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A REPORT FROM THE

URANIUM PROJECT PLANTS

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AEC RESEARCH AND DEVELOPMENT REPORT

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Hugh Kinser
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MALLINCKRODT CHEMICAL WORKS
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Date of Issue: May 1, 1953

Report Number: NYO 1351

Subject Category: Technology -
Feed Materials

CLASSIFICATION CANCELLED
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For The Atomic Energy Commission
H.P. Connel
Chief, Declassification Branch LLT

Wo-33985

Reprocessing of Uranium Bearing Barium

Sulfate Cake Produced in the M.C.W. Refinery

by

A. M. Kirby

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Classification cancelled (or changed)

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St. Louis, Missouri

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Bearing Barium Sulfate
Cake Produced in the M.C.W.
Refinery

Author: Mr. A. M. Kirby

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NYO 1351

Subject Category: Technology -
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Date of Issue: May 1, 1953

Author: Mr. A. M. Kirby

Title: Reprocessing of Uranium
Bearing Barium Sulfate
Cake Produced in the
M.C.W. Refinery.ABSTRACT

It is desired to recover the residual uranium in the barium sulfate cake produced in Mallinckrodt's Plant 6, prior to the installation of the present C-3 Recovery System. This report describes work done in the pilot plant at Mallinckrodt towards development of such a recovery process.

The investigation involved examination of chemical leaching problems, and testing of filtration equipment for recovery of the leached cake. Several additional problems uncovered during the work were:-

- (a.) Introduction of the barium sulfate cake into a slurry,
- (b.) Settling of heavy fines in process equipment, and
- (c.) Foaming of the barium sulfate slurry.

It was found that a two stage leaching of barium sulfate cake in 0.25 lbs./gal. sodium carbonate solution at a wet solids concentration of 4 lbs./gal. (with each stage including a water wash at a rate of one gallon of wash water per gallon of slurry) was necessary to guarantee production of a final cake having a maximum of 0.06% uranium. Slurrying of this barium sulfate cake in present plant barium sulfate slurry, at a concentration of 1 1/2 pounds of old cake per gallon of slurry, with subsequent separation on a horizontal Bird centrifuge produced a cake with a maximum of 0.15% uranium. A subsequent reslurry of this Bird cake at 2 1/2 to 3 1/2 lbs./gal. wet solids in 0.25 lbs/gal sodium carbonate solution for a second centrifugation yielded a cake containing a maximum of 0.06% uranium. One batch of barium sulfate cake, obtained by random sampling of the stockpile, showed 0.05% uranium out of an original 1.17% uranium to be sodium carbonate insoluble after two leaches. This same cake leached with a 0.5N nitric acid solution after one sodium carbonate leach yielded a cake with 0.01% uranium.

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The results of the filtration equipment testing showed that:

- 1) A production rate of 2500 lbs./day could be attained on the vertical basket centrifuge in the old calcium nitrate area in Plant 6 with no cake washing possible.
- 2) A production rate of 6 - 8 lbs./ft²-hr. could be attained on a FEinc Filter with sufficient washing to yield a cake having a maximum of about 0.2% uranium for one stage.
- 3) A production rate of from 20 - 50 lbs./ft²-hr. could be attained on an Oliver Precoat Filter with a washing and leaching efficiency equivalent to filtration with a FEinc Filter.
- 4) A production rate of about 11,000 lbs./day could be attained by adding the barium sulfate cake to the present plant barium sulfate recovery process at a concentration of 1 1/2 lb. of cake per gallon of slurry yielding a cake having a maximum of about 0.06% uranium.

Insufficient work was done to develop a method of slurring the old barium sulfate cake or to solve the problem of solids settling out in process equipment. Beaker scale tests indicated that foaming might be prevented by the use of any one of several non-ionic wetting agents.

It is recommended that production plans be scheduled to include processing of the old barium sulfate cake in the present plant system, and that work be initiated to develop a method of adding this cake to the present plant barium sulfate slurry.

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INTRODUCTION

About 2,980,000 pounds of barium sulfate cake stored at the airport (containing approximately 44,000 pounds of uranium) were produced in Mallinckrodt's Plant 6, prior to installation of the present C-3 process for carbonate leaching of residual uranium in such cake. It would be desirable if some convenient method could be found to recover the uranium in this cake.

At the request of the St. Louis Atomic Energy Commission Office, work was initiated by Mallinckrodt personnel in January 1952 to determine the feasibility of recovering the uranium in the old AJ-4 cake. The investigation is described in this report along the following lines:-

1. Examination of chemical problems involved in leaching.
2. Examination of possible utilization of existing equipment in Plant 6 for reprocessing.
3. Examination of other types of equipment for possible installation for a more efficient process.

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CHEMICAL PROBLEMS INVOLVED IN LEACHING AIRPORT AJ-4 CAKE

A series of beaker leaching experiments was performed to determine the extractability of the uranium in the Airport AJ-4. In these experiments, AJ-4 cake was slurried, washed and reslurried at wet solids concentrations of 2 and 4 lbs./gal. in several liquors according to the schedule shown in Table I.

The procedure followed was:-

1. Initially 250 or 500 gm of AJ-4 cake was slurried in the proper liquor and agitated at 190-200°F for 1/2 hour.
2. This slurry was filtered on a Buechner funnel and a sample of cake was taken from one side of the Buechner funnel for analysis.
3. The hole left by the taking of the cake sample was filled with cake scraped from the top of the remaining material.
4. The cake was then washed with hot water and a sample of cake was taken from the opposite side of the funnel.
5. The remaining cake was reslurried in the proper liquor and again agitated at 190-200°F for 1/2 hour.
6. Items 2, 3, and 4 were repeated.
7. In all cases of washing or reslurrying, the amount of liquor used was decreased proportionally to the amount of cake removed as samples so as to approximate constant solids content throughout the steps of the leaching operation.

