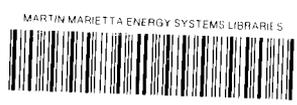


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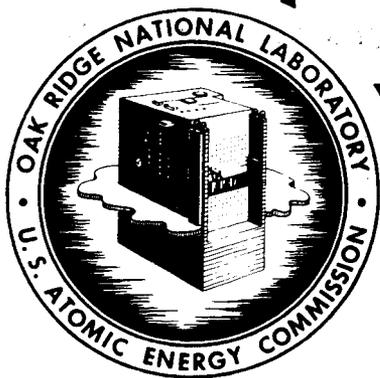
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PROGRESS REPORT OF ENGINEERING SECTION
RAW MATERIALS PROCESS TESTING

APRIL, 1955



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PROGRESS REPORT OF ENGINEERING SECTION
RAW MATERIALS PROCESS TESTING

April, 1955

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PROGRESS REPORT OF ENGINEERING SECTION
RAW MATERIALS PROCESS TESTING

April, 1955

LONG-TERM TEST OF THE AMINE EXTRACTION PROCESS

In prior studies of the amine extraction process, the effects of most of the important variables on the uranium extraction efficiency, over-all recovery, and product purity have been evaluated in runs of no more than 4 to 6 hours' duration because of the relatively short time needed to reach steady state conditions in the mixer-settler test array. Because of the short duration of the runs, it was not possible to evaluate the effect of time and repeated recycle of the organic phase on uranium recovery and the nature and distribution of organic losses. Consequently, a run was made which was long enough to obtain 200 complete cycles of the organic phase; the equivalent of about 200 hours' operation of a typical extraction plant.

The mixer-settler test array contained three mixer-settlers in the extraction section, two mixers that were operated with cocurrent flows and a combined settler-surge-tank in the stripping section as shown in Fig. 1. Raffinate leaving the extraction section was collected in carboys to facilitate recovery of entrained organic phase as well as to provide a true composite sample for determination of uranium losses.

The aqueous feed was a synthetic leach liquor, similar in composition to a "typical" Marysvale liquor (ORNL-1914). It contained 1 g/l of pentavalent vanadium so that the oxidation potential would be high enough to test the oxidation resistance of the amine. The composition of the feed liquor is given in Table 1. The organic phase was a 0.1 molar solution of amine 9D-178 in kerosene. Prior to use the organic was scrubbed with 10 volumes of 3% sulfuric acid solution to remove any soluble components. The strip solution was a 0.72 M solution of sodium carbonate.

The average flow rates of feed, organic, and strip solution were 8.1, 3.0, and 0.54 l/hr, respectively. The aqueous to organic phase flow ratio was computed by arbitrarily settling the uranium loading in the organic phase at 80% of the maximum loading and assuming that the amine loss would amount

