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X-832

OAK RIDGE NATIONAL LABORATORY

Operated By

UNION CARBIDE NUCLEAR COMPANY

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

~~ORNL~~
CENTRAL FILES NUMBER

CF-55-9-85

DATE: September 21, 1955
SUBJECT: Raw Materials Economic Studies:
A Preliminary Estimate of the Cost of
Uranium Recovery From a Slime Slurry,
I. DEPA - Capryl Alcohol
TO: H. M. McLeod, Jr.
FROM: B. B. Klima and R. R. Wiethaup

CLASSIFICATION CANCELLED
DATE 5-2-56

For The Atomic Energy Commission

H. F. Canale

Chief, Declassification Branch *Lu*

Contract No.

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RAW MATERIALS ECONOMIC STUDIES: A PRELIMINARY ESTIMATE
OF THE COST OF URANIUM EXTRACTION FROM A SLIME SLURRY

I. DEPA - Capryl Alcohol

B. B. Klima, R. R. Wiethaup

This report presents the cost of recovering uranium from a sulfuric acid slime slurry by extraction with di(2-ethyl-hexyl)phosphoric acid (DEPA) dissolved in a kerosene-capryl alcohol diluent. The estimate is based upon the results of laboratory and process testing work through July, 1955.

The process is shown in Figs. 1 and 2. Briefly, it consists of extracting the uranium in a four-unit mixer settler extractor and stripping with aqueous sodium carbonate in a two-unit mixer settler. Extraction of iron is prevented by reducing it to the ferrous state with powdered iron. After driving off the carbon dioxide by adding sulfuric acid and heating, the uranium is precipitated with ammonia and filtered. The entrained organic is recovered from the raffinate by gentle stirring in a large retention tank.

At a production rate of 1124 lbs 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 \$317,827 and that the total of direct operating costs plus amortization would be \$0.712 per pound of U_3O_8 , as shown in Tables 1 and 2. The cost of chemicals is shown in Table 3 and a breakdown of the cost of the installed process equipment in Table 4. The criteria are summarized in Table 5.

One more extraction stage would be needed if the inter-stage organic entrainment were 30 gal/ton of ore, rather than 10 gal/ton of ore, as was assumed in this estimate. The installation of this additional extraction stage would add \$34,000 to the construction cost and \$0.033 to the total cost per pound of U_3O_8 .

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 Evaluation for Uranium Recovery Plants," Grand Junction Operations Office, AEC, have been employed.

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SLIME SLURRY

Flow 192.2 gpm

Solids 60 tons

H₂O 1140 tons

U₃O₈ 1134 lb

REDUCTANT

Iron 1140 lb

REDUCTION

RECOVERED ORGANIC

Flow 1.22 gpm

U₃O₈ 2.20 lb

Kerosene 1725 gal

Caprylalcohol 241 lb

DEPA 473 lb

EXTRACTION

ORGANIC RECOVERY

RAFFINATE

Flow 193.6 gpm

Solids 60 tons

H₂O 1140 tons

U₃O₈ 9.35 lb

Kerosene 1960 gal

Caprylalcohol 456 lb

DEPA 549 lb

BARREN SLURRY

Flow 192.4 gpm

Solids 60 tons

H₂O 1140 tons

U₃O₈ 7.15 lb

Kerosene 235 gal

Caprylalcohol 215 lb

DEPA 76 lb

ORGANIC EXTRACT

Flow 30.1 gal/min

U₃O₈ 1130 lb

Kerosene 42,530 gal

Caprylalcohol 5,946 lb

DEPA 11,675 lb

ORGANIC MAKEUP

Kerosene 239 gal

Caprylalcohol 218 lb

DEPA 80.3 lb

MISC. ORGANIC LOSSES

Kerosene 3.26 gal

Caprylalcohol 0.46 lb

DEPA 0.90 lb

STRIP SOLUTION

Flow 3.18 gpm

Na₂CO₃ 3332 lb

STRIPPING

SULFURIC ACID
98 % 1797 lb

PRECIPITANT
NH₃ 328 lb

PRECIPITATION
AND
FILTRATION

Misc. U₃O₈ Loss 2.84 lb

WASTE SOLUTIONS

U₃O₈ 0.04 lb

Kerosene 112 gal

Caprylalcohol 2.04 lb

DEPA 3.37 lb

PRODUCT CAKE

U₃O₈ 1124 lb

Total Solids 1499 lb

H₂O 2248 lb

(BASIS: 24 HRS)

