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# ROLLER COASTER

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PROJECT OFFICERS REPORT—PROJECT 5.2/5.3a

## RADIOCHEMICAL ANALYSIS OF BIOLOGICAL AND PHYSICAL SAMPLES (U)

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ABSTRACT

Operation Roller Coaster was a research program sponsored jointly by the U.S. Atomic Energy Commission, the U.S. Department of Defense, and the United Kingdom Atomic Energy Authority to study the fate of fissile material scattered by non-nuclear explosions of plutonium-bearing devices in different environments. The field phase was conducted in Nevada in the spring of 1963.

Hazleton-Nuclear Science Corporation carried out laboratory analyses for plutonium and uranium and conducted special studies related to general analysis. A total of 2278 analyses was performed; of these, 1809 were Pu analyses, 151 were U analyses, and 318 were special-study analyses. Both physical and biological samples were analyzed. The physical samples consisted of impactor stages, total air filters, and various types of fallout deposition collectors. The biological specimens consisted of soft tissues, bone, and excreta from dogs, sheep, and burros which had been exposed to the debris aerosol. The amounts of plutonium per sample ranged from less than 0.02 dpm to  $6 \times 10^8$  dpm. The amounts of uranium per sample ranged from 0.004 microgram to 14,400 micrograms. Because of these very wide ranges in U and Pu contents, special care was needed to avoid sample

cross-contamination, and separate laboratories were used for biological and physical analyses. Sample weights ranged from less than a gram (small air filters) to several kilograms (burro tissue and excreta).

Except in large soil samples, plutonium was determined radiochemically using  $\text{Pu}^{236}$  as a yield tracer. The radiochemically separated plutonium was measured by alpha spectrometry using large area semiconductor detectors. Uranium was measured fluorometrically.

Two of the special studies involved the  $\text{Am}^{241}$  daughter of  $\text{Pu}^{241}$ . The  $\text{Pu}^{239,240}/\text{Am}^{241}$  activity ratio was determined radiochemically in selected deposition and air samples. There was no evidence of Am-Pu fractionation. Plutonium was determined in selected soil samples by gamma-spectrometric measurement of the 60-keV gamma-ray of  $\text{Am}^{241}$ , using a semi-empirical method for determining sample self-absorption and geometry corrections. The amounts of  $\text{Pu}^{239,240}$  found in the soils ranged from  $3 \times 10^4$  to  $6 \times 10^8$  dpm, and the sample weights ranged from 2 to 2000 grams.

The solubility of plutonium collected in the field in water-filled trays was studied. After a year's storage in glass bottles, the pH values of the water samples were in the range 6 to 8; 0.5 to 11 percent of the total activity was in solution, 0.3 to 4 percent was sorbed on the bottle walls, and the remainder was associated with sediment or filtrable solid material.

## PREFACE

The following members of the technical staff of Hazleton-Nuclear Science Corporation have participated in the work reported here:

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## CHAPTER 1 INTRODUCTION

### 1.1 ROLLER COASTER BACKGROUND

Operation Roller Coaster was a research program sponsored jointly by the U. S. Atomic Energy Commission, the U. S. Department of Defense, and the United Kingdom Atomic Energy Authority (AEC-DOD-UK) and devoted to the study of non-nuclear explosions of plutonium-bearing devices in different environments. Administrative responsibility within the DOD rested with the Defense Atomic Support Agency (DASA). Technical direction was provided by Sandia Corporation.

The objectives of Operation Roller Coaster were to:

1. Investigate the biological hazard (acute inhalation hazard) of plutonium scattered by non-nuclear explosions. To this end, animals were exposed to the airborne plutonium, and extensive physical measurements were made of the aerosol.

2. Measure the distribution of plutonium on the ground to permit detailed accountability of the amount involved in the field of measurement.

3. Evaluate the effectiveness of certain storage structures (DASA-type igloos), having varying thicknesses of earth cover, in reducing the radiological hazard from accidental non-nuclear explosion of plutonium-bearing weapons.

4. Obtain those data of special importance in improving mathematical cloud models used to forecast radiological hazards in real accidents.

Successful completion of these objectives would also provide a substantially enlarged technical basis for development of uniform US-UK standards for the storage, transport, and handling of plutonium-bearing weapons.

The field phase of this operation consisted of four shots named Double Tracks, and Clean Slate I, II, and III. These tests were conducted in the spring of 1963 on a portion of the Las Vegas Bombing and Gunnery Range and Sandia Corporation's Tonopah Test Range in southwestern Nevada, both desert environments. The four events included explosions of both single and multiple nuclear devices fired to simulate accidental detonation without producing a nuclear yield.

The Double Tracks event was designed to investigate the characteristics of plutonium-bearing particulate material dispersed by a single device located entirely in the open, one foot above a steel-faced concrete surface. Experimental animals (dogs, burros, and sheep) were exposed to the ground-level aerosol, downwind.

The three Clean Slate shots, consisting of multiple devices, were designed to contrast weapon accidents, with respect to hazard per unit plutonium mass contained, for conditions of open storage (CS-I), storage in a DASA igloo with 2 feet of earth cover (CS-II), and storage in a proposed DASA igloo with 8 feet of earth cover (CS-III).

The field, laboratory, and evaluation phases of Operation Roller Coaster were sub-divided into numerous projects carried out cooperatively by a wide variety of government agencies and commercial contractors. The magnitude of the program is suggested by the fact that several thousand field radiation surveys were completed, and approximately 20,000 samples and specimens of all types were collected. Of the latter about one-half were selected eventually for detailed radiochemical and physical analysis.

## 1.2 PARTICIPATION BY HAZLETON-NUCLEAR SCIENCE CORPORATION (H-NSC)

Hazleton-Nuclear Science Corporation did not take part in the field phases of the program but was chosen as one of four United States commercial concerns to carry out laboratory analyses for plutonium and uranium and to conduct special studies related to general analysis. Analyses also were performed by the United Kingdom Atomic Weapons Research Establishment. Radiochemical analysis at H-NSC was operated as Roller Coaster Project 5.2/5.3a, and was begun October 1, 1963, when the first biological samples were received. Tables 1.1 to 1.3 list the types of samples and number of analyses performed at H-NSC. The physical samples consisted of several types of impactor stages, total air filters, and various designs of fallout deposition collectors. The biological specimens consisted of soft tissue, bone, and excreta from three animal species. In addition, quality control analyses were performed both on samples supplied by DASA and on those generated internally; these consisted of blanks, spikes, blind duplicates, and standards. Altogether, 2278 analyses were performed; of these 1809 were Pu analyses, 151 were U analyses, and 318 were special-study analyses.

The most difficult samples to analyze were the kilogram-quantity soils, and, indeed, these were never actually completed by wet chemical methods. Instead, a procedure was developed to quantitatively assay the Am-241 content by gamma spectrometry, and to use this as a measure of the plutonium content; the Am-241 is directly related to the plutonium since it is the daughter of the Pu-241 isotope. (See the following section on the composition of Roller Coaster plutonium.)

No conclusions or recommendations are drawn from the plutonium data presented here, since they can be interpreted only together with the data which have been produced by other laboratories. These other results represent more than three-fourths of the Roller Coaster plutonium data and are not now available to us.

### 1.3 COMPOSITION OF PLUTONIUM AND URANIUM USED

The composition of heavy elements used in the four devices is given in Table 1.4. These analyses were performed by Dow Chemical Co., Rocky Flats Division.

#### 1.4 QUALIFICATION SAMPLES

Before starting analyses of collected Roller Coaster samples, the analyses of a group of qualification samples were required. These samples were prepared and distributed by Los Alamos Scientific Laboratory (LASL) to potential analytical laboratories.

These qualification, or reference, samples consisted of two solutions and eight Nevada soil samples. The two solutions were stated to contain about 95 and 950 dpm, respectively, of plutonium alpha activity per milliliter of solution ( $2 \text{ N HNO}_3$ ). The eight soil samples included two blank soils (duplicates), two contaminated soils (duplicates), and four spikes prepared at three levels by the addition of plutonium solutions to blanks. Each 5-gram soil sample had been weighed at LASL to the nearest 50 milligrams.

Two, and possibly three, of the soil samples first sent to H-NSC had leaked from their containers before they were received. Because of this, a complete second set of samples was sent to H-NSC. The soils in both sets were analyzed.

The total amount of plutonium in each set was stated to be less than 0.5 microgram, corresponding to  $6.8 \times 10^4$  d/min of Pu<sup>239</sup>. However, gamma spectrometry indicated that two of the samples might contain  $10^5$  or more d/min of Pu<sup>239</sup>. Because of this uncertainty, and because of the very limited amount of Pu<sup>236</sup> tracer available to H-NSC at that time, the suspected hot samples were held temporarily while the other six samples were processed; Pu<sup>236</sup> tracer was added to one of these (#142) before dissolution. Pu<sup>236</sup> tracer was added to aliquots of the other five samples after dissolution and preliminary rough assay by gross alpha counting but before chemical separation was begun. Thus, the results for these five samples could not be corrected for possible loss of Pu during dissolution. This loss was estimated, from subsequent Co<sup>60</sup> tracer experiments, to be in the range of 0 to 10 percent.

Pu<sup>236</sup> tracer was added before dissolution to all soils of the second set and to the two hot samples of the first set. The dissolution and radiochemical separation procedures were virtually the same as those used for the Roller Coaster aluminum collector and quality-control soils; these procedures are given in a subsequent chapter of this report.

The total Pu<sup>238,239,240</sup> d/min are given in Table 1.5 for each of the qualification samples. The result reported for each sample is based on measurement of two or more separated fractions. The error limits given are standard deviations estimated from the range of results of replicate measurements.

The ratio of (d/min Pu<sup>238</sup>)/(d/min Pu<sup>239,240</sup>) was found to be  $0.0100 \pm 0.0002$  for the solution samples, in agreement with the value of  $0.0103 \pm 0.0007$  calculated from the mean Roller Coaster plutonium composition data given in Table 1.4.

TABLE 1.1 PLUTONIUM ANALYSES PERFORMED

<u>Sample Type</u>	<u>Physical Samples</u>				<u>Total</u>
	<u>DT</u>	<u>CS-I</u>	<u>CS-II</u>	<u>CS-III</u>	
Andersen Impactor Disk	60	25	65	65	215
Andersen Impactor Filter	12	5	13	13	43
Casella Impactor Disk	104	60	96	108	368
Casella Impactor Filter	26	15	24	27	92
Total Air, TAS-D	9	11	6	20	46
Total Air, TAS-I	4	-	2	7	13
Total Air, TAS-II	8	4	7	18	37
Sequential Air Tape	-	-	2	-	2
Cylindrical Wire Swipe	-	8	-	-	8
Gummed Film	58	29	65	78	230
Aluminum Collector	4	6	14	-	24
Water-Total	-	9	16	13	38
Water-Solubility	-	8	8	8	24
	<u>285</u>	<u>180</u>	<u>318</u>	<u>357</u>	<u>1140</u>

Biological Samples, Double Tracks

	<u>Dog</u>	<u>Sheep</u>	<u>Burro</u>	<u>Total</u>
Left Femur	23	22	30	75
Kidney	23	22	29	74
Liver	23	22	27	72
Lungs	23	22	25	70
Hilar Nodes	23	22	24	69
Right Femur	-	-	9	9
Trachea	-	5	7	12
Stomach	-	5	9	14
Pharyngeal Mucosa	-	5	5	10
Nasal Mucosa	-	5	6	11
Urine	-	53	-	53
Feces	-	39	-	39
	<u>115</u>	<u>222</u>	<u>171</u>	<u>508</u>

Controls

	<u>Solutions</u>	<u>Soils</u>	<u>Biological</u>	<u>Total</u>
Qualification Analyses	4	30	-	34
DASA Quality Controls	19	16	43	78
H-NSC Internal Quality Controls, All Types				49
				<u>161</u>

Total Pu-239,240 Analyses. 1809

TABLE 1.2 URANIUM ANALYSES PERFORMED

<u>Physical Samples</u>					
<u>Sample Type</u>	<u>DT</u>	<u>CS-I</u>	<u>CS-II</u>	<u>CS-III</u>	<u>Total</u>
Andersen Impactor Disk	5	5	5	5	20
Andersen Impactor Filter	1	1	1	1	4
Casella Impactor Disk	4	4	4	4	16
Casella Impactor Filter	1	1	1	1	4
Total Air, TAS-D	1		1		2
Total Air, TAS-I				1	1
Total Air, TAS-II	1	2	1	1	5
Gummed Film	6	1	1	5	13
Aluminum Collector	1	2	1		4
	<u>20</u>	<u>16</u>	<u>15</u>	<u>18</u>	<u>69</u>
<u>Biological Samples</u>					
	<u>Sheep</u>	<u>Burro</u>	<u>Total</u>		
Lungs	5	7	12		
<u>Controls</u>					
DASA Quality Control Solutions					<u>24</u>
H-NSC Internal Controls					<u>46</u>
					<u>70</u>
Total Uranium Analyses, 151					

TABLE 1.3 SPECIAL STUDIES ANALYSES PERFORMED

	DT	CS-I	CS-II	CS-III	Total
Am-241 Analyses					
TAS-D				8	8
TAS-II				4	4
Film				9	9
TAS-II, Total $\alpha$ Spec.			1		<u>1</u>
					22
Plutonium by Gamma-Spectrometry of Am-241					
Al-Collectors	1	2	2		5
Soil	4	6	24	8	42
Preshot Soils (Th, U, K, fission products)	1	1	4	1	<u>7</u>
					54
Sequential Air Tape Surveys					3
Gross Alpha Solubility- Studies Fractions		78	82	79	239
Total Special Studies					<u>318</u>

TABLE 1.4 HEAVY ELEMENT COMPOSITION

Plutonium Components - 98.8% Pu

<u>Isotope</u>	<u>Weight Per- cent of Pu</u>	<u>Dis./Min. Per <math>\mu\text{g}</math> Pu</u>	<u>Type Decay</u>	<u>Dis./Min. Ratio to Pu -239 +240</u>
Pu-238	0.00387	$1.496 \times 10^3$	alpha	$0.0103 \pm 0.0007$
Pu-239	97.314	$1.325 \times 10^5$	alpha	$0.9123 \pm 0.00026$
Pu-240	2.530	$1.273 \times 10^4$	alpha	$0.0877 \pm 0.00026$
Pu-241	0.1487	$3.766 \times 10^{5*}$	beta	$2.59 \pm 0.52^*$
Pu-242	0.00310	0.27	alpha	$1.85 \times 10^{-6}$
Am-241	---	$2.142 \times 10^{3*}$	alpha	$0.01475 \pm 0.00120^*$
	Sum Pu -239+240	$1.452 \times 10^5$	alpha	1.000
	Total alpha	$1.489 \times 10^5$	(14.9 grams/alpha curie)	

\* As of 1 May 1963. Pu-241 decays 5.2% in one year to Am-241.  
Am-241 increases 26% in one year.

Uranium Components - 99.8% U

<u>Isotope</u>	<u>Weight Percent of U</u>	<u>Dis./Min. Per <math>\mu\text{g}</math> U</u>
U-234	$0.00074 \pm 0.00025$	0.101 alpha
U-235	$0.165 \pm 0.017$	0.0078 alpha, 0.0078 beta (Th-231)
U-238	$99.834 \pm 0.017$	0.738 alpha, 1.48 beta (Th-234, Pa-234)

Composite Uranium To Plutonium Weight Ratios

Double Tracks:	4.35	Clean Slate - II:	100.4
Clean Slate - I:	47.2	Clean Slate - III:	99.7

TABLE 1.5 AMOUNTS OF Pu<sup>238, 239, 240</sup> IN H-NSC ROLLER COASTER QUALIFICATION SAMPLES

Sample Type	Sample Number	Pu <sup>238, 239, 240</sup>	Weight ** (including bag)
		<u>d/min Per Sample</u>	
Soil	141*	1220±80	
	142	1220±60	5.62905 g.
	143	(4.18±0.09)×10 <sup>5</sup>	5.28608 g.
	144	2.3±0.3	
	145	(1.25±0.06)×10 <sup>5</sup>	5.33975 g.
	146*	1520±105	
	147*	4.8±0.5	
	148*	2130±90	
Soil	121	1.0±0.2	
	122	2365±20	
	123	1594±44	
	124	1346± 4	
	125	(1.307±0.054)×10 <sup>5</sup>	
	126	0.8±0.2	
	127	(2.50±0.04)×10 <sup>5</sup>	
	128	1303±55	
		<u>d/min Per Ml</u>	
Solution	F	902±10	
	G	89.2±0.8	
	Wtd.Avg.F***	897±0.6%	

\*Pu<sup>236</sup> tracer added after dissolution; results not corrected for any loss during dissolution.

\*\*Of leaking samples.

\*\*\*Combined "F" and "G" results assuming "G" was exactly a 0.1 concentration of "F".

## CHAPTER 2

### SAMPLE PREPARATION AND DISSOLUTION

The following sample preparation and dissolution procedures were used to prepare Roller Coaster samples for Pu analysis. Special precautions were taken to prevent cross-contamination of the samples. During dissolution and subsequent chemistry, different laboratory rooms were used to separate the physical samples from the generally lower-activity-level biological samples. The glassware, Corning Ware, centrifuge tubes, stirring rods, transfer pipets, and other items that actually contacted each sample were all new, with two exceptions. The Teflon beakers were reused a maximum of fifteen times. The plating anodes (platinum-iridium) were reused, but different anodes were used for the physical and biological samples. Once a piece of equipment was committed to either the physical or biological area it remained in that area until either it was discarded or the project was completed. Good house-keeping practice was constantly enforced during this program.

## 2.1 PHYSICAL SAMPLES

Descriptions of the various physical samples are given in Table 2.1. All the physical samples were removed from their manila envelopes (outer containers) one at a time to avoid any mixing of samples. As each sample was removed, the identifying numbers on the sample were checked against the identifying numbers on the data-handling sheet received with each sample to assure that the proper sample was being prepared. After its identity was definitely established, the sample was logged in and given an internal laboratory sample number. Then the sample was placed into a Teflon beaker for dissolution. Each beaker had been prepared previously and numbered with the same internal laboratory sample number. The Teflon beakers were cleaned meticulously by boiling with concentrated nitric acid, containing a small amount of hydrofluoric acid, for a minimum of one hour, then scouring with abrasive cleanser and steel wool and rinsing repeatedly with demineralized water. Smears were taken of ten percent of the beakers and counted in a windowless proportional alpha counter; no detectable amounts of Pu were found on these smears. Some of the beakers which had contained high-level plutonium samples were checked for activity after cleaning by placing

a new Millipore filter into each beaker and processing this completely through the dissolution and chemistry procedure as a blank. All samples were processed in order of increasing plutonium content, starting with the lowest-activity samples at the beginning of the program and ending with the highest-activity samples at the end of the program. This method of analyzing samples eliminated the possibility of contaminating a low-activity sample with the residue of a high-activity sample. Before each sample was placed in its beaker, the appropriate amount of Pu<sup>236</sup> tracer was added. During dissolution, the beakers were separated sufficiently from each other on hot plates to minimize the possibility of cross-contamination by spray or spatter. The detailed procedures of each of the physical samples are given in the following sections.

Procedures:

A. Casella Glass Impactor and Membrane Filter. Preparation of the Casella glass impactor for Pu chemistry was accomplished with the following method: The organic materials, consisting of the enclosing cellophane bags, the attached identifying sticker, the enclosed adhesive and

the cellulose acetate film stuck to the glass disk, were destroyed by heating in a mixture of concentrated nitric and sulfuric acids. The nitric acid was added in several separate portions as needed until all the organic material appeared to have been destroyed. As an added precaution on all samples, and to hasten dissolution on the more resistant samples, perchloric acid was added cautiously and fumed off. The glass disk remaining after destruction of organic matter was destroyed by adding small quantities of hydrofluoric acid and boiling off silicon tetrafluoride. The remaining salts then were dissolved in a mixture of saturated boric acid solution and concentrated nitric acid. This solution was transferred to an Autoclear (50-ml) centrifuge tube previously marked with the internal sample number. The volume of this solution was kept to a minimum. The beaker was rinsed twice with hot saturated boric acid solution plus concentrated nitric acid, and these rinses were added to the 50-ml centrifuge tube. The centrifuge tube was covered with Parafilm and stored until ready for Pu chemistry.

The membrane filters were destroyed by the method given above for the organics. However, only 3 ml of concentrated hydrofluoric acid was used to destroy any small siliceous particles.

B. Anderson Glass Impactors and Membrane Filters. The same dissolution procedure was used for the Anderson glass impactors as for the Casella glass impactors, except that the entire glass disk was not dissolved. The disk was deeply etched with hydrofluoric acid and rinsed well before being discarded.

The Anderson membrane filters were dissolved in exactly the same way as the Casella membrane filters.

C. Gelman Air Sampler Membrane Filters. The Gelman air sampler membrane filters and the protecting cellophane bags in TAS-I and TAS-II samples were put into solution easily with a mixture of concentrated nitric and sulfuric acids. However the Microsorban (polystyrene) prefilters in all Total Air Samplers were very difficult to digest; consequently, more time was needed for each filter and more personal attention was required for each sample. The Microsorban prefilter finally was digested by using high temperatures and excess sulfuric acid to char the polystyrene, adding several milliliters of concentrated nitric after each charring. After many repetitions of charring and digesting, the visible solids would disappear, leaving a straw-colored solution. To this solution,

concentrated perchloric acid was added and fumed. This was repeated until the solution was colorless, then 3 ml of concentrated hydrofluoric acid was added to destroy any siliceous material that had been picked up by the filters. After the hydrofluoric acid and the resulting silicon tetrafluoride had been volatilized, the salts were dissolved in saturated boric acid solution plus concentrated nitric acid and transferred to a centrifuge tube as described above under the section on Casella glass impactor and membrane filter.

D. Gummed Films. The dissolution of the gummed films used as deposition collectors was carried out in much the same manner as the dissolution of the Gelman Microsorban prefilters. After the sample, contained in a wax paper bag, was placed into the Teflon beaker, the digesting was done by alternating high-temperature sulfuric-acid charring and nitric-acid digestion of the charred material. The cellulose acetate and the thinner cellophane films were relatively easy to digest, but the accompanying waxed paper or polyethylene bag took several days of severe treatment to digest. After all of the visible material was digested, perchloric acid was added and fumed until the solution was colorless. This

treatment was followed by the hydrofluoric-acid treatment and sample-transfer method described previously. (See section on Casella glass impactor and membrane filter dissolution).

An alternate method of gummed film dissolution was tried and found to be very successful in regard to the quality of the prepared sample and the amount of time necessary to prepare the sample. This method consisted of carefully pre-ashing the sample in a 600-ml beaker over a bunsen burner until most of the organic material had been destroyed. The sample then was placed in a muffle furnace and ashed at 550° C. After cooling, the sample residue was put into solution easily with a mixture of nitric and sulfuric acids. The sample then was transferred to a Teflon beaker and treated with hydrofluoric acid and subsequently transferred to a centrifuge tube for Pu chemistry, as described in the section on Casella glass impactor and membrane filter.

This alternate method could not be used for many of the films because most of the muffle-furnace capacity had been assigned to, and was in use for, ashing the larger biological samples.

#### E. Aluminum Collectors and Quality Control Soils.

The aluminum collector samples, as received at H-NSC, consisted of 1-30 grams of soil. All of these samples were dissolved tracer-free because of the high level of Pu activity. Aside from this difference, both the aluminum collector and quality control soils were treated in the same manner.

Each aluminum collector sample was transferred from its test tube shipping container and carefully weighed. It was found that the use of this test tube container created several problems of transfer. The most notable of these was the retention of soil on the large surface of the rubber stopper. Also, the rubber stopper would not seal around the pouring spout and the sealing tape used retained much of the sample in all cases. After the soil weight was obtained, all material suspected of contamination was added to the sample for dissolution, with the exception of the large rubber stopper. This stopper was cleaned by wiping with Kimwipes wet with nitric acid to remove any visible contaminants. The stopper then was etched in hot concentrated nitric acid and this solution was added to the sample. The organic matter

added to these samples (the Kimwipes, sealing tape, and the etched rubber from the stopper), and any organic material already present in the sample, were digested by heating with concentrated nitric acid. The bulk of the sample was dissolved by adding hydrofluoric acid and digesting to destroy any silicates present. Perchloric acid was added to aid in volatilizing the silicon tetrafluoride formed. The hydrofluoric acid digestion was repeated until reaction had stopped. The excess hydrofluoric acid then was volatilized by fuming with the perchloric acid present. The residue left then was dissolved in saturated boric acid and concentrated nitric acid. The resulting solution was centrifuged and any remaining precipitate returned to the Teflon beaker and retreated with the nitric, perchloric, and hydrofluoric acids. This procedure was repeated three times and, if any precipitate was left after the third cycle, it was treated with aqua regia and boiled to near dryness. The sample residue then was dissolved in hot 6 N hydrochloric acid. This treatment completely dissolved all of the aluminum collector samples. For a few of the quality-control samples submitted by NASA, it was necessary to follow this procedure with the fusion of a small residue, using

sodium carbonate flux. Dissolving the cooled fusion melt in 6 N hydrochloric acid completed the dissolution of these samples.

All the resulting dissolution supernates were combined and diluted to 500 ml in a volumetric flask. From this solution, the proper aliquot was taken for analysis and equilibrated with Pu<sup>236</sup> tracer.

F. Sequential Air-Sampling Tape. The three 40-foot cellulose filter paper samples were checked for alpha activity on both sides, using a PAC-3 alpha detector. This was accomplished by rolling the tape between two reels with the PAC-3G detector resting on the tape for sufficient time to detect any significant activity. No alpha activity was detected, so each tape was dissolved in its entirety and run as a single sample. Dissolution of the tapes was accomplished by heating with a mixture of concentrated nitric and sulfuric acids until all visible organic material was in solution, then adding hydrofluoric acid to destroy any siliceous material. Perchloric acid was added cautiously and the sample was fumed until colorless. The sample residue then was dissolved in saturated boric acid solution and concentrated nitric acid as described previously under the section on Casella glass impactor and membrane filters.

G. Solubility Studies Sample Dissolution. Many of the lower-level water samples were found to contain too little activity in solution to warrant using them for a solubility study. These samples were analyzed as single debris samples. A considerable amount of solution was lost from many of these samples by leakage out of the ground-glass-stoppered bottles, but fortunately all the leaked solution appeared to have been absorbed by the surrounding corrugated packing material. In samples in which the corrugated packing material had been saturated, several milliliters of water were contained in the polyethylene bags surrounding the sample container. Leakage was found to be caused by several inherent faults in the sample containers. On some of the bottles the ends of the string that attached the ground glass stopper to the bottle had been wedged between the bottle and the stopper. This resulted in the most severe leakage. Next in severity of leakage was the bottle position during handling of the packaged shipment. If the bottle remained in any position other than upright, leakage occurred. The taped-down stoppers were found to have sufficient play so that leakage was inevitable unless the bottle remained upright. The last cause of leakage noted was the entrapment of sand particles between the stopper and the bottle allowing sufficient space for capillary action to occur. All the samples that had visibly leaked were processed with the surrounding packing material.

The corrugated packing material and the tape used to hold the stopper were placed in a large Corning Ware dish and digested with concentrated nitric acid until in solution. The solution in the bottle was placed in a Teflon beaker and evaporated to dryness. The bottle was rinsed several times with hot concentrated nitric acid while being subjected to ultrasonic cleaning. The resulting fractions of the sample eventually were all transferred to the same Teflon beaker. As soon as the entire sample, including the polyethylene bag rinses and ultrasonic cleaning solution, had been transferred, the sample was subjected to complete dissolution using a mixture of concentrated nitric and concentrated sulfuric acids to digest all organic material. The sample then was evaporated to near dryness again and concentrated hydrofluoric acid was added to insure complete dissolution of any siliceous material. The sample was then transferred from the Teflon beaker to a centrifuge tube by dissolving any residual material in concentrated nitric acid and saturated boric acid. This transferring procedure was repeated three times to assure complete transfer of the beaker contents.

## 2.2 BIOLOGICAL SAMPLES

The various biological samples and their weights are listed in Table 2.2. The biological samples were frozen when received and were stored frozen until ready for analysis. At the start of the program, about ten percent of the samples were thawed to aid in their identification, but these were then frozen again for storage.

Most of the biological samples were first dry ashed in a large muffle furnace at 550° C. The inorganic residue (ash) was then dissolved by using mixtures of nitric, perchloric, hydrochloric, sulfuric, and hydrofluoric acids. The detailed procedures are given in the following sections.

2.2.1 Initial Sample Preparation. All the biological samples were processed through H-NSC in the order of increasing (estimated) plutonium content, i.e., starting with the lowest-level samples and concluding with the highest-level samples. All samples, except the small lymph nodes, were dry ashed in Corning Ware Pyroceram containers. The small lymph nodes were processed in small-size Coors porcelain ware. Some of the larger samples had to be divided among several dishes for muffling, then combined for final analysis. These large samples included some livers, stomachs full of fodder, and feces. Before each sample was placed into its container, it was positively

identified, accurately weighed, logged in, and assigned an internal laboratory number. Then the frozen sample was allowed to thaw out in the dish and Pu<sup>236</sup> tracer was added directly to the tissue being analyzed. If the organ was large it was slit with a razor blade in several places, and the tracer pipetted into these slits. If the organ was small, or was a bone, the tracer was stippled onto the outside of the sample. The polyethylene bag which had contained each sample was also included in the analysis.

2.2.2 Dry Ashing. Before being placed in the muffle furnace, each sample was dried in one of several drying ovens for a minimum of twenty four hours; some of the large tissues were dried for seventy two hours. At this stage the feces were ignited over a Meker Burner and allowed to burn to completion before being placed in the muffle furnace. When the samples were sufficiently dry, they were placed in the muffle furnace which was slowly brought to the maximum temperature needed and maintained at this temperature for twenty four hours. Some of the larger tissues had to be ashed twice to oxidize all of the carbon present in the tissue. At this stage several urine samples shattered in the oven. Only one sample was lost completely. However, a wet dissolution method was adopted for the remaining urine samples to avoid any repetition of the shattering experience.

2.2.3 Dissolution of Dry Ash. Different procedures were used to dissolve the dry ash of different sample types. It was found necessary to continue dissolutions over a twenty-four hour period. A two-shift, sixteen-hour work day was established, and during the remaining eight hours the samples were allowed to reflux.

A. Bone Samples. After muffling, the bone ash was dissolved readily by boiling in 6 N hydrochloric acid for up to eight hours. After this treatment only a small residue was left and this was transferred to a Teflon beaker and dissolved in hydrofluoric acid. The resulting salts were dissolved in a mixture of saturated boric acid solution and concentrated hydrochloric acid. The resulting solutions were combined in a polyethylene bottle of suitable size, which was stored awaiting chemistry.

B. Urine Samples. The urine samples which had been dry ashed were dissolved in concentrated nitric acid. The bulk of the ash was dissolved easily and the residue was transferred to a Teflon beaker for dissolution by heating with hydrofluoric acid. Some of the urine samples contained appreciable quantities of dirt and this increased the dissolution time. After treatment with the hydrofluoric acid, the remaining residue was dissolved in saturated boric acid solution plus concentrated nitric acid. If any residue still remained, the hydrofluoric acid treatment was repeated until dissolution was complete.

As mentioned above, it was necessary to use a wet digestion method on most of the urine samples. Several different methods were tried. The most satisfactory procedure was to allow the large quantity of Kimpac to digest in 3 N nitric at room temperature for one week and then to heat slowly the covered container so refluxing occurred until the bulk of the Kimpac was dissolved. After this stage the sample was treated as described for the pre-ashed sample. The whole procedure took two weeks from the start until the sample was ready for chemistry.

C. Lymph Nodes, Pharyngeal Mucosa, Trachea, and Empty Stomach. After dry ashing, these tissues presented no problem of dissolution. The ash was dissolved readily by heating with 6 N hydrochloric acid. Any small residue was dissolved with hydrofluoric acid, and the resulting salts were dissolved in saturated boric acid plus concentrated nitric acid. All the resulting solutions for a sample were combined and stored in a polyethylene bottle of appropriate size awaiting Pu chemistry.

D. Lungs, Liver and Kidney. The dry-ashed lung, liver, and kidney samples were slow to dissolve. The general procedure for these tissues was to reflux the ash in concentrated nitric acid for an appropriate time, depending on the quantity of ash, until the bulk of the ash was in

solution. The residue was placed in a Teflon beaker and digested by adding hydrofluoric acid and boiling to dryness. The remaining salts were dissolved in saturated boric acid and concentrated nitric acid. If there was any residue, the hydrofluoric acid treatment was repeated. All the solutions for a single sample were combined and stored in a polyethylene bottle. Elapsed time for dissolution ranged from one to four days, depending on tissue size.

E. Feces and Stomachs Full of Fodder. The feces and stomachs which were full of food gave large quantities of ash. These samples were the most difficult to dissolve of all the biologicals and resulted in large volumes of final solution. Many days of continuous refluxing using different acids and acid mixtures were required to obtain a complete dissolution. Because of the large quantity of minerals present, large volumes of final solution were needed to keep the dissolved salts in solution. The ash obtained from the furnace first was heated with generous quantities of nitric acid and allowed to reflux for eight hours. Then, the solution was removed and the process repeated until the bulk of the ash was in solution and it was obvious that digestion with any more nitric acid would be futile. The remaining ash then was refluxed with 6 N hydrochloric acid in the same manner as with the nitric acid. After the two acid treatments, the remainder of the ash was placed in a Teflon beaker and boiled to dryness several times with hydrofluoric acid.

The salts that were formed were dissolved in saturated boric acid solution plus concentrated nitric acid. Any residue was subjected to a repeat of the hydrofluoric-acid treatment until the sample was in solution. A typical digestion and dissolution time was seven days for these samples.

TABLE 2.1 DESCRIPTION OF ROLLER COASTER PHYSICAL SAMPLES

Sample Designation	Brief General Description	Components, materials, and approximate dimensions and weights
Andersen Disk	Large soda glass disk covered on one surface with a cellulose acetate film coated with resin and dibutyl phthalate. Sample received in a cellophane bag.	Soda glass disk 8 cm diameter x 0.3 cm thick weighing 30 grams. Cellulose acetate film 8 cm diameter x 0.005 cm thick weighing 0.5 gram. Cellophane bag 10 cm x 10 cm x 0.003 cm thick weighing 0.5 gram.
Andersen Filter	Membrane filter made from cellulose esters. Received sealed in a cellophane bag.	Filter 5 cm diameter and 0.003 cm thick weighing 0.05 gram. Cellophane bag 6 cm x 6 cm x 0.003 cm thick weighing 0.2 gram.
Casella Disk	Small soda glass disk covered on one side with a cellulose acetate film coated with resin and dibutyl phthalate. Sample received in a cellophane bag.	Soda glass disk 2.5 cm diameter x 0.12 cm thick weighing 1.5 grams. Cellulose acetate film 3 cm diameter x 0.005 cm thick weighing 0.15 gram. Cellophane bag 4 cm x 4 cm x 0.003 cm thick weighing 0.10 gram.
Casella Filter	Membrane filter made from cellulose esters. Received sealed in a cellophane bag.	Filter 4.7 cm diameter x 0.003 cm thick weighing 0.05 gram. Cellophane bag 6 cm x 6 cm x 0.003 cm thick weighing 0.2 gram.
Total Air Samples	Membrane filter made from cellulose esters including polystyrene prefilter sealed in cellophane bag.	Membrane filter 4.7 cm diameter x 0.003 cm thick weighing 0.05 gram. Microsorban polystyrene prefilter 4.7 cm diameter x 0.1 cm thick weighing 1 gram. Cellophane bag 6 cm x 6 cm x 0.003 cm thick weighing 0.2 gram.
Sequential Air Samples	Rolled filter tape received on metal reel and sealed in polyethylene bag.	Whatman #41 filter paper tape 40 ft. long x 2.5 cm width.
Cylindrical Collector	Cellulose wiper used to remove petrolatum from wire cylinder. Sealed in cellophane bag.	Kleenex or Kimwipe used
Films (Deposition Sample)	Large area cellulose film coated with Canada balsam and dibutyl phthalate. Cover sheet of cellulose film coated with Simon adhesive. Films were received folded and sealed in waxed paper bag.	Cellulose film 30 cm x 30 cm x 0.004 cm thick weighing 5.0 grams. Cellulose cover film 30 cm x 30 cm x 0.006 cm thick weighing 7.5 grams. Waxed bag 23 cm x 17 cm x 0.003 cm thick weighing 3 grams.
Aluminum Collectors (Deposition Sample)	Deposition removed from a large aluminum plate coated with petrolatum. Sample received sealed in a 40-ml glass centrifuge tube. Tube sealed with a rubber stopper and masking tape.	Finely powdered debris minus petrolatum weighing 1 to 30 grams.
Water Sample (Deposition Sample)	Distilled water from deposition trays received in sealed glass bottles. Trays were rinsed out with distilled water to remove all debris which was combined with the original water.	Water sample containing 100 to 1000 milliliters.

TABLE 2.2 DESCRIPTION OF ROLLER COASTER BIOLOGICAL SAMPLES

Sample	Approximate Sample Weight			Brief Description of Samples and Remarks*
	Dog	Sheep grams	Burro	
Bone (Femur)	40	200	1200	Either right or left femur, cleaned of soft tissue.
Kidney	50	300	800	Right or left kidney.
Liver	300	600	3000	Very large tissues encountered on the burro livers. Sealed in plastic bags but considerable leakage encountered.
Lung	100	500	2000	Large tissues but easily handled.
Hilar Node	1	5	10	Small tissues difficult to find among the larger mixed tissues as the small bags were frozen to larger ones.
Trachea	25	50	150	Complete tracheas.
Stomach	900	2500	4500	Most of the stomachs were received full of fodder, therefore, were very large bulky samples.
Pharyngeal Mucosa	6	8	15	Complete lining of pharynx.
Nasal Mucosa	20	30	50	Complete lining of nasal cavity.
Urine (on Kimpac)	None Received	3000	4000	Large bulky samples due to the amount of Kimpac needed to collect sample. Some samples contained several hundred grams of dirt.
Feces	None Received	1000	None Received	Large bulky samples containing gross amounts of inorganic salts after ashing.

\*All samples received frozen with dry ice and sealed in plastic bags.

## CHAPTER 3

### RADIOCHEMICAL SEPARATION AND ELECTRODEPOSITION OF PLUTONIUM

#### 3.1 RADIOCHEMICAL SEPARATION OF PLUTONIUM

The radiochemical procedure involved a series of precipitations to carry and concentrate Pu followed by an ion-exchange separation to yield a radiochemically pure, carrier-free solution suitable for electrodeposition. (Thin, virtually weightless deposits are required for good resolution in alpha spectrometry.)

3.1.1 Usual Procedure. For most samples, the initial concentration step was a hydroxide precipitation, carrying plutonium in any of its valence states. Plutonium then was reduced to Pu (III) which was carried on  $\text{LaF}_3$ . The final ion-exchange step involved adsorbing Pu (IV) on a short anion-exchange column from 8 N  $\text{HNO}_3$  solution, rinsing the column with 8 N  $\text{HNO}_3$ , then with HCl, and finally reducing Pu (IV) to Pu (III) to remove it from the column.

A detailed procedure for isolation of Pu from relatively small samples is given in Exhibit 3.1. For larger samples, the quantities of reagents and volumes of solutions were appropriately adjusted to maintain reagent

and carrier concentrations approximately the same as those given in Exhibit 3.1. Also, for the largest samples it usually was necessary to reprecipitate hydroxides and fluorides to remove relatively large amounts of interfering elements.

3.1.2 The Anion-Exchange Step. The first groups of samples were processed using an ion-exchange separation in which the Pu (IV) was adsorbed from concentrated HCl only. The electrodeposited samples resulting from this procedure frequently had visibly thick deposits which gave poorly resolved peaks in the alpha spectra and made reprocessing necessary. It appeared that the poor-quality plates were, in most cases, due to small amounts of iron which had not been completely removed by the  $\text{LaF}_3$  step and which thus followed Pu through the subsequent anion-exchange step. Insertion of the anion-exchange step involving adsorption of Pu (IV) from  $8 \text{ N } \text{HNO}_3$  solution solved this problem, since neither iron nor any other ubiquitous stable element is adsorbed from nitric acid solution.

As might be expected, the procedure given above was also very effective in removing any alpha-emitting impurities from the Pu samples. No peaks other than those

due to Pu isotopes were detected in the alpha spectra of any of the samples processed using this procedure. Thorium, which would otherwise have followed Pu through the procedure, was removed by the HCl rinse of the anion-exchange column before elution of Pu.

### 3.1.3 Use of Zirconium Phosphate to Carry Plutonium.

Initial concentration of Pu by hydroxide or fluoride precipitation was not suitable for bone samples, or for other biological samples of high calcium content, because of the large volumes of the resulting precipitates. Zirconium phosphate was selected as being the most suitable carrier for plutonium in such samples, particularly since the sample solutions resulting from the dissolution procedures were 3 to 6 N in acid, in most cases. If the acid concentration of the sample solution was greater than 3 N, it was reduced to about 3 N by diluting with water and/or neutralizing with NaOH. Sodium nitrite then was added, and the solution heated, to insure that plutonium was present as Pu (IV). Then the Pu (IV) was carried on zirconium phosphate, using a double precipitation to increase the yield. The zirconium phosphate was dissolved in HF in the presence of La<sup>3+</sup> carrier. This resulted in

a  $\text{LaF}_3$  precipitate which carried the Pu. The subsequent procedure was the same as given previously (Exhibit 3.1), i.e. conversion of  $\text{LaF}_3$  to  $\text{La}(\text{OH})_3$ , and the final anion-exchange steps. A detailed procedure for the initial concentration of Pu (IV) on zirconium phosphate, followed by carrying on  $\text{LaF}_3$ , is given in Exhibit 3.2.

### 3.2 ELECTRODEPOSITION OF PLUTONIUM

A rapid and efficient, but non-selective, method was used for the electrodeposition of the separated and purified plutonium. This was a general method which is applicable to trace amounts of any element with a highly insoluble hydroxide. The element to be plated is dissolved in a slightly acidic solution of relatively high ammonium salt concentration for high electrical conductivity. This solution is contained in an electrolysis cell in which the source backing plate, of a non-corroding metal, is made the cathode. Passing a direct current of relatively high density, (about  $1 \text{ amp/cm}^2$ ) through the solution causes a rapid discharge of hydrogen ions at the cathode surface and produces a thin layer of solution depleted in hydrogen ions and therefore of very high hydroxide ion concentration. Insoluble hydroxides thus are precipitated

at the cathode surface. Electrolytic gas formation gives vigorous stirring which brings each part of the solution in turn to the cathode surface where the trace element is deposited virtually quantitatively in a short time. The electrolyte is made basic just before the current is turned off to prevent dissolution of the deposited hydroxides in the acidic electrolyte. Finally the electrodeposited sample is removed from the cell, rinsed with water to remove the electrolyte, and heated to redness in air to convert the hydroxide to oxide, resulting in a very adherent sample deposit.

3.2.1 Apparatus for Electrodeposition. Platinum disks, 0.875-inch diameter x 0.005-inch thick were used as sample backings. These had been highly polished to give good resolution of the plutonium isotope peaks in the alpha spectra.

The anodes used for electrolysis were of platinum-iridium alloy. Each anode was manufactured by welding a 0.50-inch diameter, 0.020-inch thick, perforated disk perpendicular to the end of a 4-inch long, 0.0625-inch diameter rod.

The electroplating cell consisted of a base of stainless steel having a circular depression in its center for the platinum disk cathode, three threaded vertical tie rods attached to the base, a disposable body of square-cut, cylindrical glass tubing, and a top ring of Teflon. In the assembled cell, a disposable Teflon gasket was used to form a leak-tight seal between the glass body and the platinum disk. The three tie rods from the base passed through 3 holes in the Teflon top ring, which was centered on top of the cylindrical glass body. Nuts on the tops of the tie rods were tightened down on the top ring, holding the assembled cell together and forcing the glass body against the Teflon washer on the platinum disk. The anode was passed through the center hole of the top ring into the assembled cell.

Relatively inexpensive direct-current power supplies (Electro Products Laboratories Model PS-2) were used and found to be quite satisfactory.

3.2.2 Procedure. Ammonium chloride was used as the electrolyte. (Ammonium sulfate and ammonium nitrate also have been used successfully in this and other laboratories). The detailed procedure used for Pu electrodeposition is given in Exhibit 3.3.

3.2.3 Reuse of Anodes. The Pt-Ir anodes were the only items contacting the radioactive sample during the electrodeposition procedure which were reused, and particular care was taken to prevent sample contamination from this source. After use on a sample, each anode was thoroughly rinsed with acids, then with water. The anode then was used as the anode in electrolysis of a blank solution and finally rinsed again before being used on another sample.

Separate apparatus, including anodes, was used for plating the physical and the generally lower-activity-level biological samples. The policy of analyzing samples in order of increasing estimated activity level also minimized the chance of contamination of a low-level sample by the residue from a preceding high-level sample. Plating blanks were run periodically; the amounts of Pu found on these blank plates either were not detectable or were a negligible fraction of the total activity of the samples being processed at the time.

3.2.4 Radiochemical Yields. The majority of the overall yields (through dissolution, chemistry, and electrodeposition) were greater than 60 percent with the peak of the yield distribution curve in the 70 to 90 percent range.

### EXHIBIT 3.1 PLUTONIUM PROCEDURE

1. Add 5 mg of  $\text{La}^{3+}$  carrier to the dilute acid solution of the sample in a 50-ml "Autoclear" centrifuge tube.
2. Precipitate the hydroxide(s) by adding 50% NaOH dropwise with stirring. Centrifuge and discard the supernate. Dissolve the precipitate in a minimum of concentrated  $\text{HNO}_3$  and dilute to about 10 ml with water.
3. Reprecipitate the hydroxides with  $\text{NH}_4\text{OH}$ . Centrifuge and discard the supernate. Dissolve the precipitate in a minimum of concentrated  $\text{HNO}_3$  and dilute to 10 ml with water.
4. Add about 20 mg of  $\text{NaHSO}_3$ , swirl, and heat the solution for about 5 minutes in a boiling water bath. Precipitate  $\text{LaF}_3$  by adding 10 drops of HF, with stirring. Continue to heat for a few minutes. Centrifuge and discard the supernate. Wash the  $\text{LaF}_3$  with a few ml of 1 N HCl - 1 N HF. Centrifuge and discard the wash solution.
5. Dissolve the  $\text{LaF}_3$  by slurring in 1 ml of saturated boric acid and heating in a boiling water bath for a few minutes, then adding 1 ml concentrated HCl, 1 ml water, and continuing to heat, with occasional swirling until a clear solution is obtained.
6. Precipitate  $\text{La}(\text{OH})_3$  by adding  $\text{NH}_4\text{OH}$ . Centrifuge and discard the supernate. Wash the hydroxide with 10 ml of water. Centrifuge and discard the wash.

7. Dissolve the hydroxide in a minimum of concentrated  $\text{HNO}_3$  by adding the  $\text{HNO}_3$  a drop at a time, stirring between each addition. When the precipitate has just dissolved, make the solution about 8 N in  $\text{HNO}_3$  by adding a volume of concentrated  $\text{HNO}_3$  (15.4 N) equal to the volume of the sample solution. Add 7.7 N  $\text{HNO}_3$  to give a total volume of about 8 ml. (Prepare 7.7 N  $\text{HNO}_3$  by diluting 500 ml of concentrated  $\text{HNO}_3$  to 1000 ml with water.) Add about 20 mg of  $\text{NaNO}_2$  to the sample, swirl, and heat in a boiling water bath for a few minutes, then allow to cool while continuing with Step 8.
8. Condition a previously-prepared ion-exchange column by rinsing with four 5-ml portions of 7.7 N  $\text{HNO}_3$ . (Each anion-exchange column was manufactured by sealing a 5-mm OD x 1-cm long glass tube to the bottom of a 15 x 125 mm Pyrex test tube, with lip. A Pyrex-wool plug was placed in the bottom of the column, and it was then filled to a height of about 1 inch with Dowex AG1-X8 (100 to 200 mesh) anion-exchange resin. A glass-wool plug was then placed on top of the resin column.)
9. Transfer the sample solution to the anion-exchange column and allow it to drain into the top glass-wool plug. Have ready 20 ml of 7.7 N  $\text{HNO}_3$  rinse solution. Rinse the sample tube with several 2-ml portions of this solution, transferring each rinse to the column. Rinse the column with the remainder of the 7.7 N  $\text{HNO}_3$  solution in 2-ml portions.

10. Rinse the column with 20 ml concentrated HCl in 2-ml portions.  
Discard the 7.7 N HNO<sub>3</sub> and concentrated HCl rinses.
11. Elute Pu from the column into a clean 50-ml glass beaker using a solution containing 20 ml HCl and 1 ml of 1 N NH<sub>4</sub>I. Add this solution in 2-ml portions. After adding the third 2-ml portion of this solution, plug the top of the column with a polyethylene stopper and let stand for 5 minutes, then remove the stopper and continue to elute with 2-ml portions of the solution. Finally, rinse the column with three 2-ml portions of HCl, collecting the effluent in the same 50-ml beaker.
12. Evaporate the solution to approximately 1 ml and proceed with the Electrodeposition Procedure (Exhibit 3.3).

EXHIBIT 3.2 INITIAL CONCENTRATION OF PLUTONIUM (IV) ON ZIRCONIUM PHOSPHATE

1. If the initial acid (HCl or HNO<sub>3</sub>) concentration is greater than 3 N, adjust to about 3 N by diluting with water and/or adding 50% NaOH dropwise, with stirring.
2. Add about 100 mg NaNO<sub>2</sub> per 100 ml of sample solution. Stir and heat for a few minutes. Add Zr carrier solution dropwise, with stirring; use 0.2 mg Zr per ml of sample solution. Stir. Add 3 ml H<sub>3</sub>PO<sub>4</sub> per 100 ml of sample solution. Stir. Allow the sample to digest hot, with occasional stirring, for at least 30 minutes. Separate the zirconium phosphate by decanting the supernate after the precipitate has settled, and/or by centrifuging.
3. Repeat Step 2 once.
4. Combine the zirconium phosphate precipitates using 3 N HNO<sub>3</sub> rinses. Centrifuge, and decant the washes. Wash the combined precipitate with 3 N HNO<sub>3</sub>.
5. Add La<sup>3+</sup> carrier solution to the zirconium phosphate precipitate and slurry; add an amount of La<sup>3+</sup> which will give a **concentration** of about 0.5 mg La<sup>3+</sup> per ml of slurry. Add about 20 mg NaHSO<sub>3</sub> per 15 ml of slurry. Transfer the slurry to a plastic centrifuge tube, or bottle, if it is not already contained in such.
6. Add 1 ml HF per ml of slurry. Swirl and heat in a water bath to dissolve the zirconium phosphate and precipitate LaF<sub>3</sub>.

Centrifuge, and decant the supernate. Wash the  $\text{LaF}_3$  with 1 N HCl - 1 N HF. Centrifuge, and decant the wash.

7. Dissolve the  $\text{LaF}_3$  by slurring in an equal volume of a mixture of saturated boric acid solution and 6 N HCl. Heat and swirl until a clear solution is obtained.
8. Precipitate  $\text{La}(\text{OH})_3$  by adding  $\text{NH}_4\text{OH}$  and stirring. Centrifuge and decant the supernate. Wash the hydroxide with 10 ml of water. Centrifuge and decant the wash.
9. Repeat **Steps 6 to 8**, if necessary, to obtain a clean, readily dissolved,  $\text{La}(\text{OH})_3$  precipitate in **Step 8**.
10. Proceed with the anion-exchange separation of Pu, starting with Step 7 of the "Plutonium Procedure" (Exhibit 3.1).

### EXHIBIT 3.3 PLUTONIUM ELECTRODEPOSITION PROCEDURE

1. Add 1 ml concentrated  $\text{HNO}_3$  to the solution from Step 12 of the "Plutonium Procedure" (Exhibit 3.1) and evaporate nearly to dryness on a hot plate. Add 1 ml concentrated  $\text{HNO}_3$  and 1 ml concentrated  $\text{HCl}$  and evaporate to dryness. Repeat the  $\text{HNO}_3$ - $\text{HCl}$  treatment until the  $\text{NH}_4\text{I}$  has been destroyed.
2. Rinse down the inside of the beaker with 1 ml concentrated  $\text{HCl}$ . Evaporate slowly to dryness. Rinse down the inside of the beaker with 2 ml concentrated  $\text{HCl}$  and evaporate slowly to 1 ml.
3. Transfer the solution to an assembled electroplating cell (Note a). Rinse the beaker twice with 0.5 ml of concentrated  $\text{HCl}$  and finally with 0.5 ml of water, transferring each rinse to the electroplating cell.
4. Add a drop of methyl red indicator to the solution in the cell. Add concentrated  $\text{NH}_4\text{OH}$  dropwise, with swirling, until the solution is just basic (color change from red to yellow) (Note b). Add 2 N  $\text{HCl}$  dropwise until the solution is just acid, then add one drop more.
5. Electroplate for 15 minutes at 2.5 amperes using a cleaned **Pt-Ir** anode adjusted to be 1/4 inch above the Pt disk. Occasional adjustment may be necessary to maintain the current at 2.5 amp during the plating period.

6. At the end of the plating period, add 1 ml of concentrated  $\text{NH}_4\text{OH}$  to the plating solution, leaving the current on for ~15 seconds. Then turn off the current and immediately transfer the solution back to the 50-ml beaker. Rinse the cell three times with a few ml of water, combining the rinses with the plating solution in the beaker.
7. Disassemble the cell and remove the Pt disk. Rinse the disk with water, then acetone. Ignite to red heat over a burner flame. Cool and place in a labelled glassine envelope.
8. Check recovery by alpha spectrometry or by gross alpha counting before finally discarding the sample solutions, column, etc.

#### Notes

- (a) Prepare the platinum disk for plating by first **scratching the** sample number on the margin of the disk. Rinse the disk with water, then acetone, and finally flame to red heat. Use a Pt-wire support for the disk in the flame. Assemble the cell and fill it with water to check for leaks.
- (b) Do not continue with the procedure if any visible precipitate forms when the solution is made basic. Such a precipitate indicates that a thick plate will be obtained. The **sample must** be reprocessed to eliminate the element(s) which **precipitate in** basic solution.

CHAPTER 4  
MEASUREMENT OF RADIOACTIVITY

4.1 ALPHA SPECTROMETRY SYSTEM

All alpha spectrometry was done using semiconductor detectors. These relatively new detectors are preferred in the H-NSC laboratory over the older gridded ionization chambers because their performance (counting efficiency, energy resolution, and background) is equal to or better than the Frisch-grid devices, while their cost is substantially less for both purchase and maintenance.

The detectors used were of the silicon surface-barrier type (ORTEC Model SBFJ450) having an active circular area of  $450 \text{ mm}^2$  (2.4 cm diameter) and a 60-micron depletion depth. With these relatively large-area detectors, the 11/16-inch-diameter electrodeposited samples could be counted with good efficiency (31 percent).

Each of the four detectors used was mounted inside a special vacuum chamber containing a sample holder assembly and connector tray assembly with detector socket (Solid State Radiations Model 302).

The output of each detector was amplified separately by a low-noise, charge-sensitive preamplifier (ORTEC Model 101) and main amplifier (ORTEC Model 201). The amplified signals were analyzed by a 400-channel pulse-height analyzer (RIDL Model 34-12) and stored in appropriate quadrants of the analyzer memory. The use of an external router-mixer circuit (RIDL Model 30-26-002) made it possible to use the four detectors simultaneously with the single analyzer. Digital readout of the analyzer was by IBM typewriter.

A photograph of a portion of the alpha-spectrometry system is shown in Figure 4.1.

#### 4.2 PLUTONIUM-236 TRACER STANDARDIZATION

A tracer stock solution containing 0.5 microcurie of Pu<sup>236</sup> was purchased from Tracerlab, Inc., Richmond, California. This solution was quantitatively transferred to a 100-ml volumetric flask and diluted to volume with 6 N HCl. A 0.100-ml aliquot of this solution was electro-deposited directly onto a platinum disk, using the standard plating procedure described previously. Alpha pulse analysis of this plate showed only the U<sup>232</sup> daughter of

Pu<sup>236</sup>, and a slight (~ 0.2 percent) amount of Pu<sup>238</sup>, in addition to the Pu<sup>236</sup> peak. The total solution then was diluted to 2 liters with 6 N NCl; this solution was designated Pu<sup>236</sup> Stock D.

A solution of Pu<sup>239,240</sup> having a concentration of 127.2 ( $\pm$  1.9 percent) dpm/ml was used to standardize the Pu<sup>236</sup> D tracer. Quadruplicate standardization samples were prepared containing 1.0 ml of D and 2.0 ml of the Pu<sup>239,240</sup> reference solution. Each solution was mixed well, evaporated to dryness, taken up in HCl, and electroplated for 20 minutes using the standard procedure. The mean concentration of the Pu<sup>236</sup> in the D tracer was 563.2 dpm/ml, as of October 8, 1963, with a standard deviation estimated from the range of the four determinations, of  $\pm$  0.8 percent. Combining this value with the standard deviation ( $\pm$  1.9 percent) of the concentration of the Pu<sup>239,240</sup> reference solution gave  $\pm$  2.1 percent as the standard deviation of the concentration of Pu<sup>236</sup> in Stock D.

Two liters of Pu<sup>236</sup> Stock E was prepared by a one-tenth dilution of Stock D.

### 4.3 ILLUSTRATIVE ALPHA SPECTRA

Figure 4.2 is the alpha spectrum of a small aliquot of the  $\text{Pu}^{236}$  tracer which was electrodeposited directly, without any radiochemical separations. This spectrum shows the 5.48-Mev alpha of the  $\text{Pu}^{238}$  isotopic impurity, the 5.31-Mev alpha of the  $\text{U}^{232}$  daughter of  $\text{Pu}^{236}$ , and the 5.41-Mev alpha of the  $\text{Th}^{228}$  granddaughter of the  $\text{Pu}^{236}$ . At the start of this analytical program (October 1963), the  $\text{Th}^{228}$  peak could not be observed but gradually grew in over a period of months.

Figure 4.3 is an alpha spectrum of the  $\text{Pu}^{236}$  tracer after radiochemical separation of the  $\text{U}^{232}$  daughter. Several plates of this type were prepared to determine the magnitude of any tailing of the  $\text{Pu}^{236}$  tracer in the  $\text{Pu}^{239}$  region, which could possibly be a correction to low activity  $\text{Pu}^{239}$  samples. The ratio of counts in the  $\text{Pu}^{239}$  region to integrated  $\text{Pu}^{236}$  peak counts was only  $0.0004 \pm 0.0001$  making it unnecessary to apply such corrections. Figure 4.3 is actually the spectrum of the plate which had the highest observed ratio, 0.00052.

