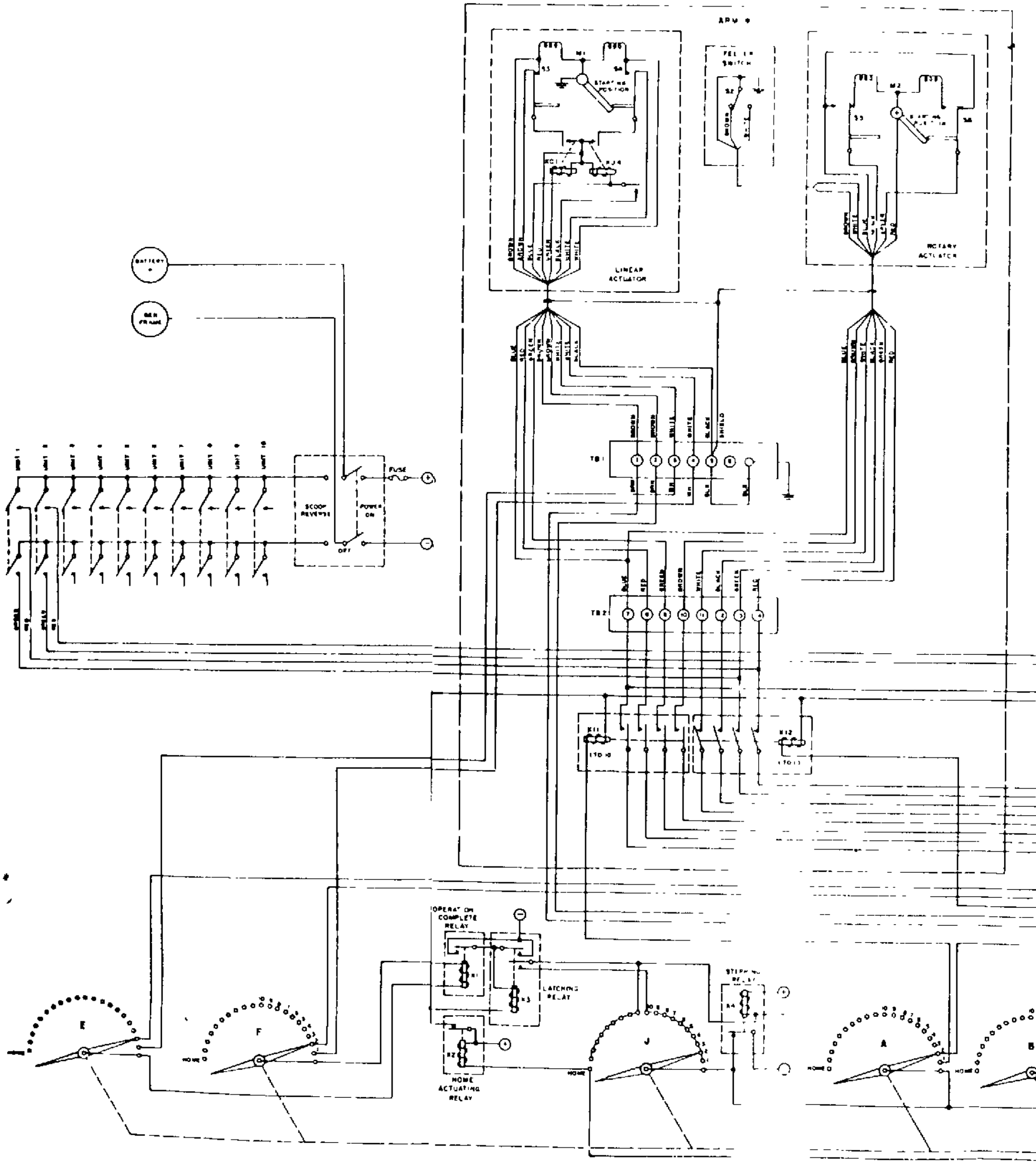
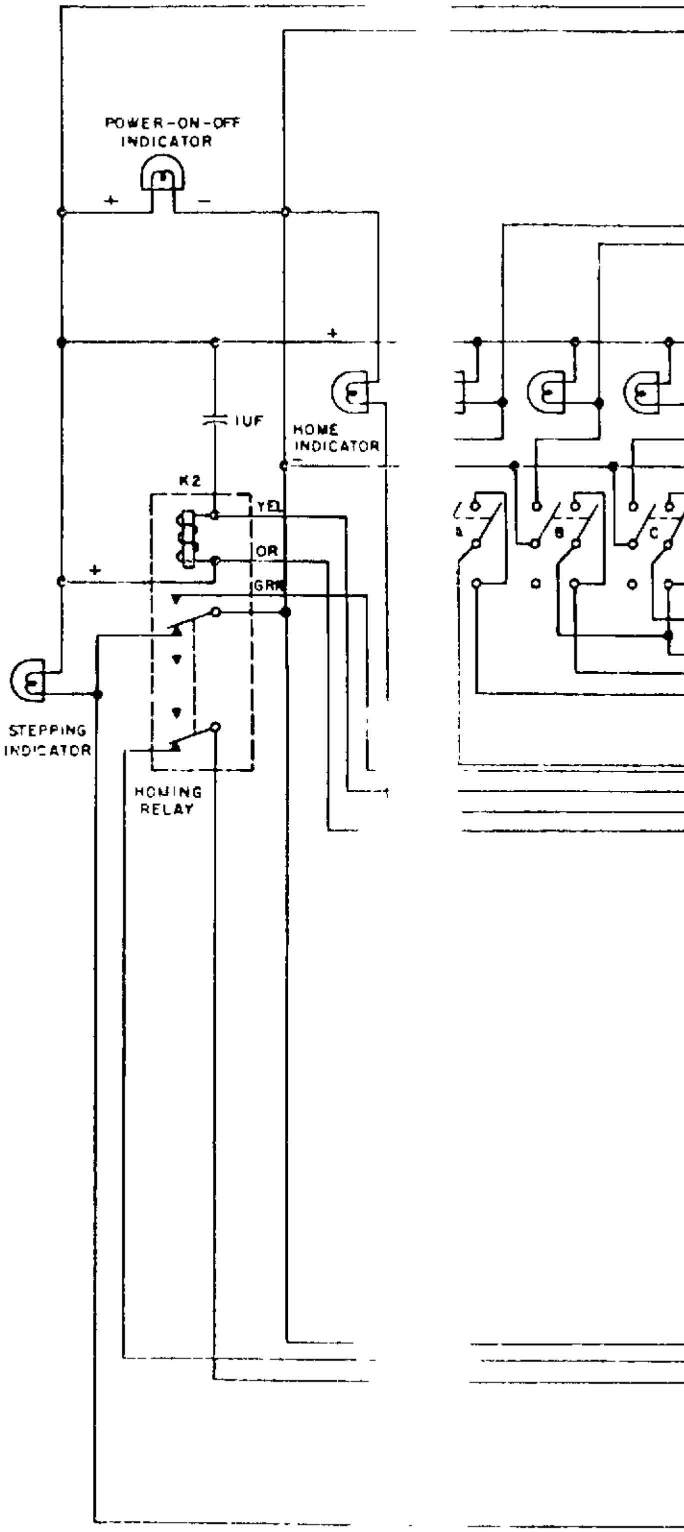