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TABLE I

BEAKER LEACHING EXPERIMENTS ON AIRPORT AJ-4 CAKE

Analysis of Initial AJ-4 Composite

% U = 0.95

% H₂O = 14.8

Liquor Schedule

A - Plant Neutralizer Liquor (0.25 lbs/gal Na₂CO₃)

B - 0.5 N. Nitric Acid

C - Water

Run Number	Initial Cake Weight	Leaching Temperature	Liquor Used for Operation Designated				CAKE ANALYSES							
			1st Leach	1st Wash	2nd Leach	2nd Wash	1st Leach				2nd Leach			
							Unwashed Cake		Washed Cake		Unwashed Cake		Washed Cake	
—	gm	°F.	1000 ml Used	900 ml Used	See Note Below	700 ml Used	% U	%H ₂ O	% U	%H ₂ O	% U	%H ₂ O	% U	%H ₂ O
2A	500	200	A	C	A	C	—	—	0.05	19.7	0.01	19.2	0.01	19.7
2B	"	"	"	none	"	none	0.11	17.5	—	—	0.05	20.0	—	—
2C	"	"	B	C	"	C	0.58	21.4	0.61	19.2	0.07	20.1	0.13	19.1
2D	"	"	"	none	"	none	0.52	24.3	—	—	0.08	22.5	—	—
6	"	"	C	C	C	C	0.82	24.2	0.89	20.5	0.84	21.8	0.87	20.1
4A	250	"	A	"	A	"	0.14	18.7	0.09	17.6	0.05	18.1	0.03	16.4
4B	"	"	"	none	"	none	0.13	18.9	—	—	0.06	18.7	—	—
4C	"	"	B	C	"	C	0.50	24.3	0.46	20.1	0.03	20.4	0.01	17.4
4D	"	"	"	none	"	none	0.49	22.5	—	—	0.08	21.0	—	—
3A	500	60-70	A	C	"	C	0.12	22.5	0.04	21.9	0.03	18.4	0.02	17.8
3B	"	"	"	none	"	none	0.13	21.3	—	—	0.04	17.0	—	—
3C	"	"	B	C	"	C	0.64	29.2	0.72	15.1	0.05	21.7	0.02	14.1
3D	"	"	"	none	"	none	0.54	22.7	—	—	0.06	19.4	—	—
5A	250	"	A	C	"	C	0.10	17.5	0.10	15.7	0.14	14.8	0.15	13.0
5B	"	"	"	none	"	none	0.14	22.1	—	—	0.13	18.7	—	—
5C	"	"	B	C	"	C	0.74	21.4	0.71	17.0	0.12	19.5	0.14	17.9
5D	"	"	"	none	"	none	0.81	19.5	—	—	0.11	18.3	—	—

Note: For Second Leach - 800 ml of liquor were used if cake had been washed previously, and 900 ml if cake had not been washed so as to maintain a constant slurry solid content throughout experiment.

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As can be seen from the results in Table I, one leaching of AJ-4 cake containing 0.92% uranium in 0.25 lbs./gal. Na_2CO_3 solution followed by a water wash was sufficient to obtain a leached cake, containing 0.1% or less uranium. For comparison with this figure, one leaching with 0.5 N HNO_3 followed by a water wash produced a cake with 0.46 to 0.72% residual uranium, while one water wash yielded a cake with 0.82 to 0.89% uranium. No explanation is readily available for the higher uranium values from the 250 gm/l leach tests than the 500 gm/l tests on the second leach. It might possibly be due to a higher uranium content in the plant neutralizer liquor used for the leaching tests.

On the basis of these results, it was assumed that leaching of the cake with 0.25 lbs./gal. Na_2CO_3 solution would be sufficient and this procedure was used for subsequent pilot plant work. However, after leaching one batch of airport AJ-4 cake in the carbonate liquor and filtering with washing on a rotary drum filter, a cake containing 0.14 to 0.17% uranium was produced. Beaker leaching experiments, as previously described, were run on the 0.14% uranium filter cake. The results of these experiments were:

<u>Original Slurry</u>	<u>Unwashed Cake</u>		<u>Washed Cake</u>	
	<u>% U</u>	<u>% H_2O</u>	<u>% U</u>	<u>% H_2O</u>
0.25 lbs./gal. Na_2CO_3 solution	0.06	21	0.05	19
0.5 N. HNO_3 solution	0.02	23	0.01	19
Water	0.15	22	0.15	19

From these results, it appears that a small fraction of the uranium in the Airport AJ-4 is insoluble in sodium carbonate solutions.

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INVESTIGATION OF POSSIBILITY OF USING EXISTING EQUIPMENT TO PROCESS AJ-4 CAKE.

Two possibilities exist for utilization of present plant equipment for processing Airport AJ-4.

1. Use of the vertical basket centrifuge in the old calcium nitrate area. This centrifuge is not in use currently and would present an ideal solution spacewise.
2. Addition of returned Airport AJ-4 cake to the present AJ-4 system. This procedure would offer the best all around solution since it would not entail additional full time manpower. A minimum of additional new work would be added to the present plant load.

Vertical Basket Centrifuging of Returned AJ-4 Slurries:

A series of runs was made with 1 to 2 lbs./gal. solids content, AJ-4 slurries to determine the possibility of using the basket centrifuge in the calcium nitrate area as a production unit. A method was developed for operating in the following manner. Centrifuge dressing was cotton duck cloths precoated with 1/2 inch of JM Hy-flo Super Cel,---solids in filtrate are prohibitively high without precoat. The slurry was fed at room temperature,---hot runs were tried, but no difference in operations was noted. The centrifuge was run full of slurry, spun for 2 minutes and then skimmed, all at slow speed. This was repeated 8 to 10 times to get a 2" thick cake. The cake was spun for 30 minutes at high speed. The cake was discharged in the usual manner with the plow while the centrifuge turned slowly. It was necessary to water wash the precoat thoroughly if an overnight shutdown was anticipated in order to prevent solidification of the precoat into an impervious medium. Operation in this manner gave production of around 125 lbs./hr. Because of this extremely low production rate and also because of the fact that this centrifuge operation would take the complete time of no less than one operator, the use of calcium nitrate centrifuge is not recommended.

Horizontal Bird Centrifuging of Returned AJ-4 Slurries:

It was thought wise to obtain data on settling rates of returned Airport AJ-4 cake prior to making horizontal Bird centrifuge runs. Therefore, a comparison was made between M-70 slurry and returned AJ-4 slurry,---both at 2.1 lbs./gal., and at room temperature. Settling rates were similar as shown in Graph 1, and it was anticipated that the returned AJ-4 would centrifuge in the same manner as M-70 slurry.

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A series of runs were then made at 200°F on the horizontal Bird centrifuge using Airport AJ-4 containing 0.35% U and 16.2% water slurried in hot neutralizer liquor. Results of these runs are summarized below:

<u>Slurry Rate</u> <u>gpm</u>	<u>Slurry Solids</u> <u>lbs./gal.</u>	<u>Filtrate Solids</u> <u>lbs./gal.</u>
2.1	2.1	0.6
2.9	2.1	negligible
4.5	2.1	"
7.5	1.6	"

On the last three runs the filtrate solids were so low as to only impart a slight stain to a filter paper from a 1 liter sample.

