PLUTONIUM CONTAMINATION MONITORING IN THE
HFEF HOT CELLS DURING SECTIONING OF
MARK-IIA SODIUM LOOPS

by

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TABLE OF CONTENTS

	Page
ABSTRACT.	7
I. INTRODUCTION.	8
II. HISTORY OF OPERATIONS IN THE ARGON AND AIR CELLS.	8
III. SECTIONING OF MARK-IIA LOOPS.	9
IV. MONITORING CELL CONTAMINATION	11
A. Swipe Samples	15
B. Argon-cell Particle-fallout Samples	15
C. Argon-cell Fallout-sample Blocks.	19
D. Argon-cell Atmosphere Samples	19
E. Loop-sodium Samples	22
F. Out-of-cell Monitoring.	22
V. COUNTING TECHNIQUES AND ACCURACY.	23
A. Swipe Samples.	23
B. Particle-fallout Activity in Fallout-sample Dishes.	23
C. Alpha Activity From the Argon-atmosphere Samples.	23
D. Plutonium in Loop-sodium Samples.	23
VI. RESULTS FROM CONTAMINATION MONITORING	24
A. Swipe Data.	24
1. Argon Cell	24
a. Table Face 2	24
b. Argon-cell Floor	28
B. Argon-cell Particle-fallout Data.	28
C. Argon-cell Fallout-sample-block Data.	33
D. Argon-cell-atmosphere Sampling Data	33
E. Loop-sodium Analyses.	33
F. Out-of-cell Results	37
VII. ACTIVITY RATIO DATA	37
VIII. CONCLUSIONS	38
A. Contamination Monitoring.	38
B. Gamma-alpha Activity Ratios	39
APPENDIX.	40
Gamma-alpha Ratio Data.	40
ACKNOWLEDGEMENTS.	46
REFERENCES.	47

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.	The RAS-TREAT H4 Loop in the HFEF/South Argon Cell	10
2.	Neutron Radiograph of the Stripped H4 Loop	12
3.	Locations for Loop Sectioning.	13
4.	Hacksaw Clamped to the L3 Loop in Preparation for a Separation	14
5.	Swipe Sample	16
6.	Layout of the HFEF Argon Cell and Air Cell Showing the Locations of the Particle-fallout and Argon- atmosphere Sampling.	17
7.	Pyrex Petri Dish Used to Collect Particle-fallout Sample . .	18
8.	Fallout-sample-block Holder.	20
9.	Vacuum Cleaner Used to Sample Argon-cell Atmosphere.	21
10.	Argon-cell Floor-swiping Apparatus Used After Jan. 1, 1974	29

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
I.	Swipe Data from Face 2 of the Argon Cell.	25
II.	Argon-cell Swipe Data	30
III.	Air-cell Swipe Data	31
IV.	Particle-fallout Samples Taken During Loop Sectioning . . .	34
V.	Argon-cell Sample Blocks.	35
VI.	Argon-atmosphere Samples Taken During Loop Cutting. . . .	36
VII.	Analysis of Loop Sodium for Plutonium	37
VIII.	Activity Ratios from Argon-cell Swipes.	41
IX.	Activity Ratios from Air-cell Swipes.	43
X.	Activity Ratios from Argon-cell Particle-fallout Samples. .	44
XI.	Activity Ratios from Sodium Samples	45

ABSTRACT

An extensive program for monitoring alpha contamination was conducted in-cell and out-of-cell in HFEF/S to establish the contamination spread from sectioning sodium loops that contained failed mixed-oxide fuel elements. The monitoring program was maintained during the sectioning of six RAS-TREAT Mark-IIA loops in the argon cell. The monitoring program provided conclusive evidence that no contamination spread resulted from sectioning the loops.

I. INTRODUCTION

Argonne National Laboratory operates the Hot Fuel Examination Facility (HFEF) at the EBR-II site of the Idaho Nuclear Engineering Laboratory. The HFEF handles and examines irradiation experiments from EBR-II, TREAT, and other reactors in support of the Liquid Metal Fast Breeder Reactor Program.¹

Among the experiments handled in HFEF are the Mark-II loop experiments, which are subjected to transient irradiation in TREAT. These loop experiments are sponsored by the Reactor Analysis and Safety Division (RAS) of ANL-East, and are designed to simulate either loss-of-coolant flow accidents or transient-overpower accidents in the Fast Flux Test Facility.

This report deals with the experience in sectioning these plutonium-bearing loops after irradiation, and more specifically, with the precautions taken to prevent spread of radioactive contamination. The results of extensive monitoring for contamination in the HFEF/South cells are discussed and tabulated.

As a background to the discussion, the following section outlines the history of the HFEF/South cells and the effects of previous operations on contamination levels.

II. HISTORY OF OPERATIONS IN THE ARGON AND AIR CELLS

One of the initial purposes of HFEF/South - formerly named the Fuel Cycle Facility (FCF) - was to demonstrate, in conjunction with EBR-II, the concept of a fast-breeder power plant with an integral fuel cycle.² In 1968-69, the mission of EBR-II changed to that of a fast-reactor-test facility, and the mission of HFEF/South changed from that of a fuel-cycle facility to that of an experiment-examination facility.

From 1964 to 1969 the air and argon cells of HFEF/South were used as a fuel cycle facility. During this time 39,000 fuel elements, the equivalent of five core loadings for EBR-II, were fabricated in the argon cell.^{3,4,5} The metallic uranium-5%-fissium fuel was refined to remove fission products by using a pyrometallurgical process called melt refining.^{6,7} The fuel-element-decanning, melt-refining, skull-oxidation, fuel-pin injection-casting, and pin-processing operations all contributed to the buildup of fission-product and uranium-fuel contamination in the argon cell during the fuel-reprocessing operations.