Figure 2.10 Schematic, S


POWER-ON-OFF INDICATOR
+
−
+
1UF
HOME INDICATOR
−
K2
YEL
OR
GRN
+
STEPPING INDICATOR
HOMING RELAY
A
B
C

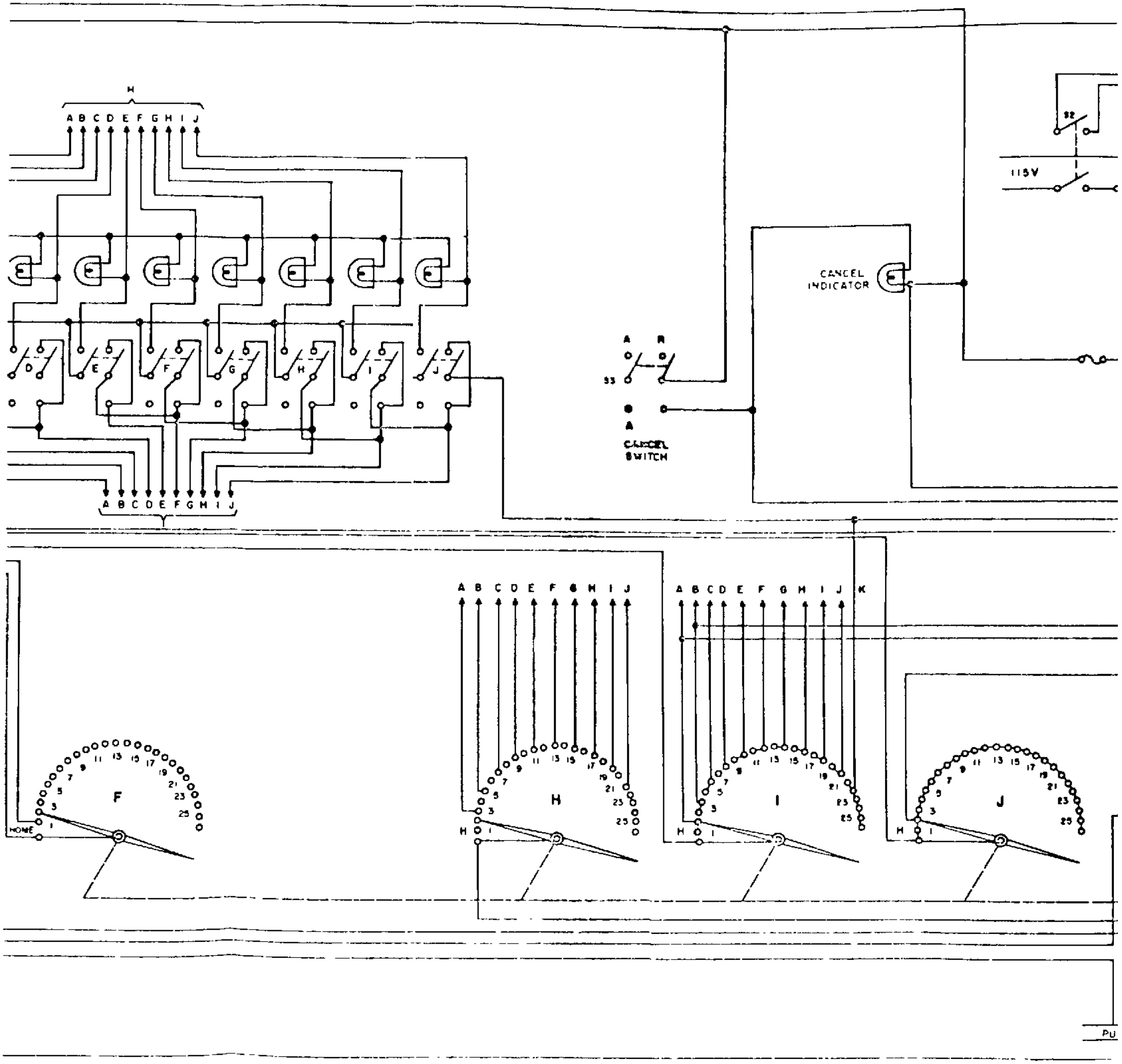
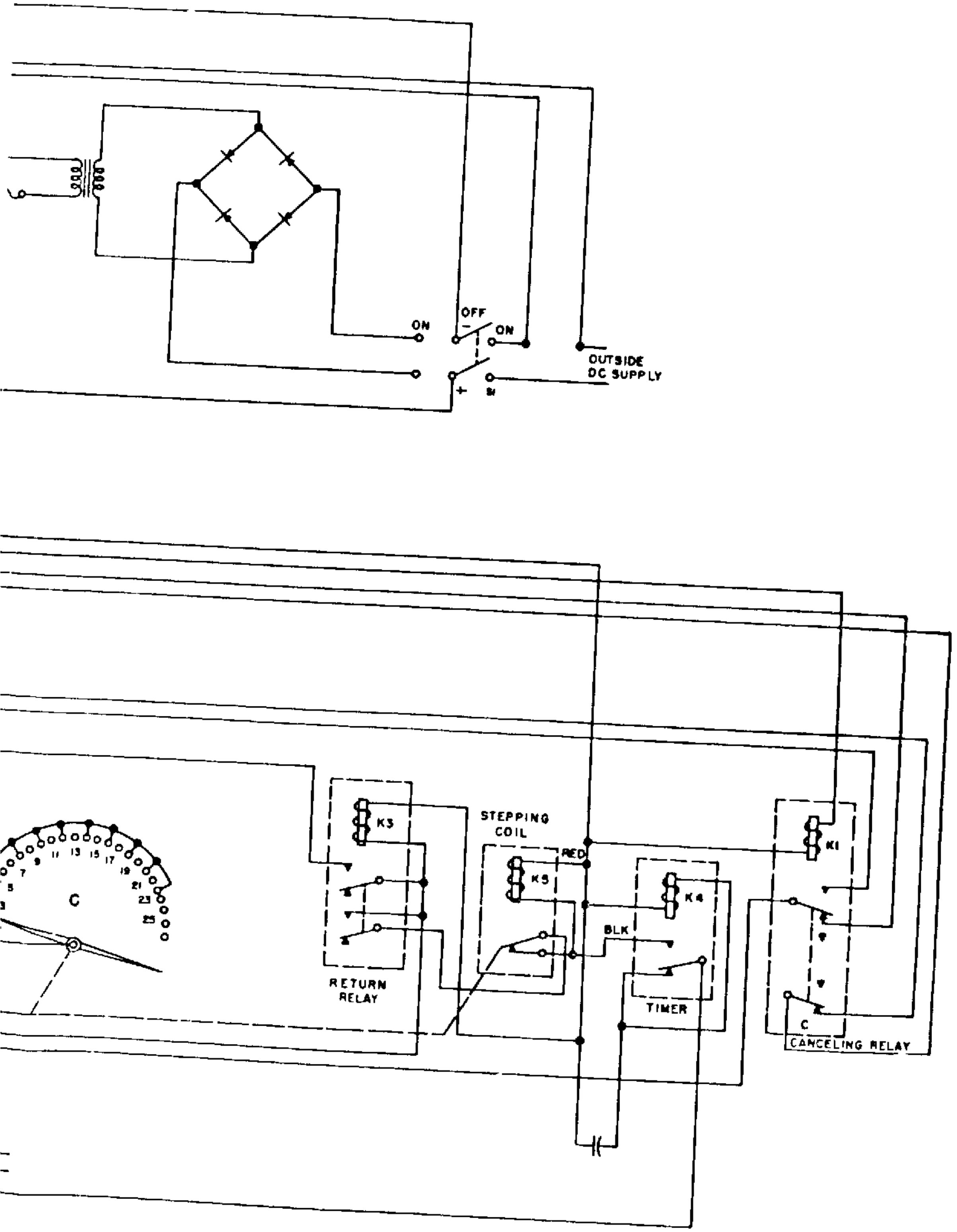


