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OPERATION SUN BEAM, SHOTS LITTLE FELLER II AND JOHNIE BOY

Project Officer's Report—Project 2.16

Residual Radiation in the Crater and Crater-Lip Area of Low-Yield Nuclear Devices

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Fort Belvoir, VA

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FOREWORD

Classified material has been removed in order to make the information available on an unclassified, open publication basis, to any interested parties. The 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 either currently classified as Restricted Data or Formerly Restricted Data under the provisions of the Atomic Energy Act of 1954 (as amended), or is National Security Information, or has been determined to be critical military information which could reveal system or equipment vulnerabilities and is, therefore, not appropriate for open publication.

The Defense Nuclear Agency (DNA) believes that though all classified material has been deleted, the report accurately portrays the contents of the original. DNA also believes 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.

OPERATION SUN BEAM

SHOTS LITTLE FELLER II AND JOHNIE BOY

PROJECT OFFICERS REPORT-PROJECT 2.16

RESIDUAL RADIATION IN THE CRATER AND CRATER-LIP AREA OF LOW-YIELD NUCLEAR DEVICES

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ABSTRACT

The purpose of Project 2.16 "Residual Radiation in the Crater and Crater-Lip Area of Low-Yield Nuclear Devices (U)" was to determine as much as possible about the residual radiation environment in and near a nuclear crater. The specific information desired was: (1) the change in gamma intensity with time, (2) the change in mean gamma energy with time and, (3) the change in gamma activity in soil with depth and particle size. The project participated in Shot Little Feller II to obtain gamma intensity versus time, and gamma activity versus soil-depth information; and in Shot Johnie Boy to obtain gamma intensity versus time, and mean gamma energy-versus-time information.

The experimental procedure was to obtain the intensity-versus-time and mean energy versus time data by placing instrument packages on a D-7 Caterpillar tractor and guiding the tractor into the crater area by radio-control as soon after the detonation as possible. The self-recording gamma-intensity gages were mounted on a steel boom and attached to the blade beam of the radio-controlled dozer at preselected intervals to obtain data from the crater and crater lip, based upon predicted crater dimensions. A gamma scintillation detector was mounted on the dozer with a cable reel. Thus, at a later time, a pulse-height analyzer could be connected to the free cable end, and gamma-energy spectrums obtained at various times. The soil samples for the gamma intensity-versus-depth data were obtained at t+4 days by driving soil core-sampling tubes into the ground at the Little Feller II crater area. Essentially no data was obtained on Shot Johnie Boy and results

and conclusions are based upon Little Feller II data.

Information from Shot Little Feller II indicated that present prediction methods give H+1 hour intensities in the crater area two or three times higher than measured. The average intensity (at H+1 hour) of the two instrument records is 2020 r/hr. The intensity-time records indicated the dose-rate decay exponent was -1.2 after H+12 hours. Test data indicates that cratering mechanisms affect the dose rates at various distances from GZ at early times.

Previous test data indicated that 90% of beta activity was concentrated in the first 12 inches of soil. This project reached the same conclusion for gamma activity on Little Feller II. A significant amount of induced nuclides was found in the soil samples, and an appreciable amount of alpha contamination. Alpha contamination can probably be expected when low-nuclear-efficiency weapons such as the and the are employed. The particle and activity distribution curves indicate an almost lineal relationship between particle size and amount of activity.

Incomplete data from Johnie Boy indicates the mean energy of residual radiation may be higher at specific times than previously postulated by experimental and theoretical data.

PREFACE

The authors wish to acknowledge the fine work of personnel and organizations which assisted in the planning and execution of this project.

Particular appreciation is expressed to Ernest Bloore, U.S. Army Nuclear Defense Laboratory, Edgewood Arsenal, Maryland, for conducting the hot lab analysis of the Little Feller II soil samples.

CONTENTS

TABLES

FIGURES

CHAPTER 1

INTRODUCTION

The range of yields and nuclear weapons systems available to the field army has greatly increased. The increased availability of tactical weapons of low yield has particularly influenced the capability of the field army to adapt to a fluid tactical situation in a nuclear conflict. However, it is necessary to be able to predict the effects from low-yield tactical weapons quickly and accurately, because of their immediate effect upon friendly and enemy tactical operations.

1.1 OBJECTIVE

The objective of this project was to obtain information about the residual radiation environment in the crater and crater-lip area resulting from the employment of low-yield fission weapons. The information needed specifically was: (1) the change in intensity with time, (2) the change in mean-gamma-energy level with time, and (3) the activity-level variation with depth in the soil.

1.2 BACKGROUND AND THEORY

The final decision as to whether a low-yield weapon will be used in a tactical situation often will depend on the character and intensity of the residual radiation resulting from the weapon's employment. The military significance of a low-yield nuclear crater and its attendant residual radiation must be known to enable tactical commanders to predict what effect it will have upon friendly and enemy operations and movements.

1.2.1 Crater Intensity. Efforts to obtain crater-intensity information on past weapon tests have been partially successful (see References 1 and 2). But in nearly all cases the data was obtained through extrapolation of late-time data to early times, using the $t^{-1.2}$ function. This method was refined on Shot Fig, Operation Hardtack, where readings were extrapolated to H+1 hours by using the decay curve of fallout samples from that detonation.

1.2.2 Mean Energy Level. The change in mean energy level of fallout radiation is also of significance in determining the shielding effectiveness of armored vehicles and field fortifications. Calculations done in Reference 3 on the energy of U^{235} fission products indicate a 30% reduction in energy level from H+1 hours to H+20 hours. This would indicate that the transmitted dose through 1 inch of steel would decrease 24%. Other experimental and theoretical data indicates the significance of this effect may be greater than previously supposed (see Reference 4).

1.2.3 Activity with Depth Distribution. Of scientific interest as well as a matter of concern to units faced with possible decontamination of a crater area is the gamma-activity variation with depth in soil. It is easy to conceive a situation where the radioactivity of a crater area would prohibit the utilization of nearby vital facilities. The knowledge of activity-depth distribution would permit planning a successful decontamination operation to eliminate this hazard. Experiments conducted during Operation Teapot indicated that 90% of the beta activity was located in a soil layer 12 inches thick. (see Reference 5). This deep activity is due to the neutron flux interacting with trace metals such as sodium, magnesium, and aluminum. Consequently, because of the relatively short half-life of induced radionuclides, this 90% depth can be expected to decrease with time as the fission products on the surface become a larger percentage of the total gamma activity.

CHAPTER 2

PROCEDURE

2.1 SHOT PARTICIPATION

This project participated in Shots Little Feller II and Johnie Boy of Operation Sun Beam. Despite the prospect of facing the severe handicaps of extremely short lead times, and lack of precedence on experimental systems proposed, a maximum effort was justified for reasons other than those previously mentioned.

2.1.1 Shot Johnie Boy. Shot Johnie Boy was to be a detonation of the

This munition is in many respects the backbone of operational demolition planning. This operational munition figures heavily in the planning of denial and demolition operations of the Army and Marine Corps. This particular shot called for an operational

to be placed in the alluvial deposits of Area 18 at the Nevada Test Site (NTS). Since one of the main concerns was the effect of small depths of burst (DOB) on cratering efficiency, the munition was to be emplaced with 1 foot of soil above the munition case or with the center of gravity (CG) of the critical assembly 23 inches below ground surface. This emplacement is practically identical with what would be the actual case in the carrying out of hasty demolition missions; therefore, of prime interest in determining the radiation environment of low-yield munitions.

2.1.2 Shot Little Feller II. Shot Little Feller II

Shot Little Feller II was to be a warhead positioned at the operational burst height of 3 feet above alluvium in Area 18 of NTS. Operational devices of this yield exist or are planned

Thus, a broad base of interest exists for the effects at these low yields.

2.1.3 Project Activity. It was planned to obtain intensity-time and intensity-depth information on Little Feller II; and obtain intensity-time and mean energy on Johnie Boy. The intensity-depth data was to be obtained by Johnie

Boy Project 2.12. There was insufficient time planned between Little Feller II and Johnie Boy to obtain mean-gamma-energy data on Little Feller II.

2.2 INSTRUMENTATION

The instrumentation and procedures explained are organized as to data objectives instead of shot participation.

2.2.1 Crater Intensity Measurement. It was planned to obtain the gamma intensity-versus-time data by mounting instrumentation on a remote-control dozer which would be able to place the instrumentation in the crater at early times. Two types of instrumentation were used, (1) scintillometer, and (2) ionization chamber.

The basic scintillometer was the Hilen-2R manufactured by the Eberline Instrument Corporation, with two intensity ranges of zero to 100 and zero to 1,000 roentgens per hour (see Figure 2.1). The instrument is basically a battery-operated, self-recording intensity gage which measures gamma intensity by recording the output current from a photomultiplier tube which is coupled to an organic scintillation crystal. The three instruments for this project were modified so they would read zero to 1,000 and zero to 10,000 r/hr. The instruments' recorders were Assembly Products Incorporated "versaprints" modified for 12-vdc operation and a 30-second print cycle. Two of these instruments were used on Little Feller II and three used on Johnie Boy.

The ionization-type instrument was basically the radiac set Model MG-3 remote-monitoring device developed by the Republic Electronic Industries Corporation for the Air Force (see Figure 2.2). This basic instrument was modified to extend its range from 1,000 to 20,000 r/hr and to replace the spring-driven recorder, with an electric recorder to increase recording time. The modified instrument was made up of a detector, indicator, and recorder, all of which were battery powered. The MG-3 was chosen for the high-range modification because of fewer technical problems and short lead times. The response of the modified MG-3 was linear at low levels and logarithmic in the higher levels of primary interest.

2.2.2 Mean Energy Measurement. The basic instrument to be used in obtaining radiation spectrum data from the Johnie Boy crater was the RCL 128 channel scaler analyzer. This scintillation counter can be used for pulse-height analysis, or it can be used as a multichannel scaler for gross counting and decay determinations. For this project, however, it was necessary to modify the scintillation detector so that it could be placed on the radio-control dozer and send signals back over a 5,000-foot cable. To minimize noise and cable problems, the preamplifier in the scintillation detector was modified to operate with an independent power supply (see Figure 2.3). The conventional preamp in the detector was replaced with a device which utilized Ni-Cad batteries for transistor power, and filters for returning the signal back on the high-voltage lead of the photomultiplier tube (see Figure 2.4).

A filter system was also required at the analyzer end of the cable to separate the incoming signal from the outgoing photomultiplier high voltage. A simple battery charger was also built for charging the Ni-Cad transistor power supply batteries in the preamp.

The scintillation detector was placed in an aluminum housing fitted with a thrust bearing at the crystal end. The other end was bolted to the wooden cable reel and the complete assembly mounted on a vertical shaft and thrust bearing fastened to the dozer running board. Thus, the cable reel and scintillation detector would rotate as the coaxial cable paid out while the dozer advanced toward the crater. To prevent an overloading of the photomultiplier, the crystal projected into a lead collimator mounted on the thrust bearing at the crystal end of the aluminum detector housing. The collimator was eccentric to the crystal axis with 2 inches of lead on the top and back and 3 inches of lead in front where the 1/32-inch window was located (see Figure 2.5). The collimating block was held stationary by a metal strap while the detector and cable reel rotated so the window would always look towards a spot in front of the dozer.

The final procedure then was to tie-off the analyzer end of the cable during reentry after zero time, and let the cable pay out as the dozer advanced toward the crater from the upwind direction. As soon as practical the 2 1/2-ton instrument van would reenter (planned for the next morning) and park near the cable tie-off point. The cable would then be connected to the analyzer equipment located inside, and necessary spectrum and decay data obtained.

2.2.3 Gamma Intensity versus Depth. The remaining instrumentation consisted of soil core samplers used to obtain soil samples at various depths for the intensity-depth determination. The approach used on Little Feller II was essentially the same as used on Project 2.5.1 of Operation Teapot in 1958 (Reference 5). Because of results obtained by Project 2.5.1

the length of the core sampler was shortened from 5 to 3 feet. The outer rotating tube was constructed of thin-wall aluminum tubing to minimize carry-down of surface contamination and to eliminate the bothersome surface-stabilization procedure. The sample slots were 4 by 3/4 inches on 6-inch centers with the slots for shallow samples 2 x 3/4 inches on 4- and 3- inch centers (see Figure 2.6).

Duplicate samples from the core samplers were to be prepared and one set sent to the Nuclear Defense Laboratory's hot lab to determine particle distribution and specific activity for each of the following particle sizes:

Fraction	Size, Microns
AA	>840
A	840 to 420
B	420 to 210
C	210 to 105
D	105 to 74
E	74 to 44
F	<44

The alternate set of samples were to undergo gamma-spectrum analysis by the RCL-128 scaler analyzer equipped with a 3-inch crystal-well counter.

2.2.4 Instrument Placement System. A radio controlled D-7 bulldozer was the means by which the self-recording intensity-time and energy-level-versus-time instrumentation was to be placed in the crater area at early times. Operational, safety, and lead-time considerations precluded practically all other methods by which the data might be obtained. The radio-controlled dozer was a tested item of equipment which was immediately available.