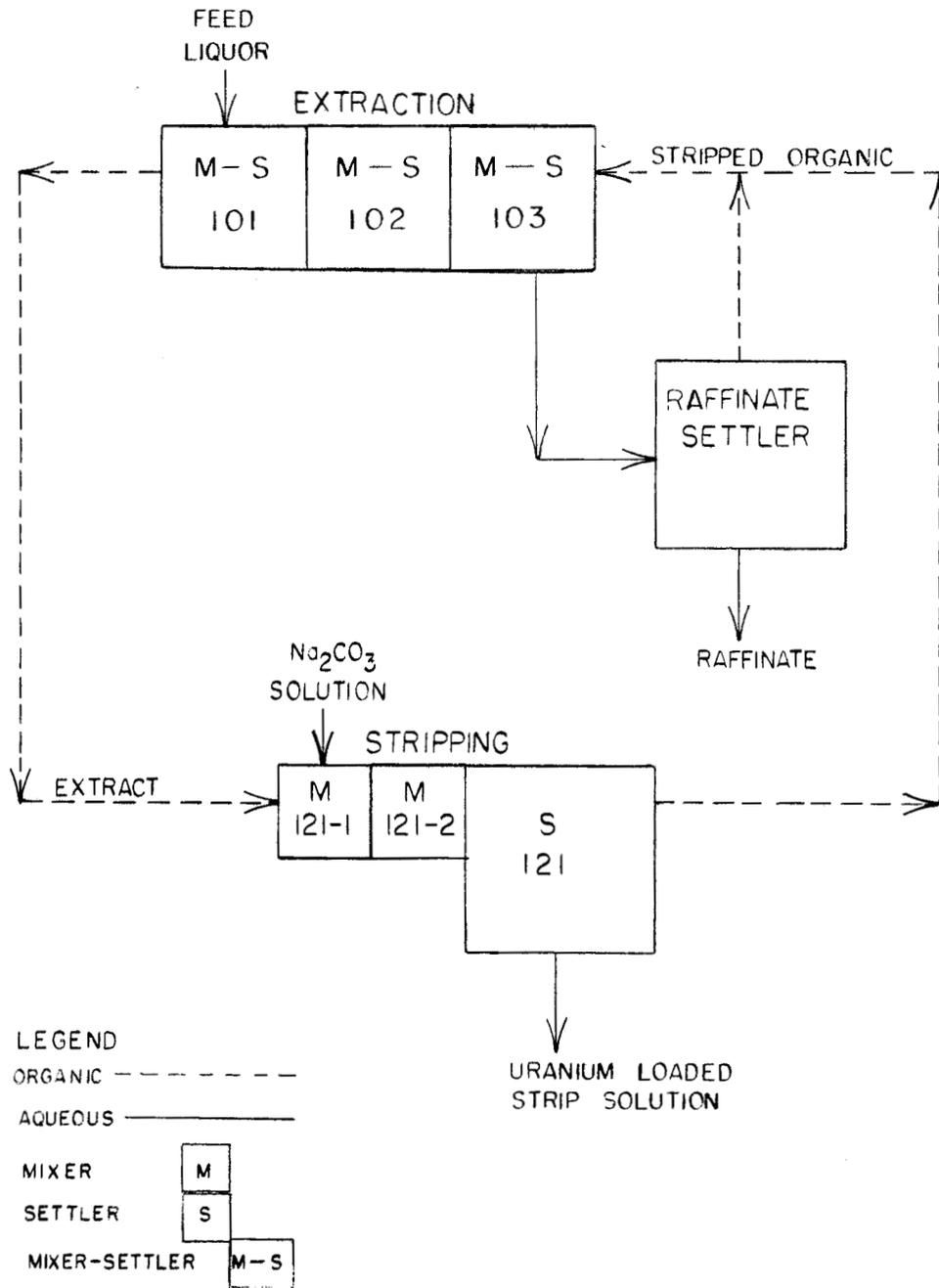


FIGURE 1 — FLOW DIAGRAM FOR LONG TERM TEST

TABLE 1. COMPOSITION OF FEED LIQUOR

(g/l)			
U	1.2	Mo	0.05
Fe ⁺³	2.2	PO ₄	2.1
Al	2.8	SO ₄	36.
V (total)	1.4	pH	1.0
V ⁺⁵	1.0		

to 0.05 moles per 50 cycles of organic. For a 0.095 M amine solution the desired uranium loading 80% maximum was 3.2 g/l and the corresponding ratio was 2.7: 1. The strip solution flow rate provided for a 50% excess of the theoretical requirement of 3 moles of sodium carbonate per mole of uranium and 1/2 mole per mole of amine.

The inventory of organic phase in the system was 1.5 liters and the time required to complete one cycle was 30 min. The total volume of head liquor processed during the run was 820 liters containing 1,170 grams of U₃O₈. The raffinate and loaded strip were collected as composites for periods of operation equivalent to about 24 cycles of the organic phase. Grab samples were collected periodically from interstage streams for uranium analysis and from the stripped organic surge tank for determination of the amine concentration. When necessary, the amine concentration in the organic phase was adjusted to the desired value by adding a concentrated solution (0.62 M) to the system.