Figure 2.11 Schematic, Pulsed Scope Selector


OFF
ON
ON
+
S1
OUTSIDE DC SUPPLY
K3
STEPPING COIL
RED
K5
K4
BLK
K1
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CANCELING RELAY

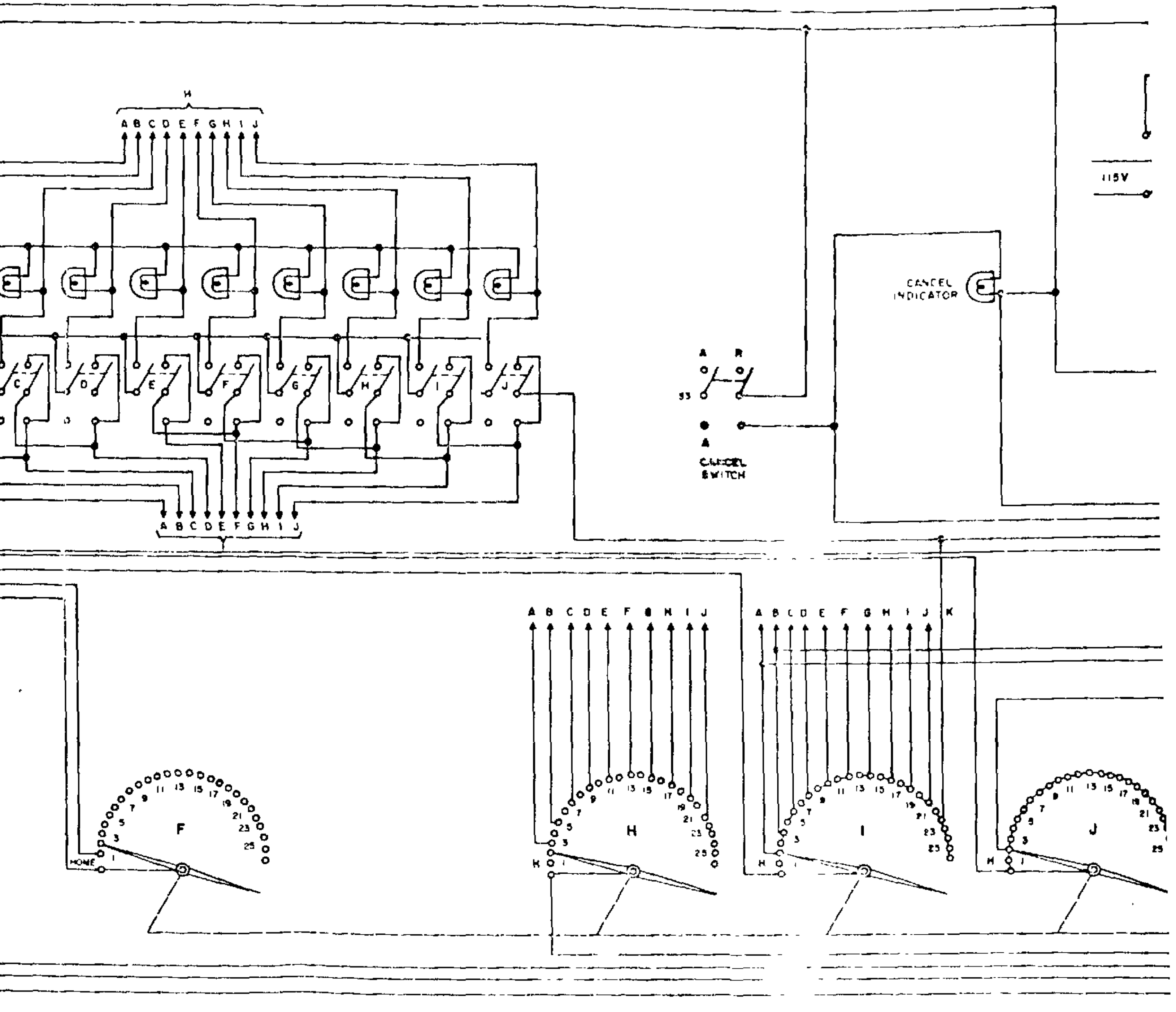

Figure 2.11 Schematic, Pulsed Scoop Selector

The individual scoop arm micro-switch feeler attachments were preset for different types of terrain encountered. For example, a very loose type of soil enabled setting the samplers for a deeper scoop. A margin of safety was furnished by an overload relay which caused the rotary actuator to reverse itself and recycle the sampling arm were a load of greater than 60 lbs. encountered. This insured that the rotary actuary motor was not damanged when overloaded. The same scoop could then be reselected at the same or another location. A complete circuit diagram of the vehicular sampling box appears in Figure 2.10. The schematic of the scoop selector which pulsed the transmitter in the Mobile Control Station appears in Figure 2.11. The sampling scoops were manually reset at the front of the weasel preparatory to additional use.

2.3.5 Radiological Telemetering

Radiological telemetering equipment was used primarily to transmit gamma rate data to the mobile control station from points at which earth samples were taken. This equipment consisted of a high level probe connected to a radiological telemetering unit containing a phase shift oscillator as shown in Figure 2.12. This equipment, employed for the underground shot, covered a gamma rate logarithmic range from 5 milliroentgens per hour to 5,000 roentgens per hour. The logarithmic output of the high level probe modulated a phase shift audio oscillator varying its frequency as the gamma rate changed. The phase shift oscillator had a high impedance output which modulated the radio transmitter. An Esterline Angus recorder was used in conjunction with an amplifier in the mobile control station to record the gamma rate.