Since the examinations of experimental fuel elements began, the main source of radioactive contamination in the argon cell has been the preparation of metallographic samples. Abrasive cut-off wheels and a portable milling machine have been used to section the EBR-II driver-fuel elements to obtain samples for metallographic examination. During these operations fission products and metallic-fuel particles have been spread within the argon cell.

The operations in the argon and air cells require transfer of fuel elements, capsules, and equipment between cells by way of the large and small transfer locks.⁸ During the transfer of items between cells, some of the contamination in the argon cell has been spread to the air cell. As a result, both cells are highly contaminated.

Until the beginning of 1973, little effort had been devoted to establishing the contamination levels in the cells. However, radiation levels in the air cell were determined prior to cleaning of the air cell and prior to personnel entry into the air cell for maintenance in October 1969.⁹

III. SECTIONING OF MARK-IIA LOOPS

During 1973 and 1974, several Mark-IIA loop experiments were sectioned in the HFEF/South argon cell as part of the HFEF posttest support of the RAS-TREAT loop experiments. The purpose of sectioning the loops is to reduce the loop experiments into smaller segments for shipment to the Materials Science Division (MSD) at ANL-East, where the detailed posttest examination of the loop experiments is performed.

Following irradiation in TREAT, the loop experiments are transferred to HFEF in the HFEF loop cask and transferred into the HFEF air cell and finally into the argon cell. In the argon cell the loop insulation, heaters, neutron filters, and miscellaneous loop outfitting are stripped from the loops. In Fig. 1, the H5 loop, with the secondary containment can removed, is shown in the argon cell before and after being stripped of the loop outfitting. The stripped loops are transferred back to TREAT and neutron radiographed. With the loop outfitting removed, a high quality neutron radiograph of the loop is obtained. Following neutron radiography, the loops are returned to the HFEF argon cell where they are sectioned prior to shipment.

(a)

(b)

Fig. 1. The RAS-TREAT H4 Loop in the HFEF/South Argon Cell (a) Before Removal of the Loop Insulation, Heaters, Filters, etc. (Loop Outfitting), and (b) After Removal of Loop Outfitting

Before the first loop, L3, was sectioned in the argon cell, a study was undertaken to determine the possible consequences of cutting the loops. A neutron radiograph of the L3 loop showed that the $\text{UO}_2\text{-PuO}_2$ fuel elements were ruptured and plutonium could be released from the loop and seriously contaminate the argon cell during the proposed loop-sectioning operation. The radiograph of the striped H5 loop, shown in Fig. 2, is representative of the posttest condition of the fuel elements in the L3, L4, and E7 loop experiments. The L3 Mark-IIA loop experiment, as well as the other loops in this report, contained seven fuel elements that were about 75% uranium and 25% plutonium. All loops referred to in this report contained between 99 and 105 g of plutonium.

The loop is sectioned by removing clamps that fasten flanged loop sections together and by cutting through loop parts with a hacksaw. The locations of these loop separations are shown in Fig. 3. The separations that would normally expose sodium, contaminated with fuel, are shown "boxed" in the figure. The loop separations A and B are accomplished by removing clamps. All other separations are made by sawing through the loop with a hacksaw. The separations through the main part of the loop are E, C2, A, and B. The two separations G and D normally do not expose sodium but go through the loop plenum.

The hacksaw that was used for cutting the loop in the argon cell is shown in Fig. 4. In this photograph the hacksaw is clamped to the L3 loop in preparation for one of the F separations.

The loop separations and cuts were made in the argon cell with the loop clamped in vises that were designed to fit into the table. A tray, shown in Fig. 4, was placed on the table under each cut to catch the debris from the hacksaw cut.

IV. MONITORING CELL CONTAMINATION

This section describes the methods that were used to monitor contamination in the air and argon cells. The monitoring plan¹⁰ had three objectives:

- (1) Establish the plutonium-contamination levels in the argon and air cells before sectioning loops.
- (2) Establish the plutonium-contamination contribution to the cells from the loop-sectioning operations.

Fig. 2. Neutron Radiograph of the Stripped H4 Loop

Mark II-A Loop Separations

- F1 Pressure relief tube
- F2 Pressure relief tube
- F3 Fixed sodium level overflow tube
- F4 Sodium drain tube
- C1 Fixed sodium level overflow tube
- C2 Loop upper bend
- A Upper pump clamp
- D Loop plenum
- G Loop plenum (optional)
- B Lower pump clamp
- E Loop lower bend

Fig. 3. Locations for Loop Sectioning

- (3) Verify that no plutonium contamination was spread outside of the cells.

The plutonium levels were established by repetitive monitoring of swipes, particle fallout, and argon-cell-atmosphere samples. In addition, the loop sodium was analyzed for plutonium and fission products to determine the potential for cell contamination.

A. Swipe Samples

The swipes used to gather the in-cell contamination data were taken with 1-in.-dia Whatman 41 filter papers. The filter paper was attached to a 1-in.-dia wooden dowel as shown in Fig. 5. Each swipe covered about a 16-in. length or 100-cm² area.

The table located at face 2 (see Fig. 6) of the argon cell was swiped and cleaned before the loop sectioning began. In addition, the floor of the argon cell was swiped. These swipes were used to establish in-situ levels of plutonium in the argon cell before the first loop was sectioned.

The tray and the table were swiped before the first loop sectioning began and then after each cut. A swipe survey was also made of the argon cell and the air cell between each loop-sectioning operation. The sectioned loop components were placed in individual shipping cans, which were swiped before leaving the argon cell and again in the air cell before the cans were loaded into the shipping cask. This swiping routine was followed for the sectioning and shipping of the six Mark-IIA loops covered in this report.