Loss of Organic Phase

The total loss of amine and kerosene was determined by inventories at the beginning and end of the run. In addition, the concentration of amine in the organic phase was measured periodically during the run to show the rate of loss of the amine from the organic phase. The material balance is shown in Table 2. The volume loss during the run was 207 ml of which less than 57 ml was due to entrainment (<0.07 ml/l)* of organic in the raffinate; the remaining loss probably was due to evaporation, leakage and spray.

The total loss of amine was 0.0939 mole of which 0.0197 mole was associated with the 207 ml of organic phase lost. The remaining 0.0742 mole represents the amine lost through

*Analysis of raffinate by steam distillation.

TABLE 2. ORGANIC PHASE MATERIAL BALANCE

	Volume, ml	Amine Concentration, molarity	Moles of Amine
<u>In</u>			
Inventory at start	1,485	0.0942	0.1398
Additions			
at 50 cycles	68.	0.618	0.0420
at 80 cycles	17.6	0.618	0.0109
at 110 cycles	14.6	0.618	0.0090
at 140 cycles	17.5	0.618	0.0108
at 170 cycles	<u>14.6</u>		<u>0.0090</u>
	1,617		0.2215
<u>Out</u>			
Samples	20	0.0752	0.0015
	20	0.0940	0.0019
	20	0.0946	0.0019
	20	0.0934	0.0019
	20	0.0923	0.0018
Final Inventory	<u>1,310</u>	0.0905	<u>0.1186</u>
	1,410		0.1276
<u>Loss (by diff.)</u>			
Volumetric	207	0.095	0.0197
Solubility and Degradation	-	-	<u>0.0742</u>
Total amine loss	-	-	0.0939

solubility and degradation as shown in Table 3. The amine loss per cycle due to solubility and degradation was estimated by assuming that the volume loss was evenly distributed over the entire run. The losses shown in Table 3 were equivalent to 56 ppm of raffinate for the first 50 cycles after which they were nearly constant at an average of 36 ppm.

TABLE 3. SUMMARY OF AMINE LOSS

Accumulative Cycles of Organic	Amine Conc. in Organic, molarity Analysis Adjusted to		Loss per Cycle, gms	Loss as ppm of Aqueous Phase
0	0.0942	-	-	-
50	0.0752		0.227	56
59		0.1001		
80	0.0940		0.138	34
90		0.1002		
110	0.0946		0.134	33
114		0.1000		
140	0.0934		0.146	36
144		0.1000		
170	0.0923		0.162	40
174		0.0979		
200	0.0905	-	0.150	37

Laboratory measurement of the solubility of the amine in the synthetic aqueous raffinate has shown the average solubility to be about 35 ppm. Therefore the steady loss of amine (36 ppm) can be assumed to be due to its solubility in the aqueous phase and no significant degradation or oxidation of the amine occurred during the 200 cycle run.

Uranium Recovery

Extraction and Stripping. During the first 47 cycles the uranium loss amounted to only 0.1% of that in the feed as shown by the uranium concentration in the raffinate in Table 4 (0.001 to 0.002 g/l). The loss during the next 23 cycles amounted to 2.7% of the feed, largely because the concentration of the amine in the organic phase decreased to 0.075 molar which was below the minimum required for complete extraction.

TABLE 4. URANIUM DISTRIBUTION

Uranium content of feed liquor, 1.2 g/l

Accumulative Cycles of Organic	Uranium Concentration, g/l				
	Extraction, Aq Phase			Strip	
	101*	102*	103**	Stripped* Organic	Loaded** Aqueous
0	-	-	-	-	-
24	0.22	0.004	0.001	0.13	19.7
47	0.82	0.12	0.002	0.16	17.8
70	1.1	0.90	0.032	0.14	18.2
93	0.16	0.004	0.002	0.11	17.3
116	0.26	0.018	0.009	0.11	18.2
139	0.31	0.008	0.019	0.15	17.8
161	0.36	0.012	0.007	0.14	17.4
184	0.48	0.013	0.006	0.15	20.0
200	0.70	0.11	0.021	0.12	21.1

*Analysis of grab samples.