The cakes from the last runs contained 0.27% uranium (wet basis). Some of the nodules from the bottom of the slurry tank analyzed 0.24% uranium. From these results it can be seen that a single horizontal Bird centrifuging of the returned AJ-4 is not feasible from the standpoint of uranium removal, but the material separated and the cake discharged from the filter satisfactorily,---no difficulty should be encountered in plant Bird centrifuging of the slurries.

In addition such a procedure of centrifuging returned Airport AJ-4 separately would not be feasible for the present AJ-4 system due to, (a.) the semi-continuous nature of the production of barium sulfate in plant operation of the system for present production and, (b.) the limitations imposed by present operation at nearly full volumetric capacity both for the centrifuge and process pumps. Information obtained from the manufacturer, however, indicated that the Bird centrifuges, although operating at near capacity liquid wise, should be capable of handling about 10 times the present amount of solids. As a result of this information, it was decided to make several pilot plant runs using plant AJ-4 slurry to which Airport AJ-4 had been added to increase the solids content.

A series of runs was made using plant AJ-4 slurry spiked with Airport AJ-4 cake so as to vary the wet solids content of the Bird slurry from 1.5 lbs./gal to about 4 lbs./gal. The centrifugation was carried out at a temperature of 170°F and a slurry feed rate of about 6 gal./min. (present plant feed rate = 6.3 gal/min). Pertinent data and results of analyses on the tested material are shown in Table II.

In addition, the Bird cakes from Runs 14, 15, and 16, were reslurried in plant neutralizer liquor at the same solids concentration, respectively, and rerun on the Bird centrifuge to simulate the second Bird centrifugation in the plant process. Data and analytical results for these runs are shown in Table III.

TABLE II

Horizontal Bird Centrifugation of Plant AJ-4 Slurry Fortified with Airport AJ-4 Cake.

Run Number	Initial Slurry Solids Lbs./Gal.	Slurry Volume gals.	Weight Airport AJ-4 Added Lbs.	Final Slurry Solids Lbs./Gal.	Final Volume Gals.	Length of Run Minutes	Slurry Feed Rate Gal./min.	Filtrate Volume Gals.	Filtrate Solids* Lbs./Gal.	Cake Weight Lbs.	Cake Production Rate Lbs./Min.	ANALYSES					
												M-70 Slurry	Composite AJ-4 Cake		Feed Slurry	Composite Bird Cake	
												U gm/l	% U	% H ₂ O	U gm/l	% U	% H ₂ O
13	1.84	170	90	2.2	172	30	5.73	136	negl.	396.5	13.2	0.47	1.24	16.8	1.01	0.04	24
13A	1.4	172	none	1.4	172	30	5.73	154	negl.	266	8.9	--	none added	--	--	0.07	24
14	1.31	170	344	2.9	174	33	5.27	136	negl.	566	17.1	0.40	0.90	16	1.6	0.07	24
15	1.15	158	210	2.45	176	27	6.51	131	negl.	354	13.1	0.39	--	--	1.8	0.06	24
16	1.52	156	338	3.4	176	28	6.29	116	negl.	574	20.5	0.71	1.82	15	3.1	0.12	23
17	2.22	184	380	3.9	204	33	6.19	175	negl.	741	22.4	1.12	1.19	14	3.4	0.12	23
21	1.6	150	225	2.38	160	30	5.33	132	negl.	516	17.2	1.5	1.14	15.6	3.3	0.12	23.2
22	1.97	150	225	3.35	164	26	6.31	122	<0.01	512	19.7	1.3	2.44	16	3.2	0.15	26
23	1.97	150	225	2.6	156	26	6.0	118	<0.01	493	19.0	1.2	2.44	16	3.0	0.13	25

* The weight of filtrate solids resulting from filtering 5000 ml of filtrate through filter paper on a Buechner was too low for accurate calculation, therefore, weights were not recorded.

TABLE III

Horizontal Bird Centrifugation of Fortified Plant AJ-4 Slurry
Bird Cake Reslurried in Plant Neutralizer Liquor

Run Number	Cake from Run No.*	Final Slurry Solids Lbs./Gal.	Final Volume Gals.	Length of Run Minutes	Slurry Feed Rate Gal./Min.	Filtrate Volume Gals.	Filtrate Solids Lbs./Gal.	Cake Weight lbs.	Cake Production Rate Lbs./Gal.	ANALYSES					
										Plant Neutralizer Liquor U, gm/l	Composite AJ-4 Cake		Feed Slurry U, gm/l	Composite Bird Cake	
											% U	% H ₂ O		% U	% H ₂ O
18	14	3.2	208	32	6.51	152	--	501	15.7	0.15	0.08	24	0.3	0.04	23.4
19	15	2.4	145	20 for 113 gal.	5.66	99	0.01	303.5	--	0.09	0.10	23	0.29	0.06	22.7
20	16	3.4	141	--	--	126	0.01	533	--	0.10	0.12	23.1	0.45	0.04	23.8

* See Table II.

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It may be observed from Tables II and III that the cake from the first centrifugations contain 0.15% or less uranium and the cake from the three second centrifugations contain 0.06% or less uranium. Operational wise, the centrifugation was no different from that with plant AJ-4 slurry or returned AJ-4 cake alone with the exception of a foaming problem discussed later. The filtrate solids in all cases were less than 0.01 lbs./gal. (obtained from weight of cake in a 5000 ml sample). Addition of Airport AJ-4 to the present plant AJ-4 slurry should present no difficulty process wise.

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INVESTIGATION OF POSSIBILITY OF USING ROTARY
DRUM FILTERS FOR RECOVERY OF AJ-4 CAKE

It was felt advisable to investigate other means of filtration for reslurried Airport AJ-4 in view of the present, near capacity volume being handled by the Bird centrifuges. If the sulfate content of future ores received for processing continues to rise in the future as it has in the past, it is conceivable that the present AJ-4 system might be overtaxed if an attempt is made to process returned Airport AJ-4 in addition to an increased load from higher sulfate ores.

Series of runs were made on both a string discharge FEinc filter and an Oliver Precoat Filter in order to determine the possibilities of using these types of filters for processing returned AJ-4 cake.

FEinc Filter:

A series of leaf filtration tests (using a string discharge type leaf) was made using Airport AJ-4 cake slurried in 0.25 lb/gal Na_2CO_3 solution. The cloth used for these tests was Satin Nylon. Newspaper pulp was added to the slurry for the last four leaf tests in the hope that it would aid in forming a mat with the wet, sticky cake usually obtained. Filtration data and analytical results are outlined in Table IV.