In addition to the above-mentioned telemetering unit, a modified AN/PDR-T1B, with a maximum range of 500 roentgens/hour, was employed for the surface shot.

2.4 AUXILIARY EQUIPMENT

2.4.1 Towers

Two 24-ft. towers were set up for all operations with the exception of a 36-ft. observation tower used on the surface shot. The towers were approximately $1\frac{1}{2}$ miles apart and each about 1 mile from ground zero. A field telephone system connected both towers with the mobile control station. The mobile control station was at the base of one tower at the head of the weasel access road. In addition

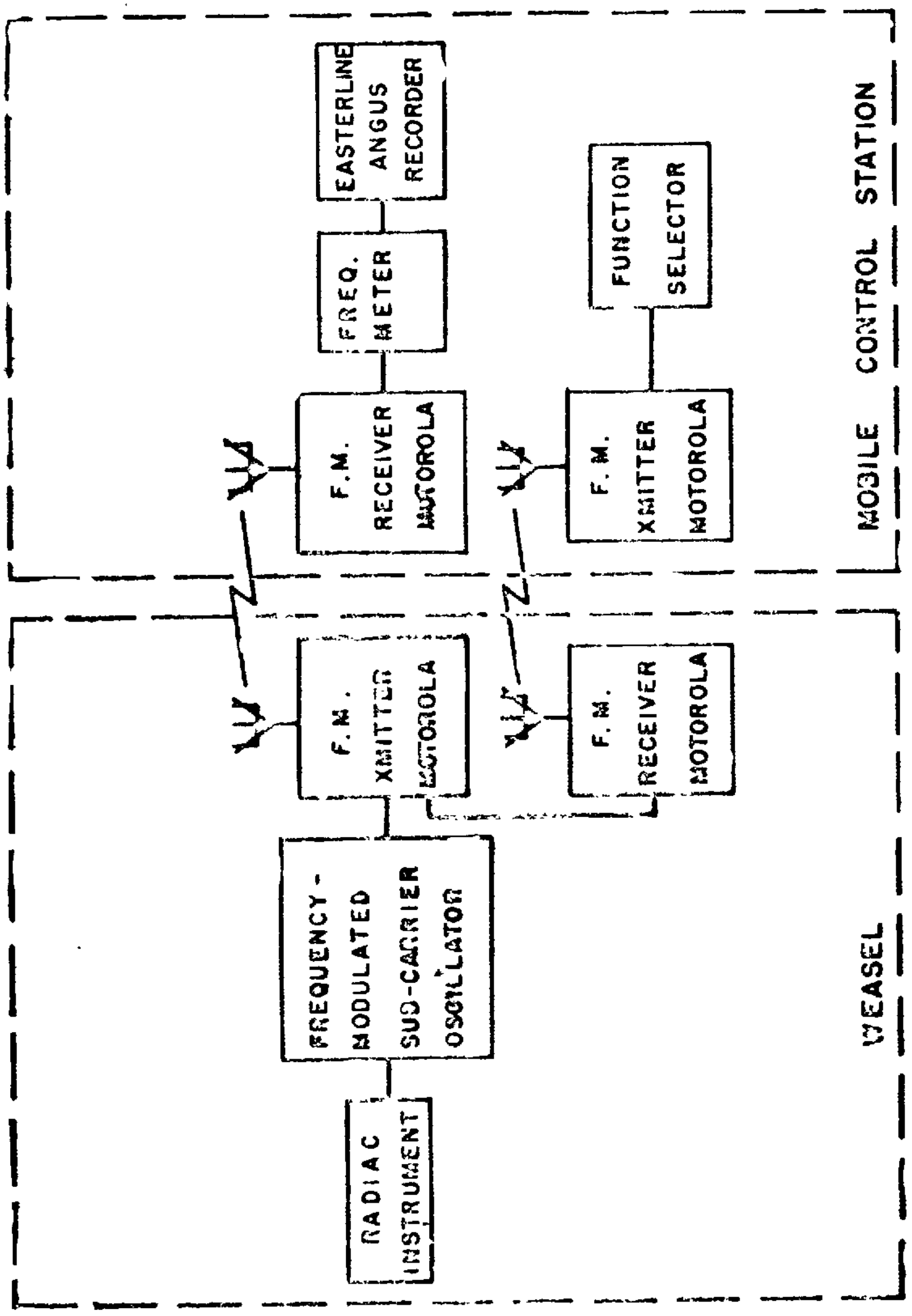

Fig. 2.12 Radiological Telemetering Equipment

to the field telephone, this tower was further equipped with a Battalion Commander's telescope, an auxiliary set of antennae and a control box for directing the weasels should any failure necessitate tower top operation. The second tower contained a field telephone and an M 65 Battalion Commander's telescope for accurate lateral positioning of the weasel and for additional aid in navigating the weasel about various obstacles.