B. Argon Cell Particle-fallout Samples

Alpha-particle fallout in the argon cell was monitored before, during, and after the loop-sectioning operations. Four in-cell monitor stations located on three tables were used for accumulating alpha-fallout data. The tables were at faces 2, 8, and 15 of the argon cell as shown in Fig. 6. The fallout samples were taken in Pyrex petri dishes with 3½-in. diameters. The petri dishes were transferred into and out of the cells in larger plastic containers (see Fig. 7). While in-cell the bottom half of the petri dishes were opened to the argon-cell atmosphere while the upper half remained protected. Atmospheric movement in the argon cell is caused by the recirculating argon-atmosphere system, which cools and purifies the

Fig. 5. Swipe Sample

Fig. 6. Layout of the HFEF Argonne Cell and Air Cell, Showing the Locations of the Particle-Fallout and Argon-Atmosphere Sampling

Fig. 7. Pyrex Petri Dish Used to Collect Particle-Fallout Sample

argon atmosphere and recirculates it in a clockwise direction.¹¹ Two dishes were placed on the table at face 2, one upwind and one downwind from the loop-sectioning operation. In addition, one sample dish was placed on the table at face 8 and one at the table at face 15.

Petri dishes were placed in-cell to establish the alpha-particle-fallout conditions before a loop was sectioned. During the sectioning of the first loop, the dishes were changed at specified time intervals. After the alpha-particle-fallout data from the first loop were analyzed, the dishes were placed in-cell and remained for each complete loop-sectioning operation. The sequence of sampling permitted a determination of any change in alpha-particle fallout that resulted from the loop-sectioning operation.

C. Argon-cell Fallout-sample Blocks

An alternate method of collecting alpha-particle-fallout data in the argon cell was to analyze Whatman 41 filter paper that was taped to 1-in.-dia dowels and placed in sample-block holders at about a 45° angle facing the direction of the argon-cell-atmosphere "wind." These fallout-sample blocks are shown in Fig. 8.

Fallout-sample blocks were placed in-cell, then removed and analyzed for alpha contamination before the loop-cutting operations began. Additional fallout-sample blocks were removed and replaced with new fallout-sample blocks as the loop-cutting operations progressed. Like the petri dishes, the fallout-sample blocks were used to determine any changes in the alpha-contamination level in the argon cell atmosphere from loop-cutting operations.

D. Argon-cell Atmosphere Samples

Argon-cell atmosphere samples were taken to monitor any spread of the alpha contamination resulting from the loop-cutting operations. The atmosphere samples were obtained by filtering the argon atmosphere for 1 hr through 1.8-in.-dia type-HA millipore filter paper placed in a sampling head attached to a small vacuum cleaner. The sampling head and millipore filter were attached to the vacuum cleaner as shown in Fig. 9. The alpha-particle analysis of the atmosphere samples taken during the loop cutting

Fig. 8 Fallout-sample-block holder.

Fig. 9. Vacuum Cleaner Used to Sample Argon-cell Atmosphere

were compared with atmosphere samples taken before the loop cutting operations began.

Tests conducted before the loop-cutting operations began showed that the vacuum cleaners could spread dust and contamination. Since vacuum cleaners were used in cleaning as well as atmosphere sampling, each vacuum cleaner used in the cells was fitted with a Scott 502-R canister filter manufactured by Acme Products.* These filters have a claimed collection efficiency of at least 99.99% on 0.3- μ -size particulate. With these filters placed in the body of the vacuum cleaner and sealed with RTV** (see Fig. 9) no observable dust or particles passed through the vacuum cleaners. Most vacuum cleaners had significant variations of air flow. A minimum air flow of 0.5 cfm was established for those vacuum cleaners used for atmosphere sampling.

E. Loop-sodium Samples

To determine the potential for the spread of plutonium contamination from the loop-cutting operation, loop sodium was routinely sampled from three loop separations -- A, B, and E (see Fig. 3). An attempt to sample sodium from a fourth separation -- C2 -- was successful only on the H4 loop. The remainder of the loops were void of sodium at the C2 separation. The sodium samples were analyzed for plutonium and for fission products.

F. Out-of-cell Monitoring

Daily smear samples were taken around the outside of the argon and air cells. In addition, each time items were removed from the air cell through the transfer port, air samples and smear samples were taken around the immediate area.

Continuous air monitoring was provided by an 8-cfm air sampling unit with a fixed filter changed every 24 hr. Each filter was counted for gross beta-gamma activity upon removal, and was then allowed to decay for 24 hr and recounted to ensure that no long-lived activity was present.

* Acme Products, South Haven, Michigan.

** Silicone Rubber Sealant, General Electric, Waterford, New York.

V. COUNTING TECHNIQUES AND ACCURACY

A. Swipe Samples

All swipes were taken with 1-in.-dia Whatman 41 filter papers. The swipes were placed in a 2-in.-dia stainless-steel planchet and directly counted in a 2π gas flow alpha-counting system. Selected swipes were dissolved by aqua regia and hydrofluoric acid, and aliquots of the resultant solution were evaporated on planchets for identification of the alpha-emitting nuclides by alpha-spectrometry. Plutonium-239 was >90% of the alpha-activity present in all swipes. The remainder of the alpha-activity was ^{241}Am , ^{234}U , and a trace of ^{235}U . Absorption of the alpha particles by the filter paper, grease, dust, etc., was approximately 10-50% for most swipes.

B. Particle-fallout Activity in Fallout-sample Dishes

The fallout samples were taken in $3\frac{1}{2}$ -in.-dia Pyrex petri dishes with a replaceable lid. The activity in the petri dishes was washed out with a hot aqua regia-hydrofluoric acid solution. The resultant solution was evaporated in counting planchets for the determination of alpha-activity and counted on a Ge(Li) counting system for the determination of gamma-activity.

C. Alpha-activity from the Argon-atmosphere Samples

The filter paper used to obtain argon-atmosphere samples was placed in a 2-in.-dia stainless steel planchet and directly counted for alpha-activity in a 2π gas flow alpha-counting system.