**Analysis of composite collected during the indicated periods.

The only other operational difficulty was the gradual accumulation of a precipitate of iron and aluminum hydroxide in the stripping section which caused entrainment of loaded strip solution in the barren organic stream returning to the extraction section. The entrainment was intermittent and while at its maximum, enough uranium was carried into the extraction section (unit 103) to cause incomplete extraction. During the last half of the run, uranium losses ranged from 0.5 to 1.8% of that in the feed. This difficulty can be avoided by: (1) withdraw the precipitate and emulsion and recycle it into the second extraction stage where the uranium content will not interfere with the extraction, (2) use two stripping stages arranged for countercurrent flow so that the uranium concentration in the entrained aqueous phase will be low, (3) use a stripping agent such as sodium chloride in which iron and aluminum are soluble and the phase separation is good.

The uranium balance over the entire run is shown in Table 5. The output was 102.9% of the input, which is within the accuracy of the uranium analyses.

Precipitation. The loaded strip composites were combined and the uranium was precipitated with sodium hydroxide after the carbonate had been destroyed with sulfuric acid and boiling. The product was washed with water and dried at 130°C. The compositions of the loaded strip solution and the uranium product are shown in Table 6. The product grade was 85.4% U_3O_8 and the impurities were all less than 1% except for vanadium (2.0%). Comparison of the composition of the strip solution with the product shows that the molybdenum concentration was reduced from 3.8 to 0.61 g/100 gm U in the precipitation step so that only 16% of molybdenum present in the loaded strip solution was precipitated and remained with the uranium product.

Summary of Chemical Consumption

The consumption of chemicals during the run is shown in Table 7. The usage of each, in lbs per lb of U_3O_8 , was based on a total of 2.58 lbs of U_3O_8 processed during the run. The total cost amounted to 16.1 cents per lb of U_3O_8 . The cost of sodium carbonate (8¢) was half of the total cost. The cost due to loss of organic phase was 2.5 cents or 16% of the total chemical cost.

TABLE 5. URANIUM MATERIAL BALANCE

	Accumulative Cycles of Organic	Vol, liters	U, gm	Total U, gm	% of U in Feed
In					
Feed		822	994		
Organic		1.5	0		
Na ₂ CO ₃		54.7	<u>0</u>		
				994	100
Out					
Raffinate	24	94	0.09		
	47	95	0.19		
	70	95	3.0		
	93	94	0.19		
	116	93	0.84		
	139	93	1.8		
	161	92	0.64		
	184	92	0.55		
	200	74	<u>1.6</u>		
				8.9	0.9
Organic Inventory		1.3	1.7	1.7	0.2
Na ₂ CO ₃ Strip Sol'ns	24	6.46	127		
	47	6.21	110		
	70	6.02	110		
	93	6.60	114		
	116	6.33	115		
	139	6.49	115		
	161	6.42	112		
	184	5.65	113		
	200	4.55	<u>96</u>		
				1012	101.8

Output/input = 102.9%

TABLE 6. COMPOSITION OF URANIUM STRIP SOLUTION AND PRODUCT

Constituent	Strip Solution		Product	
	g/l	g/100 g U	%	g/100 g U
Uranium				
as U	18.3	-	72.4	-
as U ₃ O ₈	21.6	-	85.4	-
Iron	0.03	0.18	0.37	0.51
Vanadium	0.5	2.7	2.0	2.8
Molybdenum	0.7	3.8	0.44	0.61
Aluminum	0.08	0.44	0.23	0.32
Phosphate	-	-	0.95	1.3
Loss on Ignition	-	-	5.9	-

TABLE 7. SUMMARY OF CHEMICAL CONSUMPTION

(Basis: 2.58 lb U₃O₈ processed)

