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A Preliminary Estimate of the Cost of
Uranium Recovery Using Dalplex Slurry Process

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RAW MATERIALS ECONOMIC STUDIES: A PRELIMINARY ESTIMATE
OF THE COST OF URANIUM RECOVERY
USING DALPHEX SLURRY PROCESS

B. B. Klima and R. R. Wiethaup

This report presents the cost of recovering uranium from a sulfuric acid leach slurry (50% solids) by solvent extraction with di(2-ethylhexyl)phosphoric acid (D2EHPA) dissolved in kerosene containing 3 vol. % of tributyl phosphate. The estimate is based upon the results of laboratory and process testing work through August, 1955.

The process is shown in Figs. 1 and 2. Briefly, it consists of extracting the uranium in four mixer-settler units and stripping it from the extract with aqueous sodium carbonate in two mixer-settlers. Extraction of iron is prevented by reducing it to the ferrous state with powdered iron. The loaded strip solution is neutralized with sulfuric acid, heated to remove carbon dioxide, and ammonia is added to precipitate the uranium. The extractor raffinate is diluted with water, the sands are removed by a classifier, and the entrained organic is recovered from the slime slurry by gently stirring it in a retention tank. The costs start with slurry from the leach operation and end with the filter cake ready for the calcining operation.

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At a production rate of 1136 pounds of U_3O_8 per day (a mill capacity of 200 tons of ore per day) it is estimated that the solvent extraction facility would cost \$337,522 and that the total of direct operating costs plus amortization would be \$0.699 per pound of U_3O_8 as shown in Tables 1 and 2. The cost of chemicals is shown in Table 3 and the installed costs of the process equipment in Table 4. The criteria are summarized in Table 5.

An additional extraction stage would be needed if the interstage organic entrainment were twice that assumed in this estimate (100 gal per ton of ore). The installation of this additional extraction stage would add about \$23,700 to the construction cost and \$0.021 to the total cost per pound of U_3O_8 .

Extraction directly from the 50% solids leach slurry costs \$0.067 per pound of U_3O_8 less than it does from a 5% solids slime slurry when an allowance is made for the cost of sand-slime separation (ORNL CF-55-9-127).

The above costs may be compared with those of alternative processes as shown in Fig. 3 and as described in ORNL-1927. Reports in which such costs are presented are listed in the Bibliography.

Applicable portions of "Suggested Procedure for Economic Evaluations for Uranium Recovery Plants," Grand Junction Operations Office, AEC, have been employed.

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(Basis: 24 hours)

FIGURE I. FLOW DIAGRAM

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FIGURE 2. PROCESS EQUIPMENT

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TABLE 1. COST OF RECOVERY FROM A LEACH SLURRY

	Cost per Day	Cost per lb U ₃ O ₈
Labor		
Operating <u>1/</u>	\$162.00	\$0.143
Maintenance <u>2/</u>	37.50	0.033
Supplies		
Operating <u>3/</u>	324.91	0.286
Maintenance <u>4/</u>	46.88	0.041
Utilities		
Electricity <u>5/</u>	26.35	0.023
Steam <u>6/</u>	<u>9.19</u>	<u>0.008</u>
Direct Operating Cost	\$606.83	\$0.534
Amortization <u>7/</u>	<u>187.51</u>	<u>0.165</u>
Total	\$794.34	\$0.699

1/ Three men per shift at \$18 per man shift.

2/ Four percent of the total construction cost per 360-day year (see Table 2).

3/ See Table 3.

4/ Five percent of the total construction cost per 360-day year (see Table 2).

5/ \$0.011 per kwh.

6/ \$0.90 per 1000 lbs.

7/ Twenty percent of the total construction cost per 360-day year (see Table 2).

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TABLE 2. COST OF THE SLURRY EXTRACTION FACILITY

A.	Cost of installed process equipment <u>1/</u>	\$133,600
B.	Other direct costs	
	Piping (30% of A)	40,080
	Instrumentation (3% of A)	4,008
	Electrical wiring <u>2/</u>	5,545
	Building <u>3/</u>	61,000
	Footings and foundations (5% of A)	6,680
	Painting and scaffolding (2% of A)	<u>2,672</u>
C.	Total direct costs	\$253,585
D.	Engineering and field expense (10% of C)	25,359
E.	Contingency [10% of (C+D)]	27,894
F.	Contractor's fee and overhead [10% of (C+D+E)]	<u>30,684</u>
G.	Total construction cost	\$337,522

1/ Includes material, labor, and freight (see Table 4).