Figure 4.4 is the alpha spectrum of a typical sample. The resolution (FWHM = full width at half maximum) is

50 kev, and the  $\text{Pu}^{236}$  and  $\text{Pu}^{239,240}$  are of the same order of magnitude.

The  $\text{Pu}^{238}$  peak is seen at 1 percent of the  $\text{Pu}^{239,240}$  peak.

Figure 4.5 is the spectrum of a dirty plate (visible deposit) exhibiting poor (80 kev) resolution. The  $\text{Pu}^{239,240}$  peak is only 1.4 percent of the  $\text{Pu}^{236}$  and is not resolved cleanly from the tracer tail. The  $\text{Pu}^{238}$  peak is not detected.

Figure 4.6 is the spectrum of another clean sample plate, with good (50 kev) resolution but having 500 times as much  $\text{Pu}^{239,240}$  as  $\text{Pu}^{236}$ . This spectrum also shows the long low-energy tail on the large  $\text{Pu}^{239,240}$  peak at less than 0.1 percent of the peak height.

#### 4.4 DETECTOR CALIBRATION AND BACKGROUND

Background and energy-calibration of the four detectors were checked weekly to insure proper performance of the equipment. Each amplifier gain and post-amplifier bias setting was adjusted to record alphas in the energy range of 3.90 to 6.25 Mev, only. The mercury pulser was calibrated using alphas of three different energies.

The four semiconductor detectors were designated LAD-1, -2, -3, and -4. LAD-1 and LAD-2 had been used previously; consequently, their backgrounds were higher than those of LAD-3 and LAD-4. When the former two detectors were new, their backgrounds were as low as those shown in Table 4.1 for LAD-4. Gradually the backgrounds increased until they reached the values of Table 4.1 in July 1964. The oldest detector, LAD-1, has been in service since November 1962 and once was contaminated with recoil daughters of Th and Pa samples, which subsequently slowly decayed away.

TABLE 4.1 BACKGROUNDS OF SEMICONDUCTOR DETECTORS IN JULY 1964

Peak Energy Region	Counts per 1000 minutes			
	LAD-1	LAD-2	LAD-3	LAD-4
Pu <sup>236</sup>	13	7	3	3
Pu <sup>238</sup>	11	5	4	2
Pu <sup>239,240</sup>	3	7	3	1

#### 4.5 DETECTOR EFFICIENCY

The efficiency of the four detectors was determined with independently standardized sources of Am<sup>241</sup>, U<sup>233</sup>, Pu<sup>236</sup>, and Pu<sup>239,240</sup>. The average efficiency for all four detectors was 0.310 ± 0.015. There was no evidence of alpha energy dependence. This average efficiency of 31 percent exceeds the 20 percent efficiency assumed at the time the counting requirements were specified by the Review Committee at the Roller Coaster Radiochemistry Meeting, November 12 and 13, 1963.

#### 4.6 CALCULATION OF RESULTS

Each sample requiring Pu analysis was spiked with a known amount of Pu<sup>236</sup> tracer, and the initial chemical steps were designed to insure chemical exchange between the sample Pu and the tracer Pu<sup>236</sup>. Since the counting efficiency was independent of alpha energy, and since, in a given alpha spectrum, the same fraction of each peak was integrated, the integrated peak counts and the disintegration rates were related by the equation:

$$\left( \frac{\text{peak counts Pu}^{239,240}}{\text{peak counts Pu}^{236}} \right) = \left( \frac{\text{dpm Pu}^{239,240}}{\text{dpm Pu}^{236}} \right) \quad (4.1)$$

The amount (dpm) of Pu<sup>236</sup> added to each sample was known and was corrected for decay to the time of counting, using a half-life of 2.85<sub>1</sub> years, thus:

$$\left( \begin{array}{c} \text{dpm Pu}^{239,240} \\ \text{in the sample} \end{array} \right) = \left( \frac{\text{peak counts Pu}^{239,240}}{\text{peak counts Pu}^{236}} \right) \left( \begin{array}{c} \text{dpm Pu}^{236} \\ \text{added} \end{array} \right) \quad (4.2)$$

The above equation was used to calculate the amount of Pu<sup>239,240</sup> in each sample. Notice that neither the radiochemical yield nor counting efficiency appear in this equation.

The counting precision was reported for each Pu<sup>239,240</sup> result in terms of the single standard Poisson counting error. This convention was followed whether the measured activity was higher or lower than the standard deviation.

At the Radiochemistry Meeting, 12 and 13 November 1963, the Review Committee specified a maximum counting time of four hours or 1,000 counts with a Pu<sup>236</sup>-spiked sample, or ± 10 percent if the spectra gave a positive indication of the presence of Pu<sup>239,240</sup>. These criteria were established on the assumption of 60 percent chemical yield and a 20-percent counting efficiency. The efficiency of the semi-conductor detectors used by this laboratory was about 31 percent and the tailing was negligible, enabling most samples to be counted to a precision of ± 5 percent.

A typical sample data sheet is reproduced in Exhibit 4.1, showing the typed spectrum and the calculation of the results.

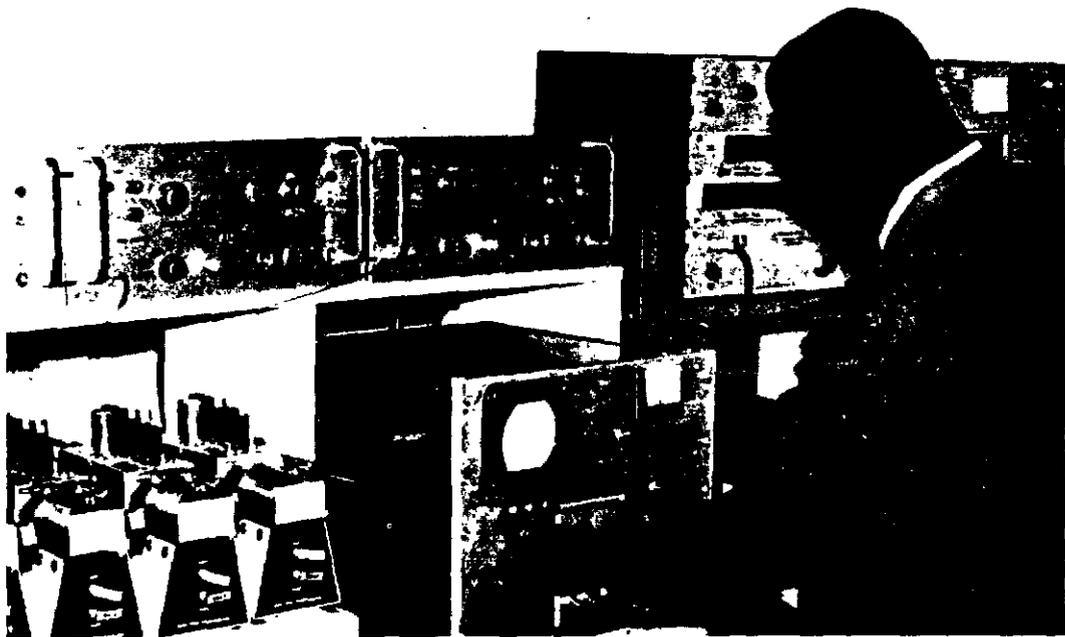


Figure 4.1 View of alpha spectrometry system showing three of the four vacuum chambers containing the semiconductor detectors (in lower left corner), two of the four amplifiers (above vacuum chambers), and the multichannel pulse-height analyzer. (Hazleton-Nuclear photo)

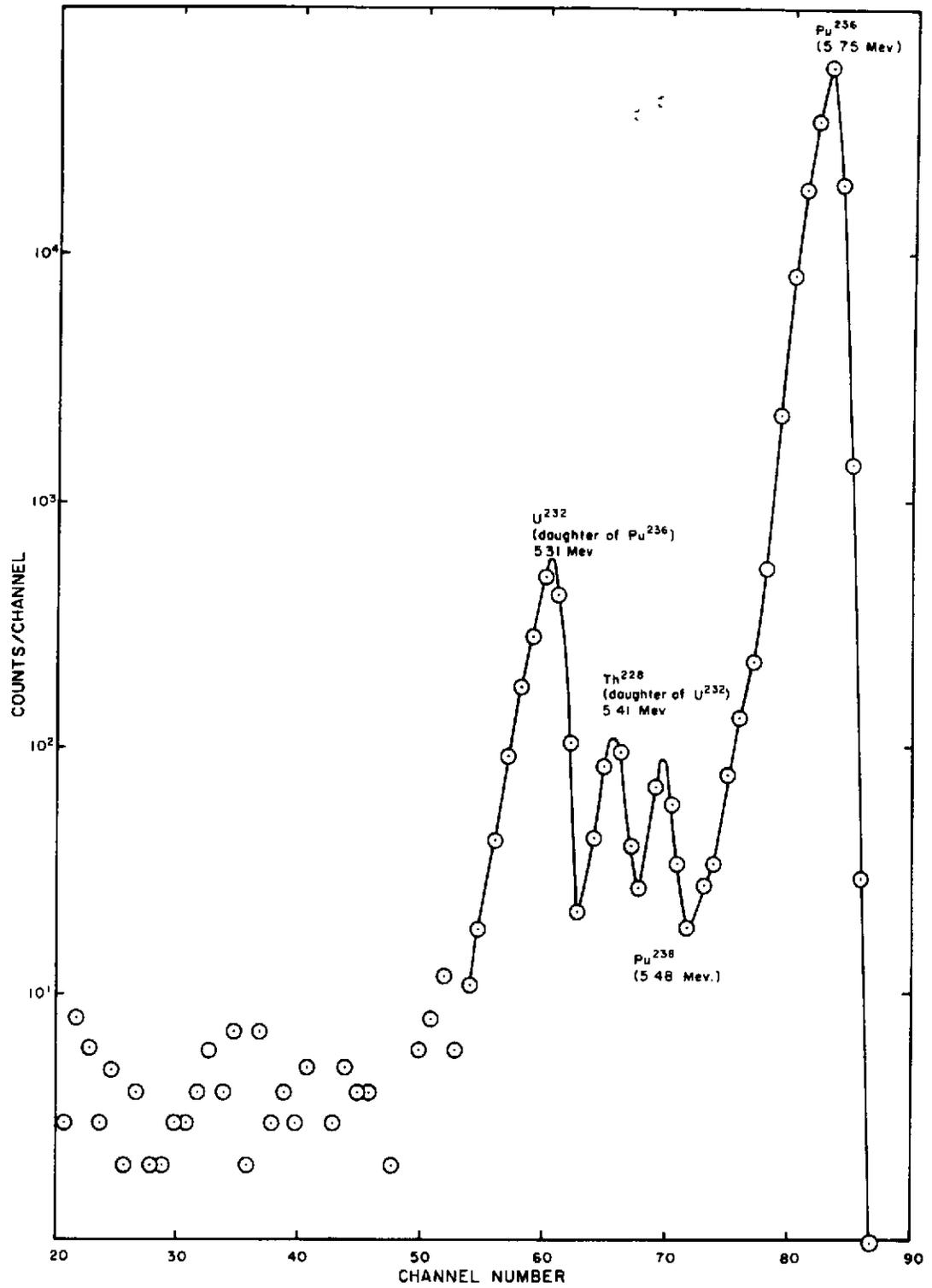


Figure 4.2 Alpha spectrum of Pu<sup>236</sup> tracer stock, showing Pu<sup>236</sup> decay products and Pu<sup>238</sup> isotopic impurity.

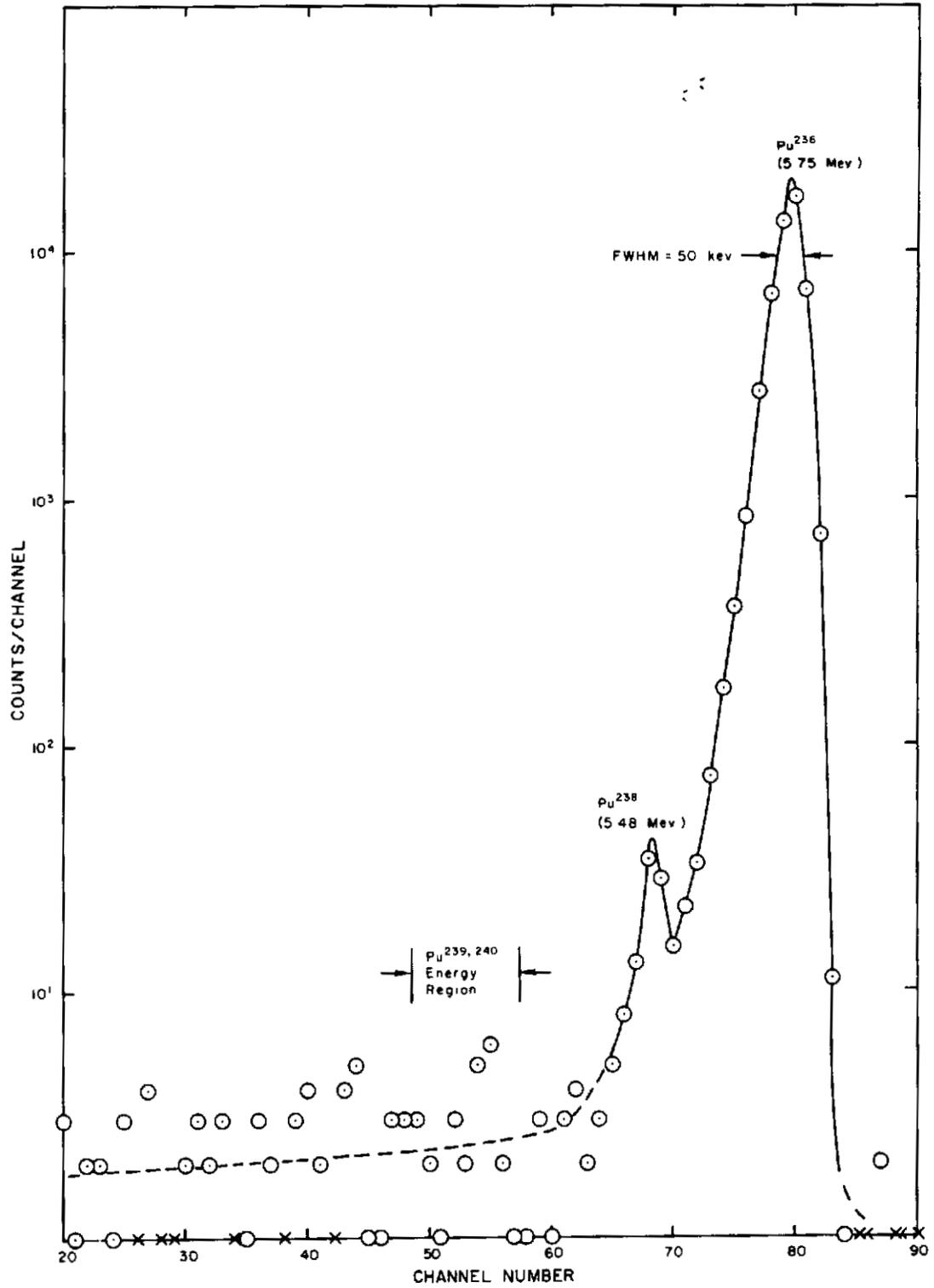


Figure 4.3 Alpha spectrum of  $Pu^{236}$  tracer after radiochemical separation of its decay products.

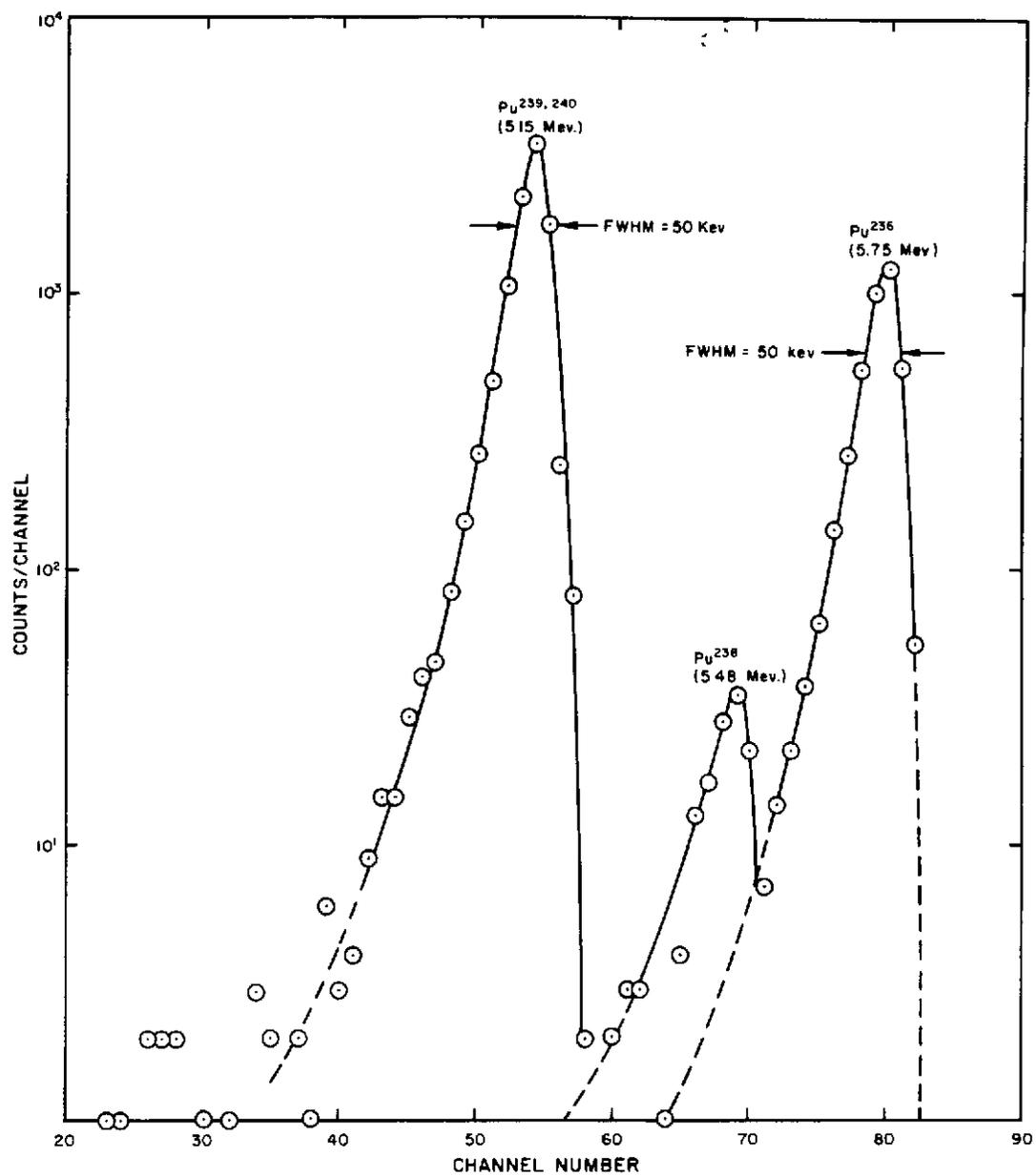


Figure 4.4 Alpha spectrum of a typical Roller Coaster plutonium sample.

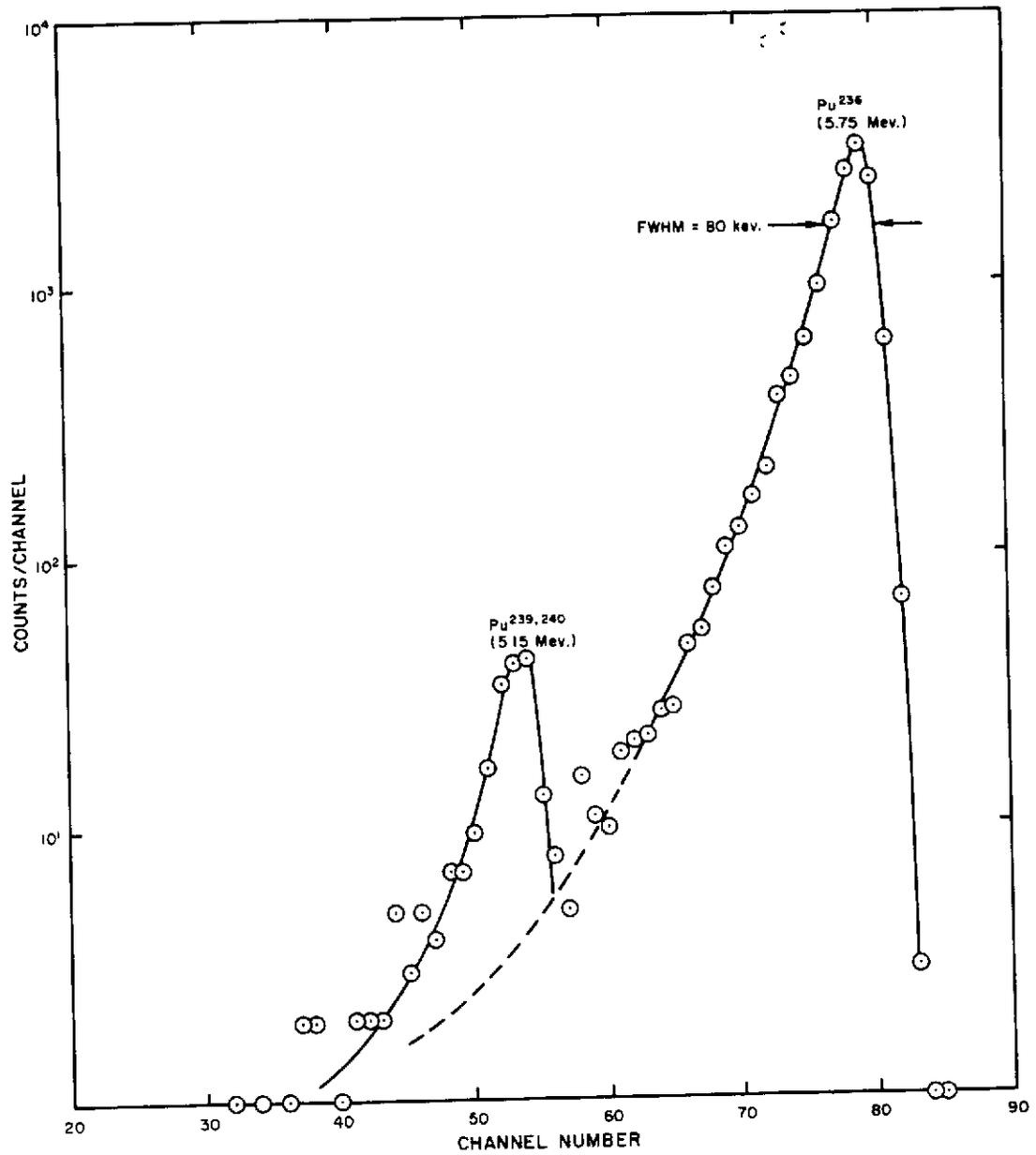


Figure 4.5 Alpha spectrum of a dirty sample plate giving poor resolution.

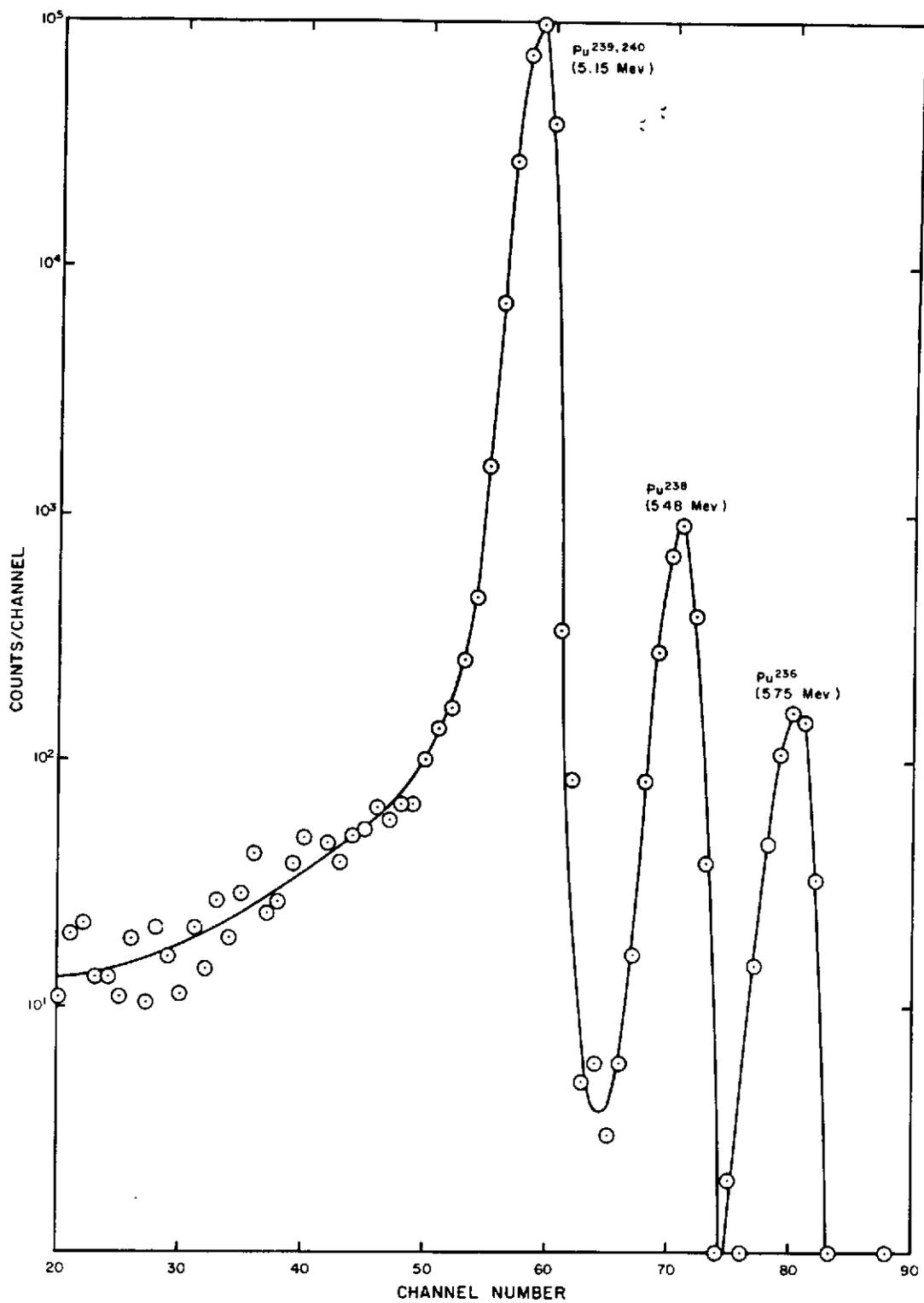


Figure 4.6 Alpha spectrum of a sample with a high ratio of sample plutonium to tracer plutonium.

PLUTONIUM DATA SHEET

Sample # 1576, Pu-236 added 2, ml of Solution E  
 Aliquot Tiz. Jan 31 1964 BWS  
 Dissolution BWS 2-10-64, Electroplating 2-14-64 SLM  
 Chemistry ES 2-13-64

---

Gross alpha cpm 1013 2-17-64  
 Detector # LAD-4, Quadrant # 4  
 Start Count 64,438, End Count 64,466, Live time 40 minutes

00000	00000	00000	00001	00000	00000	00001	00000	00001	00000
00000	00000	00000	00000	00000	00000	00000	00000	00000	00001
00000	00000	00000	00000	00000	00000	00001	00000	00001	00000
00000	00000	00000	00000	00000	00000	00000	00000	00000	00000
00000	00000	00000	00000	00000	00000	00000	00000	00000	00000
00000	(00002	00006	00013	00048	00144	00456	00689	00130)	00003
00000	00001	00002	00001	00000	00000	00000	00001	00004	00002
00007	00001	00002	00000	(00001	00003	00010	00028	00110	00285
00433	00150)	00009	00000	00000	00000	00000	00000	00000	00000
00000	00000	00000	00000	00000	00000	00000	00000	00000	00000

$$\frac{P_u \text{ 239,240}}{P_u \text{ 236}} = \frac{1488}{1020} \cdot (1.46)(101.44) = 148.1 \text{ dpm} \pm 6.1$$

$$\frac{\sqrt{1488}}{1488} = 2.59\%$$

$$(100) \frac{1020}{(40)(0.32)(101.44)} = 79\% \text{ YIELD}$$

$$\frac{\sqrt{1020}}{1020} = 3.13\%$$

$$\sqrt{(2.59)^2 + (3.13)^2} = \sqrt{16.57} = 4.1\%$$

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Exhibit 4.1 Reproduction of a typical plutonium sample data sheet showing typed alpha spectrum and the calculation of the results.

CHAPTER 5  
URANIUM ANALYSIS

The uranium content of many of the Roller Coaster samples was determined to ascertain the degree of fractionation, if any, between the uranium and the plutonium. A number of samples were chosen from each event. These were picked by choosing one or more samples from each type of collector along the hot line of debris deposition. The uranium to plutonium weight ratios of the four events were: **Double Tracks, 4.35; Clean Slate I, 47.2; Clean Slate II, 100.4; and Clean Slate III, 99.7.**

Data obtained prior to analyzing the samples indicated that the uranium content would vary from  $1 \times 10^{-4}$  to  $2 \times 10^4$  micrograms per sample; actually the range was  $4 \times 10^{-3}$  to  $1.4 \times 10^4$  micrograms uranium per sample analyzed. Wherever possible, for samples of known low uranium content, the entire sample was used for analysis by separating the uranium prior to analyzing for plutonium. The samples of high uranium content were aliquoted to obtain the proper uranium content needed for a sensitive fluorescence measurement, i.e., between 0.1 and 1 microgram of uranium.

Results of the uranium analysis indicate that serious fractionation did occur between the uranium and the plutonium of these experiments.

## 5.1 DISSOLUTION OF SAMPLES FOR URANIUM ANALYSIS

Procedures for the dissolution of both the Casella **Impactor and Anderson Impactor Specimens**, described in Chapter 2, were altered for uranium analysis to eliminate the dissolution of all, or part, of the glass disks. This was necessary to avoid addition of any uranium from the glass to the sample. Also, large amounts of calcium sulfate, produced when glass was dissolved in the presence of sulfuric acid, were eliminated. All the other samples in which uranium was determined were dissolved using the procedures given previously (Chapter 2). However, the quantity of reagents used was carefully limited and recorded so that a reagent blank could be subtracted from the samples of lower uranium content if necessary.

5.1.1 Modified Procedure for Glass Disks. The modification consisted in the removal of the glass disks before addition of hydrofluoric acid. After the sample had been placed in the Teflon beaker, the cellophane envelope, adhesive, and cellulose acetate film were

dissolved by boiling in a mixture of concentrated nitric and sulfuric acids until all visible traces of organic material were gone. Perchloric acid then was added cautiously, and the solution was boiled until it was colorless. At this stage, the glass disk was removed and rapidly rinsed with concentrated hydrofluoric acid followed by adequate demineralized water to remove hydrofluoric acid. The disks were allowed to dry and then checked for alpha activity. No alpha activity was found on any of the disks. The solution in the Teflon beaker was boiled to dryness and the residue dissolved in a minimum volume of a mixture of saturated boric acid solution and concentrated nitric acid. This solution was stored awaiting uranium analysis.

## 5.2 DETERMINATION OF OPTIMUM CONDITIONS FOR URANIUM EXTRACTION USING $U^{233}$ TRACER

Three membrane filters, spiked with  $U^{233}$  tracer, were dissolved in the same way as typical physical samples. The extraction procedure was varied in the three experiments to obtain as much data as possible. (For details of extraction procedure adopted for use, see the following section.)

5.2.1 Experiment No. 1. The residue from the membrane filter dissolution was dissolved in 10 ml of  $0.6 \text{ N HNO}_3$  containing 1 ml of saturated boric acid solution. (This represented an average physical sample.) In addition 1 ml of  $2.5 \text{ M}$  ferrous sulfamate was added.

The sample was extracted three times with 10 percent tri-butyl phosphate in hexane. Each hexane phase was back extracted with an equal volume of  $0.01 \text{ N HNO}_3$ . Each back extract was evaporated to 0.5 ml, salted with 5 ml of  $2.8 \text{ M}$  aluminum nitrate -  $0.005 \text{ M}$  tetrapropylammonium nitrate -  $2 \text{ M}$  ammonium hydroxide salting solution and extracted three times with 2-ml portions of hexone.\* All extractions were made by shaking for three minutes. The three hexone extracts were combined and evaporated on a two-inch aluminum counting planchet in a 2 pi windowless gas flow proportional counter. Its counting rate was compared with that of a reference standard, prepared by evaporating  $\text{U}^{233}$  tracer directly onto a planchet, to obtain the yield as follows:

	<u>Percent Recovered</u>
First TBP Extraction	51.7
Second TBP Extraction	14.8
Third TBP Extraction	7.4

\*Methyl Isobutyl Ketone.

The original aqueous solution then was made about 1 M in  $\text{Al}(\text{NO}_3)_3$  and extracted a fourth and fifth time with the following results:

	<u>Percent Recovered</u>
Fourth TBP Extraction	13.5
Fifth TBP Extraction	6.5
Total for the 5 extractions	93.9

leaving 6.1 percent or less in the aqueous phase.

5.2.2 Experiment No. 2. The procedure followed was the same as in the first experiment except that the solution was made about 1 M in  $\text{Al}(\text{NO}_3)_3$  at the start of the extraction procedure. The results of this experiment were as follows:

	<u>Percent Recovered</u>
First TBP Extraction	79.2
Second TBP Extraction	11.8
Third TBP Extraction	3.5
Fourth TBP Extraction	1.1
Fifth TBP Extraction	0.
Total	95.6

5.2.3 Experiment No. 3. This experiment was performed to determine the fractional extraction of Pu into the TBP (in hexane) after adding ferrous sulfamate to the solution to reduce Pu to Pu(III) and prevent its extraction. About 500 dpm of Pu<sup>236</sup> tracer was added to the sample before dissolution. After addition of the ferrous sulfamate, the sample was extracted three times with TBP in hexane, using the procedure of Experiment No. 2. The three TBP extracts were combined and evaporated for alpha counting to determine the percentage Pu extracted; this was found to be 10 percent.

From the results of these three experiments, it was decided to use the procedure of Experiment No. 2 but to limit the number of extractions to three to minimize extraction of Pu. Because the extracted Pu would follow uranium in subsequent chemistry, all the uranium fluorometric pellets were saved for possible Pu analysis; however, Pu analysis of these pellets did not prove to be necessary.

### 5.3 DETAILED URANIUM SEPARATION PROCEDURE

The uranium procedure used was adapted from procedures that have been used throughout the industry for many years

and which have proved to be extremely reliable and reproducible, yet very selective for uranium, minimizing fluorescent interference. The procedure was adapted from the one given on pp. 161-162 of Reference 1.

Purity of the reagents was of great concern, and some reagents had to be specially purified. The aluminum nitrate salting solutions were purified by extracting with 10 percent tributyl phosphate in hexane solution before use. Also, the 10 percent tributyl phosphate to be used for extraction of the samples was back extracted with 0.01 N HNO<sub>3</sub> and then equilibrated with 4 N HNO<sub>3</sub>.

To determine the reagent blank, all the reagents used for dissolution and extraction were combined in known amounts exceeding any quantities to be used for sample dissolution. These reagents were evaporated and the uranium content was determined by fluorometric analysis and found to be acceptable. (See subsequent section on Uranium Reagent Blank.)

As the samples were dissolved for uranium analysis, the quantities of reagents were controlled, as shown in Table 5.1. Knowing the amounts of reagents added, a

blank correction was applied to any of the samples if it was significant (when total U found was less than a microgram). As the dissolution procedure and subsequent sample preparation have been discussed previously in this report, only the purification by extraction and fluorescence measurement are included in the following procedure.

5.3.1 Reagents and Equipment Needed for Uranium Extraction.

<u>Reagents</u>	<u>Purity</u>
Nitric acid	Reagent grade
Aluminum nitrate, nonahydrate	Reagent grade
Tri-n-butyl phosphate (TBP)	Purified
Hexane	Purified
Hexone(methyl isobutyl ketone)	Purified
Tetrapropylammonium hydroxide	Highest purity
Ammonium hydroxide	Reagent grade
Ferrous sulfamate	Highest purity

Equipment:

Automatic Sample Shaker

Mineral Oil Bath

Hot Plates

Small Polyethylene Bottles, 1 oz

Test Tubes 145 mm x 20 mm

Equipment: (cont.)

Stoppers                    Size 0  
Transfer Pipets        9 inch  
Rubber Bulbs for Transfer Pipets  
Graduates                5 ml

5.3.2 Procedure.

1. Reduce the sample volume for the physical samples to 10 ml or less. Use the volume on the biological samples as received; these range from 50 to 200 ml.
2. The sample as received is in approximately 6 N  $\text{HNO}_3$ , so enough purified  $\text{Al}(\text{NO}_3)_3$  should be added to make the solution approximately 1 M in  $\text{Al}(\text{NO}_3)_3$ .
3. Add 0.5 ml of 2.5 M ferrous sulfamate, shake vigorously for 30 seconds and wait 5 minutes before continuing. (Ferrous sulfamate reduces plutonium to Pu(III) which does not extract appreciably.)
4. Add to the sample an equal volume of 10 percent tributyl phosphate in hexane, cap tightly and shake either by hand or on the shaker for 3

minutes. (Shake larger biological samples on the shaker for fifteen minutes.) Quantitatively remove the organic phase and repeat the extraction twice combining all three organic phases. Save the aqueous phase for plutonium analysis.

5. Back extract the uranium from the combined organic phase with an equal volume of 0.01 N  $\text{HNO}_3$ . (For the large volume biological samples back extraction was done using an aqueous volume equal to one half the organic volume.) Quantitatively remove the aqueous phase and repeat the extraction once combining both aqueous phases.
6. Evaporate the 0.01 N  $\text{HNO}_3$  solution (combined aqueous phase from step 5) to near dryness in a 20-ml test tube. (On the large biological samples concentration was made in a beaker of adequate size to a volume of 2 ml. Then the solution was transferred to a 20-ml test tube and evaporated to near dryness.)
7. Add 4 ml of uranium salting solution (Note a) to the evaporated sample and shake to mix. Add an equal volume of methyl isobutyl ketone and shake

for three minutes. Quantitatively remove the organic phase and repeat the extraction twice with methyl isobutyl ketone. Combine the three organic phases, being careful to avoid any transfer of the aqueous solution, in a 20-ml test tube and evaporate to 0.1 ml in an oil bath at 115° C. Stopper the sample and save for fluorometric analysis.

Note a. The uranium salting solution contains 1050 g aluminum nitrate nonahydrate, 67.5 milliliters of 14.8 N NH<sub>4</sub>OH, and 10 ml of 10 percent tetrapropylammonium hydroxide made to a total volume of 1 liter.

#### 5.4 URANIUM FLUOROMETRY

Uranium fluorometry was subcontracted to Radiation Detection Company (RDC), Mountain View, California. The samples sent to RDC were evaporated hexone (methyl isobutyl ketone) solutions in test tubes. These solutions were transferred to a small platinum planchet (15 mm in diameter and 3 mm deep) and evaporated. The test tube was rinsed twice with hexone and these rinses were combined on the planchet with the sample. A pellet containing approximately 0.4 gram of flux (45.5 percent sodium carbonate,

and 9 percent sodium fluoride) was placed in the planchet and fused at 680° to 700° C for 10 minutes. When the large planchets (35 millimeters in diameter and 3 millimeters deep) were used, a pellet containing approximately 4.6 grams of flux was added and fused for 20 minutes at the same temperature as the small planchets. The fused pellets were allowed to cool, tapped from the platinum planchet, and the fluorescence determined with a Jarrell—Ash Fluorometer Model JA-2600. To check for any loss on the first fusion, a second fusion was done on the sample planchet using a new flux pellet. Micrograms of uranium per sample were calculated using the formula:

$$\frac{(\text{reading of sample}) - (\text{flux blank})}{(\text{reading of standard}) - (\text{flux blank})} \left( \begin{array}{l} \text{micrograms of} \\ \text{uranium in standard} \end{array} \right) = \text{micrograms of uranium in sample} \quad (5.1)$$

Values for the flux blank and standard in the above equation were obtained from a flux blank sample and a uranium standard sample run with every four Roller Coaster samples.

#### 5.5 URANIUM REAGENT BLANK

In order to determine a U blank applicable to the amounts of reagents used for sample preparation, the following

amounts of these reagents were evaporated and assayed for uranium. All reagents were analytical reagent grade unless otherwise indicated.

<u>Reagent</u>	<u>Volume</u>	<u>Remarks</u>
HNO <sub>3</sub>	1500	
HF	100	
H <sub>2</sub> SO <sub>4</sub>	10	
H <sub>2</sub> O	1500	
HCl	100	
HClO <sub>4</sub>	20	
H <sub>3</sub> BO <sub>3</sub> , saturated solution	20	
Al(NO <sub>3</sub> ) <sub>3</sub> , saturated solution	100	Prepurified, about 3 <u>M</u> .
Ferrous Sulfamate	10	2.5 <u>M</u> solution.
10% TBP in Hexane	200	Prepurified
Hexone	100	
Salting Solution	10	Prepurified

The Al(NO<sub>3</sub>)<sub>3</sub> solution and the ferrous sulfamate were both extracted with the 200 ml of 10 percent TBP in hexane and the 30 ml of hexone. In order to include these solutions in a blank they had to be extracted, rather than evaporated, because of the large quantity of solid material present. All the other solutions were evaporated and

combined for the blank determination. The assay of this blank sample gave 0.057  $\mu\text{g U}$ , or  $1.55 \times 10^{-11}$   $\mu\text{g U/ml}$  of reagents.

Additional blanks were processed during the program as part of the internal quality-control program. The results for the internal control samples are listed in Table 5.2. The results on these blanks were in the range of  $4 \times 10^{-10}$  to  $6 \times 10^{-10}$   $\mu\text{g U}$ .

## 5.6 URANIUM INTERNAL CONTROL SAMPLES

In analyzing the first samples for uranium, some difficulty was encountered in obtaining consistent fluorometric results from RDC. Consequently, many standard samples were processed to obtain assurance that maximum accuracy was being obtained and that the method would be adequately sensitive to detect low uranium content. The results for these samples are included in Table 5.2 and are shown graphically in Figure 5.1. By altering the RDC procedure, as little as  $4 \times 10^{-10}$  grams of uranium could be determined corresponding to three sigma of the mean blank value for 17 blank determinations. This minimum detectable quantity was substantiated by submitting several additional blank samples.

The second set of biological spikes and blanks was run using horse liver purchased at a local pet shop. This liver was apportioned into approximately 200-gm samples. Two of the samples were spiked with 32.4 micrograms of uranium, two were spiked with 734 dpm of  $U^{233}$  tracer for yield determinations to compare with the RDC results on the natural uranium spike, and two were left as blanks. The results of these horse liver recovery experiments were as follows: The two samples spiked with  $U^{233}$  were dried and ashed, and complete uranium chemistry was performed as outlined in the preceding uranium procedure. The final hexane extract was evaporated and counted in a 2 pi windowless flow counter. An average yield of  $70.5 \pm 9.7$  percent (one standard deviation) was obtained.

The two samples spiked with natural uranium were run exactly the same as those in the  $U^{233}$  experiment except that the final hexane extract was evaporated and submitted to RDC for fluorometric analysis. An average yield of  $34.9 \pm 9.7$  percent (one standard deviation) was obtained.

The two blank samples (weighing 303 and 300.4 grams) were run in the same way as the  $U^{233}$ -spiked, and natural-uranium spiked, samples. An average result of 0.0018 microgram per gram (dry weight) was obtained from this liver tissue.

To establish a uranium blank and yield for the biological samples (all burro or sheep lungs), two sets of samples were run. The first set was prepared from beef liver purchased from a retail market. Duplicate 415-gram portions of this liver were spiked with 0.5 microgram of uranium, and 1.16 micrograms of uranium were found. This amount was higher than that found in the Roller Coaster burro lung tissues. It had been hoped that a blank could be obtained for application to Roller Coaster samples, and liver had been chosen as the tissue most likely to contain the same amount of uranium as a lung tissue. Reference 2 states that approximately 0.05 microgram of uranium per gram of dried tissue is found in both mammalian lungs and livers.

Reference 1 states that one can expect to find from  $1.5 \times 10^{-5}$  to 1 microgram of uranium per gram of living matter. Therefore the concentration of uranium found in the beef liver, 0.007 microgram per gram (dried weight), is not surprising.

The results of the blank samples run on beef liver and on horse liver and the results of the Roller Coaster burro lungs showed that a wide variation in the uranium content can be expected in tissues from different animals. It was hoped that a blank correction (micrograms U per gram of dry tissue) could be applied to all samples. However, some of the Roller Coaster burro lungs contained less uranium than any of the blank tissues. The range

of U contents of the burro and sheep lungs was  $3 \times 10^{-4}$  to  $1.6 \times 10^{-2}$  micrograms per gram of dry tissue.

#### 5.7 CORRECTIONS APPLIED TO FLUOROMETRIC RESULTS FOR PHYSICAL SAMPLES

Each uranium value received from RDC was first corrected for any fusion losses by adding the net uranium value from the second fusion to the value obtained from the original fusion. This corrected value was secondly corrected for loss during processing using the recovery factor obtained from standards submitted with the samples when they were analyzed. The recovery factor obtained was  $74 \pm 6$  percent, at the 95 percent confidence level. A third correction was made, where applicable, for the aliquot used. A fourth and final correction was made for uranium in the reagents used and for the natural uranium content of any soil-containing samples. The values subtracted as reagent blank corrections were: Casellas, 0.00395 microgram per sample; Andersens and Total Air Samplers, 0.00403 microgram per sample; Films, 0.00457 microgram per sample; and Aluminum Collectors, 0.0155 microgram per sample for reagents plus 6 micrograms per gram of soil. The value of 6 micrograms of uranium per gram of soil was obtained by gamma spectrometry on a large soil sample as described in Chapter 7.

The results for the physical samples are given in Table 5.3 and for the DASA Quality Control Solutions in Table 5.4.

#### 5.8 CORRECTIONS APPLIED TO FLUOROMETRIC RESULTS FOR BIOLOGICAL SAMPLES

The same corrections were applied to the biological samples as were applied to the physical samples. First, the U value from the second fusion was added to the value from the original fusion. This total was secondly corrected for loss during processing using an experimentally obtained recovery factor of  $34.9 \pm 9.7$  percent. A third correction was made for the aliquot used; since all samples for uranium were halved after dissolution, a factor of two was applied. A fourth and final correction was applied for reagents used for dissolution of the tissues. The reagent blank values subtracted from the results were  $3.1 \times 10^{-9}$   $\mu\text{g}$  uranium on the burro lungs. No correction was applied for natural uranium in the tissues of the animals; (see above discussion of attempts at determining this blank).

The results for the biological samples are given in Table 5.5.

TABLE 5.1 MAXIMUM VOLUMES (ml) OF REAGENTS USED FOR DISSOLUTION OF SAMPLES FOR URANIUM ANALYSIS

Sample Type	Reagent											Total	
	HNO <sub>3</sub>	HF	H <sub>2</sub> SO <sub>4</sub>	HCl	H <sub>2</sub> O	HClO <sub>4</sub>	H <sub>3</sub> BO <sub>3</sub>	Al(NO <sub>3</sub> ) <sub>3</sub>	Salting Sol.	Ferrous Sulfamate	10% TBP in Hexane		Hexone
Casella Glass Impactors and Membrane Filter	30	3	5	0	80	5	3	4	4	0.5	30	60	225
Andersen Glass Impactors and Membrane Filters Also TAS-1,2 & D Filters	50	3	10	0	90	5	3	4	4	0.5	30	60	260
Film Deposition Collectors	70	3	10	0	100	10	3	4	4	0.5	30	60	295
Aluminum Deposition Collectors	300	30	10	10	550	5	3	4	4	0.5	30	60	1007
Biological Lung Samples	135	40	1	5	200	0	5	30	4	0	100	100	620

TABLE 5.2 URANIUM INTERNAL CONTROL SAMPLES

Sample Description	Uranium Concentration		Percent Deviation	Size of Platinum Planchet Used (a)
	Submitted for Fluorometry	Found by Fluorometry		
	$\mu\text{g/ml}$	$\mu\text{g/ml}$		
Direct Pipetting of Sample (b)	23.5	12.8	-46%	Large
" " " "	23.5	5.8	-75%	Large
" " " "	1.01	1.13	+12%	Large
" " " "	1.01	1.38	+37%	Small
" " " "	1.01	1.38	+37%	Small
" " " "	1.01	0.238	-76%	Small
" " " "	1.01	0.760	-25%	Small
" " " "	1.01	0.740	-27%	Small
" " " "	1.01	0.560	-45%	Small
" " " "	1.01	0.802	-21%	Small
" " " "	1.01	0.666	-34%	Small
Uranium Separation Procedure (c)	1.01	0.60	-41%	Small
" " " "	1.01	0.67	-34%	Large
Direct Pipetting of Sample (b)	0.235	0.256	+9%	Large
" " " "	0.235	0.204	-13%	Small
" " " "	0.235	0.298	+27%	Small
" " " "	0.235	0.328	+40%	Small
Uranium Separation Procedure (c)	0.235	0.172	-27%	Large
Direct Pipetting of Sample (b)	0.324	0.307	-5%	Large
" " " "	0.324	0.265	-18%	Large
" " " "	0.324	0.288	-11%	Small
" " " "	0.324	0.288	-11%	Small
Uranium Separation Procedure (c)	0.324	0.256	-20%	Large
" " " "	0.324	0.248	-23%	Large
" " " "	0.324	0.229	-29%	Large
" " " "	0.324	0.229	-29%	Large
Direct Pipetting of Sample (b)	0.0101	0.0158	+56%	Large
" " " "	0.0101	0.0120	+19%	Small
" " " "	0.0101	0.0120	+19%	Small
" " " "	0.0101	0.0035	-95%	Small
Uranium Separation Procedure (c)	0.0101	0.0158	+56%	Large
Direct Pipetting of Sample (b)	0.00101	0.00100	-1%	Small
Dissolution Blank (See Section 5.5 for composition)	Unknown	0.057	--	Small
Extraction Blank for Uranium Separation Procedure (d)	Unknown	0.0006	--	Small
Extraction Blank for Uranium Separation Procedure (e)	Unknown	0.0006	--	Small
Nitric Acid Blank; 1 ml (Reagent Grade)	Unknown	0.0004	--	Small
Deminerlized Water Blank; 1 ml (Laboratory Supply)	Unknown	0.0004	--	Small
Plutonium-236 Tracer Blank; 5 ml (2500 dpm)	Unknown	0.0004	--	Small
Plutonium-239 Spike; 1 ml (1000 dpm)	Unknown	0.0004	--	Small

- (a) See Uranium Fluorometry Section.  
 (b) Samples were directly evaporated on the platinum disks from standard solutions.  
 (c) Samples were completely processed through uranium procedure used for Roller Coaster samples.  
 (d) The extraction blank consisted of a check made on a new salting solution made for biological samples. The blank was prepared by processing 200 ml of the salting solution through the uranium extraction procedure using 200 ml of 10% TBP in hexane, 50 ml of 0.01 N HNO<sub>3</sub>, and 50 ml of hexane.  
 (e) Same as (d) on another salting solution.

TABLE 5.3 PHYSICAL SAMPLE URANIUM ANALYSES

Location	Sampler Type	TL No.	Corrected Fluor.	Total	Pu <sup>239,240</sup>	Corrected
			Read., Net	μg U	dpm	Wt. Ratio U/Pu
DOUBLE TRACKS						
(Source weight ratio, U/Pu = 4.35)						
H-064	And-1	2728	0.986	1.32	2659	72.
	-2		7.06	9.46	1.76 x 10 <sup>4</sup>	78.
	-3		0.250	0.331	1869	26.
	-4		0.665	0.887	2593	50.
	-6		0.742	0.982	1309	109.
	-7		1.52	2.02	1908	154.
	Sum -			15.00	2.79 x 10 <sup>4</sup>	78.
G-060	Cas-1 (a)	9658	0.247	0.327	872	54.
	-2 (a)		0.199	0.263	241	158.
	-3		0.088	0.114	4658	3.6
	-4		1.25	1.68	3407	71.
	-5		0.050	0.063	1695	5.4
	Sum -			2.45	1.09 x 10 <sup>4</sup>	33.
G-058	TAS-D	9681	0.132	0.173	1577	16.
H-066	TAS-II	2726	0.962	1.28	3838	48.
H-030	Film	8043	0.550 x 1.34	0.737-0.0045	6615	16.
H-034	"	"	0.933	1.25	9.15 x 10 <sup>4</sup>	2.0
H-038	"	"	0.933	1.25	4.92 x 10 <sup>4</sup>	3.7
H-048	"	"	6.71	8.99	6.87 x 10 <sup>5</sup>	1.9
H-054	"	"	0.379	3.05	2.24 x 10 <sup>5</sup>	2.0
H-058	"	"	0.417	2.24	9.77 x 10 <sup>4</sup>	3.3
BL-08	Al. Coll.	9811	41.	5486.	4.98 x 10 <sup>6</sup>	161.
CLEAN SLATE-I						
(Source weight ratio, U/Pu = 47.2)						
B-022	And-1	3314	2.30	3.08	1.29 x 10 <sup>4</sup>	35.
	-2		0.155	0.204	471	63.
	-3		0.361	0.480	888	78.
	-4		0.588	0.784	747	152.
	-6		0.094	0.122	300	59.
	-7		0.147	0.193	242	116.
	Sum-			4.86	1.55 x 10 <sup>4</sup>	45.
B-026	Cas-1 (b)	2688	0.276	0.366	1410	38.
	-2 (b)		0.796	1.06	1017	151.
	-3		0.390	0.515	2939	25.
	-4		0.215	0.284	1251	33.
	-5		0.039	0.048	221	32.
	Sum -			2.27	6838	48.
B-020	TAS-II	3090	1.28	1.72	550	453.
B-026	TAS-II	3091	0.276	0.370	1006	53.
BM-09	Film	8121	51.6	69.	2.17 x 10 <sup>5</sup>	46.
BM-07	Al. Coll.	9833	43.	14,374.	1.57 x 10 <sup>8</sup>	13.
A-020	Al. Coll.	9830	42.	11,253.	8.60 x 10 <sup>7</sup>	19.
CLEAN SLATE-II						
(Source weight ratio, U/Pu = 100.4)						
F-020	And-1	3152	0.251	0.332	4994	9.7
	-2		0.062	0.079	2173	5.3
	-3		0.041	0.051	160	46
	-4		0.065	0.083	771	16
	-6		0.085	0.110	584	27
	-7		0.072	0.096	4594	30
	Sum-			1.61	1.33 x 10 <sup>4</sup>	18
F-022	Cas-1 (b)	2171	0.885	1.18	1573	109
	-2 (b)		0.056	0.071	1488	6.9
	-3		0.269	0.356	4324	12
	-4		0.248	0.328	725	66
	-5		0.342	0.446	1744	37
	Sum-			2.32	9854	35
F-014	TAS-D	4040	0.125	0.164	623	38
F-036	TAS-II	4029	0.410	0.545	4543	17
E-046	Film	8113	56	75.	2.91 x 10 <sup>5</sup>	37
B-080	Al. Coll.	9843	a. 0.421 b. 0.438	303.	5.35 x 10 <sup>6</sup>	8.2

TABLE 5.3 PHYSICAL SAMPLE URANIUM ANALYSES (cont'd.)

Location	Sampler Type	TL No.	Corrected Fluor.	Total	Pu <sup>239,240</sup>	Corrected Wt. Ratio U/Pu
			Read., Net			
			µg U	µg U	dpm	
CLEAN SLATE-III						
(Source weight ratio, U/Pu = 99.7)						
F-034	And-1	3265	3.08	4.12	2.23 x 10 <sup>4</sup>	27.
	-2		0.524	0.698	4840	21.
	-3		0.460	0.612	5416	16.
	-4		0.453	0.603	4963	14.
	-6		0.260	0.344	4558	11.
	-7		0.100	0.130	127	144.
	Sum-		6.51	6.51	4.21 x 10 <sup>4</sup>	22.
F-080	Cas-1 (b)	4897	0.089	0.115	484	35.
	-2 (b)		0.124	0.162	120	105.
	-3		0.083	0.107	275	57.
	-4		0.253	0.335	375	130.
	-5		0.125	0.164	365	65.
	Sum-		0.683	0.683	1620	76.
F-038	Film	815B	4.89	655.	3.25 x 10 <sup>6</sup>	26.
F-042	"	"	13.2	17.7	3.20 x 10 <sup>5</sup>	8.0
F-044	"	"	51.5	69.0	6.58 x 10 <sup>5</sup>	15.
F-050	"	"	2.27	15.2	6.88 x 10 <sup>4</sup>	32.
F-068	"	"	0.265	2.38	6570	52.
F-064	TAS-I	5063	0.322	0.418	4766	13.
F-378	TAS-II	5060	0.500	0.666	5388	15.

- (a) First and second Casella stages autoradiographed by Isotopes, Inc. They report that stage 1 resembled a stage 4 pattern and stage 2 resembled a stage 3 pattern. A packaging mixup is suspected, and stage 2 may also have been contaminated or doubly exposed.
- (b) First and second Casella stages autoradiographed by Isotopes, Inc.

TABLE 5.4 URANIUM ANALYSIS OF DASA QUALITY CONTROL SOLUTIONS

DASA Sample No.	Number of Analyses	μgU/ml	Standard Deviation
213	2	0.059	±0.006
217	3	0.005	±0.005
535	3	0.004	±0.004
547	2	0.053	±0.026
AA-17	5	0.056	±0.051
AA-59	2	0.214	±0.02
AB-11	5	0.220	±0.099
AC-51	2	1.38	±0.23

TABLE 5.5 DOUBLE TRACKS BIOLOGICAL SAMPLE URANIUM ANALYSES  
(Source weight ratio, U/Pu 4.35)

DASA No.	Animal Tissue	Weight wet g	Fluorometric Reading Net $\mu\text{gU}$	Total $\mu\text{gU}$	Pu <sup>239,240</sup> dpm	Weight Ratio U/Pu
2022-4	Sheep Lungs	439.1	0.020	0.161	5.62	4100
2143-4	"	356.8	0.042	0.341	67.0	740
2168-4	"	710.1	0.282	2.31	125	2700
2169-4	"	433.9	0.048	0.391	57.5	1000
2173-4	"	424.0	0.014	0.112	283	56
3019-4	Burro Lungs	1566	0.062	0.504	142	510
3032-4	"	2252	0.020	0.159	566	41
3049-4 (d)	"	1650	0.013	0.102	7.75	1900
3050-4 (a)	"	1409	0.033	0.266	1047	37
3050-4c (d)	"	1743 (b)	0.120	0.979	8.48	17,000
3139-4 (d)	"	1172	0.091	0.741	25.1	4,400
No #-4 (c)	"	1215	0.031	0.249	3553	10

(a) Sacrificed on D + 7. All other animals sacrificed on D-day.