The dozer was a Caterpillar D7, series 3T modified to permit operation either manually or remotely, using a radio link. The radio link consisted of a standard Signal Corps RG-67 transmitter and receiver with a Signal Corps developed tone-modulated coder-decoder operating on a carrier frequency of 32.1 mc. Control of the dozer was maintained by using an electrohydraulic system. The receiving radio system supplied power to actuate control relays and solenoids for gear selection, steering, and blade control. Electric motor linear actuators were used for throttle and compression control. There were 15 control functions needed in this operation:

1. throttle open
2. throttle closed
3. compression on
4. compression off
5. master clutch disengage
6. low
7. forward
8. reverse
9. left steering
10. right steering
11. left cluth and brake
12. right clutch and brake
13. blade beam up
14. blade beam down
15. diesel hot start

To enable the dozer to carry the instruments and place them at a desired spread of data points, booms were constructed of two 6-inch steel channels laced together and mounted on the hydraulically controlled blade beam. The booms were constructed to roughly conform to the estimated crater profiles, with instruments in the crater, on the lip crest, and down the lip from the crest. The estimated crater profiles used were:

The booms were mounted on the blade beam in such a way that the end of the boom was 4 or 5 feet above ground when the beam was in the up position. Thus, clearance was provided when the dozer was traveling toward the crater. The instruments were bolted to the frames at intervals so that when lowered in the crater they would be at the desired locations (see Figure 2.7).

The system developed for locating the dozer at all times consisted of a transit and a tagged steel cable. Prior to shot time, transit points were located 2,000 and 3,000 feet from Little Feller II and Johnie Boy GZ's respectively. Located along the main access road, azimuths were shot to the GZ's from a preset backshot location. The steel cable was tagged every 200 feet on the last 1,000 feet and every 10 feet for the last 100 feet. The vertical hair of the transit would thus establish a line of approach for the dozer, and the cable attached to the dozer tow bar would indicate the dozer's distance from GZ. Five headlights were arranged in a + pattern on the back of the dozer to provide a tracking point for the transit if the dust from the blast precursor or from the base surge reduced visibility.

The planned placement procedure was simply to truck the dozer with boom to the transit point, off-load via an earth ramp, start the dozer, attach the tagged cable and send it on its way. When the dozer reached the desired location, the boom was to be lowered, the throttle and compression turned off, and the reentry party return to the Control Point.

2.3 INSTRUMENT CALIBRATION

The modified MG-3 was calibrated with a cobalt source by the Republic Electronic Industries Corp. and a calibration scale supplied by them. The indicated intensity is within ± 10% of the actual intensity. The Eberline Hilen 2R's were calibrated by Eberline at the Edgerton, Germeshausen & Grier radiation facility in Las Vegas. After correction for instrument response, the Hilen 2R's were accurate to ± 8%. The instrument response corrections for the zero to 10,000 r/hr range are:

Model No. 116
True Intensity = (1.28)(recorded intensity)

Model No. 129
True Intensity = (1.00)(recorded intensity)

Model No. 130
True Intensity = (0.88)(recorded intensity)

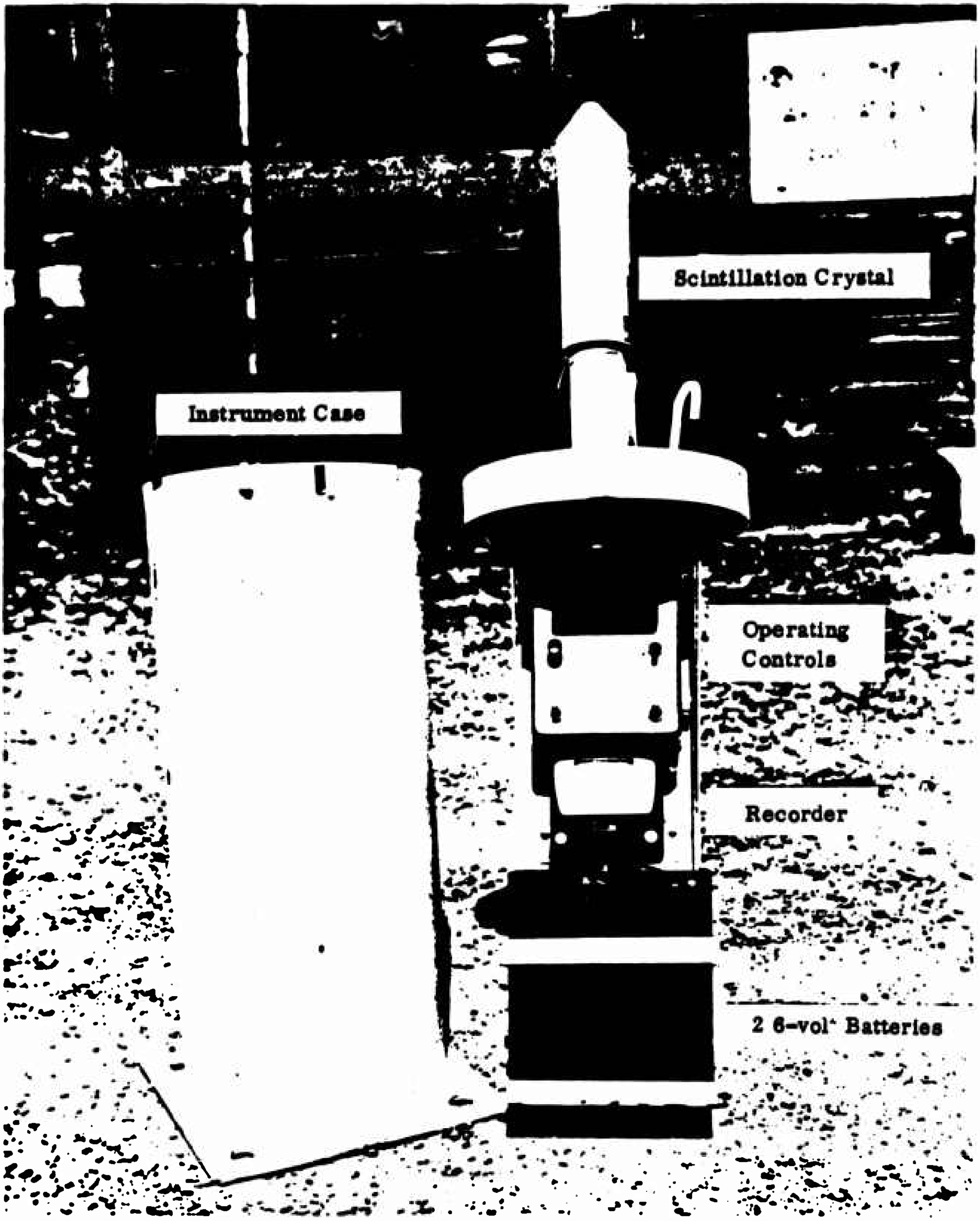


Figure 2.1 Eberline self-recording scintillometer (modified Model Hilen-2R). (ERDL photo)

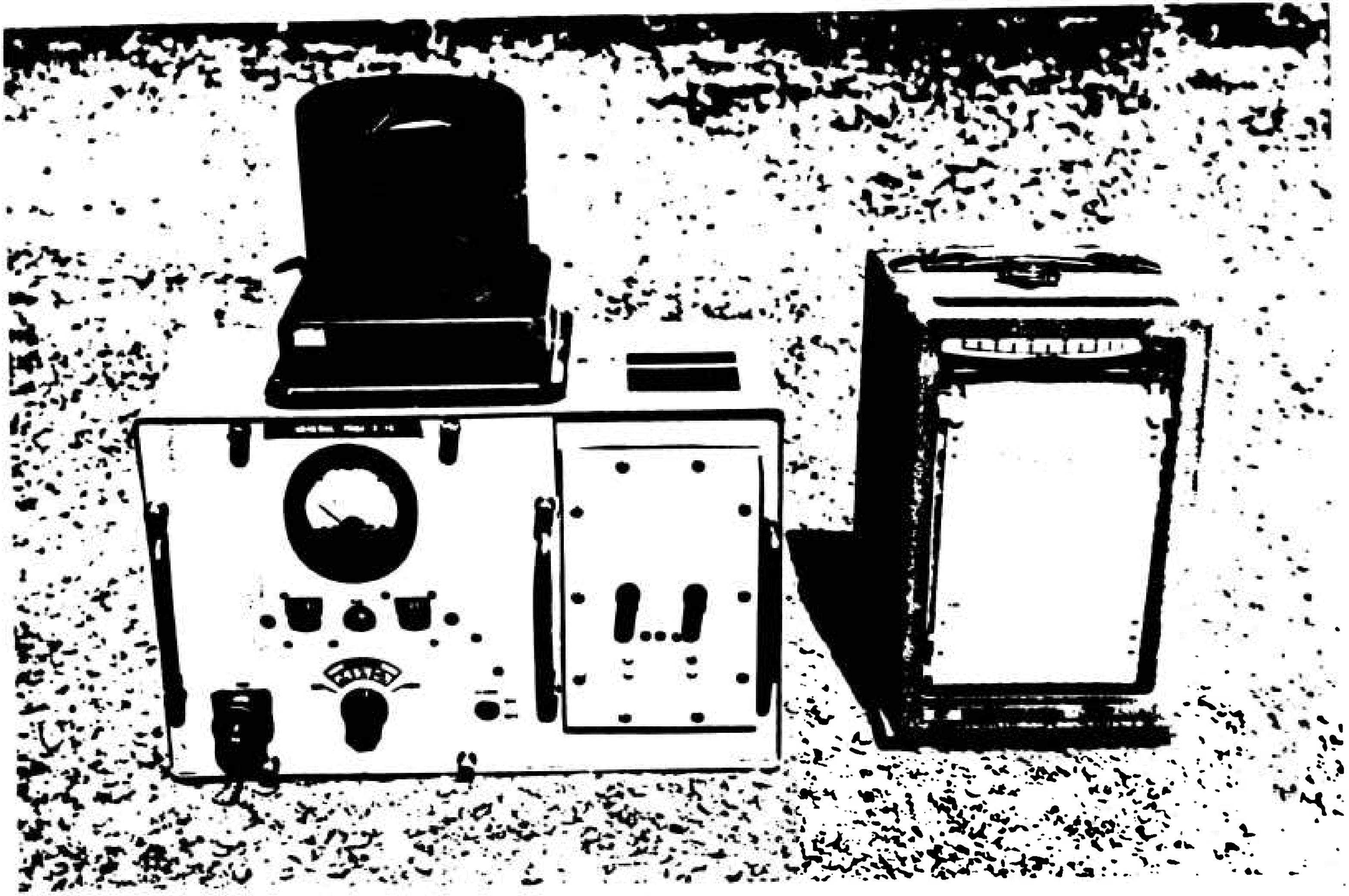


Figure 2.2 Republic self-recording ionization meter (modified Model MG-3). (ERDL photo)

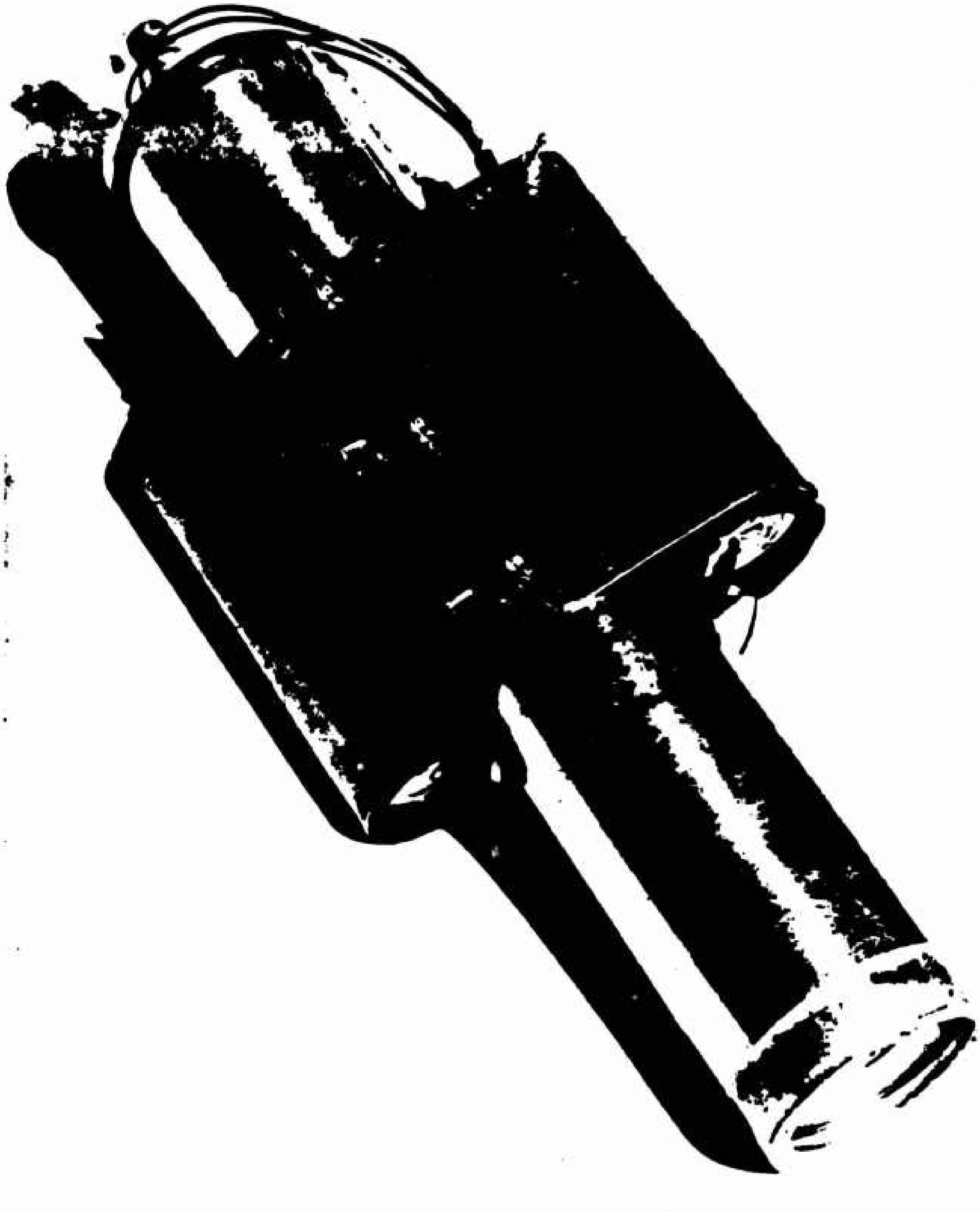


Figure 2.3 Scintillation detector modified for battery operation with external photomultiplier power supply. (ERDL photo)