2.4.2 Sample Removal Instrumentation

A jeep equipped with a mobile transmitter and antenna was used for close positioning of the weasels at the unloading point. Wooden bumpers were utilized to aid in stopping the weasel at the proper location. A semi-portable earth-filled plywood wall, 15 ft. long, 6 ft. high, and 1 ft. thick was available should the radiation level from the weasels have necessitated its use. A metal mirror was mounted to the wall for the purpose of observing the sample removal operations either with or without the shield. The shallow earth sampling scoops were placed individually in ten two-inch thick lead-lined containers. These containers contained plyofilm bags to avoid spillage of sample and consequent contamination of the containers. Samples taken from the coring tube were placed in small bottles which in turn were placed in one-inch thick lead-lined containers.

CHAPTER 3

OPERATIONS

3.1 GENERAL

Four weasels were used in the tests. Two weasels were equipped with television and surface samplers and two with television and earth corers. During sampling operations, in most instances, the weasels were used in pairs; a corer and a surface sampler. These were directed into the lip and crater area as soon as possible after each detonation. The television equipment was capable of both guiding the vehicles and viewing the sampling operations.

3.2 PRE-ZERO TIME PHASE (SURFACE & UNDERGROUND SHOTS)

Convoys were formed at H-2h at a point approximately three miles from the surface ground zero and five miles from the underground zero point. The convoys consisted of:

a. Jeep)
) Operational and Rad-Safe personnel
b. Jeep)

c. Mobile Control Station hauling a PE-95 Power Unit

d. Shallow Sampling Weasel)
) on $2\frac{1}{2}$ ton trucks
e. Deep Sampling Weasel)

f. Weapons Carrier hauling a 275 gal. tank of gasoline

g. Weapons Carrier hauling a PE-95 Power Unit which acted as an emergency repair and spare parts truck

h. Mobile Control Station hauling a PE-95 Power Unit

i. Shallow Sampling Weasel)
) on $2\frac{1}{2}$ ton trucks
j. Deep sampling Weasel)

k. Jeep) Operational personnel.

All equipment including vehicles and samplers, were checked, operated and adjusted until H-1h. At this time all equipment was turned off preparatory to moving toward ground zero at H + 1m.

3.3 POST ZERO TIME PHASE

3.3.1 Surface Shot

At h + 1m the convoy proceeded at 15 mph toward the control tower located 1 mi upwind from ground zero which served as the general area for the test base of operations. The Rad-Safe monitors checked the radiation levels enroute to insure safe entry. Upon reaching the control tower, the mobile control stations were rapidly set up at its base at the head of the weasel access road and all equipment activated. The control station contained all required transmitting and receiving equipment for remotely controlling the weasels and their instrumentation. The weasels were driven off the trucks at a nearby unloading ramp and driven manually the short distance to the head of the weasel access road. Final checks were then made on the radio, TV and sampling equipment. A Rad-Safe monitor then accompanied an observer to the second tower. At approximately H + 1 hr. a surface sampling weasel followed at a distance of 100 feet by a core sampling weasel, started down the mile road leading directly to the lip and crater area. A crew of four in the mobile control station was responsible for directing the weasels to the lip area where shallow and core samples were taken. There were two weasel operators, one TV control operator and one operations coordinator who directed the remote activities, maintained telephone contact with both towers and also conducted the sampling operations. Upon returning to the sample unloading site at H + 3 hr, monitoring the weasels demonstrated that use of the earth shield was unnecessary inasmuch as the radiation level at one foot from the weasel was approximately 3 r/hr for the shallow sampler and 15 r/hr for the corer. The unloading operation exposed two men for approximately one minute each to a smaller field since long handling tongs were used. The individual scoops were removed by pulling the appropriate pin on each arm and a long pair of tongs was used to place each scoop in separate lead containers. A hooked tool, was used to pull the pin on the coring tube and two men, each with a pair of tongs, placed the coring tube into a lead cradle where small samples were taken, placed in small bottles and then in 1-in. thick lead-lined containers. Within ten minutes of the weasel's arrival at the unloading point, all the samples in lead-lined containers, were ready for immediate delivery to the site laboratories.

At H + 4h the second pair of weasels started for the lip and crater area, operations being conducted in a similar manner to the first run. This time shallow earth samples were taken in the crater. At about H + 6 h both weasels were back at the sample unloading site although trouble had been encountered with the corer as discussed in 5.1.1.

For the surface shot, a modified AN/PDR-T1B having a maximum range of 500 r/hr was used to telemeter rate data back to the mobile control station. The recording equipment went off scale in the crater area indicating that the rates exceeded 500 r/hr. However a good deal of interference was present and readings were considered unreliable. This suggested use of a higher range instrument on future shots. During all of these activities constant communication with the observation tower helped locate and maneuver the weasels.

3.3.2 Underground Shot

The convoy was formed and a base of operations set up in a manner similar to that for the Surface Shot. On the first run, in order to expedite shallow sample recovery, a single shallow sampling weasel was directed to the lip. The radiological data, telemetered to the mobile control station appear in Table 4.2. At H + 2 h 10 m the samples in lead containers, were delivered to the site laboratories. A pair of weasels was then directed to the lip and crater area for the second run. In order to obtain some data as to the distribution of ground contamination in the lip and crater area, a pattern of shallow samples was followed on the third and final run at about H + 25 h. Ten sampling scoops were activated at approximately 50-ft. intervals along the upwind side of the lip.