FIGURE I. PROCESS FLOW DIAGRAM

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FIGURE 2. PROCESS EQUIPMENT

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FIGURE 3. DIAGRAM OF RAW MATERIALS COST ESTIMATES.

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TABLE 1. COST OF RECOVERY
FROM A SLIME SLURRY

	Cost per day	Cost per lb U ₃ O ₈
Labor		
Operating <u>1/</u>	\$162.00	\$0.144
Maintenance <u>2/</u>	35.31	0.032
Supplies		
Operating <u>3/</u>	325.12	0.289
Maintenance <u>4/</u>	44.14	0.039
Utilities		
Electricity <u>5/</u>	47.76	0.043
Steam <u>6/</u>	9.09	0.008
Direct Operating Cost	\$623.42	\$0.555
Amortization <u>7/</u>	176.57	0.157
Total	\$799.99	\$0.712

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 lb.

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

TABLE 2. COST OF THE SLIME SLURRY
EXTRACTION FACILITY

A. Cost of installed process equipment <u>1/</u>	\$121,210
B. Other direct costs	
Piping (30% of A)	36,363
Instrumentation (3% of A)	3,636
Electrical wiring <u>2/</u>	10,095
Building <u>3/</u>	59,000
Footings and foundations (5% of A)	6,060
Painting and scaffolding (2% of A)	<u>2,424</u>
C. Total direct costs	\$238,788
D. Engineering and field expense (10% of C)	23,879
E. Contingency [10% of (C+D)]	26,267
F. Contractor's fee [10% of (C+D+E)]	<u>28,893</u>
G. Total construction cost	\$317,827

1/ Includes material, labor and freight. See Table 4.

2/ 201.9 kw at \$50 per installed kw for lighting, equipment, and instruments.

3/ 124,080 ft³. Does not include lighting or sanitary facilities.

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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	239	gal	\$0.14	\$33.46	\$0.030
Capryl alcohol (95%)	229	lb	0.2046 <u>2/</u>	46.85	0.042
DEPA	80.3	lb	0.6146 <u>2/</u>	49.35	0.044
Iron (100 mesh)	1140	lb	0.0655 <u>2/</u>	74.67	0.066
Sodium carbonate	3332	lb	0.0225	74.97	0.066
Sulfuric acid (98%)	1797	lb	0.0150	26.96	0.024
Ammonia (anhyd.)	328	lb	0.0575	<u>18.86</u>	<u>0.017</u>
				\$325.12	\$0.289

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, 50,000 gal. wood, 15 hp agitator	\$ 8,130	\$ 8,130
T-2	4	Extractor mixer, 735 gal. Haveg 41, 25 hp agitator	4,800	19,200
T-3	4	Extractor settler, 3,070 gal. plastic lined steel	3,290	13,160
T-4	1	Organic recovery vessel, 23,000 gal. plastic lined steel, 3 hp agitator	20,440	20,440
T-5	2	Recovered organic tanks, 2,500 gal. plastic lined steel	1,620	3,240
T-6	1	Extract surge tank, 700 gal. plastic lined steel	780	780
T-7	2	Stripper mixer, 113 gal. Haveg 41, 1 hp agitator	1,480	2,960
T-8	1	Stripper interstage settler, plastic lined steel and Haveg 41	730	730
T-9	1	Stripper final settler, plastic lined steel and Haveg 41	1,700	1,700
T-10	2	Strip solution tank, 2,022 gal, steel, 2 hp agitator	1,120	2,240
T-11	3	Precipitation tank, 1,987 gal, wood, 2 hp agitator	1,080	3,240
T-12	1	Filtrate tank, 3,350 gal, wood	550	550
T-13	1	Organic make-up tank, 325 gal, stainless steel, 1/2 hp agitator	940	940
T-14	1	Barren organic storage tank, 22,112 gal, steel	1,580	1,580
T-15	1	Kerosene storage, 5,875 gal, steel	1,160	1,160