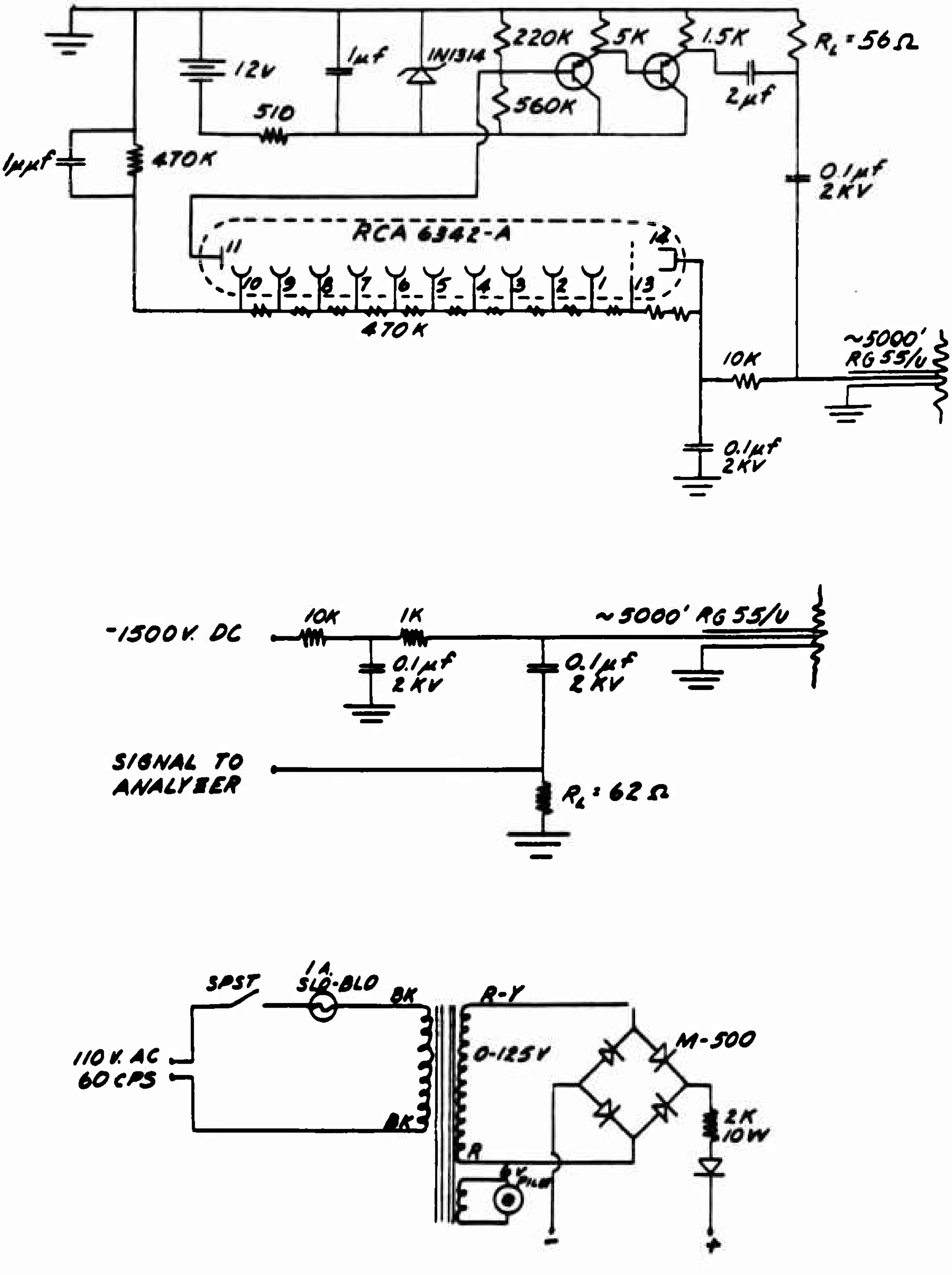


Figure 2.4 Wiring diagrams for the modified scintillation detector, signal filter, and battery charger.

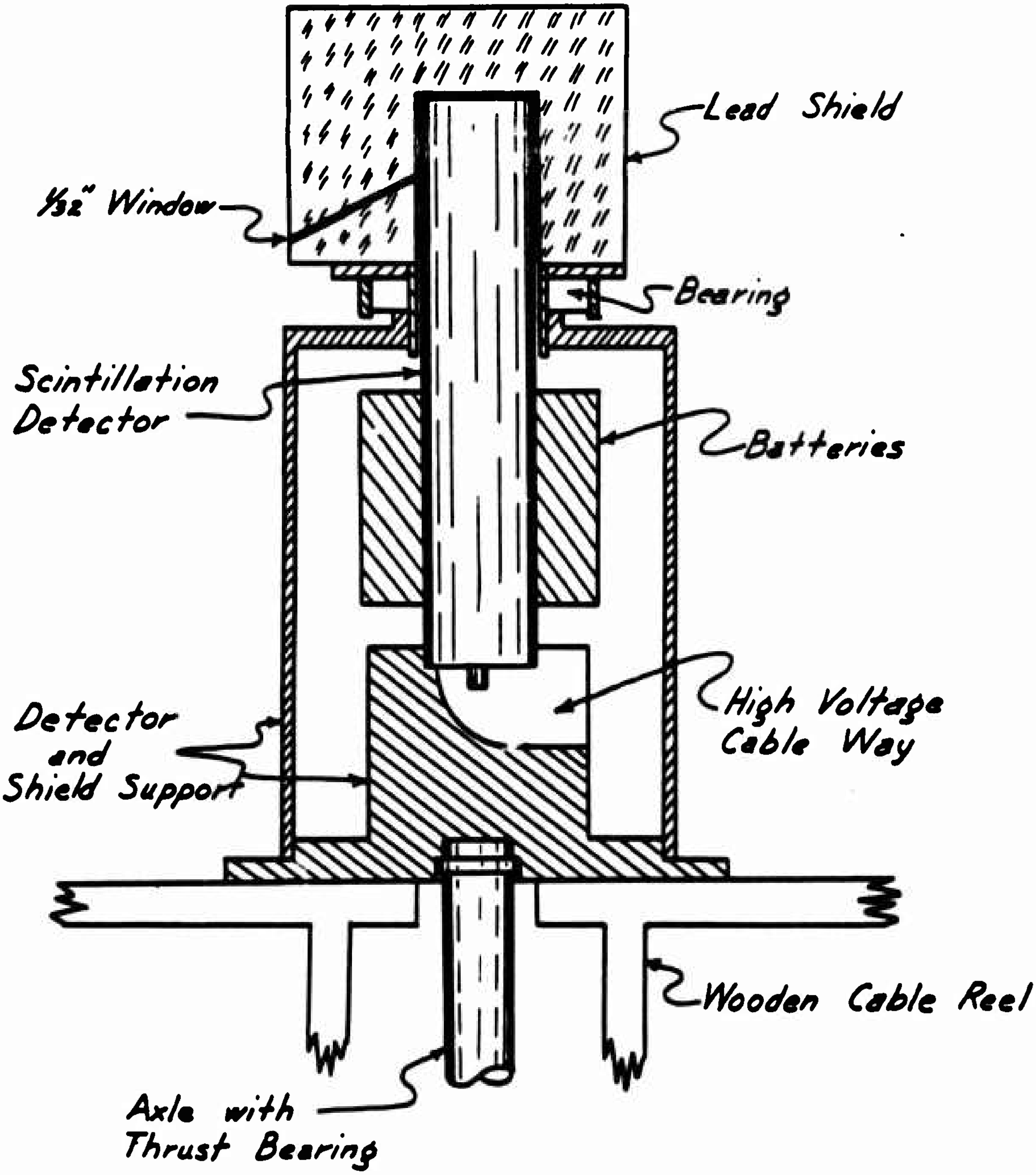


Figure 2.5 Shield and reel assembly for scintillation detector.

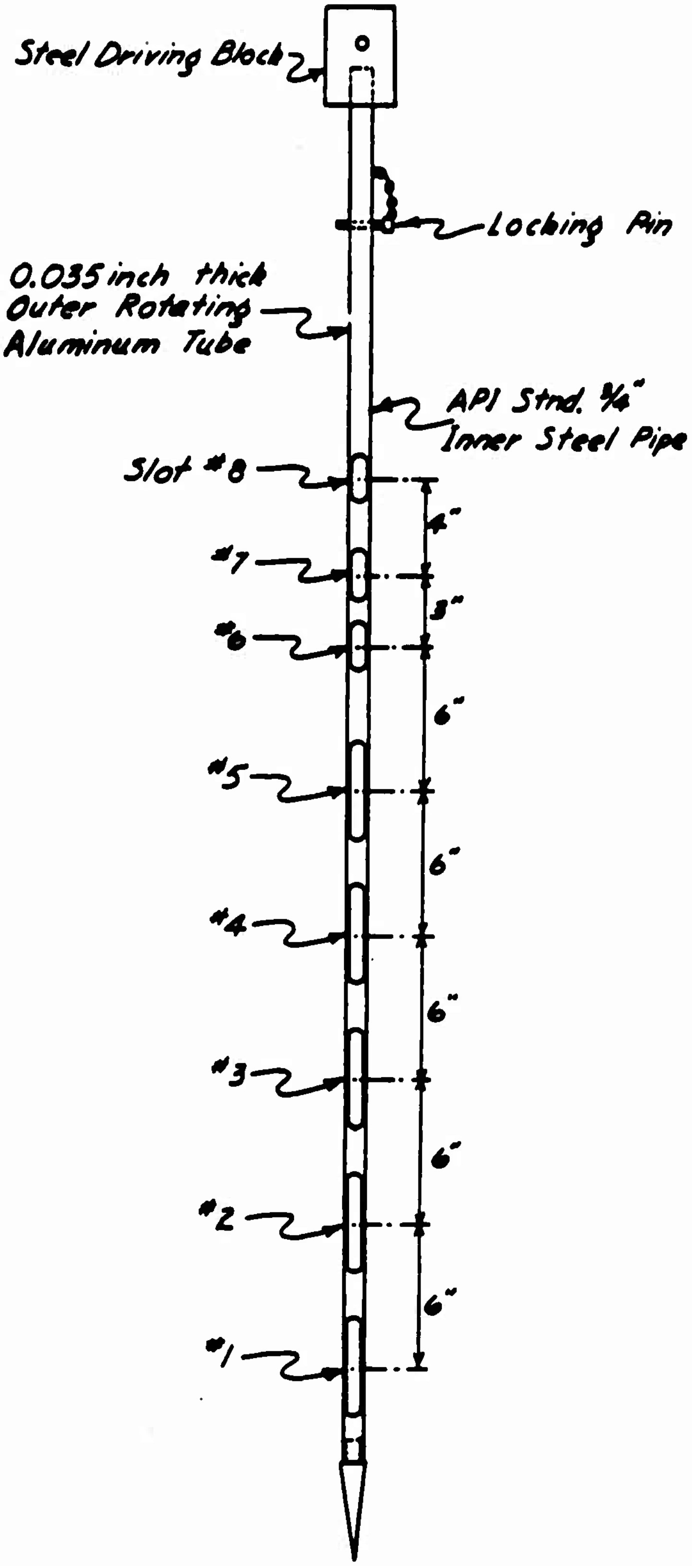


Figure 2.6 Soil sampler in open position.