In addition to these leaf tests, three runs were made on the pilot plant 3' x 1' FEinc filter. For all runs satin nylon filter cloth with a Saran fly screen backing was used. The wash blanket was also Saran. Data and analytical results are shown in Table V.

The first two FEinc filtrations were unsuccessful; Number 1 because of the poor discharge, and Number 2 because of the lowered washing efficiency resulting from efforts to improve the cake discharge. Run Number 3, to which 7 1/2 pounds of dry newspaper per 100 gallons of slurry had been added, was most successful, giving an excellent cake discharge at a rate of 6 to 8 lbs./hr.ft². The residual uranium content of the cake was 0.04 to 0.08% uranium for a cake initially analyzing 1.37% uranium.

FEinc filtration of reslurried Airport AJ-4, therefore, may be seen to be handicapped in that newspaper pulp must be added to the slurry in order to insure adequate washing and filter operation.

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TABLE IV

Leaf Filtration Tests of Airport AJ-4 Cake
Slurried in Plant Neutralizer Liquor

Analysis of Initial AJ-4 Composite (Runs 1-9)
% U = 1.25 % H₂O = 14.4

Analysis of Plant Neutralizer Liquor
U = 0.39 gm/l

Run Number	Initial Solids	Temperature	Equivalent Drum Speed FEinc Filter	Vacuum	Filtrate Volume	Wash Water Volume	Cake Thickness	Cake Weight	Equiv. FEinc Cake Production Rate	Analyses			Comments
										Cake		Filtrate	
	lb/gal.	°F.	MPR	in Hg	ml	ml	in.	gm.	lb/hr-ft ²	% U	% H ₂ O	U gm/l	
1	4.09	191	1	15-17	120	100	1/32	54	71.1	--	--	--	Progress of all runs was much the same. A wet, sticky cake which seemed to wash through cloth was obtained in all cases. Leaf discharge of cake was fair. String discharge was poor.
2	3.81	196	5	12-13	250	270	3/32	107	28.5	0.06	26.1	4.18	
3	3.91	208	5	12-13	400	270	3/16	141	37.3	--	--	--	
4	4.02	190	5	12-13	250	430	1/8	64	17	0.07	26.7	3.12	
5	4.15	200	5	12-14	250	660	1/8	65	17.3	--	--	--	
6	4.10	194	10	12-13	400	400	1/8	124	16.4	0.06	23.6	--	
7	4.15	194	10	12-13	400	370	1/8	147	19.4	0.08	24.7	--	
8	4.10	188	15	13	550	450	3/16	148	13	0.08	23.9	--	
9	4.25	190	15	13	550	570	3/16	146	12.8	0.08	24.5	--	
1A	4.69	170	10	13-14	310	210	1/16	104	13.8	0.12	24.6	5.0	0.1 lbs./gal dry newspaper pulp added on Runs 1A-4A. No change in cake discharge.
3A	4.84	170	10	13-14	290	240	1/16	92	12.2	--	--	--	
2A	5.40	180	15	13-14	500	220	1/8	158	13.9	0.20	23.8	5.9	
4A	4.67	180	15	13-14	400	345	1/8	112	9.9	--	--	--	

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TABLE V

FEine Filtration of Airport AJ-4 Cake
Slurried in Sodium Carbonate Solution (0.25 lbs./gal.)

Run Number	Initial Slurry Solids Lbs./Gal.	Length of Run Hr.-Min.	Weight Cake Collected Lbs.	Cake Production Rate Lbs./hr.-ft ²	Slurry Volume Gallons	Slurry Filtrate Rate Gal./hr.-ft ²	Volume of Wash Water Gallons	Wash Water Rate Gal./hr.-ft ²	Drum Speed MPR	Vacuum, inches Hg	Cake Thickness Inches	Estimated % Discharge	Filtration Temperature OF.	ANALYSES						
														Filtrate	Original AJ-4 Cake		Unwashed Cake		Washed Cake	
															U, gm/l	% U	% H ₂ O	% U	% H ₂ O	% U
1	3.67	1:50	72	4.17	20	1.16	13	0.75	15	15 to 16	1/8	50-70	145 to 200	---	---	---	---	---	0.08	20.2
1B	3.92	1:30	52	3.69	28	1.98	3	0.23	15	15 to 16	1/8	80-95	180 to 200	---	---	---	0.27	18.8	0.16	18.9
3	4.2	1:00	54.5	5.79	26	2.76	Wash water meter broken. 40 gallons waste wash water from entire run.		15	15 to 16	1/8-3/16	100	202 to 208	4.9	1.37	20.4	0.14	---	0.04	---
	3.97	1:00	79	8.4	22	2.34			10	15 1/2 to 16	1/8	100	190 to 208	4.9			---	---	0.07	---
	3.48	1:00	80	8.5	24	2.55			7	15 1/2	1/8-3/32	80-100	190 to 194	4.6			---	---	0.05	---
	3.28	0:30	36	7.66	12	2.55			5	15 1/2	1/16	20-30	194 to 198	4.6			---	---	0.04	---
	3.42	1:00	60.5	6.44	22	2.34			7	15 1/2 to 16	3/32	75	195 to 200	3.6			---	---	0.08	---
	3.43	1:00	85.5	9.1	40	4.25			7	15 1/2 to 16	3/32	70-75	190 to 198	4.9			---	---	0.05	---

Oliver Precoat Filtration of Returned AJ-4 Slurries:

A series of runs was made with the Pilot Plant 3' x 1' Oliver Precoat Filter using John Mansville, Hy-Flo Super Cel precoat over a Vinyon 1114 cloth with a backing of Saran matting. In general, the series of runs was very successful with the exceptions of some foaming in the slurry tank and settling of solids in the Filter Bowl. Both these problems will be discussed in more detail later in this report. Data and results for the series of runs are given in Table VI.

As can be seen in Table VI, residual uranium in the Oliver Precoat Filter cake varied from 0.04 to 0.10% (with the exception of Runs 8, 9, and 10 made with the one batch of AJ-4 cake previously mentioned). The initial cake varied from 0.52 to 1.35% uranium.

The variation of cake production rate and slurry filtration rate with slurry solids content and drum speed may be observed in Graph #2. For the two drum speeds plotted, the slower speed (1.38 RPM) would require re-precoating twice a day while the faster speed (3 RPM) would require precoating at least once a shift. These estimates are based on an initial precoat thickness of 1 3/4 to 2 inches and using a cake cut of 0.002 per revolution. As can be seen, the cake production rate varies from about 20 lbs./hr.ft² for a 2 lb./gal solids in slurry at 1.38 RPM drum speed to about 30 lbs./hr.ft.² for a 4 lb./gal solids in slurry at 3 RPM drum speed.