Chemical	Total Usage, lbs	Lbs per lb U ₃ O ₈	Unit Price, cents per lb	Cost per lb U ₃ O ₈ , cents
Organic phase				
Amine	0.077	0.0298	75.0	2.24
Kerosene	0.370	0.143	2.00	0.29
Stripping				
Na ₂ CO ₃	9.16	3.55	2.25	7.99
Precipitation				
H ₂ SO ₄	6.59	2.55	1.50	3.83
NaOH	0.960	0.372	4.65	1.73
				16.1

MIXING AND PHASE SEPARATION

The physical properties of the process streams in the amine extraction process have been determined to help define the system and provide data needed for design of plant equipment. In addition, batch tests have been made to determine the effect on phase separation of (1) temperature, (2) phase composition, (3) dispersed phase, and (4) additives for prevention of emulsions. These data serve as a supplement to the study of mixing and phase separation in the single-stage mixer-settler under continuous flow conditions.

Physical Properties

Leach Liquors. The chemical composition and physical properties of one synthetic and four actual plant liquors are shown in Table 8.

Organic Phase. The organic phase was a 0.10 molar solution of Rohm and Haas amine 9D-178 dissolved in kerosene. Samples of organic from different points in the extraction system were taken to determine density and viscosity. These data are shown in Table 9.

Strip Solutions. The density and viscosity of uranium strip solutions are shown in Table 10.

Interfacial Tension. The interfacial tensions of aqueous and organic phases at important points in the system are shown in Table 11.

Batch Phase Separation Tests

A series of batch phase separation tests was made with the five leach liquors shown in Table 1 and various organic phase compositions to determine the effects of composition, type of dispersion, and temperature on the settling rate.

The phases were mixed in a baffled mixer (volume 350 ml, liquid depth 3-5/8 in.) for two minutes, the agitation was stopped, and the time required to obtain 90% of the primary phase separation was measured. The 90% separation point was used, rather than 100%, since this point could be observed more accurately and better comparisons of settling rates could be made. All tests were made with a phase ratio of 2-1/2 aqueous to 1 organic, except as noted.

TABLE 8. PROPERTIES OF LEACH LIQUORS

	Concentration, g/l				
	Synthetic	Plant A	Plant B	Plant C	Plant D
Uranium	1.2	1.1	1.4	5.6	1.1
Vanadium (total)	0.0	0.76	2.7	4.7	4.1
Vanadium as V ⁺⁵	0.0	0.0	1.9	4.0	0.0
Iron (total)	5.6	2.0	0.72	1.3	4.8
Iron as Fe ⁺²	0.24	0.46	0.0	0.0	1.3
Aluminum	3.1	2.7	1.7	2.9	6.6
Molybdenum	0.0	0.08	0.05	0.02	0.01
Titanium	0.0	0.02	0.11	0.11	0.24
Silicon	0.0	0.22	2.4	0.04	0.02
Calcium	0.0	0.63	0.58	0.31	0.64
Sulfate	63.	41.	70.	21.	110.
Phosphate	2.1	0.75	3.8	3.1	0.41
Fluoride	1.0	0.24	0.0	0.32	0.06
Nitrate	0.0	0.32	0.0	3.5	0.0
Chloride	0.0	0.31	1.1	0.27	0.16
pH	1.0	1.1	0.5	0.7	0.5
Density (gm/cc 25°C)	1.050	1.046	1.080	1.082	1.106
Viscosity (centipoise) 25°C	1.12	1.14	1.63	1.25	1.49

TABLE 9. PROPERTIES OF ORGANIC PHASE

AND AMINE REAGENT AT 25°C

[0.1M 9D-178 (Rohm and Haas) in kerosene]

<u>Source and Conditions</u>	<u>Density, gm/cc</u>	<u>Viscosity, Centipoises</u>
Extract stage (3.6 g U/l)	0.828	2.27
After NaCl strip	0.815	2.13
After Na ₂ CO ₃ strip	0.809	1.90
Amine concentrate, as received	0.848	54.3