Figure 2.7 D7 dozer with Little Feller II instrument boom mounted on blade beam. (ERDL photo)

CHAPTER 3

RESULTS

3.1 PLACEMENT SYSTEM

The radio-controlled dozer operated satisfactorily on both shots and proved itself to be a stable and reliable platform for placing the instruments in the crater area. However, the tagged cable used to determine the dozer's distance did not prove accurate. On Shot Little Feller II, the dozer overshot the crater and had to be backed up. Consequently, the instruments were not placed exactly where desired (see Figures 3.1 and 3.2). The tagged cable again gave a false indication of distance on Shot Johnie Boy with the result that the dozer advanced too far up the lip. Before the dozer, which had been halted, could back up far enough, the lip collapsed, the dozer lost traction, and slid into the crater.

3.2 CRATER INTENSITY

No data was obtained from Johnie Boy. The two Eberlines worked satisfactorily on Little Feller II and data was obtained from H+1.25 hours to H+40 hours. The pen in the MG-3 was jarred from its mounting and no data was obtained. Although the instruments were not placed where planned, the final locations determined by photoanalysis and ground survey were satisfactory (see Figure 3.2).

3.3 MEAN ENERGY LEVEL

Although the dozer and scintillation detector slid into the Johnie Boy crater, the instrumentation remained intact. The instrumentation van was moved forward and the signal cable connected by H+30 hours. However, erratic behavior of the analyzer, later traced to a faulty diode in the memory module, prevented the acquisition of enough data for quantitative results. During the short periods of normal analyzer operation, enough data was obtained for an indication of qualitative results (as shown in Figure 3.3) until the signal cable was cut by access road traffic at about H+48 hours. The energy range in Figure 3.3 is approximately 0 to 1.4 mev.

3.4 ACTIVITY WITH DEPTH DISTRIBUTION

Soil samples from Little Feller II were obtained on D+5 days and sent to NDL for analysis. An unusually heavy workload precluded any analysis until September; consequently, the induced nuclides had greatly decayed. Samples were obtained from five locations varying from 30 to 80 feet from GZ (see Figure 3.2). The ground of Area 18 is very hard and data was not obtained at all the depths desired.

The general particle-gradation curve describes within ± 20% the curve for all samples analyzed. The activity-distribution curve is accurate to the same limits (see Figure 3.4). The gamma spectrums of all samples were very similar and Figure 3.5 is representative. A three-dimensional plot of scintillation spectrums versus particle size would disclose a gaussian distribution about the 420- to 840-micron particle size range. The scintillation spectrums and the scatter of intensity versus depth data for each data point indicates that the core samplers carried down a significant amount of surface fallout. However, the gross data indicates approximately 90% of total activity was located in the upper 12 inches of soil, as indicated in Figure 3.6.

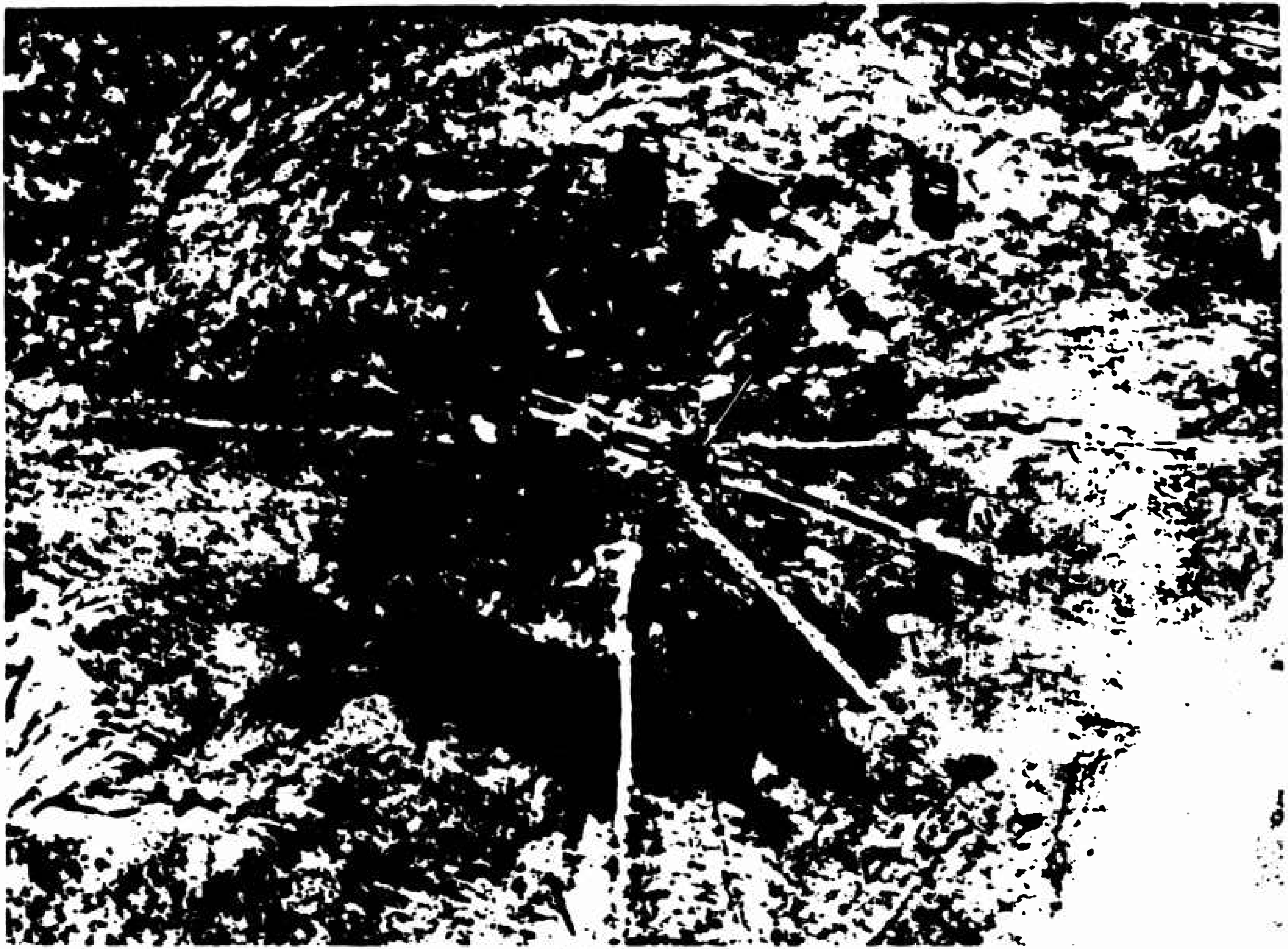
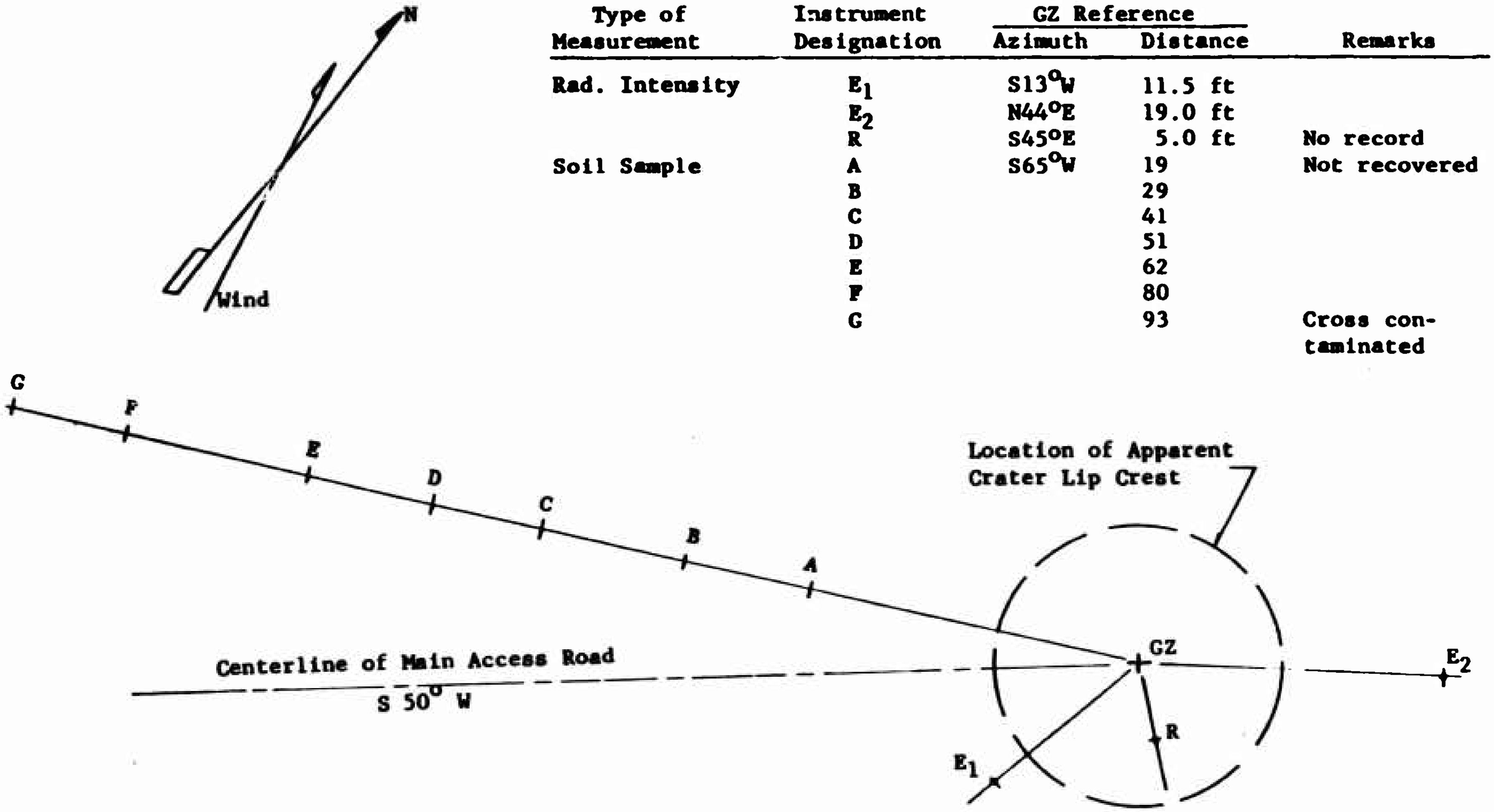


Figure 3.1 Radio controlled dozer at Little Feller II crater on D + 1. (ERDL photo)



Type of Measurement	Instrument Designation	GZ Reference Azimuth	GZ Reference Distance	Remarks
Rad. Intensity	E_1	S13°W	11.5 ft	
	E_2	N44°E	19.0 ft	
	R	S45°E	5.0 ft	No record
Soil Sample	A	S65°W	19	Not recovered
	B		29	
	C		41	
	D		51	
	E		62	
	F		80	
	G		93	Cross contaminated

Figure 3.2 Location of instruments and soil-sample points on Little Feller II.

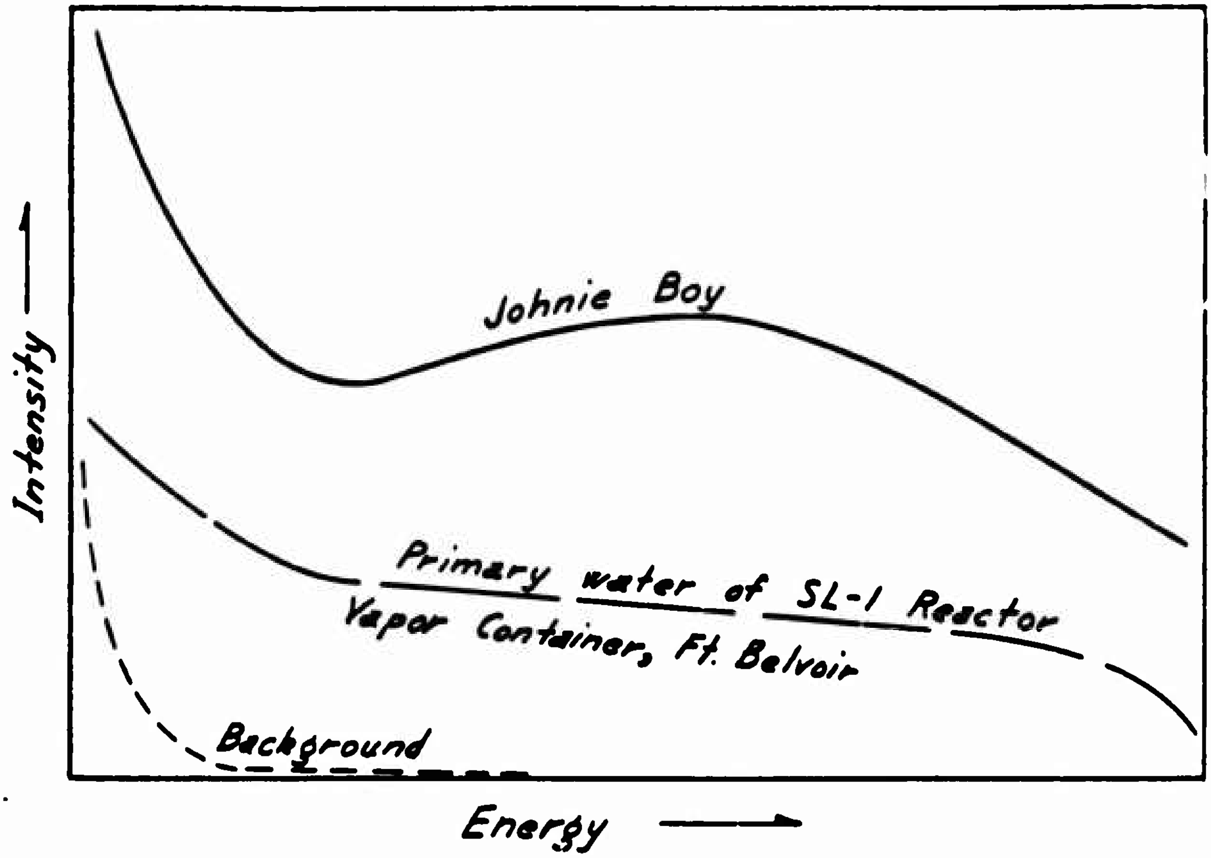


Figure 3.3 Qualitative-energy spectrum results, Johnie Boy.