2/ 110.9 kw at \$50 per installed kw for lighting, equipment, and instruments.

3/ 130,800 cu ft. Does not include lighting or sanitary facilities.

TABLE 3. CHEMICAL COSTS AND CONSUMPTION

Material	Consumption per Day	Unit Price <u>1/</u>	Cost per day	Cost per lb U ₃ O ₈
Kerosene	237 gal	\$0.14	\$ 33.18	\$0.029
Tributyl phosphate	132 lb	0.53	69.96	0.062
Di(2-ethylhexyl)phosphoric acid	81 lb	0.6146 <u>2/</u>	49.78	0.044
Iron	1,140 lb	0.0655 <u>2/</u>	74.67	0.066
Sodium carbonate	2,350 lb	0.0225	52.88	0.046
Sulfuric acid (98%)	1,686 lb	0.0150	25.29	0.022
Ammonia (100%)	333 lb	0.0575	<u>19.15</u>	<u>0.017</u>
		Total	\$324.91	\$0.286

1/ Delivered in Grand Junction, Colorado.

2/ See ORNL CF-55-3-193.

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TABLE 4. COST OF INSTALLED PROCESS EQUIPMENT

Item No.	No. Req'd	Description	Installed Cost Each	Total
T-1	1	Slurry surge tank, 12,700-gal, wood, 7-1/2 hp agitator	\$ 1,330	\$ 1,330
T-2	4	Extractor mixer, 379-gal, Haveg 41, 15 hp agitator	4,180	16,720
T-3	4	Extractor settler, 815-gal, plastic lined steel, 1 hp agitator	2,210	8,840
T-4	1	Organic recovery vessel, 46,000-gal, plastic lined steel and stainless steel, 7-1/2 hp agitator	30,450	30,450
T-5	2	Recovered organic tank, 8000-gal, plastic lined steel	3,340	6,680
T-6	1	Extract surge tank, 376-gal, plastic lined steel	660	660
T-7	2	Stripper mixer, 59-gal, Haveg 60, 1/2 hp agitator	1,100	2,200
T-8	1	Stripper interstage settler, 148-gal, plastic lined steel	630	630
T-9	1	Stripper final settler, 580-gal, plastic lined steel	1,160	1,160
T-10	2	Strip solution tank, 2,022-gal, steel, 2 hp agitator	1,120	2,240
T-11	3	Precipitation tank, 1987-gal, wood, 2 hp agitator	1,080	3,240
T-12	1	Filtrate tank, 3800-gal, wood	600	600
T-13	1	Organic make-up tank, 325-gal, stainless steel, 1/2 hp agitator	940	940
T-14	1	Barren organic storage tank, 14,000-gal, steel	1,260	1,260
T-15	1	Kerosene storage tank, 5,875-gal, steel	1,160	1,160

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TABLE 4 (continued)

Item No.	No. Req'd	Description	Installed Cost Each	Cost Total
P-20	2	Leach slurry feed pump, 70 gpm, neoprene lined	\$ 1,050	\$ 2,100
P-21	6	Aqueous interstage pump, 70 gpm, neoprene lined	1,050	6,300
P-22	4	Organic intrastage pump, 500 gpm, stainless steel	1,190	4,760
P-23	2	Barren slurry pump, 250 gpm, neoprene lined	1,150	2,300
P-24	1	Organic return pump, 25 gpm, stainless steel	800	800
P-25	2	Extract pump, 25 gpm, stainless steel	800	1,600
P-26	2	Strip solution feed pump, 10 gpm, iron	470	940
P-27	1	Stripper interstage pump, 10 gpm, iron	470	470
P-28	1	Filter feed pump, 6-35 gpm, neoprene lined	910	910
P-29	1	Filtrate disposal pump, 20 gpm, iron	470	470
P-30	1	Organic make-up pump, 10 gpm, stainless steel	740	740
P-31	1	Organic feed pump, 25 gpm, stainless steel	800	800
P-32	1	Kerosene transfer pump, 25 gpm, iron	470	470
F-40	2	Filter press, wood, 36" x 46 frames	3,790	7,580
CL-41	1	Classifier, 48" screw type, acid-proof construction	10,250	10,250
BC-42	1	Belt conveyor for sand	15,000	15,000
Total				\$133,600