Consideration of the data collected, indicates that a residual uranium content equal to or less than 0.1% in the final cake cannot be guaranteed if the particular batch of AJ-4 cake used for Runs 8, 9, and 10 is representative of more than a minor fraction of all the Airport AJ-4.

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TABLE VI

Oliver Precoat Filtration of Airport AJ-4 Cake
Slurried in Sodium Carbonate Solution (0.25 lbs./gal.)

Note: Filtrate from all runs contained a negligible amount of solids.

Run Number	Initial and Final Slurry Solids Lbs./gal.	Length of Run hr.-min.	Weight Cake Collected Lbs.	Cake Production Rate Lbs./hr.-ft ²	Slurry Volume Gal.	Slurry Filtrate Rate Gal./hr.-ft ²	Volume of Wash Water Gallons	Wash Water Rate Gals./hr.-ft ²	Drum Speed RPM	Vacuum Inches Hg.	Cake Thickness Inches	Cake Cut Inches	Filtration Temperature °F.	Analyses					
														Original AJ-4 Cake		Unwashed Cake		Washed Cake	
														% U	% H ₂ O	% U	% H ₂ O	% U	% H ₂ O
2	3.7	1:05	205	20.1	57	5.6	8	0.79	1.2	15	3/32- 3/16	0.002	170	--	--	0.24	20.2	0.10	21.6
5	4.09- 5.0	2:00	540	28.6	142	7.55	--	--	1.38	19-20	1/16+	0.002	170 to 190	0.53	13.1	0.11	19.2	0.05	20.2
6	4.3- 5.09	1:15	579	49.3	162	13.8	--	--	3	19	1/12- 1/8	0.002	184 to 200	0.82	14.6	0.21	26.0	0.10	25.6
7	4.29- 4.7	0:40	298	41.6	84	13.4	--	--	3	19	1/32+	0.002	175 to 185	0.82	15	0.13	22.0	0.04	21
8	4.2- 5.2	2:05	413	21.1	130	6.63	5.5	0.28	1.38	19	1/16- 1/8	0.002	190 to 202	1.35	17	0.33	20.4	0.17	19.8
9	3.0- 3.9	1:22	327	25.5	134	10.43	3	0.23	1.38	18-19	1/16	0.002	175 to 204	1.2	15.4	0.26	21	0.17	21.4
10	3.02- 4.3	0:50	409	52.2	144	18.4	1.5	0.19	3	18-20	1/16+	0.002	190	1.17	17	0.23	23	0.14	23
11	2.1- 2.8	1:25	258.5	19.4	150	11.3	1.5	0.11	1.38	18-15	1/32+	0.002	190 to 200	0.80	18	0.17	22	0.10	25
12	2.01- 2.9	0:40	219	35.0	136	21.7	1.2	0.19	3	16-19	1/32+	0.002	190 to 200	--	--	0.14	24	0.09	23

GRAPH NO.2
OLIVER PRECOAT FILTRATION OF RETURNED AJ-4 SLURRIES

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GENERAL PROBLEMS ENCOUNTERED IN
PILOT PLANT PROCESSING OF AIRPORT AJ-4 CAKE

Several problems were encountered in pilot plant processing of AJ-4 cake which must be considered regardless of the type of filtration equipment recommended. These problems arose in connection with:-

1. Slurrying of Airport AJ-4 cake.
2. Settling of sand in filter bowls or overhead feed tank.
3. Foaming of AJ-4 slurry during processing.

Slurrying of Airport AJ-4 Cake:

Considerable difficulty was experienced in slurrying the Airport AJ-4 cake in liquor due to (a.) the hard, lumpy (up to 6" diameter) nature of agglomerated AJ-4 resulting from weathering, (b.) the wet, sticky nature of moistened AJ-4, and (c.) the presence of from 1/2 to 3% foreign matter (rock, gravel, etc.) greater than 1/4" in size. The only practical solution discovered for pilot plant work was wet screening using the following procedure:-

- a. A 6 mesh screen, tacked on the bottom of a 2' square box, was placed over the opening of the slurry tank.
- b. Liquor was recycled from the slurry tank through a 1" hose to the end of which a 45° stainless steel funnel, measuring 10" in diameter at the base, was attached to minimize splashing. Handles were attached to the base of this funnel so that it could be used as an aid in breaking up lumps.
- c. Airport AJ-4 cake was then forced through the screen by the combined force of the recycled slurry stream and the abrasive action of the edges of the funnel.

Initial slurrying was done using hot neutralizer liquor (0.2-0.25 lbs./gal Na_2CO_3). Even after several hours of agitation and recycling through a 3/4" centrifugal pump, however, approximately 5-10% of the original screened AJ-4 cake remained in the form of small (up to 1/8" diameter) nodules. These nodules caused frequent clogging of pipes. It was not proven whether the uranium was leached from these nodules.

Beaker experiments were done in which AJ-4 was added to cold water, hot water, and hot neutralizer liquor to form 1.6 lbs./gal. wet solid slurries. After stirring for 30 minutes, the slurries were decanted and the heavy material remaining in the bottom of the beaker examined. Results showed heavy nodule formation in the neutralizer liquor, very light formation in the cold water, and no nodules in the hot water.

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Subsequent slurrying operations in 150 gallon batches at 4 lbs./gal. confirmed these observations. Adding sufficient Na_2CO_3 to the water initially to obtain a pH of 7 in the final slurry (to allow use of steel equipment) produced no observable differences in nodule formation from water reslurrying alone. At least three analyses may be cited to show that addition of Na_2CO_3 to the slurry after hot water slurrying does not have a deleterious effect on uranium leaching; Runs 7, 11, and 12 (Table VI) which yielded cakes analyzing 0.04, 0.10, and 0.09% uranium respectively. Runs 8, 9, and 10 (Table VI), for which this method of slurrying was also used, produced cake with 0.14 to 0.17% uranium. However, this high residual uranium is felt to be attributable to sodium carbonate insoluble uranium as previously discussed on Page 6.

Settling of Sand During Processing:

Prior to the development of the hot water slurry operation to eliminate nodule formation, trouble was encountered with plugging of pipe lines and settling of nodules in the slurry tank. This trouble was eliminated by institution of the hot water slurrying, but was replaced by an increased amount of "sand" settling out in the rotary drum filter bowl. As much as 30-40 pounds, out of a total of 300-400 pounds of cake recovered in a 1-2 hr. run, settled out in the bowl on several runs.