TABLE 10. PROPERTIES OF URANIUM STRIP SOLUTIONS AT 25°C

<u>Source and Conditions</u>	<u>Density, gm/cc</u>	<u>Viscosity, Centipoises</u>
NaCl (1.0M)		
Barren	1.040	0.90
Loaded (24 g U/l)	1.083	1.12
NaCO ₃ (0.7M)		
Barren	1.069	1.23
Loaded (24 g U/l)	1.099	1.21

TABLE 11. INTERFACIAL TENSION (dynes/cm) AT 30°C

Section	Aqueous	Organic 9D-178 0.1M in kerosene	I.T., dynes/cm
Extraction	Synthetic liquor	Loaded (3.6 g U/l)	6.9
Extraction	Synthetic raffinate	Stripped (NaCl)	4.9
NaCl strip	Loaded strip (24 g U/l)	Loaded 3.6 g U/l	7.0
NaCl strip	1M NaCl sol'n	Stripped	12.4
NaCO ₃ strip	Loaded strip (24 g U/l)	Loaded (3.6 g U/l)	2.0
NaCO ₃ strip	0.7M Na ₂ CO ₃ sol'n	Stripped	<0.5

Comparison of Organic Compositions. The rate of phase separation with synthetic leach liquor was determined using amines 9D-178, trioctyl, and Armeen 2-12 dissolved in either kerosene, kerosene containing 5% capryl alcohol, or Amsco G. No marked difference in phase separation was observed; the average time required for 90% separation with the synthetic liquor was 55 seconds.

Comparison of Leach Liquors. One synthetic and four plant liquors (composition in Table 8) on mixing with amine 9D-178 in kerosene show a gradual increase in the time required for settling with increasing silicon content up to 0.2 g/l of Si. With plant B liquor, which contained 2.4 g/l Si, an emulsion was formed. After 5 minutes only 40% of the aqueous phase was separated and the remaining emulsion was stable for weeks.

Selection of Dispersed Phase. Examination of the emulsion formed during mixing of plant B liquor with organic showed the emulsion was an oil in water type. Further mixing tests showed that the dispersion type in the mixer could be maintained either oil in water or water in oil by controlling the start-up conditions. To obtain the oil in water type dispersion, the aqueous phase was added slowly to the organic phase stirring in the mixer, and vice versa.

In the absence of silica phase separation was faster when the organic phase was dispersed. With head liquors having a high silicon content (e.g., plant B liquor) an emulsion formed that was stable for days when the organic phase was dispersed; with aqueous phase dispersed, very little stable emulsion was formed and 90% phase separation was obtained in less than 3 minutes.

Effect of Additives on Emulsion Formation. The plant A liquor contained 0.03 wt % of ore slime as received. With organic phase dispersed, settling rate tests before and after filtration of the liquor showed that with completely clarified liquor the settling rate was appreciably slower than it was with the original liquor. Therefore, a number of finely divided solid additives were tested for their possible effect in preventing formation of silica emulsion with the organic phase dispersed.

The tests were made with the high silica plant B liquor and amine 9D-178 in kerosene with an aqueous to organic phase ratio of 1-1/2:1. It was found that the presence of about 0.1% of Celite, kaolin, plant A ore slime, or decolorizing carbon was effective in preventing emulsion, and 90% separation of phases was obtained in less than 1 minute.

Decolorizing carbon differed from the other additives in that it remained in the organic phase and it could presumably be recycled. Tests are planned to determine the effect of recycling on the capacity of the carbon for prevention of emulsion.

A number of surface active agents, including anionic, cationic and nonionic types, were also tested for the prevention of silica emulsions, but none were found to be effective.

Effect of Temperature. The effect of temperature on phase separation was determined with 9D-178 in kerosene and plant A liquor. The time required for 90% phase separation decreased as the temperature was increased; at 12, 28, 35, and 55°C the separation times were >300, 140, 77, and 35 seconds, respectively.