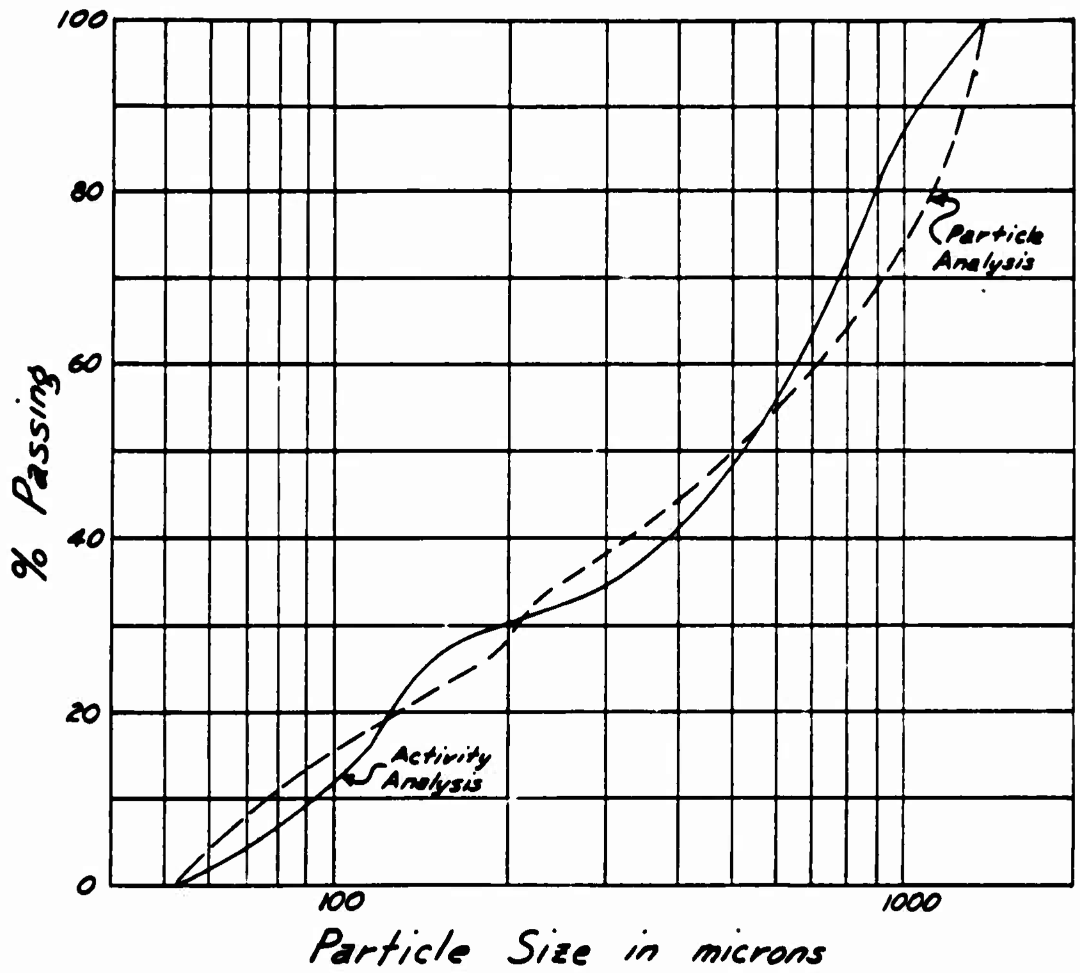


Figure 3.4 Particle and gamma activity gradation curve, Little Feller II.

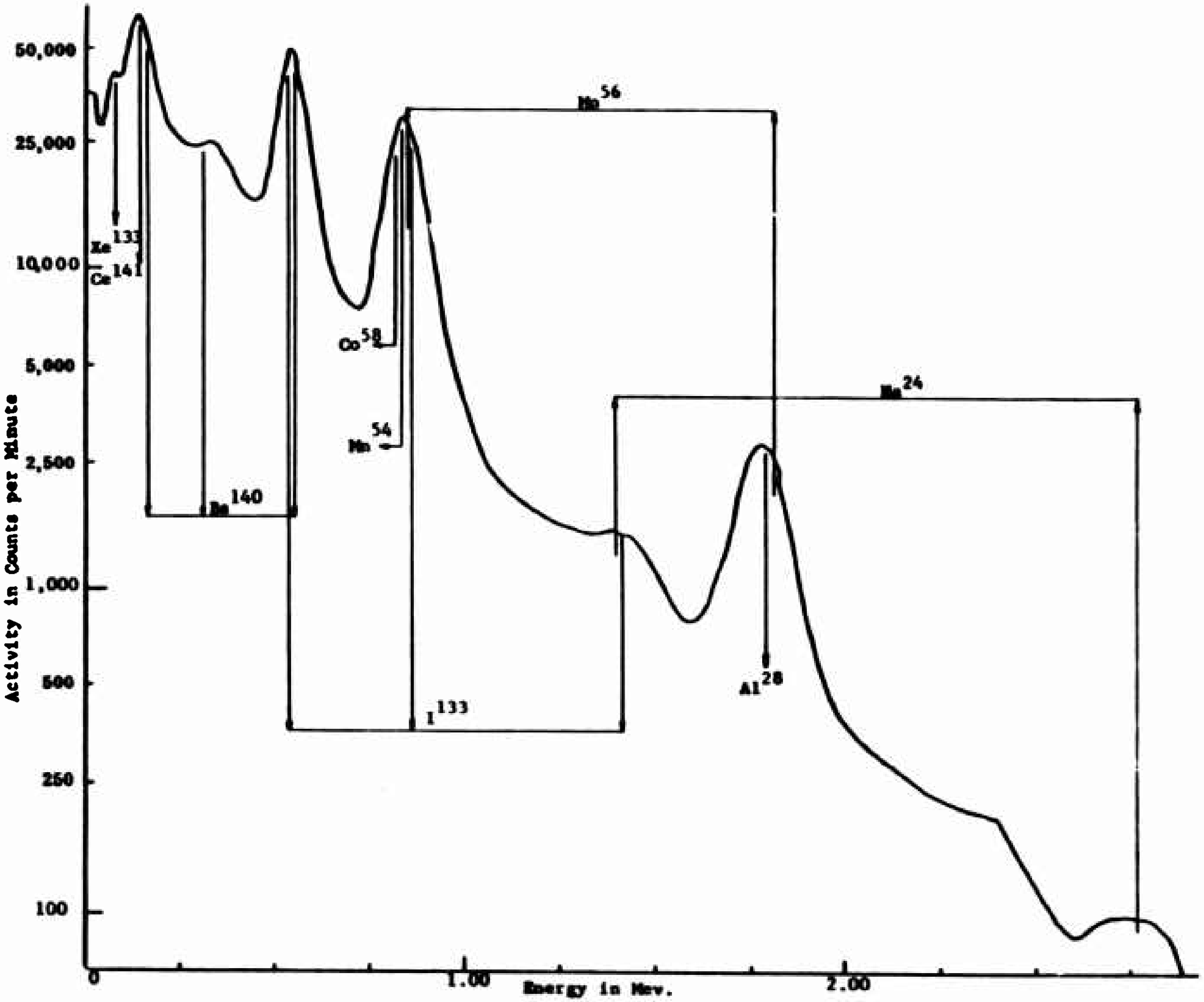


Figure 3.5 Typical scintillation spectrum from Little Feller II soil samples.

CHAPTER 4

DISCUSSION

4.1 CRATER INTENSITY

The data for all Little Feller II plots is found in Table 4.1. The intensity for H+1 hours is an extrapolated value. The value of μ, the exponent of t in the standard decay function, is computed from the ratio of the intensity of H+1 hours to the intensity at the time in question.

4.1.1 Discussion of Results.

The corrected data plots of the instrument records show good agreement (see Figure 4.1). The H+1 hour values were extrapolated from readings beginning at H+1.25 hours. The corrected data indicates intensities of 2,370 r/hr at 19.5 feet from GZ, and 1,670 r/hr 11.5 feet from GZ, at H+1 hour. The intensities at these two points became equal at H+2 hours and did not again diverge to the extent they did at H+1 hour. Figure 4.4 is a plot of average intensities. The decay curves of the two intensity records are similar in shape but do not follow the classical $T^{-1.2}$ function too well, as seen in Figure 4.2. A plot of μ versus time shows a clearer picture of this (see Figure 4.3). The change in μ with time is readily apparent, particularly in data from instrument E_2. The initial values of μ for the E_2 data suggests a significant influence is exerted by the decay of induced radiation while the E_1 data decays more in the manner of pure fission products (References 1 and 6). However, the E_2 data is from a greater distance from GZ than the E_1 data, suggesting that the E_1 data should be the data influenced by induced radiation decay. The disparity of data in regard to the greater intensity of the E_2 at early times and the apparent influence of induced-radiation decay on the E_2 decay data suggest two possible explanations:

1.The simplest explanation

is that some form of neutron shield greatly reduced the ground-incident neutron flux 11.5 feet from GZ in comparison to the incident flux at 19.0 feet. However, a consideration of just spherical divergence indicates the flux at 19.0 feet would be approximately 40% of the flux at 11.5 feet. Also

These considerations would indicate that the presence of a neutron shield was highly unlikely.

2.The other

explanation is that induced activity was concentrated in relatively shallow depths and some scour or throwout action took place.

There is some indication that the energy density of the shocked sphere was high enough when it encountered the ground surface to vaporize a relatively thin layer of material (Reference 7). Thus, a very strong ground shock would be produced. Reference 8 states that when a strong ground shock is formed from a surface burst there is a propensity for a rarefaction wave to travel from the air to the ground. As the dry alluvium has little tensile strength, a relatively weak rarefaction wave could dislodge and throw out significant quantities of material. This vaporization action, indigenous with the impact of the device vapors, could possibly be supported by two other observations. Photographs of the crater area on D+1 day indicate a clean scoured area around GZ (see Figure 3.1); also, the crater had a high diameter-to-depth ratio (Reference 9). In fact, the crater shape could best be simulated by an HE charge with a diameter-to-thickness ratio of about six, placed on the ground. The validity of this explanation will rest upon subsequent evaluation of test results by other projects.

4.1.2 Correlation with Previous Test Data. There is little previous test data to provide a check on these test results. The extrapolated H+1 hour data for Shot Fig, Operation Hardtack, agrees fairly well (Reference 1). The change in μ with time has been plotted from fission-product decay data from Shots Fig and Nancy of Operation Upshot-Knothole (see Figure 4.3). These data correlate as well as can be expected with Little Feller II data.

4.2 MEAN ENERGY LEVEL

The lack of quantitative results precludes any discussion or comparison of previous test results.

4.3 ACTIVITY WITH DEPTH DISTRIBUTION

The experimental procedure used at NDL is explained in the Appendix ; the results are also presented but without the voluminous spectrum analysis data and curves.

4.3.1 Discussion of Results. The general particle and activity-distribution curves show an almost lineal relationship between particle size and amount of activity (see Figure 3.4). The highest specific activities were found 41 feet from GZ where the average specific activity was 233.76 counts/min/μg on D+90 days. The half-life of the samples is approximately 40 hours. If this half-life were constant, this would infer a specific activity of 12,600 counts/min/μg or 84 millicuries per gm.

An analysis of the scintillation spectrums of the samples indicates the possible presence of five induced isotopes and four fission-product isotopes (see Figure 3.5). These identifications cannot be definite because decay data is lacking.