This same problem was also encountered in settling of solids in the constant head feed tank for the horizontal Bird centrifuge runs using Plant AJ-4 slurry to which Airport AJ-4 had been added.

Time did not permit any further work towards solution of this problem or an examination of the problem involved in recovering the residual uranium in this "sand".

Foaming of AJ-4 Slurry During Processings:

Some difficulty was encountered with foaming of all AJ-4 slurries during slurrying operations and processing. This trouble was more pronounced for Plant AJ-4 slurries to which Airport AJ-4 had been added, and most pronounced for a reslurry in neutralizer liquor of the Bird cake obtained from the above slurry.

Beaker scale testing of a limited number of wetting agents indicated that the following four non-ionic wetting agents would break foam induced in such a slurry by the addition of a small amount of nitric acid:

1. Triton-NE (a 33% water solution of Triton X-100).
2. Nonic #218.
3. Synthetics B-79.
4. Tergitol Dispersant NPX (S-40620).

Time did not permit testing of these wetting agents on a larger scale.

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DISCUSSION OF RESULTS

Pilot Plant work on the recovery of residual uranium in Airport AJ-4 cake has indicated that major factors regarding a proposed process may be considered under three main categories.

1. Method of slurrying AJ-4 cake for introduction into a plant process.
2. Amount of leaching necessary to insure the desired recovery of uranium.
3. Type of equipment, or process, best suited for processing the material.

Method of Slurrying AJ-4 Cake:

Wet screening of AJ-4 cake to obtain a slurry as was done in pilot plant work is hardly applicable to a large scale installation. Several methods have been suggested which might be suitable for a plant process, among them being:

1. Use of a Denver Cross-Flow Classifier.
2. Use of a Cone Tank Classifier.
3. Use of Tank M-20, which tank contains a perforated plate with 1/4" holes and a turbine type agitator both above and below the perforated plate.

None of these suggestions seem readily amenable to pilot plant testing.

The suggested use of a Denver Cross-Flow Classifier was followed up by contacting Mr. Eusilac of the Chicago Office of Denver Equipment Company. An interview resulted in Mr. Eusilac's recommendation that this equipment could not be used for initial slurrying of the AJ-4 cake, but would take care of eliminating the "sand" after the material was in a slurry form. He did not know of any equipment available on the market applicable to such a slurrying operation.

The use of a cone tank would be advantageous in that it would eliminate most of the sanding problem. However, the question has been raised if sufficient agitation would prevail in such a tank to break up the lumps of AJ-4 cake. It is felt that pilot plant testing using a small cone would still not provide a definite answer to this question.

The use of tank M-20 would be most convenient of the three suggestions since this would involve no new equipment. However, objections have been raised to this possibility involving the expected frequency of tank clean outs that might be required with a not-too-accessible, radioactive tank. In addition, use of this tank would still leave the "sand" which would tend to settle out in either a constant head tank or a filter bowl.

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Extent of Leaching Necessary:

A review of the residual uranium content of cake produced in the various pilot plant leachings allows the following generalizations to be made regarding minimum leaching efficiencies.

TABLE VII

Operation	Percent of uranium in AJ-4 cake after operation specified.
Initial slurry - up to 4 lbs./gal Na_2CO_3 solution.	0.2 to 0.3%
Water wash of above or an initial slurry of 1 1/2 lbs. of Airport AJ-4 cake per gal. of Plant AJ-4 slurry	0.1 to 0.2%
Reslurry - up to 4 lbs./gal. in 0.25 lbs./ gal Na_2CO_3 solution.	0.05 to 0.1%
Water wash of above or reslurry in 0.25 lbs/gal Na_2CO_3 solution of Bird Cake from an initial slurry of 1 1/2 lbs. of Airport AJ-4 Cake per gal. of Plant AJ-4 slurry.	0.01 to 0.06%

This tabulation excludes the possibility of there being a greater amount of sodium carbonate insoluble uranium than the 0.05% found in the one batch tested that produced the highest results in pilot plant work. To insure the limits given above, in such a case, it would be necessary to include a weak nitric acid leach in the process.

A two stage leaching with at least one stage of washing for Airport AJ-4 processed alone, or two stage leaching for Airport AJ-4 cake blended with plant AJ-4 slurry appears to be essential in producing a cake containing 0.1% or less residual uranium.

Most Suitable Type of Equipment:

A tentative criterion which calls for reprocessing of approximately 3,000,000 pounds of Airport AJ-4 cake in one year with 92.5% uranium recovery (0.1% or less uranium in residual cake) was established for evaluation and comparison of the filtration equipment tested. Assuming 300 working days a year then, 10,000 pounds of Airport AJ-4 per day must be handled in order to meet this goal. Each unit of equipment, or process, will be considered in the order previously discussed.

1. Vertical centrifuge.
2. Horizontal Bird centrifuge.
3. FEinc filter.
4. Oliver precoat filter.

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Vertical Centrifuge:

Pilot Plant work showed that a vertical centrifuge could be operated at a production rate of about 2500 lbs./day for a 20 hour day (125 lbs./hr.) using a 2 lbs./gal. slurry of Airport AJ-4. Washing was not possible, and operation would require at least one full time operator. It is not felt to be desirable to consider installation of a second centrifuge since this unit was tested mainly because it is available and not in use.

No further consideration was given the vertical centrifuge because:

1. The production figure attained indicates that about four years would be required to reprocess the Airport AJ-4 cake.
2. The residual uranium might be as high as 0.2 to 0.3% as previously discussed.

Horizontal Bird Centrifuge:

No consideration will be given to centrifugation of Airport AJ-4 slurried separately from Plant AJ-4 since the present production capacity for the plant Bird centrifuges allows no time for such a procedure, and it is not felt advisable to consider purchase of additional units. Several procedures may be examined for processing Airport AJ-4 combined with plant AJ-4 cake in the present system. They are:

1. Addition of Airport AJ-4 to the present system at Tank M-70 as the first slurry in a 2 stage, counter-current leaching system using neutralizer liquor (0.2 to 0.25 lbs./gal. Na_2CO_3).
2. Addition of Airport AJ-4 to the present system at Tank M-70 as the first slurry in a two stage leaching system using fresh neutralizer liquor for each stage.
3. Addition of Airport AJ-4 to the present system at Tank M-75 for a weak acid leach prior to a two stage counter-current leach using neutralizer liquor.