SLURRY EXTRACTION

Previous studies of the slurry extraction system have shown that a significant amount of the organic phase is entrained in the slurry raffinate and that the nature of the entrainment is mechanical rather than a surface adsorption effect. Rushton and coworkers have shown that, in a mixing operation with constant power, the ratio of internal flow to turbulence varies as the size of the impeller is varied. For example, a large-diameter, low-speed impeller produces a large ratio of flow to turbulence while a small-diameter, high-speed impeller with the same power input will give a small ratio.* In studies of the effect of mixing variables on the amount of organic entrainment in clarified raffinate (ORNL-2025 and ORNL-2026) it was found that the amount of entrainment, droplet size, and size distribution was dependent on the impeller speed in the mixing operation. Therefore, studies were initiated to evaluate the effects of power input and impeller size on the amount of phase entrainment and the rate of extraction on a batch basis.

A series of tests was completed with 50% slurry direct from the leach tank. The slurry was prepared by leaching -20 mesh Marysvale ore with dilute sulfuric acid (100 lbs conc. H_2SO_4 per ton of ore) for 16 hours. The pH was adjusted to 1.5 by addition of calcium hydroxide. The screen analysis of the ore before and after leaching is given in Table 12. The chemical composition of the aqueous portion of the 50% slurry is shown in Table 13. The organic phase was a 0.1M solution of di(2-ethylhexyl) phosphoric acid dissolved in kerosene containing 2 vol % capryl alcohol.

The tests were made in the 6-in. dia. mix tank used previously in batch stripping tests (ORNL-2026). A horizontal plate was placed 6 in. above the bottom of the mixer and the operating level of the organic phase was maintained 3 in. above the plate to minimize the possibility of dispersing air into the mixer contents.

In making the tests the mix tank was filled with organic, the impeller speed was adjusted to the desired value, and a sufficient amount of slurry was injected to give a volume phase ratio of 10 organic to 1 slurry. Samples were withdrawn at periodic intervals for uranium analysis and determination of organic entrainment by steam distillation.

*J. H. Rushton, Chem. Engr. Progress, Vol. 48, p. 33-38, 95-100; Vol. 49, p. 161-168; 267-275.

TABLE 12. SCREEN ANALYSIS OF MARYSVALE ORE

Screen Mesh*	Percent Retained on Screen	
	Before Leaching	After Leaching
+ 4	0.1	-
+ 8	0.4	-
+ 14	1.4	-
+ 28	47.2	-
+ 48	29.3	25
+ 80	11.9	12
+100	6.4	4.7
+150	2.5	6.2
+200	0.5	4.3
-200	<u>0.3</u>	<u>47.8</u>

*Tyler screens.

TABLE 13. COMPOSITION OF AQUEOUS PHASE
FROM LEACHED 50% SLURRY*
 (Sp. Gr. 1.45)

Chemical Composition	g/l
U	2.7
SO ₄ ⁼	25
Σ Fe	1.6
Fe ⁺²	0.79
PO ₄ ⁼	0.86
F	0.08
pH	1.5

Accuracy of the steam distillation method was evaluated by analyzing a number of slurry samples containing a known amount of organic phase. The maximum accuracy was obtained when the slurry in the distillation apparatus contained 1 ml or more of organic in which case the analytical values ranged from 50 to 75% of the actual organic entrained. Unless otherwise stated, all values for organic entrainment in this and subsequent reports are within these limits. The test data are reported in Table 14.

Evaluation of Data

Rates of extraction were evaluated by the use of rate constants which were computed by the method described in ORNL-2026. Here the constants were based on the uranium content of the aqueous phase.

In experimental studies of the effects of varying impeller size with power input held constant, it is convenient to use the ratio: dia. of impeller/dia. of mixer tank which is symbolized as D/T. Power input to the impeller shaft was computed by means of the equations developed by Rushton and coworkers*.

Previously it had been shown that most of the entrained organic would be recovered by slowly agitating raffinate which had been diluted with water to give a slime content of 5 wt % (ORNL-2026). Therefore, organic entrainment before (initial) and after recovery treatment (residual) was evaluated to indicate the amount of initial entrained organic that may be recovered. For cost estimating purposes residual entrainment should be regarded as the minimum loss.