4.3.2 Correlation with Previous Test Data.

Previous test data consists of the variation of beta activity with depth and correlates very well. The isotopes tentatively identified are also consistent with previous test data (Reference 2).

TABLE 4.1 CORRECTED AND RAW INTENSITY-VERSUS-TIME DATA FROM LITTLE FELLER II DETONATION

H+t in Hou.	I_a in R/hr	I_a Corrected R/hr	I_a/I_o	I_o/I_a	μ from I_o to I_t	I_b in R/hr	I_b Corrected	I_b/I_o	I_o/I_b	μ from I_o to I_t	$I_{ave.}$ in R/hr	I/I_o	I_o/I	μ from I_o to I_t
1.00		1670	1.000	1.000			2369	1.000	1.000		2020	1.000	1.000	
1.25	1450	1350	0.808	1.237	0.954	1320	1692	0.714	1.400	1.509	1521	0.753	1.328	1.272
1.50	1250	1160	0.695	1.440	0.899	1000	1282	0.541	1.848	1.512	1221	0.605	1.654	1.243
1.75	1070	965	0.578	1.731	0.980	800	1026	0.433	2.309	1.493	996	0.493	2.028	1.262
2.00	950	844	0.505	1.979	0.985	640	821	0.347	2.886	1.528	833	0.412	2.425	1.280
2.50	750	645	0.386	2.589	1.039	520	667	0.282	3.552	1.380	656	0.325	3.079	1.225
2.75	710	600	0.359	2.783	1.013	---	---	-----	-----	-----	---	-----	-----	-----
3.00	---	---	-----	-----	-----	460	592	0.250	4.002	1.263	---	-----	-----	-----
3.25	610	500	0.299	3.340	1.023	---	---	-----	-----	-----	---	-----	-----	-----
4.00	510	398	0.230	4.196	1.035	360	462	0.195	5.128	1.179	430	0.213	4.698	1.117
5.00	470	338	0.202	4.941	0.992	290	372	0.157	6.368	1.150	355	0.176	5.690	1.080
6.00	450	299	0.179	5.585	0.960	230	295	0.125	8.031	1.162	297	0.147	6.801	1.070
7.00	430	261	0.156	6.399	0.954	210	269	0.114	8.807	1.119	265	0.131	7.623	1.045
8.00	430	252	0.145	6.901	0.929	190	244	0.103	9.709	1.083	243	0.120	8.313	1.009
9.00	390	193	0.116	8.653	0.982	150	192	0.081	12.339	1.142	193	0.096	10.466	1.069
10.00	370	163	0.098	10.245	1.010	130	167	0.071	14.186	1.151	165	0.082	12.242	1.088
11.00	360	138	0.083	12.101	1.040	---	---	-----	------	-----	---	-----	------	-----
12.50	350	105	0.063	15.905	1.093	---	---	-----	------	-----	---	-----	------	-----
15.00	290	60	0.036	27.833	1.227	70	90	0.038	26.322	1.206	75	0.037	26.933	1.213
20.00	190	50	0.030	33.400	1.170	50	64	0.027	37.016	1.206	57	0.028	35.439	1.192
30.00	150	30	0.018	55.667	1.180	20	26	0.011	91.115	1.326	28	0.014	72.143	1.258
40.00	130	20	0.012	83.500	1.198	--	--			-----	--	-----		-----

I_a = Intensity measured by instrument E_1
I_b = " " " " E_2
I_o = Intensity of H+1 hour
I_t = Intensity of time t
μ = Exponent of t in $I = I_o/T^{\mu}$

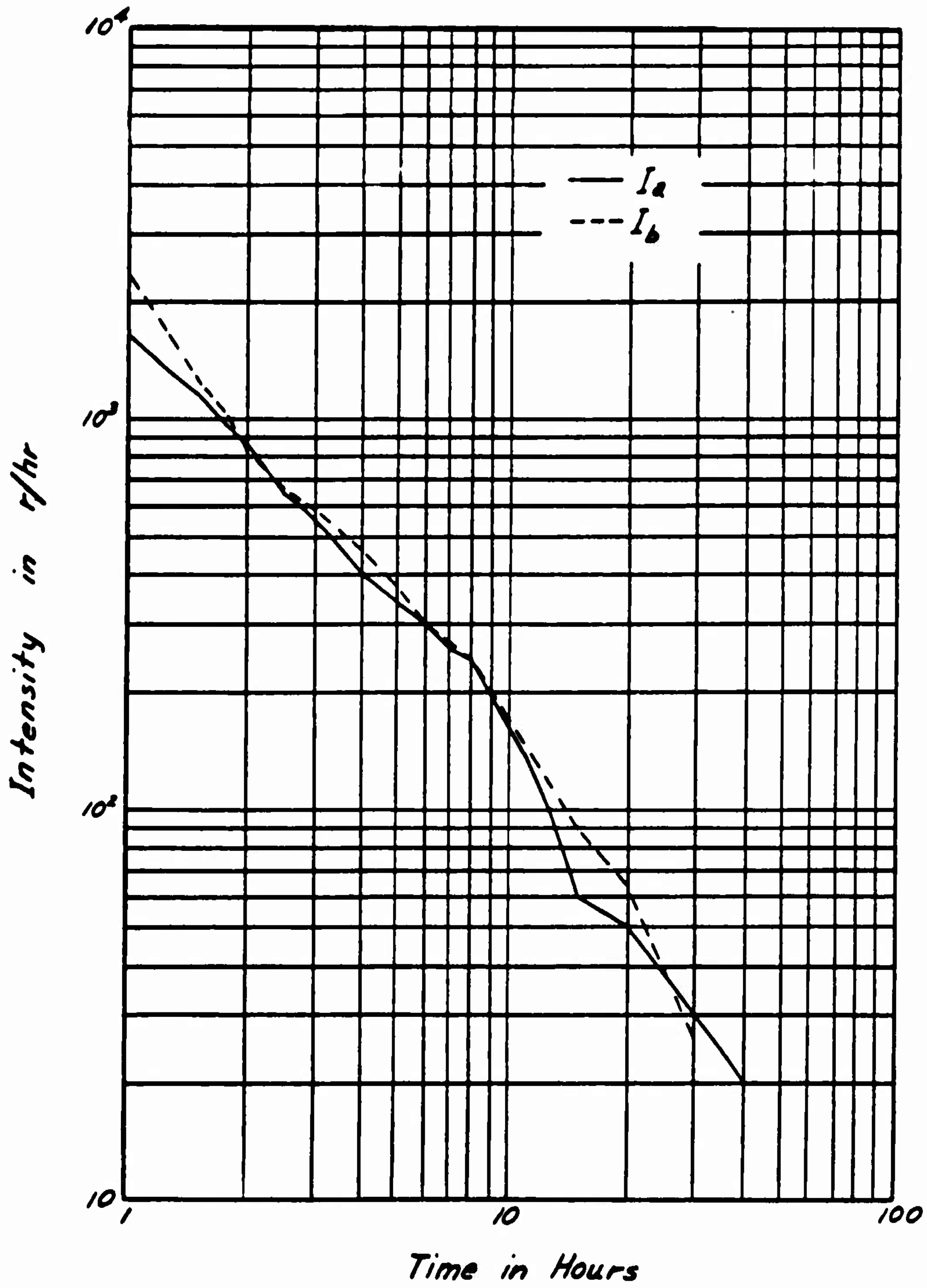


Figure 4.1 Corrected intensity plot of Little Feller II data.

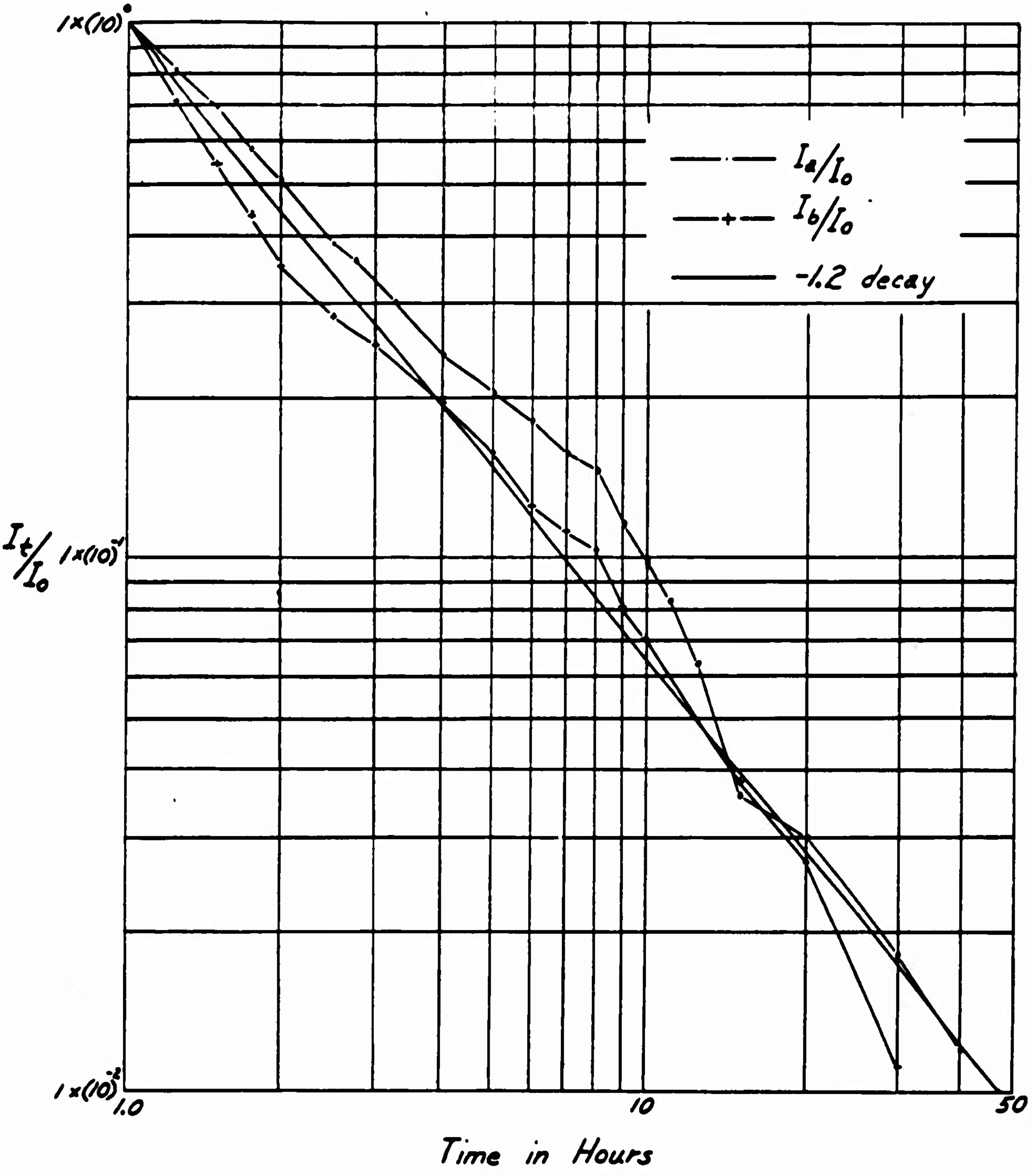


Figure 4.2 Decay plot of Little Feller II data.