(b) Weight includes two bags instead of one.

(c) This animal is shown in Major D. J. Myers' April 1964, "Samples Selected for Laboratory Analysis", as a control sheep. Tissue weights and Pu activities found in all tissues indicate that this animal was an exposed burro.

(d) Assigned as control animal in Major D. J. Myers' April 1964 "Samples selected for Laboratory Analysis."

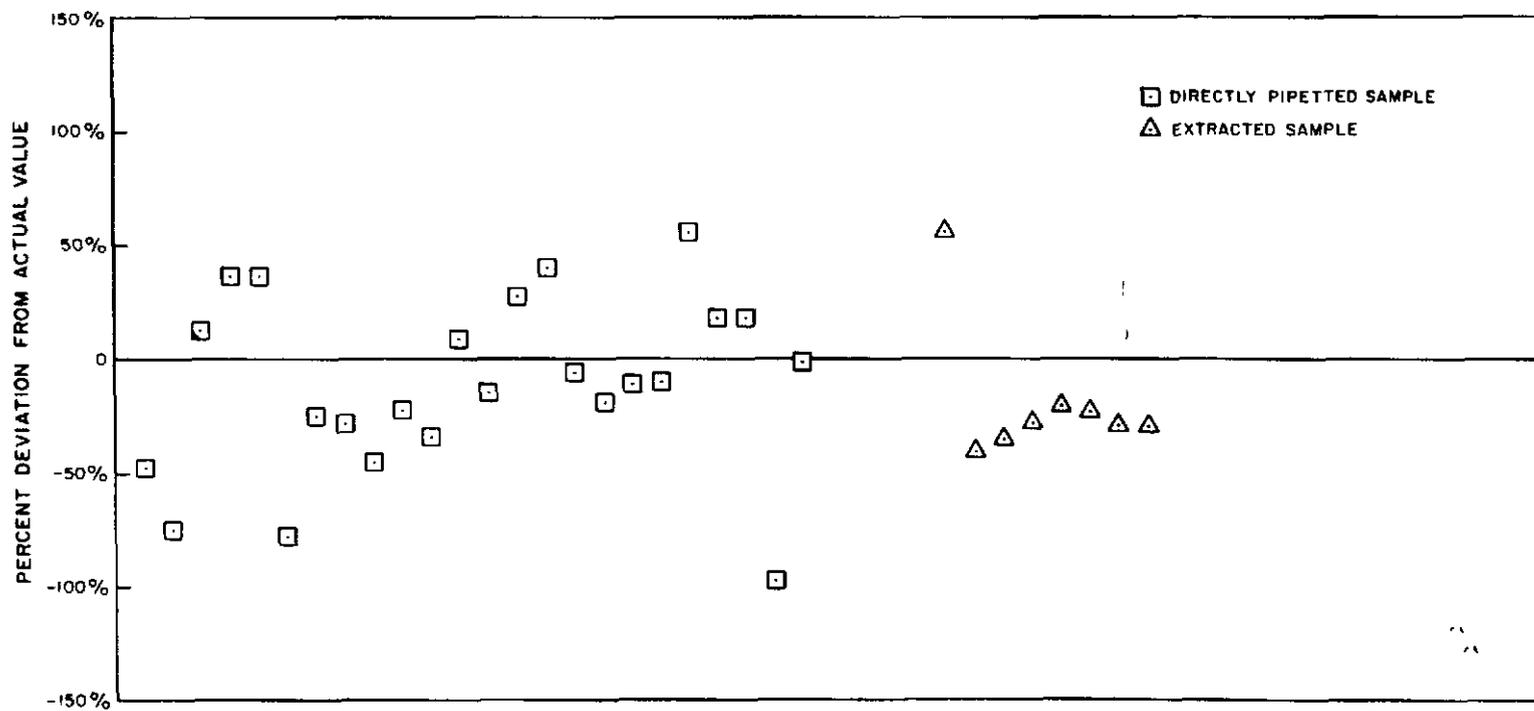


Figure 5.1 Percent deviation of the amount of uranium found fluorometrically from the amount of uranium added for internal control samples. (The points are spread horizontally for easier reading, but their location on the horizontal axis has no significance.)

## CHAPTER 6

### RADIOCHEMICAL DETERMINATION OF AMERICIUM/PLUTONIUM RATIO

In order to verify the assumption that Am and Pu did not fractionate in Roller Coaster (non-nuclear) detonations, selected clean Gummed Films and Total Air samples from **Clean Slate III** were radiochemically analyzed for both  $\text{Am}^{241}$  and  $\text{Pu}^{239,240}$ . A similar set of analyses was performed by Isotopes, Inc. on **Clean Slate II** samples. In addition, this ratio was estimated from the gross alpha spectrum of a dirt-free **Clean Slate II** sample.

#### 6.1 RADIOCHEMICAL YIELD TRACERS

$\text{Am}^{243}$  is the most convenient isotopic yield tracer for  $\text{Am}^{241}$ , but it had two potential disadvantages in this application. One was that the energy of the alpha of  $\text{Am}^{243}$  is only 210 kev less than that of  $\text{Am}^{241}$ , so that the resolution of the two peaks in the alpha spectrum would have been difficult if the electrodeposited samples were slightly dirty, i.e., not virtually weightless deposits. The second potential disadvantage was that the available  $\text{Am}^{243}$  contained about 6 percent  $\text{Am}^{241}$  which would have to be subtracted from the total  $\text{Am}^{241}$  to obtain the net

Roller-Coaster  $\text{Am}^{241}$ ; this would have been a small difference in large numbers if the amount of  $\text{Am}^{241}$  in the sample were underestimated before analysis and a much larger amount of  $\text{Am}^{243}$  added. The combination of the addition of too little tracer together with a thick electrodeposit could have resulted in the  $\text{Am}^{243}$  tracer peak being only a small bump on the low-energy tail of the  $\text{Am}^{241}$  peak in the alpha spectrum.

$\text{Cm}^{244}$  also was available for use as a tracer. Although not isotopic with  $\text{Am}^{241}$ , it had the potential advantages of having an alpha energy (5.79 Mev) well above that of  $\text{Am}^{241}$  (5.47 Mev) and of containing no detectable  $\text{Am}^{241}$ . The use of  $\text{Cm}^{244}$  as a tracer for  $\text{Am}^{241}$  is only valid, however, as long as no chemical operations separating Am and Cm are used. In general, any chemical steps which separate the actinides from the lanthanides also tend to separate the members of each of these groups from one another. Although relatively clean (dirt-free) samples had been selected for analysis, it appeared possible that separation of rare earth elements might become necessary, in which case the  $\text{Am}^{241}$  and  $\text{Cm}^{244}$  might have been fractionated.

Since the potential advantage of one tracer tended to balance the potential disadvantage of the other, and because both became available, both  $\text{Am}^{243}$  and  $\text{Cm}^{244}$  were added to each sample. With both tracers present, the resulting data could be examined for evidence of Am-Cm fractionation.

Stocks of both tracers were obtained from LASL by way of Sandia Laboratory. Each solution was quantitatively transferred to a volumetric flask and diluted to volume in 3 N  $\text{HNO}_3$ . Exactly 50 percent of each of the solutions was sent to Isotopes, Inc. Working stock solutions in 6 N  $\text{HCl}$  were prepared for H-NSC by diluting aliquots of the remaining 3 N  $\text{HNO}_3$  solutions.

Aliquots of the working stock solutions were plated directly for isotopic analysis of Am and Cm and to look for alpha-emitting impurities. The  $\text{Am}^{243}$  and  $\text{Cm}^{244}$  solutions were standardized, using separate aliquots, against an  $\text{Am}^{241}$  solution which had been independently standardized in a reliable U.S. Government laboratory. This standardization was checked by comparing the counting rate of an evaporated aliquot of the  $\text{Am}^{241}$  solution with the counting rate of a plated  $\text{U}^{233}$  standard in a 2-pi proportional counter.

The standardization of the  $\text{Am}^{243}$  and  $\text{Cm}^{244}$  tracers showed that a total of only 0.05 microcurie of each tracer had been received rather than the specified 0.1 microcurie. The composition of the two tracers, as determined here by alpha spectrometry, is given in Table 6.1. Data supplied by LASL for the  $\text{Am}^{243}$  tracer also are given for comparison.

TABLE 6.1 RADIOMETRIC ANALYSIS OF  $\text{Am}^{243}$  and  $\text{Cm}^{244}$  TRACERS

Radionuclide	Alpha DPM Percent		
	$\text{Am}^{243}$ Tracer	LASL	$\text{Cm}^{244}$ Tracer
	H-NSC	LASL	H-NSC
$\text{Am}^{243}$	93.3	93.3	-
$\text{Am}^{241}$	5.9	5.9	-
$\text{Cm}^{244}$	0.62	0.88	99.86
$\text{Cm}^{242}$	0.14	-	0.14
Date	1-30-64	Not Given	1-30-64

The slight difference in  $\text{Cm}^{244}$  content of the  $\text{Am}^{243}$  tracer probably is not significant considering the precision of the assays and the possible difference in reference times.

## 6.2 RADIOCHEMICAL SEPARATIONS

The Clean Slate III samples were wet ashed using the procedure previously described for plutonium. Tracers ( $\text{Pu}^{236}$ ,  $\text{Am}^{243}$ ,  $\text{Cm}^{244}$ ) were present during dissolution of all samples except those which were estimated to contain high levels of Pu (and therefore Am) or those for which no reliable estimates of Pu content were available. These were carefully dissolved tracer-free. Separate aliquots were first taken from the tracer-free solutions for Pu analysis, and the Pu analysis was completed to establish the Pu content and thus give a basis for estimating the aliquot size and the amounts of  $\text{Am}^{243}$  and  $\text{Cm}^{244}$  tracers needed for the determination of  $\text{Am}^{241}$ . The amounts of tracers which would have been required for tracer dissolution of the higher level samples would have exhausted the available supply.

The radiochemical separation procedure is outlined in Table 6.2. This procedure was designed to avoid fractionating Am and Cm and therefore was not intended to separate the rare-earth elements, Y, Sc, or Ac, although provision was made to insert an extraction step for this purpose, if necessary. Fortunately, no separation of the rare-earth group was necessary.

The acetyl acetone extraction step was added after it was found that a small amount of Al was still present after Step 5 in the first few samples run. Since the electroplating method used will deposit any element having an insoluble hydroxide, Al would have caused a thick plate. The acetyl acetone extraction was chosen to remove aluminum since it also would extract many other elements which might not have been completely removed in the preceding steps.

Plutonium was stripped from the ion-exchange column of Step 3 with HCl-NH<sub>4</sub>I, after first rinsing the column with HCl. The effluent containing the Pu was boiled down and plated; no additional purification was necessary.

### 6.3 ALPHA SPECTROMETRY

The alpha spectra of the electrodeposited specimens were measured with the same semi-conductor detector system used for the plutonium samples and described elsewhere in this report. The alpha spectrum of an actual sample is shown in Figure 6.1.

### 6.4 RESULTS OF ANALYSIS

The results of the analysis for Am<sup>241</sup> in the Clean Slate III samples are given in Table 6.3. The best mean

value of the  $\text{Pu}^{239,240}/\text{Am}^{241}$  ratio, obtained by taking a non-weighted average of all values with a counting statistical standard deviation of 10 percent or less, is  $64 \pm 4$  as of March 18, 1964. This may be compared with the  $55 \pm 5$  computed from original source analyses done by Dow Chemical Company.

Thus, as nearly as can be determined, Am and Pu did not fractionate in CS III, at least in total air and film deposition collections.

It can be inferred safely that soil samples are likewise unfractionated. On the other hand, this inference does not necessarily apply to individual particles of the debris.

#### 6.5 GROSS ALPHA ELECTRODEPOSITION

Sample #4033 (Clean Slate-II, TAS-II, location F-066) was selected as an especially dirt-free sample of moderate activity for this experiment. It was quantitatively dissolved tracer-free by standard acid treatment, evaporated to a drop or two of  $\text{H}_2\text{SO}_4$ , and diluted with 6 N HCl to 25 ml. A 2-ml aliquot was transferred directly to an electroplating cell and neutralized to the slightly acid condition used in our standard plating procedure. This procedure provides the same electroplating efficiency for all

heavy elements as long as the total plating yield is above 50 to 60 percent. Normally this efficiency is 95 percent or more. This method of simultaneous deposition of several heavy elements has been used here successfully many times in the past.

The plate contained very little dirt, and the observed alpha resolution was a satisfactory 60 kev. Peaks were present only for Pu<sup>239,240</sup> and Am<sup>241</sup> + Pu<sup>238</sup> (inseparable). A 10-ml aliquot of the starting solution was analyzed with Pu<sup>236</sup> tracer to provide the corrected standard analysis result. The total sample Pu<sup>239,240</sup> activity was found to be  $370 \pm 9$  dpm.

The observed alpha ratio of (Am<sup>241</sup> + Pu<sup>238</sup>) to Pu<sup>239,240</sup> was  $0.0270 \pm 0.0015$ . Subtracting the previously observed mean ratio of Pu<sup>238</sup>/Pu<sup>239,240</sup> of  $0.0100 \pm 0.004$  leaves a net Am<sup>241</sup>/Pu<sup>239,240</sup> ratio of  $0.0170 \pm 0.0016$ . This is in good agreement with the mean Roller-Coaster value of 0.0161 (with an estimated standard deviation of about 11 percent) at the same time, 4 February 1964. (No Pu<sup>241</sup> data are available for CS II; thus, the exact Am<sup>241</sup> content of CS II source material cannot be calculated for the time of interest here.) This result confirms the conclusion, based

on the radiochemical determinations of Am<sup>241</sup>, that there is no evidence of Am-Pu fractionation.

Since the great majority of samples sent to H-NSC were dirtier than the one used for this experiment, no additional analyses of this type were run.

TABLE 6.2 OUTLINE OF RADIOCHEMICAL SEPARATION OF AMERICIUM FROM SMALL-RESIDUE ROLLER COASTER SAMPLES

Step	Remarks
1. Precipitate $\text{Fe}(\text{OH})_3$ with $\text{NH}_4\text{OH}$ .	Concentrates Am and Pu from solution.
2. Precipitate $\text{Fe}(\text{OH})_3$ with $\text{NaOH}$ .	Largely removes amphoteric elements, notably Al.
3. Pass 8 M $\text{HNO}_3$ (ctg. $\text{NO}_2^-$ ) solution through a short Dowex-1 anion-exchange column.	Am not adsorbed. Pu (IV) and Th adsorbed.
4. Precipitate $\text{Fe}(\text{OH})_3$ with $\text{NH}_4\text{OH}$ .	Concentrates Am from 8 N $\text{HNO}_3$ effluent of Step 3.
5. Pass 11 N $\text{HCl}$ solution through a short Dowex-1 anion-exchange column.	Am not adsorbed. Fe (III) carrier and many other elements adsorbed.
6. Evaporate and adjust to 5 ml at pH 5. Extract twice with 1:1 acetyl acetone in chloroform.	Am not extracted. Primary purpose is to remove slight amount of Al not removed in Step 2.
7. Electrodeposit on Pt disk using standard procedure (20-minute plating period).	

\*NOTE TO AMERICIUM PROCEDURE: The above procedure is designed to remove all elements except Am, Cm (and trans-Cm), rare earths, Y, Sc and Ac. If the rare earths Y or Sc had been found to be present in amounts which would have degraded the alpha spectrum, the following extraction would have been added after Step 6: Extract Am and Cm into 0.6 M Alamine-336 (tricaprylylamine) in diethylbenzene from 11 N  $\text{LiCl}$  - 0.02 N  $\text{HCl}$ . Strip Am-Cm from the organic phase with 5 N  $\text{HCl}$ . Repeat extraction cycle as often as necessary to reduce the concentration of the interfering elements to a negligibly low level. (This extraction may fractionate Am and Cm, thus invalidating the use of  $\text{Cm}^{244}$  as a yield tracer for  $\text{Am}^{241}$ ).

TABLE 6.3 RESULTS OF Am<sup>241</sup> ANALYSIS, CLEAN SLATE III

Location	Sampler Type	Tracer-lab No.	Am <sup>241</sup> (a)	Pu <sup>239,240</sup>	[ Pu <sup>239,240</sup> / Am <sup>241</sup> ]		(Am <sup>243</sup> /Cm <sup>244</sup> ) Found (b)
					dpm/sample		
BM-05.0	TAS-D	5158	38. ± 2	2.71 ± 0.07 x 10 <sup>3</sup>	71 ± 4	1.23 ± 0.07	
A-036	"	5185	56. ± 5	3.7 ± 0.1 x 10 <sup>3</sup>	66 ± 6	1.14 ± 0.08	
J-040	"	5084	154. ± 5	9.6 ± 1.6 x 10 <sup>3</sup>	62 ± 2	1.30 ± 0.04	
CSI-E-000	"	5200	0.79 ± 0.20	56.1 ± 1.45	71 ± 18	1.14 ± 0.05	
CSI-F-000	"	5201	1.25 ± 0.22	76.6 ± 1.2	61 ± 11	1.18 ± 0.05	
CSI-N-024	"	5195	1.36 ± 0.12	93. ± 4.	68 ± 7	1.14 ± 0.03	
CSI-N-030	"	5196	0.40 ± 0.20	28.3 ± 0.09	71 ± 36	1.16 ± 0.05	
CSI-N-036	"	5197	-0.07 ± 0.31	11.1 ± 0.06	-160 ± 710	1.19 ± 0.03	
D-030	TAS-II	5149	10.6 ± 1.5	1.52 ± 0.04 x 10 <sup>3</sup>	143 ± 20	1.11 ± 0.04	
F-042	"	5054	15.5 ± 0.9	1.04 ± 0.06 x 10 <sup>3</sup>	67 ± 6	1.32 ± 0.07	
H-042	"	5035	10.7 ± 1.3	920. ± 100	86 ± 14	1.28 ± 0.16	
L-054	"	5113	0.32 ± 0.28	32. ± 3.	100 ± 90	1.10 ± 0.07	
BM-02	Film	8153	1.44 ± 0.07 x 10 <sup>5</sup>	8.93 ± 0.06 x 10 <sup>6</sup>	62 ± 3	1.20 ± 0.05	
CO-05.0	"	8152	2.90 ± 0.04 x 10 <sup>5</sup>	1.79 ± 0.08 x 10 <sup>7</sup>	62 ± 3	1.28 ± 0.03	
C-026 A	"	8155	2.82 ± 0.09 x 10 <sup>5</sup>	1.79 ± 0.07 x 10 <sup>7</sup>	64 ± 3	1.17 ± 0.04	
D-030	"	8156	2.50 ± 0.06 x 10 <sup>5</sup>	1.45 ± 0.03 x 10 <sup>7</sup>	58 ± 2	1.20 ± 0.03	
E-032	"	8157	1.35 ± 0.03 x 10 <sup>5</sup>	7.9 ± 0.2 x 10 <sup>6</sup>	58 ± 2	1.24 ± 0.03	
F-036	"	8158	8.1 ± 0.3 x 10 <sup>4</sup>	4.75 ± 0.10 x 10 <sup>4</sup>	59 ± 3	1.23 ± 0.04	
H-034	"	8160	445. ± 12	2.93 ± 0.06 x 10 <sup>6</sup>	66 ± 2	1.27 ± 0.04	
J-038	"	8161	201. ± 7.	1.27 ± 0.03 x 10 <sup>3</sup>	63 ± 3	1.23 ± 0.05	
L-038	"	8162	8.17 ± 0.40 x 10 <sup>3</sup>	5.65 ± 0.08 x 10 <sup>6</sup>	69 ± 4	1.18 ± 0.05	
Mean					64 ± 4(c)	1.20 ± 0.06(b)	

(a) Mean of values obtained via Am<sup>243</sup> tracer and via Cm<sup>244</sup> tracer, as of 18 March 1964.

(b) Ratio of Am<sup>243</sup>/Cm<sup>244</sup> added = 1.26 ± 0.02.

(c) Mean (Pu<sup>239,240</sup>/Am<sup>241</sup>) ratio of 14 samples with counting statistical standard deviations ≤ 10%.

Standard deviation about mean (+ 4) (6%).  
Standard deviation of mean (± 1) (1.6%).

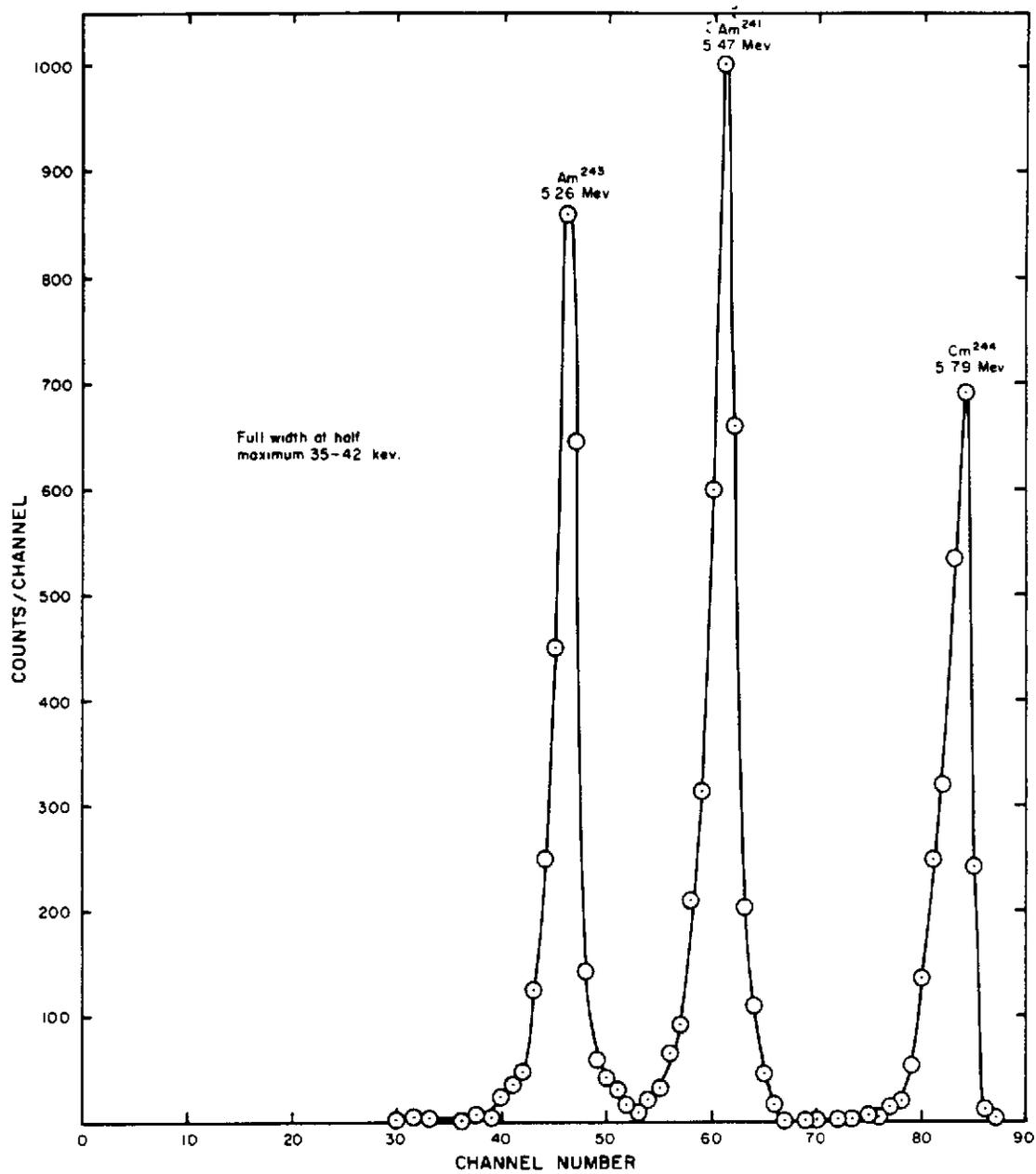


Figure 6.1 Alpha spectrum of electrodeposited americium sample.

## CHAPTER 7

### DETERMINATION OF PLUTONIUM IN LARGE SOIL SAMPLES BY GAMMA-RAY SPECTROMETRY

A difficult problem facing all of the radiochemical contractors was the determination of plutonium in kilogram amounts of soil collected as relatively close-in deposition (throwout) samples or as corings. Several attempts in other laboratories at obtaining smaller representative samples by dry aliquoting had been unsuccessful, even after thorough grinding and blending operations. Presumably, this failure was due to the fact that the large amounts of soil contained only a relatively small number of plutonium particles, and this small number was not increased significantly by the grinding operations. Attempts at partial dissolution or leaching plutonium from soil were reasonably successful but required such large solution volumes and lengthy procedures that analytical costs were prohibitive. For the same reasons, complete dissolution of the kilogram soil samples and separation of the plutonium were not attempted.

The simplest possible solution to this problem appeared to be the determination of plutonium using gamma-ray spectrometry. Relatively thin samples of Roller Coaster

plutonium were known to show both the 17-keV uranium L x-rays following alpha decay of plutonium isotopes and the 59.6-keV gamma ray (hereafter referred to as the 60-keV gamma ray) of the  $\text{Am}^{241}$  daughter of  $\text{Pu}^{241}$ . The 60-keV gamma transition occurs in 35.9 percent of the  $\text{Am}^{241}$  disintegrations.

Of the scintillation detectors available in the H-NSC laboratory, an 8-inch diameter by 4-inch thick NaI(Tl) crystal appeared to be the best one to use for these large samples, since it would give the best counting geometry with minimum sample thickness. This detector was connected to a 400-channel pulse-height analyzer for use in other work. Preliminary measurements with this detector using a thin source of Roller Coaster plutonium showed that, although there was a prominent 60-keV peak, there was no detectable 17-keV peak. Failure to detect the 17-keV radiation was due to its virtually complete absorption by the stainless steel housing of the crystal. Thus, the 60-keV gamma ray of  $\text{Am}^{241}$  was the only possibility for the gamma spectrometric determination of plutonium with the 8-inch by 4-inch detector. However, the 60-keV radiation would have been selected for measurement even if an intense 17-keV peak had been detected in the thin-source spectrum because of the

disadvantage of the much greater self-absorption of the 17-kev radiation in large soil samples. For example, it was estimated that, assuming soil had an effective atomic number of 14 (silicon), the transmission of 17-kev radiation through a  $1.5 \text{ g/cm}^2$  soil specimen (1 cm thick with bulk density of  $1.5 \text{ g/cm}^3$ ) would be only about 0.0007 as compared to about 0.7 for the 60-kev radiation. Thus, the use of the 17-kev radiation would have effectively measured only the plutonium in a thin surface layer of the soil samples.

#### 7.1 INITIAL MEASUREMENTS (CS II SAMPLES)

The initial measurements were made on a group of eight CS II soils ranging in weight from 842 to 1081 grams, plus an Aluminum Collector sample consisting of 5.7 grams of dirt. These samples were loaded into circular polystyrene boxes, 6-inch diameter by  $1\frac{1}{2}$ -inches high. This size just contained the heaviest sample; thus, the bulk density was about  $1.5 \text{ g/cm}^3$ . (Subsequently the average density of 34 samples from all four events was found to be  $1.50 \pm 0.20 \text{ g/cm}^3$  with a range of 1.2 to  $2.4 \text{ g/cm}^3$ ).

##### 7.1.1 Correction for Natural Radioactivity in the Soils.

Not surprisingly, the soils were found to contain appreciable amounts of natural radioactivity. The content of Th, U, and

K was estimated by comparing the gamma-ray spectrum (to 3 Mev) of a preshot CS II soil blank with the spectra of known amounts of natural Th (monazite) and U (carnotite) (in equilibrium with their daughters) in synthetic simulated soils and of natural K as reagent-grade  $K_2CO_3$ . Further comparisons were made with depleted  $U^{238}$  samples, which exhibited a different spectral shape; in no case was it reasonable to suppose that uranium from the Roller Coaster events contributed to the observed counting rates.

The 2.61-Mev peak of  $Tl^{208}$  (ThC'') was used to measure Th, the 1.76-Mev peak of  $Bi^{214}$  (RaC) was used to measure U, and the 1.46-Mev peak of  $K^{40}$  was used to measure K. The results were 14 ppm Th, 2 ppm U, and 3 percent K. The preshot fallout (fission-product) activity was low relative to the natural activity. The only peak detected which could not be attributed to natural radioactivity was one at about 130 kev, which was attributed to the fission products  $Ce^{144}$ - $Pr^{144}$ .

In a soil sample containing Pu (Am), the 60-kev peak was on the low-energy side and overlapping a somewhat broad natural-activity peak at ~ 80 kev. Both the natural Th and U series have peaks at about 80 kev. Of course, the higher-energy gamma rays of all of the natural activities

contributed to the Compton continuum under the 60-kev peak as well. Consequently, it was found that the sensitivity of this method was limited by the counting rate of the natural activity in the soil since this was substantially greater than the background counting rate of the detector in the energy region of interest.

To obtain maximum precision in the net plutonium counting rates, the plutonium and soil activities were resolved by an analytic method, rather than a graphic method. Graphic methods were rejected as being subjective and inherently less precise, particularly for sample counting rates low relative to the blank.

Plutonium and soil activities were resolved by solving two simultaneous equations expressing the counting rates in two energy regions of the spectrum as the sums of the plutonium and the soil counting rates. The net plutonium counting rate in the 60-kev energy region then was given by the equation:

$$A_1^p = \frac{A_1 - A_2 (A_1^s / A_2^s)}{1 - (A_2^p / A_1^p) (A_1^s / A_2^s)} \quad (7.1)$$

where: A is a counting rate, the subscripts 1 and 2 refer, respectively, to regions 1 (~60 kev), and 2 (~80 kev),

of the gamma-ray spectrum, and the supercripts, p, and s, refer, respectively, to plutonium and to soil-blank. The number of channels in the two energy regions were equal; one group of channels was centered on the 60-kev peak region 1 and the other was adjacent on the high energy side (region 2). The relative contributions of Pu and of soil to each of the regions (i.e. the values of the ratios  $A_2^P/A_1^P$  and of  $A_1^S/A_2^S$ ) were determined using, respectively, an evaporated reference Roller-Coaster Pu source and a preshot soil blank from the CS II area. The amount of Pu activity in the higher-energy region was not negligible, being several percent of the 60-kev peak activity. In effect, this computational method used the soil blank sample to determine the shape of the spectrum of natural gamma-radiation for all samples but did not involve any assumption of equal concentration of natural activity in the different samples.

Examples of the magnitudes of the counting rates and counting-rate ratios found are given in the following sample calculation, using the above equation, of the net counting rate for 1081-gram soil sample containing 10.8 micrograms of plutonium.

$$A_1^p = \frac{976 - 583 (0.534)}{1 - (0.0294) (0.534)} = 676 \text{ c/min} \quad (7.2)$$

7.1.2 Illustrative Gamma-Ray Spectra. Gamma-ray spectra of thin reference sources of Roller Coaster plutonium, of pure Am<sup>241</sup>, of a soil blank, and of varying amounts of plutonium in different soil samples (weighing about 1 kg) are illustrated in Figures 7.1 through 7.11. These spectra are reproductions of Polaroid photographs of the oscilloscope display of the pulse-height analyzer. The energy region covered is approximately 0 to 200 kev.

7.1.3 Non-Uniform Distribution of Plutonium in the Soils. From the previous work in other laboratories, it was expected that a non-uniform distribution of plutonium would occur within the samples. To estimate the effect of these non-uniformities on the measured sample counting rates, each sample was counted both face up and face down on the 8-inch by 4-inch crystal, with the results shown in Table 7.1. (These containers were too full to be re-distributed thoroughly by shaking.)

The counts shown are the integrals under the 60-kev peak corrected for instrument background. The two lowest activity samples contain a large proportion of natural

radioactivity and so might not be expected to differ greatly.

TABLE 7.1 COMPARISON OF 60-KEV PEAK COUNTING RATES FOR CS II SOIL SAMPLES COUNTED FACE UP AND FACE DOWN

H-NSC Sample No.	Up	Down	Mean
	Net Counts/5 min.		cpm
2029	8964	8900	1786 + 1%
2030	17014	16701	3372 ± 2%
2031	5899	5847	1175 ± 1%
2032	5374	5068	1044 ± 6%
2033	1715	1755	347 ± 2%
2034	2804	2973	578 ± 6%
2035	1483	1548	303 ± 4%
2036	4785	4976	976 ± 4%

It can be seen that the standard deviation of the mean counting rate is generally not much greater than expected from counting statistics and is definitely less than was expected. Subsequently, measurement of samples from other test shots did not indicate this degree of uniformity.

The magnitude of the errors due to possible non-uniform distribution of plutonium in the samples was estimated by considering two limiting cases for a 1000-gram sample. If the plutonium were concentrated at one face of the sample, the plutonium content, obtained from the average of the face-up and face-down counting rates, would

be 21 percent higher than the true value; however, the standard deviation of this mean value when estimated from the range of the two counting rates would be 44 percent, or slightly more than twice the actual error. If the plutonium were concentrated in a thin 6-inch diameter circular layer in the exact center of the sample, the value calculated from the mean of the two (equal) counting rates would be 9 percent higher than the true value with a zero theoretical standard deviation estimated from the range of the (equal) counting rates. Since both of these conditions were highly improbable, it was concluded that it was entirely feasible to assay large dirt specimens with acceptable precision by the use of gamma spectrometry alone.

#### 7.1.4 Determination of Counting Efficiency, CS II.

The most straight-forward method of determining the counting efficiency as a function of sample size would have been to count several weights of soil blanks, spiked with known amounts of CS II plutonium; but neither of these materials was available in sufficient quantity. However, several thin sources of Roller Coaster plutonium, prepared by evaporation to preserve the original Pu/Am ratio, were available, so a semiempirical correction curve was developed

to relate the counting efficiency of a thick sample to that of an infinitely-thin sample. This curve was prepared by considering separately the changes in counting efficiency due to differences in sample height and due to self-absorption and then combining these into a single correction curve.

The variation in counting efficiency with sample height (geometry correction) for samples having no self-absorption was obtained by numerical integration of a curve of counting rate versus height above the crystal for an infinitely thin source having the same diameter (6 inches) as the soil samples. The infinitely thin source used was a 5.7 gram soil (aluminum-collector) sample, containing 87  $\mu\text{g}$  of plutonium uniformly spread over the bottom of one of the sample boxes.

The self-absorption of the samples was assumed to be described by the equation:

$$\frac{A}{A_0} = \frac{1 - e^{-\mu x}}{\mu x} \quad (7.3)$$

where:  $A$  is the measured activity,  $A_0$  is the activity with no self-absorption,  $\mu$  is the mass-absorption

coefficient ( $\text{cm}^2/\text{g}$ ), and  $x$  is the sample thickness ( $\text{g}/\text{cm}^2$ ). This equation is derived in most radiochemistry reference texts as an approximate beta-ray self-absorption correction, but, since exponential attenuation is assumed in the derivation, it applies even more closely to the present problem of a low-energy gamma-emitting material.

The mass absorption coefficient was empirically determined by measuring the transmission of 60-kev radiation through CS II soil samples which contained only relatively small amounts of plutonium. (The CS II soil blank had not been obtained at that time.) The source used for the transmission measurement was the same 6-inch diameter infinitely-thin source used to determine the geometry correction described above. The mass-absorption coefficient so determined was  $0.233 \text{ cm}^2/\text{g}$ . Somewhat larger values were obtained using smaller-diameter sources because of the greater mean path length through the sample. Smaller values were obtained using the hottest soil as a source because its thickness permitted the upper edges of the source to be viewed directly by the crystal with only minor sample attenuation.

To test the validity of these corrections for geometry and self-absorption, one of the CS II samples containing a relatively high concentration of plutonium was removed from its container, then loaded back in seven increments. The amount of Am<sup>241</sup> (60-kev radiation) was measured after each addition. Corrections for geometry and self-absorption were applied separately to the observed specific activities, as shown in Table 7.2.

TABLE 7.2 VARIATION IN SPECIFIC ACTIVITY OF 60-KEV RADIATION WITH SAMPLE THICKNESS

Layer Weight	Observed Specific Activity	Reciprocal of Absorption Correction Factor	Absorption-Corrected Specific Activity	Geometry Correction Factor	Final Corrected Specific Activity
grams	cpm/gram		cpm/gram		cpm/gram
123	5.24	0.930	5.63	1.015	5.71
273	4.92	0.846	5.81	1.032	6.00
394	4.46	0.791	5.64	1.051	5.93
512	4.16	0.740	5.62	1.070	6.01
630	3.82	0.690	5.54	1.090	6.04
805	3.34	0.627	5.33	1.120	5.97
938	3.04	0.585	5.20	1.143	5.94
				Mean	5.94 ± 2%

It can be seen that, although the uncorrected specific activities have a spread of 70 percent, the standard deviation of the corrected values is only 2 percent, demonstrating

the validity of the correction methods. Such remarkably good agreement could not, of course, have been obtained if the distribution of Pu in this particular sample had not been comparatively uniform.

A combined correction curve for the effects of self-absorption and geometry was prepared for the CS II samples and is shown in Figure 7.12.

The counting efficiency for an infinitely thin source of plutonium was obtained by counting the most active evaporated Roller-Coaster plutonium standard face down on the bottom of a sample container box on the detector crystal. (This use of the standard is discussed later in this chapter.) Since the diameter of this source was less than the six-inch diameter of the samples, it was necessary to determine whether there was any variation in counting efficiency over the full (six-inch diameter) sample area. This was tested by counting a point-source of  $\text{Am}^{241}$  across several diameters of the detector face. The counting rates were within 1 percent, as expected for a gamma-ray of this relatively low energy which is absorbed near the face of the crystal.

## 7.2 ASSAY OF ADDITIONAL SAMPLES

Because of the success of this method with the first eight CS II samples, additional CS II samples and samples from the other Roller Coaster events were sent to H-NSC for analysis. These included soil belt monitor samples in addition to throwout and surface core samples.

7.2.1 Differences in Correction Factors. Corrections were measured using the method previously described but with a slightly different value of the mass absorption coefficient based on additional transmission measurements on pretest soils. Soil-blank samples for each of the other three events were obtained in addition to the one previously obtained for CS II. The mean mass-absorption coefficient for the four uncontaminated soils was  $0.245 \pm 0.009$  (3.7 percent). Since the range of the individual values for blanks from the four different events (and locations) was no greater than the range of two values from a single event (CS II), the single average value for all four events was justified. The correction curve used for all samples, except the initial 8 CS II samples, is shown in Figure 7.13. For a 1-kg sample, the overall efficiency factor used for the initial 8 CS II samples is only 3.1 percent

higher than the factor used for the remainder of the samples. A slightly different spectral shape factor (the ratio of natural activity counting rates in the two energy regions) was used for samples from each event; these were determined from the blank samples.

7.2.2 Differences in Sample Packaging. Samples received from Tracerlab, Inc., were transferred to the polystyrene boxes described above. Some of these samples were too large to fit into a single container and were split between two containers. All of these samples were counted both face up and face down.

Samples received from Isotopes, Inc., had been loaded into circular polyethylene food containers, about 3-3/4 inches high, at Isotopes, Inc. Since the dimensions of the bottom of their food container was not significantly different from those of the H-NSC polystyrene box, it was not necessary to transfer the samples before counting. However, the diameter of the top of the polyethylene container was greater than the diameter of the bottom, so these samples were not counted face up and face down. To estimate the effect of non-uniform distribution of plutonium, the samples were counted once, then shaken thoroughly to redistribute the plutonium and counted again.

Soil belt monitor samples received from Eberline Instrument Co. were enclosed in flat polyethylene bags which had been employed in the simulated belt monitor experiments. Most of these were too large to fit into single polystyrene boxes, but it was possible to fit them into three-inch high boxes made by taping together two regular box bottoms. The bag containing the sample was set in one box bottom, the bag was cut open (removing excess polyethylene from the top of the bag), the other box bottom was used to form a top, and two halves were taped together. Then, the taped box could be shaken to distribute the soil uniformly over the bottom. All of these samples were counted both face up and face down. A few of the large samples were split and recounted, after counting the total sample, to see whether there was any significant difference in the results; none was found. The excess polyethylene cut from the bags was counted separately and, in all cases, found to contain a negligible amount of plutonium. The results for these ten samples, as originally reported, were calculated using weights given by Eberline. The samples were subsequently weighed in our laboratories giving weights which were 5 to 12 percent lower than the Eberline weights. The Pu results reported here are based on H-NSC weights.

Finally, four Aluminum-Collector samples, consisting of two-to-21 grams of dirt, were obtained from USNRDL to supplement the single sample measured in the initial CS II group and were transferred to the polystyrene boxes for counting. Duplicate counting measurements were made, shaking the box between measurements to redistribute the plutonium.

All boxed soil samples were placed inside sealed polyethylene bags for counting to minimize the possibility of contaminating the counter or laboratory.

### 7.3 CONVERSION OF CORRECTED COUNTING RATES TO PLUTONIUM DISINTEGRATION RATES AND WEIGHTS

As mentioned before, the most active of three evaporated Pu reference sources (all marked 63-UK-106-RC) was used to obtain the conversion factor for americium-241 60-kev counting rate (corrected for self-absorption and geometry) to Pu<sup>239,240</sup> disintegration rate. A specific activity of  $1.45 \times 10^5$  alpha d/min Pu<sup>239,240</sup> per microgram of Pu was used to convert the disintegration rates to weights Pu.

In calculating the results for the first 8 CS II samples, it was assumed that the specified disintegration

rate of "1,368,743 d/min" was that of Pu<sup>239,240</sup>. Subsequently it was learned that this assumption was incorrect; the disintegration rate given was the total alpha disintegration rate, including Pu<sup>238</sup> and Am<sup>241</sup>, as of 1 May 1963. Consequently, the Pu<sup>239,240</sup> disintegration rates had to be adjusted. Corrected values are given in Table 7.3.

The total alpha disintegration rate of the two lower-activity evaporated Pu reference sources (containing 3289 d/min and 32,930 d/min) was independently determined by comparing their counting rates with that of an electroplated U<sup>233</sup> standard in a 2 $\pi$  proportional counter. The

H-NSC results agreed with the stated values within the counting statistical error (0.7 percent relative standard deviation). The "1,368,743 d/min" source, used for the gamma-ray measurements, was not alpha counted because of the possibility of partial loss of sample in removing the plate from its polyethylene bag and because the 2 pi counting rate would have required a coincidence-loss correction which could not be precisely determined.

The  $\text{Am}^{241}$  content of the "1,368,743 d/min" source was measured independently at H-NSC by comparing its 60-kev peak counting rate with those of a pure independently standardized  $\text{Am}^{241}$  source and of a Roller Coaster Pu source of known  $\text{Am}^{241}$  content. The Pu source was one of the more active plates obtained from radiochemical analyses; its  $\text{Am}^{241}$  content was calculated from the in-growth time since chemical separation of Am, assuming an average Roller-Coaster  $\text{Pu}^{241}/\text{Pu}^{239,240}$  ratio. A  $\text{Pu}^{239,240}/\text{Am}^{241}$  activity ratio of  $56 \pm 1$  as of 4-1-64 was obtained; the corresponding value calculated from analytical data supplied with the source was  $55 \pm 4$ .

#### 7.4 RESULTS OF ANALYSIS

The results of all gamma-spectrometric measurements of soils are summarized in Table 7.3.

The associated error limits (percent standard deviation) were estimated from the larger of two estimates:

1. from combining the counting statistical errors.
2. from the range of results obtained from the face up and face down counting rates for samples counted in this manner; or, in other cases, from the range of results obtained from the duplicate counting measurements made before and after shaking to redistribute the sample.

For one group of samples, indicated by an asterisk beside the "% S.D." in the table, there was an uncertainty in the energy calibration, due to a slight change in the gain of the electronic system during the measurement period. It was estimated that, due to this uncertainty, the minimum standard deviation, in absolute units, was  $1.5 \times 10^4$  d/min (or its equivalent, 0.1 microgram Pu). Thus the "% S.D." reported for the samples in this group was based on this minimum absolute value if it gave a greater "% S.D." than the two estimates described above.

## 7.5 MINIMUM DETECTABLE QUANTITY OF PLUTONIUM

As mentioned previously, the detection of Pu in soils by the method described here is limited by the level of natural radioactivity in the soils. Considering only the counting statistics, and assuming a 1-kg sample counted for 500-minutes with a blank sample counted for an equal length of time, a standard deviation of  $\pm 0.03 \mu\text{g}$  Pu was calculated for a sample whose counting rate was equal to, or only slightly greater than, the counting rate of the blank. On this basis, the minimum detectable quantity, when defined as that quantity having a 33 percent S.D., is 0.1  $\mu\text{g}$ . This value would be greater for larger samples.

A more conservative (and subjective) estimate, allowing for slight instrument gain shift between measurements, is three times the above quantity, or 0.3  $\mu\text{g}$  for a 1-kg sample.

TABLE 7.3 DETERMINATION OF PLUTONIUM IN SOILS BY GAMMA SPECTROMETRY OF THE 60-keV GAMMA-RAY OF  $^{241}\text{Am}$

Tracer-Lab No.	Location	Packaging (a)	Sample Type (b)	Weight(s) (grams) (c)	$\text{Pu}^{239,240}$		
					d/min	ug	% C.D. (d)
DOUBLE TRACKS							
8052	R-050	PS-D	Core	1423.	$3.07 \times 10^4$	.22	42. *
8052	N-050	PS-D	"	1178.	$5.59 \times 10^4$	.39	22. *
8052	L-050	PS-D	"	1275.	$1.26 \times 10^5$	.89	10. *
8052	F-050	PS	"	1142.	$2.07 \times 10^5$	1.43	28. *
(None)	D-060	PS	Al Coll.	1.7 (2.3)	$1.88 \times 10^6$	129.	0.2 *
CLEAN SLATE I							
(None)	C-020	PS	Al Coll.	5.5 (3.6)	$1.15 \times 10^7$	79.61	1.7 *
(None)	BK-06	PS	Al Coll.	23.2 (20.6)	$5.66 \times 10^7$	3903.9	0.2 *
8058	O-030	PE	Core	1157. (1000.)	$1.87 \times 10^5$	1.29	10. *
8058	N-032	PE	"	1012.	$5.10 \times 10^4$	.35	10. *
8058	J-030	PE	"	993.	$4.26 \times 10^5$	2.93	10. *
8058	H-032	PE	"	978.	$3.21 \times 10^4$	.23	10. *
8058	F-022	PE	"	1148.	$3.74 \times 10^5$	2.58	10. *
8058	D-030	PE	"	981.	$1.13 \times 10^6$	7.76	10. *
CLEAN SLATE II							
8164	B-024	PS	"	943.	$5.91 \times 10^5$	40.75	3. *
"	C-024	PS	"	903.	$2.80 \times 10^6$	19.29	2. *
"	E-024	PS	"	1053.	$1.54 \times 10^6$	10.64	2. *
"	F-024	PS	"	842.	$1.66 \times 10^6$	11.45	3. *
"	G-024	PS	"	1081.	$1.42 \times 10^6$	9.74	3. *
"	I-030	PS	"	939.	$.158 \times 10^6$	1.06	2. *
"	J-026	PS	"	1001.	$.59 \times 10^6$	4.06	13. *
"	L-030	PS	"	1054.	$.063 \times 10^6$	.43	10. *
9843	E-070	PS	Al Coll.	5.70	$11.36 \times 10^6$ (e)	78.3	2. *
0038	GZ, P-2-14	PG-D	Throw	1232. (1590)	$2.45 \times 10^7$	169.	1.5 *
0040	GZ, P-1-15	PS-D	Throw	1149. (1270)	$3.92 \times 10^7$	270.	3.5 *
0041	GZ, P-2-7	PE	Throw	368. (820)	$3.99 \times 10^7$	275.	2.5 *
0042	GZ, P-2-10	PS-D	Throw	945. (1360)	$7.31 \times 10^6$	504.	1.0 *
0044	GZ, P-2-15	PS	Throw	293. (730)	$1.37 \times 10^7$	938.	0.3 *
(None)	A-030a	PS	Al Coll.	10.2 (10.0)	$1.38 \times 10^7$	94.8	1.4 *
0051	GZ, P-2-4	PE	Throw	327. (383)	$1.63 \times 10^6$	1121.	0.2 *
0050	GZ, P-2-5	PE	Throw	350. (500)	$1.10 \times 10^6$	755.	1.0 *
0046	GZ, P-2-9	PE	Throw	320. (400)	$2.72 \times 10^6$	187.	0.5 *
Belt Monitor No.							
0120	P-13	PS	Belt	1663. (1772)	$4.45 \times 10^7$	308.	9. *
0122	P-6	"	"	1721. (1857)	$96 \times 10^8$	665.	11. *
0126	P-21	"	"	1321. (1517)	$1.08 \times 10^8$	742.	1. *
0130	P-22	"	"	867. (984)	$96 \times 10^7$	686.	1. *
0131	P-24	"	"	1701. (1833)	$6.32 \times 10^8$	435.	10. *
0132	P-20	"	"	1678. (1813)	$1.79 \times 10^8$	1226.	12. *
0138	P-19	"	"	1731. (1862)	$8.18 \times 10^7$	563.	7. *
0139	P-18	"	"	1663. (1793)	$4.53 \times 10^7$	311.	0.4 *
CLEAN SLATE III							
0140	P-2	"	"	2028. (2143)	$5.64 \times 10^7$	387.	1. *
0144	P-6	"	"	1927. (2035)	$4.92 \times 10^7$	339.	12. *
Location							
8186	J-036	PS	Core	850.	$6.66 \times 10^5$	4.59	7. *
"	H-040	"	"	1041.	$5.09 \times 10^5$	3.51	11. *
"	G-030	"	"	868.	$1.58 \times 10^6$	10.8	1. *
"	E-036	"	"	840.	$1.12 \times 10^6$	7.67	15. *
"	D-040	"	"	905.	$2.02 \times 10^6$	1.39	10. *
"	C-040	"	"	900.	$5.36 \times 10^4$	.37	2. *

- (a) PS - Polystyrene Boxes; PE - Polyethylene food container; D - Sample divided between two containers and each fraction measured separately. The summed result is given.
- (b) "Core" = Soil core sample; "Throw" = Throwout sample, "Belt" = Belt monitor sample; Al Coll. = Al-collector sample.
- (c) When two values are listed, the first value is the H-NCC-measured weight used to obtain the value for relative counting efficiency; the second value, in parentheses, is the weight given by the laboratory sending the samples to H-NCC.
- (d) The percent standard deviation listed is the highest of the values obtained from:
- 1) Counting statistics
  - 2) The range of results obtained by counting "face-up" and "face-down", or by counting before and after mixing by shaking.
- or, for asterisked values only,
- 3) 0.1 ug (or equivalent d/min) Pu.

See text for more complete explanation.

- (e) The Pu in this sample was subsequently determined radiochemically giving a value of  $(1.26 \pm 0.03) \times 10^6$  d/min.



Figure 7.1 Evaporated Roller Coaster Pu reference source,  $1.37 \times 10^6$  d/min, counted 10 minutes, 5,000 counts/channel full scale.

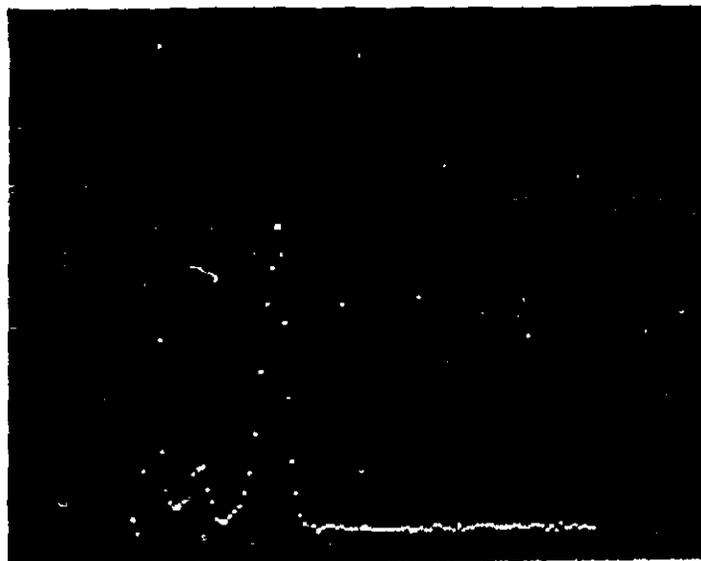


Figure 7.2 Pure  $\text{Am}^{241}$  source,  $1.48 \times 10^4$  d/min, counted 10 minutes, 2,000 counts/channel full scale.



Figure 7.3 Approximately 50  $\mu\text{g}$  Pu, in soil, counted 5 minutes, 5,000 counts/channel full scale.



Figure 7.4 Approximately 25  $\mu\text{g}$  Pu, in soil, counted 5 minutes, 2,000 counts/channel full scale.

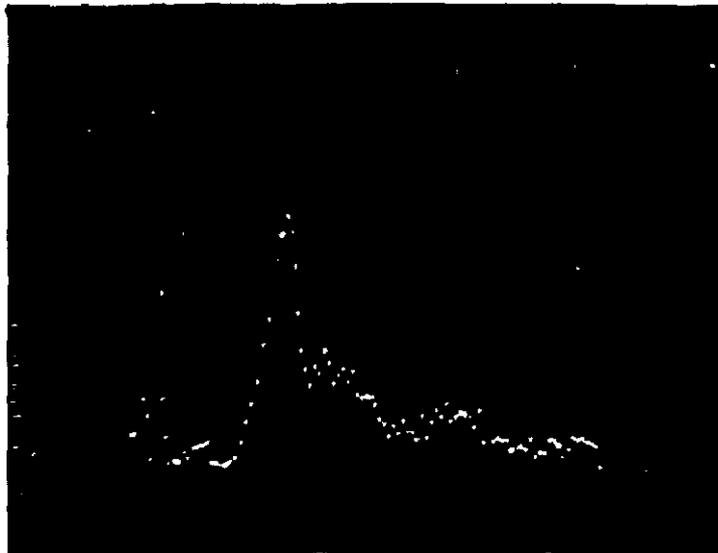


Figure 7.5 Approximately 10  $\mu\text{g}$  Pu, in soil, counted 5 minutes, 1,000 counts/channel full scale.

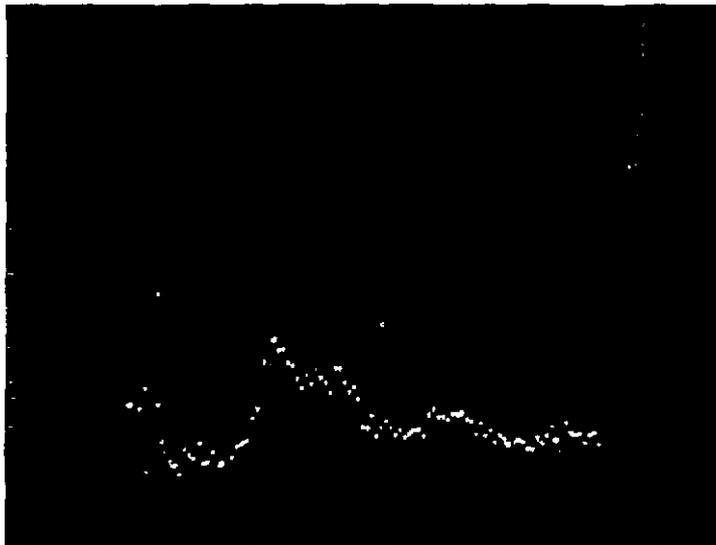


Figure 7.6 Approximately 4  $\mu\text{g}$  Pu, in soil, counted 5 minutes, 1,000 counts/channel full scale.

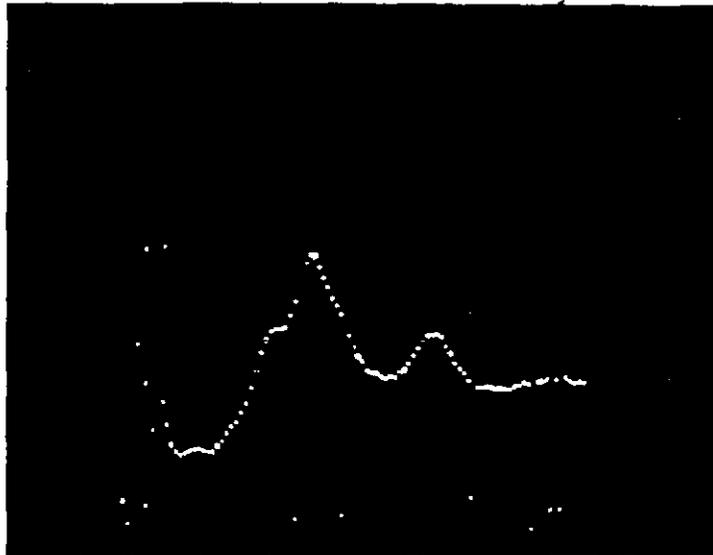


Figure 7.7 Approximately 1.2  $\mu\text{g}$  Pu, in soil, counted 500 minutes, 50,000 counts/channel full scale (few channels dropped counts).

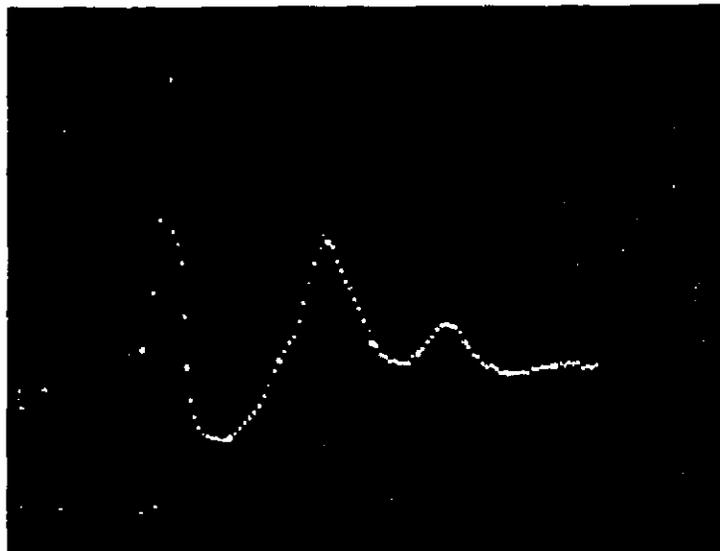


Figure 7.8 Approximately 0.5  $\mu\text{g}$  Pu, in soil, counted 500 minutes, 50,000 counts/channel full scale.