D. Plutonium in Loop-sodium Samples

The radioactive-sodium samples removed from the test loop were weighed and transferred to a dissolution flask that was continuously purged with argon. Each sodium sample was dissolved with an ethanol-water mixture and the ethanol was then boiled off. The solution was acidified with aqua regia and heated to near dryness, and a nitric-hydrofluoric acid mixture

was added to the sample and heated to dissolve any plutonium. An aliquot of the acid solution was evaporated in a planchet and counted for gamma-ray activity with a Ge(Li) counting system. A separate aliquot was analyzed for ^{239}Pu alpha activity by selective separation of plutonium by solvent extraction. The plutonium alpha activity was determined by alpha counting of the separated plutonium and by verification of the alpha energy by spectrometry.

VI. RESULTS FROM CONTAMINATION MONITORING

A. Swipe Data

1. Argon Cell

The swipes (about 380) taken in the argon cell are divided into those taken on the table at face 2 of the argon cell where the loop-cutting operation took place, and those taken on the other tables, equipment, and cell floor.

a. Table Face 2

The swipes from the table at face 2 of the argon cell were obtained by remotely swiping about a 100-cm^2 area. The data obtained from the swipes taken on this table before, during, and after the loop cutting are presented in Table I. The identity of the loop being processed, the event preceding the swipe, and the date are also presented in Table I with the alpha activity of the swipe. The first two swipes taken during November 1972 reflect the alpha-activity level on the table in the cell before loop sectioning began. One of these two swipes measured 2,860,000 dis/min alpha and represented the highest alpha activity obtained.

The series of swipes that were taken starting on June 14, 1973, represent swipes taken on the table after the table had been cleaned with damp rags. The activity on the table was reduced so that any activity resulting from the loop-sectioning operations could be detected more easily.

The major operations performed on the loops, as noted in Table I, were the sectioning of loops L3, E7, L4, H5, the recovery of the annular linear-induction pump (ALIP) from L4, the sectioning of E6, the

TABLE I. Swipe Data from Face 2 of the Argon Cell

Loop	Event or Separation	Date	Disintegrations per minute alpha per 100 cm ²				Chip Tray	Misc
			Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4		
L3	Before loop sectioning	11/20/72 2/7/73	356,000 19,400	2,860,000				
	After cleaning	6/12/73	1,530	200	1,490	75		
			130	360	180	750		
			1,600	620	330	110		
		6/14/73	90	185	99	119		
			90	161				
		6/18/73	75	1,100	220	310		
			130	180				
		6/22/73	150	130	40	180		
	Sectioning		130	750				
		7/16/73	79	48	420	58		
			222	246	310			
								saw blade and cut area
		F1	336	238			66	12 and 84
								saw blade
		C1	222				24	10
		C2	2,598	1,312			130	44
							46	194
								200
		8/1/73	1,408	1,584			344	
		A	1,774	2,506			2,178	clamp
								214
		D	2,880	742			42	saw blade
		G	1,332	1,902			376	128
		E	1,248	2,728				94
		8/8/73	1,522	80			4	
	Vacuuming	8/8/73	1,522	80				2,670
	Shipping	8/16/73	4,690	1,600	1,892	1,728		
	Post L3	9/7/73	4,536	1,964	1,194	2,456		
	Cleaning		830	99,512				
		9/10/73	766	892	522	2,758		
E7	Sectioning							saw blade
	C1	9/13/73	892	2,406	3,896		568	372
	C2	9/14/73	1,840				1,126	530

TABLE I. (Contd)

Loop	Event or Separation	Date	Disintegrations per minute alpha per 100 cm ²				Chip Tray	Misc
			Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4		
L4	A	9/17/73	1,366	1,176			514	clamp 276
	B	9/17/73	1,242	1,646			398	192
								saw blade
	F1	9/18/73	648	2,738			930	480
	D	9/19/73	4,158	3,696			2,246	754
	E	9/19/73	978	1,522			222	606
	Post E7	9/21/73	448	1,162	962	2,706		
		10/2/73	362	1,238	1,502	3,946		
	Cleaning		206	434	13,374	2,970		
			4,262	2,816				
	Sectioning							clamp
	A	10/73	1,130	2,538			6,526	232
	B		1,314	2,802				984
	C2	10/10/73	1,088	906			700	
H5	D	10/16/73	2,364	2,402	2,046	2,114	1,224	
	E	10/73	316	3,976	4,440	1,332	348	
	Cleaning	10/26/73	608	540				
		11/7/73	660	2,552	1,844	1,802		
			1,624					
	Sectioning							
L4	C2	11/9/73	916	3,014			2,308	clamp
	A	11/14/73						104
	B	11/14/73	2,026	8,932			1,348	794
	D	11/21/73	1,054	3,354	2,674	1,626	332	
	E	11/26/73	9,132	11,568			2,860	
	Post H5	12/3/73	1,564	1,442			1,014	
L4	ALIP	12/73	584	1,024				
	recovery							
	Post ALIP	12/18/73	186	222	704	1,006		
			1,330	1,032				
E6	Sectioning							clamp
	A	12/21/73						562
	B	12/21/73	252	10,276			2,250	252
	C2	12/21/73	916	3,684			11,308	
	D	12/22/73	754	4,936			502	
	E	12/22/73	2,204	2,718			838	

TABLE I. (Contd)

Loop	Event or Separation	Date	Disintegrations per minute alpha per 100 cm ²				Chip Tray	Misc
			Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4		
	Post E6	1/16/74	2,904 1,178	2,974 754	2,788	2,186		ALIP
E7	ALIP recovery	1/18/74	1,120	1,736			840	180 784 828
E6	"	1/25/74	1,670	726			1,692	988 567 368
L3	"	1/31/74	1,278	260			1,132	698 282 326
H5	"	1/31/74	2,550	2,134			1,258	836 418 1,210
	Post ALIP	2/14/74	2,804 1,544	1,826 992	2,274	1,044		
	Cleaning	3/5/74	154 214	1,582 982	228	338		
H4	Sectioning C2	3/13/74	546	446	1,478	962	1,254	saw blade 3,202 clamp
	A	3/18/74	584	244			884	170
	B	3/18/74	112	234				426
	D	3/25/74	902	658			512	
	E	3/25/74	1,434	1,710	930	1,012	1,348	
	Post H4	3/26/74	2,070	1,184	934	542	2,554	ALIP
H4	ALIP recovery	4/11/74	976	1,812	2,836	2,300		484 574 526

recovery of the ALIPs from E7, E6, L3, and H5, the sectioning of H4, and the recovery of the H4 ALIP.