Pilot plant work has shown that centrifugation of Plant AJ-4 slurry, spiked with as much as 2 lbs./gal. of Airport AJ-4 cake, is no different operational-wise from Plant AJ-4 slurry. Residual uranium in the cake from such a spiked slurry ranged from 0.04% to 0.15% for the first centrifugation. Three runs with Bird cake from the initial centrifugation reslurried in neutralizer liquor yielded analyses from 0.04 to 0.06 for residual cake uranium.

Thus, addition of 1 1/2 pounds of Airport AJ-4 cake per gallon of Plant AJ-4 slurry at the present rate of about 6.3 gal./min. would yield a production rate of 11,330 lbs./day of Airport AJ-4 cake for a 20 hour day. It has also been demonstrated, for a limited number of runs, that the criterion of 0.1% or less residual cake uranium is obtainable at least for System Number 1.

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Calculations are attached in the Appendix to show that the 0.1% criterion should be met even for a maximum of 1% uranium in Plant AJ-4 cake with a maximum of 2.5% uranium in Airport AJ-4 cake, assuming that all the uranium is sodium carbonate soluble. These calculations also indicate that the residual uranium in the final cake from a two stage leaching system using fresh liquor for each stage is so close to the residual uranium for a counter-current system (.0225% uranium as opposed to 0.0250% uranium), that it would hardly be worthwhile, considering the 7500 gal./day of extra liquor that would have to be handled.

A third set of calculations is included in the Appendix to show the residual uranium content which might be expected from system 3 with an initial acid leach. Data from Table I indicates that about 40% of the initial uranium in Airport AJ-4 cake is acid soluble, which decrease in uranium entering the 2 stage, counter-current leach should yield a final cake containing about 0.02% uranium. System 3, then, would be the most efficient process with respect to leaching, yielding the lowest residual uranium cake.

FEinc Filter:

Pilot Plant work on the FEinc filter showed that 4 lbs./gal. Airport AJ-4 slurry to which 0.05 to 0.1 lbs./gal. dry newspaper had been added could be filtered and washed successfully giving a cake production rate of 6 to 8 lbs./hr.ft² and a residual uranium in the cake of 0.04 to 0.08%. Assuming 20 hours of operation a day, 10,000 lbs./day production would require a filtration area of from 62.5 to 83.3 ft² for the 6 to 8 lbs./hr.ft² cake production rate. This figure is so much larger than the area required for Oliver precoat filtration that no further consideration will be given to FEinc filtration for this job.

Oliver Precoat Filter:

Pilot plant work on the Oliver precoat filter showed that a cake production rate of from 20-50 lbs./hr.ft² could be attained using Airport AJ-4 slurry at from 2 to 4 lbs./gal. solids content. Uranium analyses of final cake ranged from 0.04 to 0.1%.

If a cake production rate of 35 lbs./hr.ft² (for a 2 lbs./gal. slurry filtered at a drum speed of 3 rpm) is used and assuming 18 hours of operation a day (to allow for precoating a maximum of once a shift), a production rate of 10,000 lbs./day would require 15 ft² of filtration area. However, two stages of filtration are indicated if the criterion of 0.1% or less residual uranium is to be met.

Even if some method could be worked out so that two stages of leaching could be obtained using the same filter to eliminate the cost of installing a

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second filter; the possibility of a higher sodium carbonate insoluble uranium content than the 0.05% found in the one bad batch tested in pilot plant work to date poses a problem for which no easy solution is visible with this process.

A rough cost estimate for a one stage Oliver Precoat Filtration Process can be placed at \$35,000 to \$40,000. A two stage process would cost in the range of \$50,000 to \$60,000.

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CONCLUSIONS

The following conclusions may be drawn from the work described in this report.

1. One stage leaching of Airport AJ-4 cake with 0.25 lbs./gal. Na_2CO_3 solution at a wet solids concentration of 4 lbs./gal. should yield a cake with a maximum of about 0.3% uranium.
2. One stage leaching of Airport AJ-4 cake with 0.25 lbs./gal. Na_2CO_3 solution at a wet solids concentration of 4 lbs./gal. followed by a water wash at a rate of 1 gallon of wash water per gallon of slurry should yield a cake with a maximum of about 0.2% uranium.
3. A second leaching of Airport AJ-4 washed cake with 0.25 lbs./gal. Na_2CO_3 solution at a wet solids concentration of 4 lbs./gal. should yield a cake with a maximum of about 0.1% uranium.
4. A second leaching of Airport AJ-4 washed cake with 0.25 lbs./gal. Na_2CO_3 solution at a wet solids concentration of 4 lbs./gal. followed by a water wash at a ratio of 1 gallon of wash water per gallon of slurry should yield a cake with a maximum of about 0.06% uranium.
5. Addition of 1 1/2 lbs. of Airport AJ-4 cake to one gallon of Plant AJ-4 slurry with subsequent centrifugation on a horizontal Bird centrifuge should yield a cake with a maximum of about 0.2% uranium.
6. A second leach of Bird centrifuge cake (from a slurry consisting of 1 1/2 lbs. of Airport AJ-4 cake per gallon of Plant AJ-4 slurry) with 0.25 lbs./gal. Na_2CO_3 solution followed by a Bird centrifugation should yield a cake with a maximum of about 0.06% uranium.
7. Introduction of Airport AJ-4 cake into a slurry form presents a major problem which has not yet been solved.
8. Settling of fine solids ("sand") in processing equipment such as filter bowls or constant head feed tanks presents a problem.
9. The recovery of residual uranium in the "sand" which cannot be handled in ordinary equipment might be a problem.
10. Foaming of AJ-4 slurries during processing might be controlled by the addition of one of several non-ionic wetting agents
11. Use of the vertical basket centrifuge in the old calcium nitrate area for recovery of AJ-4 is not recommendable due primarily to the low production rate.
12. Use of a FEinc filter for recovery of Airport AJ-4 is not recommendable due primarily to the greater size of filter required than for other equipment tested.

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13. Use of an Oliver precoat filter for recovery of AJ-4 cake is not recommendable due primarily to the prohibitive cost of the process equipment needed.
14. Recovery of the uranium in Airport AJ-4 cake can be accomplished satisfactorily by adding this cake to the present plant AJ-4 slurry either at the last acid stage (Tank M-75) or the first neutralizer stage (Tank M-70).