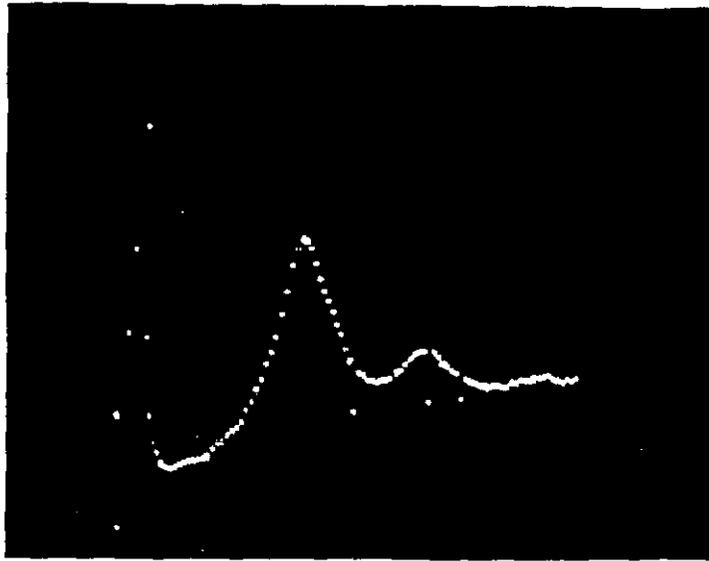


Figure 7.9 Blank soil (no Pu), counted 500 minutes, 50,000 counts/channel full scale (few channels dropped counts).

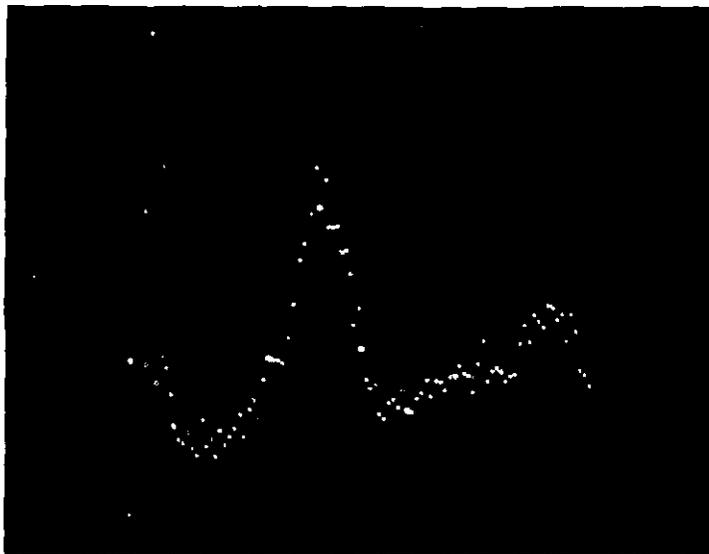


Figure 7.10 Natural U (carnotite) (25 mg) in synthetic soil, counted 10 minutes, 500 counts/channel full scale.

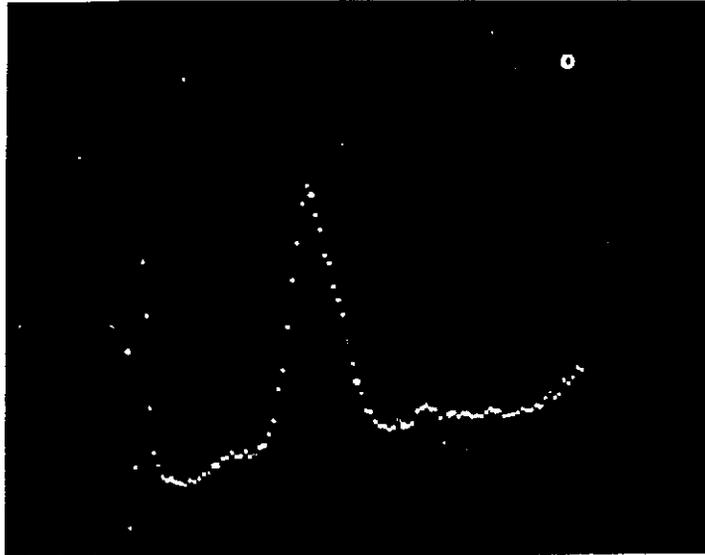


Figure 7.11 Natural Th (monazite) (70 mg) in synthetic soil, counted 10 minutes, 5,000 counts/channel full scale.

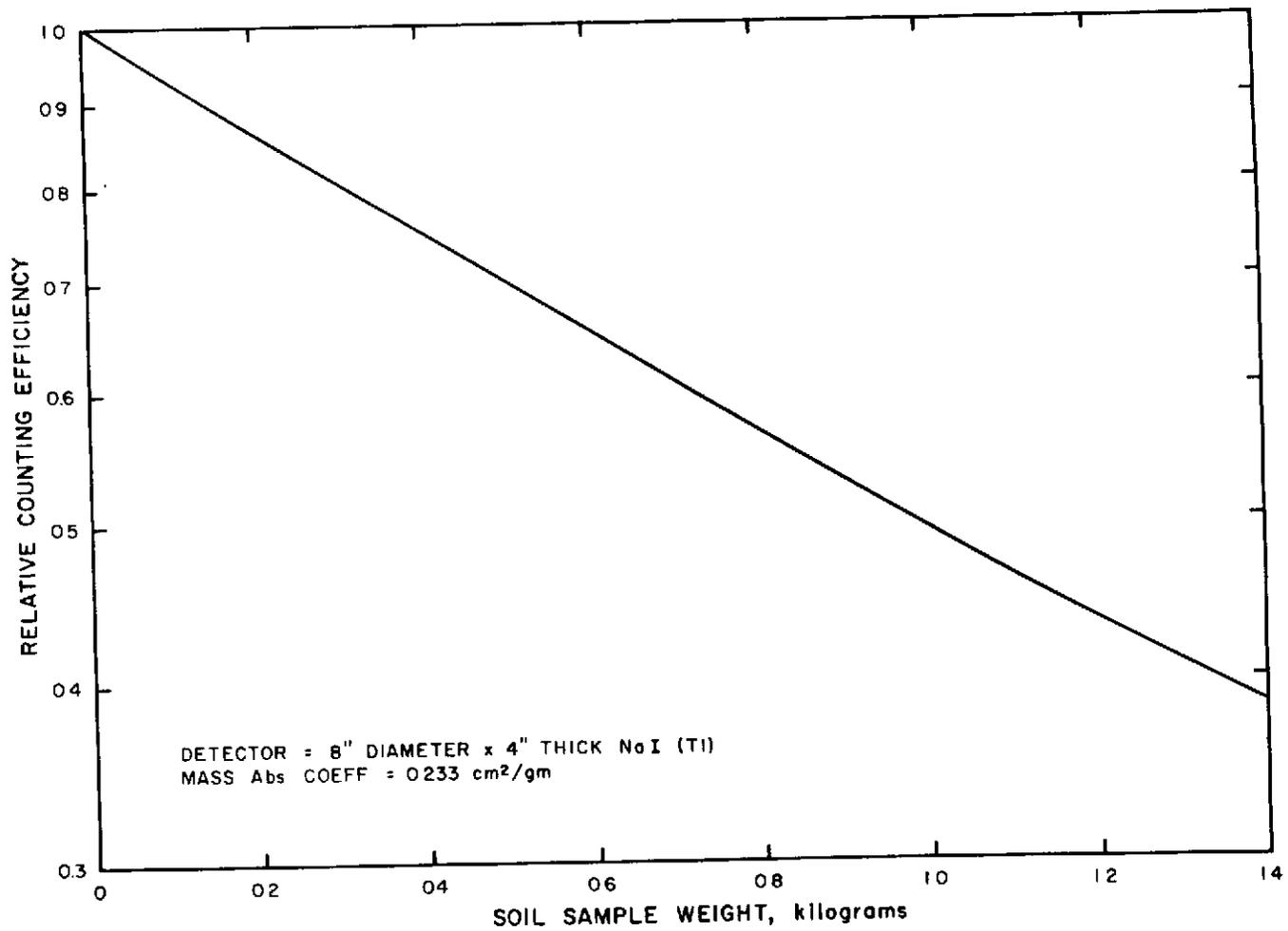


Figure 7.12 Relative counting efficiency of the 60-keV gamma-ray of Am<sup>241</sup> in initial Clean Slate II soil samples as a function of sample weight.

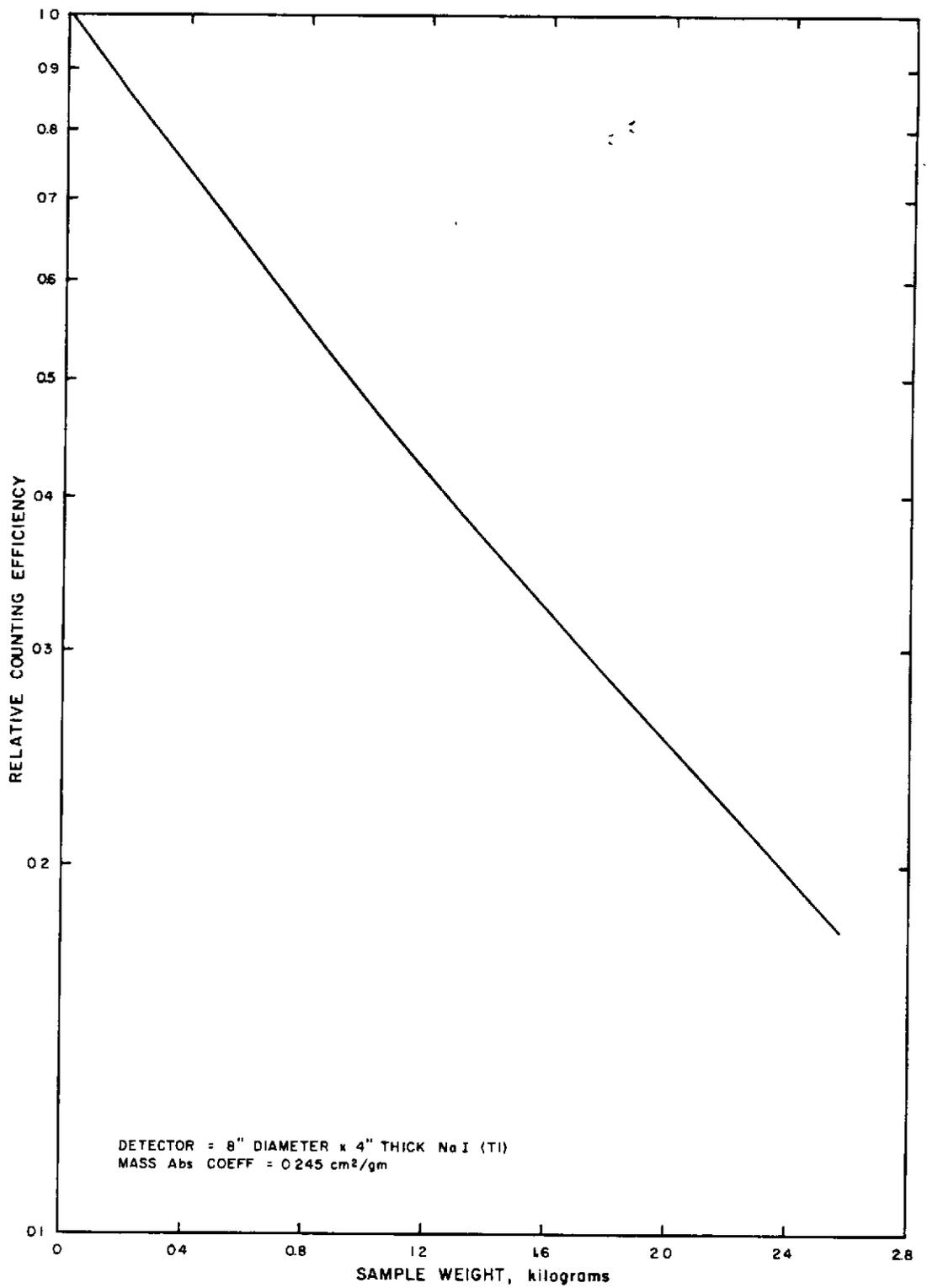


Figure 7.13 Relative counting efficiency of the 60-keV gamma-ray of Am<sup>241</sup> in Roller Coaster soil samples as a function of sample weight.

## CHAPTER 8

### SOLUBILITY STUDIES

#### 8.1 SCOPE OF THESE STUDIES

These studies were made on samples of Roller Coaster plutonium collected in water-filled trays and then transferred to glass bottles for storage. The Pu was probably in equilibrium with the water after a year of storage in glass bottles. In planning these experiments, the plutonium was assumed to be present in at least four forms:

1. That which remained in the solid phase with other debris which had fallen into the tray of water at the Nevada test site;
2. That which was dissolved in the water;
3. That which was not dissolved, but was suspended in the water in a particulate form too fine to settle out, and
4. That which plated out of solution onto the interior walls of the bottle.

Studies of Roller Coaster Pu in these four forms were undertaken to learn some of its solubility properties, especially in solutions having a pH of 7.0 (water), 6.0 (acidified water), and 1.1 (0.1 N HCl) because these pH values approximated those of biological interest: pH 7.0, blood; pH 6.0-6.2, lymphatic fluid; and pH 1.1, gastric fluid.

## 8.2 PRELIMINARY STUDY

A total of 44 water samples were received at H-NSC for study and analysis. Sample volumes ranged from 83 to 980 ml. However, 21 samples showed evidence of leakage from the bottle into the corrugated cardboard packing, and only the multiple polyethylene bags enclosing the packing material prevented loss of the water. Two samples which appeared representative were chosen for preliminary study to give some idea as to the amount and distribution of Pu within the samples. Thirty-ml aliquots each of Sample #3141 (Clean Slate I, Arc A, Station 018) and Sample #3143 (Clean Slate I, Arc A, Station 030) were removed for immediate pH measurement and then centrifuged at low speed for a few minutes. These two samples, as well as most of the other 44, contained a flocculent material, resembling lint, in addition to coarse debris. All the suspended matter appeared to be well separated after low-speed centrifugation. An aliquot of the top liquid was removed, evaporated to dryness in a counting planchet, and alpha counted in a 2-pi proportional counter. The sediment was transferred from the tip of the centrifuge tube and counted separately. The following results were obtained. The two pH values subsequently were shown to be

erroneously low as a result of sample exposure to laboratory fumes.

Sample No. (Tracerlab)	3141	3143
pH	(5.80)	(5.80)
Centrifuged Sediment, dpm/ml solution	0.655	70.88
Supernatant liquid, dpm/ml solution	0.233	8.06
Sediment, percent of total activity	74.	90.

(In converting counting rates to dpm values, any loss in counting efficiency due to sample self-absorption was neglected.) This experiment showed that the majority of the activity in the samples remained in the solid phase portion of the sample and that this solid material could be centrifuged out at low speed. However, a more convenient and reproducible method of separating out the flocculi was to let the samples stand undisturbed for several days and then carefully to draw an aliquot from the top of the water without disturbing the sediment at the bottom of the bottle.

Since the activity found in Sample #3141 was very low, it was discarded from further detailed solubility experiments. After allowing Sample #3143 to stand undisturbed for several days, a 120-ml aliquot was removed and filtered through a 0.45-micron HA Millipore filter. Gross alpha

activities were obtained on both the filter and the evaporated filtrate with the following results:

Filter, total dpm	702
Filter, dpm/ml solution	5.85
Filtrate, dpm/ml solution	2.2

These results showed that the Pu in the liquid phase of the sample was not totally in solution. Since much of the activity did not pass through the 0.45-micron filter, the Pu was apparently distributed between the solution and particulate matter which did not settle out of solution. This particulate matter was possibly biological. The Pu which passed through the 0.45-micron filter was assumed to be in solution for the purposes of these studies.

### 8.3 STUDY OF THE SAMPLES AT EQUILIBRIUM IN WATER AT ABOUT pH 7.

Of immediate interest when starting these studies was the measurement of the alpha activity in the water phase, and the pH, of all 44 water samples. Although a pH of about 7 was desired for the solutions at this point, the samples were aliquoted and counted at the existing pH (instead of adjusting the pH) in order not to upset the equilibrium obtained during the long storage period.

After being unpacked, all 44 samples were examined, shaken, and allowed to stand undisturbed for several days. Immediately upon unstoppering each sample bottle, 10 ml of the clear (sediment-free) water was transferred to a beaker, and the pH was measured on a Beckman Expanded-Scale pH meter. These pH measurements were made in a laboratory free of acid fumes in order to avoid the rapid change in pH which occurs when distilled water is exposed to air containing the slightest trace of acid fumes. At the same time, another aliquot of clear top liquid was removed, evaporated to dryness in a planchet, and alpha counted.

On the basis of these results, six samples, two from each event, were selected for detailed study. The remaining 38 water samples were not used in the study of Pu solubility but were assayed for total Pu in order to provide information concerning Pu deposition on a water surface, each sample tray representing a water surface area of 2.14 square feet (the area exposed in a Pyrex tray 14 inches x 22 inches). Where a significant portion of the sample had leaked into the packing material, the cardboard was first wet ashed and then combined with the bottle contents before assaying.

A summary of the data obtained by Pu assay of the 44 water samples, as received at H-NSC, after storage for about a year, is shown in Table 8.1. Three samples were held in reserve until completion of the detailed studies, but were not needed for detailed studies, and eventually were digested and assayed; these three results are included in Table 8.1. The total Pu content of each of the six samples taken for detailed solubility study was obtained as the sum of the Pu in the various fractions.

No relationship was found between pH and event or between pH and supernate alpha activity. The pH and activity distributions found are given in Table 8.2. The pH range was 5.86 to 8.10, with the median at 6.64. The distribution of activities in the water was as follows:

DPM/ml	No. of Samples
Not Detected	10
0.1 - 1.0	13
1 - 10	18
10 -100	3
Total	44

A few of the samples obviously contained too little total alpha activity for any to be detected in the water even if all of the Pu had been in solution. In most of the samples only a small percentage of the total activity appeared in the aqueous phase, although there was a wide range in this percentage. For example, in #3140 (Clean Slate I) the activity in the aqueous phase was only 0.13 percent, whereas in Sample #3136 (also Clean Slate I) 26.3 percent of the activity was in the water.

#### 8.4 DISTRIBUTION AND SOLUBILITY OF PLUTONIUM IN SEDIMENT-FREE WATER OF SIX SELECTED SAMPLES

The six samples listed in Table 8.3 were selected for detailed study. These were the two most active of each event and provided a broad range of starting pH values.

TABLE 8.3 SIX WATER SAMPLES SELECTED FOR DETAILED STUDY

Event	Tracerlab No.	Location	pH	dpm/ml
CS I	3143	A-030	6.80	8.65
CS I	3142	A-042	7.35	0.69
CS II	4180	D-040*	6.55	62.5
CS II	4197	H-046	7.71	28.3
CS III	5230	B-084	8.10	24.1
CS III	5242	L-078	6.04	2.3

\*True location probably IMOB-040.

The following is a description of the experiment performed to study the solubility of the Pu which did not settle out of the water phase after it had remained undisturbed for several days. The Pu which had not settled was either dissolved or suspended in the sediment-free water. An aliquot of the clear liquid above the sediment was filtered through a 0.45-micron Millipore filter. The filtrate was collected, and an aliquot was evaporated and counted for gross alpha activity. The filter was dried and cut approximately in half. Half A was placed in a stoppered glass bottle containing 100 ml of pH 6.0 water. Half B was placed in another stoppered bottle containing 100 ml of 0.1 N HCl. A 10-ml aliquot from each bottle was removed hourly for the first seven hours. The aliquots were filtered through separate 0.45-micron Millipore filters, evaporated in a counting planchet, and gross alpha counted. Two subsequent aliquots were removed from each bottle at 24 hours and 48 hours, and these were filtered and counted in the same way as the first seven. The filters used for the hourly aliquots were saved, and a radiochemical Pu assay was performed on these after combining them with the original filter half and remaining leaching solution in the bottle. The Pu originally

present on each half of the starting filter was determined by totaling the sums of the activities found in the sequential samplings with the count of this Pu assay. The room temperature during these leaching studies averaged about 20° C. The total original volume of Sample #5230 was filtered for this study. This sample and Sample #4197 were centrifuged at low speed for effective separation of the gross sediment, because of the small volumes of these samples.

The data in Table 8.4 show the distribution of activity in the Millipore-filtered sediment-free water before starting the leaching experiment described above. The percentage decrease in activity achieved by filtering the water ranged from 6.4 to 57 percent and did not show a correlation with the pH of the water. The fact that Samples #4180 and 4197 (both from Clean Slate II) and #5230 (Clean Slate III) underwent a considerably smaller drop in filtering the water than did the other samples may be related to the presence of a slimy deposit which was found on the filters of these three samples but not on the filters of the other three samples. This colloidal material was not evident on visual inspection of the original solution except by a slight amber color. The

colloidal material also may have caused, directly or indirectly, the original water activity of these three samples to be high in comparison with the activity found in nearly all of the other 44, most of which were not colored. The fact that in two cases (Samples #3142, CS I, and #5242, CS III) the total activity subsequently found on the filter halves actually exceeded the activity calculated for the sediment-free sample aliquot probably indicates that particulate matter high in Pu activity, but not visible in the solution after low speed centrifugation, or several days standing, remained in the liquid.

Data from the leaching-study on the solubility of the Millipore filter deposit are shown in Table 8.5, in which the activity of the sequential aliquots is reported as the distribution ratio, (dpm per ml solution/dpm solid phase). The activity in several of the leach solutions remained very low, and the resulting large statistical error in the counting rate, in many cases, exceeded the counting rate itself. This was true even though the counting time for each of these samples averaged about one hour and was usually not less than 30 minutes. Because of these poor counting statistics, a meaningful graph of the data could not be drawn for all 12 solutions. However, for 6

solutions in which there was a significant rise of activity above background, graphs showing the variation of the Pu distribution with time in solutions of pH 6 and 1.1 are shown in Figures 8.1 and 8.2. In general, the curves were drawn giving greater weight to the higher points, since several factors, including plating-out of the Pu on the glass of the filtering apparatus and pipets and variations in self-absorption of the evaporated samples, were assumed to contribute to an apparent low result in some of the aliquots, especially in the case of the more acidic solutions. The solutions at pH 6 apparently reached equilibrium within about 12 hours, while the more acidic solutions reached equilibrium somewhat faster, although the presence of the glutinous deposit of Samples #4197, 5230, and 4180 possibly influenced the apparent solubility of the Pu to a greater extent than did the pH. Thus, while sample #5242 (no colloidal material apparent) showed a distribution ratio of about  $1 \times 10^{-4}$  in pH 6 solution, and  $1 \times 10^{-3}$  in pH 1.1 solution, sample #5230, (with a thick slimy deposit) showed a distribution ratio of about  $3 \times 10^{-3}$  in pH 6 solution and only  $5 \times 10^{-4}$  in pH 1.1 solution.

## 8.5 STUDY OF THE SOLUBILITY OF THE GROSS-SEDIMENT PLUTONIUM IN A pH 1.1 SOLUTION

Assay of the sediment-free portion of the total water samples gave a measure of the level of activity which could be expected in an aqueous solution when the Pu was allowed to reach equilibrium at, or near, neutrality. Next, an experiment was performed in order to determine the solubility of Pu in the sediment in a solution of pH 1.1 (0.1 N hydrochloric acid). The gross sediment of the same six samples was separated from the liquid by passing the remainder of the original solution through Whatman #41 filter paper. The total sediment in the sample bottle was transferred to the filter by washing with water, and the total filter was washed several times with water. The filter was transferred to a stoppered flask containing 100 ml of 0.1 N HCl. A 2.00-ml aliquot was removed hourly for the first seven hours. The aliquots were filtered through a 0.45-micron Millipore filter, neutralized with 2 ml of 0.1 N ammonium hydroxide, evaporated in a counting planchet, and counted for alpha activity. Two subsequent aliquots were removed at 24 hours and 48 hours, and they were filtered and counted as the first seven. Since it is not likely that ingested Pu in the gastrointestinal tract would remain in contact with gastric fluid (at pH 1.1)

for longer than 48 hours, the leaching study was not continued after 48 hours. The total Pu originally available on the filter for dissolution was determined as in the previous experiment. The Millipore filter through which the separate aliquots were filtered, the filter paper containing the gross sediment, and the solution remaining in the leaching flask were combined and radiochemically assayed for Pu; the total alpha activity found in all nine of the sequential aliquots then was added to the Pu dpm from this radiochemical assay to give the total for the sediment on the filter. The distribution ratio of the Pu in each of the hourly aliquots is given in Table 8.6. A plot of the distribution ratio as a function of time in Figures 8.3, 8.4, and 8.5 shows that after the first 10 hours the rapid initial increase of activity in the acid slackened, although even after 48 hours the solution activity was still rising and had not, apparently, reached equilibrium.

#### 8.6 STUDY OF PLUTONIUM DEPOSIT ON WALLS OF GLASS CONTAINER

Retention of Pu on the walls of the glass bottles in which the water samples were stored and shipped to H-NSC, and the solubility of this Pu, were determined using a series of different acid solutions. First, the empty

bottle was filled with 0.1 N hydrochloric acid to at least the volume of the original water sample. The bottle was shaken, placed in a double polyethylene bag, and agitated in an ultrasonic cleaner for 10 minutes. An aliquot of the wash solution was removed, evaporated, and counted for gross alpha activity. The bottle was emptied and rinsed with water. Desorption efforts were repeated in the same manner with 3 N HCl, then 6 N HCl, and finally with 15.4 N (concentrated) HNO<sub>3</sub> containing a trace of HF.

The total Pu dissolved from the container walls by each successive wash solution, and the total of the Pu removed by all of the four washes combined, are reported in Table 8.7. These data are also reported in terms of the fraction of the total activity found in each of the four successive wash solutions. Figure 8.6 displays the partial dissolution pattern of the sorbed Pu by the various acid solutions. Although there was a difference of six to one in total Pu desorbed from Samples #3143 and 3142 (both Clean Slate I samples), the successive desorption behavior was quite similar. The largest portion of the deposit was removed by the 0.1 N HCl in these

samples as well as in the two **Clean Slate II** samples. However, the **patterns** of desorption of the CS III samples are mutually dissimilar and different from those of the other four samples. The two CS III samples are similar in that both sample containers refused to release the majority of their deposited Pu until the acid concentration was raised to 3 N.

## 8.7 SUMMARY AND CONCLUSIONS

A summary of data collected in the experiments on the six water samples studied in detail is shown in Table 8.8. The total sample alpha activity is simply the sum of the Pu in the gross sediment, the Pu leached from the walls of the container, and the calculated Pu content of the sediment-free water of the sample (dpm/ml x volume). A plot of the fraction of the total Pu activity sorbed on the container walls as a function of the pH of the water as it arrived at H-NSC is shown in Figure 8.7.

If Pu is to be found on the interior walls of the bottle, a three-step displacement must probably take place. First, the Pu which fell into the sample water in solid form must pass into solution; then it must move to the vicinity of a solid surface; and finally it must be sorbed

from solution onto the solid surface. To the extent that the solubilized Pu may be assumed dispersed uniformly through the available liquid volume at equilibrium, the amount of displacement from one location to another is limited only by the geometry of the containment. In projecting this situation to a natural body of water, a quantity of Pu falling into one portion of a lake or pond may, with sufficient time, be found not only dispersed throughout the water by dissolution, but also sorbed onto surfaces touched by the water. The data indicate that although small variations in pH as encountered in natural waters (about pH 6-8) seem to influence the solubility of Pu very little, the amount of Pu displaced and sorbed onto the containment surfaces may be very dependent on small pH changes (Figure 8.7). However, since Pu solubility is apparently extremely dependent upon the presence of other matter dissolved or suspended in the water, Pu displacement also may be influenced by the solution content of this other matter.

Plutonium sorbed from solution onto a glass surface is not easily removed. Treatment with 0.1 N HCl may remove much of it, but in these studies more concentrated

acid was required to remove the remaining Pu, and in two samples the 0.1 N HCl dissolved very little of the sorbed Pu.

Most of the Pu in these samples was found in the gross sediment. The percentage of total activity remaining in the gross sediment (after a year's storage) ranged 85 to 98 percent. The highest aqueous-phase activity found was 62.5 dpm per ml, in Sample #4180 (Clean Slate II), although 93 percent of the total activity of this sample remained in the gross sediment. Distribution of the aqueous alpha activity between the filterable activity and non-filterable activity varied widely among the six test samples, ranging from 22 percent to 94 percent non-filterable.

TABLE 8.1 PLUTONIUM CONTENT AND pH VALUES OF WATER SAMPLES AS RECEIVED AT H-NSC, AFTER SETTLING

Tracer- lat Number (e)	Total Pu <sup>239,240</sup> in sample (a) dpm	Concentration of Alpha Activity dpm/ml	Properties of Sediment-free Water			
			pH	Total Volume ml	Total Alpha Activity dpm (b)	Percent of Total Pu <sup>239,240</sup> (c)
CLEAN SLATE I						
3141	(5.53 ± 0.23) × 10 <sup>4</sup>	0.3	7.38	500.	150.	0.27
3143	4.71 × 10 <sup>5</sup> (d)	8.65	6.80	500.	4325.	0.92
3140	(2.97 ± 0.08) × 10 <sup>5</sup>	0.50	6.75	765.	382.	0.13
3138	57.71 ± 0.75	<0.01	6.65	675.	<68.	
3139	1.18 ± 0.02 × 10 <sup>4</sup>	<0.01	7.03	700.	<70.	<0.50
3142	3.35 × 10 <sup>4</sup> (d)	0.69	7.35	555.	383.	1.14
3137	1484. ± 42	0.1	7.60	280.	26.	1.80
3135	1197. ± 13	0.7	6.30	450.	315.	20.31
3131	1790. ± 49	0.1	6.17	530.	53.	2.92
2392	1586. ± 1.05	<0.01	6.29	635.	<16.	
2391	1206. ± 42	0.1	6.41	612.	61.	5.00
CLEAN SLATE II						
4180	Not Determined	62.5	6.56	275.	17,187.	
4181	(3.24 ± 0.05) × 10 <sup>5</sup>	4.59	6.70	713.	3280.	1.02
4182	(1.80 ± 0.03) × 10 <sup>5</sup>	6.99	6.91	560.	3905.	2.17
4196	225.1 ± 1.8	N.D.	6.89	185.	<18.	
4183	111.2 ± 2.9	N.D.	6.54	305.	<30.	
4193	(2.67 ± 0.04) × 10 <sup>4</sup>	2.8	6.30	325.	910.	3.40
4194	(1.00 ± 0.01) × 10 <sup>5</sup>	7.8	6.45	400.	3120.	3.12
4195	(7.76 ± 0.15) × 10 <sup>4</sup>	4.7	6.00	575.	2702.	3.49
4197	(5.46 ± 0.08) × 10 <sup>4</sup>	7.7	6.58	470.	2619.	4.80
4197	Not Determined	28.3	7.71	160.	4528.	
4198	80.29 ± 1.12	<0.01	6.61	935.	<94.	
4199	1101. ± 12	0.4	6.79	730.	292.	26.5
4200	159.2 ± 1.3	<0.01	6.53	910.	<91.	
2394	(2.15 ± 0.04) × 10 <sup>4</sup>	0.8	6.35	695.	556.	2.58
2397	(2.58 ± 0.05) × 10 <sup>4</sup>	1.6	5.90	960.	1562.	6.19
2398	(2.88 ± 0.10) × 10 <sup>4</sup>	0.7	6.31	975.	682.	2.41
2399	(6.07 ± 0.25) × 10 <sup>4</sup>	1.66	5.86	810.	1345.	2.23
2400	(2.67 ± 0.07) × 10 <sup>4</sup>	2.0	6.43	820.	1640.	6.13
CLEAN SLATE III						
5230	105.3 ± 0.8	N.D.	8.00	450.	<45.	
5231	Not Determined	24.1	8.10	53.	2000.	
5232	2211. ± 72	0.1	6.12	622.	62.	
5240	233.7 ± 3.0	<0.01	7.35	255.	<22.	
5241	6312. ± 120	1.1	7.15	155.	170.	2.20
5242	27.60 ± 0.41	<0.01	6.62	575.	<58.	
5250	(1.34 ± 0.03) × 10 <sup>4</sup>	1.16	7.01	340.	364.	2.93
5257	(1.13 ± 0.02) × 10 <sup>4</sup>	1.43	6.96	325.	465.	4.11
5258	(5.79 ± 0.13) × 10 <sup>4</sup>	1.51	7.01	820.	1236.	2.14
5259	(5.77 ± 0.06) × 10 <sup>4</sup>	1.04	6.45	710.	735.	1.45
5260	(7.30 ± 0.10) × 10 <sup>4</sup>	1.70	6.83	900.	1530.	2.08
5267	1607. ± 32	0.5	7.95	265.	132.	8.40
5268	4674. ± 51	1.8	8.09	300.	540.	11.0
5242	1.00 × 10 <sup>5</sup>	2.3	6.04	720.	1696.	1.56
5230	(1.50 ± 0.04) × 10 <sup>4</sup>	0.1	6.69	660.	66.	0.44

- (a) This total includes the Pu<sup>239,240</sup> on the walls of the sample bottle, in the sediment, and (for leaking samples) in the packing material, in addition to the Pu<sup>239,240</sup> in the sediment-free water.
- (b) The value in this column is the product of the alpha concentration (dpm/ml) from the third column and the total volume (ml) from the fifth column.
- (c) This percentage is the ratio (multiplied by 100) of the total dpm in the sediment-free water (in the sixth column) to the total Pu<sup>239,240</sup> dpm in the sample (in the second column).
- (d) Determined in course of solubility study.
- (e) See Appendix, Tables A.6, A.7, and A.8, for field locations.

TABLE 8.2 DISTRIBUTION OF pH VALUES AND GROSS ALPHA ACTIVITIES IN WATER SAMPLES

pH Range	Clean Slate I			Clean Slate II			Clean Slate III			Total		
	No.	Range	Median	No.	Range	Median	No.	Range	Median	No.	Range	Median
		dpm/ml	dpm/ml		dpm/ml	dpm/ml		dpm/ml	dpm/ml		dpm/ml	dpm/ml
<6.0	0	-	-	2	1.6-1.7	1.6	0			2	1.6 - 1.7	1.6
6.0-6.4	3	N.D.*-0.7	0.1	4	0.7-4.7	1.8	2	0.1-2.3	1.2	9	N.D.-4.7	0.7
6.4-6.8	3	N.D.-0.5	0.1	9	N.D.-62.5	2.0	4	N.D.-1.7	0.6	16	N.D.-62.5	0.4
6.8-7.2	1	(8.65)	(8.65)	2	N.D.-7.0	3.5	4	1.1-1.5	1.3	7	N.D.-8.65	1.4
7.2-7.6	3	N.D.-0.7	0.13	0	-	-	1	(N.D.)	(N.D.)	4	N.D.-0.7	0.2
7.6-8.0	1	(0.1)	(0.1)	1	(28.3)	(28.3)	1	(0.5)	(0.5)	3	0.1-28.3	0.5
≥8.0	0	-	-	0	-	-	3	N.D.-24.1	1.8	3	N.D.-24.1	1.8
Total	11	N.D.-8.65	0.3	18	N.D.-62.5	1.8	15	N.D.-24.1	1.1	44	N.D.-62.5	0.75

\* "N.D." - Not Detected; - Assumed to be zero in median calculation.

TABLE 8.4 DISTRIBUTION OF ACTIVITY AFTER MILLIPORE FILTRATION OF SELECTED SEDIMENT-FREE WATER SAMPLES

Event	Tracer-lab No.	Location	Sediment-free Water Before Filtration			Sediment-free Water after Filtration					
			Conc. of alpha Activity (a)	Aliquot Filtered Through 0.45 $\mu$ Filter	Calculated Activity of Aliquot	Activity of Filtrate		Activity on Filter			
						Conc. of alpha activity	Per cent of Sediment-free Water Activity	Total dpm	dpm per ml filtered	Per cent of Sediment-free Water Activity	
			dpm/ml	ml	dpm	dpm/ml					
CS-I	3143	A-030	8.65	100	865	4.9	57.	195	1.95	23.	
CS-I	3142	A-042	0.69	300	207	0.3	43	314.	1.05	152.	
CS-II	4180	D-040 (e)	62.5	100	6250	58.5	94.	576.	5.76	9.9	
CS-II	4197	H-046	28.5	100	2830	23.7	83.	659	6.59	23.	
CS-III	5230	B-074	24.1	83(b)	2000	15.7	69.	627.	7.56	31	
CS-III	5242	L-078	2.3	300	690	0.5	22.	1625.	5.42	235.	

(a) Values from Table 8.1

(b) Total volume of the sample.

(c) True location probably JMOB-040

TABLE 8.5 SOLUBILITY OF Pu FILTERED FROM SELECTED SEDIMENT-FREE WATER SAMPLES,  
CALCULATED AS THE DISTRIBUTION FACTOR:  $\frac{\text{DPM PER ml SOLUTION}}{\text{DPM SOLID PHASE}}$

					DISTRIBUTION FACTOR - $\left[ \frac{\text{dpm per ml Solution}}{\text{dpm Solid Phase}} \right] \times 10^4$									
Event	Tracer Lab No.	Location	pH of Leaching Solution	Total Pu Solid Phase dpm	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 24	Hour 48	
CS I	3143	A-030	6.	93.1 ± 3.30	12.9 ± 8.5	0.32 ± 14.	0.	9.6 ± 9.6	9.6 ± 9.6	0.	6.0 ± 9.1	2.5 ± 4.5	0.	
CS I	3143	A-030	1.1	101.8 ± 3.27	3.7 ± 7.6	0.	6.7 ± 7.5	0.	0.	0.	0.	8.8 ± 8.6	2.5 ± 3.5	
CS I	3142	A-042	6.	178.4 ± 4.30	4.4 ± 5.6	2.1 ± 4.5	2.4 ± 7.4	0.	4.6 ± 8.0	-	0.2 ± 4.5	0.	0.	
CS I	3142	A-042	1.1	135.8 ± 4.13	13. ± 17.	0.	2.8 ± 5.8	0.	0.	1. ± 5.	10. ± 7.	10. ± 7.	1.8 ± 5.7	
CS II	4180	D-040*	6.	305.9 ± 7.30	0.	1.8 ± 2.9	1.5 ± 1.2	1.3 ± 3.0	1.3 ± 2.4	3.4 ± 2.6	3.5 ± 3.1	2.0 ± 2.9	8.9 ± 3.8	
CS II	4180	D-040*	1.1	270.6 ± 8.15	3.3 ± 3.3	5.0 ± 2.1	1.4 ± 2.9	2.8 ± 2.6	0.	0.7 ± 2.7	2.8 ± 1.6	3.8 ± 3.0	15.5 ± 4.7	
CS II	4197	H-046	6.	382.7 ± 11.51	12. ± 3	17. ± 5.	15. ± 4.	7.0 ± 2.4	6.4 ± 2.3	18. ± 4.	6.0 ± 2.9	17.0 ± 1.5	30. ± 1.	
CS II	4197	H-046	1.1	276.7 ± 5.87	7.3 ± 1.9	7.5 ± 3.7	7.5 ± 3.8	6.8 ± 3.0	3.1 ± 2.5	3.5 ± 3.4	0.	0.2 ± 1.3	17. ± 5.	
CS III	5230	B-084	6.	315.6 ± 7.96	7.8 ± 1.8	11. ± 4.	14.5 ± 2.8	18.0 ± 0.9	13.4 ± 1.7	29. ± 6.	7.9 ± 3.1	36. ± 6.	26. ± 5.	
CS III	5230	B-084	1.1	312.2 ± 7.65	0.2 ± 2.	4.6 ± 3.	7.1 ± 1.9	5.2 ± 1.5	5.9 ± 2.6	6.2 ± 3.2	6.0 ± 3.2	3.9 ± 2.9	4.3 ± 3.0	
CS III	5242	L-078	6.	908.7 ± 26.3	0.	0.1 ± 0.9	0.8 ± 1.0	0.8 ± 1.0	0.1 ± 0.9	0.4 ± 0.9	0.6 ± 1.0	0.8 ± 1.0	0.6 ± 1.0	
CS III	5242	L-078	1.1	716.4 ± 25.4	2.3 ± 1.4	2.7 ± 1.4	3.2 ± 1.5	4.6 ± 1.6	7.3 ± 1.9	19. ± 3.	0.8 ± 1.5	15.5 ± 1.6	12. ± 2.	

Error limits given are calculated from counting statistics only and are at the 95% confidence level. So that there is no ambiguity in the magnitudes of the tabulated values, the first distribution factor tabulated under "Hour 1" is:

$$(\text{dpm per ml solution/dpm solid phase}) = (12.9 \pm 8.5) \times 10^{-4}$$

\* True location probably IMOB-040

TABLE 8.5 SOLUBILITY OF Pu FILTERED FROM SELECTED SEDIMENT-FREE WATER SAMPLES,  
CALCULATED AS THE DISTRIBUTION FACTOR:  $\frac{\text{DPM PER ml SOLUTION}}{\text{DPM SOLID PHASE}}$

Sample				DISTRIBUTION FACTOR - $\left[ \frac{\text{dpm per ml Solution}}{\text{dpm Solid Phase}} \right] \times 10^4$									
Event	Tracer Lab No.	Location	pH of Leaching Solution	Total Pu Solid Phase dpm	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 24	Hour 48
CS I	3143	A-030	6.	93.1 + 3.30	12.9 + 8.5	0.32 ± 14.	0.	9.6 ± 9.6	9.6 ± 9.6	0.	6.0 ± 9.1	2.5 ± 4.5	0.
CS I	3143	A-030	1.1	101.8 ± 3.27	3.7 ± 7.8	0.	6.7 ± 7.5	0.	0.	0.	0.	8.8 ± 8.6	2.5 ± 3.5
CS I	3142	A-042	6.	178.4 ± 4.30	4.4 ± 5.6	2.1 ± 4.5	2.4 ± 7.4	0.	4.6 ± 8.0	-	0.2 ± 4.5	0.	0.
CS I	3142	A-042	1.1	135.8 ± 4.13	13. ± 17.	0.	2.8 ± 5.8	0.	0.	1. ± 5.	10. ± 7.	10. ± 7.	1.8 ± 5.7
CS II	4180	D-040*	6.	305.9 + 7.30	0.	1.8 ± 2.9	1.5 ± 1.2	1.3 ± 3.0	1.3 ± 2.4	3.4 ± 2.6	3.5 ± 3.1	2.0 ± 2.9	8.9 ± 3.8
CS II	4180	D-040*	1.1	270.6 ± 8.15	3.3 ± 3.3	5.0 ± 2.1	1.4 ± 2.9	2.8 ± 2.6	0.	0.7 ± 2.7	2.8 ± 1.6	3.8 ± 3.0	15.5 ± 4.7
CS II	4197	H-046	6.	382.7 + 11.51	12. ± 3	17. ± 5.	15. ± 4.	7.0 ± 2.4	6.4 ± 2.3	18. ± 4.	6.0 ± 2.9	17.0 ± 1.5	30. ± 1.
CS II	4197	H-046	1.1	276.7 ± 5.87	7.3 ± 1.9	7.5 ± 3.7	7.5 ± 3.8	6.8 ± 3.0	3.1 ± 2.5	3.5 ± 3.4	0.	0.2 ± 1.3	17. ± 5.
CS III	5230	B-084	6.	315.6 + 7.96	7.8 ± 1.8	11. ± 4.	14.5 ± 2.8	18.0 ± 0.9	13.4 ± 1.7	29. ± 6.	7.9 ± 3.1	36. ± 6.	26. ± 5.
CS III	5230	B-084	1.1	312.2 ± 7.65	0.2 ± 2.	4.6 ± 3.	7.1 ± 1.9	5.2 ± 1.5	5.9 ± 2.6	6.2 ± 3.2	6.0 ± 3.2	3.9 ± 2.9	4.3 ± 3.0
CS III	5242	L-078	6.	908.7 + 26.3	0.	0.1 ± 0.9	0.8 ± 1.0	0.8 ± 1.0	0.1 ± 0.9	0.4 ± 0.9	0.6 ± 1.0	0.8 ± 1.0	0.6 ± 1.0
CS III	5242	L-078	1.1	716.4 ± 25.4	2.3 ± 1.4	2.7 ± 1.4	3.2 ± 1.5	4.6 ± 1.6	7.3 ± 1.9	19. ± 3.	0.8 ± 1.5	15.5 ± 1.6	12. ± 2.

Error limits given are calculated from counting statistics only and are at the 95% confidence level. So that there is no ambiguity in the magnitudes of the tabulated values, the first distribution factor tabulated under "Hour 1" is:

$$(\text{dpm per ml solution/dpm solid phase}) = (12.9 \pm 8.5) \times 10^{-4}$$

\* True location probably IMOB-040.

TABLE 8.6 SOLUBILITY OF GROSS SEDIMENT Pu IN 0.1 NORMAL HYDROCHLORIC ACID

Sample Description			Total Pu in Gross Sediment (dpm)	Alpha Activity in Leach Solution *									
Event	Tracer- lab No.	Location		Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 24	Hour 48	
CS-I	3143	A-030	$4.65 \times 10^5$	$3.08 \times 10^{-4}$	$5.45 \times 10^{-4}$	$7.93 \times 10^{-4}$	$1.01 \times 10^{-3}$	$9.08 \times 10^{-4}$	$1.15 \times 10^{-3}$	$1.18 \times 10^{-3}$	$2.44 \times 10^{-3}$	$3.03 \times 10^{-3}$	
CS-I	3142	A-042	$3.26 \times 10^4$	$3.52 \times 10^{-4}$	$4.35 \times 10^{-4}$	$5.52 \times 10^{-4}$	$6.30 \times 10^{-4}$	$5.83 \times 10^{-4}$	$4.75 \times 10^{-4}$	$8.30 \times 10^{-4}$	$1.11 \times 10^{-3}$	$1.31 \times 10^{-3}$	
CS-II	4180	D-040**	$2.48 \times 10^5$	$5.45 \times 10^{-4}$	$7.09 \times 10^{-4}$	$1.06 \times 10^{-3}$	$1.24 \times 10^{-3}$	$1.12 \times 10^{-3}$	$1.19 \times 10^{-3}$	$1.62 \times 10^{-3}$	$2.02 \times 10^{-3}$	$2.88 \times 10^{-3}$	
CS-II	4197	H-046	$2.06 \times 10^4$	$2.26 \times 10^{-4}$	$4.15 \times 10^{-4}$	$5.69 \times 10^{-4}$	$4.05 \times 10^{-4}$	$5.59 \times 10^{-4}$	$6.86 \times 10^{-4}$	$4.19 \times 10^{-4}$	$1.14 \times 10^{-3}$	$1.76 \times 10^{-3}$	
CS-III	5230	B-084	$1.60 \times 10^4$	$1.06 \times 10^{-4}$	$2.31 \times 10^{-4}$	$3.44 \times 10^{-4}$	$4.81 \times 10^{-4}$	$3.12 \times 10^{-4}$	$4.62 \times 10^{-4}$	$4.12 \times 10^{-4}$	$8.12 \times 10^{-4}$	$1.08 \times 10^{-3}$	
CS-III	5242	L-078	$1.04 \times 10^5$	$1.99 \times 10^{-4}$	$2.83 \times 10^{-4}$	$4.16 \times 10^{-4}$	$4.01 \times 10^{-4}$	$3.25 \times 10^{-4}$	$3.66 \times 10^{-4}$	$4.77 \times 10^{-4}$	$7.30 \times 10^{-4}$	$1.21 \times 10^{-3}$	

\*Activity expressed as the ratio,  $\frac{\text{dpm per ml solution}}{\text{dpm gross sediment}}$

\*\* True location probably IMOB-040.

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TABLE 8.7 RESULTS OF SUCCESSIVE LEACHINGS BY VARIOUS ACID SOLUTIONS OF INTERIOR OF GLASS CONTAINERS USED FOR STORAGE OF CLEAN SLATE WATER SAMPLES

Event	Sample		Volume of Wash Solution ml	Total Alpha Activity Found on Container Walls dpm	Total Alpha Activity Found in Acid Wash Solutions *			
	Tracer- lab No.	Loc.			0.1N HCl dpm	3N HCl dpm	6N HCl dpm	Conc. HNO <sub>3</sub> (Trace of HF) dpm
CS I	3143	A-030	500	2999	2265.0 (.756)	378.0 (.126)	297.5 (.099)	58.5 (.019)
CS I	3142	A-042	555	515.0	318.3 (.619)	77.8 (.151)	26.1 (.050)	92.8 (.180)
CS II	4180	D-040**	550	809.4	693.4 (.857)	58.0 (.072)	21.5 (.026)	36.5 (.045)
CS II	4197	H-046	480	689.5	547.1 (.794)	99.6 (.142)	3.5 (.005)	41.5 (.059)
CS III	5230	B-084	300	796.7	3.6 (.004)	471.8 (.593)	129.4 (.162)	191.9 (.241)
CS III	5242	L-078	720	422.4	121.7 (.289)	251.4 (.595)	35.5 (.084)	13.8 (.032)

\*Number in parentheses is fraction of total found in each wash solution.

\*\* True location probably IMOB-040.

TABLE 8.8 SUMMARY OF DATA ON WATER SAMPLES USED FOR SOLUBILITY STUDIES

Event	Sample		Sediment-free Water				Sediment		Bottle Walls		Total
	Tracer-lab No.	Location	pH	Volume ml	Conc. of Alpha Activity dpm/ml	Total Alpha Activity dpm	Total Alpha Activity dpm	% of Total	Total Alpha Activity dpm	% of Total	Sample Alpha Activity dpm
CS I	3143	A-030	6.80	500	8.65	4325	$4.64 \times 10^5$	98.5	2999	0.65	$4.71 \times 10^5$
CS I	3142	A-042	7.35	555	0.69	383	$3.26 \times 10^4$	97.3	515	1.55	$3.35 \times 10^4$
CS II	4180	D-040*	6.56	275	62.5	17190	$2.48 \times 10^5$	93.2	809	0.30	$2.66 \times 10^5$
CS II	4197	H-046	7.71	160	28.5	4560	$3.06 \times 10^4$	85.5	689	1.92	$3.58 \times 10^4$
CS III	5230	B-084	8.10	83	24.1	2000	$1.60 \times 10^4$	85.1	797	4.25	$1.88 \times 10^4$
CS III	5242	L-078	6.04	720	2.3	1656	$1.04 \times 10^5$	98.1	422	0.40	$1.06 \times 10^5$

\* True location probably IMOB-040.

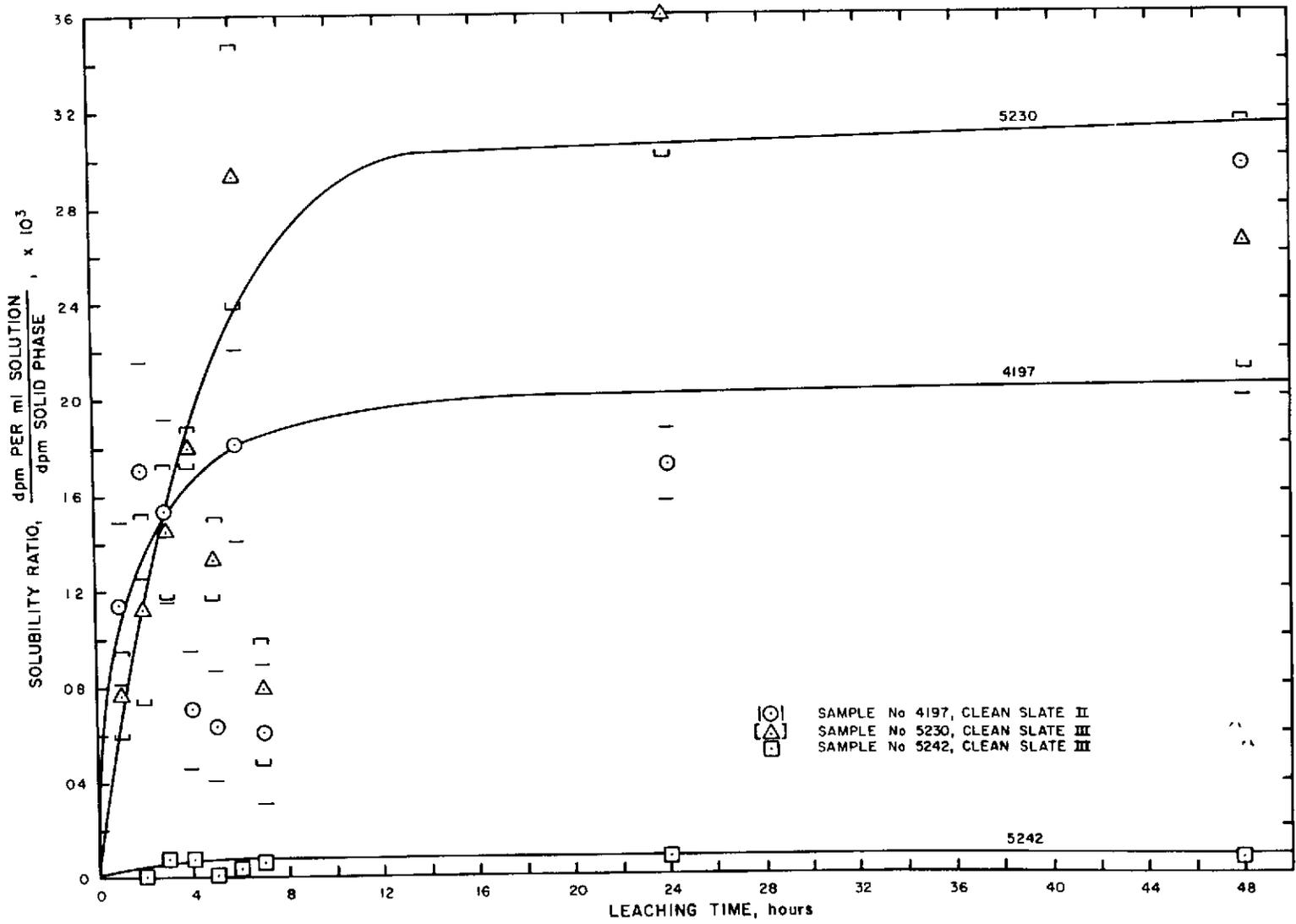


Figure 8.1 Solubility of plutonium (separated from sediment-free water by Millipore filtration) in water at pH 6.

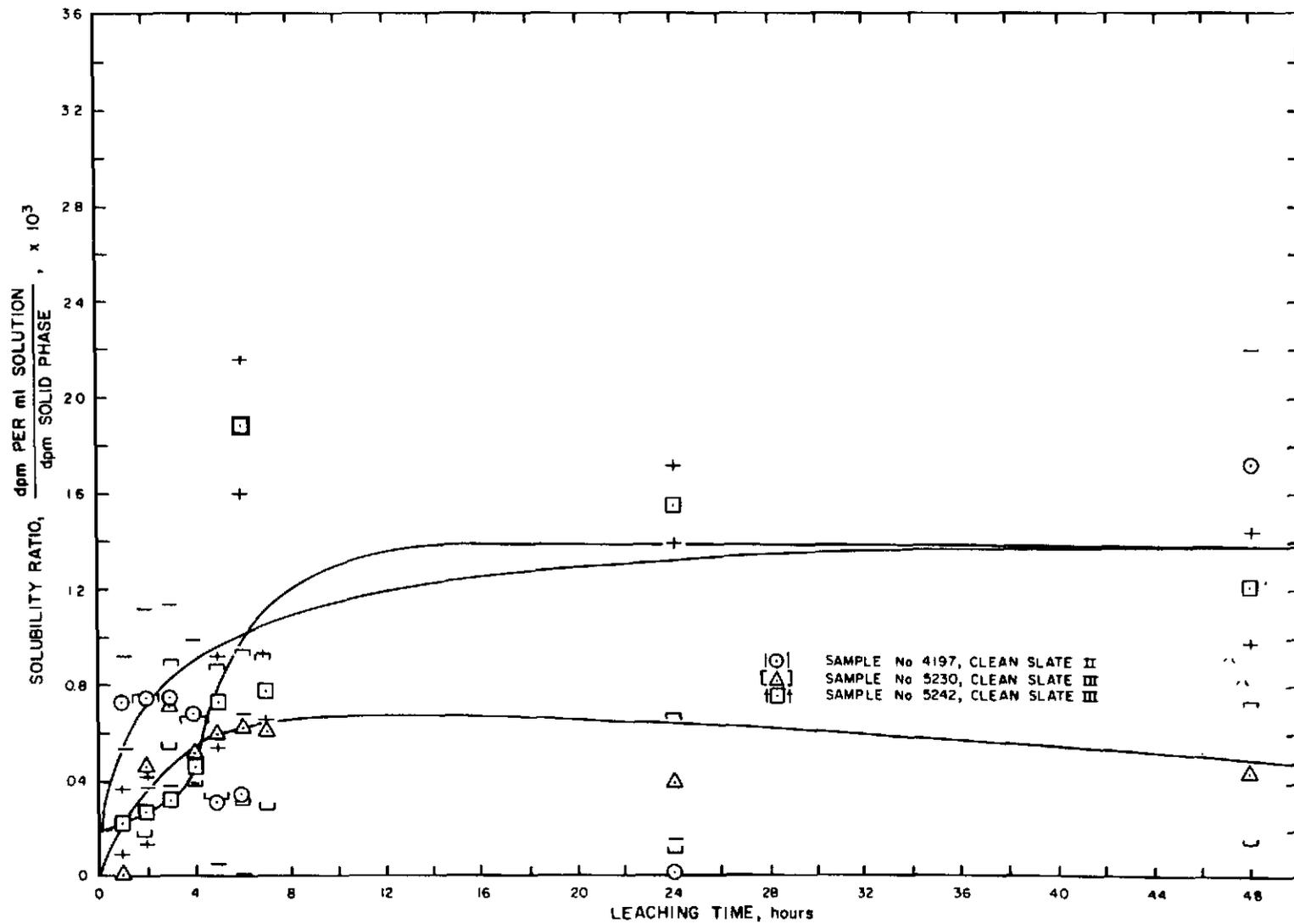


Figure 8.2 Solubility of plutonium (separated from sediment-free water by Millipore filtration) in water at pH 1.1.