b. Argon-cell Floor

The swipes taken on the floor of the argon cell were obtained by two techniques. With the first swiping technique, the wood dowel with the swipe was placed vertically in the parallel-jaws attachment of the electromechanical manipulator (EM), brought in contact with the floor, and rotated. This process was repeated for each swipe. This swiping technique did not cover 100 cm^2 but was used because in attempts to cover a 16-in. lateral swipe across the cell floor, the swipe was usually torn from the block. This rotating technique was used to obtain the swipes taken during 1972 and 1973.

After the sectioning of the L4 loop was completed and the L4 ALIP recovered, a second swipe technique was developed to obtain swipes on the argon-cell floor. For this technique, the dowel with the filter paper was attached to a spring that was attached to the dual grip of the EM (Fig. 10). The swipe was taken by lowering the EM until the block made contact with the floor. Then the EM was rotated and the block and filter paper swept out the equivalent of about 16 linear in. The dotted line drawn on Table II separates the data obtained by the different swiping techniques.

2. Air Cell

The swipes taken in the air cell were obtained on the tables with the same technique as that used on the tables in the argon cell. Those swipes taken on the floor of the air cell were all taken by placing the wooden dowel and filter paper in the parallel jaws of the EM and rotating the EM while the filter paper was in contact with the floor. The data obtained from the swipes in the air cell are presented in Table III.

B. Argon-cell Particle-fallout Data

Two sets of four petri dishes were used to collect particle-fallout samples before the sectioning of the first loop (L3) began. The first set

Fig. 10. Argon-cell Floor-swiping Apparatus Used
After Jan. 1, 1974

TABLE II. Argon-cell Swipe Data
(Alpha Contamination Levels, dis/min)

Event	Date	Face											Transfer- Lock Area	
		2	3	5	7	8	10	11	12	13	14	15		
Before loop operations	11/20/72	22,000												
		946,000												
		4,600												
		352,000												
	2/7/73	12,000												
	2/14/73	7,040												
		44,000												
		14,000												
		18,400												
	2/21/73		24,000	31,000	13,000			440,000		20,000			16,000	
6/15/73	12,500	26,400												
	17,600													
	5,060													
After L3	9/7/73	12,422	49,650	11,116		23,930	29,842		2,194		20,272			
Sectioning		14,606	9,150	29,466		23,404	108,674		54,676		15,682			
After E7	10/2/73	33,368	43,742	10,364							21,116	15,498		
Sectioning		23,250	44,226	22,364							12,030	28,066		
After L4	10/29/73	10,332	60,874	27,690							58,452	18,922		
Sectioning		15,018	18,386	12,070							3,868	10,200		
After L4	12/18/73	5,800	16,462	45,288							21,082	11,260		
ALIP recovery		13,070	3,426	63,810							29,038	10,728		
<hr/>														
After E6	1/16/74	19,564	26,562	7,300		12,448					8,904	13,376		
Sectioning		11,121	11,558	21,548		7,230					7,710	7,988		
After E7, E6,	2/14/74	6,476	16,532	7,314		3,214					54,364	5,072		
L3, and H5		8,636	22,890	11,318		14,942					29,374	2,804		
ALIP recovery			Table			Table								
			30,418			62,128								
			16,232			42,218								
			9,480			71,466								
			18,198											
After H4	4/22/74	4,938	3,652	13,432		6,590					21,790	6,034		
Sectioning and		6,058	7,092	17,800		2,740					16,776	6,620		
ALIP recovery														

TABLE III. Air-cell Swipe Data
(Alpha Contamination Levels, dis/min)

Event or Loop	Date	Face						
		A1	A4	A5	A6	A7	A8	A9
Before loop operations	12/1/72			Floor plugs 2,200 1,300		VAD		Platen 74,000 35,000 A9 4,000
	2/7/73		580					Platen 8,000
	2/14/73		5,300	8,000			8,400	220,000
	2/21/73	3,300		3,300	530 Table 11,000	2,600	440	440,000
	6/26/73			680 1,600 2,900 7,300 6 100				Platen 18,400 17,400 22,500 6,500 19,600 23,500 10,000 11,800 42,400
	7/18/73			490 580 730 2,670 160 1,110 360 390				14,800 7,800 16,200 11,900 13,300 11,900 14,500 14,900 13,300
	8/17/73			290 1,400 790 1,320 350 330 720 1,390				
After L3 Sectioning and before the transfer of loop component shipping cans								

TABLE III. (Contd)

Event or Loop	Date	Face						
		A1	A4	A5	A6	A7	A8	A9
After transfer of the loop component shipping cans	8/17/73			1,370				14,500
				1,060				9,350
				850				13,600
				720				3,100
				610				11,400
				160				15,700
				730				5,000
				1,890				15,800
								13,800
								A9
After L3, E7 and L4 sectioning and shipment	11/2/73			900	660	300	360	
				690	520	200	780	340
				230				
				290				
				1,110				
				1,880				
After H5 and E6 sectioning and shipment and ALIP recovery	3/1/74			400				
				1,620				
				1,070				22,750
				1,330				20,510
				2,290				31,830
				2,880				21,560
				800				31,270
				1,190				9,000
				1,570				7,850
				2,902				18,580

of petri dishes remained in the argon cell for nine days, and the second set for seven days. Six sets of petri dishes were used to obtain particle-fallout samples from the argon cell during the sectioning of the L3 loop. (A seventh set of petri dishes was placed in-cell, and the dishes removed at different time intervals.) After the completion of the L3 loop sectioning, only one set of petri dishes was used to collect particle-fallout samples during the complete sectioning of a loop. The results from the analyses of the fallout samples, taken during the sectioning of the six loops, are presented in Table IV.