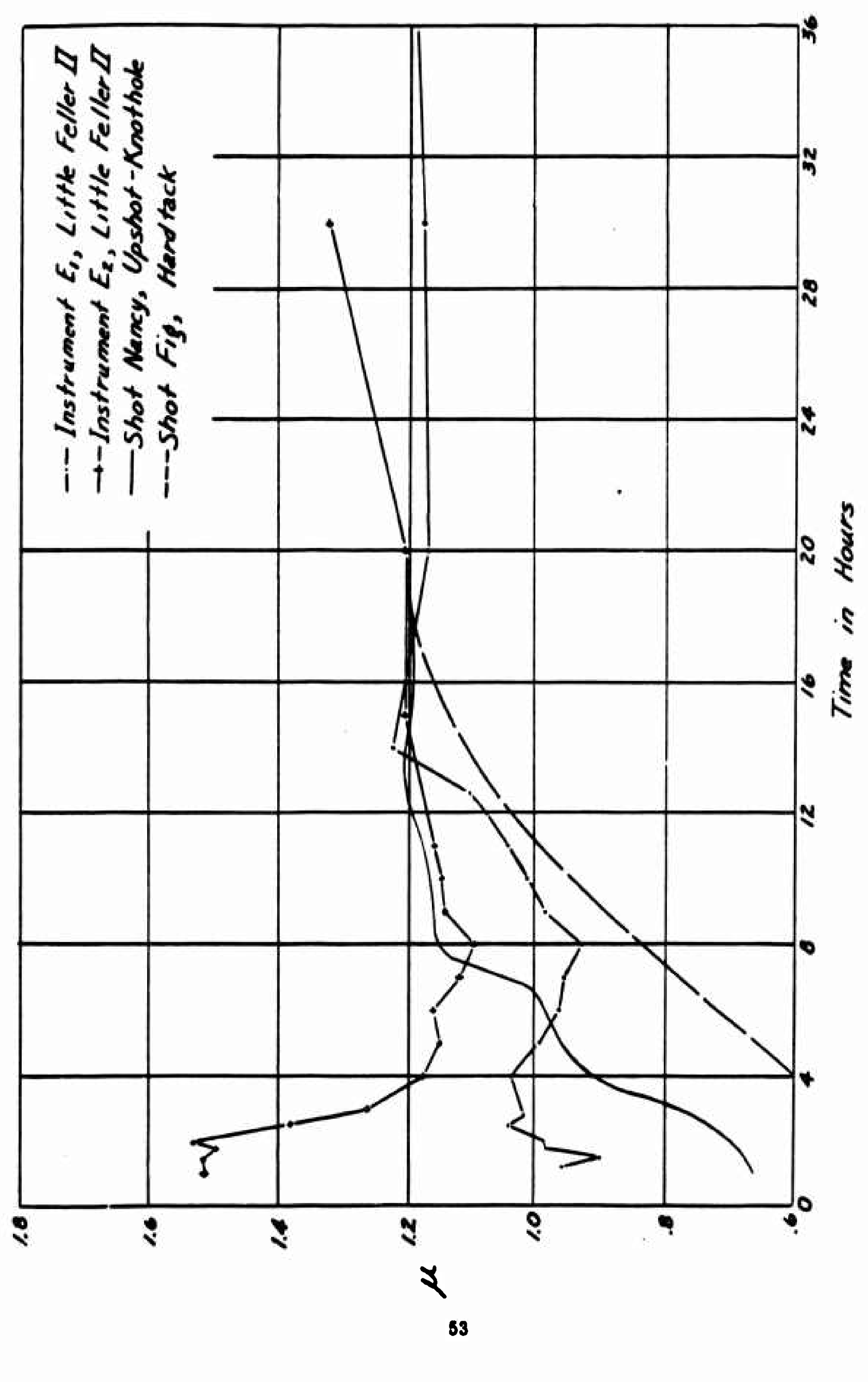


Figure 4.3 Change in time exponent, μ, with time.

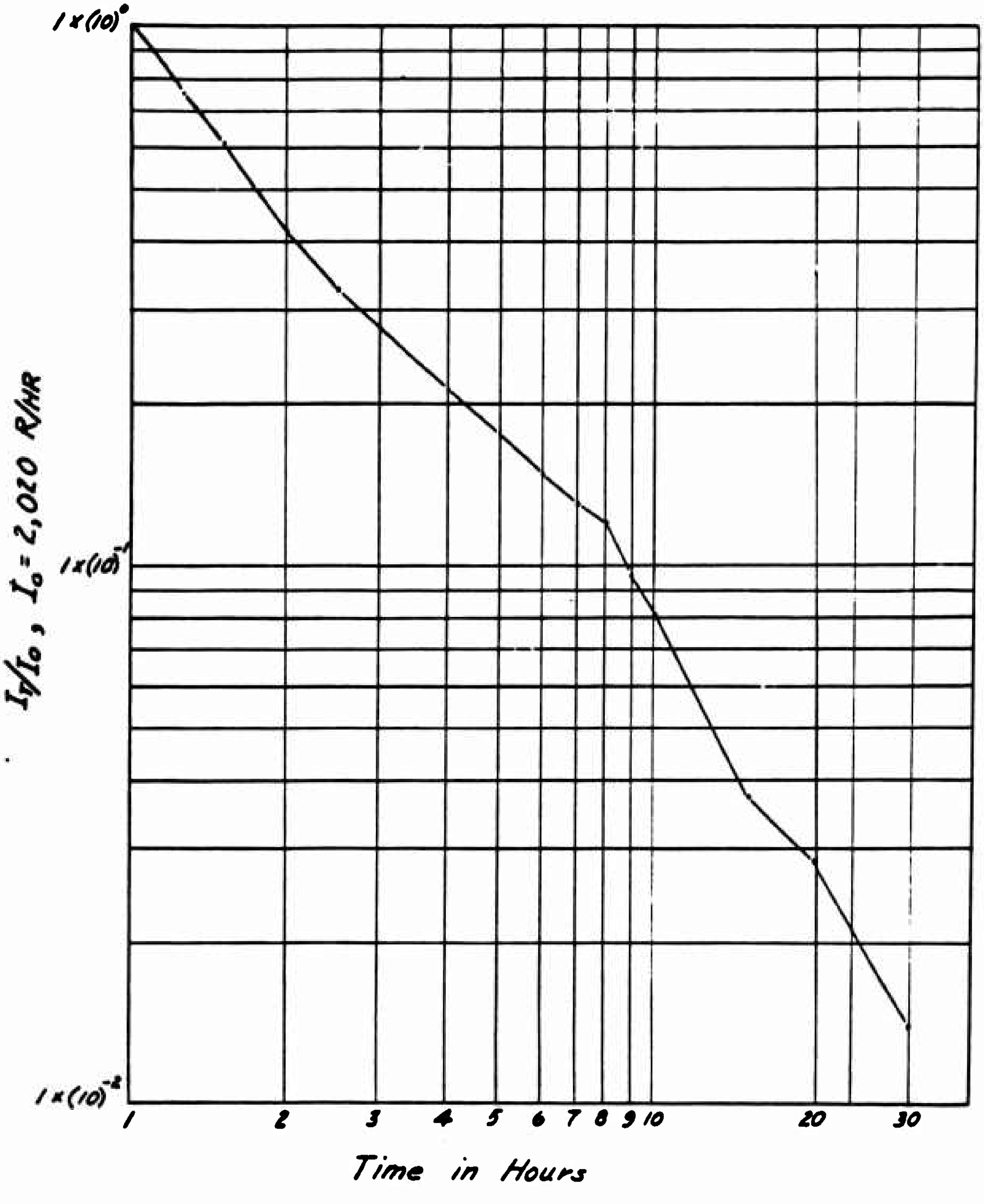


Figure 4.4 Average gamma intensity versus time, Little Feller II.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of this report are based upon results from Shot Little Feller II. Essentially no data was obtained from Shot Johnie Boy.

5.1 CONCLUSIONS

1. The average dose rate at H+1 hour of 2,020 r/hr indicates present prediction methods give results which are high by a factor of from two to three.

2. Cratering mechanisms affect the distribution of radiation for very-low-yield surface bursts.

3. Radiation follows the $T^{-1.2}$ function after H+12 hours.

4. Crater dose rates will not greatly affect armored operations for any great period of time.

5. Troops could stay in the crater area four hours at H+36 hours if unprotected and four hours at H+16 hours if protected (and receive 100 r).

6. Any operations or activities in the crater area will have to be cognizant of the alpha radiation hazard. This hazard can be expected when employing low nuclear-efficiency weapons

7. The remote-controlled, ground-approach, instrument-placement technique is effective when human error is eliminated.

5.2 RECOMMENDATIONS

1. Crater dose rates should be determined for detonations at shallow and deep burial to determine dependency of dose rates on DOB.

2. Crater dose rates should be determined for surface bursts of 1 and 10 kt to determine dependency of dose rates on yield.

3. The above data should be incorporated into present prediction methods for tactical weapons.

Appendix

CORE SAMPLE ANALYSIS

Seventeen soil samples were obtained from the Little Feller II crater area and placed in glass vials. A Beckman MX-5 was used to determine the activity levels and radiation hazards of the samples. The readings were taken by holding the GM tube in contact with the glass vial and moving the tube until a maximum reading was obtained. The background was subtracted where practical, and data is reported with the accuracy of the instrument scale used. The results are reported in Table A.1. Samples F-2 and B-3 were controls with no activity.

The samples were placed in aluminum weighing dishes, dried for one hour in an oven at 110°C, allowed to cool, and weighed to ± 1 mg.

The samples were then placed on the center of a 3- by 3-inch NaI(Tl) crystal and gamma spectra obtained with a 512-channel, Nuclear Data, Inc., gamma spectrometer. Absorbers (1/16-inch aluminum and 3/8-inch lucite) were utilized to absorb beta particles. Background was subtracted where necessary.

Next, the samples were shaken on a small 3-inch-diameter sieve shaker for 2 min. The sieves were separated and the particles retained on each sieve were weighed and counted—in the case of one sample, the gamma spectra was obtained. The samples were sieved into seven size fractions of >840, 420 to 840, 250 to 420, 149 to 250, 105 to 149, 74 to 105, and <74 micron fractions. These size fractions were then placed in stainless steel counting cups and weighed. Xylene and Canadian balsam were then added to minimize changes in the geometry and to secure the samples. The samples were then counted with a 1- by 1-inch NaI(Tl) crystal associated with a Picker Decade Spectrometer Scaler, Model 2818. The spectrometer was adjusted to accept gamma-energy pulses from 10 kev to 3.75 Mev. Samples E-2, C-1, and C-3 were chosen at random and counted at approximately 20-day intervals for decay measurements.

A survey of the samples revealed that they all contained alpha contamination. Since self-absorption correction could not be made, alpha counting was not performed.

The sieve analysis and gamma counting results are presented in Tables A.2 through A.9.

TABLE A.1 BETA-GAMMA SURVEY

Sample	Total Reading mr/hr	Corrected Reading mr/hr
B-1	0.1	0.06
B-2	1.7	1.7
B-3	0.03	Background
C-1	0.4	0.4
C-2	0.4	0.4
C-3	0.5	0.5
C-4	0.17	0.13
D-1	0.05	0.01
D-2	0.06	0.02
D-5	0.06	0.02
E-1	0.07	0.03
E-2	1.8	1.8
E-3	0.05	0.01
E-4	0.05	0.01
F-1	0.11	0.07
F-2	0.04	Background
F-3	0.18	0.14

Note: Background: 0.03 to 0.05 mr/hr

TABLE A.2 SOIL SAMPLES, TOTAL GAMMA COUNT, DAY 243, TRAY 1

DAY: 243 BACKGROUND: 101 CPM TRAY NO. 1 - FIRST COUNT

Sample Number	Size Range	Time	Total Count	Counting Time	Counts per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts/min/µg
E-2								
1-1	>840	0902	400,000	2.29	174,672	174,571	1.447	120.6
2-1	420-840	0905	400,000	1.30	307,692	307,591	1.778	173.0
3-1	250-420	0907	400,000	8.04	49,751	49,650	1.002	49.6
4-1	149-250	0915	341,567	10.00	34,157	34,056	1.359	25.0
5-1	105-149	0925	102,930	10.00	10,293	10,192	0.648	15.7
6-1	74-105	0935	121,485	10.00	12,148	12,047	0.704	17.1
7-1	< 74	0943	161,463	10.00	16,146	16,045	0.872	18.4
C-1								
8-1	>840	0956	239,831	10.00	23,983	23,882	1.707	14.0
9-1	420-840	1007	383,820	10.00	38,382	38,281	1.791	21.4
10-1	250-420	1019	75,046	10.00	7,505	7,404	1.003	7.38
11-1	149-250	1030	44,432	10.00	4,443	4,342	1.129	3.84
12-1	105-149	1040	67,434	10.00	6,743	6,642	0.473	14.0
13-1	74-105	1051	27,746	10.00	2,775	2,674	0.498	5.37
14-1	< 74	1102	33,424	10.00	3,342	3,241	0.597	5.43
15-1	Blank							
C-3								
16-1	>840	1113	400,000	7.53	53,121	53,020	2.039	26.0
17-1	420-840	1121	400,000	7.52	53,191	53,090	1.558	34.1
18-1	250-420	1129	162,238	10.00	16,224	16,123	0.887	18.2
19-1	149-250	1157	95,670	10.00	9,567	9,466	0.887	10.7
20-1	105-149	1253	43,011	10.00	4,301	4,200	0.376	11.2
21-1	74-105	1305	48,000	10.00	4,800	4,699	0.442	10.6
22-1	< 74	1315	59,199	10.00	5,920	5,819	0.605	9.62