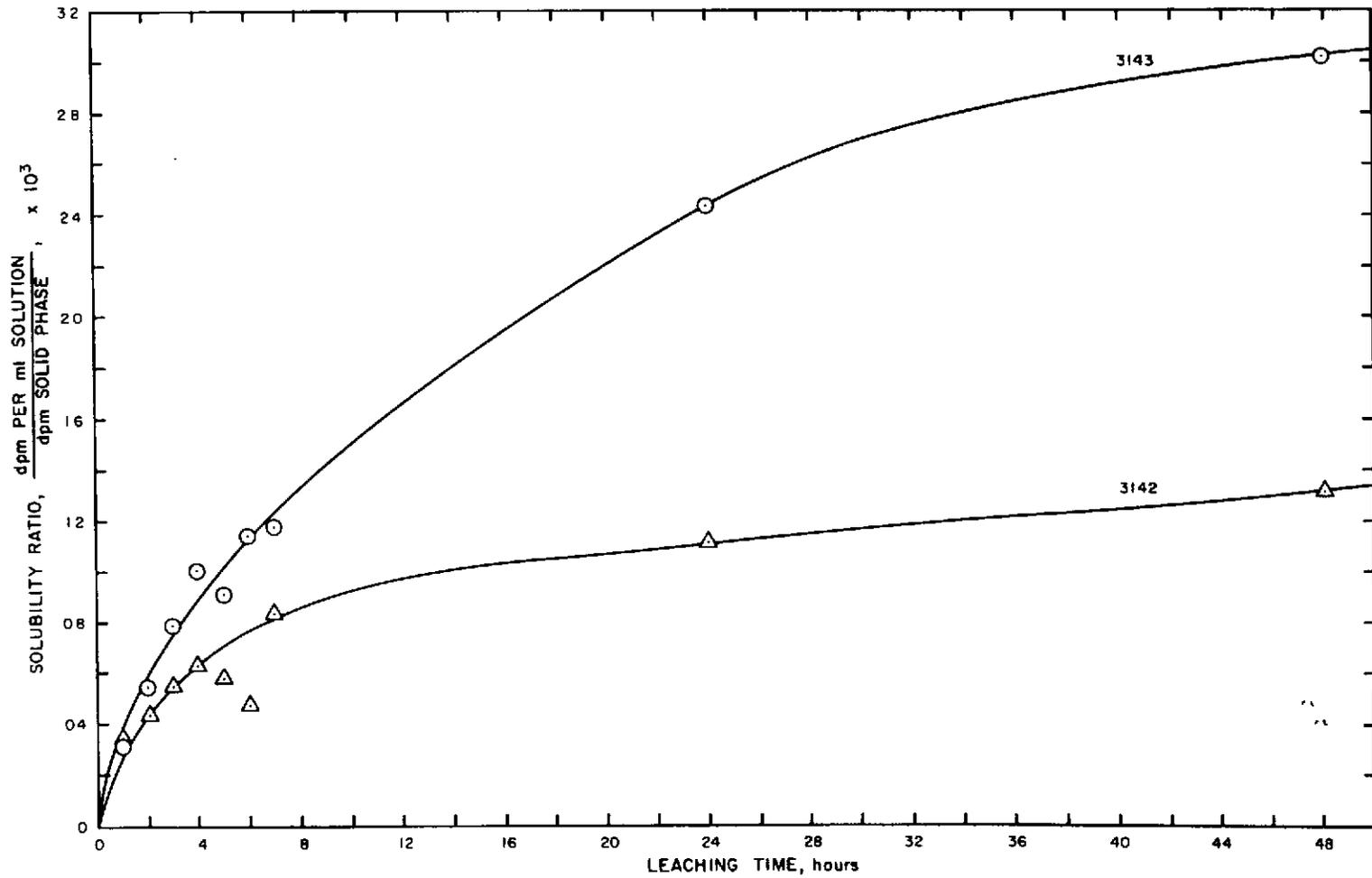


Figure 8.3 Solubility of gross sediment plutonium in 0.1 N hydrochloric acid; Clean Slate I samples.

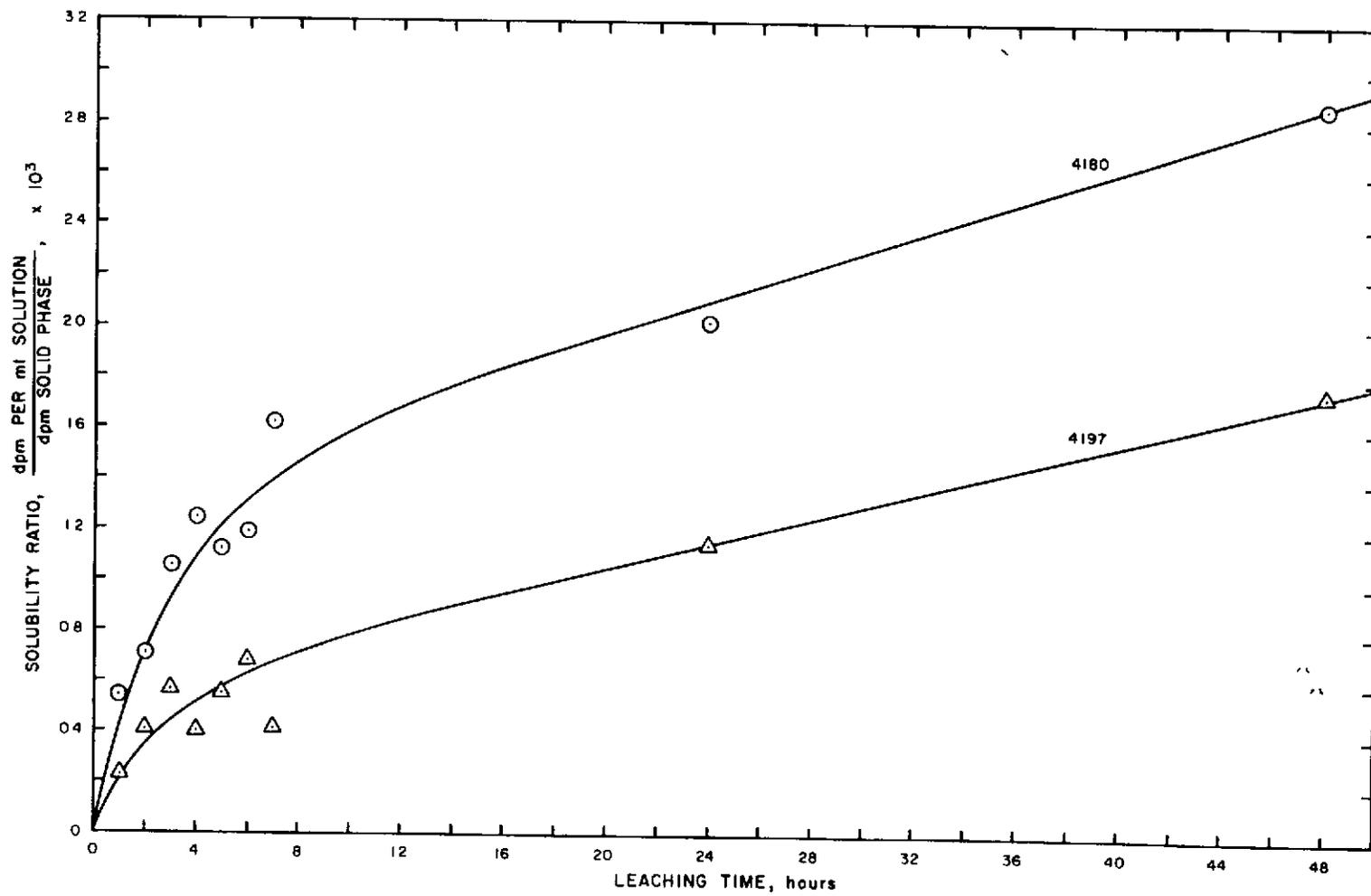


Figure 8.4 Solubility of gross sediment plutonium in 0.1 N hydrochloric acid; Clean Slate II samples.

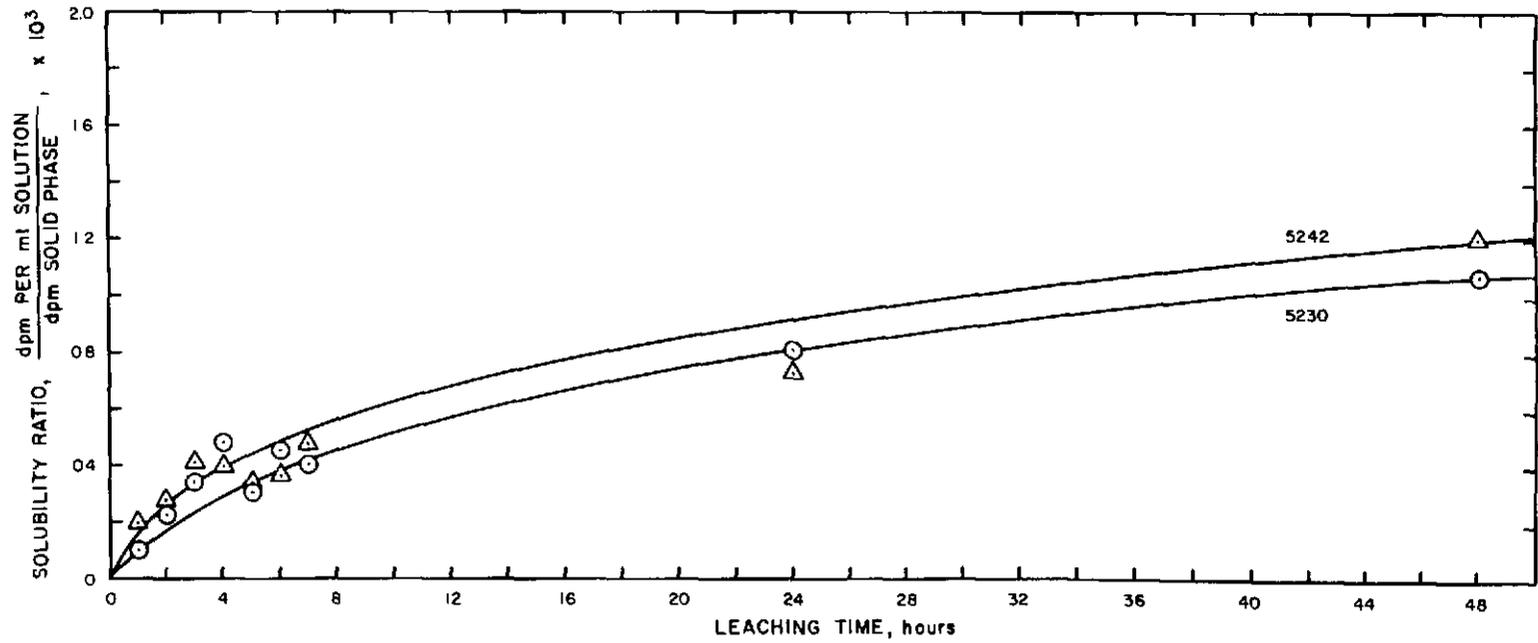


Figure 8.5 Solubility of gross sediment plutonium in 0.1 N hydrochloric acid; Clean Slate III samples.

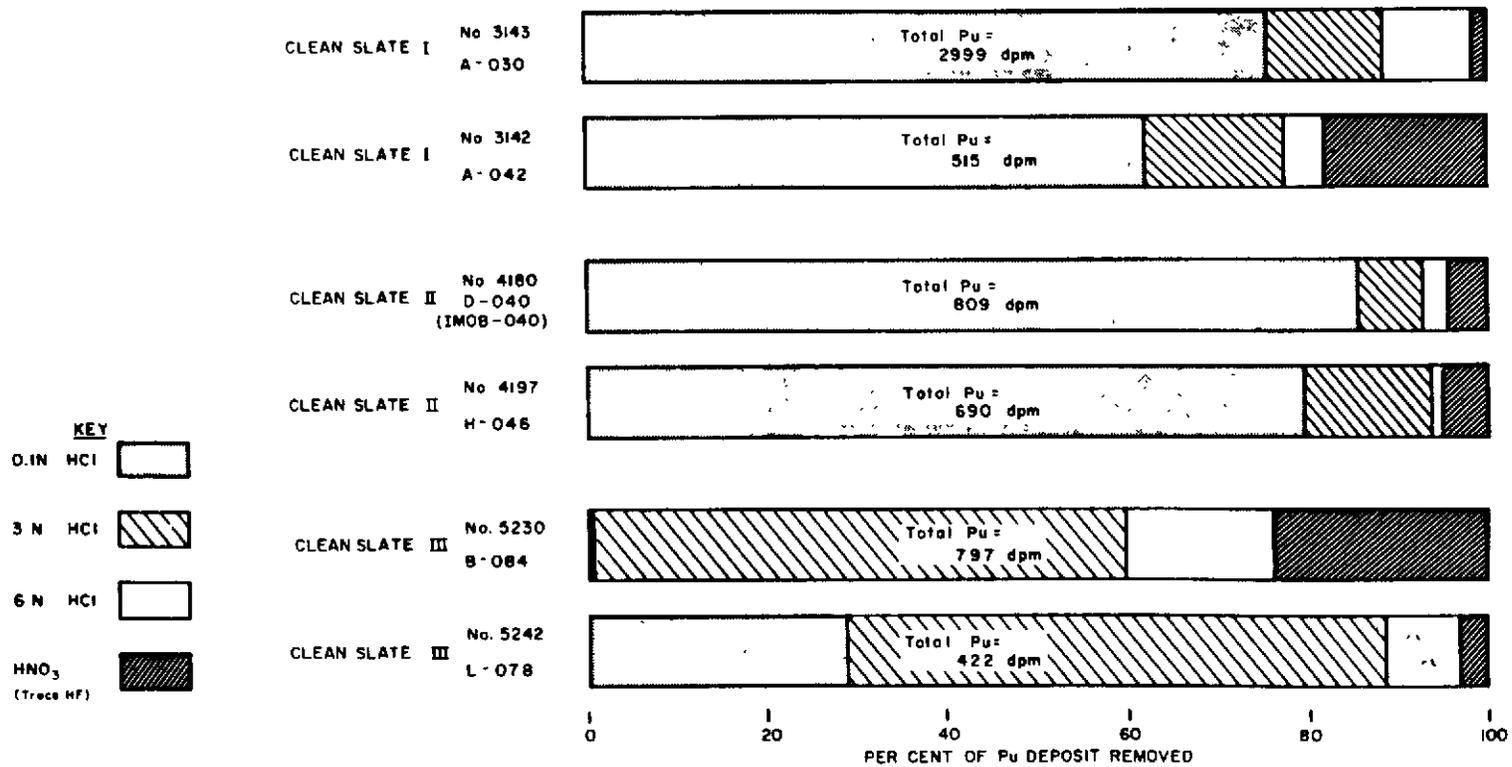


Figure 8.6 Percentage removal by various acid solutions of the plutonium sorbed on the walls of the glass bottles in which the water samples were stored. The bottles were leached with the acids in order of increasing acid concentration.

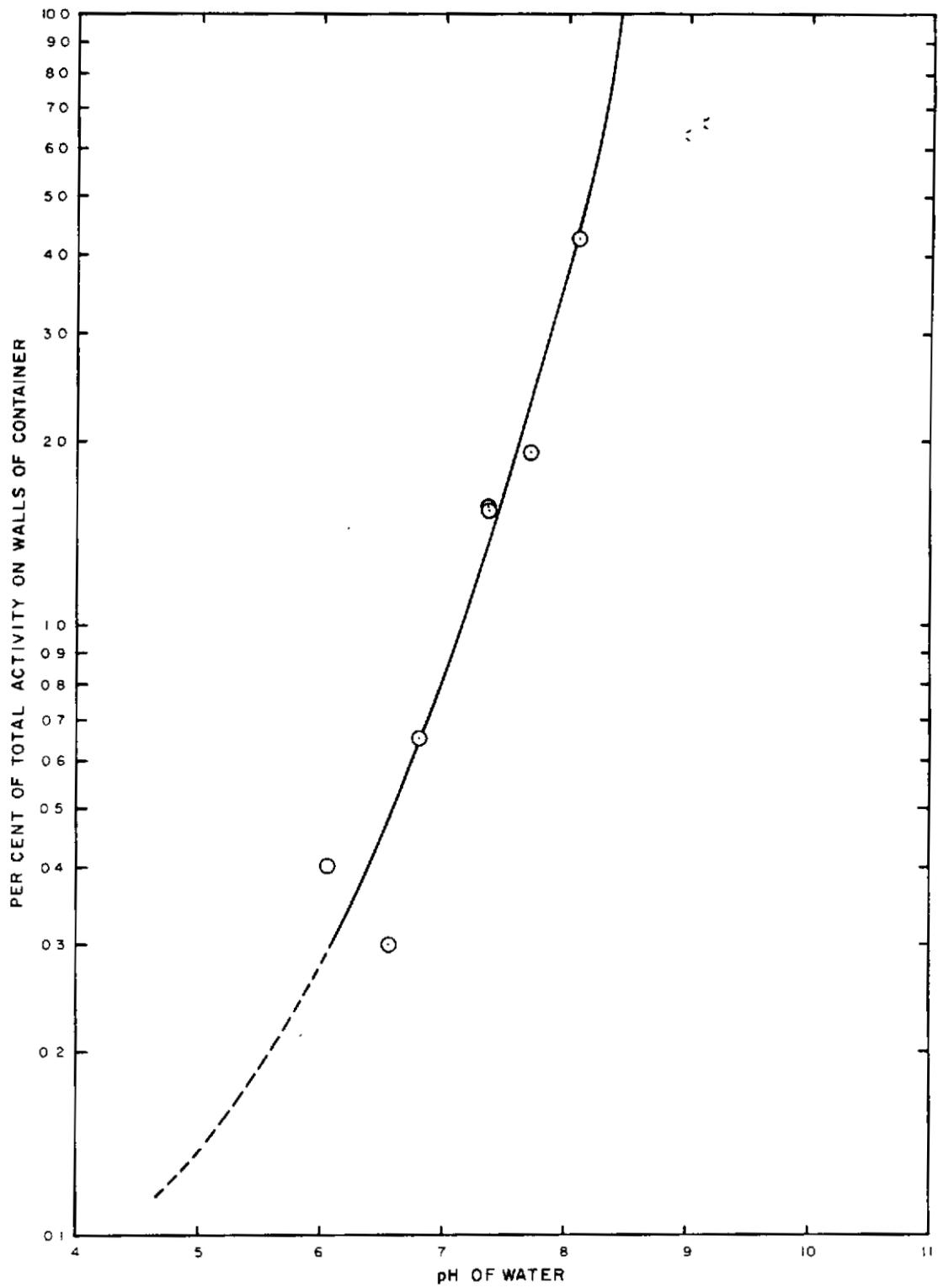


Figure 8.7 Percent of total sample plutonium sorbed on the walls of the glass bottles (sample containers) as a function of the pH of the water, after a year's storage.

APPENDIX  
PLUTONIUM DATA TABLES

The following entries have been used consistently under "Sampler Type" to describe the type of physical sample collection. Various synonyms are listed as they may appear in other project reports.

Andersen	Andersen Impactor (6 stages analyzed, including the filter)
Casella	Casella Impactor (5 stages analyzed, including the filter)
TAS-D	Total Air Sampler, disposable
TAS-I	Total Air Sampler, Type I
TAS-II	Total Air Sampler, Type II
Seq. Air.	Gelman Paper Tape Sequential Air Sampler
Wire Swipe	Cylindrical (wire) collector swipe from balloon curtain
Film	Gummed Film, Sticky Film, Deposition Samples
Al. Coll.	Aluminum Collector, Petrolatum Samples, Debris Samples, Bits and Pieces, Disk Collectors
Soil	Soil cores, throwout samples, and belt monitor samples.
Water	Distilled water, Trays. Refer also to Solubility Study, Chapter 8.

In the "Remarks" column, the Uranium or Americium notations indicate that the sample also was analyzed for this element. Other remarks either are included in their entirety or footnoted on the same page, depending on length.

There are a number of instances throughout the data tables where the analytical result has been expressed to three or four digits and the accompanying counting error does not justify such apparent precision. In this way, the data may be rounded off consistently among all laboratories when it is compiled.

A.1 PLUTONIUM ANALYSES OF DASA QUALITY CONTROL SAMPLES  
(Table A.2)

A.1.1 Soils. The results on duplicate soil samples showed that representative 4 to 5 gram samples could not be obtained by aliquoting the particular dry soil selected for this purpose. Consequently, at the request of DASA, analysis of this type of sample was stopped.

A.1.2 Quality Control Solutions. Fourteen plastic screw cap vials sealed with paraffin and containing about 7 to 10 ml each of solution were received in two lots of seven March 20, 1964 and March 25, 1964.

Ten of the 14 vials had obviously leaked and the packing tissue was damp and discolored, but there was sufficient sample left in all cases for analysis. It is not felt that there was enough cross contamination to invalidate our results, unless one or more of the samples was prepared as a complete blank instead of a spike. In this case, a small amount of contamination could have crept in during transport or during our decontamination of the outside surfaces. Samples received were as follows:

DASA No.	Date Received	Analysis For	Expected Amount	Leaky
213	3-20-64	U, Pu	Very Low	
217	3-25-64	U, Pu	" "	
535	"	U, Pu	" "	x
547	3-20-64	U, Pu	" "	x
AA17	"	U	<200 µg U/l	x
AA59	3-25-64	U	" "	
AB11	3-20-64	U	<1000 µg U/l	x
AC51	3-25-64	U	<2000 µg U/l	x
CA44	3-20-64	Pu	<25 dpm Pu/ml	x
CB34	3-25-64	Pu	<200 dpm Pu/ml	x
CC13	"	Pu	<1000 dpm Pu/ml	x
CC91	3-20-64	Pu	" "	
CD33	"	Pu	<6000 dpm Pu/ml	x
CD46	3-25-64	Pu	" "	x

A.1.3 Biological Quality Controls. Although H-NSC was told to expect activity levels up to 4500 dpm, it was disconcerting to find such overall high activity levels in the first group of these samples as contrasted with the very low activities observed in Roller Coaster animals. Consequently, all subsequent groups were treated in the laboratory areas reserved for physical samples in order to minimize contamination of the routine biologicals.

#### A.2 H-NSC INTERNAL QUALITY CONTROL SAMPLES (Table A.3)

H-NSC processed a total of 49 internal control samples consisting of 13 blank urines, 8 blank ashing dishes processed together with biological samples, 15 blank Millipore filters, and 10 chemistry blanks, processed with the physical samples. A total of 3 samples were spiked with Pu<sup>239,240</sup>. The results are given in Table A.3.

H-NSC quality control blank #1675 showed 17.2 dpm Pu contamination, which was very much higher than any other biological blank.

The blank consisted of an empty porcelain ashing dish (plus added Pu<sup>236</sup>) muffled with Rochester biological quality control sample 21B (493 dpm Pu found). This was a small muffle holding only two dishes at a time. It was used only for the Rochester samples after these were found to contain such relatively high levels of Pu that there was a risk of contaminating Roller Coaster biologicals by ashing the two types together. This blank then was put through chemistry together with Rochester samples 19B (217 dpm), 24B (1943 dpm), and 25B (591 dpm). Since the blank was being run to check for possible cross contamination from the high-level Rochester samples, exceptional care was taken at the beginning. The empty dish was examined carefully upon removal from the muffle, and no foreign matter or signs of contamination were visible. If the Rochester samples were uniformly spiked, it is difficult to imagine how this much contamination could have occurred without a visible ash being present in the blank dish. Other possible avenues of contamination were thoroughly explored as well, but no explanation could be found. The chemical yield was a satisfactory 88 percent, so poor counting statistics could not be blamed.

Samples H-NSC-839, H-NSC-1600, and H-NSC-1696 were special quality control tests to determine residual contamination in re-used Teflonware. For each test, a Teflon beaker which had been used several times for very active physical samples ( $10^4$  to  $10^6$  dpm) was cleaned by H-NSC's usual methods; then, after tracer addition, was treated as a blank with normal dissolution reagents. These

blanks were carried through the chemistry together with low-level samples in groups of eight, and showed 4.2, 5.7, and 1.1 dpm Pu, respectively. These quantities were less than 0.5 percent of any of the samples processed concurrently.

In addition to the internal quality controls processed to monitor Roller Coaster operations, plutonium analyses, with their associated controls, were carried out for other clients concurrently. Specifically, one program of analyzing large volumes of seawater for Pu applied directly to Roller Coaster operations since it involved extremely low levels of activity. In this case even the positive Pu results from seawater, a few hundredths of a dpm, could be viewed as quality control blanks for general laboratory processing.

### A.3 BIOLOGICAL SPECIMENS, DOUBLE TRACKS (Table A.4)

Of special concern was the possible cross contamination of biological samples. Shipping container number 19 had a fair amount of blood in the bottom, and a number of samples had blood on the outside. The majority of this was due to bag rupture at the initial packing, although several samples that were thawed for identification purposes and refrozen also apparently leaked. Monitoring and checking of wipes from Box 19 showed no residual alpha activity, but the possibility of contamination should be taken into account in evaluating the data.

H-NSC does not have accurate data on which Double Tracks animals were used as controls; consequently, all such assignments

are questioned under "Remarks". Various identifying letters accompany many of the biological specimens, especially the burros. These letters are the same as those used in the "Official" typed inventory made 27 September, 1964, in the presence of Capt. William Godden. A number of inaccuracies were found in the inventory and have been noted.

Double Tracks biological sample X-18B-8 (burro stomach) is reported as  $8.30 \pm 0.75$  dpm. The error was assigned on the basis of counting precision alone, but it is believed that the accuracy error is more on the order of 40 percent. A yield of only a few percent was obtained on first processing, and because of the low resulting activity, the associated counting error was large. The stored waste from this sample was reworked to provide a second sample with 11 percent yield. The two results were weighted to provide the reported value but they displayed different  $\text{Pu}^{239}/\text{Pu}^{236}$  ratios. Most of the difference can be explained by statistical reasoning, but it is suspected that the rest may be due either to contamination or, possibly, to inadequate exchange of tracer and sample, although the latter explanation seems remote for this particular sample.

Wet weights given in Table A.4 include the weights of polyethylene bags for purposes of identification with field weights. The only exceptions are special dog hilar node samples listed with the NET weights designated under 'Reworks'. Bag weights were generally 4.5 g for specimens less than 100 g, and 10 g for those above 100 g in weight. Double and triple large bags were not uncommon for the largest or leakiest specimens.

At an early stage of the analytical program a few dry weights and ash weights were obtained on biological samples. This practice was discontinued after the information given in Table A.1 was obtained. All specimens came from two dogs, thought to be control animals. The samples were dried, without the polyethylene bag, to constant weight at 110°C, and finally ashed at about 600°C. It can be seen from the wet weights that one animal appears to be heavier than the other, or else differing amounts of connective tissue were removed. The plutonium results indicate a slight positive body burden generally but no special concentration in any one tissue.

TABLE A.1 DOG SPECIMEN WEIGHTS, DOUBLE TRACKS

Dog No.	Tissue	Wet	Dry	Ash Weight		Pu-239,240
		Weight*	Weight	Wet	Dry	
		grams	percent	percent		dpm/sample
1010-1	left femur	35.49	82.5	34.3	41.6	0.016 ± 0.14
1098-1	left femur	25.50	76.6	34.8	45.5	0.38 ± 0.06
1010-2	kidneys	51.69	22.6	1.57	6.95	0.31 ± 0.05
1098-2	kidneys	44.75	25.5	1.34	5.26	1.61 ± 0.09
1010-3	liver	272.36	48.5	3.26	6.72	0.64 ± 0.07
1098-3	liver	220.97	30.1	1.62	5.38	0.30 ± 0.05
1010-4	lungs	108.03	19.1	1.28	6.68	0.62 ± 0.06
1098-4	lungs	68.92	21.5	1.31	6.08	0.53 ± 0.05
1010-5	Hilar nodes	1.20	42.3	4.33	10.5	0.07 ± 0.07
1098-5	Hilar nodes	1.75	51.5	1.95	10.0	0.18 ± 0.05

\*Net weight of specimen only. Add 4.5 grams for polyethylene bag.

TABLE A.2 PLUTONIUM ANALYSIS OF DASA QUALITY CONTROL SAMPLES

Sample No.	Type	Sample Weight	Aliquot	Pu-239,240	Remarks	Counting Time	Yield
		grams		dpm/sample		min.	approx. percent
BI-9A	DASA Soil	4.93780		26,585 ± 1170	Split by H NSC	60	15
BI-9B	" "	4.93225		13,400 ± 335	" " "	60	46
EG-2A	" "	4.11915		1985 ± 56	" " "	200	3
EG-2B	" "	4.11984		1530 ± 34	" " "	200	60
BF-1A	" "	5.37547		85.3 ± 0.68	" " "	2400	30
BF-1B	" "	5.36945		52.8 ± 0.58	" " "	2400	23
BM-2	" "	10.9594		1170 ± 30	" " "	200	70
BD-2	" "	9.12080		1.80 ± 0.25x10 <sup>4</sup>	" " "	241	2
BA-10	" "	9.49091		1.00 ± 0.15x10 <sup>5</sup>	" " "	72	6
BE-4	" "	9.69520		7459 ± 22	" " "	100	64
BJ-7	" "	9.83798		3.74 ± 0.19x10 <sup>4</sup>	" " "	50	47
BJ-8	" "	8.69849		1519 ± 61	" " "	50	72
BL-8	" "	11.21257		5.56 ± 0.26x10 <sup>4</sup>	" " "	50	58
BN-2	" "	11.26892		1414 ± 57	" " "	50	72
BL-10	" "	11.38145		5103 ± 187	" " "	120	38
BP-5	" "	9.76050		5.54 ± 0.49x10 <sup>4</sup>	" " "	18	37
CC 13 A	Slit		1.0 ml	76.63 ± 2.38	Average	180	80
CC 13 B	" "		" "	69.26 ± 1.94	72.94 ± 6.53	180	32
CD 33 A	" "		" "	4895 ± 98	" " "	60	30
CD 33 B	" "		" "	5081 ± 115	4957 ± 165	60	20
CE 34 A	" "		" "	506.9 ± 9.6	" " "	180	51
CE 34 B	" "		" "	512.8 ± 8.7	509.8 ± 5.2	180	59
CA 44 A	" "		" "	26.34 ± 1.16	" " "	240	25
CA 44 B	" "		" "	24.58 ± 0.69	25.46 ± 1.56	240	68
CB 44 A	" "		" "	43 ± 7	" " "	60	55
CC 11	" "		" "	4501 ± 5	4501 ± 08	10	80
CD 31 A	" "		" "	97.23 ± 2.10	" " "	240	13
CD 31 B	" "		" "	97.23 ± 2.10	97.23 ± 2.10	0	41
213 A	" "		" "	4.17 ± 0.15	" " "	1000	76
21 B	" "		" "	4.02 ± 0.12	4.78 ± 0.31	240	78
21	" "		" "	4.04 ± 0.11	" " "	200	75
-	" "		" "	4.66 ± 0.13	4.56 ± 1.59	1000	65
53B	" "		" "	4.47 ± 0.14	" " "	1400	75
5	" "		" "	4.23 ± 0.07	4.34 ± 0.17	1400	78
5A	" "		" "	4.18 ± 0.0	" " "	1400	57

\*Sample analyzed in "hot" laboratory accompanying 10<sup>5</sup> to 10<sup>6</sup> dpm samples.

TABLE A.2 PLUTONIUM ANALYSIS OF DASA QUALITY CONTROL SAMPLES (cont'd.)

Sample No.	Type	Weight	Pu-239,240	Remarks	Counting Time	Yield
	University of Rochester Biological Samples	grams	dpm/sample		min	approx percent
1 - B		149.3	997 ± 25	Processing Started 27 January 1964	162	71
2 - B		188.6	2101 ± 45		162	82
3 - B		169.1	720 ± 17		162	65
4 - B		163.0	2766 ± 70		165	57
5 - B		169.2	1222 ± 29		165	45
6 - B		162.6	3986 ± 95		120	29
7 - B		188.9	90 ± 2		144	92
8 - B		167.9	1916 ± 45		165	61
9 - B		172.5	1704 ± 40		165	61
10 - B		166.2	1502 ± 90	Processing Started 10 February 1964	30	99
11 - B		173.3	828 ± 27		30	85
12 - B		162.9	265 ± 10		30	60
13 - B		175.1	926 ± 50		30	35
14 - B		154.2	704 ± 22		30	4
15 - B		170.2	2572 ± 144		30	73
16 - B		172.7	641 ± 32		30	40
17 - B		137.0	190 ± 2		984	55
18 - B		159.2	737 ± 24		30	90
19 - B		171.6	217 ± 7	Processing Started 24 February 1964	60	89
20 - B		160.2	1290 ± 92		762	1
21 - B		148.8	495 ± 19		30	71
22 - B		162.5	3479 ± 230		30	76
23 - B		173.0	977 ± 37		30	73
24 - B		167.6	1943 ± 72		30	75
25 - B		157.9	59 ± 20		30	83
26 - B		182.6	3566 ± 214		30	76
27 - B		167.6	94 ± 0.7		30	65
28 - B	Mean Spike	160.5	380 ± 14	Processing Started 4 March 1964	30	79
29 - B	"	209.1	525 ± 21		30	66
30 - B	"	210.5	340 ± 13		30	90
31 - B	"	163.5	2821 ± 97		30	54
32 - B	"	185.6	1311 ± 38		45	81
33 - B	"	173.5	3171 ± 76		60	29
34 - B	"	149.7	374 ± 13		30	21
35 - B	"	168.1	1570 ± 58		30	76
36 - B	Bore Spike	150.9	1235 ± 53		90	5
37 - B	"	138.5	287 ±	Processing Started 11 March 1964	60	57
38 - B	Mean Spike	173.7	2525 ± 101		30	66
39 - B	Mean Spike	206.9	1135 ± 49		30	51
40 - B	"	175.0	3721 ± 153		30	65
41 - B	"	173.9	4.50 ± 0.50		90	67
42 - B	"	213.7	9.54 ± 0.95		120	25
43 - B	Bore Spike	92.7	33.64 ± 1.5		180	27

TABLE A.2 PLUTONIUM ANALYSIS OF H-NSC INTERNAL CONTROL SAMPLES

Sample No.	Aliquot	Pu-239,240 dpm/sample	Remarks	Counting Time min.	Yield approx. percent
H-NSC-437	Spiked urine 17.32±0.52 dpm Pu <sup>239</sup> added	1000 ml 17.92 ± 0.54		672	30
H-NSC-726	Ashing dish spiked 8.66±0.26 dpm Pu <sup>239</sup> added	8.73 ± 0.49		122	91
H-NSC-1395	Millipore filter 8.66±0.26 dpm Pu <sup>239</sup> added	9.48 ± 0.73		90	62
BLANK URINES ACCOMPANYING BIOLOGICAL SAMPLES					
H-NSC-435	1000 ml	0.117 ± 0.059		141	76
H-NSC-436	"	0.094 ± 0.027		691	34
H-NSC-1128	"	0.13 ± 0.09		67	80
H-NSC-1129	"	0.226 ± 0.058		250	85
H-NSC-1130	"	0.081 ± 0.036		751	21
H-NSC-1131	"	0.091 ± 0.034		747	30
H-NSC-1132	"	0.065 ± 0.029		626	38
H-NSC-1133	"	0.092 ± 0.031		751	34
H-NSC-1134	"	0.22 ± 0.13		60	70
H-NSC-1135	"	0.20 ± 0.12		60	72
H-NSC-1136	"	0.160 ± 0.076		747	50
H-NSC-1137	880 ml	0.73 ± 0.068		358	65
H-NSC-1138	1000 ml	0.73 ± 0.09		120	40
BLANK ASHING DISHES ACCOMPANYING BIOLOGICAL SAMPLES					
H-NSC-492		0.054 ± 0.023		382	87
H-NSC-493		-0.003 ± 0.02		930	54
H-NSC-494		0.08 ± 0.03		1074	77
H-NSC-495		0.05 ± 0.04		90	68
H-NSC-496		0.15 ± 0.10		152	35
H-NSC-497		0.10 ± 0.02		1074	79
H-NSC-498		3.75 ± 0.44	Blank Run with Rochester #19	256	54
H-NSC-499		17.19 ± 1.27	Blank Run with Rochester #19-27. See explanation in text.	120	89
BLANK MILLIPORE FILTERS ACCOMPANYING PHYSICAL SAMPLES					
H-NSC-491		0.138 ± 0.02		2400	73
H-NSC-490		0.999 ± 0.071		306	82
H-NSC-497		-0.01 ± 0.03		1130	85
H-NSC-492		0.044 ± 0.008		3400	88
H-NSC-494		0.01 ± 0.02	Used "hot" Teflon beaker. See explanation in text.	122	74
H-NSC-495		0.03 ± 0.17		60	44

TABLE A.3 PLUTONIUM ANALYSIS OF H-NSC INTERNAL CONTROL SAMPLES (cont'd.)

Sample No.	Pu-239,240 dpm/sample	Remarks	Counting time min.	Yield approx. percent
H-NSC-1000	0.83 ± 0.17		120	70
H-NSC-1060	0.13 ± 0.07		120	80
H-NSC-1110	0.08 ± 0.03		100c	30
H-NSC-1156	0.45 ± 0.11		173	36
H-NSC-1244	0.53 ± 0.14		120	51
H-NSC-1600	5.68 ± 0.97	Used "hot" Teflon beaker; see text.	60	99
H-NSC-1601	0.67 ± 0.09		960	80
H-NSC-1696	1.13 ± 0.03	Used "hot" Teflon beaker; see text.	60	90
H-NSC-1697	0.21 ± 0.21		60	76
CHEMISTRY BLANKS - NO DISSOLUTION				
H-NSC-516	-0.06 ± 0.05		315	67
H-NSC-538	-0.24 ± 0.05		697	74
H-NSC-1408	0.355 ± 0.024		565	50
H-NSC-1409	0.080 ± 0.028		565	46
H-NSC-1460	0.66 ± 0.33		60	99
H-NSC-1469	0.18 ± 0.11		60	86
H-NSC-1572	0.082 ± 0.027		420	81
H-NSC-1573	0.025 ± 0.014		422	88
H-NSC-1766	1.50 ± 0.5		60	99
H-NSC-1767	0.90 ± 0.23		60	92
H-NSC-153e	0.02 ± 0.03	Plating controls no dissolution or chemistry	328	--
H-NSC-1537	0.02 ± 0.03	" " " "	328	--
H-NSC-1538	0.02 ± 0.03	" " " "	328	--
H-NSC-1539	0.02 ± 0.03	" " " "	328	--

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet	Pu-239,240	Remarks	Counting Time	Yield
				grams	dpm/sample		min.	approx. percent
Dog	D + 3	1002-1	Left femur	42.20	0.11 + 0.35		600	47
		-2	Kidney	61.32	0.09 + 0.03		182	93
		-3	Liver	325.5	0.62 + 0.14		181	70
		-4	Lung	115.3	1.33 + 0.13		381	64
		-5	H. node	5.78	0.11 + 0.04		300	94
"	"	1003-1	Left femur	35.05	0.10 + 0.04		380	59
		-2	Kidney	51.3	0.12 + 0.03		691	51
		-3	Liver	303.8	0.18 + 0.08		75	69
		-4	Lung	87.8	1.15 + 0.16		373	36
		-5	H. node	6.12	0.02 + 0.02		719	42
"	"	1006-1	Left femur	39.0	0.10 + 0.03		380	62
		-2	Kidney	61.7	0.29 + 0.09		201	47
		-3	Liver	336.8	0.57 + 0.08		540	27
		-4	Lung	90.1	53.0 + 0.7		340	94
		-5	H. node	0.8205	0.03 + 0.02		211	95
"	"	1010-1	Left femur D	39.92	-0.02 + 0.14	Control? Dry weights taken on all tissue samples of this dog.	1076	16
		-2	Kidney	51.69	0.31 + 0.05		543	82
		-3	Liver	276.86	0.64 + 0.07		1348	43
		-4	Lung	112.53	0.62 + 0.06		939	74
		-5	H. node	1.2003	0.07 + 0.07		60	78
"	"	1011-1	Left femur	35.9	0.08 + 0.03		682	11
		-2	Kidney	51.6	0.16 + 0.05		290	84
		-3	Liver	307.6	0.31 + 0.05		1840	19
		-4	Lung	82.5	35.28 + 1.53		60	39
		-5	H. node	5.26	0.19 + 0.05		2360	11
"	"	1013-1	Left femur	41.64	0.155 + 0.04		380	71
		-2	Kidney	76.5	0.11 + 0.03		677	66
		-3	Liver	357.1	0.74 + 0.12		285	57
		-4	Lung	112.6	47.0 + 1.2		115	20
		-5	H. node	6.51	-0.03 + 0.07		300	93
"	"	1025-1	Left femur	34.0	0.04 + 0.10		600	40
		-2	Kidney	54.9	0.07 + 0.02		471	74
		-3	Liver	305.4	0.47 + 0.09		249	70
		-4	Lung	83.0	92.31 + 2.40		115	19
		-5	H. node	5.14	-0.06 + 0.05		300	95
"	"	1037-1	Left femur	38.5	0.30 + 0.11		1088	10
		-2	Kidney	42.98	0.06 + 0.02		380	80
		-3	Liver	227.1	0.16 + 0.06		249	64
		-4	Lung	72.9	32.22 + 1.09		143	59
		-5	H. node	2.51	-0.02 + 0.02	Net on official inventory *	993	63
"	"	1042-1	Left femur	29.32	0.09 + 0.03		600	49
		-2	Kidney	57.9	0.15 + 0.03		671	70
		-3	Liver	225.7	0.58 + 0.07		422	78
		-4	Lung	72.4	91.80 + 2.95		217	27
		-5	H. node	0.6289	0.12 + 0.04		543	43
"	"	1047-1	Left femur	31.84	0.08 + 0.03		745	33
		-2	Kidney	46.2	0.06 + 0.03		228	72
		-3	Liver	329.4	0.30 + 0.06		1000	79
		-4	Lung	101.5	8.03 + 0.42		719	30
		-5	H. node	1.954	0.12 + 0.03		543	93
"	"	1052-1	Left femur	40.7	0.36 + 0.10		663	16
		-2	Kidney	66.7	0.06 + 0.02		671	52
		-3	Liver	300.0	0.45 + 0.14		205	34
		-4	Lung	139.1	5.95 + 0.32		691	24
		-5	H. node	6.58	0.01 + 0.07		980	96
"	"	1055-1	Left femur	28.2	0.09 + 0.03		2360	19
		-2	Kidney	56.0	0.09 + 0.02		970	84
		-3	Liver	248.4	0.22 + 0.06		249	74
		-4	Lung	74.6	9.43 + 0.53		217	59
		-5	H. node	5.55	-0.01 + 0.03		980	83
"	"	1059-1	Left femur	30.8	0.41 + 0.14		512	13
		-2	Kidney	40.02	0.06 + 0.02		600	60
		-3	Liver	32.75	0.28 + 0.10		75	74
		-4	Lung	89.6	10.13 + 0.42		377	47
		-5	H. node	0.7598	0.04 + 0.02		492	86
"	"	1054-1	Left femur	29.01	0.59 + 0.09		600	45
		-2	Kidney	51.6	0.18 + 0.06		667	33
		-3	Liver	278.0	0.34 + 0.06		1840	11
		-4	Lung	76.3	30.45 + 1.24		377	16
		-5	H. node	5.46	0.11 + 0.03		2360	24

\* Net weight rather than gross weight given

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet	Pu-239,240		Remarks	Courting Time	Yield	
				grams	app/sample	min.		approx percent		
Dog	D + 3	1085-1	Left femur	31.9	0.15	+ 0.04	.	1055	37	
			Kidney	51.7	0.05	+ 0.02		718	23	
			Liver	459.4	0.65	+ 0.10		1840	10	
			Lung	72.1	5.58	+ 0.44		143	63	
			H. node	0.8724	0.05	+ 0.02		492	75	
"	"	1088-1	Left femur	44.3	0.52	+ 0.09	.	570	37	
			Kidney	50.3	0.05	+ 0.01		290	28	
			Liver	249.6	0.78	+ 0.06		1260	61	
			Lung	84.1	0.58	+ 0.07		1000	40	
			H. node	6.10	0.15	+ 0.004		600	44	
"	"	1091-1	Left femur	37.0	0.04	+ 0.02	.	688	25	
			Kidney	57.2	0.07	+ 0.04		225	3	
			Liver	300.2	0.29	+ 0.08		249	57	
			Lung	107.1	0.88	+ 0.23		90	63	
			H. node	5.35	-0.03	+ 0.09		600	17	
"	"	1098-1	Left femur	30.0	0.38	+ 0.06	Control* Dry weights taken on all tissue samples of this dog.	544	50	
			Kidney	50.25	1.61	+ 0.09		892	73	
			Liver	225.47	0.30	+ 0.05		1157	74	
			Lung	73.42	0.53	+ 0.05		1884	42	
			H. node	6.25	0.18	+ 0.05		588	75	
"	"	1101-1	Left femur	36.78	0.07	+ 0.02	Only 1/2 specimen received.	2360	24	
			Kidney	59.4	0.02	+ 0.01		67	1	
			Liver	328.5	0.37	+ 0.15		60	63	
			Lung	37.2	0.88	+ 0.15		589	22	
			H. node	0.6283	0.06	+ 0.02		745	54	
"	"	1104-1	Left femur	49.5	0.11	+ 0.05	.	535	21	
			Kidney	67.2	0.10	+ 0.04		223	68	
			Liver	392.8	0.44	+ 0.06		845	44	
			Lung	152.2	0.29	+ 0.09		155	69	
			H. node	1.1198	0.06	+ 0.02		745	47	
"	"	1107-1	Left femur	40.0	0.42	+ 0.16	.	688	7	
			Kidney	51.4	-0.03	+ 0.03		691	10	
			Liver	276.7	0.47	+ 0.14		.	381	92
			Lung	75.6	8.13	+ 0.27				
			H. node	0.6068	0.06	+ 0.02				
"	"	1115-1	Left femur	27.5	0.13	+ 0.03	.	616	56	
			Kidney	42.0	0.06	+ 0.02		667	90	
			Liver	229.9	0.45	+ 0.09		180	84	
			Lung	66.6	1.08	+ 0.12		381	88	
			H. node	5.11	-0.01	+ 0.06		300	87	
"	"	1131-1	Left femur	37.8	0.11	+ 0.05	.	774	7	
			Kidney	69.6	0.38	+ 0.10		164	70	
			Liver	306.1	0.24	+ 0.05		340	95	
			Lung	114.8	1.89	+ 0.23		120	91	
			H. node	1.1751	0.084	+ 0.03		492	72	
Sheep	D + 90	2001-1	Left femur	205.8	0.17	+ 0.05	.	715	13	
			Kidney	125.2	0.16	+ 0.04		90	87	
			Liver	550.0	0.07	+ 0.07		60	79	
			Lung	449.1	0.39	+ 0.09		947	41	
			H. node	10.4143	0.03	+ 0.03		141	73	
"	D - Day	2022-1	Left femur	180.3	44.20	+ 11.05	Uranium	90	13	
			Kidney	38.0	15.28	+ 6.63		240	51	
			Liver	521.5	3.36	+ 0.26		240	55	
			Lung	439.1	5.62	+ 0.35		1032	28	
			H. node	7.834	0.44	+ 0.20		140	81	
			Trachea	143.8	0.25	+ 0.03		994	36	
			Stomach	7071.0	90.57	+ 1.36		950	10	
			F. mucosa	11.16	0.16	+ 0.08		90	82	
			N. mucosa	76.5	5.56	+ 0.56		140	38	
"	D - 3	2024-1	Left femur	177.1	0.18	+ 0.04	.	902	36	
			Kidney	110.7	0.20	+ 0.14		60	52	
			Liver	486.8	0.69	+ 0.20		180	15	
			Lung	379.8	139.0	+ 7.5		123	57	
			H. node	7.1059	0.05	+ 0.02		427	55	

\* Net weight rather than gross weight given.

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet		Pu-239,240		Counting Time	Yield	
				grams	dpm/sample	min.	approx. percent			
Sheep	D + 90	2025-1	Left femur	187.3	0.24 ± 0.06	745	27			
			Kidney	97.4	0.25 ± 0.11	90	70			
			Liver	539.9	0.43 ± 0.16	60	95			
			Lung	424.1	0.46 ± 0.16	60	91			
			H. nodes	8.1933	0.08 ± 0.03	616	46			
"	21 May 20 Aug 21 Aug 22 Aug 21 May 22 May 23 May D + 30	2031-	Urine	1239.4	1291 ± 71	60	36			
			"	1669.3	12.70 ± 0.70	624	12			
			"	823.1	1.91 ± 0.38	90	42			
			"	1212.0	1.85 ± 0.70	90	42			
			Feces	901.1	936 ± 94	1000	10			
			"	671.3	5588 ± 1565	60	4			
			"	462.2	1371 ± 219	60	14			
			"	3062.0	566.2 ± 65.4	43	37			
			"	D + 3	2033-1	Left femur	182.6	0.48 ± 0.06	947	45
						Kidney	111.9	0.14 ± 0.10	60	74
Liver	695.6	1.28 ± 0.48				120	14			
Lung	189.3	5.56 ± 0.10				2680	52			
H. nodes	4.267	0.11 ± 0.040				205	87			
"	D + 90	2035-1	Left femur	201.5	0.14 ± 0.02	1979	50			
			Kidney	101.7	0.07 ± 0.07	60	74			
			Liver	631.1	0.33 ± 0.15	60	80			
			Lung	507.8	0.95 ± 0.19	90	88			
			H. node	13.35	0.66 ± 0.09	719	38			
"	21 May 22 May 20 Aug 21 Aug 22 Aug 21 May 22 May 23 May D + 30	2036-	Urine	21368	6489 ± 260	60	65			
			"	1355	7796 ± 346	120	27			
			"	Lost in muffle explosion						
			"	981.0	7.20 ± 0.48	1090	9			
			"	1541.2	13.77 ± 0.16	2514	47			
			Feces	679.6	6173 ± 2027	60	3			
			"	788.8	4278 ± 654	30	27			
			"	248.5	363.1 ± 26.1	60	65			
			"	4925.5	106.9 ± 6.5	60	26			
			"	D + 90	2037-1	Left femur	196.7	0.41 ± 0.11	845	13
Kidney	103.3	0.14 ± 0.02				1088	85			
Liver	459.8	0.52 ± 0.20				60	70			
Lung	382.9	0.28 ± 0.06				947	28			
H. node	10.9827	0.11 ± 0.00				152	76			
"	D + 90	2045-1	Left femur	197.1	0.15 ± 0.03	607	81			
			Kidney	105.0	0.14 ± 0.06	173	66			
			Liver	634.0	0.44 ± 0.08	948	78			
			Lung	590.3	0.28 ± 0.14	60	73			
			H. node	10.199	0.21 ± 0.07	1049	65			
"	D + 3	2047-1	Left femur	201.6	0.12 ± 0.04	799	24			
			Kidney	94.6	0.07 ± 0.07	60	7			
			Liver	581.0	1.37 ± 0.47	120	16			
			Lung	639.2	150.8 ± 14.6	60	35			
			H. node	7.5015	0.13 ± 0.15	386	83			
"	20 May 21 May 22 May 23 May	2057	Urine	2150.7	300.2 ± 20.4	272	5			
			Feces	744.1	143.8 ± 18.7	300	2			
			"	782.0	15.3 ± 3.8	90	4			
			"	312.5	4.60 ± 0.60	300	42			
"	D + 3	2074-1	Left femur	189.0	Sample lost					
			Kidney	124.2	2.22 ± 0.67	180	86			
			Liver	688.1	0.62 ± 0.05	2680	53			
			Lung	624.0	16.89 ± 1.07	120	38			
			H. nodes	6.7277	0.04 ± 0.01	934	81			
"	D + 90	2075-1	Left femur	211.3	0.12 ± 0.06	715	14			
			Kidney	105.4	0.14 ± 0.08	90	72			
			Liver	538.1	0.42 ± 0.16	60	88			
			Lung	441.5	0.31 ± 0.14	60	84			
			H. nodes	8.4601	0.13 ± 0.05	285	52			
"	D + 90	2082-1	Left femur	229.4	0.51 ± 0.13	908	11			
			Kidney	135.7	0.04 ± 0.04	90	79			
			Liver	839.8	0.53 ± 0.10	90	71			
			Lung	458.2	3.43 ± 0.33	118	83			
			H. node	5.3124	0.26 ± 0.05	616	51			

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS. DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, grams	Pu-239,240 dpm/sample	Remarks	Counting Time min.	Yield approx. percent
Sheep	D + 90	2085-1	Left femur	231.7	0.13 ± 0.05		525	38
			-2 Kidney	132.7	0.17 ± 0.10		60	89
			-3 Liver	668.0	1.38 ± 0.33		180	68
			-4 Lung	519.6	0.35 ± 0.09		1000	14
			-5 H. node	9.5395	0.04 ± 0.03		285	53
"	21 May 22 May 20 Aug 21 Aug 22 Aug 21 May 22 May 23 May D + 30	2087	Urine	1070	2227 ± 111		1040	3
			"	2418	737.2 ± 32.4		60	65
			"	2503.2	55.98 ± 4.89		481	2
			"	793.3	39.61 ± 0.29		722	3
			"	2324.0	10.16 ± 0.41		581	32
			Feces	848.0	481.4 ± 91.5		90	2
			"	579.0	135.8 ± 10.0		300	4
			"	366.3	1062 ± 85		90	32
			"	4690.2	475.2 ± 15.2		950	
			"	20 Aug 21 Aug 22 Aug 21 Aug 22 May 23 May D + 30	2092	Urine	1730.2	3.67 ± 0.69
"	862.0	4.64 ± 0.27					476	41
"	960.9	1.34 ± 0.37					90	34
"	1020.5	0.13 ± 0.01					570	34
Feces	803.9	1027 ± 72					330	4
"	301.0	868.2 ± 121.5					60	17
"	4108.3	216.4 ± 5.2					1000	2
"								
"	21 May 22 May 23 May 22 May 23 May	2097	Urine	1148.7	490.0 ± 10.3		981	1
			"	1240.0	139.2 ± 3.1		950	14
			"	767.9	21.49 ± 0.64		1000	1
			Feces	858.2	453.2 ± 17.2		225	20
			"	354.7	363.6 ± 24.4		120	12
"	D + 3	2104-3	Left femur	181.4	1.06 ± 0.19		799	11
			-2 Kidney	92.4	0.05 ± 0.053		85	58
			-3 Liver	540.1	61.84 ± 19.57		180	90
			-4 Lung	457.7	25.82 ± 0.28		2680	36
			-5 H. node	5.5182	0.05 ± 0.02		427	94
"	21 May 22 May 20 Aug 21 Aug 22 Aug 22 May 23 May D + 30	2111	Urine	2302	3520 ± 338		60	12
			"	1300	1493 ± 148		120	5
			"	2552.4	64.8 ± 2.7		90	40
			"	773.0	9.73 ± 0.53		1260	40
			"	1307.0	18.19 ± 0.69		764	10
			Feces	312.6	963.0 ± 42.4		120	27
			"	373.1	176.3 ± 7.9		272	12
			"	4401.2	1676 ± 156		480	4
			"					
			"	21 May 20 Aug 21 Aug 22 Aug 21 May 22 May 23 May D + 30	2133	Urine	2460.0	1998 ± 78
"	2512.2	19 ± 3					127	20
"	760.1	1.40 ± 0.12					471	63
"	1600.0	3.99 ± 0.17					1090	38
Feces	1167.0	2539 ± 279					180	3
"	655.5	1011 ± 192					80	7
"	273.7	689.2 ± 15.2					991	43
"	4524.0	510.5 ± 22.9					180	11
"								
"	21 May 22 May 20 Aug 21 Aug 22 Aug 24 Aug 21 May 22 May	2134				Urine	1105.0	1348 ± 85
			"	1518.0	2104 ± 142		120	11
			"	1991.1	289.7 ± 10.7		131	34
			"	1178.0	7.09 ± 0.44		722	16
			"	1145.8	9.23 ± 0.83		722	5
			"	795.8	9.80 ± 0.34		581	34
			Feces	764.0	2285 ± 149		225	7
			"	528.0	1709 ± 164		120	7
			"					
			"	D Day	2143-1	Left femur	174.8	0.09 ± 0.09
-2 Kidney	101.1	0.11 ± 0.11					90	98
-3 Liver	502.0	18.79 ± 0.94					120	60
-4 Lung	356.8	134 ± 4.7				Uranium	150	66
-5 H. node	10.545	0.50 ± 0.23					60	52
-7 Trachea	119.7	57.23 ± 3.72					60	79
-8 Stomach	5407.0	125.2 ± 2.6					950	14
-9 F. mucosa	14.97	12.92 ± 0.77					60	84
-10 N. mucosa	102.4	21.82 ± 0.81					120	82

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet	Pu-239,240		Remarks	Counting Time	Yield	
					grams	dpm/sample			min.	approx percent
Sheep	22 May	2157	Urine	2765.0	9131	+484		120		19
	20 Aug		"	4109.3	342.9	± 55.6		401		0.5
	21 Aug		"	864.0	6.74	± 0.71		62f		
	22 Aug		"	2526.9	16.58	± 0.97		764		
	24 Aug		"	1908.0	7.30	± 0.60		120		52
	21 May		Feces	847.0	3112	± 103		102		58
	22 May		"	1128.0	2063	± 78		102		44
	23 May		"	491.5	218.2	± 15.3		90		13
	D + 30		"	5620.4	414.1	± 24.4		438		4
	"		D + 3	2164-1	Left femur	206.4	0.35	± 0.20		60
-2 Kidney		87.2			0.07	± 0.07		60		
-3E Liver		530.5			0.81	± 0.36		127		49
-4 Lung		348.6			0.34	± 0.04		960		70
-5 H. node		5.6159			0.06	± 0.04		39f		24
"	D + 90	2166-1	Left femur	211.3	0.10	± 0.03		750		23
			-2 Kidney	101.7	0.06	± 0.06		60		80
			-3 Liver	627.8	0.71	± 0.18		120		53
			-4 Lung	381.8	0.51	± 0.25		120		65
			-5 H. node	8.34	0.06	± 0.02		688		55
"	D Day	2168-1	Left femur	190.8	40.67	± 3.05		95f		2
			-2 Kidney	163.0	2.70	± 0.21		240		83
			-3 Liver	599.0	23.82	± 1.31		1165		4
			-4 Lung	710.1	251	± 4.2	Uranium	1000		44
			-5 H. node	7.983	0.85	± 0.42		60		90
			-7 Trachea	123.3	0.21	± 0.04		994		42
			-8 Stomach	5504.0	1214	± 46		160		27
			-9 F. mucosa	9.91	0.09	± 0.06		90		80
			10- N. mucosa	65.7	2.17	± 0.24		762		17
			"		2169-1	Left femur	203.9	574.8	± 69.0	
-2 Kidney	120.0	0.60				± 0.25		90		34
-3 Liver	592.5	15.11				± 0.44		1165		21
-4 Lung	433.9	57.47				± 1.21	Uranium	400		76
-5 H. node	10.292	0.79				± 0.25		60		66
-7 Trachea	154.6	3.89				± 0.47		60		90
-8 Stomach	5959.0	149.5				± 2.7		400		47
-9 F. mucosa	11.45	1.23				± 0.08		994		85
10 N. mucosa	121.1	11.54				± 0.72		102		69
"		2172				Urine	259f	1891	± 76	
			"	952.2	2135	± 81		415		11
			"	2070.2	19.22	± 1.00		180		33
			"	680.8	3.26	± 0.21		722		32
			"	1755.4	3.00	± 0.26		764		18
			"	1104.6	2248	± 73		160		34
			"	631.9	927.1	± 139.1		60		5
			"	328.1	718.8	± 107.8		60		16
			"	3824.2	481	± 24		1000		3
			"	D - Day	2173-1	Left femur	200.6	0.30	± 0.15	Not on official inventory
-2 Kidney	92.0	2.68				± 0.75		140		11
-3 Liver	442.5	1.30				± 0.23		120		60
-4 Lung	424.0	283.1				± 4.5	Uranium	1040		48
-5 H. node	9.182	0.34				± 0.14		90		71
-6 Right femur		not received					On inventory but missing			
-7 Trachea	114.5	4.64				± 0.56		60		74
-8 Stomach	4560.0	1203				± 61		180		14
-9 F. mucosa	11.48	1.30				± 0.62		207		70
10 N. mucosa	80.5	207.4				± 4.9		762		14
"	D + 90	2182-1	Left femur	211.5	0.05	± 0.05		120		69
			-2 Kidney	91.4	0.003	± 0.05		60		26
			-3 Liver	567.5	1.04	± 0.21		90		27
			-4 Lung	468.6	0.13	± 0.09		60		83
			-5 H. nodes	11.8037	0.05	± 0.01		934		70
"		2186-1	Left femur	214.5	37.50	± 0.45		525		99
			-2 Kidney	114.7	0.10	± 0.07		90		72
			-3 Liver	742.7	0.77	± 0.21		60		74
			-4 Lung	459.0	21.89	± 0.57		85		82
			-5 H. nod.	9.318	3.31	± 0.29		28f		43