C. Argon-cell Fallout-sample-block Data

The argon cell sample blocks were changed regularly during the cutting of the L3 loop. During the major cuts on the E7 loop, samples were removed and replaced with a new set. For the remaining four loops, fallout-sample blocks were removed only after each loop was sectioned. The alpha-analysis results for the filter paper on the fallout-sample blocks are presented in Table V.

D. Argon-cell-atmosphere Sampling Data

Two argon-cell-atmosphere samples were taken simultaneously during the loop cutting by operating vacuum cleaners in the argon cell for one hour. One set of two samples was taken before and one set after the first loop was sectioned. After sectioning of the E7 loop was completed, atmosphere sampling at face 8 was discontinued, and only one atmosphere sample was taken downwind (between face 2 and face 3) from the cutting operation. The millipore filter paper, used in sampling the argon-cell atmosphere, was analyzed for alpha activity; the data are presented in Table VI.

E. Loop Sodium Analysis

The sodium from loop separations was sampled and analyzed for plutonium. Sodium was present at separations A, B, and E on all loops. The results of the analyses are tabulated in Table VII. Loop sodium was analyzed to determine the amount of plutonium present in the sodium. These analyses provided an indication of the potential for contamination of the argon cell with

TABLE IV. Particle-fallout Samples Taken During Loop Sectioning
(Alpha Contamination Levels in Petri Dish, dis/min)

Loop Number	Sampling Days	Face			
		2	2	8	15
Control samples	9	123 ^a	123 ^a	771 ^a	344 ^a
	7	356	473	1,886	662
L-3	7	530	486	411	258
	7	284	342	17,496	762
	7	234	3,298	124	90
	12	192	942	1,510	222
	10	230	154	194	172
	7	106	168	72	110
	19	1,086			432
	13		572		
E-7	21	2,086	3,814	11,934	1,940
L-4	17	576	242	16,794	424
H-5	39	966	2,106	3,352	502
E-6	22	965	824	2,952	460
ALIP tube removal	About 15	Sample Dish Broken	1,873	4,687	893
H-4	29	956	840	13,898	1,380

^a These values may be nonrepresentative because of sampling difficulties.

TABLE V. Argon-cell Sample Blocks

Loop	Sampling Date	Separation	Days Exposed to Argon-cell Atmosphere	Alpha Contamination, dis/min	
				Face 3	Face 4
L3	7/20/73	F1	2	14	20
	7/27/73	C1	9	30	22
	7/31/73	C2 partial	3	62	12
	8/1/73	C2	4	16	32
	8/3/73	D	7	2,034	2
	8/7/73	G	11	16	4
	8/8/73	E	21	8	6
E7	9/13/73	C1	48	216	186
	9/14/73	C2	49	106	156
	9/21/73	D	56	176	192
		E	32 and 56	86	310
L4	10/26/73	After L4 loop sectioning	68	72	116
			68	66	130
H5	12/3/73	After H5 loop sectioning	126 and 34 105	274 190	188 264
E6	1/16/74	After E6 loop sectioning	88	136	152
H4	3/26/74	After H4 loop sectioning	69 and 113	632	104

TABLE VI. Argon-atmosphere Samples Taken During Loop Cutting
(Alpha Contamination on Filter Paper, dis/min^a)

Loop	Separation	Face	
		3	8
Control sample	Before cutting	46	72
L 3	C 1	6	2
	C 2	9	19
	E	16	4
Control sample	After cutting	86	20
E 7	C 2	12	6
	E	22	30
L 4	C 2	30	
	E	50	
H 5	C 2	16 ^b	
	E	24	
E 6	C 2	6	
	E	4	
H 4	C 2	2	
	D and E	28	

^a Measured air flow through the vacuum cleaner and filter was 0.5 cfm, and sampling time was 1 hr. Therefore, about 30 ft³ of atmosphere passed through each filter paper.

^b Waxed paper used instead of millipore filter paper.

TABLE VII. Analysis of Loop Sodium for Plutonium (ppm)

Loop	Separation		
	A	B	E
L 3	18	1	0.5
E 7	0.2	492	0.3
L 4	4.5	48	0.2
H 5	1.3	32	0.8
E 6	120	32	1.5
H 4	a	a	0.2

^a Sodium samples not analyzed.

E. Loop Sodium Analysis (contd)

plutonium from the loop-sectioning operations. The highest plutonium level of the sodium samples analyzed was 492 ppm. Sodium was observed and sampled at separation C2 on only the H4 loop. This sample, with sodium samples from the H4 loop separations A and B, was not analyzed for plutonium.

F. Out-of-cell Results

Out-of-cell monitoring for contamination by dry smears, on-the-spot air samples, and continuous air sampling showed there was no spread of plutonium to the outside during the loop-sectioning operations.

VII. ACTIVITY RATIO DATA

Since the half-life of ^{239}Pu (2.4×10^4 yr), ^{137}Cs (30 yr), and ^{144}Ce (285 days) are considerably different, the ratios of the activity from these nuclides can give an indication of the age of the radioactive material and consequently the source of the contamination. Activity ratios were determined for selected samples (swipes, particle fallout, and sodium samples) as a means of identifying the sources of contamination by their distinct activity

ratios. For example, the activity ratio of the background contamination in the argon cell would be different from the activity ratios of the contamination in the loop sodium, and thus the activity-ratio information could identify contamination originating from the loop-cutting operations.