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TABLE 4 (Continued)

Item No.	No. Req'd	Description	Installed Cost	
			Each	Total
P-20	2	Leach slurry feed pump, 250 gpm, neoprene lined	\$ 1,150	\$ 2,300
P-21	6	Aqueous interstage pump, 250 gpm, neoprene lined	1,150	6,900
P-22	4	Organic intrastage pump, 2,500 gpm, stainless steel	3,970	15,880
P-23	1	Barren slurry pump, 250 gpm, neoprene lined	1,150	1,150
P-24	1	Organic return pump, 5 gpm, stainless steel	800	800
P-25	2	Extract pump, 50 gpm, stainless steel	850	1,700
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, 50 gpm, stainless steel	850	850
P-32	1	Kerosene transfer pump, 25 gpm, iron	470	470
F-40	2	Filter press, 36" x 46 frames, wood	3,790	7,580
Total Installed Cost				\$121,210

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TABLE 5. CRITERIAGeneral

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
Slimes in ore <u>1/</u>	30%
Feed to extractor	5% slimes slurry
U_3O_8 in slime slurry <u>1/</u>	94.5% of U_3O_8 in the ore
Misc. loss of U_3O_8 <u>1/</u>	0.25% of U_3O_8 in slime slurry

Extraction

Extractant	di(2-ethylhexyl)phosphoric acid
Conc. of extractant	0.1 molar
Molecular wt of "	322
Diluent	2 vol % capryl alcohol in kerosene
Loading of extract	3.12 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	90% at 0.3 min residence time
Internal phase ratio	10 vol organic: 1 vol aqueous
Continuous phase	organic

- 1/ AEC or section std.
2/ Laboratory.
3/ Process testing.

TABLE 5 (Continued)

Extraction (Cont'd)Settler: 3/

Type	cone bottom tank
Slurry holdup	3 min (pure slurry basis)
Organic holdup	1.2 min
U ₃ O ₈ in raffinate	0.003 g U ₃ O ₈ per liter of sol'n
U ₃ O ₈ in barren organic <u>2/</u>	0.008 g U ₃ O ₈ per liter
Organic entrained in slurry <u>3/</u>	10 gal per ton of ore
Number of theoretical stages required	3.5

Stripping

Reagent	sodium carbonate
Theoretical require- ment <u>2/</u>	3 moles CO ₃ /mole U plus 1/2 mole CO ₃ /mole excess DEPA
Usage <u>2/</u>	120% of theoretical
Conc. of U ₃ O ₈ in loaded strip sol'n <u>3/</u>	29.5 g U ₃ O ₈ per liter
Number of stages <u>2/</u>	two, countercurrent
Residence time in mixer <u>4/</u>	2 min
Residence time in inter- stage settler <u>4/</u>	2 min
Residence time in final settler <u>4/</u>	10 min
Unit power	0.0054 hp per gal

4/ Assumed.

TABLE 5 (Continued)Organic Recovery 3/

Initial organic content	10 gal per ton of ore
Final organic content	1.2 gal per ton of ore
Residence time of slurry	1 hr

Product Recovery

Precipitant	ammonia (anhydrous)
Theoretical requirement	3 moles NH_3 /mole U
Usage 3/	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
operation 3/ 1.2 gal per ton of ore

Loaded strip 4/ 0.025 vol %

Solubility 2/

DEPA in leach liquor 5 ppm

DEPA in loaded strip 75 ppm

Capryl alcohol in
leach liquor 80 ppm

Capryl alcohol in
loaded strip 410×10^{-6} lb per gal sol'n

Misc. losses 4/ 100 gal per month

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