TABLE A.3 SOIL SAMPLES, TOTAL GAMMA COUNT, DAY 281, TRAY 1

DAY: 281 BACKGROUND: 95 CPM TRAY NO. 1 - THIRD COUNT

Sample Number	Size Range	Time	Total Count	Counting Time	Counts per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts/min/μg
E-2								
1-1	>840	0913	400,000	4.53	88,300	88,205	1.447	61.0
2-1	420-840	0920	400,000	2.55	196,078	195,983	1.778	110.2
3-1	250-420	0925	251,402	10.00	25,140	25,045	1.002	25.0
4-1	149-250	0935	175,089	10.00	17,509	17,414	1.359	12.8
5-1	105-149	0946	53,126	10.00	5,313	5,218	0.648	8.05
6-1	74-105	1003	64,480	10.00	6,448	6,353	0.704	9.02
7-1	< 74	1019	82,590	10.00	8,259	8,164	0.872	9.36
C-1								
8-1	>840	1039	115,643	10.00	11,564	11,469	1.707	6.72
9-1	420-840	1052	190,462	10.00	19,046	18,951	1.791	10.6
10-1	250-420	1103	37,275	10.00	3,728	3,633	1.003	3.62
11-1	149-250	1114	22,589	10.00	2,259	2,164	1.129	1.92
12-1	105-149	1125	34,780	10.00	3,478	3,383	0.473	7.15
13-1	74-105	1137	14,616	10.00	1,462	1,367	0.498	2.74
14-1	< 74	1155	18,873	10.00	1,887	1,792	0.597	3.00
15-1	Blank							
C-3								
16-1	>840	1209	289,972	10.00	28,997	28,902	2.039	14.2
17-1	420-840	1220	269,461	10.00	26,946	26,851	1.558	17.2
18-1	250-420	1231	86,969	10.00	8,697	8,602	0.887	9.70
19-1	149-250	1242	48,339	10.00	4,834	4,739	0.887	5.34
20-1	105-149	1259	22,362	10.00	2,236	2,141	0.376	5.69
21-1	74-105	1317	24,867	10.00	2,487	2,392	0.442	5.41
22-1	< 74	1328	30,726	10.00	3,073	2,978	0.605	4.94

TABLE A.4 SOIL SAMPLES, TOTAL GAMMA COUNT, DAY 267, TRAY 1

DAY: 267 BACKGROUND: 159 CPM TRAY NO. 1 - SECOND COUNT

Sample Number	Size Range	Time	Total Count	Counting Time	Counts Per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts/min/µg
E-2								
1-1	>840	0914	400,000	3.67	108,991	108,832	1.447	75.2
2-1	420-840	0918	400,000	2.08	192,307	192,148	1.778	108.1
3-1	250-420	0921	313,627	10.00	31,363	31,204	1.002	31.1
4-1	149-250	0935	212,045	10.00	21,204	21,045	1.359	15.5
5-1	105-149	0953	64,987	10.00	6,499	6,340	0.648	9.8
6-1	74-105	1024	77,932	10.00	7,793	7,634	0.704	10.8
7-1	< 74	1035	102,542	10.00	10,254	10,095	0.872	11.6
C-1								
8-1	>840	1057	146,201	10.00	14,620	14,461	1.707	8.47
9-1	420-840	1109	241,888	10.00	24,189	24,030	1.791	13.4
10-1	250-420	1129	45,147	10.00	4,515	4,356	1.003	4.34
11-1	149-250	1141	28,593	10.00	2,859	2,700	1.129	2.39
12-1	105-149	1152	41,517	10.00	4,152	3,993	0.473	8.44
13-1	74-105	1215	17,818	10.00	1,782	1,623	0.498	3.26
14-1	< 74	1226	21,608	10.00	2,161	2,002	0.597	3.35
15-1	Blank							
C-3								
16-1	>840	1237	358,174	10.00	35,817	35,658	2.039	17.5
17-1	420-840	1248	332,508	10.00	33,251	33,092	1.558	21.2
18-1	250-420	1259	107,011	10.00	10,701	10,542	0.887	11.9
19-1	149-250	1315	58,495	10.00	5,850	5,691	0.887	6.42
20-1	105-149	1326	27,648	10.00	2,765	2,606	0.376	6.93
21-1	74-105	1350	30,160	10.00	3,016	2,857	0.442	6.46
22-1	< 74	1420	43,654	10.00	4,365	4,206	0.605	6.95

TABLE A.5 SOIL SAMPLES. TOTAL GAMMA COUNT. DAY 261, TRAY 2

DAY: 261 BACKGROUND: 153 CPM TRAY NO. 2

Sample Number	Size Range	Time	Total Count	Counting Time	Counts per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts /min/μg
E-1								
1-2	>840	1306	1,619	10.00	162	9	0.010	0.900
2-2	420-840	1318	3,841	10.00	384	231	0.043	5.37
3-2	250-420	1328	3,644	10.00	364	211	0.036	5.86
4-2	149-250	1338	8,112	10.00	811	658	0.069	9.54
5-2	105-149	1349	11,499	10.00	1,150	997	0.010	99.7
6-2	74-105	1359	11,362	10.00	1,136	983	0.030	32.8
7-2	< 74	1410	7,539	10.00	754	601	0.069	8.71
C-4								
8-2	>840	1421	400,000	2.90	137,931	137,778	2.516	54.8
9-2	420-840	1425	400,000	5.22	76,628	76,475	1.423	53.7
10-2	250-420	1431	163,645	10.00	16,364	16,211	0.590	27.5
11-2	149-250	1441	132,598	10.00	13,260	13,107	0.732	17.9
12-2	105-149	1432	70,649	10.00	7,065	6,912	0.387	17.9
13-2	74-105	1503	63,113	10.00	6,311	6,158	0.432	14.3
14-2	< 74	1514	104,632	10.00	10,463	10,310	0.605	17.0

TABLE A.6 SOIL SAMPLES, TOTAL GAMMA COUNT, DAY 262, TRAY 3

DAY: 262 BACKGROUND: 112 CPM TRAY NO. 3

Sample Number	Size Range	Time	Total Count	Counting Time	Counts per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts/min/μg
B-2								
1-3	>840	1349	400,000	4.97	80,482	80,387	3.514	29.1
2-3	420-840	0811	400,000	3.77	106,100	105,988	1.642	64.5
3-3	250-420	0816	377,339	10.00	37,734	37,622	0.675	55.8
4-3	149-250	0826	323,338	10.00	32,334	32,222	0.648	49.7
5-3	105-149	0837	121,312	10.00	12,131	12,019	0.205	58.6
6-3	74-105	0850	99,437	10.00	9,944	9,832	0.303	32.4
7-3	< 74	0903	107,801	10.00	10,780	10,668	0.313	34.1
F-2								
8-3	>840	0914	1,995	10.00	200	88	1.775	0.050
9-3	420-840	0927	2,320	10.00	232	120	1.596	0.075
10-3	250-420	0941	4,767	10.00	477	365	0.937	0.390
11-3	149-250	0952	4,931	10.00	493	381	1.334	0.286
12-3	105-149	1003	3,933	10.00	393	281	0.834	0.333
13-3	74-105	1015	5,396	10.00	540	428	1.166	0.367
14-3	< 74	1030	7,052	10.00	705	593	1.156	0.513
F-1								
15-3	>840	1041	2,165	10.00	216	104	0.003	34.7
16-3	420-840	1059	26,322	10.00	2,632	2,520	0.143	17.6
17-3	250-420	1111	5,082	10.00	508	396	0.113	3.50
18-3	149-250	1121	11,333	10.00	1,133	1,021	0.538	1.90
19-3	105-149	1134	4,943	10.00	494	382	0.468	0.816
20-3	74-105	1145	2,473	10.00	247	135	0.067	2.01
21-3	< 74	1213	2,277	10.00	228	116	0.025	4.64

TABLE A.7 SOIL SAMPLES, TOTAL GAMMA COUNT, DAY 263, TRAY 4

DAY: 263 BACKGROUND: 137 CPM TRAY NO. 4

Sample Number	Size Range	Time	Total Count	Counting Time	Counts per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts/min/μg
F-3								
1-4	>840	1355	400,000	1.81	220,994	220,899	2.602	84.90
2-4	420-840	0815	400,000	1.43	279,720	279,583	1.379	202.7
3-4	250-420	0817	400,000	4.82	82,987	82,850	0.806	102.8
4-4	149-250	0828	400,000	5.52	72,463	72,326	1.536	47.1
5-4	105-149	0840	262,426	10.00	26,243	26,106	0.575	45.4
6-4	74-105	0852	273,164	10.00	27,316	27,179	0.613	44.3
7-4	< 74	0907	294,780	10.00	29,478	29,341	0.594	49.4
E-3								
8-4	>840	0920	2,511	10.00	251	114	1.518	0.075
9-4	420-840	0949	57,070	10.00	5,707	5,570	1.022	5.45
10-4	250-420	1005	3,051	10.00	305	168	0.674	0.249
11-4	149-250	1020	3,934	10.00	393	256	1.041	0.246
12-4	105-149	1030	3,472	10.00	347	210	0.658	0.319
13-4	74-105	1041	4,120	10.00	412	275	0.913	0.301
14-4	< 74	1053	11,203	10.00	1,120	983	1.287	0.764
E-4								
15-4	>840	1117	2,247	10.00	225	88	1.705	0.052
16-4	420-840	1129	4,871	10.00	487	350	1.843	0.190
17-4	250-420	1140	4,030	10.00	403	266	1.079	0.246
18-4	149-250	1150	2,620	10.00	262	125	1.628	0.077
19-4	105-149	1206	2,354	10.00	235	98	1.045	0.094
20-4	74-105	1226	2,516	10.00	252	115	1.420	0.081
21-4	< 74	240	3,636	10.00	364	227	2.144	0.106

TABLE A.8 SOIL SAMPLES, TOTAL GAMMA COUNT, DAYS 263 AND 264, TRAY 5

DAY: 263, 264*

BACKGROUND 263: 137 CPM (Samples 1-5 through 15-5)
BACKGROUND 264: 97 CPM (Samples 16-5 through 21-5)

TRAY NO. 5

Sample Number	Size Range	Time	Total Count	Counting Time	Counts per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts/min/μg
D-1								
1-5	>840	1412	1,713	10.00	171	76	4.701	0.016
2-5	420-840	1302	1,956	10.00	196	59	2.598	0.023
3-5	250-420	1314	2,183	10.00	218	81	0.956	0.085
4-5	149-250	1332	2,351	10.00	235	98	0.767	0.128
5-5	105-149	1350	1,266	10.00	127	--	0.221	0
6-5	74-105	1403	1,212	10.00	121	--	0.179	0
7-5	< 74	1418	2,122	10.00	212	75	0.291	0.258
D-2								
8-5	>840	1424	1,579	10.00	158	63	4.142	0.015
9-5	420-840	1433	2,369	10.00	237	100	1.582	0.063
10-5	250-420	1445	2,352	10.00	235	98	0.650	0.151
11-5	149-250	1500	2,640	10.00	264	127	0.517	0.246
12-5	105-149	1511	1,259	10.00	126	---	0.145	0
13-5	74-105	1526	1,335	10.00	134	---	0.101	0
14-5	< 74	1546	1,599	10.00	160	23	0.092	0.250
D-5								
15-5	>840	1557	3,184	10.00	318	181	1.634	0.111
*16-5	420-840	0859	4,372	10.00	437	340	0.432	0.787
17-5	250-420	0910	6,159	10.00	616	519	0.167	3.11
18-5	149-250	0924	1,872	10.00	187	90	0.159	0.566
19-5	105-149	0935	1,287	10.00	129	32	0.065	0.492
20-5	74-105	0946	1,472	10.00	147	50	0.069	0.725
21-5	< 74	1013	1,677	10.00	168	71	0.084	0.845

TABLE A.9 SOIL SAMPLES, TOTAL GAMMA COUNT, DAY 264, TRAY 6

DAY: 264 BACKGROUND: 107 CPM TRAY NO. 6

Sample Number	Size Range	Time	Total Count	Counting Time	Counts per Minute	Corrected CPM	Weight	Activity Concentration
	microns			minutes			mg	counts/min/µg
B-1								
1-6	>840	1108	1,240	10.00	124	17	2.761	0.006
2-6	420-840	1120	125,254	10.00	12,525	12,418	1.659	7.48
3-6	250-420	1133	57,901	10.00	5,790	5,683	0.806	7.05
4-6	149-250	1144	86,589	10.00	8,659	8,552	1.022	8.37
5-6	105-149	1159	33,014	10.00	3,301	3,194	0.449	6.40
6-6	74-105	1212	35,078	10.00	3,508	3,401	0.261	13.0
7-6	< 74	1230	46,504	10.00	4,650	4,543	1.009	4.50
C-2								
8-6	>840	1248	92,688	10.00	9,269	9,162	0.033	277.6
9-6	420-840	1259	291,178	10.00	29,118	29,011	0.142	204.3
10-6	250-420	1318	58,237	10.00	5,824	5,717	0.245	23.3
11-6	149-250	1329	47,317	10.00	4,732	4,625	0.117	39.5
12-6	105-149	1340	16,690	10.00	1,669	1,562	0.030	52.1
13-6	74-105	1354	22,564	10.00	2,256	2,149	0.302	7.12
14-6	< 74	1405	50,364	10.00	5,036	4,929	0.939	5.25
B-3								
15-6	>840	1417	1,935	10.00	194	87	1.726	0.050
16-6	420-840	1435	59,004	10.00	5,900	5,793	1.285	4.51
17-6	250-420	1448	1,466	10.00	147	40	0.931	0.043
18-6	149-250	1459	1,381	10.00	138	31	1.400	0.022
19-6	105-149	1512	1,774	10.00	177	70	1.042	0.067
20-6	74-105	1523	1,697	10.00	170	63	1.195	0.053
21-6	< 74	1534	2,923	10.00	292	185	1.513	0.122

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