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet		Pu-239,240		Remarks	Counting Time	Yield
				grams	dpm/sample	min.	approx. percent			
Sheep	21 May	B-3078 F	Urine	2697.0	625.3 ± 32.5	28t	5			
	22 May		"	2430.0	612.6 ± 17.8	40u	19			
	20 Aug		"	3825.1	4.19 ± 0.48	180	31			
	21 Aug		"	1001.0	24. ± 5	120	9			
	22 Aug		"	2336.5	9.76 ± 0.26	970	45			
	24 Aug		"	3536.4	1.30 ± 0.081	960	55			
	22 May		Feces	809.3	90.65 ± 3.26	978	55			
	23 May		"	384.2	779.6 ± 32.7	120	30			
	Burro		D + 3	3004-1	Left Femur	1072.1	16.47 ± 0.59	95t	15	
-2 Kidney		829.0			1.11 ± 0.30	60	66			
-4 Lung		1542.8			42.16 ± 2.32	90	87			
-5 H. Node		28.77E			0.51 ± 0.06	1055	48			
D + 7		3005-1	Left Femur	918.4	6.79 ± 0.18	120	6			
			-2 Kidney	709.0	0.14 ± 0.02	890	70			
			-3 Liver	1779.3	17.76 ± 1.26	60	50			
D + 7		3006-1	Left Femur	927.3	1.20 ± 0.26	978	18			
			-2 Kidneys	724.3	0.44 ± 0.05	978	51			
			-3 Liver	1929.7	8.32 ± 0.71	60	89			
			-4 Lung	1065.0	419.8 ± 10.5	400	25			
			-5 H. Nodes	16.18	0.09 ± 0.02	978	24			
D + 7		3015-1	Left Femur	952.9	1.62 ± 0.11	978	45			
			-2 Kidneys	633.1	1.75 ± 0.16	978	72			
			-5 H. Node	19.5946	0.24 ± 0.06	313	72			
D Day		3019-1	Left Femur	989.4	15.30 ± 0.83	180	64			
			-2 Kidney	722.5	2.10 ± 0.20	180	82			
			-3 Liver	2561.0	22.44 ± 0.72	180	70			
			-4 Lung	1566.0	142.2 ± 6.3	284	24			
			-5 H. Node	12.6655	1.31 ± 0.09	1030	51			
			-6 Right Femur	1023.0	21.91 ± 1.45	102	33			
			-7 Trachea	339.2	19.81 ± 0.73	120	66			
			-8 Stomach	65.36	9.24 ± 0.17	120c	83			
			-8B Stomach	1688.0	421.6 ± 19.8	120	25			
D - Day		3020-1	Left Femur	973.7	1.90 ± 0.12	56t	69			
						980	43			
D Day		3024-5	Hilar Node	18.2350	3.79 ± 0.17	120	73			
D Day		3032-1	Left Femur	1035.0	2.52 ± 0.33	1032	40			
			-2 Kidney	583.2	13.69 ± 0.31	1040	61			
			-3 Liver	2860.0	62.27 ± 0.66	950	8			
	-4 Lung		2252.0	1132 ± 40	102	60				
	-6 Right Femur		1217.0	33.50 ± 1.32	416	71				
	-7E Trachea		447.3	263.5 ± 3.7	23F	20				
	-8 Stomach		1263.0	200.3 ± 5.6	104.0	92				
	-9 P. Mucosa		44.48	52.44 ± 0.47						
D + 7	3040-1	Left Femur	1266.0	1.24 ± 0.21	936	11				
		-2 Kidney	609.7	0.35 ± 0.05	978	45				
		-3 Liver	2725.0	11.01 ± 0.42	472	20				
		-4 Lung	1537.2	385.4 ± 20.0	740	10				
		-5 H. Node	26.109	0.13 ± 0.02	1979	45				
D Day	3049-1	Left Femur	1003.3	324.9 ± 6.6	160	87				
		-2 Kidney	1058.0	11.14 ± 0.20	120c	71				
		-3 Liver	4304.0	87.92 ± 3.87	135	55				
		-4 Lung	1650.0	7.75 ± 1.1	330	54				
		-5 H. Node	13.150	1.93 ± 0.11	980	34				
D Day	3050-1	Left Femur	1035.2	10.71 ± 0.69	102	76				
		-2 Kidney	744.0	0.64 ± 0.16	80	80				
		-2C Kidney	998.0	0.23 ± 0.13	240	99				
		-3 Liver	2688.7	21.13 ± 0.32	1010	6t				
		-4 Lung	1409.0	1047 ± 29	1010	9				
		-4C Lung	1743.0	8.48 ± 0.25	1000	45				
		-5 H. Node	11.26	3.31 ± 0.36	180	42				
		-6 Right Femur	950.8	3.71 ± 0.29	240	59				
		-7 Trachea	447.3	1.18 ± 0.24	120	51				
		-8E Stomach	38.49	1.42 ± 0.24	90	85				
D + 7	3057-1	Left Femur	1360.0	9.43 ± 0.84	890	9				
		-2 Kidney	1040.0	0.78 ± 0.23	908	5				
		-3 Liver	3777.7	160.5 ± 14.9	60	80				
		-4 Lung	2191.0	16.29 ± 1.48	60	38				
		-5 H. Node	10.7427	6.87 ± 0.45	164	83				

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Pu-239,240		Remarks	Counting Time		Yield
				Weight, Wet	dpm/sample		min.	approx. percent	
Barro	D + 3	3064-1	Left Femur	1015.5	2.37 ± 0.11		975	45	
			-2 Kidney	752.0	0.39 ± 0.05		975	43	
			-3 Liver	4089.0	115.6 ± 2.2		960	17	
			-4 Lung	1802.6	8.52 ± 1.36		60	60	
			-5 H. Node	5.304	0.12 ± 0.02		1979	29	
			-6 Right Femur	1314.2	41.52 ± 1.66		90	54	
			-8 Stomach		Not Received	On inventory but missing			
			D + 3	3065-1	Left Femur	1139.0	1.60 ± 0.37		120
	-1B Left Femur	1230.7			5.06 ± 0.33		205	70	
	-2 Kidney	779.3			0.35 ± 0.06		924	33	
	-3 Liver	2122.5			96.24 ± 5.77		60	27	
	-4 Lung	1509.7			327.7 ± 13.1		60	67	
	D + 7	3066-1	Left Femur	927.0	17.37 ± 0.97	Control?	1290	44	
			-2 Kidney	824.6	1.65 ± 0.13		60	39	
			-3 Liver	3451.0	71.88 ± 2.85		60	46	
			-4 Lung	1287.0	7.13 ± 0.65	Lung questioned on inventory	386	18	
			-5 H. Node	5.74	0.17 ± 0.07		141	60	
	D + 3	3068-1	Left Femur	1097.9	4.72 ± 0.27		60	54	
			-2 Kidney	764.8	0.10 ± 0.10		924	47	
			-3 Liver	3232.5	52.48 ± 0.63		60	78	
			-4 Lung	1421.3	117.5 ± 4.2		60	40	
			-5 H. Node	7.9607	0.07 ± 0.04		174	77	
	D + 3	3074-3	Liver*	2011.2	22.68 ± 0.36		924	54	
		Control	3022-8	Stomach	5574.2	2.79 ± 0.63	No. 3082? Questioned on inventory. Full of hay. Control?	774	12
D + 3	3101-1	(E) Left Femur	1152.5	1.39 ± 0.26		120	52		
		-2 Kidney	774.0	0.60 ± 0.07		975	43		
		-3 Liver	2832.8	75.83 ± 1.59		975	47		
		-4 Lung	1415.3	1332 ± 101		60	58		
D + 7	3102-2	Kidney	770.1	1.25 ± 0.30		60	75		
D + 7	3103-1	Left Femur	1042.9	299.3 ± 15.1		950	3		
D Day	3113-10	N. Mucosa	136.8	0.25 ± 0.06		980	2		
D + 7	3126-1	Left Femur	1114.8	1.52 ± 0.14		935	25		
		-2 Kidney	595.9	0.58 ± 0.26		60	45		
		-3 Liver	2890.3	82.17 ± 4.11	Sample spilled	1155	2		
		-4 Lung	1625.6	39.17 ± 1.96		60	53		
		-5 H. Node	22.1924	0.13 ± 0.03		1031	76		
D Day	3127-1	Left Femur	1156.3	14.45 ± 0.68		180	55		
		-2 Kidney	798.9	1.00 ± 0.17		207	54		
		-3 Liver	2718.0	126.6 ± 2.9		1032	11		
		-5 H. Node	6.447	0.21 ± 0.06		207	84		
		-6 Right Femur	1670.7	13.56 ± 0.93		120	43		
		-7 Trachea	476.2	12.70 ± 1.00		135	29		
		-8 Stomach	1652.0	2.08 ± 0.27		135	66		
		-9 P. Mucosa	57.93	1.29 ± 0.10		980	45		
		D + 7	3132-1	Left Femur	935.2	1.59 ± 0.35		60	65
-2 Kidney	770.0			1.39 ± 0.31		60	71		
-3 Liver	1350.0			81.36 ± 5.45		60	24		
-4 Lung	1491.0			17.78 ± 0.48		936	26		
D + 7	3135-1	Left Femur	997.1	1.08 ± 0.11		936	30		
		-2E Kidney	606.0	228.4 ± 22.8		1165	1		
		-3 Liver	2307.0	13.12 ± 0.94		240	19		
		-4 Lung	1300.4	13.68 ± 0.86		207	27		
		-5 H. Node	13.8985	0.06 ± 0.04		141	74		
D + 7	3137-1	Left Femur	934.8	0.86 ± 0.13		60	42		
		-3 Kidney	543.6	2.37 ± 0.24		240	52		
		-3 Liver	1641.0	15.88 ± 1.02		60	60		
		-4 Lung	1157.0	20.07 ± 0.60		980	27		
		-5 H. Node	1.1744	0.003 ± 0.020		566	87		

\* Later identified as 3004-3.

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet grams	Pu-239,240 dpm/sample	Remarks	Counting Time min.	Yield approx. percent
Barro	D - Day	3139-1	Left Femur	927.5	1.03 ± 0.21	Control?	1290	49
			-2 Kidney	652.2	1.80 ± 0.24		120	80
			-3 Liver	2202.6	24.73 ± 0.49		570	51
			-4 Lung	1172.0	25.07 ± 0.93	Uranium	272	66
			-5 H. Node	5.1005	0.22 ± 0.05		342	47
			-6 Right Femur	1045.0	0.22 ± 0.03		1290	51
			-7 Trachea	396.5	0.98 ± 0.09		960	51
			-8 Stomach	1059.0	0.73 ± 0.15		1840	5.2
			-9 P. Mucosa	52.5	0.03 ± 0.02	Not on official inventory	993	41
			-10 N. Mucosa	130.0	0.38 ± 0.04		1290	47
	D + 7	3141-1	Left Femur	1089.8	4.10 ± 0.70		60	40
			-2 Kidney	962.6	0.85 ± 0.14		948	16
			-3 Liver	3040.3	100.1 ± 8.0		60	49
			-4 Lung	1664.1	1228 ± 50		60	62
			-5 H. Node	13.518	0.81 ± 0.17		630	54
	D + 7	3177-1	Left Femur	1001.5	3.74 ± 0.32		956	41
			-2 Kidney	834.2	4.65 ± 0.40		120	70
			-3 Liver	2510.7	120.8 ± 5.8		60	40
			-4 Lung	1637.9	94.7 ± 8.5		60	10
			-5 H. Node	12.5993	0.07 ± 0.04		371	70
D + 3	3178-1	Left Femur	815.0	3.41 ± 0.20		060	20	
		-2E Kidney	762.0	0.41 ± 0.04		960	70	
		-3 Liver	2708.4	76.74 ± 0.77	Box 18 duplicate**	924	50	
		-3A Liver	2631.0	81.15 ± 2.35	" " " "	120	51	
		-4 Lung	1432.1	6.83 ± 0.66		60	20	
		-5 H. Node	9.1983	0.35 ± 0.08		164	20	
		-6 Right Femur	879.0	1.96 ± 0.24		922	41	
		-7 Trachea	446.4	0.16 ± 0.11		60	60	
		-9 P. Mucosa	202.1	0.38 ± 0.16		60	81	
		-10 N. Mucosa	103.3	0.36 ± 0.15		60	80	
D + 7	3199-1	Left Femur	1176.0	1.25 ± 0.15	Control?	745	24	
		-2 Kidney	775.0	0.637 ± 0.11		745	18	
		-3 Liver	4096.0	20.37 ± 1.00		745	9	
		-4 Lung	1616.5	1.25 ± 0.29		120	84	
		-5 H. Nodes	18.21	0.10 ± 0.03		745	59	
D + 7	3200-1	Left Femur	1327.3	1.10 ± 0.35		80	35	
		-2 Kidney	634.4	0.14 ± 0.02		890	41	
		-3 Liver	2964.4	12.20 ± 0.77		980	31	
		-4 Lung	1514.2	32.41 ± 0.85		272	51	
		-5 H. Node	7.889	0.010 ± 0.04		512	31	
Control	X-18B-8	Stomach	5209.4	2.30 ± 0.75	Full of hay, Control?	386	11	
D Day	3029	N. Mucosa	167.6	2.78 ± 0.67		980	2	
*D Day	No #	-1	Left Femur	976.3	2.02 ± 0.09		1200	63
			-2 Kidney	746.0	9.97 ± 0.18		200	41
			-3 Liver	2481.0	42.09 ± 0.90	Uranium	290	60
			-4 Lung	1215.0	35.53 ± 1.88		160	60
			-5 H. Node	8.284	7.78 ± 0.38		60	72
			-6 Right Femur	1046.6	2.14 ± 0.10		1000	72
			-7 Trachea	377.3	1029 ± 56		30	64
			-8 Stomach	1261.0	1543 ± 88		30	60
			-9 P. Mucosa	52.76	395.7 ± 10.7		100	60
			-10 N. Mucosa	176.8	184.9 ± 11.1		890	2

\* Later identified as 3011

\*\* -3 Liver identification incomplete but not 3178.  
-3A Liver actually correct 3178 specimen.

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield	
				dpm/sample				min.	approx. percent
F-034	Andersen	277R	1	0.08	+ 0.05		155	75	
			2	0.0	+ 0.0		217	49	
			3	0.58	+ 0.10		217	22	
			4	0.11	+ 0.04		205	72	
			6	0.29	+ 0.29		35	99	
			7	0.82	+ 0.09		390	80	
			Sum	1.96					
F-046	"	2771	1	3.09	+ 0.43		60	84	
			2	73.9	+ 1.4		155	76	
			3	8.11	+ 0.40		205	79	
			4	714	+ 24		100	45	
			6	0.11	+ 0.04		657	31	
			7	0.09	+ 0.05		159	83	
			Sum	799					
F-052	"	2781	1	10.9	+ 0.6		916	10	
			2	14.4	+ 1.1		35	95	
			3	40.8	+ 1.1		164	65	
			4	18.0	+ 0.9		140	51	
			6	11.19	+ 0.45		663	26	
			7	6.49	+ 0.19		941	56	
			Sum	102					
F-052	"	2767	1	50.4	+ 1.1		250	56	
			2	79.6	+ 1.8		350	20	
			3	99.6	+ 1.4		275	60	
			4	56.6	+ 0.5		1000	82	
			6	763	+ 22		73	83	
			7	12.1	+ 0.5		240	72	
			Sum	1061					
F-064	"	2759	1	919.9	+ 32.2		30	84	
			2	1264	+ 45		30	81	
			3	4008	+ 128		30	66	
			4	2266	+ 70		30	68	
			6	1108	+ 40		30	80	
			7	851	+ 19		103	60	
			Sum	10,417					
F-070	"	2764	1	132	+ 4		120	99	
			2	222	+ 5		30	87	
			3	257	+ 10		30	72	
			4	102	+ 1.5		154	84	
			6	91.4	+ 0.7		1000	60	
			7	84.0	+ 1.2		371	55	
			Sum	894					
F-071	"	2756	1	0.73	+ 0.11		565	36	
			2	0.15	+ 0.03		512	86	
			3	0.18	+ 0.08		159	55	
			6	0.24	+ 0.17		120	68	
			7	0.12	+ 0.06		159	68	
			7	0.18	+ 0.07		159	77	
			Sum	1.6					
F-034	"	2721	1	0.95	+ 0.11		745	35	
			2	2.32	+ 0.15		589	56	
			3	0.08	+ 0.03		750	30	
			4	0.30	+ 0.07		589	34	
			6	0.27	+ 0.06		390	54	
			7	0.07	+ 0.03		1020	87	
			Sum	4.0					
F-046	"	2714	1	1548	+ 67		20	27	
			2	141.1	+ 2.4		500	42	
			3	50.5	+ 1.8		254	19	
			4	4.51	+ 0.35		663	18	
			6	1.09	+ 0.10		548	50	
			7	0.15	+ 0.06		512	35	
			Sum	1748					
F-052	"	2711	1	2019	+ 91		20	77	
			2	162.6	+ 9.1		60	89	
			3	91.0	+ 1.6		156	69	
			4	53.5	+ 0.9		275	81	
			6	27.3	+ 0.8		164	95	
			7	9.04	+ 0.40		941	60	
			Sum	2362					

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting	
						Time	Yield
				dpm/sample		min.	approx. percent
H-058	Andersen	2707	1	1241 + 26		80	87
			2	527 + 10		103	70
			3	279 + 7		60	79
			4	154.3 + 2.0		202	70
			5	78.4 + 0.6		1000	70
			6	57.3 + 0.5		1000	70
			Sum	2337			
H-064	"	2728	1	2659 + 3252	Uranium	120	14
			2	1.76 + 0.05x10 <sup>4</sup>	"	10c	11
			3	1869 + 22	"	22c	30
			4	2593 + 31	"	22c	33
			5	1309 + 42	"	22c	27
			6	1908 + 46	"	22c	50
			Sum	2.79 x 10 <sup>4</sup>			
E-054	Casella	9685	1	73.0 + 1.2		745	31
			2	0.26 + 0.09		180	53
			3	0.24 + 0.06		174	61
			4	0.13 + 0.04		495	47
			5	0.43 + 0.07		300	22
			Sum	74.1			
E-056	"	9653*	1	2016 + 29		159	79
			2	338 + 4		215	60
			3	69.4 + 1.0		30c	67
			4	16.7 + 0.5		251	89
			5	15.5 + 0.4		30c	89
			Sum	245c			
E-056	"	9687	1	1752 + 37		91	70
			2	228 + 4		275	41
			3	56.3 + 5.1		60	3c
			4	14.5 + 0.5		313	4c
			5	15.7 + 0.5		280	74
			Sum	20c6			
E-058	"	9689	1	3327 + 57		30	70
			2	19.8 + 1.7		35	64
			3	8.55 + 0.27		524	73
			4**	2.49 + 0.08		142c	73
			5	3.19 + 0.19		54c	50
			Sum	3361			
E-05c	"	9690	1	243 + 5		120	3c
			2	26.2 + 0.6		524	71
			3	6.51 + 0.12		1000	74
			4	2.78 + 0.11		1000	74
			5	1.13 + 0.14		393	73
			Sum	280			
F-044	"	2766	1	29.8 + 0.2		32c	25
			2	1.16 + 0.09		723	71
			3	0.55 + 0.09		427	70
			4	0.22 + 0.05		477	15
			5	0.26 + 0.04		607	6c
			Sum	32.3			
F-050	"	2769	1	270 + 4.3		110	64
			2	8.67 + 0.18		653	51
			3	622 + 13		103	62
			4	1.41 + 0.15		525	10
			5	0.56 + 0.06		764	34
			Sum	902			
F-054	"	2761	1	235 + 5		88	1c
			2	276 + 4		226	4c
			3	103.0 + 2.4		11c	50
			4	14.5 + 0.4		300	7c
			5	0.12 + 0.03		500	7c
			Sum	636			
F-05f	"	2780	1	1470 + 44		50	7c
			2	112 + 4		7c	7c
			3	34.5 + 0.6		500	5c
			4	10.93 + 0.33		500	7c
			5	6.9 + 0.24		524	7c
			Sum	1684			

\* Stages 2 and 3 both labeled Stage 2. Assignment of stage based on color coded packaging.  
 \*\* Labeled TL #8689

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracer/lab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield	
				dpm/sample		min.	approx.	percent
F-062	Case 11a	2773	1	4497 ± 94		30	50	
	"		2	1245 ± 22		99	82	
	"		3	532 ± 14		76	51	
	"		4	88.7 ± 1.4		300	50	
	"		5	124.2 ± 2.4		120	57	
	"		Sum	6487				
F-062	"	2762	1	2730 ± 41		30	92	
	"		2	4600 ± 60		30	77	
	"		3	1726 ± 37		88	92	
	"		4	263 ± 6		82	76	
	"		5	501 ± 9		125	70	
	"		Sum	9820				
F-080	"	2755	1	0.23 ± 0.09		373	22	
	"		2	0.44 ± 0.04		1400	82	
	"		3	0.17 ± 0.07		657	17	
	"		4	0.64 ± 0.06		1000	73	
	"		5	1.75 ± 0.22		155	73	
	"		Sum	3.2				
FM-001	"	2159	1	141.3 ± 3.0		120	56	
	"		2	12.5 ± 1.2		35	85	
	"		3	1037 ± 31		88	32	
	"		4	0.99 ± 0.09		874	52	
	"		5	2.33 ± 0.06		2514	71	
	"		Sum	1164				
FM-002	"	2160	1	132. ± 25		91	88	
	"		2	10.5 ± 1.0		225	50	
	"		3	6.2 ± 0.02		1690	31	
	"		4	7.2 ± 0.21		929	31	
	"		5	0.955 ± 0.026		1407	84	
	"		Sum	1403				
FM-003	"	2161	1	61.8 ± 1.5		189	47	
	"		2	12.9 ± 0.3		1016	39	
	"		3	13.2 ± 0.2		2514	62	
	"		4	1.66 ± 0.14		306	85	
	"		5	0.12 ± 0.04		340	63	
	"		Sum	89.7				
FM-004	"	2162	1	33.8 ± 0.4		1320	56	
	"		2	32.9 ± 1.0		189	56	
	"		3	259 ± 4		710	2	
	"		4	3.33 ± 0.39		171	41	
	"		5	2.11 ± 0.21		189	76	
	"		Sum	331				
FM-005	"	2165	1	3856 ± 66		156	58	
	"		2	44.0 ± 1.0		1285	31	
	"		3	11.8 ± 0.6		911	12	
	"		4	1.28 ± 0.09		1354	67	
	"		5	1.68 ± 0.20		210	63	
	"		Sum	3915				
FM-006	"	2164	1	4.85 ± 0.22		578	56	
	"		2	13.8 ± 0.4		644	47	
	"		3	3.43 ± 0.25		416	98	
	"		4	1.05 ± 0.06		1339	70	
	"		5	1.34 ± 0.10		615	80	
	"		Sum	24.5				
F-061	"	9682	1	1444 ± 17		252	77	
	"		2	139 ± 3		208	67	
	"		3	63.2 ± 1.2		156	53	
	"		4	8.52 ± 0.66		75	79	
	"		5	11.5 ± 0.5		164	71	
	"		Sum	1715				
F-061	"	968c	1	0.12 ± 0.03		1016	44	
	"		2	0.14 ± 0.05		496	99	
	"		3	0.84 ± 0.09		581	58	
	"		4	0.06 ± 0.03		495	43	
	"		5	0.004 ± 0.022		806	83	
	"		Sum	1.2				

\* Mobile unit instruments, all at F-060.

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample				
							min.	approx. percent
G-060	Casella	9658	1	872.5	+ 31.6	Uranium	120	31
			2	241.3	+ 3.4	Uranium	150	34
			3	465.8	+ 21.9	Uranium	120	40
			4	3407	+ 37	Uranium	1000	40
			5	1695	+ 66	Uranium	150	29
		Sum		10,873				
G-062	"	9657	1	4092	+ 106		30	07
			2	1817	+ 33		97	32
			3	891	+ 16		101	33
			4	168	+ 4		120	47
			5	273	+ 4		205	64
		Sum		7241				
H-032	"	2737	1	0.003	+ 0.021		1380	60
			2	0.008	+ 0.032		1404	77
			3	-0.02	+ 0.035		1450	37
			4	0.10	+ 0.03		657	11
			5	14.89	+ 0.36		764	4
		Sum		15				
H-050	"	2720	1	142	+ 2		154	67
			2	77.3	+ 0.8		941	44
			3	110	+ 1		325	33
			4	6.4	+ 0.4		180	61
			5	5.74	+ 0.40		155	13
		Sum		341				
H-052	"	2727	1	1624	+ 31		91	33
			2	301	+ 6		103	101
			3	69.7	+ 1.0		221	30
			4	10.39	+ 0.54		373	15
			5	29.1	+ 0.7		250	
		Sum		2035				
H-074	"	2713	1	92.6	+ 1.3		280	67
			2	486	+ 13		88	51
			3	201	+ 5		119	50
			4	57.8	+ 1.2		251	53
			5	76.2	+ 1.1		226	82
		Sum		914				
E-05t	TAC-I	968t		1894	+ 36		10	81
E-05F	"	968B		1729	+ 40		70	73
E-05E	"	9700		1455	+ 32		70	55
F-04C	"	2753		1.22	+ 0.33		266	75
F-06B	"	2770		7450	+ 350		10	92
G-054	"	9665		6739	+ 320		20	73
G-05E	"	9721		1577	+ 50	Uranium	150	43
H-04F	"	2715		1.21	+ 0.03 x 10 <sup>4</sup>		72	92
H-074	"	2731		2254	+ 29		193	85
F-05t	TAC I	9654		92f	+ 14		150	69
E-06D	"	9652		273	+ 4		220	77
G-05t	"	9679		1673	+ 204		120	2
H-06C	"	9659		447	+ 4		151	71
F-03t	TAC II	2772		5.10	+ 0.30		163	63
F-054	"	2775		1627	+ 33		247	27
F-060	"	2750		1.21	+ 0.14		251	70
F-06t	"	2760		1.24	+ 0.02 x 10 <sup>4</sup>		60	37
F-07F	"	2754		2.07	+ 0.25		220	43

\*First and second Casella stages autoradiographed by Isotopes, Inc. They report that stage 1 resembled a stage 4 impaction pattern and stage 2 resembled a stage 3 pattern. A packaging pickup is suspected, and stage 2 may also have been contaminated or doubly exposed.

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES. DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracer Lab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample			
h-054	TAS II	2733		42.7 ± 1.0		30	42
f-06f	"	2726		3838 ± 127	Uranium	30	41
f-072	"	2729		1180 ± 13		283	74
EO-04	Film	8050		3358 ± 134		60	67
EO-10	"	8050		5186 ± 207		60	67
OM-09,0	"	8051		2902 ± 218		15	75
P-032	"	8041		3.24 ± 0.12 x 10 <sup>4</sup>		60	39
F-054-A	"	8041		5.49 ± 0.26 x 10 <sup>5</sup>		60	17
F-054-B	"	8041		6.70 ± 0.46 x 10 <sup>5</sup>		60	35
F-050	"	8041		1.64 ± 0.09 x 10 <sup>5</sup>		60	33
h-03	"	8043		6615 ± 265	Uranium	415	10
h-034	"	8043		9.15 ± 0.25x10 <sup>4</sup>	Uranium	120	17
f-03	"	8043		4.92 ± 0.35x10 <sup>4</sup>	Uranium	120	11
h-042-272	"	8043		2.29 ± 0.06 x 10 <sup>5</sup>		60	78
h-044-276	"	8043		4.95 ± 0.21 x 10 <sup>5</sup>		60	90
h-046-270	"	8043		5.22 ± 0.29 x 10 <sup>5</sup>		30	22
h-048-281	"	8043		6.87 ± 0.12x10 <sup>5</sup>	Uranium	120	37
h-052-283	"	8043		2.84 ± 0.15 x 10 <sup>5</sup>		30	5
h-054-294	"	8043		2.24 ± 0.13x10 <sup>5</sup>	Uranium	30	45
h-056-295	"	8043		1.07 ± 0.05 x 10 <sup>5</sup>		15	56
h-058-296	"	8043		9.77 ± 0.31x10 <sup>4</sup>	Uranium	30	50
h-062-297	"	8043		6827 ± 280		60	99
h-064-298	"	8047		1.56 ± 0.07 x 10 <sup>5</sup>		15	46
h-066-299	"	8047		3.29 ± 0.09 x 10 <sup>5</sup>		30	65
h-068-300	"	8047		6.00 ± 0.12 x 10 <sup>5</sup>		30	60
h-069-301	"	8047		2.96 ± 0.17 x 10 <sup>5</sup>		30	55
h-070-302	"	8047		3.54 ± 0.10 x 10 <sup>5</sup>		30	65
h-071-303	"	8047		3.79 ± 0.23 x 10 <sup>5</sup>		30	45
h-072-304	"	8047		2.74 ± 0.09 x 10 <sup>5</sup>		30	45
h-073-305	"	8047		1.31 ± 0.07 x 10 <sup>5</sup>		15	42
h-074-306	"	8047		9.90 ± 0.58 x 10 <sup>4</sup>		30	18
h-075-307	"	10000		1236 ± 30		70	72
h-076-308	"	10000		950 ± 41		23	71
h-077-309	"	10000		1046 ± 50		23	58
h-078-310	"	10000		1030 ± 0.25		60	96
h-079-311	"	10000		287 ± 54		23	44
h-080-312	"	10000		2154 ± 45		150	44
h-081-313	"	10000		302 ± 14		150	86
h-082-314	"	10000		700 ± 21		40	88

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample			
Stk-95	Film	10000		356 ± 10		47	91
Stk-96	"	10000		759 ± 22		47	74
Stk-97	"	10000		636 ± 17		47	91
Stk-98	"	10000		523 ± 12		88	74
Stk-99	"	10000		464 ± 9		88	98
Stk-100	"	10000		589.2 ± 21.8		60	75
Stk-101	"	10000		1315 ± 33		80	53
Stk-102	"	10000		1544 ± 46		40	87
Stk-103	"	10000		1672 ± 41		60	83
Stk-305	"	10003		146 ± 3		86	91
Stk-306	"	10003		1.39 ± 0.12		371	78
Stk-307	"	10003		0.59 ± 0.10		313	64
Stk-308	"	10003		40.9 ± 2.7		60	99
Stk-309	"	10003		47.3 ± 3.2		60	75
Stk-310	"	10003		27.6 ± 2.5		60	71
Stk-601	"	10006		125.6 ± 2.8		200	60
Stk-602	"	10006		447 ± 14		79	41
Stk-603	"	10006		259 ± 3		154	52
Stk-604	"	10006		203 ± 5		148	60
Stk-605	"	10006		148.3 ± 1.9		280	63
Stk-606	"	10006		41.8 ± 0.5		941	65
Stk-607	"	10006		122.5 ± 2.7		86	71
BK-07	Al. Coll.	9812		1.05 ± 0.01 x 10 <sup>6</sup>		10	83
BK-08	" "	9812		2.32 ± 0.03 x 10 <sup>6</sup>		10	81
BL-07	" "	9811		7.68 ± 0.05 x 10 <sup>5</sup>		60	83
BL-08	" "	9811		4.98 ± 0.06 x 10 <sup>6</sup>	Urarium	9	81
-	Sc11	For the results of plutonium analyses of soils, see Table 7.3 in the chapter on the determination of plutonium by gamma spectrometry of Am <sup>241</sup> .					

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE I

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample	min.			
E-01t	Andersen	3315	1	0.35	+ 0.25		60	95
			2	69.6	+ 2.3		67	79
			3	14.6	+ 0.7		88	99
			4	14.72	+ 0.01		2689	90
			6	30.6	+ 0.9		180	62
			7	8.05	+ 0.34		245	89
			Sum	138				
E-022	"	3314	1	1.29	+ 0.02 x 10 <sup>4</sup>	Uranium	120	41
			2	471.0	+ 14.1	"	120	60
			3	887.9	+ 15.1	"	1000	22
			4	747.2	+ 19.4	"	1000	20
			6	300.1	+ 7.5	"	980	20
			7	242.4	+ 4.6	"	1070	16
			Sum	1.55 x 10 <sup>4</sup>				
B-02E	"	3313	1	1.36	+ 0.02 x 10 <sup>4</sup>		60	51
			2	12.8	+ 0.7		90	85
			3	6.36	+ 0.35		175	94
			4	3.68	+ 0.29		159	88
			6	2.89	+ 0.29		120	91
			7	0.38	+ 0.08		240	69
			Sum	1.30 x 10 <sup>4</sup>				
E-034	"	3304	1	4.33	+ 0.54		60	78
			2	9.78	+ 0.65		143	50
			3	14.51	+ 0.01		2689	81
			4	11.4	+ 0.5		143	98
			6	21.6	+ 0.9		143	53
			7	0.06	+ 0.02		566	79
			Sum	61.7				
E-04J	"	3303	1	0.54	+ 0.18		60	86
			2	0.95	+ 0.17		120	85
			3	0.61	+ 0.04		1248	92
			4	0.34	+ 0.06		390	89
			6	0.32	+ 0.08		175	90
			7	15.3	+ 0.6		260	58
			Sum	18.1				
E-01	Casella	3365	1	0.87	+ 0.20		710	10
			2	1.98	+ 0.19		420	40
			3	0.30	+ 0.15		120	99
			4	0.18	+ 0.18		60	95
			5	0.03	+ 0.01		260	87
Sum	3.4							
E-02	"	3368	1	0.16	+ 0.03		1031	66
			2	2.69	+ 0.30		147	67
			3	0.65	+ 0.05		1031	75
			4	0.83	+ 0.36		75	76
			5	0.05	+ 0.05		76	78
Sum	4.4							
E-03	"	3370	1	0.007	+ 0.020		60	93
			2	0.21	+ 0.12		57	77
			3	0.21	+ 0.03		993	75
			4	0.25	+ 0.03		942	72
			6	0.96	+ 0.06		122	79
Sum	1.6							
E-03	"	3371	1	2.41	+ 0.42		60	78
			2	1.50	+ 0.32		60	76
			3	1.03	+ 0.15		250	55
			4	0.33	+ 0.15		60	83
			5	2.00	+ 0.18		260	73
Sum	7.3							
E-04	"	3366	1	1.08	+ 0.13		942	65
			2	0.87	+ 0.14		250	53
			3	0.04	+ 0.08		60	81
			4	0.57	+ 0.19		60	82
			6	0.04	+ 0.05		60	65
Sum	2.6							
E-04	"	3373	1	0.70	+ 0.10		330	57
			2	0.64	+ 0.10		254	72
			3	0.49	+ 0.06		710	90
			4	3.82	+ 0.23		254	86
			5	0.51	+ 0.04		1979	75
Sum	6.4							

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE I (cont'd)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240 dpm/sample	Remarks	Counting Time	Yield
						min.	approx. percent
BM-06	Casella	3372	1	157.5 ± 2.0		208	85
			2	99.6 ± 1.2		275	82
			3	26.1 ± 0.68		200	92
			4	5.07 ± 0.14		1074	74
			5	3.85 ± 0.49		75	66
		Sum	292				
BM-08	"	3369	1	24.2 ± 0.9		163	53
			2	12.8 ± 0.7		163	52
			3	23.6 ± 0.7		420	39
			4	1.44 ± 0.10		524	83
			5	3.27 ± 0.28		171	75
		Sum	65.3				
BM-10	"	3374	1	10.4 ± 0.4		420	51
			2	7.06 ± 0.51		140	60
			3	3.14 ± 0.07		2689	80
			4	1.09 ± 0.07		942	70
			5	32.0 ± 2.1		60	38
		Sum	53.7				
BM-12	"	3375	1	82.5 ± 1.3		154	92
			2	120.4 ± 2.0		200	59
			3	29.4 ± 0.9		180	64
			4	3.78 ± 0.26		200	89
			5	11.4 ± 0.8		76	67
		Sum	247				
A-030	"	3356	1	25.5 ± 0.74		164	85
			2	10.4 ± 0.6		140	51
			3	1.95 ± 0.27		122	68
			4	78.1 ± 1.2		300	89
			5	0.36 ± 0.15		120	43
		Sum	116				
B-012	"	2700	1	0.07 ± 0.01		229	40
			2	0.18 ± 0.03		566	85
			3	0.34 ± 0.07		710	31
			4	0.11 ± 0.03		251	92
			5	0.17 ± 0.04		340	81
		Sum	0.87				
B-02t	"	2688	1	1410 ± 111	Uranium First two stages autoradiographed by Isotopes, Inc.	120	15
			2	1017 ± 49		225	24
			3	2939 ± 182		980	4
			4	1251 ± 98		120	18
			5	220.8 ± 98		980	26
		Sum	6838				
B-032	"	2687	1	1.63 ± 0.21		171	66
			2	0.23 ± 0.06		200	96
			3	0.17 ± 0.17		60	96
			4	0.01 ± 0.03		60	69
			5	0.21 ± 0.12		57	77
		Sum	2.2				
B-032	"	2686	1	0.95 ± 0.06		1031	75
			2	0.54 ± 0.09		240	78
			3	3.09 ± 0.20		350	70
			4	1.42 ± 0.16		240	72
			5	0.21 ± 0.08		156	77
		Sum	6.2				
BC-07	TAS-D	3050		8.63 ± 0.25		2689	51
BC-09	"	3054		3.56 ± 0.23		260	78
BI-05	"	3051		15.4 ± 0.7		180	56
BI-15	"	3053		6.54 ± 0.31		243	86
BI-17	"	3048		2.04 ± 0.18		243	76
BM-07	"	3046		2.15 ± 0.06 × 10 <sup>4</sup>		72	50
BM-09	"	3044		2297 ± 46		91	82

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE I (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
BM-11	TAS-D	3042		233 ± 6		115	39
A-036	"	3077		432 ± 12		79	44
A-048	"	3087		2252 ± 52		70	79
A-060	"	3080		34.3 ± 0.7		243	87
B-020	TAS II	3090		550.0 ± 12.7	Uranium	332	14
B-026	"	3091		1006 ± 48	"	332	8
E-030	"	3095		1074 ± 14		202	88
B-036	"	3096		501 ± 9.0		103	82
<u>ARC B (Balloon)</u>							
L 15, P5	Wire Swipe	5296		9.70 ± 0.42 x 10 <sup>5</sup>		10	51
L 15, P6	" "	5296		1.07 ± 0.02 x 10 <sup>6</sup>		20	86
L 15, P7	" "	5296		6.43 ± 0.24 x 10 <sup>5</sup>		20	26
L 17, P5	" "	5299		3.07 ± 0.09 x 10 <sup>5</sup>		20	54
L 19, P0	" "	5342		2.59 ± 0.03 x 10 <sup>4</sup>		10	91
L 20, P0	" "	5341		1.89 ± 0.02 x 10 <sup>4</sup>		10	82
L 20, P1	" "	5341		2.65 ± 0.70 x 10 <sup>4</sup>		10	87
L 23, P0	" "	5301		1.83 ± 0.02 x 10 <sup>4</sup>		10	80
BM-04	Film	8121		3614 ± 185		60	39
BM-05	"	"		1.55 ± 0.04 x 10 <sup>6</sup>		10	47
BM-06	"	"		2.19 ± 0.04 x 10 <sup>7</sup>		100	51
BM-07	"	"		5.43 ± 0.12 x 10 <sup>6</sup>		10	65
BM-08	"	"		1.81 ± 0.11 x 10 <sup>6</sup>		30	48
BM-09	"	"		2.17 ± 0.05 x 10 <sup>5</sup>	Uranium	60	24
BM-10	"	"		3.39 ± 0.17 x 10 <sup>4</sup>		30	4
BM-11	"	"		2.98 ± 0.10 x 10 <sup>4</sup>		60	81
BM-12	"	"		9849 ± 461		70	65
FO-03	"	"		127.0 ± 5.5		120	88
EO-11	"	"		1.82 ± 0.08 x 10 <sup>4</sup>		60	78
GO-05.2	"	8120		3.18 ± 0.25 x 10 <sup>4</sup>		10	65
GU-05.3	"	"		5.52 ± 0.16 x 10 <sup>4</sup>		10	79
OO-05.4	"	"		6.49 ± 0.27 x 10 <sup>5</sup>		30	30
CO-07.0	"	"		7.65 ± 0.92 x 10 <sup>4</sup>		30	25
CO-07.1	"	"		4.64 ± 0.15 x 10 <sup>4</sup>		60	50
CO-07.2A	"	"		6.42 ± 0.54 x 10 <sup>4</sup>		60	24
CO-07.2B	"	"		4.26 ± 0.28 x 10 <sup>4</sup>		60	41
CO-07.3	"	"		3.66 ± 0.16 x 10 <sup>4</sup>		60	82
CO-09.1	"	"		7542 ± 189		60	82
CO-09.2	"	"		5192 ± 192		30	79

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE I (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting	Yield
						Time	
				dpm/sample		min.	approx percent
B-016	Film	8123		333 ± 27		60	52
D-034	"	"		1.54 ± 0.15 x 10 <sup>4</sup>		30	66
Stk-801	"	9924		63.87 ± 2.49		60	55
Stk-802	"	"		39.41 ± 3.94		90	85
Stk-803	"	"		164.7 ± 5.3		60	54
Stk-804	"	"		365 ± 16		30	57
Stk-804	"	"		505 ± 12		88	59
Stk-805	"	"		331 ± 13		101	64
Stk-806	"	"		4.45 ± 0.12 x 10 <sup>7</sup>		1.0	83
BM-05	Al. Coll.	9833		1.57 ± 0.02 x 10 <sup>8</sup>		1.0	73
BM-07	" "	"		6.00 ± 0.15 x 10 <sup>6</sup>		1.0	99
BM-09	" "	"		6.48 ± 0.17 x 10 <sup>7</sup>		1.0	87
BO-04	" "	9832		7.90 ± 0.23 x 10 <sup>6</sup>		1.0	77
BO-08	" "	9832		8.60 ± 0.11 x 10 <sup>7</sup>	Uranium	10	81
A-020	" "	9830					
	Soil			For the results of plutonium analysis of soils, see Table 7.3 in the chapter on the determination of plutonium by gamma spectrometry of Am <sup>241</sup> .			
A-018	Water	3141		5.57 ± 0.23 x 10 <sup>4</sup>		100	19
A-030	"	3143		4.71 x 10 <sup>5</sup>	Solubility Study*		
A-042	"	3142		3.35 x 10 <sup>4</sup>	Solubility Study*		
B-018	"	3138		57.71 ± 0.75		1000	31
B-030	"	3140		2.87 ± 0.08 x 10 <sup>5</sup>		12	25
B-042	"	3139		1.18 ± 0.02 x 10 <sup>4</sup>		1000	19
L-044	"	3137		1484 ± 42		60	57
D-056	"	3136		1197 ± 13		60	28
FM-020	"	3131		1790 ± 49	TL #3031 in POIR	60	72
H-018	"	2392		15.86 ± 1.05		120	39
H-042	"	2391		1206 ± 42		60	44

\*Determined from sum of several fractions during solubility studies. This value may be less than total Pu deposited in water tray.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES. CLEAN SLACE II

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
F-020	Anderser	3152	1	4994 ± 210	Uranium	150	11
			2	2173 ± 148	"	150	12
			3	159.6 ± 3.2	"	1070	14
			4	770.9 ± 70.9	"	1070	2
			6	583.6 ± 39.1	"	1070	3
			7	4594 ± 505	"	1070	3
			Sum	1.33 x 10 <sup>4</sup>			
F-034	"	3155	1	1568 ± 43		80	51
			2	77.6 ± 4.3		90	46
			3	12.4 ± 0.7		100	70
			4	2.50 ± 0.10		1165	72
			6	2.20 ± 0.26		120	80
			7	1.01 ± 0.24		76	72
			Sum	1664			
F-040	"	3151	1	1908 ± 134		30	71
			2	44.0 ± 1.8		90	41
			3	25.3 ± 1.1		100	50
			4	6.95 ± 0.55		120	50
			6	3.47 ± 0.31	Sample spilled	1000	11
			7	1.76 ± 0.30		76	77
			Sum	1989			
F-042	"	3153	1	671 ± 30		30	55
			2	83.3 ± 4.5		60	68
			3	32.7 ± 2.4		60	94
			4	12.45 ± 1.06		60	40
			6	4.31 ± 0.43		139	53
			7	3.69 ± 0.37		110	78
			Sum	807			
F-044	"	3156	1	1039 ± 45		30	57
			2	590 ± 7		984	23
			3	18.4 ± 0.9		100	74
			4	5.92 ± 0.65		60	79
			6	21.5 ± 1.4		180	20
			7	2.72 ± 0.18		310	83
			Sum	1658			
F-042	"	3144	1	962 ± 12		984	55
			2	102 ± 6		60	44
			3	23.5 ± 1.0		97	72
			4	6.53 ± 0.43		120	91
			6	12.5 ± 1.0		60	64
			7	5.40 ± 0.26		310	82
			Sum	1112			
F-052	"	3145	1	2176 ± 59		100	82
			2	142.1 ± 6.0		40	79
			3	25.9 ± 2.2		60	85
			4	9.84 ± 0.18		1165	66
			6	4.75 ± 0.52		60	87
			7	5.99 ± 0.46		123	75
			Sum	2371			
F-044	"	3146	1	1434 ± 66		30	50
			2	117.7 ± 3.0		60	79
			3	40.3 ± 2.0		90	68
			4	13.65 ± 0.37		326	95
			6	7.83 ± 0.49		120	79
			7	3.42 ± 0.56		120	26
			Sum	1624			
F-044	"	3148	1	670 ± 36		60	55
			2	60.8 ± 2.7		60	84
			3	17.4 ± 0.7		144	81
			4	17.5 ± 0.7		213	84
			6	13.6 ± 0.5		213	80
			7	31.0 ± 1.5		50	86
			Sum	811			
F-044	"	3150	1	732 ± 32		30	71
			2	176 ± 7		60	95
			3	48.4 ± 1.6		165	37
			4	60.7 ± 2.7		120	70
			6	9.46 ± 0.92		60	57
			7	4.73 ± 0.49		100	62
			Sum	1031			

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
F-078	Andersen	3149	1	2074 + 110		30	37
			2	205 + 9		60	85
			3	128.2 + 1.4		340	71
			4	30.0 + 1.4		118	42
			6	12.68 + 0.39		1088	77
			7	7.30 + 0.55		90	82
			Sum	2457			
IM-13	"	3206	1	948 + 47	*	30	74
			2	11.2 + 0.6		120	74
			3	10.4 + 0.4		245	83
			4	3.59 + 0.31		130	85
			6	1.35 + 0.14		245	89
			7	0.17 + 0.06		110	82
			Sum	975			
IM-14	"	3207	1	87.4 + 3.4	*	120	63
			2	530 + 53		60	97
			3	9.78 + 0.77		90	56
			4	12.8 + 0.6		120	82
			6	1.10 + 0.19		120	74
			7	0.068 + 0.039		156	88
			Sum	641			
F-022	Casella	2171	1	1573 + 58	Uranium First 2 stages autoradiographed by Isotopes, Inc.	150	30
			2	1488 + 88		330	5
			3	4324 + 285		220	10
			4	725.2 + 4.4		120	10
			5	1744 + 91		120	10
Sum	9854						
F-032	"	2183	1	631.7 + 14.3		90	64
			2	46.2 + 1.3		128	71
			3	10.3 + 0.8		60	88
			4	0.69 + 0.15		356	69
			5	0.66 + 0.13		156	79
Sum	690						
F-038	"	2182	1	216 + 6	Sample Spilled	43	84
			2	34.6 + 1.4		60	93
			3	12.60 + 0.63		112	85
			4	2.02 + 0.23		1000	12
			5	0.73 + 0.13		172	50
Sum	266						
F-042	"	2184	1	888 + 24		60	72
			2	41.4 + 1.1		150	68
			3	34.4 + 1.6		50	80
			4	260 + 11		75	11
			5	1.55 + 0.30		75	70
Sum							
F-044	"	2195	1	785 + 15		105	80
			2	28.6 + 1.1		150	42
			3	50.5 + 1.2		134	74
			4	3.47 + 0.34		137	68
			5	2.23 + 0.30		110	69
Sum	870						
F-050	"	2189	1	435 + 7		340	34
			2	142 + 4		103	32
			3	13.5 + 1.1		90	30
			4	2.97 + 0.25		152	79
			5	1.04 + 0.40		156	73
Sum	600						
F-054	"	2182	1	69 + 15		88	75
			2	134 + 4		56	79
			3	53.6 + 2.1		50	79
			4	27.6 + 1.0		110	70
			5	1.70 + 0.14		356	73
Sum	920						
F-05t	"	2186	1	1130 + 30		46	94
			2	90.4 + 2.8		60	68
			3	114 + 4		128	68
			4	10.8 + 0.4		310	90
			5	1.19 + 0.32		245	79
Sum	1357						

\* Mobile unit at I-040, i.e., IMOB-040.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample				
F-060	Casella	2185	1	324	+	8	75	58
			2	126.5	++	1.9	172	80
			3	121.1	+++	3.2	55	74
			4	21.2	++++	1.0	165	40
			5	6.01	++++	0.58	67	85
			Sum	599				
F-062	"	2187	1	1146	+	40	30	86
			2	107.2	++	1.6	310	43
			3	236.8	+++	7.3	43	75
			4	7.58	++++	0.62	60	84
			5	13.7	++++	0.9	67	82
			Sum	1511				
F-066	"	2192	1	1648	+	51	51	64
			2	163.9	++	3.3	75	93
			3	89.5	+++	2.1	77	81
			4	8.47	++++	0.14	2680	53
			5	18.5	++++	0.9	115	66
			Sum	1928				
F-074	"	2193	1	1982	+	53	53	82
			2	391	++	9	90	68
			3	120.3	+++	3.2	55	77
			4	28.9	++++	1.0	116	82
			5	27.5	++++	1.8	60	44
			Sum	2550				
F-07P	"	2194	1	1315	+	40	46	73
			2	504	++	11	90	75
			3	73.8	+++	1.5	116	81
			4	33.3	++++	1.0	132	71
			5	22.5	++++	1.2	100	45
			Sum	1949				
F-080	"	2191	1	1092	+	42	60	33
			2	277	++	7	75	71
			3	106.5	+++	3.1	50	68
			4	13.4	++++	0.9	60	86
			5	15.7	++++	0.8	127	56
			Sum	1505				
F-101	"	2190	1	2058	+	52	53	89
			2	322	++	18	30	85
			3	76.2	+++	1.0	103	65
			4	27.8	++++	1.0	103	79
			5	21.9	++++	1.2	127	37
			Sum	2506				
IM-01	"	2268	1	0.22	+	0.05	137	85
			2	0.57	++	0.16	120	59
			3	0.82	+++	0.12	275	83
			4	0.52	++++	0.06	1000	23
			5	0.47	++++	0.09	1000	20
			Sum	2.6				
IM-02	"	2264	1	36.8	+	1.1	110	87
			2	67.9	++	1.6	361	21
			3	2.23	+++	0.29	153	55
			4	0.32	++++	0.08	112	79
			5	0.97	++++	0.16	153	70
			Sum	103				
IM-03	"	2263	1	3.93	+	0.29	153	91
			2	1.64	++	0.09	165	93
			3	20.0	+++	0.6	180	99
			4	0.34	++++	0.09	200	68
			5	2.49	++++	0.25	153	84
			Sum	28				
IM-04	"	2262	1	7.33	+	0.30	560	44
			2	0.62	++	0.21	120	50
			3	2.68	+++	0.25	200	66
			4	40.5	++++	1.5	100	58
			5	0.30	++++	0.10	200	59
			Sum	51				

\* Mobile unit at I-040, i.e., IMOB-040.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
IM-05	Casella	2266	1	93.6 ± 2.2	**	77	37
			2	28.0 ± 0.8		145	45
			3	0.20 ± 0.08		124	25
			4	0.32 ± 0.10		112	27
			5	0.27 ± 0.08		112	11
			Sum	122			
IM-06	"	2269	1	376 ± 8	**	90	73
			2	0.62 ± 0.21		120	25
			3	6.41 ± 0.67		240	25
			4	0.24 ± 0.07		300	25
			5	0.46 ± 0.13		120	25
			Sum	384			
IM-07	"	2265	1	385 ± 13	**	44	62
			2	19.4 ± 0.8		90	25
			3	1.45 ± 0.21		120	25
			4	176 ± 4		101	67
			5	0.55 ± 0.28		60	99
			Sum	582			
IM-11	"	2261	1	631 ± 13	**	105	71
			2	164 ± 5		43	25
			3	37.6 ± 1.3		150	47
			4	0.35 ± 0.03		1248	41
			5	0.19 ± 0.02		1245	43
			Sum	833			
IM-12	"	2260	1	690 ± 12	**	105	83
			2	74.9 ± 1.7		115	21
			3	3.78 ± 0.34		120	27
			4	2.30 ± 0.43		120	99
			5	0.45 ± 0.10		200	25
			Sum	771			
F-000	TAS-D	4041		46.7 ± 1.4		173	43
F-014	"	4040		622.7 ± 38.6	Uranium	1211	3
F-040	"	4042		3050 ± 160		16	70
F-052	"	4039		445 ± 17		47	41
F-092	"	4038		1531 ± 48		51	62
F-120	"	4043		3147 ± 148		16	87
F-055	TAS-I	4045		1312 ± 35		51	87
F-054	"	4044		2192 ± 54		60	84
F-037	TAS II	4029		4543 ± 418	Uranium	180	4
F-042	"	4028		151 ± 1.7		340	69
F-043	"	4037		510 ± 1.1		-	90
F-054	"	4031		204 ± 9		30	57
F-050	"	4030		335 ± 9		75	60
F-056	"	4033		370 ± 9	Am-241 from gross alpha plate*	132	21
F-072	"	4034		330 ± 9		60	87
D-012	Seq. Air	4141	1		Sampler inoperative analysis cancelled		
D-042	"	4149		410.2 ± 10.3	No observable activity by alpha survey meter-entire tape run as one sample.	120	84

\* Am-241 determined by alpha spectrometry of a gross electrodepositon of sample aliquot; see Chapter C.