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TABLE 5. CRITERIA

General

Location of mill <u>1/</u>	Grand Junction, Colorado
Mill capacity <u>1/</u>	200 tons of ore per day
Ore assay <u>1/</u>	0.3% U_3O_8
Solids in leach slurry <u>1/</u>	50%
Slimes in leach slurry <u>4/</u>	30% of solids
Dissolved U_3O_8 in leach slurry <u>4/</u>	95% of U_3O_8 in ore
Misc. loss of U_3O_8 <u>1/</u>	0.25% of U_3O_8 in leach slurry

Extraction

Extractant	di(2-ethylhexyl)phosphoric acid
Conc. of extractant	0.1 molar
Molecular wt of extractant	322
Diluent	3 vol % tributyl phosphate in kerosene
Loading of extract	5.52 g U_3O_8 per liter
Mixer: <u>3/</u>	
Type	Baffled mixer
Impeller diameter	1/2 tank diameter
Unit power	0.031 hp per gal
Stage efficiency	85% at 0.6 min residence time
Internal phase ratio	10 vol organic: 1 vol aqueous
Continuous phase	Organic
Settler: <u>3/</u>	
Type	Cone bottom tank
Slurry holdup	3 min (pure slurry basis)
Organic holdup	1.2 min
U_3O_8 in raffinate	0.003 g U_3O_8 per liter of sol'n
U_3O_8 in barren organic <u>2/</u>	0.008 g U_3O_8 per liter
Organic entrained in slurry <u>3/</u>	100 gal per ton of ore
No. of theoretical stages req'd	2.4

- 1/ AEC or section standard.
2/ Laboratory.
3/ Process testing.
4/ Assumption.

TABLE 5 (continued)

Stripping

Reagent	Sodium carbonate
Theoretical requirement <u>2/</u>	3 moles CO_3 /mole U + 1/2 mole CO_3 /mole excess DEPA
Usage <u>2/</u>	120% of theoretical
Conc. of U_3O_8 in loaded strip sol'n <u>3/</u>	29.5 g U_3O_8 per liter
No. of stages <u>2/</u>	Two, countercurrent
Residence time in mixer <u>4/</u>	2 min
Residence time in interstage settler <u>4/</u>	2 min
Residence time in final settler <u>4/</u>	10 min
Unit power <u>4/</u>	0.0054 hp per gal

Organic Recovery

Initial organic content <u>3/</u>	100 gal per ton of ore
Final organic content <u>3/</u>	1.2 gal per ton of ore
Classifier overflow <u>3/</u>	5% slime slurry
Classifier discharge <u>4/</u>	75% sand, 25% water
Size of sands <u>4/</u>	+100 mesh
Organic in sands <u>4/</u>	none
Residence time of slime slurry <u>3/</u>	1.75 hours

Product Recovery

Amount of sulfuric acid	neutralize all CO_3 and acidify to pH = 1.5
Precipitant	ammonia (anhydrous)
Theoretical requirement	3 moles NH_3 per mole U
Usage <u>3/</u>	150% of theoretical
Product grade	75% U_3O_8
Filter cake	60% water
U_3O_8 in filtrate	0.001 g U_3O_8 per liter

Reduction 2/

Reducing agent	iron
Particle size	100 mesh
Theoretical requirement	0.5 moles Fe per mole Fe(III) reduced
Usage	125% of theoretical
Reaction time	30 min
Fe(III) in liquor	twice conc. of U_3O_8
Degree of completion of reduction	80% of Fe(III) in liquor

TABLE 5 (continued)

Loss of Organic Materials

Entrainment in:	
Slurry after recovery	1.2 gal per ton of ore
operation 3/	
Loaded strip 4/	0.025 vol %
Solubility 2/	
D2EHPA in leach liquor	5 ppm
D2EHPA in loaded strip	75 ppm
TBP in leach liquor	30 ppm
TBP in loaded strip	40 ppm
Misc. losses 4/	100 gal per month

FIGURE 3. DIAGRAM OF RAW MATERIALS COST ESTIMATES.

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