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RECOMMENDATIONS

It is recommended that production plans be scheduled to include reprocessing of Airport AJ-4 cake combined with Plant AJ-4 slurry in the present plant Bird centrifuge system for the following reasons:

1. The ability, as indicated by the work reported here, of the present plant system to handle up to 10,000 lbs./day of Airport AJ-4 cake with satisfactory recovery of uranium and involving no appreciable increase in liquor volume or other operational difficulties.
2. The prohibitive cost of the Oliver Precoat or FEinc filter installation necessary to yield the same uranium recovery.
3. The demonstrated inability of the existing vertical centrifuge in the calcium nitrate area to process the Airport AJ-4 through only one stage of leaching in less than four years.

It is further recommended that the necessary work required to develop a procedure for introduction of Airport AJ-4 cake to Plant AJ-4 slurry, and to develop a method for satisfactory recovery of the uranium in the "sand" that will be produced, be initiated. It is suggested that such work might include:

1. Testing of slurry operations in a cone settling tank on as large a scale as possible to determine if sufficient agitation can be obtained in such a unit to break up the larger lumps of AJ-4 cake.
2. Slurrying of Airport AJ-4 cake in M-70 slurry using Tank M-20 in order to obtain some idea of the feasibility of using this tank and the problems involved.

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APPENDIX

1. Calculation of uranium content of cakes to be expected from Bird centrifugation of Plant AJ-4 slurry fortified with 1 1/2 lbs./gal. of Airport AJ-4 followed by a reslurry of such cake in Plant Neutralizer Liquor (0.25 lbs./gal. Na_2CO_3).

Assumptions:

All uranium is sodium carbonate soluble.

Volume change on addition of Airport AJ-4 cake is negligible.

Amount of AJ-4 cake soluble in Plant Neutralizer Liquor is negligible.

Maximum uranium content of Plant AJ-4 cake - 1%.

Maximum solids content of Plant AJ-4 slurry - 2.5 lbs./gal.

Maximum uranium content of Airport AJ-4 cake - 2.5%.

Amount of Airport AJ-4 cake to be added per gallon of Plant AJ-4 Slurry - 1.5 lbs./gal.

Average moisture content of Bird Cake - 25%.

Uranium remaining in cake is only that associated with water in cake.

One gallon slurry contains 8.33 lbs. of water.

Basis of Calculation: One gallon of slurry.

Amount of uranium present from Plant AJ-4 cake
= 2.5 lbs. cake/gal. (0.01 lbs. U/lbs. cake) = 0.025 lbs.U/gal.

Amount of uranium present from Airport AJ-4 cake
= 1.5 lbs. cake/gal. (0.025 lbs.U/lbs. cake) = 0.0375 lbs.U/gal.

Total uranium present in slurry = 0.0625 lbs.U/gal.

4 lbs. of cake @ 25% moisture contains: 4 (0.25) = 1 lb. H_2O /4 lbs. cake

Amount of uranium remaining in cake after one leach is:

1 lb. H_2O /4 lbs. cake (0.0625 lbs. U/gal) = 0.0075 lbs. U/4 lbs. cake
8.33 lbs. H_2O /gal.

0.0075 lbs. U
4 lbs. cake (100) = 0.1875% U in cake from first stage.

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Amount of Uranium remaining in cake after second leach is:

$$\frac{1 \text{ lb. H}_2\text{O} / 4 \text{ lbs. cake (4 lbs. cake/gal.)}}{9.33 \text{ lbs. H}_2\text{O/gal.}} (0.0075 \text{ lbs. U} / 4 \text{ lbs. cake}) = 0.0009 \text{ lbs. U} / 4 \text{ lbs. cake}$$

$$\frac{0.0009 \text{ lbs. U}}{4 \text{ lbs. cake}} (100) = 0.0225\% \text{ U in cake from second stage.}$$

2. Calculation of uranium content of cakes to be expected from two stage counter-current Bird Centrifugation of Plant AJ-4 slurry fortified with 1 1/2 lbs./gal. of Airport AJ-4.

Assumptions: Same as previous calculation.

Basis of Calculation: One gallon of slurry.

A material balance on the process yields the following equations:

$$(a) \quad y + 7.33/8.33 \, b = 0.0625$$

$$(b) \quad 7.33/8.33 \, a + 0.0625 = x + 7.33/8.33 \, b$$

$$(c) \quad 7.33/8.33 \, a + y = x$$

In addition, since each 4 lbs. of cake contains 1 lb. of H₂O.

$$(d) \quad x = 1/1 + 7.33 \, b$$

$$(e) \quad y = 1/1 + 7.33 \, a$$

Substituting for y in equation (c) using equation (e)

$$7.33/8.33 \, a + 1/8.33 \, a = x$$

$$a = x$$

Substituting x for a in equation (b) and eliminating b by using equation (d)

$$7.33/8.33 \, x + 0.0625 = x + 7.33/8.33 (8.33x)$$

$$7.45 \, x = 0.0625$$

$$x = 0.0625/7.45 = 0.00839 \text{ lbs. U} / 4 \text{ lbs. cake}$$

0.00839 lbs. U/4 lbs. cake (100) = 0.21% U in cake from first stage.

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solving for y from equation (e)

$$y = 0.00839/8.33 = 0.00101 \text{ lbs. U/4 lbs. cake}$$

0.00101 lbs. U/4 lbs. cake (100) = 0.0252% U in cake from second stage

3. Calculation of uranium content of cakes to be expected from a two-stage, counter-current Bird centrifugation of Plant AJ-4 slurry fortified with 1 1/2 lbs./gal. of Airport AJ-4 assuming that 40% of the uranium in Airport AJ-4 is removed in a prior acid leach*.

Additional assumptions: Same as previous calculations.

Basis of Calculation: One gallon of slurry.

Amount of uranium present from Plant AJ-4 cake
= 2.5 lbs. cake/gal. (0.01 lbs. U/lbs. cake) = 0.025 lbs. U/gal.

Amount of uranium present from acid leached Airport
AJ-4 cake =
1.5 lbs. cake/gal. (.60)(0.025 lbs. U/lbs. cake) = 0.0225 lbs. U/gal.

Total uranium present in slurry 0.0475 lbs. U/gal.

Using the same material balance as in calculations in part 2, one may substitute 0.0475 for 0.0625 to obtain:

$$x = 0.0475/7.45 = 0.00638 \text{ lbs. U/4 lbs. cake}$$

0.00638 lbs. U/4 lbs. cake = 0.16% U in cake from first stage.

and

$$y = 0.00628/8.33 = 0.00077 \text{ lbs. U/4 lbs. cake}$$

0.00077 lbs. U/4 lbs. cake (100) = 0.0192% U in cake from second leach.

* See Table I.

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