\*\* Mobile unit at I-040, i.e., IMOB-040.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
D-054	Seq. Air	4150		dpm/sample 402.5 ± 10.1	No observable activity by alpha survey meter. Entire tape run as one sample.	min. 120	approx. percent 85
E-040	Film	B113		3.56 ± 0.10 × 10 <sup>5</sup>		10	75
E-042	"	"		3.47 ± 0.09 × 10 <sup>5</sup>		10	98
E-044	"	"		3.15 ± 0.09 × 10 <sup>5</sup>		12	63
E-046	"	"		2.91 ± 0.08 × 10 <sup>5</sup>	Uranium	60	58
E-048	"	"		2.73 ± 0.08 × 10 <sup>5</sup>		10	78
E-050	"	"		2.31 ± 0.09 × 10 <sup>5</sup>		10	44
E-052	"	"		1.84 ± 0.10 × 10 <sup>5</sup>		15	34
E-054	"	"		1.96 ± 0.09 × 10 <sup>5</sup>		30	28
E-056 A	"	"		1.71 ± 0.06 × 10 <sup>5</sup>		30	37
E-056 B	"	"		1.81 ± 0.06 × 10 <sup>5</sup>		30	22
E-058	"	"		1.44 ± 0.08 × 10 <sup>5</sup>		30	17
F-060	"	"		1.31 ± 0.07 × 10 <sup>5</sup>		30	17
F-062	"	"		1.15 ± 0.05 × 10 <sup>5</sup>		30	26
E-064	"	"		1.00 ± 0.04 × 10 <sup>5</sup>		30	37
E-066	"	"		8.50 ± 0.31 × 10 <sup>4</sup>		30	39
E-068	"	"		8.17 ± 0.26 × 10 <sup>4</sup>		30	55
E-070	"	"		7.56 ± 0.24 × 10 <sup>4</sup>		30	50
E-072	"	"		6.89 ± 0.19 × 10 <sup>4</sup>		30	75
E-074	"	"		6.75 ± 0.22 × 10 <sup>4</sup>		90	18
F-076	"	"		6.03 ± 0.18 × 10 <sup>4</sup>		30	58
E-078	"	"		5.93 ± 0.24 × 10 <sup>4</sup>		30	33
E-080	"	"		5.23 ± 0.19 × 10 <sup>4</sup>		30	38
E-082	"	"		5.44 ± 0.20 × 10 <sup>4</sup>		30	41
E-084	"	"		4.85 ± 0.11 × 10 <sup>4</sup>		30	99
E-086	"	"		4.70 ± 0.12 × 10 <sup>4</sup>		30	84
E-088	"	"		4.46 ± 0.12 × 10 <sup>4</sup>		60	37
E-090	"	"		5.33 ± 0.11 × 10 <sup>4</sup>		60	65
E-092	"	"		4.10 ± 0.07 × 10 <sup>4</sup>		60	80
F-094	"	"		4.14 ± 0.08 × 10 <sup>4</sup>		60	65
F-096	"	"		4.49 ± 0.08 × 10 <sup>4</sup>		60	90
E-098	"	"		4.17 ± 0.09 × 10 <sup>4</sup>		60	75
E-100	"	"		4.41 ± 0.10 × 10 <sup>4</sup>		60	55
F-102	"	"		4.13 ± 0.09 × 10 <sup>4</sup>		60	70

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx percent.
E-104	Film	8113		$3.79 \pm 0.08 \times 10^4$		60	70
E-106	"	"		$3.27 \pm 0.06 \times 10^4$		66	75
E-108	"	"		$3.19 \pm 0.06 \times 10^4$		66	65
E-110	"	"		$2.57 \pm 0.04 \times 10^4$		66	75
E-112	"	"		$2.98 \pm 0.06 \times 10^4$		66	70
E-114	"	"		$2.06 \pm 0.06 \times 10^4$		30	65
F-022-1	"	8119		3012 $\pm$ 133		20	78
F-022-2	"	"		8182 $\pm$ 221		60	72
F-022-3	"	"		9005 $\pm$ 279		30	55
F-022-4	"	"		$1.15 \pm 0.03 \times 10^4$		60	65
F-022-5	"	"		5077 $\pm$ 240		20	60
F-026-2	"	"		5248 $\pm$ 183		30	40
F-026-3	"	"		7696 $\pm$ 316		30	43
F-026-4	"	"		3509 $\pm$ 90		60	75
F-026-5	"	"		7244 $\pm$ 311		30	33
F-030-5	"	"		$1.18 \pm 0.02 \times 10^4$		90	70
F-038-1	"	"		$7.81 \pm 0.31 \times 10^4$		30	34
F-038-2	"	"		$5.31 \pm 0.21 \times 10^4$		30	33
F-038-3	"	"		2582 $\pm$ 66		60	78
F-042-1	"	"		$4.34 \pm 0.14 \times 10^4$		30	50
F-042-2	"	"		$8.34 \pm 0.42 \times 10^4$		15	40
F-042-3	"	"		$1.49 \pm 0.04 \times 10^4$		60	77
F-042-4	"	"		3563 $\pm$ 98		60	65
F-046-3	"	"		$3.89 \pm 0.09 \times 10^4$		60	69
F-046-4	"	"		$3.24 \pm 0.09 \times 10^4$		30	74
G-016	"	8115		$1.02 \pm 0.03 \times 10^5$		30	55
G-018	"	"		$5.41 \pm 0.24 \times 10^5$		10	36
G-020	"	"		$2.08 \pm 0.05 \times 10^5$		10	57
G-024	"	"		$2.87 \pm 0.06 \times 10^5$		10	65
G-026	"	"		$2.80 \pm 0.07 \times 10^5$		10	50
G-028	"	"		$1.50 \pm 0.04 \times 10^5$		10	20
G-030	"	"		$6.51 \pm 0.15 \times 10^5$		30	20
B-040	Al. Coll.	9843		$7.08 \pm 0.21 \times 10^7$		1.0	78
B-050	"	"		$4.32 \pm 0.12 \times 10^7$		1.0	87
B-070	"	"		$1.26 \pm 0.03 \times 10^7$		1.0	87
B-080	"	"		$5.35 \pm 0.06 \times 10^7$	Uranium	10	83
B-090	"	"		$3.14 \pm 0.04 \times 10^6$		10	94
D-040	"	9845		$1.37 \pm 0.04 \times 10^7$		1.0	82
D-050	"	"		$7.90 \pm 0.06 \times 10^6$		10	90

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
D-085	Al. Coll.	9845		dpm/sample 2.44 ± 0.03 x 10 <sup>6</sup>		min. 10	approx. percent 80
D-090	" "	"		1.90 ± 0.01 x 10 <sup>6</sup>		60	80
H-040	" "	9844		3.81 ± 0.05 x 10 <sup>6</sup>		10	91
H-050	" "	"		4.51 ± 0.06 x 10 <sup>6</sup>		10	87
H-070	" "	"		1.46 ± 0.01 x 10 <sup>6</sup>		60	91
H-080	" "	"		1.44 ± 0.01 x 10 <sup>6</sup>		30	84
H-090	" "	"		1.30 ± 0.01 x 10 <sup>6</sup>		60	84
	Soil				For results of plutonium analyses see Table 7.3 in Chapter 7 on the determination of plutonium by gamma spectrometry of Am <sup>241</sup> .		
D-040	** Water	4180		2.66 x 10 <sup>5</sup>	Exposed at location I-040 according to POIR, not D-040 Solubility Study*		
D-040	** "	4181		3.24 ± 0.05 x 10 <sup>5</sup>	Exposed at location I-040 according to POIR, not D-040	10	57
D-040	** "	4182		1.80 ± 0.03 x 10 <sup>5</sup>	" " "	10	15
H-010	"	4188		225.1 ± 1.8		950	55
H-014	"	4189		111.2 ± 2.0		120	39
H-018	"	4190		2.67 ± 0.04 x 10 <sup>4</sup>		10	73
H-034	"	4194		1.00 ± 0.01 x 10 <sup>5</sup>		10	69
H-038	"	4195		7.76 ± 0.16 x 10 <sup>4</sup>		10	31
H-043	"	4196		5.46 ± 0.08 x 10 <sup>4</sup>		10	56
H-040	"	4197		3.58 x 10 <sup>4</sup>	Solubility Study*		
L-010	"	4198		80.29 ± 1.12		967	22
L-011	"	4199		1101 ± 12		60	47
L-018	"	4200		159.2 ± 1.3		1000	48
L-022	"	2394		2.15 ± 0.04 x 10 <sup>4</sup>		10	89
L-034	"	2397		2.58 ± 0.05 x 10 <sup>4</sup>		30	26
L-038	"	2398		2.88 ± 0.10 x 10 <sup>4</sup>		10	25
L-041	"	2399		6.07 ± 0.25 x 10 <sup>4</sup>		10	18
L-045	"	2401		2.67 ± 0.05 x 10 <sup>4</sup>		10	50

\*Determined from the sum of several fractions during solubility studies. This value may be less than the total Pu deposited in the water tray.

\*\* Sample labels and shipping papers indicate location as D-040, but from Tracerlab Handling Record, these samples probably were exposed by the mobile unit at IMOB-040

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample				
							min.	approx. percent
F-010	Andersen	3266	1	0.17	+ 0.04		100t	30
			2	0.17	+ 0.06		172	35
			3	0.09	+ 0.05		120	37
			4	0.48	+ 0.13		120	75
			6	0.10	+ 0.06		120	35
			7	0.12	+ 0.06		120	35
			Sum	1.1				
F-034	"	3265	1	2.23	+ 0.08x10 <sup>4</sup>	Uranium	180	6
			2	4840	+ 97	"	1000	34
			3	5416	+ 162	"	1000	14
			4	4863	+ 277	"	120	25
			6	4558	+ 104	"	1000	22
			7	127.3	+ 1.4	"	2017	25
			Sum	4.21 x 10 <sup>4</sup>				
F-052	"	3258	1	63.7	+ 4.5		60	17
			2	0.84	+ 0.19		90	32
			3	1.47	+ 0.44		60	50
			4	2.31	+ 0.12		100t	40
			6	0.56	+ 0.18		60	34
			7	0.08	+ 0.08		60	33
			Sum	69				
F-082	"	3261	1	280	+ 12		120	44
			2	161	+ 7		120	41
			3	87.7	+ 1.7		144	52
			4	58.6	+ 2.1		165	25
			6	90.0	+ 2.4		150	33
			7	17.2	+ 1.0		85	64
			Sum	705				
F-10f	"	3263	1	3.25	+ 0.52		60	61
			2	5.78	+ 0.50		97	74
			3	28.7	+ 1.1		1090	29
			4	4.24	+ 0.61		60	54
			6	3.81	+ 0.50		60	35
			7	0.34	+ 0.22		495	47
			Sum	46.22				
J-010	"	3268	1	0.16	+ 0.09		60	95
			2	0.07	+ 0.07		60	70
			3	0.58	+ 0.15		120	64
			4	0.22	+ 0.08		120	83
			6	0.18	+ 0.09		120	60
			7	0.24	+ 0.12		60	87
			Sum	1.4				
J-034	"	3270	1	406	+ 9		101	60
			2	0.06	+ 0.06		60	82
			3	4.50	+ 0.54		60	53
			4	0.14	+ 0.05		325	63
			6	0.17	+ 0.09		90	83
			7	0.33	+ 0.07		224	85
			Sum	411				
J-04E	"	3271	1	0.34	+ 0.14		80	63
			2	0.01	+ 0.02		60	80
			3	0.24	+ 0.12		60	80
			4	0.14	+ 0.07		120	75
			6	0.39	+ 0.17		60	77
			7	0.19	+ 0.09		107	77
			Sum	1.3				
J-05B	"	3272	1	0.25	+ 0.13		60	54
			2	1.67	+ 0.26		110	72
			3	1.73	+ 0.35		60	75
			4	0.21	+ 0.09		90	82
			6	0.135	+ 0.043		204	67
			7	0.27	+ 0.12		101	59
			Sum	4.3				
J-070	"	3275	1	65.0	+ 1.7		77	95
			2	57.1	+ 1.7		165	38
			3	24.6	+ 1.0		110	77
			4	19.5	+ 0.7		90	68
			6	7.94	+ 0.64		90	68
			7	1.62	+ 0.30		60	93
			Sum	175				

TABLE A.3 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield	
				dpm/sample				min.	approx. percent
J-10c	Andersen	3274	1	0.09	+	0.09	90	40	
			2	0.54	++	0.04	116	75	
			3	1.06	+++	0.12	54	42	
			4	0.48	++	0.15	90	73	
			6	0.63	+++	0.07	100	44	
			7	3.08	+++	0.42	112	46	
			Sum	5.9					
L-10c	"	3294	1	0.01	+	0.03	60	58	
			2	0.50	+++	0.17	120	57	
			3	0.42	+++	0.21	120	70	
			4	0.12	+++	0.09	60	88	
			6	0.38	+++	0.17	60	63	
			7	0.25	++	0.15	60	62	
			Sum	1.7					
L-11c	"	3293	1	0.14	+	0.05	224	82	
			2	0.17	+++	0.09	90	51	
			3	0.18	+++	0.06	57	33	
			4	0.23	+++	0.14	60	70	
			6	0.44	+++	0.18	70	70	
			7	0.11	++	0.05	25	57	
			Sum	1.3					
F-002	Casella	4881	1	0.19	+	0.08	120	82	
			2	0.03	+++	0.03	120	82	
			3	0.16	+++	0.05	175	85	
			4	0.06	++	0.04	120	83	
			5	0.17	++	0.06	200	63	
			Sum	0.61					
F-014	"	4882	1	0.06	+	0.04	120	92	
			2	0.06	+++	0.04	120	80	
			3	0.18	+++	0.07	120	89	
			4	102.3	+++	2.9	213	94	
			5	0.12	++	0.06	120	88	
			Sum	103					
F-02c	"	4883	1	1.04	+	0.19	120	80	
			2	0.31	+++	0.16	120	77	
			3	2.09	+++	0.09	955	76	
			4	0.46	++	0.13	120	71	
			5	0.08	++	0.08	80	44	
			Sum	4.0					
F-050	"	4891	1	253	+	3.4	241	68	
			2	52.2	++	1.5	103	70	
			3	16.1	++	0.6	224	80	
			4	2.39	+++	0.40	60	78	
			5	0.17	++	0.08	120	74	
			Sum	324					
F-060	"	4890	1	441	+	11	60	83	
			2	11.73	++	0.76	118	53	
			3	12.0	++	1.1	60	50	
			4	1.07	++	0.29	60	68	
			5	3.99	++	0.38	123	69	
			Sum	470					
F-074	"	4892	1	71	+	14	105	81	
			2	81.9	++	1.4	122	74	
			3	53.4	++	1.3	126	74	
			4	19.3	++	1.0	127	60	
			5	7.53	++	0.67	60	90	
			Sum	223					
F-070	"	4893	1	483.9	+	8.7	2037	10	
			2	113.5	++	1.9	1211	2	
			3	275.0	+++	3.6	2037	18	
			4	275.3	+++	13.5	1211	4	
			5	366.7	+++	11.4	1211	6	
			Sum	1504					
F-084	"	4894	1	30.9	+	1.0	134	74	
			2	86.0	++	1.9	116	64	
			3	33.2	++	1.1	103	86	
			4	9.79	++	0.52	103	78	
			5	10.2	++	0.7	103	76	
			Sum	171					

TABLE A.2 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample				
							min.	approx. percent
F-106	Casella	4896	1	6.22	0.47		120	100
			2	7.78	0.66		60	
			3	8.95	0.50		120	
			4	2.57	0.16		60	
			5	0.89	0.10		955	
			Sum	26.4				
J-014	"	4902	1	1.40	0.14		120	100
			2	0.03	0.03		120	
			3	0.09	0.09		60	
			4	0.42	0.07		320	
			5	0.16	0.09		50	
			Sum	2.1				
J-026	"	4899	1	21.32	1.09		60	100
			2	0.12	0.07		120	
			3	0.03	0.03		120	
			4	0.03	0.03		120	
			5	0.04	0.04		120	
			Sum	21.5				
J-042	"	4900	1	3828	76		120	100
			2	41.0	1.4		100	
			3	18.3	0.8		103	
			4	0.165	0.083		131	
			5	0.32	0.11		120	
			Sum	3886				
J-050	"	4213	1	612	13		100	100
			2	4.42	0.57		60	
			3	2.36	0.35		120	
			4	145.5	3.9		60	
			5	0.19	0.11		60	
			Sum	764				
J-060	"	4906	1	62.8	1.6		134	100
			2	1.39	0.25		90	
			3	0.92	0.38		210	
			4	23.73	1.76		1165	
			5	-0.01	0.02		60	
			Sum	88.8				
J-078	"	4905	1	114	4		120	100
			2	70.6	2.1		125	
			3	27.9	1.0		116	
			4	13.0	0.8		90	
			5	7.17	0.65		90	
			Sum	233				
J-092	"	4910	1	0.02	0.03		120	100
			2	13.4	0.8		90	
			3	7.76	0.35		224	
			4	3.12	0.44		60	
			5	3.14	0.20		270	
			Sum	27.4				
J-114	"	4909	1	0.14	0.10		60	100
			2	0.45	0.05		955	
			3	99.3	2.0		120	
			4	0.20	0.09		67	
			5	0.41	0.16			
			Sum	101				
K-006	"	4941	1	0.07	0.07		60	100
			2	0.16	0.03		934	
			3	0.01	0.04		60	
			4	0.10	0.06		123	
			5	0.56	0.32		60	
			Sum	0.90				
F-017	"	4931	1	1.40	0.27		60	100
			2	11.0	0.7		120	
			3	0.74	0.13		172	
			4	1.34	0.26		60	
			5	0.23	0.03		200	
			Sum	15.7				

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
K-032	Casella	4932	1	1304 ± 78		51	82
			2	22.1 ± 1.0		90	72
			3	0.54 ± 0.14		123	71
			4	0.32 ± 0.11		126	69
			5	3.08 ± 0.42		85	64
			Sum	1330			
K-048	"	4930	1	273 ± 4		241	74
			2	13.7 ± 1.8		80	55
			3	0.06 ± 0.04		120	80
			4	0.07 ± 0.07		60	77
			5	0.38 ± 0.14		101	57
			Sum	287			
K-064	"	4942	1	72.2 ± 1.6		144	74
			2	4.98 ± 0.65		90	41
			3	0.44 ± 0.16		60	70
			4	0.13 ± 0.08		90	80
			5	0.99 ± 0.21		116	58
			Sum	79			
K-072	"	4934	1	23.7 ± 1.8			
			2	22.5 ± 0.8		134	74
			3	20.5 ± 0.9		115	77
			4	14.53 ± 0.61		1274	47
			5	1.72 ± 0.25		205	75
			Sum				
K-094	"	4938	1	2.68 ± 0.43		60	74
			2	7.48 ± 0.64		90	62
			3	13.4 ± 1.0		60	68
			4	4.34 ± 0.90		90	54
			5	5.19 ± 0.60		115	46
			Sum	34.1			
K-112	"	4937	1	0.03 ± 0.03		120	74
			2	3.81 ± 0.33		120	93
			3	0.51 ± 0.12		120	86
			4	0.45 ± 0.01		175	79
			5	0.25 ± 0.13		60	82
			Sum	5.0			
I-002	"	4954	1	0.09 ± 0.05		120	68
			2	0.43 ± 0.12		120	85
			3	0.045 ± 0.032		574	24
			4	0.06 ± 0.02		955	46
			5	0.13 ± 0.09		60	80
			Sum	0.76			
I-004	"	4954	1	0.06 ± 0.06		60	80
			2	0.06 ± 0.06		60	83
			3	0.05 ± 0.05		90	70
			4	0.05 ± 0.05		120	55
			5	0.053 ± 0.013		934	76
			Sum	0.27			
E1-06	240-E	5185		2514 ± 71	Americium	10	77
E-03	"	5154		3714 ± 104	Americium	10	78
E-120	"	5069		2.69 ± 0.31		125	71
E-040	"	5094		956 ± 161	Americium		
E-042	"	5043		93.0 ± 2.3		120	79
E-120	"	5094		0.41 ± 0.09		204	49
E-004	"	5102		0.19 ± 0.04		204	84
E-012	"	5100		0.32 ± 0.32		90	35
E-020	"	5090		14.0 ± 0.7		132	82
E-101	"	5101		3.01 ± 0.38		97	67
E-120	"	5105		3.99 ± 0.45		90	69

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
CSI-D-000	TAS-D	5199		10.0 ± 0.5		211	61
CSI-E-000	"	5200		56.1 ± 1.4	Americium	1002	9
CSI-F-000	"	5201		76.6 ± 1.2	Americium	95*	99
CSI-G-000	"	5202		173.9 ± 27.8		60	31
CSI-H-000	"	5203		398 ± 10		60	78
CSI-I-000	"	5204		722 ± 31		23	72
CSI-N-024	"	5195		92.6 ± 4.2	Americium	120	85
CSI-N-030	"	5196		28.3 ± 0.9	Americium	120	87
CSI-N-036	"	5197		11.1 ± 0.6	Americium	120	83
F-05E	TAS-I	5062		110.6 ± 4.0		120	64
F-064	"	5063		4766 ± 114	Uranium	1000	11
K-052	"	5095		231 ± 3		5*	4*
K-060	"	5091		465 ± 30		60	26
K-068	"	5094		165 ± 4		8*	71
K-092	"	5092		123.0 ± 7.4		60	54
K-100	"	5089		30.3 ± 1.9		90	92
D-030	TAS-II	5149		1574 ± 70	Americium	10	75
F-006	"	5051		0.39 ± 0.19		97	74
F-018	"	5053		57.6 ± 2.0		118	36
F-042	"	5054		1044 ± 63	Americium	60	14
F-078	"	5060		5388 ± 248	Uranium	1000	3
F-114	"	5061		7.58 ± 0.41		211	67
H-042	"	5035		923 ± 101	Americium	60	14
J-00E	"	5074		0.90 ± 0.24		90	54
J-018	"	5073		6.64 ± 0.52		118	65
J-030	"	5071		0.45 ± 0.05		1085	50
J-054	"	5079		1030 ± 62		60	43
J-06E	"	5070		44.2 ± 7.1		60	69
J-102	"	5072		10.34 ± 0.52		361	21
J-114	"	5075		1.02 ± 0.17		135	79
K-02E	"	5095		0.68 ± 0.39		60	74
K-03E	"	5097		8262 ± 148		120	44
K-044	"	5096		781 ± 21		60	72
L-064	"	5113		32.1 ± 3.3	Americium	60	15
EM-02	Film	8153		8.93 ± 0.05 x 10 <sup>6</sup>	Americium	30	83
CO-050	"	8152		1.79 ± 0.08 x 10 <sup>7</sup>	"	10	9*
C-026A	"	8155		1.79 ± 0.07 x 10 <sup>7</sup>	"	10	64
D-030	"	8156		1.45 ± 0.03 x 10 <sup>7</sup>	"	10	62

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES. CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx percent
E-032	Film	8157		$7.93 \pm 0.17 \times 10^6$	Americium	10	65
E-042	"	8157		$1.02 \pm 0.08 \times 10^5$		30	33
E-050	"	"		$4.52 \pm 0.20 \times 10^4$		30	66
E-054	"	"		$1.01 \pm 0.04 \times 10^4$		30	86
E-056A	"	"		$7030 \pm 220$		30	63
E-058	"	"		$6651 \pm 180$		30	58
F-062	"	"		$9797 \pm 362$		30	48
E-066	"	"		$1.10 \pm 0.03 \times 10^4$		30	80
E-068	"	"		$1.13 \pm 0.03 \times 10^4$		30	62
E-070	"	"		$1.40 \pm 0.04 \times 10^4$		30	28
E-072	"	"		$1.09 \pm 0.03 \times 10^4$		30	76
E-074	"	"		$1.30 \pm 0.04 \times 10^4$		30	57
E-078	"	"		$9778 \pm 313$		30	20
E-082	"	"		$7133 \pm 128$		60	66
E-084	"	"		$6597 \pm 172$		60	81
E-086	"	"		$4908 \pm 133$		60	71
E-088	"	"		$3845 \pm 154$		30	86
F-006	"	8158		$819 \pm 24$		60	59
F-028	"	"		$2.39 \pm 0.06 \times 10^5$		60	82
F-034	"	"		$4.51 \pm 0.12 \times 10^6$		10	46
F-036	"	8158		$4.75 \pm 0.10 \times 10^6$	Americium	10	62
F-038	"	"		$3.25 \pm 0.05 \times 10^6$	Uranium	10	61
F-040	"	"		$1.29 \pm 0.04 \times 10^6$		10	67
F-042	"	"		$3.20 \pm 0.04 \times 10^5$	Uranium	120	54
F-044	"	"		$6.58 \pm 0.14 \times 10^5$	"	60	24
F-046	"	"		$2.14 \pm 0.07 \times 10^5$		30	51
F-050	"	"		$6.88 \pm 0.17 \times 10^4$	Uranium	30	85
F-052	"	"		$3.46 \pm 0.08 \times 10^4$		90	30
F-056	"	"		$5955 \pm 197$		60	49
F-058	"	"		$4495 \pm 400$		15	82
F-062	"	"		$4252 \pm 149$		30	84
F-066E	"	"		$6670 \pm 354$		30	60
F-068	"	"		$6.57 \pm 0.22 \times 10^3$	Uranium	30	54
F-070	"	"		$5866 \pm 164$		60	67
F-072	"	"		$6452 \pm 265$		30	64
F-074	"	"		$4274 \pm 171$		71	27
F-076E	"	"		$6804 \pm 265$		30	42
F-078	"	"		$5021 \pm 156$		60	49
F-090	"	"		$4805 \pm 125$		60	76

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES. CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
F-082	Film	8158		4493 ± 315		15	42
F-084	"	"		3832 ± 138		30	83
F-086	"	"		2844 ± 78		60	69
G-028	"	8159		1.23 ± 0.06 × 10 <sup>5</sup>		30	60
G-030	"	"		9.88 ± 0.30 × 10 <sup>5</sup>		30	57
G-032	"	"		2.80 ± 0.05 × 10 <sup>6</sup>		10	99
G-034	"	"		3.30 ± 0.02 × 10 <sup>6</sup>		10	82
G-036	"	"		3.33 ± 0.02 × 10 <sup>6</sup>		10	68
G-038	"	"		2.82 ± 0.09 × 10 <sup>6</sup>		10	65
G-040	"	"		1.20 ± 0.03 × 10 <sup>6</sup>		10	80
G-042	"	"		7.61 ± 0.24 × 10 <sup>5</sup>		30	53
G-044	"	"		4.63 ± 0.24 × 10 <sup>5</sup>		30	65
G-046	"	"		2.52 ± 0.14 × 10 <sup>5</sup>		75	23
G-048	"	"		1.43 ± 0.09 × 10 <sup>5</sup>		30	42
G-050	"	"		1.01 ± 0.04 × 10 <sup>5</sup>		30	62
G-052	"	"		5.19 ± 0.18 × 10 <sup>4</sup>		15	90
G-054	"	"		4989 ± 115		30	81
G-056	"	"		5339 ± 235		30	68
G-072	"	"		3869 ± 159		30	80
G-074	"	"		4374 ± 114		30	62
G-076	"	"		3414 ± 130		30	46
H-026	"	8160		271.0 ± 10.8		947	33
H-032	"	"		1.49 ± 0.04 × 10 <sup>6</sup>		30	71
H-034	"	"		293 ± 0.06 × 10 <sup>6</sup>	Americium	10	69
H-036	"	"		2.15 ± 0.05 × 10 <sup>6</sup>		10	55
H-040	"	"		1.09 ± 0.03 × 10 <sup>6</sup>		10	62
H-042	"	"		7.62 ± 0.24 × 10 <sup>5</sup>		10	69
H-044	"	"		4.40 ± 0.16 × 10 <sup>5</sup>		30	40
H-046	"	"		1.83 ± 0.04 × 10 <sup>5</sup>		30	30
H-048	"	"		1.79 ± 0.06 × 10 <sup>5</sup>		60	28
H-054	"	"		3747 ± 124		71	39
H-066	"	"		3815 ± 244		15	50
H-070	"	"		2635 ± 29		30	29
J-036	"	8161		1.27 ± 0.02 × 10 <sup>6</sup>	Americium	10	52
J-038	"	8162		5.65 ± 0.08 × 10 <sup>5</sup>	Americium	31	87
	Soil			For results of plutonium analyses of soils, see Table 7.3 in the chapter on the determination of plutonium by gamma spectrometry of Am <sup>241</sup>			
E-111	water	8163		1.87 ± 0.11		20	61
E-112	"	"		188 × 10 <sup>4</sup>	Solubility Study*		

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240 dpm/sample	Remarks	Counting Time	Yield approx. percent
B-108	Water	5229		2811 ± 72		100	30
D-012	"	5246		233.7 ± 3.0		950	21
D-084	"	5244		6312. ± 120		10	90
DMob-074	"	5253		27.60 ± 0.41	**	1000	50
DMob-074	"	5254		1.34 ± 0.03 x 10 <sup>4</sup>	**	30	23
DMob-074	"	5255		1.13 ± 0.02 x 10 <sup>4</sup>	**	10	80
IMob-050	"	5260		5.79 ± 0.13 x 10 <sup>4</sup>		10	27
IMob-050	"	5261		5.07 ± 0.06 x 10 <sup>4</sup>		60	44
IMob-050	"	5262		7.36 ± 0.10 x 10 <sup>4</sup>		12	57
L-006	"	5237		1609 ± 32		10	84
L-054	"	5240		4674 ± 51		40	70
L-078	"	5242		106 x 10 <sup>5</sup>	Solubility Study*		
L-102	"	5234		1.50 ± 0.04 x 10 <sup>4</sup>		60	60

\*Determined from the sum of several fractions during solubility studies. This value may be less than the total Pu deposited in the water tray.

\*\* Sample bottles and shipping papers labeled with two locations Location assigned to DMob-074 instead of IMob-050 based on Tracerlab Sample Handling Record

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2. H.J.M. Bowen and D. Gibbons; "Radioactivation Analysis"; 1963; Oxford University Press (Oxford at the Clarendon Press); Great Britain.

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TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet	Pu-239,240		Remarks	Counting Time	Yield	
					grams	dpm/sample				
Sheep	22 May	2157	Urine	2765.0	9131	+484		min.	approx. percent	
	20 Aug		"	4109.3	342.9	± 55.6		120	19	
	21 Aug		"	864.0	6.74	± 0.71		481	0.5	
	22 Aug		"	2526.9	16.58	± 0.97		622		
	24 Aug		"	1908.0	7.30	± 0.60		764		
	21 May		Feces	847.0	3112	± 103		120	52	
	22 May		"	1128.0	2063	± 78		102	58	
	23 May		"	491.5	218.2	± 15.3		102	44	
	D + 30		"	5620.4	414.1	± 24.4		90	13	
								438	4	
"	D + 3	2164-1	Left femur	206.4	0.35	± 0.20		60	45	
		-2	Kidney	87.2	0.07	± 0.07		60	77	
		-3E	Liver	530.5	0.81	± 0.36		127	40	
		-4	Lung	348.6	0.34	± 0.04		960	70	
		-5	H. node	5.6159	0.06	± 0.04		386	84	
"	D + 90	2166-1	Left femur	211.3	0.10	± 0.03		750	89	
		-2	Kidney	101.7	0.06	± 0.06		60	80	
		-3	Liver	627.8	0.71	± 0.18		120	53	
		-4	Lung	381.8	0.51	± 0.25		120	65	
		-5	H. node	8.34	0.06	± 0.02		688	55	
"	D Day	2168-1	Left femur	190.8	40.67	± 3.05		956	2	
		-2	Kidney	183.0	2.70	± 0.21		240	83	
		-3	Liver	599.0	23.82	± 1.31		1165	4	
		-4	Lung	710.1	281	± 4.2	Uranium	1000	44	
		-5	H. node	7.983	0.85	± 0.42		60	79	
		-7	Trachea	123.3	-0.21	± 0.04		994	42	
		-8	Stomach	5504.0	1214	± 46		160	27	
		-9	P. mucosa	9.91	0.09	± 0.06		90	80	
		-10	N. mucosa	65.7	2.17	± 0.24		762	17	
			2169-1	Left femur	203.9	574.8	± 69.0		1000	1
"		-2	Kidney	120.0	0.60	± 0.25		90	34	
		-3	Liver	592.5	15.11	± 0.44		1165	21	
		-4	Lung	433.9	57.47	± 1.21	Uranium	400	76	
		-5	H. node	10.292	0.79	± 0.25		60	66	
		-7	Trachea	154.6	3.89	± 0.47		60	93	
		-8	Stomach	5959.0	149.5	± 2.7		400	47	
		-9	P. mucosa	11.45	1.93	± 0.08		994	85	
		-10	N. mucosa	121.1	11.54	± 0.72		102	69	
			2170	Urine	2595	1891	± 76		415	9
		21 May	"	952.2	2135	± 81		415	11	
	20 Aug	"	2070.2	19.22	± 1.00		180	33		
	21 Aug	"	680.8	3.26	± 0.21		722	32		
	22 Aug	"	1756.4	3.00	± 0.26		764	18		
	21 May	Feces	1104.6	2248	± 79		160	34		
	22 May	"	631.9	927.1	± 130.1		60	5		
	22 May	"	328.1	718.8	± 107.8		60	16		
	D + 30	"	3824.2	481	± 24		1000	3		
"	D + 30	2173-1	Left femur	200.6	0.30	± 0.15	Not on official inventory	762	18	
		-2	Kidney	92.0	2.68	± 0.75		140	11	
		-3	Liver	442.5	1.30	± 0.23		120	60	
		-4	Lung	424.0	283.1	± 4.5	Uranium	1040	48	
		-5	H. node	9.182	0.39	± 0.14		90	71	
		-7	Right femur				not received Or. inventory but missing			
		-8	Trachea	114.5	4.64	± 0.56		60	78	
		-9	Stomach	4560.0	1203	± 61		120	14	
		-10	P. mucosa	11.45	1.30	± 0.62		207	70	
			-10	P. mucosa	80.5	207.4	± 4.9		762	14
"	D + 30	2182-1	Left femur	211.5	0.08	± 0.05		120	69	
		-2	Kidney	91.4	0.003	± 0.05		60	96	
		-3	Liver	567.5	1.08	± 0.21		90	87	
		-4	Lung	468.6	0.13	± 0.09		60	83	
		-5	H. nodes	11.8037	0.05	± 0.01		934	70	
"	D + 30	2180-1	Left femur	211.5	37.50	± 0.45		525	90	
		-2	Kidney	114.7	0.10	± 0.07		90	72	
		-3	Liver	748.7	0.77	± 0.21		60	74	
		-4	Lung	459.0	21.89	± 0.57		85	82	
		-5	H. nod.	9.318	3.31	± 0.29		225	43	

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet		Pu-239,240	Remarks	Counting Time	Yield	
				grams	dpm/sample				min.	approx percent
Sheep	21 May 22 May 20 Aug 21 Aug 22 Aug 24 Aug 22 May 23 May	B-3078 F	Urine	2697.0	625.3	+ 32.5		286	8	
			"	2430.0	612.6	+ 17.8		400	19	
			"	3825.1	4.19	+ 0.48		180	51	
			"	1001.0	24.	+ 5		120	9	
			"	2336.5	9.76	+ 0.26		977	46	
			"	3536.4	1.30	+ 0.081		962	46	
			Feces	809.3	90.65	+ 3.26		978	5	
			"	384.2	779.6	+ 32.7		120	30	
			"							
Burro	D + 3	3004-1	Left Femur	1072.1	16.47	± 0.59		951	16	
			-2 Kidney	829.0	1.11	± 0.30		60	66	
			-4 Lung	1542.8	42.10	± 2.32		90	87	
			-5 H. Node	28.772	0.51	± 0.06		1055	48	
	D + 7	3005-1	Left Femur	918.4	0.79	± 0.18		120	6	
				709.0	0.14	± 0.02		890	70	
				-2 Kidney	1779.3	17.76	± 1.26		60	59
				-3 Liver					428	9
				-6 Right Femur	940.9	0.69	± 0.17		978	18
	D + 7	3006-1	Left Femur	927.3	1.20	± 0.26		978	17	
				724.9	0.44	± 0.05		60	80	
				-2 Kidneys	1929.7	8.32	± 0.71		400	51
				-3 Liver	1065.0	419.8	± 10.5		957	63
				-4 Lung	16.18	0.09	± 0.02			
	D + 7	3015-1	Left Femur	952.9	1.62	± 0.11		978	46	
				653.2	1.75	± 0.16		978	51	
				-2 Kidneys	19.5946	0.24	± 0.06		317	70
				-5 H. Node						
	D Day	3019-1	Left Femur	989.4	15.30	± 0.83		187	54	
				722.8	2.10	± 0.20		180	86	
				-2 Kidney	2561.0	22.44	± 0.72	Uranium	286	76
				-3 Liver	1566.0	142.2	± 6.3		1033	24
				-4 Lung	12.6655	1.31	± 0.09		102	51
				-5 H. Node	1023.0	21.91	± 1.45		120	33
				-6 Right Femur	339.2	19.81	± 0.73		120	86
-7 Trachea				65.36	9.24	± 0.17	Duplicate stomachs found	1206	83	
D - Day	3020-1	Left Femur	973.7	1.90	± 0.12	Control?	120	20		
							566	63		
							980	47		
D Day	3024-5	Hilar Node	18.2350	3.79	± 0.17		170	73		
D Day	3032-1	Left Femur	1035.0	2.52	± 0.33		1032	40		
			583.2	13.69	± 0.31		1040	61		
			-2 Kidney	2860.0	66.27	± 0.66	Uranium	960	7	
			-3 Liver	2252.0	1182	± 40		102	60	
			-4 Lung	1217.0	33.80	± 1.32		415	75	
			-6 Right Femur	447.3	263.5	± 3.7		286	29	
			-7E Trachea	1263.0	200.3	± 5.6	Duplicate stomachs found	1040	92	
			-8 Stomach	44.48	58.44	± 0.47	Not on inventory	120	20	
			-9 P. Mucosa							
D + 7	3040-1	Left Femur	1266.0	1.24	± 0.21		976	31		
			609.7	0.30	± 0.05		978	47		
			-2 Kidney	3753.2	11.01	± 0.42		978	20	
			-3 Liver	1537.2	389.4	± 20.0		240	10	
			-4 Lung	26.109	0.13	± 0.02		1979	46	
			-6 H. Node							
D Day	3049-1	Left Femur	1003.3	324.9	± 6.9		160	37		
			1056.0	11.14	± 0.20		1207	71		
			-2 Kidney	4304.0	87.93	± 3.87		135	55	
			-3 Liver	1650.0	7.75	± 1.1	Uranium	330	64	
			-4 Lung	13.150	1.93	± 0.11		380	34	
D Day	3050-1	Left Femur	1036.2	10.71	± 0.69	Control?	102	70		
			744.0	0.64	± 0.16	Box 19 inventory	20	86		
			998.0	0.83	± 0.13	Box 18 inventory	240	59		
			-2C Kidney	2685.7	26.13	± 0.34		1017	60	
			-3 Liver	1409.0	1047	± 29	Uranium, Box 19	1010	5	
			-4 Lung	1743.0	8.48	± 0.25	Control?, Box 18	1000	42	
			-4C Lung	11.26	3.31	± 0.36		187	56	
			-5 H. Node	950.8	3.71	± 0.29		340	47	
			-6 Right Femur	447.3	1.18	± 0.28		120	57	
			-7 Trachea	38.49	1.42	± 0.24		90	85	
D + 7	3057-1	Left Femur	1760.0	9.47	± 0.84	Sample spilled during chemistry	890	9		
			1040.0	0.78	± 0.23		908	5		
			-2 Kidney	3777.7	160.5	± 14.9		60	38	
			-3 Liver	1192.0	16.29	± 1.48		90	81	
			-4 Lung	10.7427	6.87	± 0.45		164	63	

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight,	Pu-239,240	Remarks	Counting	Yield
				Wet			Time	
				grams	dpm/sample			
						min.	approx. percent	
Barro	D + 3	3064-1	Left Femur	1015.5	2.37 ± 0.11		975	45
		-2	Kidney	752.0	0.39 ± 0.05		975	43
		-3	Liver	4089.0	115.6 ± 2.2		960	17
		-4	Lung	1802.6	8.52 ± 1.36		60	80
		-5	H. Node	5.304	0.12 ± 0.02		1579	89
		-6	Right Femur	1314.2	41.52 ± 1.66		90	54
		-8	Stomach		Not Received	On inventory but missing		
		D + 3	3065-1	Left Femur	1139.0	1.60 ± 0.37		120
	-1B		Left Femur	1230.7	5.06 ± 0.33		205	79
	-2		Kidney	779.3	0.35 ± 0.06		924	25
	-3		Liver	2122.5	96.24 ± 5.77		60	27
	-4		Lung	1509.7	327.7 ± 13.1		60	87
	-5		H. Node	7.430	1.71 ± 0.18		60	67
	D + 7	3066-1	Left Femur	927.0	17.37 ± 0.97	Control?	1290	44
		-2	Kidney	824.6	1.65 ± 0.13		751	39
		-3	Liver	3451.0	71.88 ± 2.85		60	46
		-4?	Lung	1287.0	7.13 ± 0.65	Lung questioned on inventory	386	18
		-5	H. Node	5.74	0.17 ± 0.07		141	80
	D + 3	3068-1	Left Femur	1097.9	4.72 ± 0.27		60	54
		-2	Kidney	764.8	0.10 ± 0.10		60	47
-3		Liver	3232.5	52.48 ± 0.63		924	78	
-4		Lung	1423.3	117.5 ± 4.2		60	77	
-5		H. Node	7.9607	0.07 ± 0.04		174		
E + 3	3074-3	Liver*	2011.2	22.68 ± 0.36		924	54	
Control	3082-8	Stomach	5574.2	2.79 ± 0.63	No. 3082? Questioned on inventory. Full of hay. Control?	774	12	
D + 3	3101-1 (E)	Left Femur	1152.5	1.39 ± 0.26		120	52	
	-2	Kidney	774.0	0.60 ± 0.07		975	43	
	-3	Liver	2832.8	75.83 ± 1.59		975	47	
	-4	Lung	1415.3	1332 ± 101		60	58	
D + 7	3102-2	Kidney	770.1	1.25 ± 0.30		60	75	
D + 7	3103-1	Left Femur	1042.9	299.3 ± 15.1		950	3	
D Day	3113-10	N. Mucosa	136.8	0.25 ± 0.06		980	2	
D + 7	3126-1	Left Femur	1114.8	1.52 ± 0.14		936	25	
	-2	Kidney	535.9	0.58 ± 0.26		60	45	
	-3	Liver	2890.3	82.17 ± 4.11	Sample spilled	1165	2	
	-4	Lung	1625.6	39.17 ± 1.96		60	53	
	-5	H. Node	22.1924	0.13 ± 0.03		1031	76	
D Day	3127-1	Left Femur	1156.3	14.45 ± 0.65		180	55	
	-2	Kidney	798.9	1.00 ± 0.17		207	54	
	-3	Liver	2718.0	126.6 ± 2.9		1032	11	
	-5	H. Node	6.447	0.21 ± 0.06		207	84	
	-6	Right Femur	1670.7	13.56 ± 0.93		120	43	
	-7	Trachea	476.2	12.70 ± 1.00		135	29	
	-8	Stomach	1652.0	2.05 ± 0.27		135	68	
	-9	P. Mucosa	57.23	1.29 ± 0.10		980	45	
D + 7	3132-1	Left Femur	935.1	1.59 ± 0.15		60	65	
	-2	Kidney	770.0	1.39 ± 0.11		60	71	
	-3	Liver	1850.0	21.30 ± 5.45		60	24	
	-4	Lung	1491.0	17.78 ± 0.48		936	26	
D + 7	3135-1	Left Femur	997.1	1.08 ± 0.11		936	30	
	-2E	Kidney	606.0	228.4 ± 22.8		1165	1	
	-3	Liver	2307.0	14.10 ± 0.94		240	19	
	-4	Lung	1370.4	13.18 ± 0.86		207	27	
	-5	H. Node	13.8985	0.06 ± 0.04		141	74	
D + 7	3137-1	Left Femur	944.8	0.81 ± 0.33		60	42	
	-2	Kidney	543.6	2.37 ± 0.24		240	52	
	-3	Liver	1641.0	15.88 ± 1.02		80	60	
	-4	Lung	1157.0	23.03 ± 0.60		980	27	
	-5	H. Node	6.1744	0.07 ± 0.020		566	87	

\* Later identified as 3004-3

TABLE A.4 PLUTONIUM ANALYSIS OF BIOLOGICAL SPECIMENS, DOUBLE TRACKS (cont'd.)

Animal Type	Sampling Time	DASA No.	Tissue	Weight, Wet	Pu-239,240	Remarks	Counting Time	Yield
				grams	dpm/sample		min.	approx. percent
Burro	D - Day	3139-1	Left Femur	927.5	1.03 ± 0.22	Control?	1290	45
			-2 Kidney	652.2	1.80 ± 0.24		120	80
			-3 Liver	2202.6	24.73 ± 0.49		570	53
			-4 Lung	1172.0	25.07 ± 0.93	Uranium	272	62
			-5 H. Node	5.1005	0.22 ± 0.05		341	47
			-6 Right Femur	1045.0	0.22 ± 0.03		1290	51
			-7 Trachea	396.5	0.98 ± 0.09		900	52
			-8 Stomach	1059.0	0.73 ± 0.15		1840	5.7
			-9 P. Mucosa	52.5	0.03 ± 0.02	Not on official inventory	99*	41
			-10 N. Mucosa	130.0	0.38 ± 0.04		1290	47
D + 7	3141-1	Left Femur	1089.8	4.10 ± 0.70		60	42	
		-2 Kidney	962.6	0.85 ± 0.14		948	18	
		-3 Liver	3040.3	100.1 ± 8.0		60	49	
		-4 Lung	1664.1	1228 ± 50		60	62	
		-5 H. Node	13.518	0.81 ± 0.17		630	54	
D + 7	3177-1	Left Femur	1001.5	3.74 ± 0.31		956	41	
		-2 Kidney	834.2	4.65 ± 0.40		120	78	
		-3 Liver	2510.7	120.8 ± 5.8		60	46	
		-4 Lung	1637.9	94.7 ± 8.5		60	12	
		-5 H. Node	12.5993	0.07 ± 0.04		371	72	
D + 3	3178-1	Left Femur	815.0	3.41 ± 0.20		95*	21	
		-2 Kidney	762.0	0.41 ± 0.04		960	50	
		-3 Liver	2708.4	76.74 ± 0.77	Box 18 duplicate**	924	51	
		-3A Liver	2631.0	81.15 ± 2.35		120	52	
		-4 Lung	1432.1	6.83 ± 0.65		50	25	
		-5 H. Node	9.1983	0.35 ± 0.088		141	41	
		-6 Right Femur	879.0	1.96 ± 0.24		924	16	
		-7 Trachea	446.4	0.16 ± 0.11		60	81	
		-9 P. Mucosa	202.1	0.38 ± 0.16		60	80	
		-10 N. Mucosa	103.3	0.36 ± 0.15		60	80	
D + 7	3199-1	Left Femur	1176.0	1.25 ± 0.15	Control?	745	24	
		-2 Kidney	775.0	0.637 ± 0.11		745	18	
		-3 Liver	4096.0	20.37 ± 1.00		745	9	
		-4 Lung	1616.5	1.25 ± 0.29		120	84	
		-5 H. Nodes	18.21	0.10 ± 0.03		745	59	
D + 7	3200-1	Left Femur	1127.3	1.10 ± 0.35		80	16	
		-2 Kidney	634.4	0.14 ± 0.02		890	41	
		-3 Liver	2964.4	12.20 ± 0.77		980	21	
		-4 Lung	1514.2	32.61 ± 0.85		270	51	
		-5 H. Node	7.889	0.010 ± 0.04		512	31	
Control	X-18B-8	Stomach	5209.4	8.30 ± 0.75	Full of hay. Control?	380	11	
D Day	3029	N. Mucosa	167.6	2.78 ± 0.67		980	2	
*D Day	No #-	1	Left Femur	876.3	2.08 ± 0.09		1206	63
			-2 Kidney	746.0	9.97 ± 0.18		206	52
			-3 Liver	2481.0	42.89 ± 0.90		246	61
			-4 Lung	1215.0	35.57 ± 1.85	Uranium	160	56
			-5 H. Node	8.284	0.08 ± 0.03		60	64
			-6 Right Femur	1046.6	2.14 ± 0.10		1000	72
			-7 Trachea	379.3	1.029 ± 56		30	72
			-8 Stomach	1261.0	154 ± 88		30	64
			-9 P. Mucosa	52.76	395.7 ± 10.7		130	67
			-10 N. Mucosa	176.8	184.9 ± 11.1		890	2

\* Later identified as 3011

\*\* -3 Liver identification incomplete but not 3178.  
 -3A Liver actually correct 3178 specimen.

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. Percent
F-034	Andersen	2778	1	0.08 ± 0.01		155	75
"	"	"	2	0.01 ± 0.01		217	49
"	"	"	3	0.58 ± 0.10		217	82
"	"	"	4	0.11 ± 0.04		205	72
"	"	"	6	0.29 ± 0.09		35	99
"	"	"	7	0.88 ± 0.09		390	80
"	"	"	Sum	1.96			
F-046	"	2771	1	3.09 ± 0.43		60	84
"	"	"	2	73.9 ± 1.4		156	76
"	"	"	3	8.11 ± 0.40		205	79
"	"	"	4	714 ± 24		100	45
"	"	"	6	0.11 ± 0.04		657	31
"	"	"	7	0.09 ± 0.05		159	23
"	"	"	Sum	799			
F-052	"	2781	1	10.9 ± 0.6		916	10
"	"	"	2	14.4 ± 1.1		35	98
"	"	"	3	40.8 ± 1.1		164	65
"	"	"	4	18.0 ± 0.9		140	51
"	"	"	6	11.19 ± 0.45		663	26
"	"	"	7	6.49 ± 0.19		941	56
"	"	"	Sum	102			
F-055	"	2767	1	50.4 ± 1.1		250	56
"	"	"	2	79.6 ± 1.8		350	20
"	"	"	3	99.6 ± 1.4		275	60
"	"	"	4	56.6 ± 0.5		1000	82
"	"	"	6	763 ± 22		73	89
"	"	"	7	12.1 ± 0.5		240	72
"	"	"	Sum	1021			
F-054	"	2759	1	919.9 ± 32.2		30	84
"	"	"	2	1264 ± 45		30	81
"	"	"	3	4008 ± 128		30	66
"	"	"	4	2266 ± 70		30	68
"	"	"	6	1108 ± 40		30	80
"	"	"	7	861 ± 19		103	60
"	"	"	Sum	10,417			
F-070	"	2764	1	132 ± 4		120	98
"	"	"	2	222 ± 0		30	87
"	"	"	3	257 ± 10		30	72
"	"	"	4	102 ± 1.5		154	84
"	"	"	6	97.4 ± 0.7		1000	60
"	"	"	7	84.0 ± 1.2		371	55
"	"	"	Sum	894			
F-071	"	2756	1	0.73 ± 0.11		565	36
"	"	"	2	0.16 ± 0.03		512	86
"	"	"	3	0.18 ± 0.06		159	55
"	"	"	4	0.24 ± 0.17		120	68
"	"	"	6	0.12 ± 0.06		159	68
"	"	"	7	0.12 ± 0.07		159	77
"	"	"	Sum	1.6			
F-034	"	2721	1	0.96 ± 0.11		745	35
"	"	"	2	2.32 ± 0.15		589	56
"	"	"	3	0.08 ± 0.03		750	30
"	"	"	4	0.30 ± 0.07		589	34
"	"	"	6	0.27 ± 0.06		390	54
"	"	"	7	0.07 ± 0.07		390	87
"	"	"	Sum	4.0		1026	
F-044	"	2714	1	1548 ± 67		20	27
"	"	"	2	141.1 ± 2.4		500	42
"	"	"	3	50.9 ± 1.2		254	19
"	"	"	4	4.61 ± 0.35		663	18
"	"	"	6	1.09 ± 0.10		548	50
"	"	"	7	0.18 ± 0.06		512	35
"	"	"	Sum	1746			
F-052	"	2711	1	2019 ± 91		20	77
"	"	"	2	162.6 ± 9.1		60	89
"	"	"	3	91.0 ± 1.6		156	69
"	"	"	4	53.5 ± 0.9		275	81
"	"	"	6	27.3 ± 0.8		164	85
"	"	"	7	9.04 ± 0.40		941	60
"	"	"	Sum	2362			

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240 dpm/sample	Remarks	Counting Time		yield approx. percent
						min.		
H-058	Andersen	2707	1	1241 + 26		80	87	
			2	527 ± 10		105	87	
			3	279 ± 7		60	80	
			4	154.3 ± 2.0		208	76	
			6	78.4 ± 0.6		1000	70	
			7	57.3 ± 0.5		1000	75	
			Sum	2337				
H-064	"	2728	1	2659 + 3252	Uranium	120	14	
			2	1.76 ± 0.05x10 <sup>4</sup>	"	102	11	
			3	1869 ± 22	"	220	35	
			4	2593 ± 31	"	225	31	
			6	1303 ± 42	"	221	21	
			7	1908 ± 46	"	220	50	
			Sum	2,79 x 10 <sup>4</sup>				
E-054	Casella	9685	1	73.0 ± 1.2		745	31	
			2	0.26 ± 0.09		180	55	
			3	0.24 ± 0.08		174	64	
			4	0.13 ± 0.04		495	47	
			5	0.43 ± 0.07		300	82	
Sum	74.1							
E-056	"	9653*	1	2016 + 29		159	70	
			2	338 ± 4		215	65	
			3	69.4 ± 1.0		306	67	
			4	16.7 ± 0.5		251	89	
			5	15.5 ± 0.4		306	80	
Sum	2456							
E-056	"	9687	1	1752 + 37		91	75	
			2	228 ± 4		275	41	
			3	56.3 ± 5.1		60	35	
			4	14.5 ± 0.6		313	47	
			5	15.7 ± 0.5		280	74	
Sum	2066							
E-058	"	9689	1	3327 + 57		30	76	
			2	19.8 ± 1.7		35	64	
			3	8,557 ± 0.27		524	73	
			4**	2,491 ± 0.08		1420	73	
			5	3,197 ± 0.19		540	50	
Sum	3361							
E-060	"	9690	1	243 ± 6		120	38	
			2	25.2 ± 0.6		524	45	
			3	5,517 ± 0.12		1000	74	
			4	2,757 ± 0.11		303	73	
			5	1,137 ± 814				
Sum	280							
F-044	"	2766	1	29.8 ± 0.9		326	85	
			2	1,164 ± 0.09		223	71	
			3	0,857 ± 0.09		427	70	
			4	0,227 ± 0.05		427	65	
			5	0,267 ± 0.04		607	68	
Sum	32.3							
F-050	"	2769	1	270 ± 4.3		150	64	
			2	8,677 ± 0.18		683	51	
			3	622 ± 13		103	62	
			4	1,111 ± 0.15		620	10	
			5	0,567 ± 0.08		751	31	
Sum	902							
F-054	"	2761	1	236 ± 5		88	62	
			2	276 ± 4		220	45	
			3	108.9 ± 2.4		115	50	
			4	14.5 ± 0.4		300	56	
			5	0,127 ± 0.03		500	75	
Sum	636							
F-05f	"	2780	1	1470 ± 44		50	63	
			2	162 ± 4		77	65	
			3	34.5 ± 0.6		500	63	
			4	10,997 ± 0.33		500	63	
			5	6,257 ± 0.24		524	63	
Sum	1684							

\* Stages 2 and 3 both labeled Stage 2. Assignment of stage based on color coded packaging.  
 \*\* Labeled TL #8889.

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES. DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield	
				dpm/sample				min.	approx. percent
F-062	Casella	2773	1	4497	+ 94		30	50	
			2	1245	+ 22		99	82	
			3	532	+ 14		77	51	
			4	88.7	+ 1.4		300	50	
			5	124.2	+ 2.4		120	57	
			Sum	6487					
F-068	"	2762	1	2730	+ 41		30	92	
			2	4600	+ 60		30	77	
			3	1726	+ 37		88	92	
			4	263	+ 6		88	76	
			5	501	+ 9		125	70	
			Sum	9820					
F-080	"	2755	1	0.23	+ 0.09		373	22	
			2	0.44	+ 0.04		1400	82	
			3	0.17	+ 0.07		657	17	
			4	0.64	+ 0.06		1000	73	
			5	1.75	+ 0.22		155	73	
			Sum	3.2					
FM-001	"	2159	1	141.3	+ 3.0		120	56	
			2	12.5	+ 1.2		35	85	
			3	1037	+ 31		88	36	
			4	0.99	+ 0.09		874	58	
			5	2.33	+ 0.06		2514	71	
			Sum	1194					
FM-002	"	2160	1	1.2	+ .25		91	88	
			2	66.9	+ 1.0		226	80	
			3	6.36	+ 0.02		1690	31	
			4	3.22	+ 0.21		929	31	
			5	2.255	+ 0.026		1407	84	
			Sum	1403					
FM-003	"	2161	1	61.8	+ 1.5		189	47	
			2	12.9	+ 0.3		1016	39	
			3	13.2	+ 0.2		2514	62	
			4	1.66	+ 0.14		306	85	
			5	0.12	+ 0.04		340	63	
			Sum	89.7					
FM-004	"	2162	1	33.8	+ 0.4		1320	56	
			2	32.9	+ 1.0		189	56	
			3	259	+ 4		710	2	
			4	3.33	+ 0.39		171	41	
			5	2.11	+ 0.21		189	76	
			Sum	331					
FM-005	"	2165	1	3856	+ 66		156	58	
			2	44.0	+ 1.0		1285	31	
			3	11.8	+ 0.6		911	12	
			4	1.28	+ 0.09		1354	57	
			5	1.68	+ 0.20		210	83	
			Sum	3915					
FM-006	"	2166	1	4.85	+ 0.22		578	56	
			2	13.8	+ 0.4		644	47	
			3	3.43	+ 0.25		416	98	
			4	1.05	+ 0.09		1339	70	
			5	1.34	+ 0.10		615	80	
			Sum	24					
F-061	"	9662	1	1444	+ 17		252	77	
			2	189	+ 3		208	67	
			3	63.2	+ 1.2		156	53	
			4	8.52	+ 0.66		75	79	
			5	11.5	+ 0.6		164	71	
			Sum	1716					
F-067	"	9682	1	0.12	+ 0.03		1016	44	
			2	0.14	+ 0.03		496	99	
			3	0.84	+ 0.09		581	58	
			4	0.06	+ 0.03		495	43	
			5	0.004	+ 0.028		806	83	
			Sum	1.2					

\* Mobile unit instruments, all at F-060.

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield	
				dpm/sample				min.	approx. percent
G-060	Casella	9658	1	872.3	+ 33.6	Uranium Stages 1 and 2 autoradiographed by Isotopes, Inc.*	120	31	
			2	241.3	+ 3.4		180	32	
			3	465.8	+ 21.9		120	40	
			4	3407	+ 37		1000	20	
			5	1695	+ 66		150		
			Sum	10,273					
G-062	"	9657	1	4092	+ 106		30	57	
			2	1817	+ 33		30	63	
			3	591	+ 16		120	47	
			4	168	+ 4		200	64	
			5	273	+ 4				
			Sum	7241					
H-032	"	2737	1	0.003	+ 0.021		1380	69	
			2	0.008	+ 0.032		1404	71	
			3	-0.02	+ 0.035		1450	37	
			4	0.12	+ 0.05		657	45	
			5	14.89	+ 0.36		764		
			Sum	15					
H-050	"	2720	1	142	+ 2		154	60	
			2	77.3	+ 0.8		341	44	
			3	110	+ 1		325	33	
			4	6.4	+ 0.4		180	45	
			5	5.74	+ 0.40		155	53	
			Sum	341					
H-052	"	2727	1	1624	+ 31		91	33	
			2	301	+ 5		103	61	
			3	69.7	+ 1.0		227	70	
			4	10.39	+ 0.54		373	30	
			5	29.7	+ 0.7		280	45	
			Sum	2035					
H-074	"	2713	1	92.6	+ 1.3		280	67	
			2	486	+ 13		80	47	
			3	201	+ 5		119	90	
			4	57.0	+ 1.2		251	59	
			5	77.2	+ 1.1		226	82	
			Sum	914					
E-056	TAS-D	9687		1894	+ 31		10	81	
E-052	"	9692		1729	+ 40		70	70	
E-058	"	9700		1455	+ 32		70	98	
F-040	"	2753		7.22	+ 0.33		260	75	
F-029	"	2770		7450	+ 350		10	92	
G-054	"	9665		6739	+ 320		20	73	
G-050	"	9681		1577	+ 50	Uranium	150	43	
H-042	"	2715		1.21	+ 0.05 x 10 <sup>4</sup>		72	90	
H-074	"	2721		2254	+ 27		195	85	
F-051	TAS I	9684		280	+ 14		180	68	
E-060	"	9682		273	+ 4		220	71	
J-050	"	9677		1473	+ 254		120	2	
J-050	"	9659		647	+ 4		151	71	
H-037	TAS II	2772		10	+ 0.30		165	63	
F-054	"	2775		1627	+ 33		240	27	
F-060	"	2750		1.21	+ 0.14		251	77	
F-066	"	2750		1.24	+ 0.02 x 10 <sup>4</sup>		60	37	
F-072	"	2754		2.07	+ 0.25		220	43	

\*First and second Casella stages autoradiographed by Isotopes, Inc. They report that stage 1 resembled a stage 4 impaction pattern and stage 2 resembled a stage 3 pattern. A packaging mixup is suspected, and stage 2 may also have been contaminated or doubly exposed.