The data obtained from these analyses are presented in the Appendix in Tables VIII through XI in the form of ratios. Table VIII contains ratios from swipes that were taken in the argon cell, and Table IX contains the ratio information from swipes taken in the air cell. Table X presents the ratios obtained from analyses of the particle-fallout samples for additional fission products. Table XI contains the activity ratios for the sodium samples taken from loops during cutting and sectioning.

VIII. CONCLUSIONS

A. Contamination Monitoring

A thorough examination of the tabulated analyses showed large variations in the alpha and gamma activities obtained from the various monitoring methods, especially the results from swiping. The sampling techniques were known beforehand to be nonexact, but an effort was made to obtain the best samples possible under the adverse conditions of an operating hot cell. An obvious oversampling was performed on the first loop-sectioning operation to partially offset the variations in sampling and to obtain background for future operations involving plutonium fuel. Variations in the activity level of individual samples of $\pm 50\%$ would not conceal a spread of gross plutonium contamination in the argon cell. From the results of the large number of samples analyzed by the monitoring techniques, several observations were made pertaining to the overall spread of contamination.

The alpha activity on the table at face 2, swiped three times before the table was cleaned in preparation for the loop-sectioning operations, was comparable to the alpha-contamination level of the argon cell. After the loop-sectioning operations began, the alpha-contamination level of the table was generally maintained at least an order of magnitude less than cell background by contamination-control techniques. The working area around the loop-sectioning operation showed no significant increase in the alpha-contamination level from the loop-sectioning operation.

The results of the analyses of the swipes taken in the air cell indicate that the alpha background level in the air cell did not increase during the loop-sectioning operation in the argon cell. The results of the particle-fallout monitoring by use of the petri dishes, fallout-sample blocks, and atmosphere sampling provide additional evidence that no significant increase in the alpha activity resulted in the argon cell from sectioning the loops.

The results of the loop-sodium analyses show that the potential for contamination of the argon cell from the sodium displaced during the loop-cutting operation was small. The low concentration of plutonium in the sodium can be partially attributed to the low solubility of plutonium in sodium. Also, the spread of contamination was suppressed because very little sodium was displaced during loop-cutting operations (the sodium is self-adhering), and because the very small amount of sodium that was displaced was contained in the chip tray and easily removed with a vacuum cleaner.

The out-of-cell monitoring of contamination provided conclusive evidence that no contamination (alpha or beta-gamma) was spread outside the hot cells during the loop-sectioning operation.

B. Gamma-alpha Activity Ratios

A comparison of the gamma-alpha activity ratios from the monitoring samples from the argon and air cells shows $^{144}\text{Ce}/\alpha$ and $^{137}\text{Cs}/\alpha$ ratios generally of 10^2 to 10^4 . Cerium-144 was not detected in the loop sodium, probably because the solubility of cerium in sodium is negligible. Since the contamination from the loop is different (low or no ^{144}Ce) from the background contamination in the hot cells, the two sources of contamination should be distinguishable. The gamma-alpha ratios from all particle-fallout samples analyzed fit within the range of the gamma-alpha ratios of the samples taken from the background argon and air cell contamination, while the gamma-alpha ratios from the contamination from the loop were outside the range of ratios of the background contamination.

Therefore, the most likely source of the majority of the contamination collected in the argon cell particle-fallout samples taken during the sectioning of the loops was the normal redistribution of the argon cell background contamination. A continuous redistribution of the background contamination was shown to take place during the collection of the argon cell particle-fallout samples obtained before the loop sectioning began (see Appendix - Table X).

Appendix

Gamma-Alpha Ratio Data

Tables VIII, IX, X, and XI, contain the gamma/alpha ratio data for the argon-cell swipes, air-cell swipts, particle-fallout samples, and sodium samples respectively.

TABLE VIII. Activity Ratios from Argon-cell Swipes

Date	Argon-cell Swipes	$^{144}\text{Ce}/\alpha$	$^{137}\text{Cs}/\alpha$	$^{134}\text{Cs}/\alpha$	$^{95}\text{Nb}/\alpha$	$^{95}\text{Zr}/\alpha$	$^{54}\text{Mn}/\alpha$	$^{137}\text{Cs}/^{144}\text{Ce}$
Swipes taken before the loop operations were initiated								
11/20/72	Table 2	75.0	150.0	a				2.0
		88.8	53.8	Trace	Trace	Trace	Trace	0.7
	Floor 2	62.8	55.8	Trace	11.4			0.9
		35.7	523.8					14.7
		9.4	50.0					5.3
		48.0	60.0					1.3
2/ 7/73	Table 2	6,950	22,273	1,136		227.2	238.6	3.4
	Floor 2	2,109	12,363	109	90.9	Trace	Trace	5.9
2/14/73	Floor 2	750	6,156					8.2
		365	2,025					5.5
		875	2,469	Trace				2.8
		928	2,476	Trace	Trace	Trace	Trace	2.7
2/21/73	Floor 3	172	536	Trace				3.1
	Floor 5	150	493	Trace	Trace	Trace	Trace	3.3
	Floor 7	217	317	Trace	Trace	Trace	b	1.5
	Floor 11	355	595	Trace				1.7
	Floor 13	279	677	Trace	Trace	Trace		2.4
	Floor 16	115	2,113	Trace	Trace	Trace		18.3
Swipes taken after cleaning table and before loop operations were started								
6/12/73	Table 2	1,029	1,043	a				1.0
		875	1,500					1.7
		1,222	1,444					1.2
		1,341	1,951					1.5
		1,343	1,791					1.3

^a Many samples were analyzed only for ^{144}Ce and ^{137}Cs

^b Trace of ^{58}Co

Table VIII (contd)