Extraction

Since the reaction rate was very fast in all tests there was no marked effect of either power input or D/T on the rate constant. As shown in Table 15 the rate constant decreased only from 5 to 2 seconds as the power input to the impeller shaft was increased from 0.03 to 0.31 hp per gal. With constant power (0.03 hp/gal), an increase in D/T from 0.33 to 0.66 resulted in a decrease in the rate constant from 7 to 5 seconds. From the standpoint of extraction rate these results indicate that a power input of 0.03 hp/gal and a D/T ratio in the range of 0.33 to 0.66 should be satisfactory for extraction of uranium from 50 wt % slurries.

*Loc. cit.

TABLE 14. TEST DATA FOR 50 WT % MARYSVALE SLURRY

Mixing Conditions			Uranium Concentration in Raffinate, g/l							Rate Constant, sec,
Turbine Diameter, in	Turbine Speed, rpm	Power Input hp/gal	Mixing Time, sec							
			0	14	34	54	74	124	304	
2	1380	0.03	2.7	0.14	0.025	0.012	0.011	0.014	0.005	7
3	700	0.03	2.7	0.04	0.007	0.004	0.003	0.002	0.001	4
3	1100	0.12	2.7	0.005	0.001	0.001	0.001	0.001	0.001	2
3	1500	0.31	2.7	0.005	0.002	0.001	0.001	0.001	0.001	2
4	430	0.03	2.7	0.073	0.011	0.006	0.003	0.002	0.001	5
4	680	0.12	2.7	0.012	0.003	0.002	0.001	0.001	0.001	2
4	930	0.31	2.7	0.01	0.002	0.001	0.001	0.001	0.001	2

TABLE 14 (continued)

Mixing Conditions			Organic Entrainment			
Turbine Diameter, in.	Turbine Speed, rpm	Power Input hp/gal	Before Dilution		After Dilution	
			ml Kg Slurry	gal ton ore	ml Kg Slurry	gal ton ore
2	1380	0.03	80	40	9	4
3	700	0.03	100	50	6	3
3	1100	0.12	120	60	20	10
3	1500	0.31	120	60	30	15
4	430	0.03	140	70	10	5
4	680	0.12	120	60	20	10
4	930	0.31	140	70	20	10

TABLE 15. RATE OF EXTRACTION

Power/Input, hp/gal	Rate Constant, sec		
	D/T*	D/T*	D/T*
	0.33	0.50	0.67
0.03	7	4	5
0.12	-	2	2
0.31	-	2	2

*Diameter of impeller/diameter of tank.

Entrainment

The data in Table 16 indicate that with D/T ratio constant, there was no marked effect of power input on initial entrainment. With power constant at 0.03 hp/gal, there was an increase in initial entrainment with increase in D/T from 0.33 to 0.67.

As shown in Table 17, the lowest residual entrainment after dilution and slow agitation was 3 gal/ton which was obtained with a power input of 0.03 hp/gal.

The cost of organic phase is estimated to be about \$0.33 gal. On this basis the cost of 3 gallons of organic entrained in raffinate would amount to about \$1.00 per ton of ore.

TABLE 16. ORGANIC ENTRAINMENT BEFORE DILUTION

Power Input, hp/gal	Entrainment, gal/ton of ore		
	D/T*	D/T*	D/T*
	0.33	0.50	0.67
0.03	40	50	70
0.12	-	60	60
0.31	-	60	70

*Diameter of impeller/diameter of tank.

TABLE 17. ORGANIC ENTRAINMENT AFTER DILUTION

Power Input, hp/gal	D/T*	D/T*	D/T*
	0.33	0.50	0.67
0.03	4	3	5
0.12	-	9	9
0.31	2	15	10

*Diameter of impeller/diameter of tank.

Future Work

The batch extraction tests will be continued with 40 wt % slurry to determine the effect of mixing variables on extraction efficiency and organic entrainment.