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracerlat No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
F-054	TAS II	2733		42.7 ± 1.0		30	42
F-061	"	2726		3838 ± 127	Uranium	30	41
H-072	"	2729		1180 ± 13		223	74
FO-08	Film	8050		3358 ± 134		60	67
FO-10	"	8050		5186 ± 207		60	67
OM-07.0	"	8051		2902 ± 218		15	75
F-038	"	8041		3.24 ± 0.12 x 10 <sup>4</sup>		60	39
F-054-A	"	8041		5.49 ± 0.26 x 10 <sup>5</sup>		60	17
F-054-B	"	8041		6.70 ± 0.46 x 10 <sup>5</sup>		60	35
F-070	"	8041		1.64 ± 0.09 x 10 <sup>5</sup>		60	33
H-095	"	8043		6615 ± 265	Uranium	415	10
H-034	"	8043		9.15 ± 0.25x10 <sup>4</sup>	Uranium	120	17
F-038	"	8043		4.92 ± 0.35x10 <sup>4</sup>	Uranium	120	11
-042-272	"	8043		2.29 ± 0.06 x 10 <sup>5</sup>		60	76
-044-279	"	8043		4.95 ± 0.21 x 10 <sup>5</sup>		60	90
-046-280	"	8043		5.22 ± 0.29 x 10 <sup>5</sup>		30	22
-048-281	"	8043		6.87 ± 0.12x10 <sup>5</sup>	Uranium	120	37
-052-283	"	8043		2.84 ± 0.15 x 10 <sup>5</sup>		30	5
-054-284	"	8043		2.24 ± 0.13x10 <sup>5</sup>	Uranium	30	45
-058-285	"	8043		1.07 ± 0.05 x 10 <sup>5</sup>		15	56
-062-287	"	8043		9.77 ± 0.31x10 <sup>4</sup>	Uranium	30	50
-064-289	"	8043		6827 ± 280		60	99
-031-331	"	8047		1.56 ± 0.07 x 10 <sup>5</sup>		15	46
-042-333	"	8047		3.29 ± 0.09 x 10 <sup>5</sup>		30	65
-044-341	"	8047		6.00 ± 0.16 x 10 <sup>5</sup>		30	60
-046-342	"	8047		2.96 ± 0.17 x 10 <sup>5</sup>		30	55
-050-343	"	8047		3.54 ± 0.10 x 10 <sup>5</sup>		30	65
-052-344	"	8047		3.79 ± 0.23 x 10 <sup>5</sup>		30	45
-054-345	"	8047		2.64 ± 0.09 x 10 <sup>5</sup>		30	45
-056-346	"	8047		1.31 ± 0.07 x 10 <sup>5</sup>		15	42
-058-347	"	8047		9.90 ± 0.56 x 10 <sup>4</sup>		30	19
-060-348	"	10000		1251 ± 30		80	72
-062-349	"	10000		750 ± 41		23	71
-064-350	"	10000		1046 ± 50		23	58
-066-351	"	10000		10.90 ± 0.25		60	96
-068-352	"	10000		98f ± 54		23	44
-070-353	"	10000		2154 ± 46		150	44
-072-354	"	10000		909 ± 14		150	86
-074-355	"	10000		700 ± 21		40	86

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, DOUBLE TRACKS (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. Percent
Stk-95	Film	10000		356 ± 10		47	91
Stk-96	"	10000		759 ± 22		47	74
Stk-97	"	10000		636 ± 17		47	91
Stk-98	"	10000		523 ± 12		58	78
Stk-99	"	10000		464 ± 9		82	92
Stk-100	"	10000		589.2 ± 21.8		60	75
Stk-101	"	10000		1315 ± 33		80	52
Stk-102	"	10000		1544 ± 46		40	87
Stk-103	"	10000		1672 ± 41		60	83
Stk-305	"	10003		146 ± 3		86	91
Stk-306	"	10003		1.39 ± 0.12		371	78
Stk-307	"	10003		0.59 ± 0.10		313	64
Stk-308	"	10003		40.9 ± 2.7		60	99
Stk-309	"	10003		47.3 ± 3.2		60	75
Stk-310	"	10003		27.6 ± 2.5		60	71
Stk-601	"	10006		125.6 ± 2.8		200	60
Stk-602	"	10006		447 ± 14		79	41
Stk-603	"	10006		259 ± 3		154	52
Stk-604	"	10006		203 ± 5		143	66
Stk-605	"	10006		148.3 ± 1.9		260	63
Stk-606	"	10006		41.8 ± 0.5		941	65
Stk-607	"	10006		122.5 ± 2.7		80	71
BK-07	Al. Coll.	9812		1.05 ± 0.01 × 10 <sup>6</sup>		10	83
BK-08	"	9812		2.32 ± 0.03 × 10 <sup>6</sup>		10	81
EL-07	"	9811		7.68 ± 0.05 × 10 <sup>5</sup>		60	83
EL-08	"	9811		4.98 ± 0.06 × 10 <sup>6</sup>	Uranium	9	81
-	Soil	For the results of plutonium analyses of soils, see Table 7.1 in the chapter on the determination of plutonium by gamma spectrometry of Am <sup>241</sup> .					

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE I

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample	min.			
B-016	Andersen	3315	1	0.35	+ 0.25		60	95
			2	69.6	+ 2.3		67	79
			3	14.6	+ 0.7		88	98
			4	14.72	+ 0.01		2689	90
			6	30.6	+ 0.9		180	62
			7	8.05	+ 0.34		243	89
			Sum	138				
B-022	"	3314	1	1.29	+ 0.02 x 10 <sup>4</sup>	Uranium	120	41
			2	471.0	+ 14.1	"	120	60
			3	887.9	+ 15.1	"	1000	22
			4	747.2	+ 19.4	"	1000	20
			6	300.1	+ 7.5	"	980	20
			7	242.4	+ 4.6		1070	16
			Sum	1.65 x 10 <sup>4</sup>				
B-023	"	3313	1	1.36	+ 0.02 x 10 <sup>4</sup>		60	51
			2	12.8	+ 0.7		90	85
			3	3.36	+ 0.35		175	94
			4	3.68	+ 0.29		159	88
			6	2.89	+ 0.29		120	91
			7	0.38	+ 0.08		240	69
			Sum	1.30 x 10 <sup>4</sup>				
B-034	"	3304	1	4.33	+ 0.54		60	78
			2	9.75	+ 0.65		143	50
			3	14.51	+ 0.01		2689	81
			4	11.4	+ 0.5		143	98
			6	21.6	+ 0.9		143	53
			7	0.06	+ 0.02		566	79
			Sum	61.7				
B-040	"	3303	1	0.54	+ 0.18		60	86
			2	0.95	+ 0.17		120	85
			3	0.61	+ 0.04		1248	92
			4	0.34	+ 0.06		390	89
			6	0.32	+ 0.08		175	90
			7	15.3	+ 0.6		260	58
			Sum	18.1				
B1-01	Casella	3365	1	0.07	+ 0.20		710	10
			2	1.92	+ 0.19		420	40
			3	0.30	+ 0.15		120	99
			4	0.19	+ 0.18		60	95
			6	0.03	+ 0.01		260	87
			Sum	3.4				
B1-02	"	3368	1	0.16	+ 0.03		1031	60
			2	2.69	+ 0.30		147	67
			3	0.65	+ 0.05		1031	75
			4	0.83	+ 0.36		75	76
			5	0.05	+ 0.05		76	78
			Sum	4.4				
B1-03	"	3370	1	0.007	+ 0.020		60	93
			2	0.21	+ 0.12		57	77
			3	0.21	+ 0.03		993	75
			4	0.23	+ 0.03		942	72
			6	0.96	+ 0.06		122	79
			Sum	1.7				
B1-02	"	3371	1	2.41	+ 0.42		60	78
			2	1.50	+ 0.32		60	76
			3	1.03	+ 0.15		250	55
			4	0.36	+ 0.15		60	83
			5	2.00	+ 0.18		260	73
			Sum	7.3				
B1-12	"	3364	1	1.08	+ 0.13		942	65
			2	0.87	+ 0.14		250	53
			3	0.06	+ 0.06		60	86
			4	0.57	+ 0.19		60	82
			5	0.04	+ 0.05		60	65
			Sum	2.7				
B1-04	"	3373	1	0.70	+ 0.10		390	57
			2	0.64	+ 0.10		254	72
			3	0.43	+ 0.06		710	90
			4	3.42	+ 0.23		254	86
			5	0.21	+ 0.04		1979	75
			Sum	7.4				

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES. CLEAN SLATE I (cont'd)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
BM-06	Casella	3372	1	157.5 ± 2.0		208	85
			2	99.6 ± 1.2		275	82
			3	26.1 ± 0.68		200	92
			4	5.07 ± 0.14		1074	74
			5	3.85 ± 0.49		75	87
		Sum		292			
BM-08	"	3369	1	24.2 ± 0.9		163	53
			2	12.8 ± 0.7		163	52
			3	23.6 ± 0.7		420	39
			4	1.44 ± 0.10		524	83
			5	3.27 ± 0.28		171	75
		Sum		65.3			
BM-10	"	3374	1	10.4 ± 0.4		420	51
			2	7.06 ± 0.51		140	60
			3	3.14 ± 0.07		2689	90
			4	1.09 ± 0.07		942	70
			5	32.0 ± 2.1		60	38
		Sum		53.7			
BM-12	"	3375	1	82.5 ± 1.3		154	92
			2	120.4 ± 2.0		200	50
			3	29.4 ± 0.9		180	64
			4	3.78 ± 0.26		200	80
			5	11.4 ± 0.8		70	67
		Sum		247			
A-030	"	335f	1	25.5 ± 0.74		164	82
			2	10.4 ± 0.6		140	61
			3	1.95 ± 0.27		122	68
			4	78.1 ± 1.2		300	80
			5	0.36 ± 0.15		120	43
		Sum		116			
P-018	"	2700	1	0.07 ± 0.01		229	40
			2	0.18 ± 0.03		566	85
			3	0.34 ± 0.07		710	31
			4	0.11 ± 0.03		251	92
			5	0.17 ± 0.04		340	81
		Sum		0.87			
F-02f	"	2688	1	1410 ± 111	Uranium First two stages autoradiographed by Isotopes, Inc.	120	18
			2	1017 ± 49		225	24
			3	2939 ± 182		980	4
			4	1251 ± 98		120	18
			5	220.8 ± 1		980	2f
		Sum		6838			
E-032	"	2687	1	1.63 ± 0.21		171	60
			2	0.23 ± 0.06		200	96
			3	0.17 ± 0.17		60	96
			4	0.01 ± 0.03		60	69
			5	0.21 ± 0.12		57	77
		Sum		2.2			
E-03R	"	268c	1	0.95 ± 0.06		1031	75
			2	0.54 ± 0.09		240	78
			3	3.09 ± 0.20		350	70
			4	1.42 ± 0.16		240	72
			5	0.21 ± 0.08		150	77
		Sum		6.2			
EC-07	TAS-D	3050		8.63 ± 0.25		2689	51
PC-09	"	3054		3.50 ± 0.23		260	78
EI-05	"	3051		15.4 ± 0.7		180	50
EI-15	"	3053		6.54 ± 0.31		243	87
FI-17	"	3048		2.04 ± 0.18		243	77
BM-07	"	304e		2.15 ± 0.06 x 10 <sup>4</sup>		72	50
BM-09	"	3044		2297 ± 46		91	82

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE I (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
BM-11	TAS-D	3042		233 ± 6		115	39
A-03f	"	3077		432 ± 12		79	44
A-04b	"	3087		2252 ± 52		70	79
A-060	"	3080		34.3 ± 0.7		243	87
B-020	TAS II	3090		550.0 ± 12.7	Uranium	332	14
B-02f	"	3091		1006 ± 48	"	332	8
B-030	"	3095		1074 ± 14		202	82
B-036	"	3096		501 ± 9.0		103	82
<u>ARC B (Balloon)</u>							
L 15, P5	Wire Swipe	5296		9.70 ± 0.42 x 10 <sup>5</sup>		10	51
L 15, P6	" "	5296		1.07 ± 0.02 x 10 <sup>6</sup>		20	86
L 15, P7	" "	5296		6.43 ± 0.24 x 10 <sup>5</sup>		20	26
L 17, P5	" "	5299		3.07 ± 0.09 x 10 <sup>5</sup>		20	54
L 19, P4	" "	5342		2.59 ± 0.03 x 10 <sup>4</sup>		10	91
L 20, P6	" "	5341		1.89 ± 0.02 x 10 <sup>4</sup>		10	82
L 20, P15	" "	5341		2.65 ± 0.70 x 10 <sup>4</sup>		10	87
L 23, P2	" "	5301		1.83 ± 0.02 x 10 <sup>4</sup>		10	80
BM-04	Film	8121		3614 ± 185		60	39
BM-05	"	"		1.55 ± 0.04 x 10 <sup>6</sup>		10	47
BM-06	"	"		2.19 ± 0.04 x 10 <sup>7</sup>		100	51
BM-07	"	"		5.43 ± 0.12 x 10 <sup>6</sup>		10	65
BM-08	"	"		1.81 ± 0.11 x 10 <sup>6</sup>		30	48
BM-09	"	"		2.17 ± 0.05 x 10 <sup>5</sup>	Uranium	60	24
BM-10	"	"		3.39 ± 0.17 x 10 <sup>4</sup>		30	4
BM-11	"	"		2.98 ± 0.10 x 10 <sup>4</sup>		60	81
BM-12	"	"		9849 ± 461		70	65
EO-03	"	"		127.0 ± 5.5		120	88
EO-11	"	"		1.82 ± 0.08 x 10 <sup>4</sup>		60	78
EO-07 2	"	8120		8.18 ± 0.25 x 10 <sup>6</sup>		10	65
EO-05 3	"	"		5.52 ± 0.16 x 10 <sup>6</sup>		10	79
EO-05 4	"	"		6.49 ± 0.27 x 10 <sup>5</sup>		30	30
EO-07 0	"	"		7.65 ± 0.92 x 10 <sup>4</sup>		30	25
EO-07 1	"	"		4.64 ± 0.15 x 10 <sup>4</sup>		60	50
EO-07 2A	"	"		6.42 ± 0.54 x 10 <sup>4</sup>		60	24
EO-07 2B	"	"		4.26 ± 0.28 x 10 <sup>4</sup>		60	41
EO-07 3	"	"		3.66 ± 0.16 x 10 <sup>4</sup>		60	82
EO-09 1	"	"		7542 ± 189		60	82
EO-09 2	"	"		5182 ± 192		30	79

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE I (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting	Yield	
						Time		
				dpm/sample		min.	approx. percent	
B-016	Film	8123		333 ± 27		60	52	
D-034	"	"		1.54 ± 0.15 x 10 <sup>4</sup>		30	66	
Stk-801	"	9924		63.87 ± 2.49		60	55	
Stk-802	"	"		39.41 ± 3.94		90	85	
Stk-803	"	"		164.7 ± 5.3		60	54	
Stk-804	"	"		368 ± 16		30	57	
Stk-805	"	"		505 ± 12		88	59	
Stk-806	"	"		331 ± 13		101	64	
BM-05	Al. Coll.	9833		4.45 ± 0.12 x 10 <sup>7</sup>		1.0	83	
BM-07	" "	"		1.57 ± 0.02 x 10 <sup>6</sup>		1.0	73	
BM-09	" "	"		6.00 ± 0.15 x 10 <sup>6</sup>		1.0	99	
BO-04	" "	9832		6.48 ± 0.17 x 10 <sup>7</sup>		1.0	87	
BO-06	" "	9832		7.90 ± 0.23 x 10 <sup>6</sup>		1.0	77	
A-020	" "	9830		8.60 ± 0.11 x 10 <sup>7</sup>	Uranium	10	81	
	Soil	For the results of plutonium analysis of soils, see Table 7.3 in the chapter on the determination of plutonium by gamma spectrometry of Am <sup>241</sup> .						
A-018	Water	3141		5.57 ± 0.23 x 10 <sup>4</sup>		100	19	
A-030	"	3143		4.71 x 10 <sup>5</sup>	Solubility Study*			
A-042	"	3142		3.35 x 10 <sup>4</sup>	Solubility Study*			
B-018	"	3138		57.71 ± 0.75		1000	31	
B-030	"	3140		2.87 ± 0.08 x 10 <sup>5</sup>		12	25	
B-042	"	3139		1.18 ± 0.02 x 10 <sup>4</sup>		1000	19	
D-044	"	3137		1484 ± 42		60	67	
D-055	"	3136		1197 ± 13		60	32	
FM-020	"	3131		1790 ± 49	TL #3031 in POM	60	72	
H-018	"	2392		15.86 ± 1.05		120	32	
H-042	"	2391		1206 ± 42		60	44	

\*Determined from sum of several fractions during solubility studies. This value may be less than total Pu deposited in water tray.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
F-020	Andersen	3152	1	4994 + 210	Uranium	150	11
			2	2173 + 148		180	8
			3	159.6 + 3.2		1070	14
			4	770.9 + 70.9		1070	2
			6	583.6 + 39.1		1070	3
			7	4594 + 505		80	3
			Sum	1.33 x 10 <sup>4</sup>			
F-034	"	3155	1	1568 + 43		80	51
			2	77.6 + 4.3	90	46	
			3	12.4 + 0.7	100	70	
			4	2.50 + 0.10	1165	72	
			6	2.20 + 0.26	120	80	
			7	1.01 + 0.24	76	73	
			Sum	1664			
F-040	"	3151	1	1908 + 134		30	71
			2	44.0 + 1.8	90	46	
			3	25.3 + 1.1	100	60	
			4	6.95 + 0.55	120	50	
			6	3.47 + 0.31	1000	11	
			7	1.76 + 0.30	75	77	
			Sum	1989			
F-042	"	3153	1	671 + 30		30	55
			2	83.3 + 4.5	60	65	
			3	32.7 + 2.4	60	67	
			4	12.45 + 1.06	60	96	
			6	4.31 + 0.43	60	40	
			7	3.69 + 0.37	130	53	
			Sum	807	110	75	
F-044	"	3156	1	1039 + 45		30	57
			2	590 + 7	964	23	
			3	18.4 + 0.9	100	74	
			4	5.92 + 0.55	60	79	
			6	21.5 + 1.4	180	20	
			7	2.72 + 0.18	310	83	
			Sum	1658			
F-052	"	3144	1	962 + 12		984	55
			2	102 + 6	60	44	
			3	23.5 + 1.0	97	72	
			4	6.53 + 0.43	120	91	
			6	12.5 + 1.0	60	64	
			7	5.40 + 0.26	310	82	
			Sum	1112			
F-055	"	3145	1	2176 + 59		100	82
			2	148.1 + 6.0	40	79	
			3	25.9 + 2.2	60	85	
			4	9.84 + 0.18	1165	55	
			6	4.75 + 0.52	60	87	
			7	5.99 + 0.46	123	75	
			Sum	2371			
F-014	"	3146	1	1434 + 66		30	50
			2	117.7 + 3.0	60	70	
			3	42.3 + 2.0	90	68	
			4	13.65 + 0.37	326	95	
			6	7.83 + 0.49	120	79	
			7	3.42 + 0.56	120	28	
			Sum	1624			
F-070	"	3148	1	670 + 36		60	55
			2	60.8 + 2.7	60	84	
			3	17.4 + 0.5	144	81	
			4	17.5 + 0.6	213	84	
			6	13.5 + 0.5	213	80	
			7	31.5 + 1.5	50	86	
			Sum	811			
F-010	"	3150	1	732 + 32		30	71
			2	176 + 7	60	95	
			3	48.4 + 1.6	165	37	
			4	60.7 + 2.7	120	70	
			6	9.46 + 0.92	60	57	
			7	4.72 + 0.49	100	62	
			Sum	1031			

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample	min.			
F-078	Andersen	3149	1	2074	+ 110		30	37
			2	205	+ 9		60	37
			3	128.2	+ 1.4		340	41
			4	30.0	+ 1.4		112	42
			6	12.68	+ 0.39		1028	74
			7	7.30	+ 0.55		90	82
			Sum	2457				
IM-13	"	3206	1	948	+ 47	*	30	71
			2	11.2	+ 0.6		120	74
			3	10.4	+ 0.4		245	83
			4	3.59	+ 0.31		133	83
			6	1.35	+ 0.14		245	82
			7	0.17	+ 0.06		110	82
			Sum	975				
IM-14	"	3207	1	87.4	+ 3.4	*	120	73
			2	530	+ 53		60	74
			3	9.78	+ 0.77		90	74
			4	12.8	+ 0.6		120	74
			6	1.10	+ 0.19		120	74
			7	0.068	+ 0.039		15	82
			Sum	641				
F-022	Casella	2171	1	1573	+ 58	Uranium First 2 stages autradio-	150	32
			2	1488	+ 88	graphed by Isotopes, Inc.	332	6
			3	4324	+ 285	"	205	12
			4	725.2	+ 4.4	"	77	12
			5	1744	+ 91	"	127	12
			Sum	9654				
F-032	"	2183	1	631.7	+ 14.3		90	64
			2	46.2	+ 1.3		128	71
			3	10.3	+ 0.8		60	83
			4	0.69	+ 0.15		356	69
			5	0.66	+ 0.13		156	70
			Sum	690				
F-038	"	2182	1	216	+ 6		45	84
			2	34.6	+ 1.4		60	93
			3	12.60	+ 0.63		112	88
			4	2.02	+ 0.23	Sample Spilled	1000	12
			5	0.73	+ 0.13		172	80
			Sum	256				
F-042	"	2184	1	888	+ 24		60	72
			2	41.4	+ 1.1		150	68
			3	34.4	+ 1.6		50	80
			4	260	+ 11		75	11
			5	1.55	+ 0.30		75	70
			Sum					
F-044	"	2195	1	785	+ 15		105	80
			2	28.5	+ 1.1		150	48
			3	50.0	+ 1.2		134	72
			4	3.46	+ 0.34		137	65
			5	2.23	+ 0.30		110	69
			Sum	870				
F-050	"	2189	1	435	+ 7		340	34
			2	142	+ 4		103	32
			3	13.5	+ 1.1		90	41
			4	2.97	+ 0.22		152	45
			5	1.04	+ 0.40		152	43
			Sum	600				
F-054	"	2189	1	698	+ 15		88	75
			2	134	+ 4		55	79
			3	58.6	+ 2.1		50	79
			4	27.6	+ 1.0		110	73
			5	1.70	+ 0.14		35	73
			Sum	920				
F-05c	"	218c	1	1130	+ 30		40	94
			2	94	+ 2.8		67	64
			3	114	+ 4		128	69
			4	10.4	+ 0.4		310	90
			5	1.60	+ 0.32		245	79
			Sum	1350				

\* Mobile unit at 1-040, i.e., IMOB-040.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield
				dpm/sample			min.	approx. percent
F-060	Casella	2185	1	324	+	8		59
			2	126.5	++	1.9	75	80
			3	121.1	+++	3.2	172	74
			4	21.2	++	1.0	55	40
			5	6.01	+	0.58	165	85
			Sum	599			67	
F-062	"	2187	1	1146	++	40	30	86
			2	107.2	+++	1.6	310	43
			3	236.8	+++	7.3	43	75
			4	7.58	++	0.68	60	84
			5	13.7	+	0.9	67	82
			Sum	1511				
F-062	"	2192	1	1648	+	51	51	64
			2	163.9	+++	3.3	75	93
			3	89.5	+++	2.1	77	81
			4	8.47	+++	0.14	2680	53
			5	18.5	++	0.9	115	66
			Sum	1928				
F-074	"	2193	1	1982	+	53	53	82
			2	391	+++	9	90	68
			3	120.3	+++	3.2	55	77
			4	28.9	+++	1.0	116	82
			5	27.5	++	1.8	60	44
			Sum	2550				
F-072	"	2194	1	1315	+	40	46	73
			2	504	+++	11	90	75
			3	73.8	+++	1.5	116	81
			4	33.3	+++	1.0	132	71
			5	22.5	++	1.2	100	45
			Sum	1949				
F-080	"	2191	1	1092	+	42	60	33
			2	277	+++	7	75	71
			3	106.5	+++	3.1	50	68
			4	13.4	+++	0.9	60	86
			5	15.7	++	0.8	127	56
			Sum	1505				
F-104	"	2190	1	2052	+	52	53	89
			2	322	+++	18	30	85
			3	76.2	+++	1.9	103	66
			4	27.8	+++	1.0	103	79
			5	21.9	++	1.2	127	37
			Sum	2506				
IM-01	"	2269	1	0.22	+	0.05	137	85
			2	0.57	+++	0.16	120	59
			3	0.82	+++	0.12	275	83
			4	0.52	++	0.05	1000	23
			5	0.47	++	0.09	1000	20
			Sum	2.6				
IM-02	"	2264	1	36.8	+	1.1	110	87
			2	67.9	++	1.6	361	21
			3	2.23	+++	0.29	153	55
			4	0.32	+++	0.08	112	79
			5	0.97	++	0.16	153	70
			Sum	106				
IM-03	"	2263	1	3.93	+	0.29	153	91
			2	1.14	++	0.09	165	93
			3	20.0	++	0.4	180	99
			4	0.34	+++	0.09	200	68
			5	2.49	++	0.25	153	84
			Sum	28				
IM-04	"	2262	1	7.33	+	0.30	560	44
			2	0.12	+++	0.21	120	50
			3	2.68	+++	0.25	200	66
			4	40.5	++	1.5	100	58
			5	0.37	+++	0.10	200	59
			Sum	51				

\* Mobile unit at I-040, i.e., IMOB-040.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240 dpm/sample	Remarks	Courting Time min.	Yield approx. percent
IM-05	Casella	2266	1	93.6 ± 2.2	**	115	55
			2	28.0 ± 0.8			
			3	0.20 ± 0.02			
			4	0.32 ± 0.10			
			5	0.27 ± 0.08			
	Sum	122			112	51	
IM-06	"	2269	1	376 ± 8	**	120	50
			2	0.52 ± 0.21			
			3	6.41 ± 0.57			
			4	0.24 ± 0.07			
			5	0.46 ± 0.13			
	Sum	384			120	50	
IM-07	"	2265	1	385 ± 13	**	110	53
			2	19.4 ± 0.8			
			3	1.45 ± 0.21			
			4	17.6 ± 4			
			5	0.55 ± 0.28			
	Sum	582			110	53	
IM-11	"	2261	1	631 ± 13	**	105	71
			2	164 ± 5			
			3	37.6 ± 1.3			
			4	0.35 ± 0.03			
			5	0.19 ± 0.02			
	Sum	833			105	71	
IM-12	"	2260	1	690 ± 12	**	115	89
			2	74.9 ± 1.7			
			3	3.78 ± 0.34			
			4	2.30 ± 0.43			
			5	0.45 ± 0.10			
	Sum	771			115	89	
F-000	TAS-D	4041		46.7 ± 1.4		173	43
F-014	"	4040		622.7 ± 38.6	Uranium	1211	3
F-040	"	4042		3050 ± 160		18	70
F-058	"	4039		445 ± 17		47	41
F-072	"	4032		1531 ± 48		51	52
F-120	"	4043		3147 ± 148		16	87
F-054	TAS-I	4045		1312 ± 35		51	87
F-014	"	4044		2189 ± 54		60	84
F-034	TAC II	4029		4543 ± 418	Uranium	180	4
F-042	"	4022		151 ± 1.7		340	69
F-042	"	4037		50.0 ± 1.6		77	30
F-054	"	4037		204 ± 9		30	54
F-060	"	4030		335 ± 9		75	60
F-072	"	4033		370 ± 9	Am-241 from gross alpha plate*	132	80
F-072	"	4034		380 ± 9		60	87
D-012	Seq. Air	4140	1		Sampler inoperable analysis cancelled		
D-042	"	4140		410.2 ± 10.3	No observable activity by alpha survey meter-entire tape run as one sample.	120	54

\* Am-241 determined by alpha spectrometry of a gross electrodepositon of sample aliquot: see Chapter 6

\*\* Mobile unit # 1-040, i.e., IMOB-040.

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
D-054	Seq. Air	4150		dpm/sample 402.5 ± 10.1	No observable activity by alpha survey meter. Entire tape run as one sample.	min. 120	Approx. percent 85
E-040	Film	8113		3.56 ± 0.10 x 10 <sup>5</sup>		10	75
E-042	"	"		3.47 ± 0.09 x 10 <sup>5</sup>		10	98
E-044	"	"		3.15 ± 0.09 x 10 <sup>5</sup>		12	63
E-046	"	"		2.91 ± 0.08 x 10 <sup>5</sup>	Uranium	60	58
E-047	"	"		2.73 ± 0.08 x 10 <sup>5</sup>		10	78
E-050	"	"		2.31 ± 0.09 x 10 <sup>5</sup>		10	44
E-052	"	"		1.84 ± 0.10 x 10 <sup>5</sup>		15	34
E-054	"	"		1.96 ± 0.09 x 10 <sup>5</sup>		30	28
E-056 A	"	"		1.71 ± 0.06 x 10 <sup>5</sup>		30	37
E-056 B	"	"		1.81 ± 0.06 x 10 <sup>5</sup>		30	22
E-058	"	"		1.44 ± 0.08 x 10 <sup>5</sup>		30	17
E-060	"	"		1.31 ± 0.07 x 10 <sup>5</sup>		30	17
E-062	"	"		1.15 ± 0.05 x 10 <sup>5</sup>		30	26
E-064	"	"		1.00 ± 0.04 x 10 <sup>5</sup>		30	37
E-067	"	"		8.50 ± 0.31 x 10 <sup>4</sup>		30	39
E-068	"	"		8.17 ± 0.26 x 10 <sup>4</sup>		30	55
E-070	"	"		7.56 ± 0.24 x 10 <sup>4</sup>		30	50
E-072	"	"		6.89 ± 0.19 x 10 <sup>4</sup>		30	75
E-074	"	"		6.75 ± 0.22 x 10 <sup>4</sup>		90	18
F-075	"	"		6.03 ± 0.18 x 10 <sup>4</sup>		30	58
E-075	"	"		5.93 ± 0.24 x 10 <sup>4</sup>		30	33
E-077	"	"		5.23 ± 0.19 x 10 <sup>4</sup>		30	38
E-078	"	"		5.44 ± 0.20 x 10 <sup>4</sup>		30	41
E-079	"	"		4.85 ± 0.11 x 10 <sup>4</sup>		30	99
E-081	"	"		4.70 ± 0.12 x 10 <sup>4</sup>		30	84
E-082	"	"		4.46 ± 0.12 x 10 <sup>4</sup>		60	37
E-090	"	"		5.33 ± 0.11 x 10 <sup>4</sup>		60	65
E-092	"	"		4.10 ± 0.07 x 10 <sup>4</sup>		60	80
E-094	"	"		4.14 ± 0.08 x 10 <sup>4</sup>		60	65
E-095	"	"		4.49 ± 0.08 x 10 <sup>4</sup>		60	90
E-097	"	"		4.17 ± 0.08 x 10 <sup>4</sup>		60	75
E-100	"	"		4.41 ± 0.10 x 10 <sup>4</sup>		60	55
E-102	"	"		4.13 ± 0.08 x 10 <sup>4</sup>		60	70

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
E-104	Film	8113		$3.79 \pm 0.05 \times 10^4$		66	75
E-106	"	"		$3.27 \pm 0.06 \times 10^4$		66	75
E-108	"	"		$3.19 \pm 0.06 \times 10^4$		66	65
E-110	"	"		$2.57 \pm 0.04 \times 10^4$		66	75
E-112	"	"		$2.98 \pm 0.06 \times 10^4$		66	70
E-114	"	"		$2.06 \pm 0.06 \times 10^4$		30	65
F-022-1	"	8119		3012 $\pm$ 133		20	78
F-022-2	"	"		8192 $\pm$ 221		60	72
F-022-3	"	"		9005 $\pm$ 279		30	55
F-022-4	"	"		$1.15 \pm 0.03 \times 10^4$		60	68
F-022-5	"	"		5077 $\pm$ 240		20	69
F-026-2	"	"		5248 $\pm$ 183		30	40
F-026-3	"	"		7696 $\pm$ 316		30	63
F-026-4	"	"		3509 $\pm$ 90		60	72
F-026-5	"	"		7244 $\pm$ 311		30	33
F-030-5	"	"		$1.18 \pm 0.02 \times 10^4$		90	70
F-038-1	"	"		$7.81 \pm 0.31 \times 10^4$		30	34
F-038-2	"	"		$5.31 \pm 0.21 \times 10^4$		30	33
F-038-3	"	"		2582 $\pm$ 66		60	79
F-042-1	"	"		$4.34 \pm 0.14 \times 10^4$		30	50
F-042-2	"	"		$8.34 \pm 0.42 \times 10^4$		15	43
F-042-3	"	"		$1.49 \pm 0.04 \times 10^4$		60	77
F-042-4	"	"		3563 $\pm$ 98		60	69
F-046-3	"	"		$3.89 \pm 0.09 \times 10^4$		60	62
F-046-4	"	"		$3.24 \pm 0.09 \times 10^4$		30	74
G-016	"	8115		$1.02 \pm 0.03 \times 10^5$		30	55
G-012	"	"		$5.61 \pm 0.24 \times 10^5$		10	36
G-020	"	"		$2.08 \pm 0.05 \times 10^6$		10	5
G-024	"	"		$2.87 \pm 0.06 \times 10^6$		10	62
G-028	"	"		$2.96 \pm 0.07 \times 10^6$		10	52
G-029	"	"		$1.50 \pm 0.04 \times 10^6$		10	62
G-030	"	"		$6.51 \pm 0.15 \times 10^5$		30	82
B-040	Al. Coll.	9843		$7.08 \pm 0.21 \times 10^7$		1.0	75
B-050	"	"		$4.32 \pm 0.12 \times 10^7$		1.0	87
B-070	"	"		$1.26 \pm 0.03 \times 10^7$		1.0	87
B-080	"	"		$6.21 \pm 0.06 \times 10^6$	Uranium	10	83
B-090	"	"		$3.14 \pm 0.04 \times 10^6$		10	94
D-040	"	9845		$1.37 \pm 0.04 \times 10^7$		1.0	62
D-050	"	"		$7.90 \pm 0.06 \times 10^6$		10	90

TABLE A.7 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE II (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	PL-239,240	Remarks	Counting Time	Yield
D-08u	Al. Coll.	9845		dpm/sample 2.44 ± 0.03 x 10 <sup>6</sup>		min. 10	approx. percent 85
D-090	" "	"		1.90 ± 0.01 x 10 <sup>6</sup>		60	80
H-040	" "	9844		3.81 ± 0.05 x 10 <sup>6</sup>		10	91
H-050	" "	"		4.51 ± 0.06 x 10 <sup>6</sup>		10	87
H-070	" "	"		1.46 ± 0.01 x 10 <sup>6</sup>		60	91
H-080	" "	"		1.44 ± 0.01 x 10 <sup>6</sup>		30	85
H-090	" "	"		1.30 ± 0.01 x 10 <sup>6</sup>		60	64
	Soil				For results of plutonium analyses see Table 7.3 in Chapter 7 on the determination of plutonium by gamma spectrometry of Am <sup>241</sup> .		
D-04u	** Water	4180		2.66 x 10 <sup>5</sup>	Exposed at location I-040 according to PCIR, not D-040 Solubility Study*		
D-040	** "	4181		3.24 ± 0.05 x 10 <sup>5</sup>	Exposed at location I-040 according to PCIR, not D-040	10	57
D-040	** "	4182		1.80 ± 0.03 x 10 <sup>5</sup>	" " "	12	15
H-010	"	4188		225.1 ± 1.8		950	55
H-014	"	4189		111.2 ± 2.0		120	39
H-016	"	4190		2.67 ± 0.04 x 10 <sup>4</sup>		10	73
H-014	"	4194		1.00 ± 0.01 x 10 <sup>5</sup>		10	69
H-037	"	4195		7.76 ± 0.16 x 10 <sup>4</sup>		10	31
H-042	"	4196		5.46 ± 0.08 x 10 <sup>4</sup>		10	56
H-045	"	4197		3.58 x 10 <sup>4</sup>	Solubility Study*		
L-010	"	4198		80.29 ± 1.12		967	22
L-014	"	4199		1101 ± 12		60	47
L-016	"	4200		159.2 ± 1.3		1000	48
L-022	"	2394		2.15 ± 0.04 x 10 <sup>4</sup>		10	89
L-034	"	2397		2.58 ± 0.05 x 10 <sup>4</sup>		30	26
L-037	"	2398		2.88 ± 0.10 x 10 <sup>4</sup>		10	25
L-041	"	2399		6.07 ± 0.25 x 10 <sup>4</sup>		10	18
L-042	"	2400		2.67 ± 0.07 x 10 <sup>4</sup>		10	50

\*Determined from the sum of several fractions during solubility studies. This value may be less than the total Pu deposited in the water tray.

\*\* Sample labels and shipping papers indicate location as D-040, but from Tracerlab Handling Record, these samples probably were exposed by the mobile unit at IMOB-040

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield	
				dpm/sample				min.	approx. percent
F-010	Andersen	3266	1	0.17	+ 0.04		1006	92	
			2	0.17	+ 0.06		172	85	
			3	0.09	+ 0.05		120	87	
			4	0.48	+ 0.13		120	76	
			6	0.10	+ 0.06		120	75	
			7	0.12	+ 0.06		120	85	
			Sum	1.1					
F-034	"	3265	1	2.23	+ 0.08x10 <sup>4</sup>	Uranium	180	6	
			2	4840	+ 97	"	1000	34	
			3	5416	+ 162	"	1000	14	
			4	4863	+ 277	"	120	33	
			6	4558	+ 104	"	1006	22	
			7	127.3	+ 1.4	"	2037	25	
			Sum	4.21 x 10 <sup>4</sup>					
F-058	"	3258	1	63.7	+ 4.5		60	17	
			2	0.84	+ 0.19		90	82	
			3	1.47	+ 0.44		60	60	
			4	2.31	+ 0.12		1006	40	
			6	0.56	+ 0.18		60	34	
			7	0.08	+ 0.08		60	63	
			Sum	69					
F-082	"	3261	1	280	+ 12		120	44	
			2	161	+ 7		120	41	
			3	87.7	+ 1.7		144	62	
			4	58.6	+ 2.1		175	28	
			6	90.0	+ 2.4		150	33	
			7	17.8	+ 1.0		85	64	
			Sum	705					
F-10c	"	3263	1	3.25	+ 0.52		60	61	
			2	5.78	+ 0.50		97	74	
			3	28.7	+ 1.1		1090	29	
			4	4.34	+ 0.61		60	54	
			6	3.81	+ 0.50		60	75	
			7	0.34	+ 0.22		425	47	
			Sum	46.22					
J-010	"	3268	1	0.16	+ 0.09		60	95	
			2	0.07	+ 0.07		60	79	
			3	0.58	+ 0.15		120	64	
			4	0.22	+ 0.08		120	93	
			6	0.18	+ 0.09		120	53	
			7	0.24	+ 0.12		60	87	
			Sum	1.4					
J-034	"	3270	1	406	+ 9		101	60	
			2	0.06	+ 0.06		60	87	
			3	4.50	+ 0.54		60	83	
			4	0.14	+ 0.05		326	63	
			6	0.17	+ 0.09		90	83	
			7	0.33	+ 0.07		224	85	
			Sum	411					
J-046	"	3271	1	0.34	+ 0.14		80	60	
			2	0.01	+ 0.02		60	80	
			3	0.24	+ 0.12		60	88	
			4	0.14	+ 0.07		120	75	
			6	0.39	+ 0.17		60	67	
			7	0.19	+ 0.09		101	67	
			Sum	1.3					
J-058	"	3272	1	0.25	+ 0.13		60	84	
			2	1.67	+ 0.26		110	72	
			3	1.73	+ 0.35		60	75	
			4	0.21	+ 0.09		90	83	
			6	0.135	+ 0.043		204	56	
			7	0.2	+ 0.12		101	59	
			Sum	4.2					
J-070	"	3275	1	65.0	+ 1.7		77	95	
			2	57.1	+ 1.7		165	38	
			3	24.6	+ 1.0		110	77	
			4	19.5	+ 0.7		90	68	
			6	7.94	+ 0.54		90	68	
			7	1.68	+ 0.30		60	93	
			Sum	175					

TABLE A.3 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield	
				dpm/sample				min.	approx percent
L-106	Andersen	3274	1	0.09	+	0.09	90	40	
			2	0.54	++	0.04	115	75	
			3	1.06	+++	0.12	540	45	
			4	0.49	++	0.15	90	73	
			5	0.63	++	0.07	1006	44	
			6	3.08	+++	0.42	112	45	
			Sum	5.9					
L-106	"	3294	1	0.01	+	0.03	60	58	
			2	0.50	+++	0.17	120	57	
			3	0.42	++	0.21	120	70	
			4	0.12	++	0.09	60	88	
			5	0.28	++	0.17	60	63	
			6	0.25	++	0.15	60	62	
			Sum	1.7					
L-118	"	3293	1	0.17	++	0.05	224	82	
			2	0.17	+++	0.09	90	91	
			3	0.15	+++	0.06	574	133	
			4	0.28	+++	0.14	60	75	
			5	0.44	+++	0.18	60	70	
			6	0.11	++	0.07	25	57	
			Sum	1.3					
F-002	Casella	4881	1	0.19	++	0.03	120	82	
			2	0.03	++	0.03	120	82	
			3	0.16	+++	0.05	175	80	
			4	0.06	++	0.04	120	99	
			5	0.17	++	0.06	200	63	
			Sum	0.61					
F-014		4882	1	0.06	++	0.04	120	92	
			2	0.06	+++	0.04	120	80	
			3	0.19	+++	0.07	120	89	
			4	102.3	+++	2.9	213	34	
			5	0.12	++	0.06	120	82	
			Sum	103					
F-021		4883	1	1.04	++	0.19	120	80	
			2	0.31	+++	0.16	120	77	
			3	2.09	+++	0.09	955	75	
			4	0.46	+++	0.13	120	71	
			5	0.09	++	0.08	80	44	
			Sum	4.0					
F-050		4891	1	253	++	3.4	241	68	
			2	52.2	+++	1.5	103	70	
			3	10.1	+++	0.5	224	80	
			4	2.39	+++	0.40	60	76	
			5	0.17	++	0.08	120	75	
			Sum	324					
F-070		4890	1	441	+	11	60	83	
			2	11.73	++	0.76	115	53	
			3	12.0	++	1.1	60	50	
			4	1.07	++	0.29	60	65	
			5	3.99	++	0.39	123	69	
			Sum	470					
F-074		4887	1	716	+	14	105	81	
			2	91.9	++	1.6	120	74	
			3	53.4	++	1.3	120	76	
			4	19.7	++	1.0	127	50	
			5	7.53	++	0.67	60	90	
			Sum	979					
F-080	"	4887	1	483.9	+	2.7	2037	10	
			2	113.5	++	1.9	1211	2	
			3	275.0	+++	5.6	2037	18	
			4	278.2	+++	13.5	1211	4	
			5	366.5	+++	11.4	1211	6	
			Sum	1517.1					
F-091		4884	1	30.9	++	1.0	134	76	
			2	56.9	+++	1.3	110	64	
			3	33.2	+++	1.1	103	86	
			4	9.79	++	0.62	103	78	
			5	10.2	++	0.7	103	76	
			Sum	171					

TABLE A.2 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240		Remarks	Counting Time	Yield	
				dpm/sample				min.	approx. percent
F-10f	Casella	4896	1	6.22	+	0.47	120	74	
			2	7.78	+	0.66	60	92	
			3	8.95	+	0.50	120	92	
			4	2.57	+	0.16	60	53	
			5	0.89	+	0.10	955	93	
			Sum	26.4					
J-014	"	4902	1	1.40	+	0.14	120	51	
			2	0.03	+	0.03	120	47	
			3	0.09	+	0.09	60	73	
			4	0.42	+	0.07	324	24	
			5	0.16	+	0.09	30	71	
			Sum	2.1					
J-026	"	4899	1	21.32	+	1.09	60	99	
			2	0.12	+	0.07	120	71	
			3	0.03	+	0.03	120	64	
			4	0.03	+	0.03	120	59	
			5	0.04	+	0.04	120	70	
			Sum	21.5					
J-042	"	4900	1	3828	+	76	120	75	
			2	41.0	+	1.4	100	70	
			3	18.3	+	0.8	103	91	
			4	0.165	+	0.083	101	71	
			5	0.32	+	0.11	124	76	
			Sum	3885					
J-050	"	4913	1	612	+	13	100	73	
			2	4.42	+	0.57	60	76	
			3	2.36	+	0.35	120	48	
			4	145.5	+	3.9	55	73	
			5	9.19	+	0.11	60	80	
			Sum	764					
J-060	"	4906	1	62.8	+	1.6	134	50	
			2	1.39	+	0.25	90	77	
			3	0.92	+	0.38	210	34	
			4	23.73	+	1.76	1145	15	
			5	-0.01	+	0.02	60	78	
			Sum	88.8					
J-075	"	4905	1	114	+	4	120	72	
			2	70.6	+	2.1	125	77	
			3	27.9	+	1.0	116	75	
			4	13.0	+	0.8	90	61	
			5	7.17	+	0.25	90	80	
			Sum	232					
J-078	"	4910	1	0.02	+	0.03	120	77	
			2	13.4	+	0.8	90	71	
			3	7.70	+	0.35	224	90	
			4	3.12	+	0.44	60	90	
			5	3.14	+	0.20	270	86	
			Sum	27.4					
F-114	"	4909	1	0.14	+	0.10	60	74	
			2	0.45	+	0.05	955	67	
			3	99.3	+	2.0	111	61	
			4	0.21	+	0.09	120	61	
			5	0.41	+	0.11	60	43	
			Sum	101					
F-002	"	4941	1	0.07	+	0.07	60	77	
			2	0.11	+	0.03	934	47	
			3	0.01	+	0.04	60	83	
			4	0.10	+	0.05	123	77	
			5	0.55	+	0.32	60	87	
			Sum	0.90					
K-014	"	4931	1	1.40	+	0.27	60	83	
			2	11.5	+	0.7	120	77	
			3	0.74	+	0.13	172	76	
			4	1.38	+	0.20	60	75	
			5	0.23	+	0.03	200	83	
			Sum	15.3					

TABLE A.6 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
K-C3e	Casella	4932	1	1304 ± 78		51	20
			2	22.1 ± 1.0		90	72
			3	0.54 ± 0.14		123	71
			4	0.32 ± 0.11		126	66
			5	3.08 ± 0.42		85	64
			Sum	1330			
K-04e	"	4930	1	273 ± 4		241	74
			2	13.7 ± 1.2		80	56
			3	0.06 ± 0.04		120	20
			4	0.07 ± 0.07		60	11
			5	0.38 ± 0.14		101	5
			Sum	287			
X-014	"	4942	1	72.2 ± 1.6		144	44
			2	4.98 ± 0.65		90	41
			3	0.44 ± 0.16		60	7
			4	0.13 ± 0.08		90	40
			5	0.99 ± 0.21		116	56
			Sum	79			
K-072	"	4934	1	23.7 ± 1.8			
			2	22.5 ± 0.8		134	74
			3	20.5 ± 0.9		116	76
			4	14.53 ± 0.11		1274	45
			5	1.72 ± 0.25		205	76
			Sum				
K-081	"	4938	1	2.68 ± 0.43		60	74
			2	7.42 ± 0.64		90	60
			3	13.4 ± 1.0		60	60
			4	4.34 ± 0.90		90	64
			5	6.10 ± 0.60		116	46
			Sum	34.1			
K-1 e	"	4937	1	0.03 ± 0.03		120	74
			2	3.21 ± 0.33		120	93
			3	0.51 ± 0.12		120	85
			4	0.45 ± 0.01		120	75
			5	0.25 ± 0.13		175	75
			Sum	5.0		60	82
L-002	"	4956	1	0.09 ± 0.05		120	86
			2	0.43 ± 0.12		120	85
			3	0.045 ± 0.032		574	24
			4	0.06 ± 0.02		955	46
			5	0.13 ± 0.09		60	80
			Sum	0.76			
L-004	"	4954	1	0.07 ± 0.06		60	80
			2	0.06 ± 0.06		60	83
			3	0.05 ± 0.05		90	70
			4	0.05 ± 0.05		120	55
			5	0.05 ± 0.013		934	76
			Sum	0.27			
F-05	TAC-I	5145		2514 ± 71	Americium	10	77
F-03		5147		3716 ± 104	Americium	10	78
F-12C		5010		2.69 ± 0.31		125	71
F-040		5024		956 ± 161	Americium		
F-070		5023		33.0 ± 2.3		120	79
F-024		5021		0.41 ± 0.06		204	49
F-004		5102		0.17 ± 0.04		204	34
F-012		5103		0.32 ± 0.32		90	35
F-020		5003		14.0 ± 0.6		132	82
F-10		5101		3.01 ± 0.38		97	67
F-120		5105		3.99 ± 0.45		90	79

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
CSI-D-000	TAS-L	5199		10.0 ± 0.5		211	61
CSI-E-000	"	5200		56.1 ± 1.4	Americium	1000	0
CSI-F-000	"	5201		76.6 ± 1.2	Americium	956	00
CSI-G-000	"	5202		173.9 ± 27.8		60	31
CSI-H-000	"	5203		398 ± 10		60	75
CSI-I-000	"	5204		722 ± 31		23	72
CSI-N-024	"	5195		92.6 ± 4.2	Americium	120	55
CSI-N-030	"	5196		28.3 ± 0.9	Americium	120	27
CSI-N-036	"	5197		11.1 ± 0.6	Americium	120	40
F-056	TAS-I	5062		110.6 ± 4.0		120	24
F-064	"	5063		4766 ± 114	Uranium	1000	11
K-052	"	5095		231 ± 3		86	40
K-060	"	5091		46.5 ± 3.0		60	20
K-068	"	5094		165 ± 4		86	1
K-092	"	5092		123.0 ± 7.4		60	54
K-100	"	5089		30.3 ± 1.9		90	92
D-030	TAS-II	5149		1574 ± 70	Americium	10	75
F-006	"	5051		0.39 ± 0.19		97	74
F-018	"	5053		57.6 ± 2.0		118	36
F-042	"	5054		1044 ± 63	Americium	60	14
F-072	"	5060		5382 ± 242	Uranium	1000	3
F-114	"	5061		7.58 ± 0.41		211	67
H-042	"	5035		923 ± 101	Americium	60	24
J-006	"	5074		0.90 ± 0.24		90	54
J-018	"	5073		6.64 ± 0.52		1.2	65
J-030	"	5071		0.45 ± 0.05		1033	50
J-054	"	5079		1030 ± 62		60	43
J-066	"	5070		44.2 ± 7.1		60	60
J-102	"	5072		10.34 ± 0.56		361	2
J-114	"	5073		1.02 ± 0.17		131	70
K-022	"	5093		0.68 ± 0.39		60	74
K-036	"	5097		8222 ± 192		120	44
K-044	"	5096		781 ± 21		60	72
L-054	"	5113		32.1 ± 3.3	Americium	60	11
EM-02	Film	8153		8.93 ± 0.05 x 10 <sup>6</sup>	Americium	30	23
CO-05.0	"	8152		1.79 ± 0.08 x 10 <sup>7</sup>	"	10	95
C-026A	"	8155		1.72 ± 0.07 x 10 <sup>7</sup>	"	10	14
E-030	"	9156		1.45 ± 0.03 x 10 <sup>7</sup>	"	10	62

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES. CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample			
E-032	Film	8157		$7.93 \pm 0.17 \times 10^6$	Americium	10	65
E-042	"	8157		$1.02 \pm 0.08 \times 10^5$		30	33
E-050	"	"		$4.52 \pm 0.20 \times 10^4$		30	66
E-054	"	"		$1.01 \pm 0.04 \times 10^4$		30	86
E-056A	"	"		$7030 \pm 220$		30	63
E-057	"	"		$6651 \pm 180$		30	58
E-062	"	"		$9797 \pm 362$		30	48
E-066	"	"		$1.10 \pm 0.03 \times 10^4$		30	80
E-068	"	"		$1.13 \pm 0.03 \times 10^4$		30	66
E-070	"	"		$1.40 \pm 0.04 \times 10^4$		30	26
E-072	"	"		$1.09 \pm 0.03 \times 10^4$		30	76
E-074	"	"		$1.30 \pm 0.04 \times 10^4$		30	57
E-078	"	"		$9778 \pm 313$		30	20
E-082	"	"		$7133 \pm 128$		60	66
E-084	"	"		$6597 \pm 172$		60	81
E-086	"	"		$4908 \pm 133$		60	71
E-092	"	"		$3845 \pm 154$		30	86
F-008	"	8158		$819 \pm 24$		60	59
F-022	"	"		$2.39 \pm 0.06 \times 10^5$		60	82
F-034	"	"		$4.51 \pm 0.12 \times 10^6$		10	46
F-036	"	8152		$4.75 \pm 0.10 \times 10^6$	Americium	10	62
F-032	"	"		$3.25 \pm 0.05 \times 10^6$	Uranium	10	61
F-040	"	"		$1.29 \pm 0.04 \times 10^6$		10	67
F-042	"	"		$3.20 \pm 0.04 \times 10^5$	Uranium	120	54
F-044	"	"		$6.58 \pm 0.14 \times 10^5$	"	60	24
F-046	"	"		$2.14 \pm 0.07 \times 10^5$		30	51
F-050	"	"		$6.88 \pm 0.17 \times 10^4$	Uranium	30	85
F-052	"	"		$3.46 \pm 0.08 \times 10^4$		90	30
F-054	"	"		$5955 \pm 197$		60	49
F-056	"	"		$4495 \pm 400$		15	82
F-058	"	"		$4258 \pm 149$		30	84
F-062	"	"		$6670 \pm 354$		30	60
F-064	"	"		$6.57 \pm 0.22 \times 10^3$	Uranium	30	54
F-070	"	"		$5866 \pm 164$		60	67
F-072	"	"		$6452 \pm 265$		30	64
F-074	"	"		$4274 \pm 171$		71	27
F-076	"	"		$6804 \pm 265$		30	42
F-078	"	"		$5021 \pm 166$		60	49
F-080	"	"		$4805 \pm 125$		60	76

TABLE A.5 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240	Remarks	Counting Time	Yield
				dpm/sample		min.	approx. percent
F-082	Film	8158		4493 ± 315		15	42
F-084	"	"		3832 ± 138		30	53
F-086	"	"		2844 ± 78		60	69
G-028	"	8159		1.23 ± 0.06 × 10 <sup>5</sup>		30	50
G-030	"	"		9.88 ± 0.30 × 10 <sup>5</sup>		30	57
G-032	"	"		2.80 ± 0.05 × 10 <sup>6</sup>		10	99
G-034	"	"		3.30 ± 0.02 × 10 <sup>5</sup>		10	80
G-036	"	"		3.33 ± 0.02 × 10 <sup>6</sup>		10	68
G-038	"	"		2.82 ± 0.09 × 10 <sup>6</sup>		10	65
G-040	"	"		1.20 ± 0.03 × 10 <sup>5</sup>		10	60
G-042	"	"		7.61 ± 0.24 × 10 <sup>5</sup>		30	53
G-044	"	"		4.63 ± 0.24 × 10 <sup>5</sup>		30	65
G-046	"	"		2.52 ± 0.14 × 10 <sup>5</sup>		75	23
G-048	"	"		1.43 ± 0.09 × 10 <sup>5</sup>		30	42
G-050	"	"		1.01 ± 0.04 × 10 <sup>5</sup>		30	62
G-052	"	"		5.19 ± 0.18 × 10 <sup>4</sup>		15	90
G-054	"	"		4989 ± 115		30	81
G-056	"	"		5339 ± 235		30	68
G-072	"	"		3869 ± 159		30	80
G-074	"	"		4374 ± 114		30	62
G-076	"	"		3414 ± 130		30	44
n-028		8160		271.0 ± 10.8		947	33
n-032		"		1.42 ± 0.04 × 10 <sup>6</sup>		30	71
n-034		"		293 ± 0.06 × 10 <sup>6</sup>	Americium	10	69
n-036		"		2.15 ± 0.05 × 10 <sup>6</sup>		10	55
n-040		"		1.09 ± 0.03 × 10 <sup>6</sup>		10	62
n-042		"		7.68 ± 0.24 × 10 <sup>5</sup>		10	69
n-044		"		4.40 ± 0.16 × 10 <sup>5</sup>		30	40
n-046		"		1.83 ± 0.04 × 10 <sup>5</sup>		30	90
n-048		"		1.79 ± 0.05 × 10 <sup>5</sup>		60	28
n-054		"		3747 ± 124		72	39
n-060		"		3815 ± 244		15	50
n-070		"		2635 ± 29		30	29
n-038		8161		1.27 ± 0.03 × 10 <sup>6</sup>	Americium	10	52
n-038		8162		5.65 ± 0.08 × 10 <sup>5</sup>	Americium	31	87
				For results of plutonium analyses of soils, see Table 7.3 in the chapter on the determination of plutonium by gamma spectrometry of Am <sup>241</sup> .			
B-11	Water	5230		105 ± 0.6		47	65
B-12	"	5231		188 × 10 <sup>4</sup>	Solubility Study*		

TABLE A.8 PLUTONIUM ANALYSIS OF PHYSICAL SAMPLES, CLEAN SLATE III (cont'd.)

Location	Sampler Type	Tracerlab No.	Stage	Pu-239,240 dpm/sample	Remarks	Counting Time min.	Yield approx. percent
B-108	Water	5229		2611 ± 72		100	30
D-012	"	5246		233.7 ± 3.0		950	21
D-084	"	5244		6312. ± 120		10	90
DMob-074	"	5253		27.60 ± 0.41	**	1000	50
DMob-074	"	5254		1.34 ± 0.03 × 10 <sup>4</sup>	**	30	23
DMob-074	"	5255		1.13 ± 0.02 × 10 <sup>4</sup>	**	10	80
IMob-050	"	5260		5.79 ± 0.13 × 10 <sup>4</sup>		10	27
IMob-050	"	5261		5.07 ± 0.06 × 10 <sup>4</sup>		60	44
IMob-050	"	5262		7.36 ± 0.10 × 10 <sup>4</sup>		10	77
L-006	"	5237		1609 ± 32		10	84
L-054	"	5240		4674 ± 51		40	70
L-078	"	5242		106 × 10 <sup>5</sup>	Solubility Study*		
L-102	"	5234		1.50 ± 0.04 × 10 <sup>4</sup>		60	61

\*Determined from the sum of several fractions during solubility studies. This value may be less than the total Pu deposited in the water tray.

\*\* Sample bottles and shipping papers labeled with two locations. Location assigned to DMob-074 instead of IMob-050 based on Tracerlab Sample Handling Record.

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