Date	Argon-cell Swipes	$^{144}\text{Ce}/\alpha$	$^{137}\text{Cs}/\alpha$	$^{134}\text{Cs}/\alpha$	$^{95}\text{Nb}/\alpha$	$^{95}\text{Zr}/\alpha$	$^{54}\text{Mn}/\alpha$	$^{137}\text{Cs}/^{144}\text{Ce}$
6/14/73	Table 2	1,118	1,529	a				1.4
		735	3,824					5.2
		964	1,071					1.1
		1,438	1,625					1.1
		1,000	733					1.4
		982	929					0.9
		11,428	18,367					1.6
		609	439	a				0.7
		893	929					1.0
		800	978					1.2
6/15/73	Floor 2	444	722					1.6
		219	219					1.0
		185	244					1.3
		228	737	a				3.2
		662	1,712					2.6
		300	1,783					5.9
6/18/74	Table 2	73	391	a				5.3
		470	735	a				1.6
		443	107					0.2
		960	62					0.06
		648	747					1.1
		260	210					0.8
6/22/74	Table 2	509	1,298					2.6
		826	1,884	a				2.3
		1,060	867					0.8
		824	1,088					1.3
		1,066	3,443					3.2
		51	167					3.3
		1,724	2,586					1.5

^a Many samples were analyzed only for ^{144}Ce and ^{137}Cs

Table IX. Activity Ratios from Air-cell Swipes

Date	Air-cell Swipe Location	$^{144}\text{Ce}/\alpha$	$^{137}\text{Cs}/\alpha$	$^{134}\text{Cs}/\alpha$	$^{95}\text{Nb}/\alpha$	$^{95}\text{Zr}/\alpha$	$^{54}\text{Mn}/\alpha$	$^{137}\text{Cs}/^{144}\text{Ce}$	^{58}Co	^{60}Co
12/ 1/72	A5 (floor plugs)	16,200	37,300	a				2.3		
	"	20,000	15,167					0.7		
	A9 (platen)	10,615	16,353					Trace		
	"	12,212	22,225					Trace		
	A9	39,389	24,444					0.6		
2/ 7/73	A9 (platen)	2,917	7,500	Trace	Trace	Trace	Trace	2.6		
	A4	5,385	308					153		
2/14/73	A4	1,292	4,208	Trace	Trace	Trace	Trace	3.3	Trace	Trace
	A5 (floor plugs)	2,806	889	Trace	Trace	Trace	Trace	0.3		
	A9 (platen)	1,240	2,310	Trace	Trace	Trace	265	1.9		
	"	730	1,435	Trace	Trace	Trace		2.0		
	A8	1,000	3,105	Trace	Trace	Trace	Trace	3.1		
2/21/73	A8	1,300	2,500	Trace	Trace	Trace		1.9	Trace	Trace
	A6	1,583	3,250	Trace	Trace	Trace		2.0	Trace	Trace
	A1	440	573	Trace	Trace	Trace	Trace	1.3	Trace	Trace
	A5	1,867	1,467	Trace	Trace	Trace	Trace	0.8	Trace	Trace
	A7 (VAD)	2,583	1,417	Trace	Trace	Trace	Trace	0.5	Trace	Trace
	A6 (table)	1,354	1,708	Trace	Trace	Trace	Trace	1.3	Trace	Trace
6/15/73	A5 (floor plugs)	1,226	1,194	a				1.0		
	"	1,507	1,315					0.9		
	"	1,077	708					0.7		
	A9	19	16					0.8		
	"	3,481	4,074					1.2		
	"	702	532					0.8		

^a Many samples were analyzed only for ^{144}Ce and ^{137}Cs .

TABLE X. Activity Ratios from Argon-cell Particle-fallout Samples

Argon-cell Particle-fallout Sample	Face	$^{144}\text{Ce}/\alpha$	$^{137}\text{Cs}/\alpha$	$^{134}\text{Cs}/\alpha$	$^{95}\text{Nb}/\alpha$	$^{95}\text{Zr}/\alpha$	Miscellaneous	$^{137}\text{Cs}/^{144}\text{Ce}$
Before loop operations were initiated	2	364	727	a				2.0
	2	273	545					2.0
	8	1,543	1,800					1.2
	15	267	1,400					5.3
E 7	2	2,766	851	Trace	245	Trace	Trace ^{106}Ru Trace ^{58}Co	0.3
	2	14,705	14,118					1.0
	8	2,906	962					0.3
	15	2,988	1,494					0.5
L 4	2	1,145	7,812	a				6.8
	2	1,116	3,016					2.7
	8	3,864	1,536					0.4
	15	1,250	3,066					2.5
H 5	2	423	1,227	a				2.9
	2	632	1,053					7.8
	8	1,520	1,667					1.1
	15	478	1,217					2.5
E 6	2	341	2,692	a				8.0
	2	1,214	4,005					3.3
	8	1,287	1,118					0.9
	15	630	8,696					13.8
ALIP tube removal	2	491	5,072	a			$^{60}\text{Co}/\alpha$ 90	10.3
	8	384	1,067					2.7
	15	784						--

^a Many samples were analyzed only for ^{144}Ce and ^{137}Cs .

Table XI. Activity Ratios from Sodium Samples

Loop	Sodium Sample Location	$^{144}\text{Ce}/\alpha$	$^{137}\text{Cs}/\alpha$	$^{134}\text{Cs}/\alpha$	$^{95}\text{Nb}/\alpha$	$^{95}\text{Zr}/\alpha$	$^{54}\text{Mn}/\alpha$	$^{125}\text{Sb}/\alpha$
L 3	A	a	29,204	618				
	B	a	c	c				
	E	a	c	c				
E 7	A	b	2,200,000					433
	B	b	3,100					
	E	b	c	c				
L 4	A	a	c	c				
	B	a	c	c				
	E	a	c	c				

a ^{144}Ce not detected (detection limit $< 4 \times 10^{-3} \mu \text{Ci/g}$)

b ^{144}Ce not detected (detection limit $< 4 \times 10^{-2} \mu \text{Ci/g}$)

c Activity identified but not measured

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