CHAPTER 4

TEST RESULTS

4.1 GENERAL

A tabulation of the principle results obtained with the sampling equipment appears in Table 4.1. The results include the total of five runs made on the two shots of Operation JANGLE.

TABLE 4.1

Sampling Operations

Shot	Run No.	Approx. Time of Sample Unloading	No. of Shallow Samples	Depth of Core Taken	Location
Surface	1	H + 3 h	8	18 in.	At the lip
	2	H + 6 h	5	__(a)	Inside edge of crater lip
Underground	1	H + 2 h	7	__(b)	At the lip
	2	H + 4 h	__(a)	18 in.	At the lip
	3	H + 27 h	7	__(b)	Pattern about the lip

(a) Equipment failure described in 5.1
(b) Deep soil sampler not used during this run.

4.2 LOGISTICS

Personnel, material, and time requirements were aptly anticipated as witnessed by the close conformance of operational tests with predicted schedules. This was true in both pre-test and test periods. Various obstacles were encountered as might be expected with a project of this scope, but these were all overcome in such a manner as to offer minimum impediment to operational smoothness.

4.3 INSTRUMENTATION

4.3.1 Radio and TV Equipment

Occasional failure of components, particularly relays in the mobile radio receivers, necessitated clearing of contacts and insertion of spare units so as not to interfere with operational schedules. The radio and TV equipment then performed their intended functions. The twenty-eight remote functions proved adequate in conducting all operational plans. The TV equipment proved adequate in guiding the weasels in and about the lip and crater area. The remotely controlled weasels were more easily directed and maneuvered using the TV equipment than was possible without TV from the tower top. This proved especially true at increasing distances from the control tower.

4.3.2 Sampling Equipment

As shown in Table 4.1 both shallow and deep samples were obtained on each shot although not with the maximum possible capacity. The irregularity of the terrain about the lip resulted in several of the shallow samplers not obtaining a sample although run through a cycle. The reasons for the various failures encountered are discussed in 5.1.1 and 5.1.2. The results, obtained with the system of samplers used, were good although certainly not the ultimate system to be desired. It did, however, successfully achieve for the first time, the early collection of shallow and deep samples from a highly contaminated area.

4.3.3 Radiological Telemetering

A tabulation of results obtained with the radiological telemetering equipment on each of the two shots appears in Table 4.2. A discussion of the reliability of these results appears in 5.1 and 5.2.

4.3.4 Weasels

The weasels operated satisfactorily proving adequate in reaching the desired points and capable of providing the required power for all electronic and mechanical equipment. The system of changing gears was somewhat slow and experience in operation was required to

TABLE 4.2

Radiological Telemetered Rate Data

Shot	Time	Rate r/hr	Distance fm Ground Zero (a) mi.	Max. Rate Measurable r/hr
Surface	H + 1 h 50 m	>500	(In lip area)	500
"	H + 2 h 10 m	>500	"	"
"	H + 2 h 44 m	120	.1	"
"	H + 2 h 56 m	110	.2	"
"	H + 2 h 58 m	85	.3	"
Underground	H + 57 m	6	.5	5,000
"	H + 59 m	10	.4	"
"	H + 1 h 5 m	700	.2	"
"	H + 1 h 7 m	>5,000	(In lip area)	"
"	H + 1 h 20 m	3,000	(In lip area)	"
"	H + 1 h 22 m	>5,000	(In lip area)	"

(a) Distance is given on the upwind side in a direction approximately 165° from true north.

avoid unnecessary grinding of gears. Actually, the top speed of the various weasels differed somewhat and a higher speed could have been beneficially tolerated without consequent reduction in vehicular control.

The maneuverability of the weasels, utilizing TV equipment proved adequate in observing the various sampling operations, in turning around in confined areas and in avoiding various obstacles.

The sampling weasels were sufficiently maneuverable to climb over the lip into the crater edge on the surface shot to take samples at the edge just within the crater lip area. Previously, performance tests had been made over obstacle courses at the Aberdeen Proving Grounds, Maryland, to insure its capabilities over rough and difficult terrain conditions. These samplers were also designed for positioning at various levels above ground for operation over different conditions of terrain.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

5.1.1 Surface Shot

For the surface shot, there was no set pattern followed for taking samples due to the presence of various obstacles such as steel spikes at various stations, foxholes and vehicles distributed about the crater area. The weasels were directed straight to the lip during the first run at which point eight shallow samples and one core sample were obtained. Due to the irregularity of terrain at the shallow sampling point, depression beneath a sampling arm would result in missing a sample although the micro-switch feeler attachment is properly set. Due to a layer of caliche beneath the surface, the depth of a core sample obtainable was limited to approximately 1½ ft. During the second run five shallow samples were taken at the inside edge of the crater lip. Additional samples were not obtained because of the weakened signal received with the weasel on the inside edge of the crater lip. Using the radio transmitting antennae atop the tower enabled the weasel to be backed out of this position but no further shallow samples were taken. During this phase of the operation the pile driving mechanism on the coring weasel was rendered inoperative due to a kink in the hammer cable which caused the cable to wrap around the hammer arm thereby leading to failure of the coring equipment.

The radiological telemetering equipment used incorporated a modified AN/PDR-T1B with a maximum range of 500 r/hr. This range was inadequate in obtaining readings in the lip and crater area inasmuch as the equipment went off scale indicating rates in excess of 500 r/hr. In addition readings obtained were considered unreliable due to excessive drift and rf interference. The need for an improved probe on subsequent shots was thereby indicated.

An analysis of all data obtained from the samples collected appears in the Project 2.6a final report.

5.1.2 Underground Shot

For the underground shot, a single shallow sampling weasel was directed to the lip from which point seven samples were obtained and the weasel directed back to the sample unloading point. This minimized the sample recovery time which was of particular interest since information was desired on decay of the samples of residual contamination at the earliest possible time. At H + 2 h 10 m the samples, in lead containers, were ready for delivery to the site laboratories. In order to minimize the sample recovery time it was necessary to avoid the delay and danger of breakdown involved in stopping the weasels (changing gears, checking, etc.) therefore, no readings were taken after their exit from the lip area. During the second run the shallow samplers could not be actuated because of an inoperative relay in the radio receiver on the weasel. Due to the finely pulverized and dry texture of the earth at the lip, although the coring tube was rapidly driven 4 ft. down, upon extraction of the tube only 1½ ft. of core sample remained. In order to obtain some data as to the distribution of ground contamination in the lip and crater area, a pattern of shallow samples was followed on the third and final run. Ten sampling scoops were activated at approximately fifty-foot intervals along the upwind side of the lip and the weasel returned with seven shallow samples, including a sizeable rock which was considered valuable for obtaining data on neutron-induced activities.

During the test operations for this shot a different probe with a logarithmic scale going to 5,000 r/hr was used. Readings obtained at low level radiation points indicated quantitative agreement with other instruments. However, radiation rates in the lip and crater area exceeded 5,000 r/hr so that no absolute reading was obtained. Three film badges placed on the weasel making the first run received a total dosage of 1925 r which indicates a radiation rate in the order of 5,000 r/hr at the time the telemetering equipment indicated a reading in excess of 5,000 r/hr. An analysis of all data obtained from the samples collected appears in the Project 2.6c final report.

5.1.3 Instrumentation

The telemeter and the film badges on each of the weasels were located approximately three feet above the ground to offer minimum shielding conditions and to absorb the least amount of scattered radiation from the weasel.

The minimum reliability figure of the rates at the crater falls within ± 20% of the true rates, with each estimate having the same degree of reliability.

5.2 CONCLUSIONS

The main objectives of the project were successfully attained. The method of using television-guided, remotely-controlled weasels to perform and view sampling operations in a highly contaminated area as well as to telemeter radiation rate data has proved to be practical. Additional development and improvement is required on all instrumentation. These new techniques utilized enabled rapid acquirement of both radiological rate information and samples for early analysis. From experience gained during Operation JANGLE various improvements in the current equipment can be made. It was concluded that shields would not be necessary for sample removal for nominal sized surface or underground atomic detonations.

5.3 RECOMMENDATIONS

Utilizing experience gained during Operation JANGLE various recommendations as to improvement of equipment and operations are made. It would be desirable to conduct a test without the presence of the various obstacles encountered in the lip area such that it would be possible to take a full pattern of samples. This would yield considerable data on the distribution of ground contamination. Radiological information should be telemetered at frequent intervals or be continuously recording to afford a correlation between rate and sampling data. This rate data could be recorded by means of instrumentation on the weasel, as a function of time and location and then later recovered. A probe capable of operating up to rates considerably higher than 5,000 r/hr is also desirable.

Various refinements and improvements in the instrumentation are recommended for consideration in the light of experience gained. The remote function control relays in the radio receivers which were not designed for field use and caused occasional erratic receiver response should be replaced by rugged hermetically sealed snap relays. The shallow sampling scoop selector should be redesigned for more uniform time intervals between pulses. The television system should incorporate larger receivers as well as improved TV camera shock mounts to reduce vibration.

Certain features of the shallow sampling equipment should be improved. The overload relay operation should be more certain and design changes should insure a sample collection although a depression may exist directly beneath the shallow sampling scoop arm. More extensive changes on the deep earth sampler are indicated to insure that when the coring tube is driven down to its full depth, a representative sample is obtained upon tube withdrawal. A more rapid system less susceptible to failure than the hammer-driven pile should be contemplated. Also, depth gage feelers should be modified to prevent entanglement or damage in rough terrain.

Changes should be made on the weasel itself. Recommendation is made that an automatic transmission be incorporated providing a wider smooth variation of speeds. This will insure more rapid operation and will eliminate the possibility of failure of the clutch gear shifting motor. A change in the electrical system will improve the TV transmission characteristics and avoid battery discharge thereby eliminating the necessity for racing the weasel engine while performing stationary functions.

It is considered that a "weasel" incorporating the foregoing recommendations will be capable of performing many required sampling operations over difficult terrain on future weapons tests.